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BOOK OF ABSTRACTS

in alphabetical order by first author

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GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Fakultät für Geowissenschaften und Geographie

Dachverband Geowissenschaften DVGeo

01.06 Tectonic Systems – TSK Open Session

The importance of inherited lithospheric architecture on foreland basin architecture: inferences from the Molasse Basin

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The architecture of a foreland basin records the adjacent mountain range's tectonic evolution and climatic history. The Northern Alpine Foreland Basin, also known as the Molasse Basin, has a non-cylindrical architecture, hinting at along-strike variations in Alpine tectonics and climate history. Previous studies suggest that slab tearing, a process by which slab breakoff propagates along-strike, is the primary driver of the foreland basin's non-cylindrical evolution. However, a quantitative assessment of the slab tearing on the evolution of Molasse Basin architecture is lacking. Moreover, the heterogeneity present in the European passive margin architecture can add further complexity to the slab tear evolution and associated foreland basin evolution. Here, we integrate geodynamic and stratigraphic (depositional) forward models to evaluate the effect of potential drivers and compare them to Molasse Basin architecture. In the geodynamic models, we vary along-strike passive margin age, initial obliquity of the passive margin with respect to the upper plate, and presence of microcontinent. We quantify the effects of these processes on the slab tear evolution, subsequent continental collision and resulting along-strike variable foreland basin development. Our results highlight that the subduction of the irregular European passive margin caused a cascade of regional tectonic events leading to the heterogeneous architecture of the Molasse Basin. More specifically, the lateral propagation of slab tearing was the dynamic response to the collision of the irregular passive continental margin. The resultant along-strike variations in slab pull controlled the contrasting evolution of depositional environments in the Molasse Basin along the strike.

07.02 Geothermal energy – Potential and utilisation of geothermal energy resources for the heat transition

Uncertainty Quantification of THC Reactive Transport in the Middle Buntsandstein Fractures: A Numerical Reservoir Simulation Study at the Wörth am Rhein site in the Upper Rhine Graben, Germany

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Thermo-hydro-chemical (THC) reactive transport in fractured geothermal reservoirs plays a critical role in optimising thermal energy extraction and ensuring sustainable management. This work presents an integrated modelling framework that couples geochemical simulations using PHREEQC with thermo-hydraulic calculations in COMSOL Multiphysics via the iCP software program. It focuses on the Middle Buntsandstein sandstone unit in the Wörth am Rhein area, where the Dekapalatin project is currently being implemented.

This study investigates the influence of varying brine and mineralogical compositions on a fractured geothermal reservoir. Therefore, a series of scenarios is designed to explore these effects on the reservoir behaviour. These scenarios investigate spatial and temporal changes in the reservoir characteristics. Explicitly, detailed alterations in porosity and permeability resulting from mineral dissolution and precipitation are evaluated, along with their implications for geothermal flow-path development and thermal breakthrough dynamics in the fracture network.

The results indicate that variations in brine and mineralogical compositions can lead to spatially heterogeneous alterations in fracture apertures. These alterations, in turn, modulate local fluid velocity and heat transfer. Secondary precipitation processes, notably of carbonate minerals, are expected to have a relatively significant influence on reservoir porosity and permeability. On the other hand, dissolution processes may promote the development of additional flow paths within the fracture network.

This study improves our understanding of thermo-hydro-chemical interactions in fractured geothermal reservoirs and provides a clear framework for quantifying uncertainty in reservoir management. The coupled approach improves the reservoir performance predictions and informs sustainable decision-making for geothermal exploitation.

01.20 Process oriented microfabric characterisation of geomaterials

To form or not to form? The epic struggle of jadeite in a water-limited world

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The occurrence of jadeite in metagranites is typically interpreted as an indicator of high-pressure conditions during metamorphism. Moreover, the albite breakdown reaction to jadeite and quartz has long been employed for the calibration of piston-cylinder. It is therefore paradoxical that jadeite is frequently absent in metagranitic rocks, even when these are associated with mafic eclogites. Possible explanations for the absence of jadeite include sluggish reaction kinetics under fluid-absent conditions, retrograde overprinting, and mechanical pressure differences between mafic eclogites and adjacent granitic lithologies.

This experimental study investigates the reaction mechanisms and the role of fluid in nominally dry jadeite formation. Piston-cylinder experiments were conducted at 2.2 GPa and 800 °C on two natural granitic rocks. One sample is a fresh granite from Finland, and the other a metagranite from Monte Rosa (Western Alps) with a complex metamorphic history involving two orogenic cycles. The history of the latter led to exsolution of magmatic plagioclase into albite and zoisite and partial replacement of biotite by white mica.

While jadeite formed in the fresh granite at albite–biotite interfaces, no jadeite developed in the Monte Rosa metagranite under identical conditions. Although the albite breakdown reaction is thermodynamically overstepped, jadeite formed not through simple albite breakdown but through localized reactions at albite–biotite interfaces. The results indicate that jadeite formation is controlled by several factors, including biotite stability dependent on aluminium content, slow reaction kinetics in the absent of fluid, and the metamorphic history of the rock, which influences local equilibrium.

03.06 Multiscale characterization of structure, flow and transport dynamics in fractured porous media and karst systems

Unresolved issues in fractured rock hydrogeology

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A brief historical review starts from the double porosity approach of Barenblatt in 1960; various versions of it are still used today despite the difficult evaluation of the exchange coefficient between the two media. Later, the homogenisation theory was applied, but it stopped before solving the macroscopic equations. A decisive step was achieved in 1980 by viewing a fracture network as a set of disks randomly distributed in space. This was the starting point of our own works with additional ideas such as the crucial role of the dimensionless density for convex fractures and the use of systematic numerical experiments in order to rationalize the results.

Today, with the powerful computers at our disposal, very complex configurations can be addressed, but the theoretical and methodological gains are limited.

Therefore, the basic issues have not changed for real networks. They can be summarized and illustrated by our simple approach. First, what are the most salient features of the measurements made on oucrops and wells? Some of them provided a basis to the theoretical predictions of quantities such as percolation and macroscopic permeability, but alternative approaches could certainly be developed. Second, how can we reconstruct, i.e., generate realistic networks based on these measurements? Statistical techniques have been extensively used, but more advanced techniques such as AI should be envisioned. Third, experimental results are usually scarce and often not easily compared with numerical predictions.

Despite and/or because all these difficulties, this field is expected to remain very active in the future.

01.25 Geochemical Databases and Data Analysis Tools

Fluid property data for the online geothermal information system GeotIS

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The LIAG Institute for Applied Geophysics operates the Geothermal Information System for Germany (GeotIS) since its inception in 2006. A significant nationwide expansion of geothermal energy requires a systematic enhancement of the available research data infrastructure with data on thermal waters, including chemical constituents and physico-chemical properties. To address these challenges, the THC-Prognos project aims to augment GeotIS by incorporating comprehensive fluid data. This expansion will involve collecting and standardizing thermal water analyses from various publications and datasets from various sources, ensuring their integration into a cohesive and accessible database. Enhanced functionality will be introduced to GeotIS, including the visualization of measurement locations, interactive query capabilities, and time series analysis of thermal water compositions. This will significantly aid both scientific research and operational planning by providing crucial insights into the hydrochemical properties of geothermal fluids, ultimately supporting the sustainable management and development of geothermal resources in Germany.

06.04 Stressors in Hydrogeology: Interactions and Impacts

Lead and benzene contamination in drinking water wells of an unconfined aquifer in the Niger Delta, Nigeria

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Groundwater in the Niger Delta remains a critical source of potable water, yet it is increasingly threatened by contamination from petroleum-related activities and other anthropogenic sources. Few studies have comprehensively assessed the presence of contaminants in unconfined Niger Delta aquifers. This study investigates the spatial distribution of lead and benzene in both closed and open wells within the highly permeable floodplain sands of the Benin Formation underlying oil-producing municipalities in Rivers State, Nigeria. Groundwater samples were collected during the dry season in January 2025. Benzene was analysed from closed wells only, and lead was measured in both well types, ensuring representative spatial coverage. Results reveal significant spatial variation of benzene concentration, with the highest detected concentration reaching 26,460 µg/L, near petroleum infrastructure. A total of 16.7% of groundwater samples exceeded the WHO standard limit of 0.01 mg/L for lead in drinking water. More closed wells, which sample deeper into the aquifer, are contaminated with lead (20.6%) compared to shallower open wells (4.5%). Dissolved oxygen (DO), averaged 5.88 mg/L, was lower in samples containing benzene, suggesting natural attenuation processes. Ongoing work seeks to contextualize these findings relative to groundwater recharge estimates using a water balance approach based on climatic data. By translating our conceptual model into a numerical flow and transport model, we aim to shed light on the potential long-term implications of lead contamination in the aquifer. Our results highlight the urgent need for improved management and stricter regulation of petroleum activities to safeguard groundwater resources in the Niger Delta.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

A new 3D geological model of Germany

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3D geological models are an essential source of information for research as well as for the safe and efficient use of the underground. They provide not only a visualization of the subsurface structures, but also serve as geometry input for geophysical and numerical models, e.g., gravimetric, mechanical or thermal models. The set-up of a geological model for a numerical simulation is often a time-consuming task. During the last two decades several 3D geological models have been created for specific regions in Germany. However, up to now only one attempt has been made to combine several of them to a Germany-wide model. We present a new Germany-wide 3D geological model combining information of 27 individual models. The model has a resolution of 1 x 1 km^2 and is vertically and horizontally subdivided into 146 units. Where possible, the model has been extended to neighbouring states, e.g., Netherlands, France, Austria or Switzerland. In order to combine all models with their different sizes, resolutions and stratigraphic subdivisions, a point-set approach was chosen which has a number of advantages with regard to the flexibility and usability.

01.20 Process oriented microfabric characterisation of geomaterials

The mechanisms and rates of fracture sealing in carbonates

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Geological observations, seismic data as well as laboratory experiments have shown that faults lithify and recover their strength (heal) during inter-seismic periods. The mechanical-chemical process of fault healing is a key in understanding many aspects of fault behavior, such as earthquake recurrence and rupture dynamics, but is also pivotal for the application of deep geothermal energy, CO_2 sequestration and the underground storage of radioactive waste. In this contribution we investigate the mechanical-chemical recovery of fractures in carbonates at upper crustal conditions. In the upper crust, fractures are dominantly sealed through mineral precipitation from supersaturated fluids that are chemically out of equilibrium with the host rock. Such fracture sealing processes are inferred to be either relatively fast under high fluid availability and through mineral precipitation from supersaturated fluids (advective transport) or relatively slow by dissolution-precipitation processes, also known as self-sealing (diffusive transport). In order to improve the understanding of the mechanism and rate of the damage-recovery cycle of fractures, this project investigates how different sealing mechanisms (advection vs. diffusion) as well as fracture sealing rates are coupled. For this purpose, observations from natural vein systems are combined together with fracture sealing experiments with a percolation cell apparatus. In order to quantitatively document the sealing process, the selected rock samples are analyzed by laboratory-based X-ray computed microtomography and scanning electron microscopy. In summary, this work will advance knowledge about the damage-recovery cycle in fractured carbonates through the investigation of sealing processes active at the microscale.

01.10 The co-evolution of the Earth and life from the early Archean until today

Temperature of Moodies Group (3.2 Ga) fluid-escape structures: implications for microbial preservation

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The mechanisms that preserved the microbial mats of the Paleoarchean Moodies Group sandstones (c. 3.22 Ga) remain unclear. These kerogenous, microbially laminated structures occur abundantly in medium- to coarse- grained tidal-flat sandstones. They are readily mappable along a 15 km-long ridge of silicified strata in the central Barberton Greenstone Belt, South Africa. Silicification is thought to be attributable to the Moodies-age Lomati River Sill (LRS), a large mafic laccolith, c. 1 km below. Tidal-flat sandstones overlying the LRS feature abundant, isolated or clustered fluid-escape structures (FES) up to 6 m high. µ-XRF-generated elemental maps of nine slabbed and polished FES samples show enrichment of Fe, Cr, Ti and V along their central conduits and margins. S-Fe maps show thick pyrite rinds overgrowing detrital grains, possibly attributable to sulfur-reducing bacterial processes, magma degassing or breakdown of minerals. We speculate that the FES represent discrete pathways of potentially hot and silica-rich fluids migrating within the halo of the LRS and erupting into sand volcanoes, in which sand grains, primarily of volcanic provenance, underwent local argillic alteration. Precompaction surficial silicification (or carbonatization) by mineralized fluids may have preserved composition and texture perfectly. Current challenges to our research include modifications by Archean aggressive weathering, regional greenschist-facies metamorphism, recent weathering, lack of recent analogs, and reset of the original isotopic systems, all of which blur detailed insights.

01.13 Sedimentary basins as multi-proxy and multi-process recorders

Stratigraphic tectonic framework of Eocene sediments in the North German Basin

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Dynamic tectonic processes and significant fluctuations in sea levels affected the North German Basin during the Eocene epoch, which affected the deposition and the structure of the basin. This study integrates literature, seismic data, mud logs, and well data from about 700 wells in northwestern Germany to clarify the stratigraphic framework and thickness distribution of the Middle Eocene strata. The focus is on the interaction between tectonic events, especially the regional uplift and salt domes and the regional subsidence that followed the onset of North Atlantic seafloor spreading and the resulting marine sandstone deposits, including the Brussels Sand or Glinde Formation. Preliminary results indicate that local thickness variation in the Middle Eocene strata is associated with the margins of salt domes and Tertiary faults, suggesting Syn-sedimentary tectonic influences. Furthermore, well and mud logs reveal frequent shifts in Eocene lithology, which indicate cycles of sea level fluctuations. The sediment supply must be considered to comprehend the evolutionary history of the basin comprehensively. Reconstructing Eocene depositional environments and clarifying the causes of the thickness variability provide a strong basis for resource assessment, particularly for geothermal exploration in the North German Basin.

09.02 Museen als Fenster in die Forschung

Ein Audioguide in Leichter Sprache als Beitrag zur Inklusion am Geologischen und Mineralogischen Museum des Instituts für Geowissenschaften der Christian-Albrechts-Universität zu Kiel

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Die Geschichte der Sammlungen des Geologischen und Mineralogischen Museums in Kiel lässt sich bis ins 17. Jahrhundert zurück verfolgen. Erste öffentliche Ausstellungen erfolgten in unregelmäßigen Abständen seit 1846. Nach völliger Zerstörung des Instituts- und Museumsgebäudes im August 1944, erfolgte am 21. März 1970 eine Wiedereröffnung am jetzigen Standort. Heute gibt das Geologische und Mineralogische Museum einen Einblick in das vielfältige Fach der Geowissenschaften. Präsentiert werden unter anderem verschiedene Minerale, Gesteine, Meteoriten und Fossilien. Anhand der Sammlungsstücke wird der Aufbau und die Entwicklung der Erde und der Lebewesen erläutert. Ein besonderer Schwerpunkt liegt dabei auf der regionalen Geologie Norddeutschlands und des Ostseeraumes. Mit seinem Angebot richtet sich das Museum nicht nur an Studierende und Universitätsangehörige, sondern auch an Interessierte aus der Öffentlichkeit. Führungen und Veranstaltungen für Kindergärten, Schulen oder andere Gruppen werden regelmäßig durchgeführt.

Da die Ausstellung nicht durchgehend durch Personal betreut werden kann, bewegen sich viele Besucher*innen alleine durch das Museum. Um einen Besuch attraktiver und gewinnbringender zu gestalten, wurde mit Unterstützung des Inklusionsfonds der Universität Kiel ein Audioguide entwickelt zu den Kapiteln „Kristalle, Minerale und Gesteine“, „Meteoriten: Gesteine außerirdischer Herkunft“, und „Ein Gang durch die Erdgeschichte“. Zusätzlich wurde in Kooperation mit dem Institut für Leichte Sprache der Lebenshilfe Schleswig-Holstein eine Führung in Leichter Sprache entwickelt. Dieses Angebot soll Barrieren im Zugang zu Informationen reduzieren und Menschen einen Einblick in die Geowissenschaften ermöglichen, welche aus verschiedenen Gründen über eine geringere Kompetenz in der deutschen Sprache verfügen. Eine gedruckte Version der Führung in Leichter Sprache ist in Bearbeitung.

03.05 Advances in Paleoclimate Proxies and Their Applications

Deciphering the stable isotope ($\delta^{18}O$, $\delta^{13}C$) record of Holocene oyster shells from the Yangtze River Delta, China

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High-resolution stable isotope ($\delta^{18}O$, $\delta^{13}C$) data of 7,000 to 6,000 year-old oyster shells from the Yangtze River Delta constitute a combined record of climatic and oceanographic patterns (see Alberti et al., 2024). The results reflect prominent seasonal changes in temperature, precipitation, and river discharge. Summer months experienced warm temperatures and a distinct increase in rainfalls and river discharge. In contrast, winter months were dry and characterized by cool temperatures causing growth breaks in the oyster shells. Furthermore, the stable isotope analyses indicate regular summer upwelling in the study area during the mid-Holocene. Finally, the presented palaeo-proxy data offer the opportunity to evaluate available climate models for the region and thereby improve predictions for the future.

Reference

Alberti, M., Veiga, S.F., Chen, B., Hu, L., Fang, Z., Zhou, B., Pan, Y. 2024. The Yangtze River Delta experienced strong seasonality and regular summer upwelling during the warm mid-Holocene. Communications Earth & Environment 5: 492.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Reevaluating the India-Asia Collision in the Pakistani western Himalayas: Sedimentary Evidence for a ~56 Ma Onset

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The timing and sequence of the India–Asia collision along the western suture remain debated, with estimates ranging from 60 to 40 Ma. This study presents the first detailed provenance analysis of Mesozoic to Cenozoic strata in the Sulaiman-Katawaz fold-thrust belts, which preserve a continuous depositional record across the collision interval. We analyzed detrital zircon U-Pb ages and Nd-Sr isotopic signatures from Triassic to Miocene strata, complemented by zircon (U-Th)/He thermochronology data from Early Mesozoic units exposed in the hinterland region of the Sulaiman-Katawaz fold-thrust belt. These datasets collectively constrain sediment source regions, distinguishing between Indian and Asian provenance.

Detrital zircon U-Pb age spectra from the Cretaceous Pab and Paleocene Ranikot formations are dominated by Precambrian to early Paleozoic zircons (1 Ga–500 Ma), diagnostic of Indian sources. A significant shift in provenance is observed in the early Eocene Ghazij and Nisai formations, characterized by the first appearance of Early Jurassic to Eocene zircons (178–55 Ma). The Oligocene Chitarwatta and Khojak formations exhibit dominant age peaks between 194–32 Ma, along with minor older age populations, reflecting sustained input from Asian sources and nascent Himalayan tectonostratigraphic units.

A corresponding shift in εNd(0) values (from –17.2 to –8.3) and a decline in $^{87}Sr/^{86}Sr$ ratios from the Paleocene–Eocene transition to the Miocene further support this provenance reorganization. Integrated with Eocene ZHe cooling ages, shift in paleocurrents and sedimentary facies trends, these results indicate a major reorganization of sediment sources around ~56 Ma, consistent with a single-stage India–Asia collision in the western Himalayas.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Economic and Social Impact of the UNESCO Global Geopark Thüringen Inselsberg-Drei Gleichen and its related projects on the regional development

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The UNESCO Global Geoparks were established in 2015 and developed alongside a corresponding increase in the demand for geotourism. The UGGps are also developing their own strategies to enhance environmental education and to actively improve the economic and social conditions of the regions where they are located. Despite this, the lack of dedicated personnel and projects to evaluate the Geoparks' impact represents a challenge for all Geoparks worldwide.

To address this challenge, the UGGp Thuringia Inselsberg Drei Gleichen has already developed several surveys to improve its offerings. For example, the Bromacker fossil site, despite its scientific importance, accessibility, and central role in obtaining UNESCO Geopark recognition, was found to be almost unknown among locals and tourists in the region. By leveraging the potential of the Bromacker and other Geopark-related projects, interviews and surveys with citizens and tour operators were carried out and evaluated. Furthermore, the opinions of companies cooperating with the Geopark were included. Among the preliminary results, the interviews with companies highlighted the Geopark-related project as a significant economic opportunity, and the visibility of the Bromacker fossil site has increased dramatically.

03.07 Risks from a Changing Cryosphere

Exploring permafrost's role in containing legacy contaminants in the Mackenzie River Delta using electrical resistivity tomography

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Oil and gas exploration activities of the past century have left the Mackenzie River delta of the Canadian Northwest Territories dotted with more than 200 drilling mud sumps. These sumps are pits created by excavating the ground, placing drilling fluid wastes and drilled cuttings inside and backfilling with excavated material. The initial assumption was that the permafrost would provide a containment and prevent the escape of the contaminated material to the environment. However, as the Arctic warms due to climate change, it is uncertain whether permafrost will keep performing this containing role in the long-term. In this work, we monitor the apparent electrical resistivity of the shallow subsurface using repeat Electrical Resistivity Tomography (ERT) measurements in order to understand the freezing and thawing of the sumps. This also allows us to observe changes in the temperature and ice content of permafrost beneath the sumps and the surrounding tundra. We look at data collected from August 2023 until August 2025 from 4-day to seasonal intervals, examining changes of the sumps over time and contrasting them with the surrounding tundra. With our results we aim to shed light on the thermal effect these legacy contaminated sites have on the surrounding landscape and describe changes that might affect their containment function.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Quantifying the amphibole-forming peritectic reaction in mafic calc-alkaline and alkaline systems: an experimental study

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Amphibole is a common hydrous mineral in mafic calc-alkaline and alkaline magmas that typically crystallizes via a peritectic reaction. Due to its flexible crystal structure, amphibole covers a wide range of chemical composition, making it a crucial mineral phase for thermobarometry, oxybarometry, or diffusion chronometry. Up to date, only a limited amount of experimental studies focused on the amphibole peritectic reaction in basaltic to basaltic-andesitic systems, showing that the reaction involves various silicate minerals, such as plagioclase, olivine, orthopyroxene and clinopyroxene. However, although these studies provide first insights, systematic investigations allowing us to predict amphibole crystallization are still missing. The aim of our contribution is to experimentally quantify the amphibole-forming peritectic reaction, and to understand its dependence on various parameters (e.g. pressure or bulk composition). Equilibrium crystallization experiments were performed in internally heated pressure vessels (IHPV) between 200 and 400 MPa and temperatures between 900 and 1000 °C employing varying initial bulk H_2O contents. Oxygen fugacity was buffered at conditions ranging from NNO^{+2} to $NNO^{+2.3}$. So far, two different starting compositions were explored: a high-Mg basalt from the Adamello Batholith (Italy), and a magnesian basalt from the Cascades magmatic arc (USA), covering the typical compositional range of mafic arc magmas. Our preliminary results indicate that, minerals assemblages (e.g. plagioclase or orthopyroxene) involved in the amphibole peritectic reaction vary as a function of pressure and bulk system composition. Combining our dataset with literature data, we formulated a preliminary, quantitative model of the amphibole-forming peritectic reaction for calc-alkaline and alkaline magmas.

07.03 Quantifying surface and near-surface dynamics with remote sensing and geophysics

Linking microbial dynamics to geophysical signals in porous media

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Understanding near-surface biogeochemical dynamics is vital in the context of rapid environmental change. Spectral induced polarization (SIP), a non-invasive geophysical method, holds potential for monitoring microbial activity and abundance. A key driver of subsurface biogeochemical processes. We investigated the SIP responses of Shewanella oneidensis MR-1 in reactors packed with alginate beads as an inert porous medium. By analysing the imaginary conductivity (response of the SIP signal, we found that SIP signals closely tracked microbial growth phases, as confirmed by measured colony forming units, CFUs, (R2 = 0.80) and ATP (R2 = 0.90) measurements. SIP responses peaked during exponential growth and declined in the stationary phase. Notably, the bead-packed systems provided stable signals due to reduced cell settling (often a drawback of pure suspension experiments). Our results demonstrate that SIP can effectively detect and monitor biologically driven changes in the electrical properties of porous media. By working with inert beads, we have isolated cells' responses from interactions between cells and mineral or organic colloids. This study supports the advancement of SIP as a high-resolution method for quantifying dynamic microbial activity in porous media. Ongoing research aims to upscale our findings to study the effect of microbial metabolic state on their electrical properties. Planned retentostat experiments are expected to improve our quantitative understanding of microbially generated SIP signals and contribute to their eventual deployment as an off-the-shelf monitoring tool for non-geophysicists.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Chronology of the oldest CC planetesimals inferred from Cr isotopes in group IVB irons

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Magmatic iron meteorites sample the metal cores of differentiated planetesimals formed through segregation and crystallization of metallic melts. Group IVB irons are the most depleted in volatile elements and have the youngest Hf–W ages among magmatic irons [1]. Variations in their metallographic cooling rates suggest that the IVB core cooled without an insulating mantle, likely removed during a collisional disruption of the parent body [2]. To better understand the chronology of the IVB parent body, and to search for isotopic signatures that may record post-core formation re-mixing of metal and silicates, we applied the ^{53}Mn-^{53}Cr system to chromites from four IVB irons. Chromites were chosen because they are unaffected by cosmic ray-induced Cr isotope shifts [3]. All four samples exhibit indistinguishable nucleosynthetic ^{54}Cr, similar to CV chondrites, supporting a genetic link to the carbonaceous chondrite (CC) reservoir. However, the samples show distinct radiogenic ^{53}Cr, corresponding to an apparent ^{53}Mn–^{53}Cr model age spread of ~3 Ma. This spread likely does not reflect differences in metal segregation timing, as all samples yield identical Hf–W ages [1]. Instead, the 53Cr variations likely result from the addition of mantle-derived radiogenic 53Cr during partial metal–silicate re-equilibration caused by impact disruption. This interpretation is supported by metallographic cooling rates for outward crystallization of the IVB core [2] and our observation that later-crystallized IVBs display more radiogenic ^{53}Cr.

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01.24 Fieldwork as common playground: the importance of geological survey to unravel Earth processes

Challenges and societal consequences of downsized bedrock mapping: A case study from Sweden

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A bedrock map constitutes a conceptual model derived from a synthesis of field and laboratory observations, data extrapolation and interpolation, and conceptual thinking grounded in empirical evidence. Bedrock mapping is therefore inherently dependent on technological and scientific advancements and must be approached as a long-term, continuous process of knowledge accumulation.

The societal demand for bedrock mapping is extensive. Accurate and detailed mapping underpins assessments of mineral resources, construction materials, and groundwater reserves, as well as the geological premisses for infrastructure development, including the construction of subsurface facilities such as, tunnels, nuclear waste repositories, carbon capture storage sites, and facilities for extraction and storage of thermal energy. Furthermore, it provides critical support to disciplines such as, for example, environmental geochemistry, archaeology, forensic science, historical industrial studies, and forestry.

In Sweden, systematic and long-term basic mapping of the bedrock is today, in practice, non-existing and restricted to the location of known mineral deposits and narrow corridors of infrastructure. As a consequence, the bedrock information for large parts of the country is outdated or overly generalized, adversely impacting economic development, technological innovation, and efforts to address climate and environmental challenges. This deficiency is exemplified by three cases: (i) the deceleration of development and increased costs for infrastructure projects within the construction intensive Stockholm region; (ii) difficulties in modelling the build-up of the subsurface bedrock, affecting investment decisions for underground facilities; and (iii) challenges in interpreting analytical results in the absence of an up-to-date field context.

01.02 Anthropogenic geomorphology

Whispers from the Depths: tracing a century of environmental shifts in the Central and Kashmir Himalayas

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Environmental changes in the Indian Himalayas due to human activities remain poorly understood. To investigate this, we analyzed lake sediment cores from the Central and Kashmir Himalayas to reconstruct pollution, eutrophication, and fire history over the past-century. We measured concentrations, compositional variations, and temporal trends of alkylated-polycyclic aromatic hydrocarbons (PAHs), monosaccharide anhydrides, fecal biomarkers, and aliphatic hydrocarbons, including n-alkanes, acyclic and cyclic isoprenoids. We hypothesize that pyrogenic processes, particularly low-intensity forest-fires, play a significant role in lake eutrophication by delivering nutrient-rich ash and altering catchment biogeochemistry, thus accelerating ecological changes in these sensitive alpine ecosystems.

Our findings show a steady rise in total PAHs since the 1970s, with compositional shifts reflecting intensified socio-economic activities and pollution. Diagnostic ratios of multiple methylated and non-methylated PAHs suggest that pyrogenic sources are the main contributors to sedimentary PAHs. Botryococcenes (C31–34) and n-alkanes concentrations also displayed an increasing trend, peaking in the 1980s. This peak coincided with changes in the composition of long (nC26–36), mid (nC21–25), and short-chain (< nC21) n-alkanes, reflecting environmental shifts likely driven by both pollution and fire-related inputs. The detection of monosaccharide anhydrides supports the occurrence of regional low-intensity fires, likely contributing to nutrient influx through ash deposition and post-fire runoff, further altering lake trophic states.

This study proposes a fire-induced nutrient enrichment mechanism 'pyroeutrophication', acting in tandem with anthropogenic pollution. As the first of its kind from the Indian subcontinent, our findings offer valuable molecular insights into historical environmental changes and shed light on mitigation strategies for fragile Himalayan landscapes.

04.06 Coupled Fluid-Rock Deformation: Unraveling Multiscale THMC Dynamics for Fundamental Geological Processes and Societal Challenges

Thermo-Hydro-Mechanical-Chemical (THMC) reactive transport modeling of Mg isotope fractionation to constrain the timescales of fluid-driven rock transformation in the crust

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Fluid-rock interactions can induce significant chemical changes, resulting in metasomatic rock transformations or formation of metasomatic fronts when mass transfer is substantial. Among the chemical agents driving metasomatism, magnesium (Mg) plays a critical role in mafic/ultramafic rock systems, altering bulk composition and mineralogy. Additionally, the mass difference between ^{24}Mg and 26Mg isotopes enables detectable kinetic fractionation.

This study examines a metasomatic reaction zone in the Voltri Massif (Ligurian Alps, Italy), formed through high-pressure diffusional metasomatism of metagabbro by Mg-rich fluids equilibrated with serpentinite. This zone is an ideal natural analogue for reactive fluid flow between the subducting hydrated mantle and the overlying mafic crust. Evidence for Mg metasomatism includes a continuous MgO gradient, transitioning from serpentinite (~40 wt.%) to metagabbro (~5 wt.%). Isotopic analysis reveals significant fractionation: δ^{26}Mg values range from +0.09‰ in serpentinite to -1.1‰ in the reaction zone, then increasing to -0.1‰ in metagabbro. This trend indicates kinetic isotope fractionation driven by Mg diffusion.

A reactive transport model incorporating viscous rheology is applied to investigate porosity- permeability evolution and estimate process duration. Integrating bulk rock major element and Mg isotope geochemistry with fully coupled Thermo-Hydro-Mechanical-Chemical (THMC) model for reactive transport and phase equilibria, we analyze geochemical and mineralogical transformations across the reaction zone. The model results are validated by fitting field-based geochemical and isotopic data, ensuring consistency with observed MgO gradients and δ^{26}Mg fractionation patterns. Systematic numerical simulations and analyses provide insights into the timescales of Mg metasomatism, shedding light on the dynamics of such metamorphic processes.

04.01 Prospection and extraction of critical and strategic raw materials in Europe

Targeting deep-seated critical minerals in Poland using symbolic artificial intelligence

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The Suwałki Anorthosite Massif in northeastern Poland contains deep-seated Fe-Ti-V mineralisation associated with anorthosite-related mafic intrusions—resources deemed critical by the European Union. Hidden beneath ~800 metres of sedimentary cover, these deposits require advanced exploration techniques. This study applies knowledge-driven fuzzy inference systems (FIS), a symbolic AI method that integrates expert geological knowledge into computer models, to predict mineral potential using geospatial datasets.

FIS uses fuzzy logic to define key mineralisation indicators, such as magnetic and gravity anomalies and structural features, based on a mineral systems model. This model outlines three critical components for Fe-Ti-V mineralisation: mantle or lower-crust-derived magmas or mushes in post-collisional extensional settings, deep crustal faults as magma conduits, and structurally controlled traps that enable magma differentiation and oxide enrichment. GIS-based predictor maps are generated and combined using logical if-then inferencing rules to produce a continuous prospectivity map.

Due to the depth of mineralisation, limited data availability presents a challenge. Innovative data engineering techniques were used to extract meaningful features from available geophysical datasets, including nationwide magnetic and gravity data and a 3D p-wave seismic velocity model. From these, key features such as deep magma sources, structural conduits, and intrusive bodies were identified. The resulting FIS-based prospectivity map highlights unexplored areas with high potential, supporting future mineral exploration in the Suwałki region by guiding future exploration strategies.

10.01 Open Paleontology Session

Frozen mid-flight: Parasitism of dipteran hosts by parasitengonan mite larvae in amber

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A syninclusion is composed of more than one specimen, fossilised in the same amber piece. In rare cases, clear signs of interactions between organisms before their entrapment in the tree resin can be observed. This is known as “frozen behaviour”. “Frozen behaviour” in amber is valuable not only due to its scarcity, but also because it offers information to reconstruct the network of interactions between organisms of past ecosystems. One of the most common forms of interaction in amber is parasitism, and among these, the most commonly reported parasites are mites. Mites of the group Parasitengona have a complex life cycle in which their larvae are parasitic, while during active post-larval stages (deutonymph and adult) they are predatory. Larvae feed on their hosts, but also use them to disperse. Most lineages of terrestrial parasitengonans parasitise other euarthropodans during their larval stage, feeding on their haemolymph, with the exception of some groups associated with vertebrates and very few non-parasitic ones. Due to their strong attachment devices that keep their mouthparts still connected to their host during the process of amber formation, they are among the most frequently reported fossil parasites. Here we present and describe the parasitic relationship of fossil terrestrial parasitengonan larvae with dipteran hosts. We show around 50 new records of such associations, more than doubling the previously reported cases. Moreover, we further discuss the relevance of dipterans as hosts of terrestrial parasitengonan larvae both in the fossil record and for modern lineages.

01.05 From mantle to crust: following melt evolution from source through the lithosphere

Magmatic evolution and secondary silica mineralisation in the amethyst-hosting lavas of the Paraná-Etendeka Large Igneous Province, Uruguay: Insights from a multidisciplinary study

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The Paraná-Etendeka large igneous province (PELIP) covers ca. 1.5 million km^2 in South America and Africa. Its voluminous continental basalt flows are related to the opening of the South Atlantic Ocean in the Early Cretaceous (~135–132 Ma). In South America, the geochemical and petrological evolution of the PELIP has been extensively studied in Brazil, where the largest exposures are found, while the Uruguayan portion remains less studied. We conducted a multidisciplinary study on the Uruguayan lavas, which host the world-class amethyst-agate deposits of Los Catalanes. Our study integrates field observations, petrography (including cathodoluminescence microscopy), whole-rock geochemistry, isotopic compositions, and mineral chemistry, to provide new insights into the magmatic evolution of the PELIP in Uruguay, and its role in conditioning the system for secondary silica mineralisation. Unaltered lava levels show loss on ignition (LOI) < 2 wt.%, and support our petrogenetic interpretation. The lavas are low-Ti tholeiites and range in composition from basaltic andesite to andesite. They are enriched in incompatible elements relative to MORBs and present “arc-like” trace element patterns, such as Large-Ion Lithophile Elements enrichment relative to High-Field Strength Elements, and negative Nb anomalies. The trace element patterns and Sr, Nd, and Pb isotope signatures suggest an enriched mantle source subsequently modified by magma-crust interaction. On the other hand, amethyst-hosting levels within individual flows show higher LOI (up to 9 wt.%) and lower Ca, Mg and Al concentrations, suggesting low-temperature hydrothermal alteration and/or weathering. The association between mineralised geodes and altered lavas demonstrates that the silica mineralisation was controlled by pervasive fluid infiltration.

03.01 Recent Advances in the Geological Research of Marine Environments

The discovery of a chain of mud volcanoes in the SW Barents Sea: unveiling the Polaris Mud Volcano Complex

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Global estimates on the number of submarine mud volcanoes are highly uncertain, as well as their role in the deep-sea biosphere and methane budgets. Several expeditions have been conducted in the Norwegian sector of the Barents Sea over the last two decades, with hundreds of hydrocarbon seeps being mapped and investigated. Still, the only mud volcanoes known so far are the Håkon Møsby Mud Volcano (confirmed in 1995) and Borealis (2023). I will report on the recent discovery of ten mud volcanoes in the Southwestern Barents Sea. They form flat-topped mounds which are connected to seismic chimneys rooted within the infilling of a buried Pleistocene mega-slide scar. I will show ROV seafloor imagery depicting sedimentary features and chemosynthetic habitats, and discuss the 3D seismics and gas geochemistry. Methane-derived carbonates collected from the top of the mud volcanoes exhibit various facies linked to fluid seepage, providing evidence of prolonged activity.

01.12 Coastal dynamics in different timescales: from seconds to millennia

Echoes of past extreme wave events: Paleoenvironmental reconstruction in Vatika Bay, SE Peloponnese (Greece)

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Situated in a tectonically active region, the Peloponnese is susceptible to large earthquakes, submarine landslides and volcanism, hazards capable of generating destructive tsunamis. Despite this, the triggering mechanisms and recurrence intervals of such events remain poorly understood. Coastal lagoons serve as valuable geoarchives, preserving the sedimentological footprints of such high-energy wave events. These fragile environments are highly sensitive to environmental and sea-level changes, making them ideal for reconstructing coastal dynamics.

Within the framework of the MULTI-MAREX project, this study investigates the sedimentary archives of Vatika Bay to identify traces of past marine geohazards. A multi-proxy approach was employed to analyze the sediments, including grain size, magnetic susceptibility, inorganic geochemistry and microfaunal composition.

Sedimentary records across the study area exhibit features of extreme wave deposits. These include abrupt changes in sedimentation with distinct coarser layers intercalated within muddy lagoonal and alluvial deposits, reflecting low-energy background sedimentation interrupted by an extreme marine incursion event. Sharp basal contacts and fining upwards sequences further support the marine origin of the deposits. Preliminary geochemical and foraminiferal analyses reveal delimited elevated concentrations and ratios for marine indicators, alongside sharp increases in foraminiferal assemblages, dominated by species typical of coastal environments.

Nevertheless, the shape and preservation potential of these deposits are influenced by the complex interplay between local tectonics, coastal morphology and lagoonal dynamics. Overall, this work provides new insights into the paleoenvironmental evolution of the coastal lagoon and its extreme wave event history, contributing to our understanding of marine geohazards in Greece.

06.01-b Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

The rocky foundation of the GSEU project: a pan-European machine-readable hierarchical vocabulary to describe the lithology on geological maps and of boreholes

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To understand geological information across political boundaries, harmonisation (semantically and geometrically), is crucial. The GSEU project (Geological Service for Europe) within the EU Horizon Europe programme, addresses this challenge by building a geological framework which encompasses a pan-European data model, a metadata system, methods to visualize 3-D models and hierarchical, machine-readable vocabularies based on existing terminologies.

Building spatial geological databases for the European continent started from 1995 to 2005 with the project of the International Geological Map of Europe and Adjacent Areas (IGME 5000). Later, based on the OneGeology-Europe project vocabularies (2008–2010), the geology data specification of the European INSPIRE Directive became European standard in 2013.

While these past vocabularies are comprehensive, they lack terms to describe large scale geological map information and specific thematic properties. GSEU fills that gap and hierarchical scientific vocabularies for lithology, anthropogenic deposits and lithotectonic units are developed to define the concepts to which geometrical descriptions (lines, polygons, and volumes) can be linked. Custom programming scripts, written in Python and JavaScript help to automatize the data handling and visualisation of the hierarchical relations.

- The endeavour faces considerable challenges, such as:
- setting up vocabularies that take into account differing classification which describe the same concept (term),
- coping with obsolete and/or strictly regional terms,
- taking into account multiple hierarchies and
- including genetically related terms, qualifiers and compound names.

The presentation demonstrates the project's approach to build pan-European lithological vocabularies, its challenges and provides an outlook to the future development.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Transport and trapping of sediment in the Triassic Buntsandstein Group: New insights based on a multimethodological approach

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What is the status for sediment-transport reconstructions of the Lower Triassic intracontinental Buntsandstein Group and equivalents? Where and why was sediment trapped? Can central Europe be compared to equivalents in the interconnected North Sea? We answer these questions with a multimethodological approach. Sedimentation took place during arid climate in a sag basin of the Central European Basin in Pangea. Fluvial palaeotransport directions indicate detritus transported into a large central endorheic playa lake from the Massif Central in the west and the Bohemian Massif in the east. Aeolian transport mainly was from the south, causing sediment mixing between different fluvial catchments as indicated by zircon grain-size and U-Pb-age correlations, and zircon grains from the Variscan belt and the Bohemian Massif in Denmark. They indicate temporary desiccation of the playa lake. Alongshore lacustrine transport modified the detrital composition further. Also several submerged topographic barriers influenced sediment routes. In Denmark, heavy-mineral, zircon, and seismic data demonstrate that the Ringkøbing-Fyn High prevented sediment supply from the Fennoscandian Shield. In the central basin, transport around the Eichsfeld-Altmark Swell caused seemingly contradicting provenance results from petrography, cathodoluminescence of quartz, and zircon data due to sorting processes. Further north in the central North Sea, seismic and petrophysical data indicate that sediment traps were more local due to mobilisation of underlying Zechstein-Group salt, creating Triassic minibasins. Zircon and whole-rock geochemical data are in progress to reveal if the sources were local or if the area rather was comparable with the more regional sediment-transport systems in continental Europe.

01.29 Environmental Hazards and Risks

Environmental and Social Impact Assessment of hydrocarbon Exploration Well, Garmian, Kurdistan Region- Iraq

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The study encompassed a detailed description of existing environmental and social baseline conditions based on conducted surveys, scoping of the anticipated impacts, and description of the most significant adverse impacts during well construction and operations. The study area is part of the Zagros Fold Thrust Belt and represents the Low Folded Thrust Zone. Vegetation cover in the area is limited to the typically thin cover of native grasses and herbaceous species.

Field surveys for the project area identified 66 taxa that were observed in this study. The area lies within the edge of an important flyway for birds, with at least 68 species documented, including residents and several migratory species.

The potential impacts of the project on the environment and their significance were assessed before the project development. The primary environmental and social concerns associated with hydrocarbon exploration in the area were: Loss of pasture for livestock, grassland steppe habitat for wildlife and displacement of wildlife, and loss of productivity on cultivated lands. We found that the impacts associated with the project are; the risk of wildlife mortality and displacement, human activity, exposure to contaminants and hazardous substances, the potential for spills, produced water and drill cuttings, and emissions including dust and noise; risks to groundwater as a result of drilling and waste management practices, potential reduction in local water resources as a result of water withdrawals, increased traffic safety risk: and impacts to socio-economic and cultural well-being and cumulative effects, particularly where a discovery is made.

01.06 Tectonic Systems – TSK Open Session

Tectono-magmatic history of meta-igneous rocks from Nordaustlandet, Svalbard, inferred from $^{40}Ar/^{39}Ar$ and U-Pb geochronology and microstructural analyses

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Situated in the High Arctic, the island of Nordaustlandet is one of the least understood geological terranes on Earth regarding Precambrian and Paleozoic geodynamic processes. Such knowledge is, however, essential to reconstruct the geological evolution of the continental crust surrounding the Arctic Ocean. To elucidate the age of intrusion and tectono-metamorphic activity, the foliation-forming mineral phases, alkali feldspar and zircon grains from a total of 10 samples of meta-igneous rocks from northern Nordaustlandet were dated by $^{40}Ar/^{39}Ar$ and U-Pb geochronology. The geochronological study was complemented by a regional compilation of planar metamorphic fabrics and a microstructural analysis. The geochronological results reveal that the emplacement of metagranitoid rocks occurred during the Late Meso- to Early Neoproterozoic era (Stenian – Tonian), followed by Late Caledonian (Scandian) deformation and metamorphism during a Late Silurian to Early Devonian event. Neoproterozoic magmatic bodies intruded at mid-crustal level and were exhumed during the Caledonian orogeny between 420.1 ± 2.3 Ma and 399.9 ± 1.7 Ma. Structural observations allowed us to constrain the mechanisms, intensities and shortening directions of this deformation, which occurred under medium-grade metamorphism. This study indicates that Meso- to Neoproterozoic granitoid rocks, pervasively exposed at the northern coast of Nordaustlandet, were exhumed during Late Silurian to Early Devonian times and served as host to Late Caledonian felsic intrusions.

01.04 Latest Achievements in Scientific Ocean and Continental Drilling

Analysis of brittle shear faults of IODP-ICDP expedition 364 drill core: testing numerical models of late-stage impact cratering

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Drilled rocks from the Chicxulub impact crater are pervasively affected by decimeter-scale brittle shear faults. Measurements of the orientations and slip senses of 602 shear faults in shocked granitoid target rocks resulted in a unique fault-slip data set of unprecedented detail. The shear faults most likely represent a late stage of cratering, during which the crater grew horizontally. Based on numerical models, deformation during this stage is characterized by concentric and vertical extension and uniform radial shortening. Extracting principal strain axis directions from the inversion of brittle shear faults allowed us to test to what extent the observed brittle deformation corresponds to the deformation regime predicted by numerical models. As the fault-slip data were measured on drill core segments in horizontal position, the data had to be rotated back with regard to the *in-situ* positions of the segments prior to inversion. Results of the inversion show that the principal directions of observed brittle strain adhere to numerically predicted directions in the vicinity of a most prominent deformation zone at a depth between 1,220 and 1,316 m below the sea floor. By contrast, elsewhere above this deformation zone, principal strain orientations seem rather non-uniform. It remains to be determined to what extent the variation of strain axis orientations with depth may be systematic or abrupt across possible structural or lithological discontinuities. At any rate, the local orientation of the principal strains is more variable than predicted for the apparently simple strain regime during late-stage crater growth predicted by numerical models.

01.26 Alpine-Zagros-Himalayan Orogenic System: Case Studies

The Collisional Iranian Plateau: Reassessing Geological History, Structure, and Surface Dynamics

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Located within the Arabia–Eurasia collision zone, the Iranian Plateau (IP) constitutes the second largest and elevated collisional plateau on Earth. The IP is predominantly situated on the Eurasian upper plate, has an average elevation of approximately 2 km and is characterized by a crustal thickness of up to 50–60 km, underlain by a thin mantle lithosphere with a lithosphere-asthenosphere boundary at depths of 100–120 km. The surface of the plateau exhibits a contractional basin-and-range morphology, encompassing both internally and externally drained sedimentary basins. Its interior is arid and displays relatively low topographic relief, in contrast to its steep, highly dissected margins, which locally form significant orographic barriers.

Although the uplift of the IP must have occurred after the most recent marine transgression (i.e., post ~17 Ma), several key questions remain unresolved. These include the development of a comprehensive geological model for the plateau, constraints on the timing and mechanisms of surface uplift, and the role of surface processes in shaping, preserving, or locally eroding the characteristic plateau morphology.

This contribution seeks to synthesize existing data and incorporate previously unpublished findings in order to provide an updated overview of the current state of knowledge. It further aims to identify key research challenges that will advance our understanding of collisional plateau evolution.

01.06 Tectonic Systems – TSK Open Session

2D Kinematic Modelling of the Gorski Kotar Region (NW Croatia): Influence of Lower Jurassic Extension on Cenozoic Deformation in the Northern External Dinarides

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The Dinarides fold-and-thrust belt formed during the Cenozoic collision between the Adriatic microplate and Eurasia. In the External Dinarides, thick carbonate platform deposits dominate, and structures generally strike NW–SE with SW-directed thrust vergence due to Eo-Oligocene shortening. In the Gorski Kotar region (NW Croatia), structures shift to a N–S trend with localized east-directed thrusting. Field data and geological profiles suggest that before Cenozoic contraction, the area experienced E–W-directed extension during the Lower Jurassic, leading to a ~2.7 km thick syn-rift sequence, about ten times thicker than coeval strata in adjacent regions.

To investigate thickness variations and structural architecture, we developed three geological cross-sections based on field measurements and geological maps. These were used in 2D kinematic forward models to simulate deformation over time. Raman Spectroscopy of Carbonaceous Material (RSCM) was applied to the highest structural unit to assess thermal maturity.

RSCM results show that Permian strata overlying Jurassic and Triassic units were heated to 227 ± 15 °C, implying ~7 km exhumation, assuming a geothermal gradient of 30 °C/km. The cross-sections reveal a NE- to E-directed passive roof thrust developed above a complex triangular structure. This present-day architecture is largely inherited from Lower Jurassic extension, accommodated by WSW-dipping normal faults. Lower Jurassic extension across the Adriatic shelf contributed to basin development in the Eastern Alps, Southern Alps, Apennines, and Dinarides, representing an early phase of intracontinental rifting prior to the opening of the Piemont-Liguria Ocean. These results emphasize the long-lasting influence of inherited structures on Cenozoic deformation.

07.02 Geothermal energy — Potential and utilisation of geothermal energy resources for the heat transition

Deep Geothermal Energy – Key for the heat transition and cornerstone for an european battery production

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Tiefe Geothermie ist für die Wärmewende in Deutschland eine Schlüsseltechnologie. In Hochpotenzialgebieten wie dem Oberrheingraben, dem Molassebecken und dem Norddeutschen Becken stellt Tiefe Geothermie oftmals heute schon die wirtschaftlichste Wärmegewinnungsmethode für kommunale Wärmenetze dar, die zudem auch mit Abstand den niedrigsten CO_2-Ausstoß aller erneuerbaren Energien aufweist. Die Wirtschaftlichkeit ist dabei aber vom lokalen Wärmebedarf und der Größe des bestehenden Fernwärmenetzes und der Bereitschaft der kommunalen Wärmeversorger dieses zeitnah auszubauen und die damit einhergehenden Kosten stemmen zu können, abhängig.

Die Gewinnung von Lithium aus den geförderten Thermalsolen des Oberrheingrabens oder Norddeutschen Beckens stellt dabei einen signifikanten weiteren Einnahmestrom aus der Geothermieanlage dar und kann über entsprechende Abnahmeverträge zur Reduzierung der Wärmegestehungskosten verrechnet werden. Anhand von spezifischen Beispielen kann dargestellt werden, wie hierdurch unerwünschte Steigerungen des Endkundenpreises für die Wärme minimiert und somit ein Anschluss and das Wärmenetz attraktiver gestaltet werden können. Die Gewinnung des Lithiums wiederum erfolgt durch die parallele Wärme- und ggf. Stromgewinnung bilanziell CO_2-frei und in Europa und stärkt damit die europäische Unabhängigkeit für kritische Rohstoffe.

02.01 The Tethys Ocean – the cradle of modern tropical life

Widespread fossil freshwater gobies (Teleostei, Gobioidei): true distributions or wastebasket taxa?

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Fossil remains of gobies are well known from Miocene freshwater deposits in the North Alpine Foreland Basin (NAFB) and Central Paratethys. Some of those have reportedly large distributions almost akin to extant invasive gobies. One example is “Gobius” (now Eleogobius) brevis (Agassiz, 1839), known from six localities across Western and Central Europe. Given this rather large distribution, the question stands whether this is the actual distribution of a single species or a wastebasket taxon.

Here, we reassess the taxonomic diversity of fossil remains known as Eleogobius brevis by focusing on two Middle Miocene palaeolakes from southern Germany (Ries crater, Oehningen) using historical material from museum collections (97 skeletons, many with otoliths preserved *in situ*). Based on comparative morphology using both osteological traits and otoliths, we show that the material comprises an unexpected taxonomic diversity of at least five previously unrecognized species.

Notably, none of the Ries gobies correspond to previously described species from the NAFB or Central Paratethys. Given the short time span of life-sustaining environmental conditions in the Ries crater lake and its isolation from major river systems, we thus infer a rapid goby radiation.

In contrast, otoliths preserved *in situ* in the Oehningen goby species indicate that these species had a broader distribution across the Middle Miocene freshwater systems of the NAFB.

Thus, E. brevis can be considered a wastebasket taxon. A careful re-examination of all specimens that were previously assigned to E. brevis is needed to confirm their taxonomic assignment.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Methodical derivation of expected and deviating evolutions (scenario development) for a potential repository site

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A safety case is a formal compilation of evidence, analyses and arguments that quantify and substantiate a claim that a repository will be safe. The description of the future evolution of a final repository system is a fundamental requirement for assessing its long-term safety and therewith part of the safety case. The deviation of future evolutions includes the analysis of relevant influencing factors and the uncertainties regarding the actual evolution of the final repository system.

The systematic determination of evolutions for a potential disposal site bases on a climatic and geological long-term forecast and a FEP catalogue (features, events and processes) for the respective site. For this purpose, the FEPs have to be classified according to their probability, their significance regarding their impact on safety functions, and based on regulatory requirements (FEP screening).

The objective of this project is the development of a comparable workflow for all host rocks and a rationale as to where this workflow must branch into different paths for various host rocks and emplacement concepts. Therefore, the project will focus on specific characteristics in the scenario development regarding the different host rocks and emplacement concepts. Subsequently, we plan to compile options for host rock specific standardizations for the methodology and to compare existing national and international workflows for the derivation of evolutions. The project therefore serves to harmonize scenario development in the course of the site selection process in Germany, pursuant to the Repository Site Selection Act (StandAG).

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

U-Pb zircon geochronology of metasedimentary and meta-igneous rocks of the Palatinate and Northern Vosges

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The (meta-)sedimentary succession of the Northern Vosges and adjacent scarce outcrops of crystalline basement in the Palatinate Forest are located in a key position at the transition between the Mid-German Crystalline Zone (MGCZ) and the Saxo-Thuringian Zone of the Central European Variscides.

Their geotectonic positions have been discussed widely in the past; while the crystalline rocks of the Palatinate are typically assigned to the MGCZ, the Northern Vosges are considered to be part of the Saxo-Thuringian Zone sensu strictu. Detrital zircon grains reveal different age spectra, showing a wide range of source areas and supply routes from source to sink. Maximum depositional ages in the Northern Vosges range from the Neoproterozoic to Cambrian (ca. 580 – 550 Ma) in the Villé unit (Southern succession) to Upper Devonian/Lower Carboniferous (ca. 360 Ma) in the Bruche unit (Northern succession) and the adjacent Palatinate Forest. The maximum depositional ages of the detrital zircon populations are in general agreement with biostratigraphic subdivisions of the respective units.

The zircon spectra of the Villé unit are very similar to those derived from the Saxo-Thuringian Zone, indicating sediment supply from the North Gondwana margin, whereas the spectra derived from the Bruche unit and the Palatinate Forest point to a close affinity to the MGCZ. This is additionally supported by a U-Pb concordia age of ca. 370 Ma estimated for the Albersweiler Gneiss, during this and previous studies. Our new results have consequences for the interpretation of the evolution and plate tectonic reconstruction of the Central European Variscides.

01.04 Latest Achievements in Scientific Ocean and Continental Drilling

Implications of radiogenic initial osmium isotopes in lower crust from the CM-1A drill site of the Oman Drilling Project (Oman ophiolite)

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One of the goals of the Oman Drilling Project has been to advance our understanding of the processes that formed and modified the oceanic crust in the Wadi Tayin massif of the Oman ophiolite. In a reconnaissance study of samples from the CM-1A drill core we show that both the lower layered gabbros with dunite-troctolite and dunite-wehrlite layers and the 150 m thick dunite units of the crust-mantle transition zone (CMTZ) mostly display suprachondritic initial γOs up to +54 (γOs represents the deviation of $^{187}Os/^{188}Os$ from a mean chondritic value) at the time of their formation around 97-95 Ma. In contrast, underlying mantle harzburgites and dunites at the drill site display mantle-like γOs (95 Ma) of -8 to +2, implying that most magmas that crystallized the lower layered gabbros and the CMTZ dunites never equilibrated with the local mantle rocks underneath. Other data on gabbros further up in the lower crust of the Wadi Tayin massif also indicate positive γOs (95 Ma), however, because of the high Re/Os of some samples, it is difficult to calculate reliable initial γOs (95 Ma)-values (Peucker-Ehrenbrink et al. 2012, Geology 40, 199–202). Nevertheless, from the limited data it appears that most of the lower oceanic crust in the Wadi Tayin massif may have been affected by magma or fluid with suprachondritic γOs (95 Ma). We will discuss hypotheses concerning the origin of the radiogenic osmium in the lower crust and propose ways of testing these ideas.

01.07 Stratigraphy in Earth System Science: methods, applications and case studies

The complexity of biozonations, with Devonian ammonoid examples

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Biostratigraphy explores the distribution of fossils in time and space to identify intervals that can be correlated regionally/globally. The time resolution of Devonian ammonoid biozones varies between 200 Ka (upper Givetian) and >2 Ma (middle Eifelian). Precision for zone bases and tops is shorter. Due to complex environments, the nature of biozones is also complex, which is not visible in common biozone terminology. Marine animal ranges are in general affected by sea-level, condensations, facies shifts, and sedimentary gaps. Despite their open shelf, pelagic lifestyle, even ammonoids were highly facies-sensitive. Different zone types are proposed:

Global Phylozones are defined by speciations and FADs (first appearances) within non-endemic, branching lineages, suggesting changes in pantropical populations (middle Frasnian Beloceratidae). Endemozones are defined by the FADs of endemic taxa (regionally different Famennian Prolobitidae). Migrozones reflect sudden immigrations of lineages that have a longer evolutionary history elsewhere (Triainoceratidae in Europe-North Africa-North America). Cryptozones are defined by the sudden spread of taxa with unknown ancestry (Frasnian Devonopronoritidae in the Altai Mts. and Iran). Ecozones include epiboles (population bursts) in wide-spread event beds (“Archoceras” in Upper Kellwasser Beds). Desaster zones can be recognized after major extinctions by blooms of opportunistic survivors (e.g. Postclymenia Zone after the Hangenberg Extinction). LAD zones follow small-scale disappearances of index taxa (e.g. upper Anarcestes Zone in the upper Emsian).

Internationally, the best correlation is achieved using genozones, with FADs of index genera (or genus groups) but different oldest species in different regions. This implies a mixture of phylogeny and migration.

01.12 Coastal dynamics in different timescales: from seconds to millennia

Evidence of Mediterranean tsunamis preserved in karst pockets on Malta

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The Mediterranean Sea has experienced numerous tsunamis, triggered by earthquakes along the Hellenic and Calabrian arcs, submarine landslides, and volcanic eruptions in Italy and Greece. Nonetheless, patterns related to the timing, frequency, intensity, and dominant triggering mechanisms of these events remain poorly understood. The Maltese archipelago is vulnerable to tsunamis from multiple directions in the surrounding Mediterranean seascape. Malta differs from other Mediterranean coasts because no onshore tsunami-related deposits other than coastal boulders have been reported. However, coastal boulder deposits are difficult to date or link to known events. To fill this gap, our study presents the first identification of sand-grade sediments in northern Malta (L-Aħrax Peninsula) interpreted as tsunami deposits. Found within karst pockets (natural solution hollows in limestone), these shelly sands overlie terra rossa soils and are well-preserved due to the relatively protected nature of the karst hollows. The work provides the first description of tsunami sediments in Malta, characterizing their granulometric properties, sedimentary structures, and micro-faunal assemblages, all indicative of a marine origin. Notably, the presence of the foraminifera Amphistegina lobifera, a species introduced to the Mediterranean after the 1869 opening of the Suez Canal, provides a relative age constraint. The close spatial association of these sands with large coastal boulders supports a tsunami origin. These findings offer the first robust evidence of tsunami deposits in Malta and highlight the utility of karst features in preserving such records. They also expand understanding of tsunami hazards in the Central Mediterranean, with implications for regional coastal risk assessments.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

TUNB Velo 2.0: Towards a Regional Seismic Velocity Model for the North German Basin

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The TUNB project, conducted from 2014 to 2021, marks an important step in the geological 3D modelling of the North German Basin. Through the collaboration of the State Geological Surveys of the participating federal states and the Federal Institute for Geosciences and Natural Resources, a comprehensive 3D model was created, comprising 13 geological horizons and important structural elements such as faults and salt structures. The model serves as a basis for a wide range of subsurface applications, from CO_2 storage to the final disposal of radioactive materials.

The ongoing follow-up project, TUNB Velo 2.0, builds on this foundation by developing a parameterized, seismic velocity-based volume model. In this project, each participating Geological Survey contributes its own model component using regionally available data, workflows, and modelling strategies. Depending on data availability and local priorities, this includes, for example, stacking velocities, checkshots, and borehole sonic logs. The aim is to enable a more accurate time-to-depth conversion of seismic data and to support improved geometric interpretations of the subsurface on a regional scale.

Now TUNB Velo 2.0 is progressing towards its final phase. This poster presents an overview of the project's goals and background, summarizes the current status of model development, and outlines the modelling concepts used to integrate velocity information into a geological framework. Detailed contributions on specific methods, datasets, and regional modelling strategies are presented in accompanying talks and posters, and illustrate how the resulting model components may support further geological investigations in the respective regions.

01.21 Advances in Geochronology: from tradition to avant-garde

First steps of LA-ICPMS U-Pb magnetite geochronology

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The density of metamorphic reactions occurring in subduction zones, due to intense fluid-melt activity, is very high. One of the minerals resulting from all these reactions, both in the downgoing slab and in the serpentinized mantle wedge, is magnetite. Its study is crucial to understanding geodynamic processes, as it gives information about oxidized fluids, temperature, trace elements mobility, etc... It encompasses not only metamorphic petrology but also tectonic processes of accretion, exhumation/obduction, as well as ore geology, as it is a ubiquitous mineral in numerous ore deposit types. Being able to date magnetite, providing a temporal framework to all these reactions, is to put in one more piece of this big puzzle.

Advances in the LA-ICPMS have made that currently, the U-Pb dating reaches far beyond the traditionally dated minerals (zircon, monazite, rutile, etc.). In this context, at the FIERCE laboratory of the Goethe University-Frankfurt, we have investigated the possibility of dating magnetite. Magnetite from several localities has been studied, resulting in a variety of U and Pb contents (up to a few µg/g for U) as well as a significant spread on the U/Pb ratios. This has allowed us to date the studied samples, with internal precisions as good as 1.5% in the best of the studied cases.

Recognising the possibility of dating such a mineral is only the first step in the implementation of the technique. Currently, we are comparing the ages obtained by different methods and different minerals, to search for a magnetite reference material.

04.06 Coupled Fluid-Rock Deformation: Unraveling Multiscale THMC Dynamics for Fundamental Geological Processes and Societal Challenges

Microscale Controls on Garnet Textures: The Role of Fluids and Local Equilibrium in Fjørtoft Metapelites (WGR, Norway)

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Garnet textures in metamorphic rocks provide valuable insights into fluid–rock interactions, metamorphic reactions, and the mechanisms driving mineral transformations during retrogression. This study focuses on metapelitic samples from the Blåhø Nappe on Fjørtoft Island (Western Gneiss Region, Norway), part of the Caledonian allochthon. The aim of this work is to investigate how local mineralogical composition and fluid availability during retrogression influence garnet textures. Chemical mapping reveals a systematic association between grossular-enriched garnet rims and the presence of plagioclase and biotite, suggesting a coupling between garnet zoning and the surrounding mineralogy. Geothermobarometric and thermodynamic constraints, support amphibolite overprinting over older eclogite facies. Thermodynamic calculations based on Gibbs free energy minimization were performed to better understand the reactions involved. In particular, the breakdown of phengite in the presence of quartz and fluid is considered a key process leading to the formation of biotite and plagioclase, with implications for garnet zonation. This case study highlights how microscale equilibrium conditions and mineral interfaces can interact with high-grade metamorphism garnets.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Regional velocity modelling of the North German Basin in Saxony-Anhalt as part of the TUNB Velo 2.0 project

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Reliable velocity models are crucial for accurate seismic time-to-depth conversion. Existing regional velocity models in Saxony-Anhalt date back to the 1970's, indicating the demand for updated models based on recent data. Current best practices in geophysical modelling call for the development of three-dimensional velocity models to account for the structural complexity of the subsurface.

A modelling workflow has been developed for the northern part of Saxony-Anhalt, building upon the 3D structural model of the North German Basin from the TUNB project. Vertical seismic profiles from more than 200 boreholes form the essential data basis. Initial velocities and depth gradients for 8 velocity intervals from top Cenozoic to base Zechstein were determined. Linear interval velocity-depth functions were derived and calculated within a 3D voxel-based model. Finally, the model is aligned with recently developed ones of the neighboring federal states and compared to vintage velocity models.

Our workflow represents an efficient and modern approach for 3D velocity modelling and can be easily extended to other areas and 3D models. The large-scale velocity model will serve as starting model for future (re-)processing campaigns and supports planning and interpretation of upcoming local seismic studies.

03.05 Advances in Paleoclimate Proxies and Their Applications

Effects of mineralogy on carbonate clumped isotope composition below analytical resolution

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Phosphoric acid digestion of carbonates is associated with fractionations of both bulk oxygen and clumped isotopes. Accurate knowledge of the effect of cation substitution on the degree of isotopic clumping in the carbonate phase (Δ63, Δ64) and on acid fractionation factors (Δ*47, Δ*48) is crucial for accurate temperature reconstructions based on clumped isotope measurements (Δ47, Δ48) of the extracted CO_2. Previous studies have yielded contradicting results whether a universal Δ*47 acid fractionation factor and Δ47-T relationship is valid for all carbonate mineralogies, and a systematic investigation of mineralogy-specific effects on Δ48 and Δ*48 is still lacking.

We have determined Δ47 and Δ48 values of stochastic (i.e, Δ63 = Δ64 = 0) and non-stochastic calcites, aragonites, dolomites, witherites, and siderites with outstanding precision. We demonstrate that stochastic calcite, aragonite, dolomite, witherite and siderite exhibit statistically indistinguishable Δ47, CDES90 and Δ48, CDES90 values. In addition, Δ47, CDES90 and Δ48, CDES90 values of non-stochastic aragonites, (proto-)dolomites and witherite correspond to calcite equilibrium values[1] predicted by their independently known formation temperatures. These results provide evidence that calcite, aragonite, dolomite and witherite share indistinguishable Δ*47, Δ*48 and equilibrium Δ63-Δ64-T relationships. Consequently, the calcite-specific equilibrium Δ63-Δ64-T relationships[1] can be reliably applied to aragonite, dolomite, and witherite. More investigations are necessary to clarify its validity for siderite.

Reference

[1] Fiebig, J. et al. Chem. Geol. 670, 122382 (2024)

01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

Timing of magma segregation governs distinct geochemical traits of late-stage mineral and melt phases in alkaline volcanic rocks

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Three primitive alkaline SiO2-undersaturated volcanic edifices from the southern Central European Volcanic Province (SW Germany) comprise coarse-grained, mm- to cm-thin veinlets and pockets of low-pressure differentiates, representing a missing link in an evolutionary trend towards phonolites. [1] In the Hegau region (Hohenstoffeln), a melilite-bearing olivine nephelinite contains ijolite pockets with skeletal perovskite, titanomagnetite, and euhedral fluorapatite. [2] Compositionally similar olivine melilitite from Urach (Sternberg) is crosscut by lileyite- and wadeite-bearing ijolite veinlets, in which titanomagnetite and perovskite lack skeletal shape. [3] Nepheline syenitic domains in a phlogopite-nepheline basanite from the Kraichgau region (Steinsberg) contain less clinopyroxene, titanomagnetite, and apatite, but accessory titanite. Despite variable host magma compositions, most differences between the occurrences are related to the exact timing of residual melt separation, a key factor in explaining the trace element evolution of late mineral and melt phases: at advanced clinopyroxene crystallization and perovskite saturation (Sternberg), massive trace element fractionation caused high Nb/Ta and Zr/Nb, but low LREE/HREE and Zr/Hf ratios in clinopyroxene and perovskite. Stabilization of LILE, Zr and Hf in the enriched residue, favoured by high F contents, finally lead to crystallization of an agpaitic assemblage. In contrast, melt separation before perovskite saturation (Hohenstoffeln) resulted in strong, uniform enrichment of LILE, HFSE, and REE in clinopyroxene and perovskite. The nepheline syenitic residues (Steinsberg) experienced a similar evolution with incompatible element enrichment in clinopyroxene and titanite, but their mineral assemblage differs from the ijolites due to higher aSiO2 and aH_2O and lower F and P concentrations in the host melt.

05.02 Understanding (geo)materials with advanced experimental and computational methods

Challenges in powder XRD-based Rietveld analyses of Carbonates and Sulfates from Lechuguilla Cave (New Mexico, USA)

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Lechuguilla Cave, located near Carlsbad in New Mexico, USA, displays an extraordinary spectrum of speleothems formed by unusually diverse secondary cave minerals, among them various carbonates, sulfates, oxides, silicates, and halides.

Various samples of mineral assemblages taken in the context of a study on unusual speleothems formed by either barite and/or celestine were analyzed using powder XRD-based Rietveld analyses (BRASS software [1]). The samples were crushed and ground thoroughly and filled into flat sample holders. However, when celestine, barite and/or calcite constituted the dominant part of the samples, we encountered strong textures and often more than one preferred crystallographic orientation.

Some samples were re-ground several times, but no significant improvement was achieved, and sample deterioration commenced, as indicated by additional broadening of reflections. Accordingly, the samples had to be analyzed after normal grinding.

The issues could be resolved by using several instances of the same phase, which had most parameters in common except for scale factors, preferred orientations and, sometimes, peak broadening parameters. This approach had additional merits compared to multi-texture models with a single phase, since the relative amounts of the orientational variants could be determined.

This procedure also resulted in better matches of patterns and the retrieval of additional significant information, such as the co-occurrence of two different dolomites and Mg-calcite with various magnesium concentrations. In one case, two different Mg-calcites were present, which could only be identified by peak shoulders.

Reference

[1] J. Birkenstock, T. Messner & R.X. Fischer (2025). BRASS 2.4, Universität Bremen, Germany, www.brass.uni-bremen.de

03.04 All about carbonates

Dehydration-Driven Glass Formation in Aqueous Carbonates

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Amorphous carbonates, in both their liquid and solid (glassy) forms, have been identified to play an important role in biomineralization, volcanism, and deep element cycling. Anhydrous amorphous calcium and calcium-magnesium carbonate (ACC and ACMC05) are structural glasses which exhibit a glass transition upon heating. Here we report a significant effect of water content on glass formation. The results yield a parameterization enabling prediction of the stability of their liquid and solid amorphous phases as a function of temperature and water content. These results, obtained through novel fast differential scanning calorimetry, demonstrate that hydrous ACC and ACMC05 do indeed exhibit the behavior of structural glasses and that dehydration of these materials by lyophilization is a route that can be used to cross the glass transition isothermally. This presents a viable process for a significantly wider range of geo- and biomaterials. Dehydration controlled formation of glassy ACC therefore constitutes the missing link in the transformation from supersaturated aqueous solutions through an intermediate amorphous glassy state to crystalline CaCO3 polymorphs. These results yield direct implications for the mechanistic interpretation of geological processes and biomineralization.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

GeoBUS – Geological Modeling by Bayesian Updating of Scalar Fields

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In structural geological modeling, interfaces between different rock units are typically represented as sharp boundaries. However, geophysical methods such as electrical resistivity tomography (ERT) often depict these interfaces as smooth transitions of geophysical properties. This representation can obscure the precise locations of geological features that are critical for utilizing the models. To address this challenge, we present GeoBUS (Geological modeling by Bayesian Updating of Scalar fields), a novel workflow for creating probabilistic geological models that seamlessly incorporates information from probabilistic geophysical inversion results through Bayesian updates.

The GeoBUS workflow consists of three key steps: [1] We employ the Kalman Ensemble Generator (KEG) to invert geophysical data and generate probabilistic images in terms of a geophysical property. [2] We perform implicit structural geological modeling by creating an ensemble of scalar fields based on interface point information for geological units while accounting for associated uncertainties. This ensemble serves as the foundation for our probabilistic model. [3] We use the same subsurface discretization as in geophysical inverse modeling and assign probabilistic scalar field values to each cell based on our ensemble of geological models to build a discrete prior for a second KEG application. Based on literature-derived probability density functions for geophysical properties across different geological units, we formulate a corresponding likelihood. The KEG then returns a discretized posterior scalar field that integrates petrophysical likelihoods with geophysical inversion data. We demonstrate this novel workflow for ERT data and simple 2D structural geological models.

03.01 Recent Advances in the Geological Research of Marine Environments

Asphalt volcanism investigated in the deep southern Gulf of Mexico, Campeche-Sigsbee Salt Province

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After the discovery of an approximately 1 km^2 area of solidified asphalt on a seamount (knoll) in the southern Gulf of Mexico, scientists defined the term asphalt volcanism for the process of formation because of the numerous other signs of eruptive deposition on the seafloor. They named the structure Chapopote, after the word asphalt in the Aztec language. Subsequent visual examinations of the seafloor revealed extensive surface deposits of solidified asphalt and light crude oil seeping from locations along the rim of a crater-like structure at 2,900 m water depth. Large areas of the asphalt deposits were colonized by vestimentifera tubeworms, bacterial mats, and other biological communities. Further seafloor mapping showed that most of these knolls have crater-like areas associated with seepage. During recent expeditions, the crater structures of Mictlan Knoll and Tsanyao Yang Knoll were mapped in high resolution, sampled in detail and visually examined with MARUM ROV QUEST4000. Although large areas are also covered with lava-like asphalt sheets, the asphalt seems not to be flown at higher temperatures. Extrusion of heavy liquid oil in form of whips or sheets were observed at several locations which indicate a slow consolidation of the liquid oil to form firm asphalt. After extrusion, chemical and physical changes in the asphalt generate increasing viscosity gradients both along the flow path and between the flow's surface and core. This allows the asphalt to form pāhoehoe lava-like shapes and to support dense chemosynthetic communities over timescales of hundreds of years.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Development of a Regional 3D Geological Model in the Bavarian Molasse Basin: A Pilot Study for Integrated Seismic-Well Interpretation and Seismostratigraphic Framework Construction

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The increasing demand for reliable geothermal resources highlights the necessity for robust geological models of the deep subsurface. In this context, we present a pilot study aimed at constructing a regional 3D geological model of the Bavarian segment of the North Alpine Foreland Basin (NAFB). This work, conducted under the auspices of the Bavarian Environment Agency (LfU), integrates legacy 2D and 3D seismic data, well logs, and borehole information into a unified geoscientific framework enabled by recent advances in data availability (geological data ect) and modelling infrastructure.

The methodological workflow encompasses seismic reprocessing, log correlation, synthetic seismogram generation, and reflector calibration through seismic-to-well ties. A consistent seismostratigraphic framework is derived by correlating predefined key reflectors and regionally traceable unconformities across heterogeneous lithological domains.

The iterative integration of geophysical and geological datasets enables precise depth-to-time conversion and enhances both structural and stratigraphic resolution. A preliminary velocity model supports time-depth conversion and volumetric parametrization. The approach facilitates the incorporation of external datasets (e.g., geothermal assessments) and promotes standardized modelling practices across institutional and scientific domains.

This pilot application within a defined test area serves to validate internal workflows and model components, ultimately contributing to a comprehensive 3D subsurface framework for future geothermal exploration and reservoir characterization in the Bavarian Molasse Basin.

01.13 Sedimentary basins as multi-proxy and multi-process recorders

Upper mantle controls on the Paleozoic to Cenozoic evolution of intracontinental Western and Central Europe

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Shear-wave tomography models of the upper mantle below intracontinental Central Europe are indicative of a thermally very heterogeneous lithosphere-asthenosphere system. Low shear-wave velocities indicate the presence of a deep 1300 degC isotherm and thus thick (200 km) lithosphere in the SW North Sea and the Paris Basin, which contrasts with a shallower (< 120 km) lithosphere-asthenosphere boundary observed across the ECRIS and much of the British Isles. These major, long-wavelength depth fluctuations of the thermal boundary layer are locally superposed by a number of smaller-scale thermal anomalies situated within the lithospheric mantle (such as the Eifel mantle thermal anomaly). In an earlier study, we discussed how present-day density and strength variations in the mantle lithosphere may affect the distribution of earthquakes in this intraplate setting. With this new contribution, we focus on discussing potential ages of those upper mantle thermal anomalies in an attempt to delineate their roles in the geological past. The overlying crystalline crust and sediments provide us with records of a multiphase tectonic and sedimentary evolution that extends from Paleozoic to Cenozoic times. To better understand upper mantle controls on crustal deformation phases, we investigate spatial correlations between upper mantle temperature variations as derived from shear-wave tomography models with major crustal structures of known geological age and setting. We will also discuss existing correlations in the light of thermal field variations across the lithosphere produced by numerical simulations of conductive heat transport.

03.04 All about carbonates

An isotope view on calcium gradients in the Baltic Sea

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The modern Baltic Sea (BS) surface water is characterized by an excess in dissolved calcium (Ca) of still unknown origin. Our hydrogeochemical study uses the stable isotopes of Ca and carbon to identify potential calcium sources. The composition of dissolved Ca was analyzed in bottom waters of the deep BS basins, in potential freshwater sources, like rivers and creeks draining the southern coastline, as well as submarine groundwater discharge. The role of sediments was followed in a porewater gradient from the Gotland deep basin in the central BS. The results are traced compared to the North Sea and selected tributaries.

Values of Ca isotope in the bottom waters of the BS deeps shift towards more negative values with decreasing salinity and increasing Ca excess. In the porewater, a downward increase in Ca concentrations and decrease in Ca isotope values is associated with weathering of carbonates and/or Ca desorption from clays. The isotope composition of dissolved Ca in the Warnow river draining into the southern BS was within the range of other European rivers, lower than seawater, but more positive than that of rivers draining into the North Sea. Weathering of carbonates by groundwater was found to be a further Ca source depleted in 44Ca. Seasonal variations in the Warnow River, with most positive values during summer, are likely due to internal processes that cause Ca carbonate formation in the water column. Concluding, dissolved Ca in the fresh part of salinity gradients originates from carbonate weathering.

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03.04 All about carbonates

CO_2 agility in hardwater creeks discharging to the southern Baltic Sea: Seasonal source and fate controls

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Mineral formation from hard water creeks is sensitive to variations of physico-chemical boundary conditions, biological factors, and climate change. Groundwaters are often equilibrated with aquifer $CaCO_3$, but supersaturated in CO_2 wrt. to the atmosphere emerge from springs near the German coastline. Upon contact with the Earth's atmosphere, CO_2 starts to degas, absorbs O_2, and after exceeding a critical threshold carbonate starts to precipitate. Ferruginous groundwaters may be dominated by the precipitation of iron oxyhydroxides. Trace element and stable isotope partitioning upon crystallization are controlled by non-equilibrium processes. The spring composition characterizes element sources and subterrestrial water-microbe-rock interaction related to subterrestrial weathering. The spatial gradients display exchange with the atmosphere and mineral precipitation, controlled by morphology and season. The hardwater creeks form a source for carbon and will finally contribute to the coastal waters, modulating their buffer capacity, and, therefore, impact surface water acidification and their CO_2 release potential.

Examples for hard water systems were chosen from different aquifer lithologies at Gespensterwald, Rügen Island, and Meschendorf beach.

Besides *in-situ* parameters, the hydrogeochemistry (major and trace elements) and multiple stable isotope partitioning between dissolved and solid phase were analyzed. The aqueous solution was subjected to physicochemical PHREEQC analysis. Carbonate or iron oxyhydroxide precipitation and CO_2 degassing rates, are estimated based on different methods:

- Hydrochemical gradients along the flow path;
- Direct measurements using a new *in-situ* placer technique (Peters, MSc thesis 2025);
- Comparison of field findings with lab-based trace element partitioning into the solid.

02.01 The Tethys Ocean – the cradle of modern tropical life

Combined stable isotope records and skeletal growth properties of the reef-building coral Porites reveal biological response to environmental forcing relationship (early Tortonian, Crete/Greece)

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Late Miocene reefs were widespread over the entire Mediterranean. Knowledge of their long-term sedimentary and ecological variability on orbital time-scales and their responses to climatic changes is well established, while understanding of annual to inter-annual dynamics is poor because of inappropriate coral preservation related to the dissolution and cementation of the skeletal aragonite. Exceptionally well-preserved Porites corals retaining the aragonite mineralogy and primary skeletal porosity have been reported by the authors previously from an early Tortonian mixed clastic-carbonate system at Psalidha site (Crete/Greece, Eastern Mediterranean). Here, we present a review of all sub-annually resolved stable isotope chronologies ($\delta^{18}O$, $\delta^{13}C$) and corresponding skeletal growth data (skeletal extension rate and density, calcification rate) available from the Psalidha site, covering a total of 266 years, together with data on sedimentary facies and paleontological inventory. Based on categories of present-day Porites regarding calcification properties and stable isotope systematics, we find average annual SST ~23 °C with mean seasonal SST amplitudes ~7.5 °C. Overall low skeletal growth was limited most during the cool seasons, fully consistent with paleontological inventory (low diversity of reef-building corals) and sedimentary facies, Mediterranean region geographic latitude (subtropics) and biogeography (near northern limit of global reef belt). No evidence for bleaching events has been identified so far. We discuss the growth responses of an important reef-building coral genus in the Late Miocene Mediterranean Sea to environmental variability on seasonal to decadal time-scales in the light of ancient climatic variability and modern reef dynamics during the ongoing reef crisis.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Post-Saalian neotectonic fault activity on the Aller fault system

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In the last decade, paleoseismological studies executed in northern Germany have extended the record of fault activity further into the past, partly leading to controversial discussions. Although it has been possible to identify GIA as a potential key trigger mechanism for the neotectonic, historic and recent fault activity in northern Germany, the major controlling factors for the distribution of tectonic activity are still underexplored. We investigate the basin-fill architecture and subsidence mechanisms of the Lehringen basin as a key example of an important Eemian archaeological archive. Based on the interpretation of shear-wave seismic sections, a ground penetrating radar (GPR) survey, borehole data, DEM analyses and numerical simulations of Coulomb failure stress, we assume that Eemian and Weichselian sediments near Lehringen were deposited in small fault-related basins that formed as a consequence of neotectonic movements along the Aller fault system. Two phases of subsidence can be derived, based on the seismic sections and the GPR survey, which points to two phases of fault activity after the late Saalian glaciation. This supports the idea that the Aller fault system is a glacially triggered fault and indicates that two separate phases of fault activity might have occurred. The identification of neotectonic activity on the Aller fault system has implications for a future seismic hazard assessment of Northern Central Europe and the definition of seismo-tectonic areas.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

The neotectonic activity of northern Central Europe – the current picture

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Northern Central Europe is a slowly deforming, low-strain intraplate area. Nevertheless, there is evidence for neotectonic fault activity, as well as for historic and recent earthquakes. The current knowledge is that the tectonic activity is mainly concentrated at major WNW-ESE striking lithospheric structures, from north to south, the Sorgenfrei-Tornquist Zone, the southern and northern margins of the Ringkøbing Fyn high and at individual faults like the Osning thrust or the Harz boundary fault, with some recent earthquake activity in between, possibly at the Thor suture. The Ringkøbing-Fyn high is a region of thicker crust separating the northern from the southern Permian basin. The Sorgenfrei-Tornquist Zone, the Osning thrust and the Harz boundary fault are located at the northern and southern margin of the Central European Basin System, respectively and these are the two areas, where the Late Cretaceous inversion phase that is characteristic of northern Central Europe, had a very pronounced effect. The faults in these areas have in common that they penetrate large parts of the crust, partly down to the Moho. Therefore, they represent stress-sensitive, first-order lithospheric features, where past, present, and potentially future seismic events are manifested. Repeated reactivation of these structures might have caused large-scale fatigue processes that can have weakened the faults and made them prone to stress release and neotectonic movements and enhance the potential for a reactivation due to stress field changes induced by glacial isostatic adjustment (GIA). This has implications for the seismic hazard assessment of northern Central Europe.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Structural and sedimentary controls on tunnel-valley evolution: Insights from high-resolution 3D seismic data

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This study investigates the distribution, morphology, and infill of buried Pleistocene tunnel valleys in northern Germany and adjacent offshore areas, with implications for long-term safety assessments of radioactive waste repositories. Tunnel valleys, formed by pressurized subglacial meltwater, are prominent erosional landforms reaching depths of up to 600 meters b.s. Using the high-resolution 3D seismic dataset GeoBasis3D (2021), acquired in the German EEZ, we examine intersecting tunnel valleys, including one located above the Belinda salt dome.

The 3D seismic data enable detailed mapping of tunnel valley geometries and sedimentary facies. The lower parts of the tunnel valley are marked by steep flanks and chaotic internal reflectors, indicative of rapid, subglacial infill processes. Tunnel-valley infills reveal cut-and-fill structures, erosional unconformities, and parallel reflectors that indicate multiple depositional phases. Crestal faults above the Belinda salt dome displaced the tunnel-valley fill and locally reach the seafloor, confirming Pleistocene fault activity. However, fault activity did not impact the incision depth and only slighty affect the course of the tunnel valley.

On a regional scale, structural controls were evaluated by correlating tunnel-valley orientations with the trends of faults and salt structures. While some tunnel valleys align with (neotectonically active) faults, particularly where ice flow paralleled fault trends, no consistent correlation with salt structures was observed.

Our findings highlight the importance of integrating seismic stratigraphy and structural geology to understand tunnel-valley evolution. They also underscore the limited predictive value of structural trends for future subglacial erosion, which is essential for assessing repository site integrity over long timescales.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

A high-resolution record of soil erosion based on portable luminescence reader derived colluvium chronologies from the Lower Rhine Area

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Anthropogenic soil erosion has shaped European agricultural landscapes since thousands of years. Reconstructing their past dynamics is crucial for understanding associated driving and feedback mechanisms as a basis for numerical models that predict future trends. While colluvial deposits provide abundant records of Holocene soil erosion, their use for reconstructing spatial and temporal patterns is limited by poorly-resolved and low-resolution chronologies. For colluvial deposits from a loess landscape at the southeastern rim of the Lower Rhine Area, we show how unprecedented high-resolution chronologies can be constructed using a portable optically stimulated luminescence (pOSL) reader in combination with conventional OSL dating and Bayesian age modelling. The resulting cm-scale chronologies for the past ~3500 years reveal unique insights into colluvium formation by capturing variations in deposition rates over several orders of magnitude. These variations include phases with virtually absent erosion and several hundred years duration in the Early Middle Ages, but also short episodes or even single events with drastically accelerated erosion during Roman Times and the Late Middle Ages. Within the loess-derived colluvium of our study site the pOSL-based dating approach also offers huge possibilities for upscaling, since additional colluvium cores can be dated with little effort once a robust relation between pOSL and conventional OSL has been established. This approach sets the foundation for reconstructing not only temporal but also spatial patterns of local soil erosion dynamics with exceptional resolution.

01.24 Fieldwork as common playground: the importance of geological survey to unravel Earth processes

Integrating 60 years of paleontological research: A new geologic map of the Madygen Geopark, Kyrgyzstan

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The southwestern margin of the Central Asian Fergana Basin is a tectonically complex region with a 500 million year record of sedimentation. Cambrian to Middle Carboniferous passive margin and carbonatic shelf sediments were intensively deformed by the closure of the Turkestan Ocean in the Late Carboniferous. After a period of uplift and erosion, a sucession of small Triassic-Jurassic nonmarine basins with a highly diverse and globally significant fossil record formed. Following repeated marine incursions in the Upper Cretaceous, the Fergana Gulf connected the eastern Peri-Tethys, Tethys, and Siberian epicontinental sea during major phases of global climate change in the Paleogene. Repeated convergence and uplift in the Neogene and Quaternary formed todays' topography. Soviet 1:200,000 scale mapping in the 1950's was predicated on geosynclinal theory and failed to recognize the nappe architecture of the South Fergana Zone, leading to inaccurate ideas on basin configuration and paleoenvironmental reconstructions. Building on a field mapping campaign in 2007–2009, the core area of the Madygen Geopark is being remapped at a 1:25,000 scale by a combination of field work, remote sensing and geomorphological analysis. Together with newly logged profiles of the most important fossiliferous sucessions, the paleogeographic and paleoenvironmental history of the Madygen geopark is being reassessed.

The results will enable the reinterpretation of the voluminous fossil collections of the past six decades of paleontological research in terms of paleoecology, depositional environment and possible migratory pathways. Finally, the new geologic map will facillitate further research, educational and geotouristic activities at the Madygen Geopark.

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

An arthropoda-dominated trace fossil assemblage from the Upper Triassic of the Madygen Geopark, Kyrgyzstan

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The Middle Triassic Madygen Formation of southwestern Kyrgyzstan has yielded a remarkably diverse non-marine flora and fauna, but few ichnia. The overlying Rhaetian to Lower Jurassic alluvial-fluvial sediments contain a moderately diverse ichnofossil record in an ephemeral pond that is characterized by the dominance of two types of traces assigned to different arthropod groups. The first type is assigned to Kouphichnium pterodactyli (Winkler) Malz 1964 and linked to xiphosuran tracemakers. This type is well-documented in marine and freshwater environments from the Pennsylvanian onwards. The second type represents a new ichnospecies in the ichnogenus Heteropodichnus Walter 1983 which so far is only known from the Lower Permian of central Germany and northern Italy. Twelve recovered traces of this type show signficant along-track changes in morphology that reflect the transition from swimming to walking locomotion and the dragging or rhythmic beating of the telson. Morphological comparisons indicate Kazachartra as likely tracemakers, in this case specifically Almatium gusevi Chernyshev 1940 which is preserved as fragmentary exuviae in the same horizon and more completely and abundantly in the lacustrine sediments of the underlying Madygen Formation. This find represents the first walking traces of Kazachartra, an order so far only known from the Middle Triassic to Lower Jurassic of China and Central Asia. For the Permian Heteropodichnus a notostracan tracemaker can be suggested.

The trace fossil assemblage is completed by three further types of invertebrate traces, the fish swimming trace Undichna unisulcata Gibert 1999 and rare swimming traces of small tetrapods, Lunichnium rotterodium Walter 1983.

01.12 Coastal dynamics in different timescales: from seconds to millennia

Storm surges and the un-diked coast: tracing prehistoric events in the Holocene sediment sequence of northwest Germany

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The rising sea level has shaped the northwest German coast since the beginning of the Holocene, which resulted in a general progradational shift of the coastline. Additionally, extreme events such as storm surges affected the paleo-coast and must be considered to further complement the understanding of landscape evolution in the region.

Unlike the modern coast, the paleo-coast was un-diked. Therefore, it can be assumed, that prehistoric storm surges had substantial different effects on the coastal environment at the time. While storm surge deposits have been identified along the northwest German coast, they have not yet been systematically studied.

The interdisciplinary project CoastAdapt aims to close this gap by investigating the inland reach of prehistoric storm surges, the geological conditions that may have favoured inundation, and whether some transgressions attributed to sea-level rise may have actually been storm-driven. Focus lies on cm-thick clastic layers (known as Klappklei) found within Holocene peat. These layers form when storm surges temporarily disturb coastal peat horizons, allowing fine sediments to be deposited and preserved within the peat horizon. As Klappklei only forms during high water levels, it is considered to be a valuable marker of prehistoric storm surge activity.

We present a comprehensive mapping of these deposits for different time intervals of the Holocene, alongside estimates of associated inundation extent. The results are based on borehole archive data, integrated with updated sea-level reconstructions. A preliminary regional case study from the East Frisian coast provides new insights into landscape development and effects of storm surge events.

01.10 The co-evolution of the Earth and life from the early Archean until today

Tracing Early Earth Processes: Geochemical and Metamorphic Evolution of felsic veins in TTG-Associated Rocks of the Isua Supracrustal Belt

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The Isua supracrustal belt (ISB) represents a key example of Archean crustal development and is renowned for containing some of Earth's oldest supracrustal rock sequences. However, the precise conditions and timing of its metamorphic history remain subjects of ongoing debate. Crucially, this understanding forms the foundation for competing hypotheses regarding Eoarchean vs. Neoarchean tectono-metamorphic evolution.

This study investigates felsic (Qz + Pl) veins associated with Grt-Bt-Pl-Qz schists located near a large tonalite-trondhjemite-granodiorite (TTG) body with an intrusion age estimated at 3.7 Ga. These felsic veins may represent either in-situ melts of the host rock or TTG-derived melts and subsequent interaction with surrounding rock.

Special focus is placed on observed mineral textures within the host rock, the felsic veins, and their interfaces. Garnet porphyroblasts in the host rock exhibit rounded grains and complex zoning pattern, particularly in grossular and spessartine components, along with various mineral inclusions. In contrast, garnet grains in the veins are larger, irregular and more homogeneous in composition and host polyphase melt inclusions, suggesting distinct growth mechanisms between the host rock and the veins.

Zircon and monazite grains in felsic veins, garnet porphyroblasts and in the host rock will be dated and rare earth element (REE) patterns will be analyzed to distinguish detrital and crystallization ages to constrain the timing and nature of melting and/or melt-rock interaction events and to compare these data with the known history of the ISB. This integrated approach will clarify the formation of felsic veins and contribute to models of Archean crustal evolution.

01.24 Fieldwork as common playground: the importance of geological survey to unravel Earth processes

New research results and a new digital map of the West Eifel Volcanic Field

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Within a funded project of the UNESCO Global Geopark Vulkaneifel, the Quaternary West Eifel Volcanic Field (WEVF) was comprehensively re-mapped to create a digital geological map. Compared to earlier maps created by von Dechen (1:80,000), Rahm (1:25,000), and Büchel (1:50,000), the new mapping benefits from high-resolution lidar data, enabling the creation of detailed 3D terrain models. This intensive remapping campaign in 2022-2025 has led to an increase in the number of recognized volcanoes, especially of old maars. Notably, three of these maars are filled with basalts, as relicts of lava lakes. Many large scoria cones exhibit an initial maar phase, with their craters filled by scoria, agglutinates, dykes, plugs, and small lava lakes. Most of the scoria cones have produced lava flows. Tuff-ring volcanoes, rich in juvenile clasts, exhibit palagonitization – evidence of intense magma-water interaction. Additionally, a new volcano type has been identified that generated large deposits of phreato-strombolian tephra. Moreover, quarrying has revealed distinct tensile fault systems along the marginal rims of scoria cones with initial maar phases. These extensional fault structures likely collapsed progressively in the transition zone between the initial maar crater and the diatreme, as a result of the growth of the maar-diatreme volcanoes.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Revision of Ichniotherium track-trackmaker correlation and implications for models of diadectid locomotion

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Recent excavations at the early Permian Bromacker locality (Thuringian Forest, Germany) yielded body and trace fossil finds that shed new light on diadectid track-trackmaker correlation. A partially articulated skeleton assigned to Diadectes absitus includes a pes – which was absent in the type material of this species – and, in contrast to the expected similarity to North American Diadectes and the track type Ichniotherium cottae, the foot proportions of D. absitus are in better agreement with co-occurring Ichniotheirum sphaerodactylum tracks. Furthermore, despite the differences in bone proportions, the ratio of trunk length (distance between shoulder and hip joints measured along the vertebral column) to foot size was similar in both species, D. absitus and O. pabsti. To infer the likely sequence of footfalls that defines the gait pattern of the track producer, the skeletal proportions of D. absitus and O. pabsti were put in relationship to the footprint proportions and trackway pattern of I. sphaerodactylum. Based on a large sample of I. sphaerodactylum trackways from the Tambach Formation and assuming different degrees of lateral trunk bending and of flesh cover for fitting the autopodia into the footprints, we find that the skeletal proportions of both possible producers support a lateral sequence walk or even a pace gait instead of a common walking trot (the latter was assumed in previous models of O. pabsti as the producer of I. sphaerodactylum). According to our results, the type of gait should be taken into account as a critical variable in future models of diadectid walk.

09.02 Museen als Fenster in die Forschung

Evolution und Geowissenschaft zum Mitnehmen

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Bei der Gestaltung und Durchführung museumspädagogischer Programme gibt es einige Freiheiten und Vorzüge gegenüber dem Schulunterricht. Besonders bei dem Thema „Biologische Evolution und Geschichte des Lebens auf der Erde“ kann man auf eine große Fülle an Beispielen und auf aktuellere Konzepte wie Stammesgeschichte und phylogenetisches Denken („tree thinking“), Massenaussterben und Phasen der Erholung (recovery), Schlüsselinnovationen wie z.B. die Entstehung von Lichtsinnesorganen und der Fähigkeit zur Biomineralisation, evolutionäre Schranken, Ökosystem-Evolution, Superkontinent- und Klimazyklen, heute nicht mehr beobachtbare Evolutionsprozesse und Ereignisse wie die „Kambrische Explosion“ und den Landgang der Vielzeller eingehen. Bei der Veranschaulichung hilft das Vorhandensein von Originalen, die man aus der Nähe ansehen, unter das Mikroskop legen und gelegentlich auch berühren kann. Zudem ist man am Museum nicht dazu gezwungen, Schulkindern abprüfbares Wissen zu vermitteln, sondern kann (z.B. zum Ursprung der Schildkröten und des Schildkrötenpanzers) widersprechende Lehrmeinungen aufzeigen. Im Zweifelsfall sollten Kinder auch dann schöne Erinnerungen aus dem Museum mitnehmen, wenn sie mal keine Lehrinhalte aufnehmen konnten oder wollten. Diese positive Erfahrung versuchen wir am Museum für Naturkunde Magdeburg z.B. im Rahmen von Ferienprogrammen und Projekttagen durch Objekte zum Selbstanfertigen und Mitnehmen zu unterstützen. Dazu gehören u.a. Abgüsse von Fossilien unterschiedlicher, aber verwandter Formen (wie Kopffüßer-Gehäuse, Saurier-Fußspuren und Saurierkrallen) zum Selbstkolorieren; Miniatur-Dinosauriernester, bestehend aus gruppenspezifischer Nistmulde, Eiern und Sauriermodell (z.B. als Osterferien-Thema) das selbst gebastelte Miniaturmuseum zum Bestücken mit eigenen Exponaten; Linolschnitt-Drucke und Schablonen-Bilder zum Thema Großsäuger der Eiszeit und Höhlenmalerei; Daumenkino und Popup-Bild zum Thema Saurierspuren und Fortbewegung. Diese Beispiele werden auch beim Public-Outreach-Event der Geo4Göttingen vorgestellt.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Isotope genealogy and chronology of individual chondrules from ordinary chondrites

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Chondrules are a ubiquitous high-T component in primitive meteorites, and as such are key for reconstructing the evolution of dust in the accretion disk surrounding the young Sun. To better constrain the composition of the inner, non-carbonaceous (NC) disk reservoir, and ultimately the source material and growth history of the terrestrial planets, we present here a comprehensive petrographic, chemical, O, Ti, and Cr isotopic, and Al-Mg and Mn-Cr chronometric study of chondrules extracted from ordinary chondrites. We find that chondrules of different textures and chemical compositions (Mg# 67-99) exhibit a narrow range of O, Ti, and Cr isotopic variations. Only one chondrule exhibits ε50Ti and ε54Cr values that are outside the range of bulk NC materials, likely due to the presence of AOA-like material in its precursor assemblage. Internal Al-Mg isochrons yield an average age of ~1.8±0.6 (2sd) Myr after the start of the Solar System, in line with an age of ~2.2±0.8 Myr obtained from a Mn-Cr bulk chondrule isochron. Overall, the data suggest that the majority of the OC chondrules formed at around 2 Myr after the start of the Solar System in a well-mixed reservoir dominated by NC dust, with only little contribution of anomalous materials from the outer Solar System. This implies that the parent bodies of NC chondrites predominantly accreted dust from their local orbit, and that the barrier separating the inner and outer disk effectively blocked the passage of ~mm-sized dust.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Closely related tetrapods from the early Permian of North America and Germany had different life history traits

CANOVILLE, AURORE

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A wealth of studies show that the paleoecosystem recovered from the early Permian Bromacker locality of central Germany was unique and differed from coeval North American (NA) fossil assemblages. The latter mostly represented lowland environments with perennial rivers and tetrapod communities of aquatic to terrestrial taxa dominated by large carnivores. On the contrary, Bromacker paleoclimate was highly seasonal with ephemeral water bodies. Its tetrapod fauna was exclusively terrestrial, with abundant herbivores, but scarce and small predators.

Environmental conditions are expected to impact the growth strategies and lifestyle adaptations of tetrapods. However, this has rarely been reported for early Permian tetrapod communities. Here we investigate, for the first time, the long bone histology of the six largest tetrapod species recovered from Bromacker (i.e. Seymouria sanjuanensis, Diadectes absitus, Orobates pabsti, Dimetrodon teutonis, Martensius bromackerensis, Tambacarnifex unguifalcatus), with the aim to infer their life history traits and compare them to NA relatives.

Preliminary observations reveal that most specimens found at Bromacker consist in subadult to adult individuals, with few young juveniles. Unlike all other investigated species, Bromacker diadectids exhibit highly remodeled long bone cortices; a feature potentially related to fossorial adaptations. D. teutonis shows nearly avascular and thin bone walls, differing from the well vascularized and thicker cortices of its diminutive NA counterpart, D. natalis. Overall, Bromacker species show relatively slower growth rate than their NA relatives. Local environmental conditions might explain these contrasting growth strategies.

06.04 Stressors in Hydrogeology: Interactions and Impacts

The Dominant Role of the Aquifer Matrix in Regulating Electron Acceptor Attenuation Rates

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Electron acceptors, such as nitrate, in aquifers are attenuated via biologically mediated redox reactions in groundwater. Their reduction is coupled to the oxidation of electron donors. The main source of electron donors, particularly over long water-sediment contact times is the sediment/rock matrix. The physical and chemical properties of aquifer matrices, thus, govern the rate and extent of natural attenuation. In addition to catalyzing redox reactions, subsurface microorganisms, actively scavenge electrons from reduced mineral phases or, in the case of organic carbon, hydrolyze solid- to dissolved-organic-carbon (DOC). The release of aqueous electron donors is often the reaction-limiting step. Moreover, at the aquifer scale, both the quantity and heterogeneous distribution of electron donors influence the overall extent of reduction. The extent of reaction hinges on flow paths that ensure long-enough contact time between aqueous electron acceptors and solid-phase electron donors, intrinsically linking hydraulic conductivity and sediment makeup with reactivity. Here, we show both analytically and numerically that hydrolysis of DOC from the matrix limits and conditions the rate of electron acceptor reduction. Our results show that this conditioning drives otherwise complex non-linear reactions to simple zero-order kinetics. In ongoing experiments with biostimulated aquifer sand, via a nitrate injection, preliminary results highlight that this limiting step is also relevant for matrices dominated by reduced iron minerals constitute the dominant electron donors. We expect to validate our theoretical analysis experimentally, and propose a framework to address the challenges in better representing both the reaction and transport properties of aquifers by accounting for sedimentological information.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

Quantitative Provenance Analysis of Sediment Routing Systems Across Temporal Scales: Challenges and Future Directions

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Integrating geomorphology, sedimentology, sedimentary petrology, and provenance analysis has significantly advanced our understanding of sedimentary processes. Depositional dynamics—particularly sediment partitioning, landscape evolution, and signal propagation—are now closely linked to tectonic and climatic forcing within the Sediment Routing System (SRS) framework. Quantitative provenance analysis (QPA) contributes a compositional dimension that enhances sediment budget estimates and enables the quantification of anthropogenic impacts. Nevertheless, a fully integrated, multidisciplinary approach remains underdeveloped.

This study addresses these gaps through three objectives: refining Sediment Generation Models (SGM) by coupling lithology, relief, and climate; developing a streamlined QPA–SRS workflow for sand and silt apportionment; and assessing the resolution of sedimentary signal reconstruction at historic (10^2 yr), intermediate (10^2–10^6 yr), and deep-time (≥10^7 yr) scales.

At historic timescales, compositional and morphotectonic analyses capture the impact of human activity on sediment generation, while QPA integrated with OSL and sedimentological data successfully traces drainage responses to Holocene climatic variability. In deep-time systems, the combination of high-resolution provenance techniques and detailed sedimentology underscores a key limitation: the need for precise, coeval dating of climatic, tectonic, and depositional events.

While identifying natural controls in modern settings is relatively straightforward, transient landscapes often obscure the geological record. Focusing on sfirst-cycle SRS, this study develops an integrated framework with SGM providing essential baseline data. Systematic application of these models across diverse lithological, tectonic, and climatic settings will promote greater unification of sedimentary geology sub-disciplines, offering more accurate reconstructions of ancient systems and refined predictions of future landscape and climate evolution.

01.07 Stratigraphy in Earth System Science: methods, applications and case studies

Reconstructing Basin Architecture of the Mesozoic Multiphase Back-Arc and Retroarc Foreland Basin System in Colombia

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The present-day Middle Magdalena Valley, Eastern Cordillera, and Llanos Basin were once part of a large, multiphase basin system that began as an extensional basin during the Late Triassic–Early Jurassic and evolved into a retroarc foreland basin by the Late Cretaceous. By the late Eocene, this system was segmented into hinterland and foreland basins. Although the tectonostratigraphic evolution of these transitions is well understood, the basin architecture during each phase has not been fully reconstructed. In this study, we integrate stratigraphic and chronostratigraphic data from these basins and adjacent areas to develop a comprehensive regional framework. This correlation enabled the identification and mapping of Late Campanian and Maastrichtian maximum flooding surfaces, associated with the back-arc and retroarc foreland basin stages. Tracing these surfaces from the Llanos Basin to the Middle Magdalena Valley allows reconstruction of the basin's spatial configuration through each tectonic phase. Our results document how basin architecture evolved in response to northeastward orogenic loading and the development of intrabasin structural highs, which led to localized erosion and non-deposition during the Campanian–Maastrichtian. These insights are critical for predicting the distribution and preservation of Lower Cretaceous marine deposits, which represent significant hydrocarbon source rocks. Additionally, we assess whether Maastrichtian sediment load and burial conditions were sufficient to trigger hydrocarbon generation in these source units, using the maximum flooding surfaces as chronostratigraphic markers.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Dating heavy minerals in European rivers: What do they record?

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Heavy minerals are essential for reconstructing provenance, paleogeography, and the evolution of continental crust, as well as for understanding petrological and tectonic processes. Moreover, analysing heavy minerals from modern rivers can be a more efficient way to assess the diversity of rock types exposed in a region than direct sampling of individual outcrops. Among these heavy minerals, detrital zircon has been extensively studied due to its robustness and suitability for U-Pb geochronology, providing critical age information on source rocks. However, the detrital zircon record in European rivers often does not quantitatively reflect the contributing drainage areas. This discrepancy is largely due to two factors: sediment recycling and the highly variable zircon fertility of different source rocks. To overcome these limitations, we expanded our analysis to include other heavy minerals from European river sediments. We focused on minerals that are both datable by the U-Pb method and less affected by recycling, such as titanite and apatite, as well as those found in zircon-poor lithologies, like rutile from mafic and metamorphic rocks. Our findings show that the U-Pb record of detrital rutile is similarly influenced by recycling, but in the case of the Variscan Orogeny, it records earlier events than zircon. In contrast, titanite, largely first-cycle in origin, best reflects the Alpidic Orogeny, an event that is nearly invisible in the detrital zircon and rutile records. Dating detrital apatite in combination with trace element analysis, is a useful tool for distinguishing between different geological processes, especially within the Variscan Orogeny.

09.02 Museen als Fenster in der Forschung

Ich glaub, ich steh im Wald! – oder wie man sich einen Karbonwald baut

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Nach vierjähriger Planungs- und Umbauphase eröffnete das Museum am Schölerberg in Osnabrück im April 2023 seine rundum erneuerte Dauerausstellung. Das Highlight der neuen Ausstellungen ist das immersive Diorama eines Sumpfwaldes aus dem Späten Karbon, das sich im Zentrum des Hauses um das Original eines riesigen Stigmaria-Wurzelorgans herum erhebt. Die Rekonstruktion dieses Karbonwaldes basiert auf Funden der Fossillokalität des Piesberg im Norden Osnabrücks (Oberes Moskovium).

In die Rekonstruktion flossen aktuelle Forschungsergebnisse zu Flora, Fauna und Ablagerungsbedingungen der Piesberg-Lokalität, sowie zu ökologischen Strukturen spätkarbonischer Sumpfwälder ein (e.g. Leipner & Chellouche 2019). Die Modelle der dargestellten Lebewesen entstanden in enger Abstimmung zwischen Modellbauer:innen und Wissenschaftler:innen, um das höchstmögliche Maß an Authentizität zu gewährleisten. Augmented Reality-Stationen erwecken das Diorama zum Leben und erweitern die Vermittlungsebene auf nicht dargestellte Biotope und Interaktionen. Anfasspräparate und eine Mitmach-Station komplettieren den multisensorischen Zugang zum Ausstellungsthema.

Im Zentrum des Ausstellungsbereichs werden zu den Themen „Flora“, „Fauna“ und „Ökologie“ Originalfunde vom Piesberg präsentiert. So wird die direkte Assoziation zwischen Original und Rekonstruktion geschaffen.

Durch die Einbindung des Ausstellungsbereichs „Karbonwald“ in den Erzählstrang „Klima und Klimawandel“ der neuen Dauerausstellung wird der Klimawandelbedingte Rückgang der Sumpfwälder am Ende des Karbon (Carboniferous Rainforest Collapse) in Dialog mit der Entwicklung tropischer Regenwälder im rezenten Klimawandel gesetzt und die aktuelle Relevanz der Thematik aufgezeigt.

Literatur

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04.04 Hydrogen in the energy transition –white to green hydrogen and subsurface storage

Geochemical reactivity of hydrogen with sandstone reservoir rocks: feasibility of underground porous storage

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Underground hydrogen storage in porous rocks presents a promising solution for renewable energy storage. While geochemical reactions between hydrogen and reservoir minerals are generally believed to have minimal impact on hydrogen loss or reservoir integrity, this assumption is based on limited experimental evidence. To accurately assess hydrogen's role in geochemical interactions, it is essential to conduct comprehensive batch experiments with appropriate control scenarios that distinguish hydrogen-induced effects from those arising solely from fluid–rock interactions. This study investigates the geochemical reactivity of hydrogen with reservoir sandstones containing less than 2% pyrite. Batch experiments were conducted using cylindrical core samples under conditions of 100 °C and 100 bar hydrogen partial pressure for five weeks. Three scenarios were examined: (1) dry samples exposed to hydrogen, (2) synthetic saline fluid-saturated samples with hydrogen, and (3) synthetic saline fluid-saturated samples with helium (as a control). Pre- and post-experimental analyses included measurements of permeability, porosity, magnetic susceptibility, thin-sections, fluid elemental concentrations (via ICP-OES and IC), and gas composition. In contrast to our previously studied pyrite-free Buntsandstein reservoir sandstones, the results from this study provide evidence that pyrite is reactive with hydrogen, potentially influencing other reservoir parameters. Specifically, samples exposed to hydrogen showed more than a twofold increase in magnetic susceptibility compared to those in the helium control group, indicating a potential formation of pyrrhotite from pyrite. Ongoing research into pyrite-bearing rocks aims to enhance the generalizability of these findings and contribute to more robust risk assessments for underground hydrogen storage.

01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

Rapid Emplacement of the Lower Deccan Traps and its Implications for Late Cretaceous Environmental Change

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The Deccan Volcanic Province (DVP) represents one of Earth's most voluminous continental flood basalt events, erupting an estimated 1.3 × 106 km^3 between ~66.3 and 65.5 Ma (Jay and Widdowson, 2008; Schoene et al., 2019). This study focuses on the Thakurvadi Formation (erupted ~66.3–66.1 Ma), and the overlying giant plagioclase basalt units, to understand magma evolution, crustal assimilation, and volatile element behaviour during eruption. Field mapping and trace element geochemistry of the Thakurvadi formation reveal systematic Cu/Ag variability that correlates with proxies for mantle heterogeneity. To test whether this variability reflects primary mantle signatures or is attributable crustal processes (assimilation, fractionation, degassing), we will integrate whole rock radiogenic isotope analyses (Sr, Nd, Pb, W). Preliminary Cu/Ag trends for my samples suggest links with radiogenic isotope signatures observed by Pakulla et al., (2023), potentially indicating ancient mantle source characteristics. By combining new isotopic data for my samples with the existing trace element and isotope datasets by Pakulla et al. (2023), we will be able to establish parental melt compositions, understand the extent of crustal contamination, and assess toxic element release (e.g., As, Se) during magma ascent and weathering. The resulting comprehensive geochemical framework will advance our understanding of DVP eruption dynamics, inform models of Large Igneous Province formation, and, by understanding the role of toxic elements, potentially contribute to understanding the environmental impacts of early Deccan volcanism on the Late Cretaceous environment.

01.13 Sedimentary basins as multi-proxy and multi-process recorders

Mixed siliciclastic-carbonate heterolith from the Mesoproterozoic Kurnool Group, India: insights into rift-to-passive margin evolution of the Purana Basins

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Mixing of siliciclastic-carbonate sediments is a common occurrence throughout geological time, that typically records contemporaneous deposition of pure carbonate and siliciclastic end-members. These heterolith develop in microscopic compositional to mesoscopic stratigraphic scale, under the influence of allocyclic (sea-level fluctuations, climate, tectonism) and autocyclic (depositional dynamics) controls. This study examines an approximately 15m-thick, laterally extensive (over-100 km) mixed siliciclastic-carbonate heterolithic unit, positioned between the Banaganapalle siliciclastic and Narji Limestone from the Mesoproterozoic (approximately 1.3–1.2 Ga) lower Kurnool Group, India. Sedimentological and stratigraphic observations of the mixed siliciclastic-carbonate heterolithic unit reveal three facies associations, namely (1) glauconitic sandstone interbedded with clayey siltstone, (2) mixed calcareous shale-siliciclastic-carbonate heteroliths, and (3) carbonate-clast conglomerates with calcareous shale and thin bedded limestone. The facies associations represent transition from storm-dominated middle to inner shelf depositional environment to open-marine distal shelf setting, punctuated by episodic high-energy events (e.g., storms, tsunamis). Two primary sediment-mixing modes are identified: (i) stratal mixing-microscopic bed to lithofacies scale-driven by sea-level oscillations and high-energy events, and (ii) compositional mixing at microscopic scale-driven by *in-situ* mixing of transported nearshore siliciclastic with subtidal carbonate mud. This mixed siliciclastic-carbonate heterolithic unit helps to bridge the transition from the intracratonic siliciclastic rift system of the Banaganapalle Formation to the passive margin carbonate platform of the Narji Limestone. Intracratonic rift-related faulting, triggered by post-Columbia breakup, likely induced rapid subsidence, facilitating widespread marine transgression and the heterolith deposition. This mixed siliciclastic-carbonate heterolith serves as an archive to understand the tectono-sedimentary evolution, preserving the complex interactions among tectonism, sea-level changes, and sediment supply.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Estimation of Variogram Parameters with Seismic Forward Modelling

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Variogram modelling is a useful method to characterise spatial uncertainty of geological formations. For underground radioactive waste repositories, the spatial definition of the formation containing the repository is critical, as several geometric requirements need to be met to achieve safety standards. We propose to characterise the geometrical uncertainties of the formation containing the repository through the definition of a variogram range, sill and nugget from 2D seismic data. Starting from an initial model of acoustic impedance, we perturb it by adding a Gaussian field to it that is generated by sampling from range, sill and nugget distributions; and compute its corresponding seismic forward simulation to later measure the misfit with respect to the 2D seismic data. By converting the misfit to a probability value that represent the feasibility or likelihood of that realization, and by analysing the time shifts between the same-coordinate seismic traces of the seismic forward simulation and seismic data, we obtain distributions of the variogram parameters that can later be used to characterise the uncertainty in other points of the formation containing the repository, in 3D, where seismic data or other sources of information are not available.

03.05 Advances in Paleoclimate Proxies and Their Applications

Application of Dual Clumped Isotopes to Last Interglacial Climate of the Persian/Arabian Gulf

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The last interglacial warm period and eustatic sea level high stand, MIS 5e, is increasingly used as an analog for near-term effects of anthropogenic global warming. Quaternary sea level fluctuations created complex stratigraphy and diagenetic environments around the Persian/Arabian Gulf, which has impeded the formation of a coherent climate record in this region. Tridacna squamosina, an aragonitic bivalve favored in sclerochronology for its large body and exceptional growth banding, can be found in MIS 5e deposits near Abu Dhabi, UAE. Dual clumped isotopes (paired measurement of Δ47 and Δ48) can produce high quality paleotemperature (and by extension δ^{18}Owater) records from carbonates, including built-in assessment of potential kinetic biases. We collected material from winter and summer growth bands for 10 consecutive years of growth on a single MIS 5e T. squamosina, resampling 6 growth increments to test the effect of frictional heating during drilling (varying drill speed and crushing by mortar and pestle) and bleaching with sodium hypochlorite. Δ47- Δ48 values were indistinguishable from equilibrium regardless of preparation method. Seasonality was not analytically resolvable (< 4°C) and reconstructed δ^{18}Owater indicates normal marine salinity. However, there was an absolute spread of ~20–28°C across all samples, with a decreasing trend in temperatures across 10 years. This range is on the lower end of modern water temperatures in The Gulf but aligns with habitats of modern T. squamosina. Further work on other T. squamosina specimens as well as corals is underway to confirm these relatively cool MIS 5e temperatures.

02.01 The Tethys Ocean – the cradle of modern tropical life

Calibrating Early Triassic biotic rebound and carbon cycles based on coupled Bayesian zircon eruption age and Bayesian age-depth models

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Robust time scale is essential for understanding geological processes and biotic evolution. Following the Permian-Triassic mass extinctions, the Early Triassic recorded a series of climatic, environmental and biotic events. However, the tempo of these events remains poorly constrained.

In this work, we present four new high-precision zircon U-Pb dates from the Induan in South China using high precision CA-ID-TIMS techniques. We then adopted coupled Bayesian eruption age and Bayesian age-depth models to interpret these dates and built age model, based on which, we provided, for the first time, absolute time estimations for the Griesbachian-Dienerian and Induan-Olenekian boundaries, i.e. 251.562 +0.090/-0.101 Ma and 250.626 +0.140/-0.214 Ma, respectively.

Then, we applied the same analytical approach on published U-Pb dates of 25 ash beds. The resulting age-depth models, combined with biostratigraphic data, allow us to update age estimations for all Early Triassic stage/substage boundaries. The new time scale shows significant differences from those based on cyclostratigraphy, as well as some minor differences from the low MSWD weight mean age interpretations.

The timing of three negative and four positive excursions of Early Triassic carbon isotope were precisely constrained based on the new age models. The new age models also provide a robust timeline to evaluate biotic evolution in the aftermath of the Permian-Triassic mass extinction. For instance, the first remarkable biotic rebound in the late Griesbachian is ~0.3 Myr after the Permian-Triassic mass extinction, much faster than expectation.

03.04 All about carbonates

Exploring the World of Carbonates: Mechanochemical Synthesis and *In Situ* X-ray Powder Diffraction (XRPD) Studies

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Carbonates and carbonatite melts are integral to the geodynamics of the upper mantle and transition zone, influencing processes such as subduction, magma generation, mantle metasomatism, and diamond formation. The laboratory synthesis of many carbonate minerals is challenging due to the high pressures and temperatures required for their formation. Understanding the synthesis and reaction pathways of alkali and alkaline-earth metal carbonates is essential for advancing knowledge of their stability, transformations, geological relevance and potential applications. They exhibit diverse crystallographic structures and variable stability conditions, often necessitating specific environmental factors for their formation. Therefore, the development of alternative approaches is essential to enable controlled carbonate formation under more feasible laboratory conditions.[1]

Mechanochemical synthesis presents a promising alternative, facilitating carbonate formation without the need for extreme pressures or temperatures. This technique utilizes high-energy ball milling to induce structural and physicochemical modifications, promoting chemical reactions through shear forces, or impact.[2] This study systematically investigates the mechanochemical synthesis of various carbonate systems, including $K_2Ca(CO_3)_2$ polymorphs[3], dolomite, and sodium-rich natrocarbonatites such as nyerereite and pirssonite. Employing a Retsch MM400 shaker mill in combination with *ex situ* laboratory analysis and *in situ* XRPD, we explore reaction pathway, phase transitions, and crystallographic transformations to understand their phase stability and polymorphic behavior.[4,5]

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03.04 All about carbonates

Towards Sustainable Carbonate Synthesis: Mechanochemical Synthesis and *In situ* X-ray Powder Diffraction Studies

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Alkaline-earth metal carbonates like magnesite ($MgCO_3$), dolomite ($MgCa(CO_3)_2$), and calcite ($CaCO_3$) are typically formed via atmospheric CO_2 carbonatization. For the synthesis of many carbonates, high pressures or temperatures are required. Unlike these methods, the mechanochemical synthesis of carbonates utilizes ball milling to apply mechanical energy, inducing structural and physicochemical changes and enabling chemical reactions through shear forces, abrasion, impact, and extrusion.[1]

This study investigates the mechanochemical synthesis of $K_2Ca(CO_3)_2$ polymorphs, specifically fairchildite and buetschliite, synthesized from $CaCO_3$ and K_2CO_3 in a shaker mill (Retsch MM400). The synthesis and phase transformation pathways were explored using both *ex situ* laboratory analysis and *in situ* X-ray powder diffraction, providing insights into reaction pathways and crystallographic transformations. The primary objective of this systematic investigation is to examine how variables such as milling frequency and water/hydroxyl content influence the transformation pathway between the structurally disordered high-temperature polymorph fairchildite and the thermodynamically stable polymorph buetschliite.[2]

This mechanochemical approach also opens pathways for synthesizing other carbonate systems, such as eitelite ($Na_2Mg(CO_3)_2$), dolomite ($MgCa(CO_3)_2$), and nyerereite ($Na_2Ca(CO_3)_2$). Similar studies can be conducted to investigate how variables like temperature, moisture, reactant ratios, and milling conditions influence their polymorphic transformations, providing broader insights into phase control across diverse carbonate systems.

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01.04 Latest Achievements in Scientific Ocean and Continental Drilling

Age and radiogenic isotope geochemistry of the Agulhas Plateau (SW Indian Ocean) drilled during IODP Exp. 392

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The Agulhas Plateau is an oceanic plateau located in the gateway between the South Atlantic and Indian Oceans. It is thought to have formed during the late Cretaceous together with the Maud Rise (MR) and Northeast Georgia Rise (NEGR) as a joint plateau. Igneous rocks, cored from the volcanic basement of Agulhas during IODP Expedition 392 (Uenzelmann-Neben et al., 2023, IODP Proceedings 392), include tholeiitic sills and pillow lavas. $^{40}Ar/^{39}Ar$ ages range from 78.61 ± 0.68 to 87.36 ± 0.19 Ma. Lavas from the Agulhas sites were also analyzed for Sr-Nd-Pb-Hf isotopic composition together with newly sampled legacy core samples from MR (ODP Leg 113) and NEGR (ODP Leg 114). The Agulhas rocks are less enriched compared to the adjacent and slightly older Mozambique Ridge lavas, which trend towards an “enriched mantle” composition (Jacques et al., 2019, Chem. Geol. 507). Instead, the Agulhas lavas show systematically lower initial $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios for a given $^{206}Pb/^{204}Pb$ and thus plot closer to the Northern Hemisphere Reference Line while forming a trend towards the Bouvet hotspot composition. In contrast, analyzed MR and NEGR lavas have a more enriched isotopic composition similar to Mozambique Ridge. In the light of these results and applying new plate tectonic reconstructions, we discuss if Agulhas shared a common magma source with MR and NEGR or whether the latter two plateaus formed as part of the earlier Mozambique event, which would result in a revised geodynamic history of oceanic plateau formation in the southern African marine gateway.

01.29 Environmental Hazards and Risks

Biodegradation of organic micropollutants at the sediment-water interface of aquatic ecosystems

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Organic micropollutants are a growing environmental concern, due to their ecotoxicological risks and impact on human health. Aquatic environments are particularly vulnerable, receiving inputs from multiple sources, with pesticides from agricultural run-off and pharmaceuticals from wastewater treatment plant effluents being among the most frequently detected contaminants. In these ecosystems micropollutants undergo non-transformative processes such as sorption and dilution, as well as transformative processes like bio- and photodegradation. However, transformative processes under different environmental conditions remain poorly constrained, even though they determine the persistence of micropollutants and can lead to transformation products that are more toxic or mobile than their parent compounds. To assess the effect of varying environmental conditions on the biodegradation of selected micropollutants, degradation experiments were conducted in single and co-occurrence of the antibiotic sulfamethoxazole and the herbicide S-metolachlor. River water and sediment microcosms from agricultural and urban sites enabled the evaluation of the effect of different matrices, organic matter and oxygen availability on biodegradation kinetics and transformation pathways. Within these conditions the half-lives varied between 4.2 ± 0.1 days and persistence after 90 days for sulfamethoxazole and 37 ± 7 days to persistence after 284 days for S-metolachlor. The results indicated that the presence and type of sediments are key factors of biodegradation. Furthermore, the detection of 4-aminobenzenesulfonamide, resulting from the ε-cleavage of sulfamethoxazole, as the main transformation product exhibits a novel biodegradation pathway. These findings provide environmentally relevant insights into micropollutant transformation and highlight key factors affecting their dissipation in aquatic environments.

01.02 Anthropogenic geomorphology

Post-fire impacts in the Central European Uplands: linking surface dynamics and contamination hazards in unmanaged forests to landscape and forest recovery

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Central Europe is emerging as a new fire region, with climate change increasing the likelihood of forest fires. In contrast to “classical” fire regions, such as the Mediterranean, little is known about Earth surface dynamics following fires in Central European upland forests. In August 2022, a 13-hectare fire burned a spruce forest disturbed by a wide-spread bark beetle infestation in Harz National Park. We monitored the site at roughly six-month intervals, comparing burned and unburned areas using unoccupied aerial vehicles equipped with multispectral, thermal, high-resolution RGB, and LiDAR sensors. Derived orthoimages, 3D point clouds, and canopy height were employed to estimate standing deadwood, succession indicators such as fractional vegetation cover, microclimate regimes, and small-scale morphological changes. We additionally collected soil samples with different burn severities, including soils associated with charcoal kilns that repesent legacies of past land use, to better understand post-fire nutrient and pollutant dynamics over time. We particularly focused on the point-source contamination by polycyclic aromatic hydrocarbons, which are considered toxic to organisms, including human health, and that could be measured in soils sampled over time. We found a dynamic setting associated with fire severity, subsurface tunneling, and the long-term legacy of granite landscape evolution, collectively affecting post-fire mass movements, vegetation recovery, and pollutant loads. Here, we present first insights into deadwood breakdown, vegetation succession, surface erosion and soil property changes, to bridge the knowledge gap between well-studied fire-prone regions and emerging ones like Central Europe and to provide base-knowledge for future research and management strategies.

03.01 Recent Advances in the Geological Research of Marine Environments

The Jøtul hydrothermal field: High H_2 production in sediment-hosted hydrothermal vent fluids at an ultraslow spreading mid-ocean ridge

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We present results from our seagoing mission MSM131 aboard R/V Maria S. Merian to the Jøtul hydrothermal field, located on the ultraslow-spreading northern Knipovich Ridge. In autumn 2024, we conducted water column surveys, geological investigations, and collected hydrothermal vent fluids using isobaric gas-tight samplers. The Jøtul hydrothermal field lies near the continental shelf of Svalbard, where clastic sediments are deposited within the rift valley. The hydrothermal vent fluids are metal-poor, alkaline and exhibit the highest methane concentrations ever recorded at mid-ocean ridge hydrothermal vent sites, all indicating the importance of fluid-sediment interactions in the subsurface of this vent site. Unexpectedly, the vent fluids also contain hydrogen (H_2) concentrations that are substantially higher than those found in other sediment-hosted vent systems. Together with low hydrogen sulfide (H_2S) concentrations, this composition is typically associated with fluids that have interacted with ultramafic rocks. The presence of altered ultramafic rocks on the seafloor near the Jøtul field suggests that such interaction may have contributed to the fluid composition. However, our thermodynamic calculations indicate the high H_2/H_2S ratios are not necessarily related to ultramafic rock alteration, but rather may arise from thermal degradation of organic matter, followed by abiotic oxidation of methane at reaction-zone temperatures around 400°C. While high H_2 concentrations are often considered indicative of fluid-rock reactions with ultramafic rocks, our findings demonstrate that

high-pressure, high-temperature fluid sediment interactions can also be a significant source of H_2 emissions into the ocean.

07.04 Challenges in geoscientific applications

Shaping an inter- and transdisciplinary research agenda on land use under climate change in the highly dynamic northern Ecuadorian Andes

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Global climate change, resource depletion, and land use change require local solutions that acknowledge the configuration and history of its landscapes and the related social-ecological processes. Particularly sensitive to climate change are high-mountain tropical regions. The Andes, where Ecuador's capital Quito is home to c. 3 million people, host globally-important biodiversity hotspots, organic rich soils and water storage capacity of utmost importance for rural and urban areas.

We would like to present 1) how we co-designed an inter- and transdisciplinary research agenda on land use and landscape dynamics under global and local change that considers local knowledge and landscape evolution, and 2) what challenges we identified to make this research happen. With researchers from Ecuador, Germany, and Poland and members of NGOs and local communities we

explored future study areas and the most pressing subtopics in a region of active geodynamics (volcanism, earthquakes) and highly sensitive to climatic extremes that co-drive Earth surface processes (e.g., soil erosion, vegetation fires). We discussed about “landscape” as a potential conceptual framework and about decolonial methodologies on “how to research together”. We furthermore explored lakes as sedimentary archives of past landscape dynamics, as well as current ecosystem functioning using vegetation surveys, state-of-the-art remote sensing and field mapping. Overall, we recognize high potential to co-create actionable knowledge that addresses the interconnectedness between societal and natural systems, and to contribute to tackling ongoing and future land use challenges in the tropical Andes.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

We need better models! How geomorphic expertise in environmental seismic models leverages our understanding of landscape dynamics

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Throughout the last years, several physically based models have been introduced that allow to estimate the seismic signatures of environmental processes. Hence, in an inverse way, we can turn seismometers into efficient probes of earth surface dynamics that are otherwise hard to quantify, such as snow avalanches, debris flows, river sediment transport, rain intensity and large scale atmospheric pressure systems. However, most of these models lack a profound geomorphic representation or operate under very simplified assumptions. In addition, novel methods of seismic noise cross correlation are increasingly utilised to probe the water fluxes as well as geomorphically driven material property changes within the shallow to deep subsurface. These techniques also operate under sometimes very simplified representations of the Critical Zone's architecture, water flow paths, and hydrological or geomorphic concepts.

Here, I survey geomorphic processes and landscape dynamics that are already represented by environmental seismic models and summarise, which unique insights they allow beyond what classic survey techniques can deliver. I also point out important processes that hitherto lack proper representation. I argue for an alliance across disciplines to close these gaps in knowledge, skill and application, to further boost our scientific capabilities to understand landscape reaction to ongoing change.

01.29 Environmental Hazards and Risks

Post-fire landscape evolution – insights from passive seismic monitoring of atmosphere-weathering zone coupling at the Quesenbank succession site, Harz mountains, Germany

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The August 2022 forest fire event in the Harz National Park has suddenly shifted head water catchments to a new, unknown and short-lived state of equilibrium. The majority of standing bark beetle ceased trees were either burned or severely charred so that they fell in the weeks and months after the fire, giving way to the selective establishment of successive species. From studies in other fire-affected regions it was anticipated to see enhanced surface runoff and rain-driven sediment export. However, only little surface hydrophobicity was found months after fire, while measurements of diffusive fluxes out of the site are hard to constrain with typical state of the art approaches. Here, we present first results of the information that can be derived from a small seismic network in the Quesenbank site, a severely affected 12 ha patch in the Wormke headwater catchment on the southern slope of the Brocken towards the town of Schierke. In March 2024, we set up a triangular array of 4.5 Hz geophones with an aperture of about 100 m. We show successive changes in the response of soil moisture and deeper zone water dynamics to rainfall events and over multiple seasons. We use the array to detect and locate brief periods of seismic activity due to uprooting of trees and large branches falling off the dead trees, and compare the multi-seasonal evolution of event rates. We further inspect the state of coupling between atmosphere, biosphere and pedosphere by comparing meteorological time series and seismic ground response patterns.

08.01 Young Scientist Session

Experimental investigation of the role of lower-crustal strength on upper-crustal deformation in obliquely convergent tectonic settings

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Obliquely convergent plate margins and continental collision zones, such as the Andes and Tibet, respectively, are often characterized by crustal-scale, rhomb-shaped basins enveloped by transpression zones. The geometries and sizes of such basins, typically evident as low-strain upper-crustal domains, and their transpressive margins are highly variable. The strength of the viscously deforming lower crust may significantly influence deformation patterns of the upper crust. For this reason, we tested two viscous materials as lower-crustal analogues with regard to the deformational behavior of the model upper crust, induced by a piston driven obliquely into the materials. For modelling a weak lower crust, Laponite, a low-viscosity gel, was used. By contrast, Polydimethylsiloxane (PDMS), a silica polymer, mixed with corundum grains was used for modelling a strong lower crust. Digital image correlation of the top surfaces of experiments allowed us to monitor the evolution of displacement vector fields, vertical-axis rotations and strain gradients. In all experiments, we observed the formation of high-amplitude ramp anticlines above the inclined piston, followed respectively by a well-defined zone of rhomb-shaped deformation domains and a low-strain zone of distributed deformation. In experiments using low-viscosity Laponite mixtures, ramp anticlines with unrealistically large amplitudes formed above the piston. Moreover, rhomb-shaped domains appeared more elongate than in experiments with PDMS, regardless of shortening directions. Apart from the viscosity of modal lower crust, we note that the distance between the piston and the back wall of the modelling box influences deformation patterns significantly, a most important result to be considered in physical experiments.

01.26 Alpine-Zagros-Himalayan Orogenic System: Case Studies

Regional Structure of the Zagros Fold-Thrust Belt in Kurdistan, Northern Iraq

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This study examines the regional structure of the Zagros fold-thrust belt in Kurdistan, northern Iraq, utilizing field studies, remote sensing-GIS analyses, and cross-section restorations. The study area lies in the frontal zone of the north-western part of the Zagros fold and thrust belt in Kurdistan, near the north-eastern margin of the Arabian Plate. It is characterized by WNW-ESE striking, doubly-plunging, upright symmetric to asymmetric detachment folds that encompass 8.2–10.9 km of Paleozoic to Quaternary layers. Several regional structural sections were created, with a deep basal detachment identified at the base of the Paleozoic sequences. The area has experienced thin-skinned detachment folding along with thick-skinned thrusting from the Mid Miocene to the present. Detachment folding caused a maximum NNE-SSW-directed shortening of about 18.62 km (19.71%) over a section length of 94.45 km, while thrust faults resulted in a maximum shortening of around 1.98 km (1.95%) over a section length of 101.55 km.

06.02 Recent advances in fossil imaging

Possibilities of Virtual Paleohistology: A Comparative Study with Sauropod Dinosaurs

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Paleohistology, the study of fossilized bone microstructure, is crucial for understanding the growth and life history of extinct vertebrates. Traditional methods rely on destructive thin-sectioning, limiting its application. Micro-computed tomography (µCT) offers a non-destructive alternative using X-ray, but its reliability for paleohistological analysis remains underexplored. This comparative study evaluates the effectiveness of µCT by analyzing 14 sauropod specimens representing multiple genera, ontogenetic stages, and geological formations, using µCT scanning and thin-section microscopy.

µCT successfully visualized key histological features, including vascularization, secondary osteons, and lines of arrested growth (LAGs), with a strong correspondence to thin-section data (K = 0.71–1.0). Scans of specimens under 15 mm in diameter showed all considered structured with a level of detail comparable to the thin sections. In some cases, µCT revealed features more clearly than microscopy, especially when diagenetic infilling obscured thin sections. While artifacts and noise can often be mitigated, larger specimens require scanning at greater distances, increasing voxel size and thus reducing resolution – a trade-off determined by field-of-view limitations rather than bone size. Advances in technology and reconstruction algorithms continue to improve image quality, highlighting the importance of archiving raw data for future reprocessing.

µCT's advantages include three-dimensional visualization and the ability to study intra- and interskeletal series non-destructively. This approach preserves fossil integrity and promotes data sharing and reproducibility. Our findings validate µCT as a powerful tool for virtual paleohistology. Future directions include the standardization of protocols and integration with advanced imaging techniques and machine learning to further enhance resolution and accessibility.

04.01 Prospection and extraction of critical and strategic raw materials in Europe

Experience from Plant-Based Exploration in Europe: Reduced Impact, Enhanced Results

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Our research evaluates and optimizes using plants as a geochemical sampling medium, aiming to enhance its applicability and effectiveness in European geological surveys. We share our experience in applying this low-impact, fast, and cost-effective exploration tool gained as part of the EU-funded project SEMACRET, which focused on sustainable exploration for orthomagmatic deposits in Europe.

Biogeochemical exploration has proven particularly valuable in areas with limited geological information, such as those with unknown lithologies, coarse geological maps, and blind deposits. By conducting surveys in typical European settings (from Portugal via Central Europe to Finland), we've gained insights into the effectiveness of biogeochemical exploration in a variety of contexts, including temperate and boreal forests where remote sensing capabilities are limited due to extensive sediment and/or vegetation cover as well as areas with monoculture agriculture. Our work demonstrates how biogeochemical exploration can complement standard geological mapping techniques, providing valuable information for national exploration programs while promoting environmentally and socially responsible practices in domestic exploration.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

U-Pb-He detrital zircon double dating of Cretaceous synorogenic sandstones of the Eastern Alps

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The Cretaceous period of the European Alps is constrained mostly by thermobarometric and geochronologic data obtained on metamorphic basement units complemented by investigations on the sedimentary record. Our advanced sediment provenance approach using detrital zircon double-dating reveals high- and low-temperature age constraints that allow for (i) assigning potential source formations to Cretaceous siliciclastic sequences of the Eastern Alps and (ii) derive a model of sediment pathways through space and time.

We performed U-Pb-He double dating on 970 detrital zircon grains from 12 samples, deposited from Early Cretaceous to early Eocene in the Eastern Alps. Additionally two reference samples from the Alps and from the Bohemian Massif were also dated. The detrital U-Pb age spectra are compared to published zircon U-Pb age distributions obtained on the potential source units. The Fflysch and Gosau samples show different age patterns: while the Flysch shows strong similarities to age patterns obtained on the Bohemian Massif, the characteristic Variscan and Caledonian age components are largely missing in the Gosau samples. The (U-Th)/He low-temperature cooling ages form three, well distinguishable age groups: 250–180 Ma, indicating provenance from the European craton; 160-100 Ma, indicating Upper Austroalpine hanging wall units and the Jurassic nappe complex; and 70-50 Ma hinting to the Austroalpine core complexes. The Flysch is dominantly European in origin with some Alpine detritus, while the Gosau sediment derived mostly from the Eoalpine core complexes. We present a reconstruction of the sediment supply pathways in four time slices for the Early Cretaceous to Paleogene Eastern Alps.

03.07 Risks from a Changing Cryosphere

Organic Matter Characteristics in a changing Thermokarst Landscape: Insights from the Baldwin Peninsula, Alaska

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Permafrost degradation is accelerating in ice-rich Arctic lowlands, reshaping thermokarst landscapes and mobilising formerly frozen organic carbon. As permafrost thaws, microbial decomposition speeds up, producing greenhouse gases (GHG) and altering carbon cycling. GHG emissions are closely linked to the microbial degradability of organic matter (OM), which depends on both physical accessibility and substrate quality. This study investigates OM characteristics in five landscape units on the Baldwin Peninsula, Alaska, representing successive stages of thermokarst-driven transformation: undisturbed Yedoma upland, thermokarst lake, semi-drained lake basin (SDL), drained lake basin (DLB), and a near-shore marine deposit as an end-member. Focusing on the uppermost meter of sediment, we applied a multi-proxy approach including n-alkane biomarker analysis, elemental composition (TOC, C/N), $\delta^{13}C$ stable isotopes, radiocarbon dating, and sedimentological characterisation. We addressed two main questions: (1) How does OM quality vary across these landforms? (2) What is the potential for future OM decomposition and mobilisation? Our findings show that OM in thermokarst-influenced units (lake, SDL, DLB) is more strongly degraded than in upland deposits. The DLB represents a refrozen talik, while the SDL retained an unfrozen talik at the time of coring; OM degradation was highest in the SDL. These results highlight the role of talik dynamics in shaping OM decomposition potential and underscore the vulnerability of carbon stored in yedoma uplands under future thermokarst activity. Our study contributes to understanding permafrost carbon dynamics and the climate sensitivity of Arctic lowland systems.

01.06 Tectonic Systems – TSK Open Session

A premier field-based slip rate and total offset estimate for the Motagua Fault, Guatemala

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The Motagua Fault in Guatemala is the southern one of two sinistral strike-slip faults that make up the North American-Caribbean plate boundary system. Both faults are known to produce large earthquakes, the most recent one being a magnitude 7.5 on the Motagua Fault that caused severe damages to the infrastructure of the country and about 23,000 deaths. Together both faults accommodate ca. 20 mm of slip per year. At present, the Motagua Fault is more active than the Polochic Fault to the north, taking up most of the slip, while in the past the contrary was the case. However individual slip rate estimates thus far are very vague and mainly based on GPS measurements. At the Río El Tambor site southwest of Cabañas, multiple river terraces are laterally offset by the Motagua Fault. We used optically stimulated luminescence and radiocarbon dating on these terraces to provide the first field-based estimate for the slip rate of the Motagua Fault. Additionally, we used satellite imagery, drone lidar surveys, and historical data to map and systematically evaluate offsets on geomorphic markers. These indicate that the total offset on the Motagua Fault is at maximum ca. 20 km and thus, the switch of the high slip rate from the Polochic to the Motagua Fault probably did not happen earlier than in the Pleistocene.

05.02 Understanding (geo)materials with advanced experimental and computational methods

Towards parallel geochemical and mineralogical proficiency testing: GeoPT and MinPT

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For geochemical proficiency testing well established schemes are existing. One of which is organized by the International Association of Geoanalysts (IAG), named GeoPT. Recently, the need for a proficiency testing that includes the mineralogical composition has been formulated, as the mineral composition does indeed have an impact on the geochemical methods to be used and their respective results. We therefore proposed a simultaneous testing: GeoPT and MinPT. MinPT is to be developed for both classical analysis of the phase composition using bulk methods (e.g. quantitative XRD) and for methods of the so-called "automated mineralogy" (AM) approach using SEM- or µ-XRF-based techniques. We identified and collected five different rock types suitable for a first round of combined GeoPT and MinPT testing scheme, one of which was characterised by a number of analytical techniques in order to define suitable parameters (particle sizes, sufficient complexity, homogeneity of the minerals etc.) for the later material to be used in the combined proficiency testing. The results will be presented. We identified a quite narrow grain size (38–150µm) to which the rock material was ground and sieved, being aware that the material is by no means representative of the initial rock. Nevertheless, the material is now suitable for further processing towards a combined testing scheme. In later steps more complex materials including ores can be developed for these combined proficiency testing.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Tin isotope composition as a fingerprint for the evolution of granitic ore deposits

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Understanding the formation of Sn deposits, with cassiterite (SnO_2) commonly being the predominant ore mineral, is crucial for efficient mining and ensuring sustainable Sn utilization. Since cassiterite crystallization is accompanied by redox change from mainly Sn^{2+} in silicate melts (or fluids) to Sn^{4+} in SnO_2, and heavier tin isotopes preferentially bond to Sn^{4+}, studying Sn isotope compositions may help track the redox conditions in the melt and/or fluid during Sn enrichment and cassiterite crystallization.

As a case study, we comparatively investigated the Sn isotope and trace element evolution of cassiterites from the rare metal granite system of Argemela (Portugal) and the greisen system of Sadisdorf (Germany). While in Argemela, Sn transport and cassiterite formation are thought to have mainly occurred by melts, metal transport and enrichment in Sadisdorf occurred during fluid-assisted processes.

Tin isotope and trace element analyses of individual zones reflecting different crystallization stages of the cassiterite grains were conducted *in situ* using femtosecond-LA-MC-ICP-MS. This method reveals conditions and evolution of the metal transport medium during cassiterite crystallization and ore formation.

Preliminary results indicate that cassiterite crystals from Sadisdorf have frequently high W concentrations and a trend from lighter Sn isotope ratios in the core towards heavier values at the rim, indicating increasing oxidizing conditions during crystallization. In contrast, crystals from Argemela mostly show high Nb-Ta concentrations and decreasing Sn isotope values from core to rim, possibly explained by Rayleigh crystallization. The ore-forming conditions in both localities will be further tackled by the investigation of Li isotopes in Li-micas.

04.04 Hydrogen in the energy transition –white to green hydrogen and subsurface storage

Hydro-Geomechanical Reservoir Modelling of Underground Hydrogen Storage in a Saline Aquifer of the North German Basin

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To manage seasonal fluctuations in renewable energy, hydrogen can be produced from excess electricity and stored in geological formations. Saline aquifers, due to their large capacity and widespread presence in sedimentary basins, show strong potential for underground hydrogen storage (UHS). However, their viability in porous formations remains largely unproven. This study focuses on the Triassic Stuttgart Formation near Ketzin in the North German Basin, a former CO_2 storage site. Its heterogeneous lithology and anticlinal structure offer structural trapping potential, but a fault zone at the reservoir top presents a risk of gas migration, potentially intensified by geomechanical effects from cyclic hydrogen injection.

Previous UHS models have emphasised hydrodynamic behaviour, focusing less on geomechanical effects. However, understanding these effects is crucial for safe, long-term storage. This study presents a coupled hydro-geomechanical reservoir model to evaluate risks such as fault reactivation (assessed using slip tendency analysis of major faults near the wellbore) and ground deformation due to hydrogen injection and withdrawal. Site-specific simulations using CMG GEM indicate that faults remain stable and vertical displacements are within a small to moderate range.

The results provide valuable insight into flow and geomechanical behaviour during UHS in a saline aquifer setting. While based on a specific site, the analysis enhances understanding of reservoir integrity and supports the broader development of hydrogen storage technologies. The findings contribute to assessing the feasibility of UHS and aid in the design of a potential hydrogen storage demonstrator in the North German Basin.

07.02 Geothermal energy – Potential and utilisation of geothermal energy resources for the heat transition

Structural geology and reservoir properties of the Middle Buntsandstein in Göttingen and the related risks for a hydrogeothermal project

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Within the sedimentary succession of Zechstein to Lower Jurassic in the Leinetalgraben, stacked channel sandstones of the Middle Buntsandstein are the most promising geothermal reservoirs for Göttingen. Located in depths of ca. 800–1.400 m, reservoir temperatures are estimated to vary from 35-55°C.

Two seismic sections were interpreted and a 3D-structural model was built in combination with outcrop and scarce well data. Structural analysis confirmed the two-phased tectonic model for graben formation proposed previously, with an early W-E extension and later NW-SE compression. The pinnate eastern boundary faults continue towards the graben centre, resulting in highs and lows within the graben.

Statistical analysis of petrophysical properties of the Middle Buntsandstein was based on core plug data from wells in Lower Saxony. The average sandstone porosity is ca. 9.3% (p10: 1.8%, p90: 21.1%), the average permeability is ca. 7.8 mD (p10: 0.005 mD, p90: 263 mD). The very high range of both parameters most likely reflects not only sample depth but also the abundance of authigenic minerals within the intergranular volume and their degree of dissolution. Due to the complex fault evolution and mudstone interlayers, an enhancement of reservoir properties within fault damage zones cannot be assumed.

Following the wide range of petrophysical data, for a geothermal doublet a flow rate between 1.3 l/s (p90) and 101 l/s (p10) has been calculated, with a mean of 29.5 l/s. However, as typical for geothermal doublets in northern Germany and neighbouring regions, this wide range poses a significant economic risk for a geothermal project.

07.03 Quantifying surface and near-surface dynamics with remote sensing and geophysics

From Pixel to Processes in Soil Erosion Research: Advancing 4D Analysis for Spatiotemporal Process Disaggregation and Model Evaluation

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Current soil erosion models are constrained by parameter uncertainty, limited empirical data, and an inability to capture the complex spatiotemporal dynamics of surface processes. This study introduces a novel image-based approach using 3D photogrammetric time series to detect and quantify both erosive and non-erosive soil processes.

Using Structure from Motion (SfM) and high-frequency time-lapse photogrammetry, we generate dense 3D surface models of bounded experimental plots during controlled rainfall simulations. These multi-site datasets capture surface evolution in detail, enabling analysis of processes such as soil compaction, aggregate breakdown, sheet erosion, and rill formation.

To address early-stage surface subsidence (e.g., due to compaction) that masks initial sediment yield measurement, we develop a correction method. Based on soil and plot properties, non-linear regression is used to derive s-shaped correction functions that estimate and adjust for these masking effects.

A hierarchical, time series-based change detection strategy supports automated process classification by analyzing full surface model sequences, moving beyond bitemporal comparisons. This enables the temporal segmentation of overlapping erosional phases, enhancing interpretation of subtle and high-magnitude changes.

The datasets also support the calibration of a runoff-driven soil erosion model using microtopographic inputs. Multiple spatiotemporal averaging techniques are assessed to identify robust calibration metrics. Results show no single metric captures all aspects of erosional behavior, highlighting the need for multi-metric evaluation.

By integrating time-lapse imaging, 4D analysis, and advanced model evaluation, a comprehensive pathway from pixel-level measurements to supporting process-level understanding is introduced to improve soil erosion modeling under dynamic environmental conditions.

05.02 Understanding (geo)materials with advanced experimental and computational methods

Human-Guided vs. Push-Button Machine Learning for Hidden-Phase Raman Mapping

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Raman mapping routinely acquires thousands of spectra, yet fluorescence, weak signal and peak overlap can mask key phase information. We contrast two open-source workflows – an interactive, human-guided pipeline and a fully automated machine-learning routine – to reveal hidden structural differences in complex (geo)materials.

The case study is a cross-section of a prior analysed oxide-rich corrosion layer on a ferritic model alloy. Corrosion control demands separating protective from non-protective oxides e.g., magnetite, chromite and mixed spinels. In the human-guided routine, an analyst applies dimensionality reduction, chooses a clustering method, inspects cluster quality and, where warranted, performs pseudo-Voigt peak-position analysis before re-clustering. This loop resolves all the chemically distinct populations and quantifies magnetite – chromite band shifts of up to 7 cm^{-1}, revealing mixed spinels that standard Raman maps miss.

The automated path eliminates human decisions: a convolutional autoencoder compresses spectra to latent features and an information-criterion optimiser determines cluster numbers. While faster, the automated routine tends to merge subtle spinel variants and is more sensitive to noise. The present study dissects trade-offs in interpretability, reproducibility and library dependence, showing when expert oversight adds value.

These workflows turn phase-tagged Raman maps into quantitative micro-atlases that can be generated on notebooks using scikit-learn[1] and TensorFlow[2]. The presentation shows how both workflows deliver large-scale, detailed insight into chemically similar phases with differing functions.

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01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Our legacy: how human impact takes on climatic changes to control floodplain dynamics in the Upper Rhine area

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While the dynamics of central European fluvial systems were originally controlled mainly by climatic changes, human impact has fundamentally altered the catchments' sediment dynamics. During the Middle to Late Holocene, a transition occurred to anthropogenically controlled fluvial systems, which got stored in floodplain sediments as these record both past river dynamics and human activities (e.g., settling, mining, logging).

Since insights from the meso-scale rivers are largely lacking, two rhenian tributaries were studied with a higher (Kinzig river, Black Forest, Germany) and lower (Fecht river, Vosges, France) impact of mining and timber drift and raft. We use geophysical surveys, sedimentological investigations, luminescence dating, and geochemical analyses to study floodplain stratigraphies and heavy metal contaminations.

Our sedimentological data reveal distinct phases of floodplain accumulation (Kinzig: 0.1 mm/a for Late Pleistocene/Early Holocene till 9.00 ka, 0.3 mm/a for Mid/Late Holocene 9.00-0.82 ka, 1.1 mm/a for modern 0.81-0 ka). Additionally, floodplain sediment contaminations and historic land use seem closely related as suggested by the timing and rise in heavy metal concentrations (Kinzig: enrichment factors of Ba, Pb, Cu peaking at ca. 2.5, 4.0, 3.0). Preliminary results from the Fecht also point to increasing accumulation rates over a similar time span.

Hence, cross-referencing floodplain stratigraphy with land use history supports our understanding of a gradual shift to an anthropogenically dominated fluvial system. Said transition occurred in the Kinzig after human settlement in the Upper Rhine plain, finding higher anthropogenic impact on floodplains over the last ca. 2500 years as found in the unprecedented accumulation rates.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

3D Seismic Interpretation and Modeling to Assess Regional Geothermal Potential in Lower Saxony

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The Uppermost Maastrichtian calcarenites in the North German Basin are considered a promising mid-depth geothermal reservoir. However, their subsurface architecture is highly variable due to a complex tectono-stratigraphic evolution, making it difficult to predict reservoir geometry and quality based solely on borehole data, especially in structurally heterogeneous areas.

To enhance spatial understanding and reduce geological uncertainty, 3D seismic data originally acquired for hydrocarbon exploration were reinterpreted and analyzed using OpendTect software. The seismic interpretation workflow involved the application of various filtering techniques aimed at reducing noise and improving the visibility of geological structures. Filters were applied to highlight discontinuities and improve the resolution of fault patterns. In addition, parametrized volumes were generated to assist in identifying and delineating potential fault zones. A suite of seismic attributes was used to further analyze and characterize the reservoir's structural and stratigraphic framework. Key reservoir horizons were tracked using the 'Inversion+' method, allowing for more accurate and geologically consistent horizon interpretation.

These methods significantly improved the visualization of critical geological features, including fault systems, stratigraphic boundaries, and lateral thickness variations. By integrating seismic interpretation with borehole data, a detailed 3D subsurface model was developed. Based on the model, the evolution of the reservoir should be reconstructed, the structural framework should be checked for consistency, and zones with enhanced geothermal potential should be identified. The combined approach enables more accurate reservoir characterization and helps reduce exploration risk in complex geological settings. Our presentation will provide initial insights into our ongoing work.

01.13 Sedimentary basins as multi-proxy and multi-process recorders

3D Seismic Analysis of a Salt Tectonic-Controlled Geothermal Reservoir in the North German Basin

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The calcarenites of the Reitbrook Formation represent a promising mid-depth geothermal reservoir in the North German Basin. A comprehensive re-evaluation of borehole data from the hydrocarbon industry indicates that these units were variably truncated by the Paleocene transgression and exhibit significant variations in depth and thickness. To better constrain their spatial distribution and reservoir geometry, a 3D seismic dataset was reinterpreted, focusing on salt structures, faults, and key stratigraphic horizons.

The results indicate that (i) inversion tectonics ceased during the Campanian, whereas salt structures continued to evolve independently during the Maastrichtian, and (ii) each salt structure, together with its associated marginal trough, experienced a distinct developmental history that directly influenced reservoir configuration. Salt movement shaped the reservoirs during both synsedimentary and post-sedimentary phases. Synsedimentary salt tectonics, in particular, led to the formation of minibasins, localized highs, and differential subsidence. These processes controlled sediment thickness, facies distribution, and early reservoir compartmentalization. In contrast, post-depositional salt movement deformed pre-existing stratigraphy, generating folds, faults, and structural traps that affect fluid compartmentalization, vertical migration, and pressure regimes.

This study emphasizes salt tectonics as a key control on the geometry and heterogeneity of the Reitbrook calcarenites. Accurate reservoir models, geothermal assessments, and sustainable energy development require a thorough understanding of the temporal interplay between salt deformation and sedimentation. Understanding the salt-tectonic evolution of the basin is essential for the development of exploration strategies, such as identifying thick, well-preserved zones, deeper areas with elevated reservoir temperatures, and fault zones that enhance permeability.

06.04 Stressors in Hydrogeology: Interactions and Impacts

New investigative monitoring tools for assessing the chemical and ecological state of groundwater within drinking water catchments

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The incorporation of the World Health Organisation's water safety plans into German law through the groundwater catchment regulations (Trinkwassereinzugsgebietsverordnung), which will come into effect in 2025, will allow for, but also demand, new investigative groundwater monitoring tools. As part of the BMBF project iMolch, new tools and strategies are being developed to enable sustainable groundwater management. These tools will provide new insights into the ecological and chemical status of drinking water catchments. Two catchments within the Düsseldorf water supply network will be presented as examples. Both are affected by multiple land uses and different proportions of bank filtration from the Rhine. To evaluate the chemical status, non-target analytical methods are compared with hot target analytical methods based on the principle of indicator compounds (over 136 organic micropollutants) and main water chemistry. The ecological status will be investigated using an improved DAC index and beta diversity. Community composition was analysed using 16S rRNA gene sequencing; cell density was measured using flow cytometry; and internal ATP was determined using the BacTiter-Glo microbial cell viability assay. Principal component analysis (PCA) is used to analyse the ecological data and non-target chemical analytics, and the results are presented and discussed. The impact of floods in the Rhine on the groundwater composition was evaluated using both chemical and ecological data. Furthermore, it was possible to calculate the amount of bank filtrate in the individual supply wells based not only on the indicator compounds, but also on the ecological data.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Sulfidation kinetics of olivine and diopside at Mercury surface conditions

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The surface of Mercury is enriched in sulfur, reaching concentrations of up to 4 wt.%, according to findings from NASA's MESSENGER mission. One proposed explanation for this enrichment involves volcanic degassing, whereby reduced sulfur is released from the planet's interior and subsequently initiates sulfidation reactions with the surface rocks. However, the underlying mechanisms involved in the sulfidation of silicate minerals remain poorly understood. In this study, we explore the kinetics and mechanisms of the reaction between reduced gaseous sulfur and two common silicate minerals on Mercury's surface – olivine and diopside. Our approach included high-temperature experiments, in which the silicate mineral – with a polished surface – and sulfur powder were placed separately into graphite crucibles and subsequently loaded into an evacuated silica glass tube. The samples were subjected to temperatures between 800 and 1,250 °C. Under these conditions, the sulfur powder forms a gas which fills the tube, enabling a reaction with the silicate mineral. The duration of the experiments was varied between 1 hour and 1 month. The highly reducing conditions on Mercury were simulated by buffering the oxygen fugacity through the graphite-CO reaction. Our results reveal a fundamental contrast in the mechanism of the sulfidation reaction between olivine and diopside. In olivine, the reaction is primarily limited by diffusion, whereas diopside develops intermediate reaction layers at its surface, including Ca-depleted pyroxene. These findings offer new insights into sulfidation processes on Mercury, which has implications for observations by the BepiColombo mission currently en route to the planet.

01.25 Geochemical Databases and Data Analysis Tools

A Screening Tool for REE Data Quality Assessment

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The growing availability of advanced analytical techniques has led to a rapid increase in published geochemical data, much of which is now accessible through curated, domain-specific synthesis databases. These resources offer significant opportunities for innovative research in geochemistry and related fields through the analysis of compositional data from rocks, minerals, and other natural materials. However, integrating and evaluating data that were collected over several decades using widely different analytical methods is a challenge.

The rare earth elements (REEs) are widely used in geochemistry as tracers of chemical transport, differentiation, and broader Earth system processes. To address common issues in REE data usability, we developed an automated method to identify scattered, anomalous, or potentially erroneous REE patterns. Our approach draws on the expected geochemical behaviour of REEs, focusing on the “smoothness” of normalised REE patterns, the detection of single or multiple outliers, and various forms of scatter.

We validated our method using large datasets from the GEOROC (n=176,611) and PetDB (n=30,659) databases. Distinct types of anomalous REE patterns are related to potential artefacts and data quality issues. Additionally, we test the application of our REE screening method on individual published data sets from various sources and dare to give some recommendations.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

In-situ antimony (Sb) isotope variations as geochemical tracers of hydrothermal fluid evolution in the Harz Mountains, Germany

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The St. Andreasberg deposit in the Upper Harz region (Germany) is one of the most famous historical silver deposits worldwide. According to [1], the deposit was formed during four distinct mineralization stages, each characterized by differences in mineralogy, temperature conditions, and fluid composition. Antimony is one of the main components of each mineralization stage occurring as various sulfides (tetrahedrite, pyragyrite, and stibnite) and antimonides (breithaupite, and dyscrasite). Given the variable mineral assemblages and mineralisation stages, this deposit serves as a model system to better understand Sb isotope behaviour during the hydrothermal evolution of the mineralization.

In-situ Sb isotope analysis following the method of [2] show significant Sb isotope variations: The earlier (oxidic-carbonatic) stage and the main sulfidic stage show relatively constant δ^{123}Sb values of 0.2–0.3‰, probably related to higher formation temperatures. In the main arsenic-antimonide stage and the last stage, however, significantly more variable δ^{123}Sb values between 0.1–1.1‰ are reported, indicative of a late-stage overprinting by hydrothermal fluids. Antimony minerals associated with the early oxidic/carbonatic and the last stage are isotopically heavier than later formed minerals. This trend of decreasing δ^{123}Sb values can be explained by a Rayleigh fractionation model, resulting in a depletion of ^{123}Sb in the residual hydrothermal fluid during progressive crystallization. Our results highlight the applicability of Sb isotopes as a valuable tool to reconstruct the genesis and fluid evolution in complex hydrothermal deposits such as the St. Andreasberg.

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09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

German Geoscience Olympiad – Correlation between curricula and results

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The umbrella organisation for the geosciences DVGeo has been organising the German Geoscience Olympiad for school pupils since 2023.

This nationwide competition builds on school knowledge from geography as well as chemistry, physics and biology and provides deeper insights into the geosciences. Students from year 9 to Q1 (qualification year 1 for the Abitur) can take part, i.e. up to and including year 11 for G8 and year 12 for G9. The German Geosciences Olympiad was conceived by representatives of the DVGeo's supporting organisations from the fields of geology, geophysics, palaeontology and mineralogy.

The German Earth Science Olympiad is also the national selection competition for the established International Earth Science Olympiad (IESO), which will take place in China in 2024 and 2025. Participants have to demonstrate their knowledge of geology, mineralogy, geophysics and geochemistry in an online test. In the second round, they also completed practical tasks, including rock speeches.

The aim of the competition is to arouse pupils' interest in the geosciences and to make teachers aware of the geoscientific content of current topics. To this end, it uses the name of an Olympiad, which is commonly used in Germany for science competitions (see also Maths Olympiad). The tasks are predominantly competence-orientated.

The results achieved show a clear connection between the geoscientific content anchored in the curricula of the federal states and the results of the Olympiad.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Construction of hydrostratigraphic grid models of the Northwest German Basin for the estimation of subglacial erosion during past and future glaciations

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The shallow subsurface of the North German Basin consists of unconsolidated Quaternary sediments. During the Elsterian glaciation subglacial tunnel valleys were deeply incised below the ice sheets. These tunnel valleys commonly range in depths between 100–400 m, but may reach depths of more than 500 meters. Given that the BGE is focusing on depths of 300 to 1500 meters for high-level radioactive waste repository sites, the potential for future subglacial erosion must be considered to ensure the long-term safety of a selected site.

We develop hydrostratigraphic 3D reservoir grid models of the Northwest German Basin as input for numerical hydraulic subglacial erosion modelling to assess tunnel valley formation during future glaciations. These hydrostratigraphic 3D reservoir grid models are constructed with different resolutions. All models cover Permian to Cenozoic sediments and have a depth of 2000 m. They are constructed with a layered-structural-model, voxel-grid-models approach. To construct the layered structural model, we used existing stratigraphic 3D models (GTA3D, TUNB3D-NI) and additional borehole data. The reservoir grids are constructed as hydrostratigraphic grids, integrating constant permeability values based on hydrogeological properties of the stratigraphic units. This approach allowed fast and successful construction of large grid models (up to 40,000 km^2 in size) despite the heterogeneous database.

By implementing grid models with different resolutions in the numerical erosion model, we will test the impact of grid size on the outcome of the erosion modelling. The results will help in the process of site selection and long-term safety assessment for potential repository sites.

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

New research work on the palaeoenvironment and biota of the late middle Permian Hornburg Formation, central Germany

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A series of excavations in the fossiliferous Blätterton Member of the Hornburg-Formation (Eisleben municipality, Saxony-Anhalt) was carried out between 2022 and 2024 by an international team of scientists, students and volunteers on an area of about 60 m^2 and covering a thickness of 4.5 meters. The fieldwork included a finestratigraphic documentation and yielded a vast amount of trace fossils – about 2000 specimens that were collected with exact assignment to lithological units; it expanded our knowledge about a crucial middle Permian ichnofauna. The Blätterton Member is dominated by silt- and claystones with some intercalation of laterally tapering bodies of standstone; it represents a succession that is typical for a playa lake environment. Given the muddy substrates that barely show signs of vegetation cover, footprints of larger herbivores are missing. In this aspect, the Blätterton ichnofauna differs from the somewhat younger Mammendorf assemblage, which is marked by tracks of larger tetrapods including herbivores, plant roots and burrows within predominantly sandy substrates that were deposited in a floodplain environment with steppe-like vegetation cover. In the Blätterton succession, however, relatively small tracks of the type Dromopus are abundant. They were produced by reptiles that likely fed on small arthropods, whose abundance and diversity is testified by mass occurrences of arthropod tracks in addition to aquatic insect larvae preserved as body impressions. A second tetrapod footprint type, tentatively referred to the ichnogenus Capitosauroides, is often associated with swimming traces made by the same producers indicating a lifestyle in proximity to small ponds and shallow water bodies.

01.12 Coastal dynamics in different timescales: from seconds to millennia

Microfacies and cyclicity of two Paleo Lagoons in Oman – potential insight into Last Interglacial coastal evolution?

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The last interglacial (around 125 Ma, MIS 5e) is the youngest timeframe that produced higher global sea level than observed nowadays and thus offers critical insight into coastal dynamics under future climate-change- and sea-level scenarios. Despite a global effort to record last interglacial shorelines, the Indian Ocean remains understudied in this respect. The northeastern coastline of Oman, from Muscat to Ras Madraka, shows seven shallow marine sedimentary successions located up to 4 m above mean sea level in areas that are tectonically stable. The sediments that include coral reefs, beachrocks, lagoonal and sabkha deposits are studied regarding their initial relationship to mean sea level and age to establish sea-level index points. Since radiocarbon dating has been ineffective, as deposition ages exceed the range of 14C methods, optically stimulated luminescence dating presents a promising avenue for chronological data. Special emphasis is placed on two lagoonal successions near Al Haddah and Ras Ru'ays. While the outcrop at Al Haddah shows more evaporitic sabkha deposits overlain by alluvial successions, Ras Ru'ays coastal cliff presents a choked lagoonal system overridden by a coastal barrier, before alluvial sedimentation sets in. As both outcrops record cyclic deposition that are potentially controlled by transregional processes, they allow to understand Late Pleistocene coastal evolution in more detail. In a multiproxy approach, macro- and micro facies analysis, as well as geochemistry, are applied to link cyclicity within the two lagoonal systems and unravel likely controls.

05.03 Archaeometry – Geosciences4Humanities

The Characteristics of Nephrite Jade from Baoding, Hebei, China and Its Potential Uses in the Neolithic Period

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The origin of raw materials is a key focus in jade archaeology, offering valuable insights into the interactions and exchanges between ancient cultures. Among various jade materials, tremolite nephrite, with its distinctive mineralogical characteristics, was widely used across multiple jade-using cultures in prehistory. Studying the sources of minerals allows for a deeper understanding of the organizational structures and social dynamics of ancient societies. In China, jade artifacts were symbols of status, power, and virtue, with numerous remarkable discoveries from the Hongshan, Dawenkou, Lingjiatan, Liangzhu, and Daxi cultures underscoring jade's esteemed position in ancient society. These artifacts played a crucial role in the formation of these early cultures. The Nephrite jade deposits in Hebei Province, China, hold significant archaeological and cultural value, particularly concerning the Neolithic period and the archaeological cultures of China. Nephrite jade was highly prized during the Neolithic era, and its use is evident in various archaeological sites. Geochemical analysis of raw material sources has become an indispensable tool in archaeology, providing a clearer understanding of how ancient cultures sourced and valued jade, facilitating the study of cultural exchanges. The geographical distribution of Hebei nephrite jade, along with its gemmological properties, suggests its central role in understanding the importance of jade within Neolithic Chinese cultures. The use and craftsmanship of this material reflect its cultural, spiritual, and social significance, further emphasizing its integral role in early Chinese history and its potential as a medium for intercultural interaction.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

CO_2 Diffusion in Basaltic Melts: The Role of H_2O

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Carbon dioxide (CO_2) is the second most abundant volatile component in magmatic systems after H_2O and plays a crucial role in controlling magma ascent, bubble nucleation, and eruption dynamics. Accurate knowledge of CO_2 solubility and diffusivity in silicate melts is therefore fundamental for understanding and modeling volcanic processes. Despite its significance, experimental constraints on CO_2 diffusion in silicate melts—particularly under hydrous conditions—remain limited.

This study presents new experimental data on CO_2 diffusion in basaltic melts, with a specific focus on the effect of dissolved H_2O. Diffusion couple experiments were conducted at 300 MPa and temperatures between 1200 and 1350 °C using a rapid-quench, internally heated pressure vessel. The resulting glass charges were doubly polished and analyzed using Fourier-transform infrared (FT-IR) micro-spectroscopy to obtain concentration–distance profiles. CO_2 diffusion coefficients (DCO_2) were calculated by fitting these profiles with error functions.

Preliminary results from anhydrous basaltic compositions exhibit clear Arrhenian behavior, with DCO_2 values consistent with previous measurements in Fe-free systems. Ongoing experiments are aimed at quantifying the influence of dissolved H_2O on CO_2 diffusivity, providing new insights into volatile mobility and transport mechanisms in hydrous basaltic melts.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

Learning with HALI: Personification as a Gateway to Geoscience for Young Learners

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The Schülerforschungszentrum (Student Research Centre) at the University of Applied Sciences Nordhausen (SFZ) is part of the MINT-Regionen Thüringen (Thuringian STEM Regions) initiative – a project by the Thuringian Foundation for Technology, Innovation, and Research (STIFT), supported by the Thuringian Ministry of Education, Science, and Culture. The program fosters regional STEM networks to promote science education in schools and beyond.

Since joining the SFZ, I have expanded this commitment to include geoscience topics by launching various geo-educational activities and establishing new collaborations. Northern Thuringia's landscape, economy, and cultural history are deeply shaped by salt and gypsum mining, making these materials a natural starting point for our outreach.

In November 2024, in collaboration with K-UTEC Salt Technologies AG and the National GeoPark Kyffhäuser, I led a full-day project—repeated three times—for the three fourth-grade classes (65 pupils) at Franzberg Primary School in Sondershausen. The program included crystal-growing experiments and activities highlighting the local geological and economic significance of salt.

To engage our 9–10-year-old audience, I created a plush toy in the form of a personified halite crystal, named Hali, which became the project's narrative centrepiece. Follow-up evaluations five months later confirmed that personification is a highly effective didactic method in geoscience education, enhancing understanding and enthusiasm among young learners. Thanks to the positive response, the project will be replicated in Autumn 2025.

The Hali's project is still at the very beginning and will not end with Hali: Additional mineralogical figures and their histories are being designed. Stay tuned!

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Deformation style along a fossil transform plate boundary; geophysical investigation of the Central European Variscides

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The boundary between the Saxo-Thuringian and Rheno-Hercynian zones represent a Gondwana-Laurussia transform plate boundary in the Bohemian Massif. To the west of the Bohemian Massif, Permo-Mesozoic sedimentary rocks cover the transform plate boundary, which limits our understanding of its spatial and temporal development. We reinterpret Dekorp-2S and 4N and create a composite profile in between, perpendicular to the transform plate boundary. Based on the seismic reflection facies, we define Southeastern, Central and Northwestern Saxo-Thuringian domains (SE, Central and NW domains). Magnetic field intensity and Bouguer gravity anomaly maps and their derivatives further strengthen our interpretation of the Saxo-Thuringian domains and their regional-scale deformation style.

The SE-domain show sub-horizontal and high-amplitude reflections in the southwest and medium-amplitude reflection in the northeast and it is correlated to the medium-grade metamorphosed areas of the Fichtelgebirge and northeastern Münchberg nappe. The Central-domain is characterized by low reflectivity in the upper and the middle crust and it is not developed in the southwest along the Dekorp-2S. The Central-domain is correlated to the early Carboniferous turbidites and the SE Schwarzburg anticline. The NW-domain show high-amplitude and dipping reflections occupying broader areas in the southwest. We interpret the lateral changes along the NW-domain resulting from the regional stress field rotation in the latest Variscan times and thrust reactivation of the former strike-slip shear zones developed along the transform plate boundary. Our results highlight noncylindrical nature of the Variscan lithostructures west of the Bohemian Massif and the regional scale spatiotemporal development of a fossil transform plate boundary.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Miocene sediment provenance and drainage pathways in Northern Calabria, Italy

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The Calabrian arc represents a segment of the western Mediterranean Alpine orogenic belt characterised by a nappe stack composed of Apennine carbonates, the oceanic Liguride complex, and a Variscan lower to upper crustal section. The nappe stack was piled in the Eocene-Oligocene and became exhumed during the late Oligocene-Miocene. Strong tectonic activity still persists with renewed uplift during the Quaternary. On both sides of the Calabrian arc, Miocene to recent basins exist, with more pronounced extension at the eastern side (forearc) controlled by the retreating subduction zone. We have analysed Aquitanian to Messinian sandstones fringing the central crystalline massifs of Northern Calabria (Sila Massif, Catena Costiera), complemented by pebble populations and modern sand samples. Methods applied comprise Raman-based heavy mineral analysis, detrital mineral chemistry, as well as apatite U-Pb and zircon U-Pb-He geochronology.

Results indicate some striking similarities between Aquitanian-Langhian and Messinian deposits on the eastern forearc side, while the Serravalian-Tortonian deposits suggest a distinct source-to-sink system. This is exemplified by the Crotone sub-basin, where heavy mineral assemblages and chemistry, in addition to apatite U-Pb ages, constrain nearby sources from the Sila granitoids; meanwhile further north, low- to medium-grade metamorphic rocks along with Liguride-derived materials prevail. The present-day steep western coast (Catena Costiera) reflects a region of pronounced exhumation and uplift since at least Serravalian time. All available data are compiled and will be used to derive a model of Miocene sediment provenance and drainage pattern of Northern Calabria through space and time.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

Landscape evolution reconstructed from lake sediment archives in the Northern Ecuadorian Andes

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Lake sediments are valuable natural archives of environmental change, providing insights into sediment transport, deposition, and landscape evolution. To better understand the landscape evolution and past environmental change in the northern Andes, a region known for its high biodiversity and vulnerability to climate change, we analyzed lake sediment archives from three areas near Ecuador's capital, Quito. Our pilot study combined sub-bottom profiling (SBP) with a multi-proxy analysis of short sediment cores from lakes Muertepungo, San Pablo, as well as Caricocha and Chiriyacu in the Mojanda Lake Region. These lakes are situated at high elevations (2500–4000 m a.s.l.) and are of different volcanic origin.

In this contribution, we focus on SBP data to understand the bathymetry, morphology, and sediment infill characteristics of the studied lakes, providing a first interpretation of the sedimentary evolution. We used an Innomar "compact" parametric sediment profiler to record sub-bottom profiles in lakes with water depths ranging from a few meters to over 100 m. Stratigraphic correlation was supported by five short sediment cores collected from different water depths. Radiocarbon and tephra analysis were used to establish a chronological framework.

Preliminary results indicate differences in sediment properties and thicknesses, as well as distinct layering patterns, which may be linked to past environmental conditions such as shifts in water levels, temperature, trophic state, and other factors. These findings have important implications for understanding the complex interactions between climate, geology, ecosystems, and natural hazards, such as volcanic eruptions and landslides, in this region.

10.01 Open Topic

The evolutionary history of leafy liverworts: an approach using the fossil record from worldwide amber deposits

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Leafy liverworts (Marchantiophyta: Jungermanniidae) are important components of extant ecosystems, for example in peatlands of the northern hemisphere and in tropical forests where they constitute a large part of the epiphytic biomass. While the early evolution of this diverse lineage remains obscured by its sparse Paleozoic and early Mesozoic fossil record, amber inclusions found since the mid-Cretaceous have provided significant insights into its diversification. To date, ten amber deposits have yielded leafy liverwort inclusions, with the most diverse floras preserved in Cenozoic deposits. Amber fossils have been described from the mid-Cretaceous of Myanmar (Kachin) and Alaska, the Paleogene of India (Cambay), the Baltic region, Germany (Bitterfeld), and Ukraine (Rovno) as well as the Miocene of Ethiopia, China (Zhangpu), the Dominican Republic, and Mexico (Chiapas). The life-like, three-dimensionally preserved amber fossils reveal minute morphological details critical for identifying leafy liverworts and therefore allow for a reliable classification. The fossil evidence also provides age constraints for molecular phylogenies of extant taxa. The resulting divergence time estimates and diversification analyses indicate that — while many lineages probably predate the Permian-Triassic boundary — most extant genera originated during the Cretaceous or Cenozoic, coinciding with the rise of angiosperms. The profound changes of terrestrial ecosystems during the Angiosperm-Terrestrial-Revolution seem to have largely affected the epiphytes which exhibit a steep increase in lineage diversification, while generalists or largely terrestrial taxa were not affected.

08.01 Young Scientist Session

Life on the brink: Silicifications from central Germany elucidate ecosystems of Permian supervolcanoes

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The Permian saw a strong diversification and spread of dryland ecosystems and is therefore a heyday of terrestrialisation. However, as life spread in environments with low preservation potential, fossil evidence of this evolutionary progress is extremely rare. Most knowledge in recent times resulted from studying fossiliferous strata of volcanic settings in the Euramerican tropics, such as the Chemnitz Fossil Forest (Germany) and the Athesian Volcanic Group (Italy). This talk elucidates the stratigraphy, taphonomy and paleoecological significance of silicifications found on fields and in river beds near Gnandstein/central Germany for two centuries. High-resolution sedimentological logging of the strata reveals that the fossils derive from epiclastic and pyroclastic deposits of the basal Kohren Formation (Asselian, lower Permian), representing the initial deposits of the voluminous NW Saxony Volcanic Complex. Anatomical studies and UV spectroscopy of polished samples from three collections identify various taphotypes in the silicifications and yielded anatomically preserved stems of tree ferns, calamitaleans and pycnoxylic gymnosperms. While the varicolored cherts formed in limnic settings, sizeable fossil trunks 1.5 m in diameter from Gnandstein could indicate the presence of an *in-situ* forest near the base of the Rüdigsdorf Tuff. Based on our results, the basal Kohren Fm. has a strong potential to disclose Permian tropical ecosystems that coped with extensive volcanism and advocate for future excavations in these occurrences. In addition, the Gnandstein fossils underpin the importance of late-to-post-Variscan volcanism in Euramerica to form fossil archives of deep-time life.

01.04 Latest Achievements in Scientific Ocean and Continental Drilling

Updated lithospheric 3D model(s) of the Sea of Marmara: thermal and rheological characteristics of the Main Marmara Fault – a segment of the North Anatolian Fault

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The active strike slip North Anatolian Fault poses significant seismic hazard in Turkey. One of its parts – the Main Marmara Fault – extends across the northern Sea of Marmara close to the metropolitan area of Istanbul, where a potentially hazardous earthquake 7 is overdue according to paleoseismic statistics. At the same time the Main Marmara Fault exhibits a segmentation along-strike with creeping and locked parts, the understanding of which is still a challenge. To address this challenge the GONAF observatory was initiated by ICDP and enabled continuous research in the recent years. We present results obtained in the frame of the DFG-ICDP priority program that include a new 3D lithospheric-scale model of the Sea of Marmara that combines gravity modelling and seismic tomography analysis with thermal and rheological modelling. Using forward and inverse gravity modelling with free-air gravity data and available constraints of geological units we derived the intra-crustal density structure. Shear-wave velocity tomography models provided insights into the temperature and density configuration of the uppermost mantle, and the geometry of the 1330°C isotherm. We find crustal density variations with a lower-density crust over the western and creeping part of the Main Marmara Fault, and a denser crust below the Istanbul Zone where the Main Marmara Fault is supposed to be locked. We analysed the combined effects of the density structure and of the thermal field on the rheological configuration and discuss which implications this configuration may have for the deformation of the Main Marmara Fault.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Automating Mining Site Classification with Machine Learning: Near-surface raw materials in Bavaria

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Economic development requires substantial raw mineral resources. The construction industry, in particular, is dependent on the supply of domestic raw materials such as sand, gravel and clay. Monitoring the evolution of extraction sites is crucial for assessing current resource usage and future availability. The Landesamt für Umwelt – Bayern currently employs manual analysis of remote sensing data (e.g., aerial imagery, digital elevation models) and GIS software to classify open-pit mining regions as active or inactive – a resource-intensive process. This work presents a machine learning approach to partially automate this classification. We developed and trained a Random Forest model using existing manually-classified data. Initial validation demonstrates the significant potential of this methodology, achieving an accuracy exceeding 90% in preliminary tests. This contribution will demonstrate the first promising results of our automated classification system and discuss the challenges and future directions for model refinement and enhanced classification accuracy. This approach offers a pathway to reduce the resources required for monitoring mineral extraction activities.

01.03 Chaotic rocks – characteristics, formation and geodynamic significance

Mélanges and their significance in the evolution of subduction-accretionary complexes and orogenic belts

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Mélanges and chaotic units represent significant components of most subduction complexes and orogenic belts worldwide, regardless of their age (from the Precambrian to the present day), tectonic evolution, or location (e.g., from the circum-Pacific region to the Alpine-Himalayan belt). However, the mode and nature of the processes responsible for their formation, as well as the geological environments in which different mélange types develop, remain a topic of debate.

Most chaotic units preserved in exhumed subduction complexes, particularly metamorphic ones, are commonly interpreted as products of tectonic processes (i.e., underplating and return flow) occurring at intermediate to great depths during convergent stages. However, our observations from both modern and ancient subduction complexes indicate that different types of mélanges and chaotic units already form at shallow structural levels ($T < 250$ °C) through different processes (tectonic, sedimentary, and diapiric) and their interplay. This suggests that (i) mixing mechanisms are not exclusive of deep processes, (ii) the internal architecture of exhumed subduction complexes may be highly heterogeneous even at shallow structural levels, and (iii) tectonics is not the sole process responsible for mélange formation.

Using field-based stratigraphic and structural criteria, we show that mélanges formed through different processes and in distinct tectonic environments can be distinguished by diagnostic block-in-matrix arrangements. Therefore, the study of mélanges provides valuable constraints for improving our understanding of the tectonic evolution of Precambrian to Phanerozoic subduction complexes and metamorphic orogenic belts worldwide.

08.01 Young Scientist Session

Morphological diversity of dragonfly and damselfly larvae over the last 300 million years

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The larvae of dragonflies and damselflies (Odonatoptera) exhibit great morphological diversity, underpinning their important role as aquatic predators in freshwater ecosystems. Depending on species, odonatopteran larvae develop through 10–15 moults, with the metamorphosis to a flying adult taking place in the last moult, so they spend most of their lifetime under water. This pattern of aquatic larvae and flying terrestrial adults is generally referred to as “merolimic”. Their highly prominent compound eyes as well as the specialised extendable mouthparts (“labial mask”), which can be moved forward rapidly, enable the larvae to efficiently capture prey. Prey items include small crustaceans, other merolimnic larvae, but also tadpoles and small fishes. Fossil finds of odonatopterans, including a possible larva, reach back into the Carboniferous, over 300 million years ago. We here report new finds of odontopteran larvae from a more unusual type of preservation, amber. Amber less often preserves aquatic specimens, making odonatopteran larvae in amber rather rare. The new fossil comes from about 100 million years old Kachin amber. So far, less than a handful of odonatoperan larvae have been reported from this deposit, hence expanding the known diversity of these larvae. This includes also larvae with rather slender labial masks. We compared the shapes of the labial masks within a quantitative frame to reconstruct the evolutionary changes of this structure.

03.05 Advances in Paleoclimate Proxies and Their Applications

Dual clumped isotope thermometry of speleothems

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Speleothem carbonates are key archives for the reconstruction of terrestrial paleo-environmental conditions, but it is challenging to resolve between the temperature, hydrological and kinetic information that is recorded in their stable isotopic composition. Recently, it has been demonstrated that dual clumped isotope thermometry, i.e., analysis of Δ48 alongside Δ47 in CO_2 evolved from phosphoric acid digestion of carbonate [1], holds the potential to detect and quantify kinetic departures from isotopic equilibrium without having to know the oxygen isotope composition of the parent water, and, moreover, to correct for kinetic biases in carbonate formation temperatures [2].

We performed paired Δ47–Δ48 measurements on speleothems to investigate to which extent isotopic disequilibrium is recorded in these archives. No significant disequilibrium bias is recorded in slowly grown pool carbonates and cryogenic carbonates, and Δ47 derived temperatures agree with expected formation temperatures. Most stalagmites, sampled closest to their growth axis where disequilibrium should be least pronounced, record a slight, but significant -Δ47 disequilibrium bias. While the bulk set of investigated stalagmites exhibits a significant +Δ48 offset from equilibrium, the extent of Δ48 disequilibrium in individual samples remains below analytical resolution. Disequilibrium biases originate from rapid dehydration/dehydroxylation of bicarbonate occurring dissolved in the drip water. These results demonstrate that stalagmite Δ47 values, without any additional evidence, should only be considered upper estimates of cave temperature, even if corresponding dual clumped data plots indistinguishably from the Δ47-Δ48 equilibrium line.

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01.12 Coastal dynamics in different timescales: from seconds to millennia

Delineating storm- and wave-dominated deltaic systems to improve geothermal reservoir prediction, Bückeberg Group, Lower Saxony Basin, Germany

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Deltaic sandstone deposits of the Berriasian Bückeberg Group in the Lower Saxony Basin are potential geothermal reservoirs. Detailed sedimentological and ichnological analysis of subsurface expressions to underpin the paleodepositional interpretation as deltaic have yet to be presented, but are crucial to understanding reservoir quality and distribution.

Deltaic intervals in two cores were logged with a focus on sedimentological and ichnological character, e.g., grain size, sedimentary structures, lithological accessories, bioturbation index (BI) and ichnological elements. Facies are grouped into facies associations.

Two types of deltaic successions are identified [(1)] wave-dominated deltaic deposits and [(2)] storm-dominated deltaic deposits. Wave- and storm-dominated deltaic facies associations display coarsening-upward successions, variable bioturbation intensities (BI 0–5) and host overall low-diversity, facies-crossing assemblages with marine ichnological elements. Wave- and storm-dominated deltaic successions differ in sedimentological and ichnological expression. Wave-dominated deltaic deposits display abundant wave-ripple lamination, normal and inverse graded mudstone beds, and overall moderate to elevated bioturbation intensities (BI 3–5). By contrast, storm-dominated deltaic deposits display abundant hummocky cross-stratification and fewer burrowed beds (BI 2–5).

Reservoir quality and distribution differs in studied wave- and storm-dominated deltaic successions. Wave-dominated deltaic successions display sandstone beds with abundant biogenically reworked mudstone beds. Sandstones in storm-dominated deltaic deposits display fewer and less burrowed mudstone beds. Reservoir distribution in purely wave-dominated deltas is expected to form relatively smooth shoreline protrusions, whereas storm-dominated reservoirs are associated with subaqueous channel deposits. Results highlight the importance of sedimentological and ichnological facies analysis to improve geothermal reservoir exploration in the Bückeberg Group.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

The multiple sulfur isotope composition of diagenetic and hydrothermal sulfides from the Barney Creek Formation (McArthur Basin, Australia): implications for Zn metallogenesis

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The mid-Proterozoic McArthur Basin (Australia) hosts exceptionally well-preserved sedimentary rocks and giant clastic-dominant (CD-type) Zn deposits. Previous δ34S-based studies aimed to reconstruct sulfide precipitation pathways; however, interpretations of δ34S values are challenging due to overlapping signatures from organoclastic sulfate reduction (OSR), anaerobic oxidation of methane coupled with sulfate reduction (AOM-SR), and thermochemical sulfate reduction (TSR).

Here, we present new multiple sulfur isotope data from mineralized and unmineralized bulk rock samples of the Barney Creek Formation, host to the Teena Zn deposit, to resolve different diagenetic and hydrothermal sulfate reduction pathways. The sulfide paragenesis includes early diagenetic fine-grained pyrite, overgrown and partially replaced by coarser pyrite and sphalerite. Sulfur was extracted as chromous-reducible sulfur (CRS; n=40) from pyrite, and as acid-volatile sulfur (AVS; n=13) from sphalerite. CRS and AVS show broadly overlapping sulfur isotope compositions, with a wide range of $\delta^{34}S$ (–2.8 to 35.7‰), $\Delta^{33}S$ (–0.08 to 0.05‰), and $\Delta^{36}S$ (–0.40 to 0.67‰). The multiple sulfur isotope data will be integrated with redox-sensitive trace element data to reconstruct the local depositional redox environment (anoxic, euxinic conditions) in the Teena sub-basin.

Microbial fractionation models and Rayleigh distillation trends suggest sulfides formed mainly via OSR, as the data plot on a convex array in $\delta^{34}S$–$\Delta^{33}S$ space. No evidence of mixing with AOM-SR, which would result in a concave trajectory; nor for TSR, which would produce lower $\Delta^{33}S$ values. Importantly, the results suggest that hydrothermal sulfides most likely precipitated from sulfur that was derived from the replacement of pre-existing diagenetic pyrite.

01.04 Latest Achievements in Scientific Ocean and Continental Drilling

Isotopic evidence for dynamic continental ice sheets during the latest Cretaceous

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For much of the Meso- and Cenozoic epochs, the high latitudes were significantly warmer than at present and especially the Cretaceous world has been generally considered a time of strong greenhouse climate and therefore presumed to be ice-free. Accordingly, the first large permanent ice sheets of the past 100 m.y. originated in the earliest Oligocene (ca. 33.7 Ma), with small ephemeral ones perhaps present during the late Eocene. This broad view of a warm and stable Cretaceous climate has been challenged in recent decades by the publication of a considerable amount of new data suggesting more variability in climate. In this study, we aim to test for potential glaciation episodes in the latest Cretaceous by generating the first ever high-resolution δ^{18}Osw record for the late Maastrichtian from Ocean Drilling Program (ODP) Sites 1209 and 1210 (Leg 198, Shatsky Rise, western Pacific Ocean). Our results reveal evidence for a dynamic late Maastrichtian ice sheet waning and waxing on the Antarctic continent. Interglacial periods suggest ice sheets covering 0–19% of the modern Antarctic volume, whereas glacial ice sheets reached 55–80% of the present-day Antarctic ice volume, causing glacioeustatic relative sea-level falls of up to 50 m. Additionally, an ice-free Antarctic continent is further been inferred for the warm climate of the Mid-Maastrichtian Event. These findings indicate that fairly large ice sheets could grow and decay equally rapidly under the climatic conditions of the latest Cretaceous and that the Cretaceous was far from being ice free.

01.11 Micropalaeontology – Advancements and Perspectives in Multiproxy Studies

Digital Processing and Statistical Analysis of Archived Micropaleontological Surveys

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The former German Democratic Republic (GDR) conducted extensive hydrocarbon exploration in northern Saxony-Anhalt, the Altmark, a region geologically characterized by numerous salt dome structures. Drilling operations reached depths of up to 4,000 meters and an average depth of 2,000 meters, often penetrating the entire Cenozoic and Mesozoic strata.

Micropaleontological surveys were conducted at 423 drill sites and produced valuable stratigraphic and paleoenvironmental data. Once disclosed, these reports were scanned and archived in a conservation effort, remaining as non-OCR PDFs, limiting accessibility and modern analytical use. The digitization and standardization of these archived reports have now been completed, resulting in a unified dataset comprising approximately 1,600 unique, quality-controlled taxonomic and petrographic markers. Where possible, taxonomic names have been verified against the World Register of Marine Species (WoRMS). This dataset forms the basis for ongoing statistical analyses, including cluster and co-occurrence studies, to explore distribution patterns and relationships within the micropaleontological record.

The project aims to refine the stratigraphic framework of the region and provide supplementary paleoenvironmental indicators. High-resolution, high-density stratigraphic data can help refine existing subsurface models and improve ties between borehole and seismic data. A comparative assessment against the GDR's lithological-paleogeographical maps (scale 1:500,000) is planned to evaluate consistency and identify areas for model updates. With the digitization phase completed and statistical evaluations in progress, this study highlights the untapped potential of historical exploration data for modern geoscientific applications.

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

A late Eocene rhinochimaeroid egg capsule from marine coastal strata of British Columbia, Canada

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A new fossil chimaeroid egg capsule of the ichnogenus Vaillantoonia (previously designated as Chimaerotheca), V. jonasoni, is described from marine lower Carmanah Group strata at Botanical Beach, along the West Coast of Vancouver Island, British Columbia, Canada. According to foraminifera biostratigraphy and strontium isotope dating it is late Eocene (latest Priabonian) in age. The three dimensionally preserved fossil is about 220 mm long and 80 mm wide. The elongated capsule shows a spindle-shaped central body with a constriction at the anterior end that tapers into a spatula-shaped beak. At the posterior end is a long and slender tail that broadens basally. The wing-like lateral membrane has numerous pronounced and narrow ribs (costae) that split in a V-shape.

The producer fish of V. jonasoni is unknown, since no associated skeletal or dental remains have been found. However, the elongated capsule shape and the number and shape of the membrane ribs are most similar to egg capsules of extant longnose chimaeras (Rhinochimaeridae) suggesting a rhinochimaerid-like fish with a “long” nose, in comparison to other modern chimaeroid capsules and their beak shapes.

Following earlier discoveries of V. alaskana (middle Oligocene, Alaska), V. sp. (Oligocene, Washington), and V. sp. (late Eocene, Oregon), which all show rhinochimaerid egg capsule features, this is the fourth Paleogene chimaeroid egg capsule discovered from the Pacific Northwest. All four fossils have in common that they were fossilized in tectonic foreland basins in bathyal water depths, which perfectly correlate with the known bathyal habitats and nesting sites of extant rhinochimaerids.

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

The fossil egg capsule Palaeoxyris – Indirect evidence of hybodontid sharks in the Late Paleozoic Remigiusberg Formation, Saar-Nahe Basin, Germany

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The Remigiusberg lagerstaette is an outstanding fossil site with abundant and diverse aquatic and terrestrial biota from the base of the Rotliegend in the Saar-Nahe Basin, SW Germany. It refers to an about 50 m thick succession of fluvio-lacustrine sediments of the Remigiusberg Formation (Gzhelian–Asselian, Pennsylvanian–Permian boundary) that is exposed by an active quarry near Kusel, Rhineland-Palatinate. Between 2022 and 2023, during long-term excavations by the Urweltmuseum GEOSKOP, a total of six chondrichthyan egg capsule remains were found in paleotropical delatic mudstones of a silting distributary channel.

The compressed specimens, showing transverse rhombic pattern, are composed of eight bands, were originally about 55 mm long and 12 mm wide at their widest points. According to size, shape and banding characteristics they belong to the fossil chondrichthyan egg capsule morphotype Palaeoxyris. According to the size measurements, size ratios, pedicle shape with transverse band pattern, and the number, width and breadth pattern of the bands these specimens can be assigned to Palaeoxyris carbonaria, SCHIMPER 1850 (synonym = P. appendiculata). This is the most common Paleozoic Palaleoxyris species, known so far from the Late Carboniferous (Westphalian–Stephanian) of paleoequatorial Europe and North America. The capsules are assigned to hybodontid sharks as the most probable producers. Thus they indirectly prove their existence in the Remigiusberg ecosystem, while skeletal remains or teeth are absolute rarities. In addition, these new findings double the number of known shark egg capsule fossils from the Saar-Nahe Basin and increase the number of herein known Palaleoxyris specimens to eight.

04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

Adsorption of pharmaceuticals and personal care products in hydrophobic zeolites – Linking simulations and experiments

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The pollution of different environmental compartments by pharmaceuticals and personal care products (PPCPs) is an issue of increasing concern. In order to increase the efficiency of PPCP removal in wastewater treatment plants, various technological options are being explored. In the field of adsorption-based removal techniques, synthetic high-silica zeolites, which exhibit hydrophobic properties, could be an interesting option [Jiang et al., 2018]. Due to their well-defined pore size and shape, zeolites are likely to be most attractive for scenarios in which the affinity towards one or a few species should be optimised, for example, in the treatment of wastewaters from pharmaceutical production facilities. As the number of possible zeolite-PPCP combinations is very large, atomistic simulations can be a suitable pathway to identify zeolites that might be particularly promising for the removal of a specific compound. This contribution will summarise some of our recent research efforts in this area, covering screening studies of numerous zeolite-PPCP combinations using force field methods [Brauer & Fischer 2024] as well as in-depth investigations of the adsorption of individual PPCPs using density functional theory [Fischer 2024, 2025]. For the specific case of carbamazepine adsorption, initial results of a joint computational-experimental study will be presented.

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01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

From Drilling Core to Model: A Multimethod Approach to Subsurface Characterization at Asse Salt Dome

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In accordance with § 57b of the German Atomgesetz, the Asse II potash and salt mine has to be closed down immediately after the retrieval of the stored radioactive waste. Due to the current technological and geological status of the mine, a new retrieval mine is indispensable for achieving this goal. Thus, an extensive exploration of the currently undisturbed part of the Asse salt dome in the southeast of the current mine is required.

Given the internal complexity of steep salt formations and the resulting challenges with exploring those, a cross-discipline approach was and still is irreplaceable for creating the required geological model of the Asse salt dome. This presentation discusses the used multi-method workflow starting with detailed drill core analysis utilising a combination of traditional geological core description and a variety of non-destructive and destructive geochemical analyses. The resulting lithology log is subsequently extrapolated into the 3D-space using mainly borehole ground-penetrating radar with different frequency ranges. In the last step a detailed model of the subsurface is constructed using the results of the afore mentioned methods in combination with modern surface based geophysical measurements like 3D seismic and rechecked or partially revised historical data like mine plans and drill logs. The approach contributes to best practices in geological modelling of salt structures (e.g., for deep geological repositories), and can serve as a template for similar projects in comparable geological settings.

01.29 Environmental Hazards and Risks

Environmental Seismology as a Complementary Tool for Groundwater and Hydrological Landscape Functioning in Upland Headwater Catchments

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Extreme hydrological events such as pluvial floods are increasing in magnitude and frequency due to environmental change, causing severe impacts on critical infrastructure and inhabited areas. However, it remains uncertain how extreme floods alter subsurface flow paths and sediment dynamics—and vice versa. Groundwater and the critical zone may play a key role in buffering the landscape response to such events. This study investigates subsurface responses to rainfall and flooding using passive seismic techniques, which use ambient seismic noise to non-invasively monitor subsurface water dynamics over time.

A network of ten seismic stations has been deployed across two sub-catchments in the upper Ahr Valley to measure relative seismic velocity changes (dv/v). These signals are used to infer temporal variations in subsurface water content, including groundwater fluctuations and vadose zone saturation. Seismic data are analyzed alongside environmental drivers such as rainfall intensity, soil moisture, river discharge, and groundwater levels. We focus on continuous data from May 2024 to June 2025, aiming to present dv/v responses to seasonal groundwater dynamics and to a 5-year flood event in January 2025, when the landscape was fully saturated.

This approach offers insight into the role of subsurface water pathways in shaping the hydrological and erosional response of upland headwater catchments. It supports the long-term monitoring of critical zone processes and erosion risk, and highlights the value of environmental seismology as a spatially integrative tool in hydrological research.

04.04 Hydrogen in the energy transition –white to green hydrogen and subsurface storage

How much natural hydrogen must be present down there?

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The number of scientific articles on molecular hydrogen in the subsurface is exploding, indicating a growing interest in this potential energy resource. Various concentrations of hydrogen in naturally occurring gases and ppm values are reported, sometimes combined with projections of invoked large volumes of these gases based in part on overly optimistic assumptions. However, these figures are rarely placed into the context of a reserve estimate for an energy resource. Reserves are reliably proven quantities of raw materials that can be extracted with today's technology and at current prices. Although extraction technologies are still under development, recent cost estimates suggest that natural hydrogen may be price-competitive with hydrogen produced from renewable electricity. Nevertheless, volumetric quantities are very rarely estimated and reliably determined.

Three types of possible hydrogen deposits are predominantly discussed in the literature: accumulations over longer periods of time that could be extracted in the same way as hydrocarbon reservoirs, accumulations that are continuously replenished and source rocks that are artificially stimulated to produce hydrogen. The generation rates of H_2 in the main processes, but also the reservoir properties, are crucial for assessing these possible hydrogen deposits.

We use reported gas flow rates for different geological settings and standardise these. These values are compared with reported and estimated production volumes of H_2 per year that would be necessary to make a deposit economically viable. This contribution attempts to estimate the order of magnitude of a deposit that would be required for relevant, economic extraction of natural hydrogen.

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

Niche Differentiation within the Crinoid Community from the Lower Devonian Hunsrück Slate, Germany

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The Lower Devonian Hunsrück Slate exhibits a remarkable diversity of stalked crinoids, with approximately 61 species from 31 genera, representing all major Paleozoic taxa. Among them are forms with highly branched or unbranched arms, with or without pinnules. Prominent anal tubes or spines are present in many species. The calyces are typically small, and the stalks relatively slender and of varying lengths.

This study investigates the composition of this crinoid community, assessing whether the individuals coexisted in competition or if the community structure provides benefits to them. The latter is assumed, because the great variety of different forms, especially in the construction and branching of the arms, indicates that these crinoids possessed a wide food spectrum.

To test this hypothesis, the model of niche differentiation by Ausich (1980) is applied. The most important parameters are column length, which indicates the level of filtration above the seafloor, and filtration fan density, from which information about the food particle selection can be derived.

Fossil material from the Lehmann Collection at the University of Bonn was investigated. Radiographs were taken of the specimens to make all structures visible. Filtration fan densities were calculated for as many genera and species as possible. The results reveal clear differences between the taxa depending on their typical arm-branching patterns and presence or absence of pinnules. To advance this study, column lengths, and more parameters, such as arm width or ambulacral groove width, will be included in the niche differentiation analysis.

01.09 HEATin ´EUROPE during the Carboniferous and Permian: causes and effects

HEATin ´EUROPE – Variscan orogenic vs. anorogenic polyphase heating

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Studies in all Variscan orogenic belts have revealed magmatic and HT/LP metamorphic events which are incompatible with the collisional evolution of the Variscides. U–Pb datings on zircon and monazite from granitoid intrusions, felsic and mafic volcanism, granulites and migmatites have yielded age clusters between ca. 360 and 270 Ma, i.e., before, during and after Variscan collision. In foreland fold and thrust belts (FTB), these clusters are represented by K/Ar ages of anchizonal metapelites and fine-grained volcanic ashes. They may occur in zones cutting across sutures and even in areas outside the Variscan orogen (Scotland).

Diachronous collisional deformation and metamorphism are best documented by progradation of the synorogenic flysch wedge and tectonic deformation in its wake (datd by K/Ar on clavage). Some pre-orogenic heat pulses have survived in the external parts of FTB, where syn- and post-orogenic heating were weak.

Anorogenic age clusters are best explained by the activity of mantle plumes, which have repeatedly heated and softened the crust, thus permitting formation of Devonian and Carboniferous marine basins even within crystalline parts of Variscides and preventing formation of Tibetan-style plateaus. These processes are best explained by the position of Europe over the plume generation zone TUZO (after Tuzo Wilson), from the early Carboniferous onwards, which is responsible for the notorious high-T events in pre-Mesozoic rocks of entire Europe.

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01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Invertebrate trace fossils and bioturbation at the lower Permian lagerstätte Bromacker in the Thuringian Forest

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We investigate trace fossils and bioturbation degree of two sediment cores extracted from the Tambach Formation and from excavations at the Bromacker locality.

The degree of bioturbation of the investigated silt- and sandstones is rather low in most parts of the sections, averaging at about 8%. Thus, the low degree of bioturbation varies between grade 0 and 2 following the classification of Reineck (1963). Most frequent structures are burrows of 2-38 mm diameter. In general, the dominating small burrows of <5 mm penetrate the bedding planes perpendicular or with a steep angle (Skolithos), whereas larger burrows of a few cm in diameter are mostly horizontal. Burrows are simple, unbranching and show no internal or surface structures. They are characterized by passive infill, similar to (Palaeophycus) or slightly different from the host rock (Planolites).

Some additional trace fossils are preserved as convex hyporeliefs on sandstone slabs. Most abundant is Tambia spiralis (Müller, 1956), which was selected by Paläontologische Gesellschaft as Fossil of the Year in 2024. This trace fossil is characteristic of the Tambach Formation and geographically and stratigraphically almost restricted to it. Less common is the feeding trace fossil Striatichnium bromackerense Martens, 1982. Very rare are trackways and trails of Arthropoda, such as Diplichnites, Diplopodichnus and Lithographus.

The investigated sediments were deposited as fluvial overbank and channel sediments with short transport routes as low rounding degree of grains indicates. Degree and type of bioturbation point to a Scoyenia ichnofacies with strong seasonal effects under a wet-and-dry tropical climate.

01.11 Micropalaeontology – Advancements and Perspectives in Multiproxy Studies

The Quaternary Ostracoda of Eastern Germany

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Ostracoda (Crustacea) are important proxies of palaeolimnological analysis, especially in Quaternary continental sediments. They allow tracing temperature changes, salinity, oxygen availability, productivity, pollution, or turbulence to name only a few environmental factors. Autecological tolerances allow the reconstruction of habitats and environmental parameters, often in a quantitative way. Despite there is a long and intense history of ostracod research in Germany, no compilation is available since Klie (1938).

Within a new research project, we intend to compile all information about Recent and Quaternary Ostracoda of Germany and began in the Baltic Sea and the East, i.e. the area of the former GDR. Plenty of material and many publications are available: Thousands of micropalaeontological slides with picked Quaternary ostracods and foraminifera from the former exploration company Erdöl-Erdgas Gommern, similar numbers of slides from the Museum für Naturkunde Berlin filled by Kurt Diebel und Erika Pietrzeniuk in the 1960ies to 1990ies and many more at museums and geological surveys of the eastern Federal states plus several dozens of widely scattered papers on Recent and Quaternary ostracods provide a huge and unique dataset to make use of. This dataset will be palaeoecologically and biostratigraphically analysed and made accessible to the public within a searchable database. We expect distinct progress by using documented association data for better characterizing habitats, climatic changes and biogeographic patterns. Furthermore, the biostratigraphic values of ostracod species will be improved.

We kindly ask colleagues for information about hidden collections or documentations of German Quaternary ostracods to enlarge our database.

01.03 Chaotic rocks – characteristics, formation and geodynamic significance

Blocks of fault-bounded imbricate stacks of Devonian limestones, a diagnostic feature for a tectonic origin of chaotic rock fabrics in the Harz Mountains (Eastern Rhenohercynian Belt, Germany)

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The distinction between sedimentary and tectonic processes in the formation of chaotic block-in-matrix fabrics is especially difficult in ancient mountain belts, where sedimentary structures are usually overprinted by orogenic deformation (e.g. Festa et al. 2019, GR, 74). This also applies to the chaotic rock units occurring widespread in the allochthonous domain of the Harz Mountains. For these units, it has previously been assumed that their rock fabric was sedimentary in origin and subsequently only tectonically overprinted by late Carboniferous Variscan deformation. In contrast, it could be shown, that tectonic deformation is crucial for the formation of the "chaotic" fabric (Friedel et al. 2019, Int.J.Earth.Sc., 108). This is particularly evident in the structural characteristics of blocks of (hemi)pelagic limestone of different Devonian ages, which are incorporated in a slaty clayey matrix. So far, the blocks were mostly regarded as olistoliths and thus considered as clear proof for a sedimentary origin of the chaotic units being olistostromes. However, our investigations show that these blocks are fault-bounded, tectonically folded and internally imbricated stacks of limestone strata, whose final fragmentation and isolation occurred after folding. Similar to rootless folds, these blocks of fault-bounded imbricate stacks are an outcrop-scale diagnostic feature to identify a strong fault-tectonic overprint or even a tectonic origin of chaotic rock fabrics, provided that the tectonic character of folding and faulting is sufficiently proven. The regionally widespread occurrence of such blocks, together with meso- to micro-scale faulting criteria, suggests a predominantly tectonic origin for the chaotic rock units in the Harz.

02.01 The Tethys Ocean – the cradle of modern tropical life

Tracing the Devonian Roots of the Parallelodontidae (Bivalvia): Origin and Evolution

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The Parallelodontidae is one of six families of the Arcoidea that is assumed to range from the Devonian to the Recent. Despite over 150 years of research, the origins and early history of the family remain largely unresolved. We reviewed the Devonian taxa that match the typical parallelodontid morphology regarding hinge details or external shell characteristics, leading to a list of some 50 species. However, most of them can only be vaguely attributed to Parallelodontidae, as poor preservation can obscure diagnostic features, causing potential confusion with contemporaneous genera showing comparable characteristics.

Here, we present details of the Devonian species that show parallelodontid morphology in the strict sense. All Ordovician and Silurian taxa previously attributed to Parallelodon or presumed to possess parallelodontid characteristics turned out to be misclassified. Parallelodon mandelensis from the upper Emsian Rhenotypic Facies of Germany undoubtedly has a parallelodontid hinge and seems to be the earliest member of the family. Next unequivocal parallelodontids have been noted in the Middle Devonian, primarily in the shelf region deposits of the Rheic Ocean in Central Europe and eastern North America, where up to ten species were identified. The relatively high sea level and, accordingly, wide shelf areas during this period provided ideal conditions for the diversification of parallelodontids. The Late Devonian evolution of the group is mainly documented in North America, as facies conditions in Europe seem to have been unfavorable. With the transition from the Devonian to the Carboniferous, a remarkable radiation of parallelodontids led to significantly higher parallelodontid diversity.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Concept, goals and progress of the BROMACKER project 2020-2025 – A synergy of science & knowledge transfer

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The BMBF-funded BROMACKER project (2020-2025) uniquely combines multidisciplinary research on the early Permian Fossillagerstätte Bromacker in the Thuringian Tambach Basin and UNESCO Geopark with innovative, experimental and multimedia science communication formats, involving the general public with novel and interactive formats. The site provides an exceptional window into the evolution of early terrestrial vertebrates and their ecosystems, preserving extraordinary fossils of tracks, traces, burrows and body fossils primarily of vertebrates in Lagerstätten-quality. Spectacular vertebrate fossils display distinct autecological specializations such as herbivory, bipedality and fossoriality. Another unique selling point is the earliest evidence of the modern trophic pyramid in terrestrial vertebrate ecosystems. The 2020–2025 project further revealed the earliest body impressions and evidence of epidermal scales and aggregation behavior in synapsids as well as the earliest occurrence of complex vertebrate burrows. The natural science research is accompanied by diverse and cutting-edge science communication formats, including special exhibitions, social media, podcasts, 360° projections, interactive websites, school projects, as well as in-person and live virtual public tours and events at the excavation site, in the partner institutions and external venues. This multidisciplinary and interactive approach of communicating scientific processes and results to the general public successfully increases the understanding and acceptance of geoscientific research in general. Visitor numbers at the excavations and in the entire region also increased, reflecting the importance of Bromacker research and outreach for tourism and networking with enormous potential for the future.

01.06 Tectonic Systems – TSK Open Session

The eastern termination of the Southern Steep Belt (Central Alps)

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The Southern Steep Belt (SSB), an E–W-striking, north-block-up mylonite zone, juxtaposes high-grade metamorphic Europe-derived basement nappes and the unmetamorphic Southern Alps. At its eastern end in the upper Valle dei Ratti, the SSB apparently terminates at the calc-alkaline Bergell pluton (BP). There, a large antiform at the base of the BP translates the intrusive rocks and underlying gneisses into the SSB. However, the relationship between the SSB and the units farther north (Gruf complex, Adula nappe) remains unclear.

We present a new geological map of this critical area. An alternating sequence of Bt-rich gneisses and schists adjacent to more leucocratic gneisses, as well as metasedimentary and meta-ultramafic rocks, clearly represents a single basement unit beneath the BP. This contradicts previous maps, which assigned different tectonic units to the two limbs of the antiform. Stretching lineations and fold axes consistently plunge eastward. Structural, microstructural, and EBSD data indicate upper-unit-to-the-east shearing, which transitions into north-block-up, left-lateral shearing within the SSB. We propose that the mylonitic shear zone of the SSB is folded together with the base of the BP and continues into the right-lateral, south-block-up shear zone at the northern border of the Gruf complex. Hence, top-to-the-east shearing beneath the BP would exhume the entire Lepontine, not just the Gruf complex. This scheme would explain the metamorphic gap on the northern and southern sides of the Gruf complex as well as the absence of the SSB east of the BP.

04.06 Coupled Fluid-Rock Deformation: Unraveling Multiscale THMC Dynamics for Fundamental Geological Processes and Societal Challenges

Dynamically evolving fluid transport properties in mylonitic shear zones

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Deforming rocks in mylonitic shear zones are first-order fluid conduits in the crust, where fluids are hosted by grain boundaries, cracks and pores, all of which evolve during deformation and synkinematic reactions. This evolution, which entails coupled chemical, hydraulic and mechanical processes on multiple scales, controls where fluids will migrate and interact with rocks. However, we have no systematic and comprehensive knowledge of how these processes, and feedbacks between them, combine to form the dynamic transport properties of natural mylonitic shear zones. This shortcoming severely affects our multi-scale assessments of fluid-rock interaction at plate boundaries and at other societal interfaces with the geosphere.

In this presentation, I will provide a brief overview of mechanisms that produce (and destroy) porosity in mid-crustal mylonites. I will use high-resolution µCT and SEM data from natural shear zones and operando experiments to derive a conceptual model for how porosity and permeability evolve as a function of shear strain. This model highlights critical but measurable parameters that enable its integration into forward simulations of fluid migration in deforming crustal rocks.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Crustal Magmatic Evolution of the Oyut Porphyry Cu–Mo Deposit, Northern Mongolia

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Copper (Cu) is essential for modern technologies, with demand expected to increase significantly due to the global transition towards green energy. Porphyry Cu deposits, which supply ~75% of the world's Cu, are primarily associated with subduction-related magmatism in calc-alkaline arcs. Despite the widespread presence of such magmas, large porphyry Cu deposits are rare and increasingly challenging to discover. This study investigates the Permian–Triassic magmatic evolution of the Oyut Cu–Mo deposit in northern Mongolia through zircon U–Pb geochronology, lithogeochemistry, and mineral thermobarometry. The deposit is hosted in porphyritic andesite and basaltic andesite, intruded by (mostly) barren quartz-diorite and granodiorite, as well as mineralized granodiorite and dacite porphyries exhibiting intense K-feldspar and sericite alteration. Zircon U–Pb ages range from 254–246 Ma for the barren intrusions to 240–237 Ma for the mineralized porphyries. All magmatic rocks are high-K calc-alkaline and peraluminous to metaluminous, with Nb and Ta depletion indicating a continental arc setting. REE patterns distinguish two magmatic episodes: older barren intrusions show high overall REE contents and weak negative Eu anomalies, suggesting evolved melts. In contrast, mineralized intrusions (240–230 Ma) exhibit lower REE contents and positive Eu anomalies, indicating plagioclase accumulation or retention and a more oxidized, water-rich magma, favorable for Cu–Mo mineralization. Thermobarometric estimates (635–843 °C, 0.2–4.6 kbar) and trace element signatures suggest derivation from an enriched, volatile-rich mantle source and crystallization at mid-crustal depths. These findings highlight the importance of crustal differentiation, the role of plagioclase accumulation, and fluid evolution in forming Cu–Mo porphyry systems in continental arcs.

04.07 Mineralogy of Secondary Raw Materials

Evaluating Microstructure and Mineral Chemistry for an Economical Lithium Recovery from Slag

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Established pyrometallurgical processes enable the recovery of many valuable metals from lithium-ion-batteries (LIB) (e.g. Ni, Cu, Co) as an alloy or a metal sulfide. However, lithium dissolves into the slag, from which it cannot currently be recovered economically. One recently discussed approach is called “Engineering of Artificial Minerals” where the lithium is collected in a specifically designed phase.[1] A recent study demonstrated β-eucryptite as a lithium collector phase with high potential.[2]

To achieve an economically feasible process, the collector phase requires optimized characteristics: 1) High lithium content; 2.) Low amounts of process impeding impurities; 3.) A suitable microstructure for liberation and sorting. The sampled crystalline slag was investigated using scanning electron microscopy (SEM), electron probe microanalysis (EPMA), and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to investigate these parameters.

The investigated lithium collector phase, β-eucryptite identified in slag from an industrial LIB recycler, shows a lithium content of 5.54 ± 0.19 mass %, close to the stoichiometric content of 5.51 mass %. Furthermore, it shows only minor amounts of cationic impurities, mostly iron and calcium. These impurities could be easily removed while coprocessing β-eucryptite with spodumene in a primary lithium converter.[3] In addition to grain size distributions, for the quantitative description of the microstructure the implementation of the envelope parameters was tested. A more detailed quantification of the grain shape than conventionally used descriptors was demonstrated.

References

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03.06 Multiscale characterization of structure, flow and transport dynamics in fractured porous media and karst systems

Estimation of recovery efficiency in high-temperature aquifer thermal energy storage

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High-temperature aquifer thermal energy storage (HT-ATES), with its high storage capacity and energy efficiency and its compatibilities with renewable energy sources, has generated widespread interest. One main criterion for a feasible HT-ATES is the thermal recovery efficiency, i.e., how much of the invested heat can be recovered. The heat lost during the HT-ATES is mainly due to the heat conduction and the density-driven buoyancy flow, which are more significant with HT-ATES compared to the conventional low-temperature ATES. Thus, understanding the fluid displacement and thermal transport processes during HT-ATES is essential for assessing the performance of HT-ATES. A group of key dimensionless parameters regarding the thermal recovery efficiency for HT-ATES are identified in this study. The numerical model is set for a typical HT-ATES based on the geological in the Burgwedel region and the designed operational parameters. Over one thousand cases are simulated for a sweep of the key parameters for multiple cycles and storage volumes, and the resulting recovery efficiency for each case is obtained. The hot water injection and displacement processes and the correlation between the recovery efficiency and the key parameters are investigated. The correlation functions are built to estimate the thermal recovery efficiency, which can be used for a quick assessment of potential HT-ATES sites when the properties of the aquifer are known.

01.26 Alpine-Zagros-Himalayan Orogenic System: Case Studies

Structural Evolution of Mud-Intrusive and Mud-Extrusive System in the Makran Accretionary Wedge: Tectonic Insights from the India-Arabia-Eurasia Triple Junction

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The Makran Accretionary Wedge (MAW) in Pakistan and Iran, situated at the India-Arabia-Eurasia triple junction, provides a unique environment to investigate the mud-intrusive and mud-extrusive system (MIES) within an ultra-slow subduction zone. The MAW formed by northward subduction of the Arabian Plate beneath the Eurasian Plate, with convergence started during the Late-Cretaceous with a renewed phase since Middle-Miocene. This compressional regime has caused intense tectonic imbrication, deformation of pre-existing strata and formation of piggyback basins that preserved detailed records of tectono-sedimentary interactions. We utilized two-dimensional seismic reflection profiles, satellite imagery, and bathymetric data to map and characterize the geometry, spatial distribution, and connectivity of surface and subsurface mud-structures within the MAW. The MIES in this region form a complex plumbing system comprising mud-volcanoes (MVs), mud-diapirs (MDs), feeder-pipes, gas-chimneys, and mud-chambers etc., primarily sourced from the overpressured Makran Turbidite Deposits. These hemipelagic mud-rich deposits undergo compaction and tectonic loading, driving vertical and lateral fluid migration along structural conduits. Our study classifies the mud-structures into four types: (i) deep-sourced MVs, (ii) shallow-sourced MVs, (iii) multisource MVs, and (iv) multisource MDs. These structures typically exhibit conical, bifurcating, and Christmas-tree-like geometries with 75°–105° inclinations, commonly aligned with thrust-related anticlines, reflecting strong structural control. Active mud/fluid migration triggers coastal slope instability and normal faulting. Bottom-simulating reflectors further indicate ongoing fluid migrations and thermogenic gas generation within the MAW. The MAW, shaped by compressional tectonics and distinct sedimentary architecture, offers a valuable model for understanding mud-structures and tectonic processes in convergent margins worldwide.

04.06 Coupled Fluid-Rock Deformation: Unraveling Multiscale THMC Dynamics for Fundamental Geological Processes and Societal Challenges

Carbonated ultramafic and mafic rock sequences from Point-Rousse Complex, Newfoundland: insights for carbon and sulfur mobility along plate-scale shear zones

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Carbonation of ultramafic and mafic rocks is an important process that can occur in subduction zones, trapping and/or mobilizing carbon, sulfur, and fluid-mobile elements. Here we investigate two exceptional sequences of carbonated ultramafic and mafic rocks from the Point-Rousse Complex (Newfoundland, Canada) to understand the element mass-transfer, redox processes and physicochemical conditions triggered by fluid-flow along a major shear zone.

The complex comprises ophicarbonates (≤5.2 wt% CO_2), soapstones (3.4–26.1 wt% CO_2), carbonate-bearing greenschists (6.2–8.5 wt% CO_2) and albite-dolomite rocks (29.1–35.4 wt% CO_2). Petrography and chemical mapping reveal replacement and dissolution/precipitation textures of carbonation reactions. In ophicarbonate, serpentine is pseudomorphically replaced by magnesite and dolomite, preserving relict bastite and mesh textures. Foliated ophicarbonate exhibits the replacement of serpentine by coarse-grained talc and magnesite. Soapstone is characterized by corona-shaped reaction rims of quartz and talc surrounding dolomite crystals. Coarse-grained magnesite displays chemical zoning with increasing Fe content and core-to-rim decreasing of magnetite inclusions. Albite-dolomite rocks, composed primarily of dolomite, albite and muscovite are crosscut by centimetric albite veins. Carbonated greenschist, composed of albite, chlorite, dolomite, and pyrite, exhibits dissolution/precipitation structures associated with the formation of albite and carbonate veins. Pyrite mineralization is concentrated along albite vein margins in carbonated mafic rocks (bulk-rock S ≤3.3 wt%).

The reported carbonation occurred simultaneously in mafic and ultramafic rocks. Thus, this rock assemblage represents an ideal natural laboratory to investigate CO_2 entrapment, sulfur mobility, and the sources and compositions of involved fluids.

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03.07 Risks from a Changing Cryosphere

A TRANSDISCIPLINARY, COMPARATIVE ANALYSIS REVEALS KEY RISKS FROM ARCTIC PERMAFROST THAW

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Permafrost thaw poses significant risks to Arctic environments and livelihoods, impacting societies, cultures, health, ecosystems, and economies. However, existing studies lack comprehensive frameworks for understanding such impacts on coupled socio-ecological systems from a transdisciplinary perspective. To address this gap, we introduce a holistic, comparative, and transdisciplinary risk analysis based on multidirectional knowledge exchanges and thematic network analysis (Gartler, Scheer and Meyer et al. 2025). Local stakeholders and scientists' perceptions shape our understanding of risks that we holistically define as dynamic socio-natural phenomena involving physical processes related to permafrost thaw, ensuing key hazards, and societal consequences. Consolidating findings from four regions (Longyearbyen, Svalbard, Norway; Avannaata Municipality, Greenland; Beaufort Sea region and Mackenzie River Delta, Canada; Bulunskiy District, Sakha Republic, Russia), we identify five key hazards of permafrost thaw: infrastructure failure, disruption of mobility and supplies, decreased water quality, challenges for food security, and exposure to diseases and contaminants. The novelty of this study resides in the comparative approach spanning different environmental and societal contexts, and transdisciplinary synthesis considering various risk perceptions. We present the main local risks from permafrost thaw faced by diverse Arctic communities, seen through the lenses of multiple scientific disciplines and local experts. Developing such an understanding is vital for informed policy-making and adaptation efforts.

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01.20 Process oriented microfabric characterisation of geomaterials

The Role of Fluid Salinity in Wollastonite Reaction Rim Formation

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Mineral reaction textures such as coronae are commonly observed features in metamorphic rocks and serve as valuable indicators for quantifying metamorphic processes. Their formation is typically controlled by pressure, temperature, chemical composition, as well as the presence/absence of fluids and their composition. While highly saline fluids have been reported from various metamorphic environments, their impact on reaction rim growth remains elusive.

In this study, we experimentally explored the role of fluid salinity on the formation of wollastonite reaction rims between quartz and calcite using a piston-cylinder apparatus. The starting material comprised a mixture of fine-grained calcite and coarse-grained quartz (95:5 by mass), along with 1 wt% fluid. Fluid composition was set at an XCO_2 of ~0.3 with variable $CaCl_2$ between 0 and 40 wt%.

Experiments involved two steps: (1) annealing at 1 GPa and 800 °C for ~2 days to promote recrystallization and produce a synthetic impure carbonate, followed by (2) reaction at 1000 °C for 24 hours to initiate wollastonite formation. Results reveal wollastonite rim formation on calcite surfaces at low $CaCl_2$ concentrations (0-6 wt%), while wollastonite growth on quartz surfaces has been observed at high $CaCl_2$ concentrations (up to 40 wt%).

We interpret our finding that fluid salinity affects solubility of minerals and therefore element mobility in grain boundary fluids, which in turn controls local mineral growth/dissolution recorded in metamorphic textures. Hence, the role of fluid composition in interpreting natural metamorphic microstructures provide potential for future studies.

08.01 Young Scientist Session

Not quite alike – Changing skull shapes in archeopterodactyloidean ontogeny could point towards heterochony mediated niche differentiation

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Archeopterodactyloidea are a monophyletic group of early branching Pterosaurians that likely originated in the early to middle Triassic. They are often characterized by their elongated skull and neck as well as their short tail. Their feeding ecology is a much debated topic, describing them to be anything from insectivores to piscivores. Here we attempt to understand their feeding ecology better by trying to quantify skull shape as a possible ecological proxy. A major focus here are differences between immature and adult specimens of the same species and possible implications for their diet. We used Elliptic Fourier Analysis to quantify pterosaurian skulls outlines as a quantitative representation of overall skull shape. Our results show a varying degree of heterochrony for all four species of archeopterodactyloidean pterosaurians in the analysis. This heterochronic change is largely cause by the elongation of the skull throughout ontogeny. Germanodactylus cristatus shows clear differences between short immature skulls and more elongated adult skulls. In Pterodactylus antiquus these differences become even more pronounced. In Aurorazhdarcho micronyx the difference lessens, with more elongated immature skulls. In Ctenochasma elegans these differences are even less pronounced, with already strongly elongated immature skulls. This could either imply early branching archeopterodactyloideans had some sort of ecological niche differentiation between stages or that they were more nidicolous. This then likely changed through phylogeny with different late branching representatives of archeopterodactyloidea being either less ecologically differentiated between stages or possibly being more nidifugous.

01.13 Sedimentary basins as multi-proxy and multi-process recorders

The Quaternary sediment record of the Upper Rhine Graben

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The Upper Rhine Graben (URG) is the central part of the European Cenozoic Rift System, and has repeatedly been subsiding since ca. 50 ka. Consequently, it has been filled by a kilometre-thick sediment sequence including several hundred metres of Quarternary strata. Fed by the Rhine and its tributaries, the URG collects deposits derived from the Alps as well as from the graben shoulders and their hinterlands – deposits that have built up a significant stratigraphic archive that links the Alpine realm with the Central European lowlands.

The work summarised here is based mainly on drill cores that recovered diverse successions and illustrate the Quaternary infill of the URG along a transect from south to north. It begins with (glacio-)fluvial gravels and sands as a distal signal of the Pleistocene glaciations of the Alps. Towards the north, these interfinger, among others, with palustrine and lacustrine deposits that contain abundant biological remains that are indicative of climatic conditions and the general environmental setting. The architecture of the deposits is determined by patterns of differential subsidence that is still ongoing, as indicated by neotectonic dislocations. Even in the Heidelberg area, the depocentre affected by highest subsidence and deposition rates, unconformities can be observed.

Overall, the URG is one of Europe's longest-reaching, best-resolved and thus most significant Quaternary archives. Although its infill allows inferences on a variety of processes acting on and below surface, such as sediment dynamics, development of palaeoenvironments, and neotectonic activity, it is still largely untapped and further investigation is warranted.

05.01 Spectroscopic methods in modern geosciences

Measurement of polarizability tensor for muscovite and potential application to microstructural characterization

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An accurate quantification of the crystallographic-preferred orientation of weak minerals is the key step to decipher the rock deformation history. Measuring the crystallographic orientations in a thin section provides detailed 2-D information about the microtexture. An established method for this task is the electron backscattered diffraction technique. However, the high-level polishing required by EBSD analysis can produce a bias especially in the modal percentage of fragile minerals such as mica. An alternative method is Raman spectroscopy, which requires minimal amount of sample preparation and surface polishing. This method relies on the fact that the intensity of Raman bands varies depending on the mutual orientation between the polarization direction of the incident laser and the crystallographic axes. Given the polarizability tensor, it is possible to inversely calculate the crystallographic orientation by collecting the band intensity as a function of laser polarization direction. In order to calculate the polarizability tensor of the A and B mode of muscovite, we measured the Raman band intensity as a function of orientation around 360° for a muscovite sample cut parallel to the c-axis. We found that the 196 cm^{-1} and the 263 cm^{-1} bands are most suitable for orientation measurements. The polarizability tensor can be fitted, which makes it possible to perform mapping of the crystallographic orientation on a thin-section, such as mica schist deformed under deviatoric stress.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Multi-method luminescence dating of late Cenozoic northern Upper Rhine Graben sediments

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The Upper Rhine Graben (URG) hosts one of the most continuous sequences of unconsolidated late Cenozoic sediments in central Europe. Its location between the northern European inland and alpine glaciation during the Pleistocene provides the opportunity to investigate the interactions of tectonic and climatic control on sedimentation and erosion processes. In 2020/21, a new continental drilling campaign was carried out by the Hessian State Agency for Nature Conservation, Environment and Geology (HLNUG) near Riedstadt-Erfelden in the northern part of the URG to obtain information on the development of the graben system and its infillings, complementing results from previous drillings. This study presents geochronologic data derived from combined luminescence dating approaches. Preliminary results using optically stimulated luminescence (OSL) and infrared-radiofluorescence (IR-RF) are supplemented with infrared-stimulated luminescence (IRSL), post-infrared-IRSL (pIRIR) and infrared photoluminescence (IRPL) signals. The latter represents an innovative approach, utilising a potentially non-destructive and non-fading signal from K-feldspar. For the first time, we applied the multiple elevated temperature (MET)-pIRIR-IRPL single aliquot regenerative dose (SAR) protocol suggested by Kumar et al. (2021) to fluvial samples. Furthermore, the results are compared to ΔIRPL signals derived from the same protocol.

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08.01 Young Scientist Session

Facies analysis and formation of insect-bearing marine black shales from the Lower Jurassic of Schandelah (Lower Saxony/Germany)

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Black shales are often key archives of past life, thanks to the preservation of organogenic tissues in the absence of oxygen. However, various taphonomic constraints and processes can strongly alter the fossil assemblages and may lead to false palaeoecological conclusions. This talk discusses insect preservation in the Lower Jurassic Posidonia Shale of Schandelah (NW Germany), a window into Mesozoic entomofaunas of central Pangaea. For this purpose, we present a cm-scale analysis of lithofacies and fossil content of a c. 2 m thick and 7 m wide excavation section, stretching the siemensi- to borealis-ammonoid subzones. Emphasise is put on dm-sized polished slabs from intercalated early diagenetic calcite concretions. Consistent with previous studies, the marly strata formed in a fully marine setting close to small islands with limited fluvial input. However, water stagnation and depth seem to have increased over time, given the profile-up decrease in grain size, extent in bioturbation and abundance of macrobenthos in the peloidal concretions. This trend improved the preservation of insects sunken to the sea floor, as reflected by their taphonomy and occurrence: insects are absent in the lowermost siemensi concretions, while resistant coleopteran remains rarely occur in the capillatum and elegantulum concretions. In the uppermost borealis concretions, insects are most abundant, diverse and dominated by isolated wings. Increasing annihilation of anatomical detail in the insect fossils towards the concretion margins attest to chitin dissolution during diagenesis. These results call for more bed-by-bed documentations of fossil content and preservation, and disclose ways to reconstruct the Posidonia-Shale environment.

08.01 Young Scientist Session

Parasitic 3D-preserved fossil organisms from the Ordovician of Sweden

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Parasites are ubiquitous and an important part of the modern biodiversity, representing at least half of all extant organisms. Many of them play an important role in biological interactions, like in food webs, and in the co-evolution between host and parasite. Parasitism evolved convergently many times in Metazoa, and we can find parasitic forms in all larger lineages of animals. They demonstrate a huge diversity in morphology, niche occupation, or life cycle. Also in Euarthropoda, parasites appeared several times, with better and with less known forms, such as ticks, parasitic wasps, fleas, barnacles, or tongue worms. All of them evolved convergently to a parasitic mode of life. Despite this important diversity in parasitic organisms, they are still overlooked, and many things remain to be understood, especially concerning their evolution. Fossil specimens are often neglected, and several studies focus on observations of living species. In addition, fossil parasites tend to have a lower chance of preservation, because many of them possess small and soft bodies, or they infect internal organs (soft tissue) of their hosts. In Euarthropoda, the fossil record is better than in other lineages due to their cuticle composed of chitin that shows a rather high preservation potential. An exceptional fossil assemblage from the Ordovician of Sweden delivered organisms in beautiful three-dimensional Orsten-type preservation, representing unusual parasitic organisms. Those fossils yield important information about the early specialisation of parasitism during the Palaeozoic.

01.26 Alpine-Zagros-Himalayan Orogenic System: Case Studies

New Constraints on the Structural and Exhumation History of the Kirthar Fold-and-Thrust Belt, Western Pakistan

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The western fold-and-thrust belt (FTB) of Pakistan is structurally divided into the Sulaiman FTB in the north and the Kirthar FTB in the south, separated by the Quetta syntaxis. We investigate the spatiotemporal structural evolution of the Kirthar FTB with low-temperature thermochronology (Apatite U-Th-Sm/ He (AHe), Fission track (AFT), and Zircon U-Th/He (ZHe)) age data. Our dataset includes 14 AHe, 9 AFT, and 4 ZHe surface ages, supplemented by 18 AFT, 56 vitrinite reflectance (VR), and 9 Rock-Eval (Ro) samples from foreland wells.

In the Northern Kirthar, partially reset Eocene AHe ages and AFT age of 135 ± 34 Ma, combined with unreset ZHe ages (187.7-424.6 Ma) from Cretaceous samples, indicate shallow burial and preserved signatures of pre-Oligocene uplift. In contrast, Central Kirthar records resetting of Paleocene to Oligocene samples with AHe ages (~6–8 Ma), however; the AFT (~119 ± 43 Ma) and ZHe ages ages (63-433 Ma) show partial resetting, suggesting Late Miocene to Pliocene rock uplift from ~3 km depth. In Southern Kirthar, the westernmost samples yield Oligocene AHe ages of 5.3 ± 1.7 Ma, AFT ages of 23.3 ± 8.3 Ma, and un-reset ZHe ages (202.0 to 390.7 Ma), suggesting burial of ~3 km before exhumation. However, range-front samples show different patterns with a partial reset age (21.2–6.5 Ma) for, hanging-wall Oligocene and footwall Miocene samples (18 Ma). In the Katawaz Basin, deeper burial (~3-5km) is evident in the northern sector, while southern sectors experienced only limited burial, insufficient to reset AHe and AFT ages.

01.13 Sedimentary basins as multi-proxy and multi-process recorders

Contourite-drift archive links periodic anoxic shelf water cascading with Late Devonian bioevents (Tafilalt, Morocco)

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The analysis of Devonian cephalopod limestones in the eastern Anti-Atlas of Morocco (Tafilalt) reveals the formation of a contourite terrace on the uppermost slope of northern Gondwana. The inner terrace was bounded by a contourite channel and an associated mounded drift. The Eifelian–Frasnian record includes pelagites and bioclastic contourites with coquinas of planktonic and nektonic fauna, forming integral parts of bi-gradational sequences. Frequent hiatuses at sequence midpoints are marked by lag - deposits of intraclasts, ferromanganese nodules, and conodonts draping erosional surfaces. Deposition was primarily driven by oxic, clear-water bottom currents.

Of particular palaeoceanographic interest are widespread erosional hiatuses and associated organic-rich calcarenitic contourites (black styliolinid coquinas), many formed penecontemporaneously with Devonian evolutionary events. These deposits record intensified bottom currents coinciding with the expansion of a dysoxic–anoxic water mass. Facies- and drift-scale features indicate northwest-directed along-slope circulation. We attribute these palaeocirculation events to repeated overflows of anoxic water from the North African Epicontinental Sea via the Ougarta Trough, likely driven by dense (saline) shelf water formed on the northern Gondwana margin. These overflows cascaded downslope until reaching a density equilibrium, probably forming an intermediate water mass.

This evidence for dense shelf-water cascading supports the photic-zone eutrophication (top-down) model proposed for the Kellwasser Crisis and related Devonian anoxic events. We therefore propose a direct link between these anoxic overflows and Devonian evolutionary events.

01.13 Sedimentary basins as multi-proxy and multi-process recorders

Facies variability and depositional architecture of bioclastic bottom-current deposits formed on a Devonian contourite terrace (Tafilalt Platform, Morocco)

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This study investigates bioclastic carbonate contourite deposits from the Eifelian–Frasnian of the Tafilalt Platform (Morocco) to enhance the understanding of carbonate sedimentation under bottom-current influence. In contrast to the classical bi-gradational contourite facies model, which is based on continuous deposition of fine-grained siliciclastics, these contourites reflect intermittent accumulation, resulting in thin, condensed successions with abundant hiatuses.

Five facies associations are identified, recording pelagic sedimentation and contourite deposition on a contourite terrace, an inclined section of the uppermost slope of northern Gondwana shaped by a shifting water-mass interface. Deposition was primarily controlled by oxic, clear-water bottom currents, as evidenced by bioturbated limestones with hydrogenetic ferromanganese nodules and low organic-carbon contents. In contrast, episodes of anoxic bottom-current activity are recorded by interbedded organic-rich coquinas featuring well-preserved traction structures, minimal bioturbation, and syngenetic pyrite framboids.

The large-scale depositional architecture includes an abraded surface, an alongslope contourite channel, and a small mounded drift. Microfacies analysis reveals frequent alternations between suspension settling, winnowing, bedload traction, dynamic sediment bypassing, and concomitant seafloor cementation. Coquinas composed of planktonic and nektonic organisms are integral components of bi-gradational sequences, which also feature lag deposits of carbonate intraclasts, conodonts, and ferromanganese nodules draping hardgrounds.

This high-resolution record provides a unique opportunity to investigate the spatial and temporal variability of bed-scale contourite features in conjunction with drift-scale depositional architecture—both shaped by palaeoceanographic processes during the Devonian greenhouse climate.

02.01 The Tethys Ocean – the cradle of modern tropical life

Plant fossils from the Carnian Pluvial Episode (CPE) of Monte Pora (N-Italy)

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The Carnian Pluvial Episode (CPE) is marked by a major climate shift with prevailing humid conditions in the paleotropics during the Late Triassic. It coincided with the key origination and/or radiation of several major groups (e.g., ammonoids, conodonts) as well as the diversification of terrestrial tetrapods and plants such as several modern fern and conifer families, and the Bennettitales. Despite extensive research carried out in the last years, particularly in the Tethys Realm, questions remain regarding the origin and impact of this climatic episode.

The Natural Science Museum “Enrico Caffi” of Bergamo, houses an extensive collection (more than 1,000 specimens) of plant fossils from the Carnian of Mount Pora. The plant fossil assemblage has been described partly by Passoni & van Konijnenburg-van Cittert (2003), who documented a diverse assemblage including Pseudodanaeopsis aberi, Sphenozamites spp., and Elatocladus porensis. It includes, however also several horsetail stem fragments of the species Equisetites arenaceus, broad-leaved conifers belonging to the species Pelourdea vogesiaca and several taxa of Brachyphyllum type conifers. Rare are fern frond fragments and smal droplets of amber. The latter were identified using a Dino-Lite digital microscope, equipped with 465 nm blue excitation LEDs and a 510–545 nm emission filter. Also Coprolites were detected together with the plants on the slabs.

02.01 The Tethys Ocean – the cradle of modern tropical life

Initial reef building of the Devonian Elbingerode barrier reef complex, Harz Mts., Germany

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The Elbingerode reef complex is a large Devonian reef system in the central Harz Mountains of Germany. It is well known for its massive, thick and fossil-rich limestones that formed an oceanic barrier reef system in the Rhenohercynian Basin of the Paleotethys Ocean. The initial reef building of this barrier reef system is less well known, but exposed in the form of small outcrops at the boundaries of underlying volcanic rocks and superposed reef limestone. Also, waste rock piles of ore mining have contributed to the knowledge of these deposits, especially to their fossil content. These limestones have been revisited and investigated with regard to sedimentology, mineralogy, and biostratigraphy. The initial reef building is reflected in the occurrence of biogenic packstones, grainstones, and wackestones deposited in close relationship to volcanic activity. The limestones are rich in crinoidal debris (as the main constituent particle), brachiopods, rugose and tabulate corals, stromatoporoids, bryozoa, trilobites, tentaculites, ostracodes, conodonts, goniatites, and holothurians. Clasts of volcanic rocks are common. The fine-grained matrix of the deposits contains 60–80 % carbonate and considerable amounts of non-carbonate fines. Reef frameworks did not form, but the common occurrence of numerous organism groups underlines that a highly diverse fauna had developed in a stressed environment including volcanic activity, and likely elevated turbidity and reduced water transparency. The textures and fabrics encountered suggest deposition below the fair-weather wave base, i.e., in water depths of several meters to a few tens of meters, however, not in shallow, agitated water.

07.02 Geothermal energy – Potential and utilisation of geothermal energy resources for the heat transition

Biogeochemical processes in anoxic saline siliciclastic aquifers induced by Aquifer Thermal Energy Storage between 20°C and 80°C

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Aquifer Thermal Energy Storage (ATES) is a promising technology for storing excess energy in urban environments, offering high energy storage capacity with a minimal surface area footprint. Despite its potential to support urban decarbonization efforts, the planning, approval, and implementation of ATES systems in Germany remains limited, partly due to uncertainties regarding long-term performance and environmental impacts within the subsurface. In particular, mineral precipitation and biofilm formation may clog wells and aquifers, thus posing operational challenges.

To assess temperature-dependent biogeochemical processes, sterile and non-sterile water-saturated column and batch experiments are performed at 20°C, 40°C, and 80°C. Natural siliciclastic sediment, derived from an ATES exploration drilling in Berlin, is used in the column experiments, while artificial siliciclastic sediment is applied as analog material in the batch experiments. All experiments are carried out using natural saline groundwater from a potentially ATES-suitable ~200 m deep saline aquifer in Berlin. The column experiments are conducted under an Ar/CO_2 atmosphere and focus on investigating dissolution and precipitation processes, (de-)sorption phenomena, (bio)clogging, microbial activity, and shifts in microbial community composition. The batch experiments examine the change of microbial abundance, activity and community composition, under four distinct gas atmospheres: N_2/CO_2, H_2/CO_2, Ar, and air.

Preliminary microbiological results indicate proliferation and higher microbial activity under anoxic compared to oxic conditions, and at low to moderate temperatures relative to high temperatures. The presence of microorganisms appears to induce changes in iron mineralogy.

The results will support the understanding and mitigation of mechanisms responsible for efficiency loss in ATES systems.

01.10 The co-evolution of the Earth and life from the early Archean until today

Metasomatic Alteration and Element Mobility in the 3.8 Ga Felsic-Metavolcanic Rocks of the Isua Supracrustal Belt

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The Isua supracrustal belt (ISB) is one of the earth's oldest preserved rock sequences and provides crucial insights into early Archean evolution. Polyphase metamorphism and variable degree of metasomatism have significantly obscured primary signatures requiring an understanding of metasomatic processes to reconstruct the evolution of the ISB.

A local metasomatic reaction zone in the western 3.8 Ga felsic-metavolcanic zone has been sampled, covering a traverse with decreasing alteration from the centre to the rim to identify the protolith, quantify element fluxes and reconstruct metamorphic conditions. Progression of the metasomatic front is characterised by four mineral assemblages: (1) talc-chlorite, (2) talc-chlorite-quartz, (3) chlorite-cordierite-biotite-quartz±kyanite, (4) cordierite-biotite-quartz±kyanite. While high Mg#: > 90 in ferromagnesian minerals appear to be constant across the outcrop, a systematic decrease in whole rock magnesium and nickel accompanied by an increase in silica, potassium, sodium, calcium and phosphorus can be observed. We interpret the element fluxes to be the consequence of infiltration by a fluid previously equilibrated with ultramafic rocks. Thermodynamic calculations indicate P-T conditions of 600–650°C and 0.5–0.7 GPa. The protolith has been constrained as dacitic to rhyolitic. In addition, the comparison of the least altered sample with a calculated average composition of the 3.8 felsic-metavolcanic rocks lead to the conclusion that they originate from the same protolith and had the same whole-rock chemistry before metasomatism. Further research is needed to constrain the origin of the fluid and the temporal relationship between metasomatism and metamorphism.

04.02 Lithium Rescources

BRIDGE – German-Chilean Institute for Element Extraction from Brines and Integrated Geological Reservoir Modeling

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Mit dem Deutsch-Chilenische Projekt BRIDGE soll zur Technologieentwicklung und Erschließung von Fluidlagerstätten in beiden Partnerländern eine binationale Forschunskooperation institutionalisiert werden. Das Ziel von BRIDGE ist es, die Expertise im Bereich Rohstoff-Extraktionstechniken aus Fluiden unterschiedlicher Reservoire beider Länder zu bündeln, zu vergleichen und damit die Innovationskraft beider Bergbausektoren zu stärken. Hierbei werden geologisch relevante Reservoire in Deutschland und Chile detailliert charakterisiert und modelliert, um einen umfassenden Einblick in deren geochemische, mineralogische, petrologische und hydraulische Eigenschaften zu erhalten, die einen direkten Einfluss auf die Gewinnung kritischer Rohstoffe haben. Parallel dazu werden neue Extraktionstechnologien für Rohstoffe wie Lithium, Kalium, Mangan, Strontium und Brom an ausgewählten Standorten untersucht und ihre Potenziale sowie standortspezifischen Herausforderungen verglichen. Neben der Bewertung der Extraktionsmethoden wird untersucht, wie technologiebedingte Einflüsse auf die Fluidchemie die Interaktion zwischen der rohstoffverarmten Sole und dem Reservoir beeinflussen. Darüber hinaus sind Studien zu den Wasser-Gesteins-Wechselwirkungen sowohl hinsichtlich mineralischer Ausfällungen (Scaling) in den Anlagen als auch möglicher physiko-chemischer Reaktionen im Reservoir für die sichere Implementierung der Extraktionssysteme von großer Bedeutung. Durch diese länderübergreifende Zusammenarbeit sollen wichtige Erkenntnisse für eine nachhaltige und effiziente Gewinnung kritischer Rohstoffe aus Fluiden gewonnen werden, die sowohl für die deutsche als auch die chilenische Industrie von erheblichem Interesse sind.

04.07 Mineralogy of Secondary Raw Materials

Metal recovery from secondary raw materials – the importance of mineralogical characterization and processing methods: Commemorative lecture on receiving the Georg Agricola Medal

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Mineral raw materials from geogenic deposits end up as waste after extraction, processing and use. However, if these wastes are regarded as anthropogenic ores, the cycle can be closed if their contents are returned to the product cycle. From the perspective of a geoscientist with knowledge of the formation of deposits and the formation of mineral phases with the corresponding concentration of valuable carriers, there are opportunities to develop efficient recycling systems in adapted technological process chains.

The interplay between the findings on the formation of natural ores and the geochemical modeling of the processes, for example, with the knowledge of thermodynamic models in metallurgy, offers the option of saving even the previously unrecoverable proportion of “spice metals”. The interplay of mineralogical characterization, mechanical processing and the further processing of concentrates in metallurgical processes can achieve what is known as the “engineering of artificial minerals”.

However, mineralogical analysis not only provides the basis for understanding the structure of the material to be processed in cases where slags are specifically influenced and processed as anthropogenic magmas, but also along the entire range of waste streams from mining tailings to electronic scrap. Liberation and sorting as well as subsequent chemical processes are based on this.

The conference contribution aims to present a small kaleidoscope of experience from around 40 years of dealing with various legacies from production and consumption.

04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

Application of renewable carbon sources in self-reducing agglomerates for sustainable metal processing in cast iron foundries

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The development and application of self-reducing agglomerates through the use of biogenic carbon carriers in the form of biochar in the melting process of an iron foundry was carried out. Biogenic residues for the production of suitable biochar through their use in pyrolysis plants as well as fine-grained residues from the production chain of a cast iron foundry were selected, on the basis of which the recipes of the subsequent agglomerates for industrial use were developed. A key aspect is the chemical composition and thermophysical properties of the residual materials.

To evaluate the metallurgical suitability of the agglomerates, systematic trials were conducted under varying process conditions. These trials focused not only on the mechanical performance and handling of the agglomerates but also on their impact on the chemical composition of both the molten cast iron and the resulting slag. Variations in raw material composition, binder type, and furnace parameters were considered to assess how the agglomerates influence the final product quality and slag characteristics. The chemical analyses of metal and slag samples taken after the melting process provide insights into the interaction of the agglomerate components during high-temperature exposure, their effect on impurity levels, and possible slag-forming tendencies. This comprehensive evaluation helps to identify suitable agglomerate formulations that ensure metallurgical compatibility and stable process conditions. The results contribute to the development of environmentally friendly, resource-efficient melting practices in foundries and support the broader goal of integrating sustainable secondary materials into industrial metallurgical processes.

08.01 Young Scientist Session

An exceptional window into Carboniferous arthropod diversity and taphonomy from the Westphalian of central Germany

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Arthropods are one of the most successful groups in continental ecosystems. Unfortunately, their fossil record is incomplete, due to the low preservation potential of their fragile exoskeletons and collection bias related to their mostly small size. This study elucidates the arthropod diversity and their fossilization pathways in the Pennsylvanian Zwickau Formation (Westphalian D, Zwickau-Oelsnitz Basin, central Germany). For 150 years, these strata have been known to yield well-preserved arachnids, myriapods and pterygote insects, including large-winged blattoids and Kreischeria wiedei, the largest known trigonotarbid. Detailed study of the embedding architectures and the fossils—involving HF maceration as well as combined transmitted-light and epifluorescence microscopic analysis—reveal an unusually diverse community that inhabited an intramontane peat-forming wetland near alluvial fans. The arthropod remains mainly occur in dm-thick distal crevasse-splay deposits. Accumulation and preservation of the arthropods was likely facilitated via rapid, (sub)autochthonous burial in water-logged overbank sediments that faced limited rhizoturbation after deposition and formed repeatedly due to the tropical, humid climate. As a result, the Zwickau strata became an extraordinary archive for delicate arthropod body fossils. Outstanding examples comprise a unique group of five phalangiotarbids. Various trigonotarbids are available in different preservation types and even reveal insights into their detailed three-dimensional cuticle morphology. HF maceration provided a considerable content of arthropod cuticle remains in the deposits, once more highlighting the significance of host rock processing and mesofossil analysis for filling the gaps in the arthropod fossil record.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Late Holocene sediment dynamics in a human-dominated fluvial landscape: The Wiesent River catchment in Bavaria, Germany

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Central European floodplains represent dynamic and sensitive socio-environmental hotspots significantly reshaped by human activity, particularly since the Early Middle Ages. This transformation fundamentally changed fluvial morphology, dynamics and sedimentary systems, raising questions about when and to what extent these landscapes can be understood as a ‘Fluvial Anthroposphere’. Our study focuses on the Wiesent River catchment in Northern Bavaria, Germany, as a case study to investigate the transition from naturally controlled to human-dominated floodplain systems.

Utilizing a multi-proxy approach including sedimentological, geophysical and chronostratigraphical analyses, we explore how direct (e.g. hydrotechnical installations) and indirect influences (e.g. catchment-wide soil erosion due to agriculture) have altered the fluvial morphology and sedimentary dynamics of the area. Detailed examination of floodplain architecture reveals thick overbank deposits and shifts in sediment dynamics that serve as proxies for anthropogenic activity. Optically stimulated luminescence (OSL) dating allowing us to link increases in sedimentation rates directly to the intensification of human activities within the catchment.

Sedimentation patterns along the Wiesent River correlate well with the Aufsess River sub-catchment (Fuchs et al. 2010, 2011). OSL ages show elevated sedimentation rates during the Migration Period (375-500 CE) and Early Middle Ages (500–1000 CE). Interestingly, while sedimentation was high, substantial human influence, like deforestation appears more prominent from the High Middle Ages on (1000 CE onwards). This temporal disconnection highlights the inherent time lag in the sediment cascade model, suggesting material eroded during the High Middle Ages may still be moving through the sediment cascade system, yet to be deposited in floodplains.

07.02 Geothermal energy — Potential and utilisation of geothermal energy resources for the heat transition

The GeoLaB 1 exploration borehole in the Odenwald Crystalline Complex: constraints for the development of the geothermal research infrastructure GeoLaB

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The 500 m deep, fully cored and logged GeoLaB1 exploration borehole was drilled in Q1/2025 into the Tromm ridge in the south-eastern Odenwald. The up to 578 m a.s.l. high Tromm ridge is a N-S-trending, morphologically distinct feature and the explored potential target for the first geothermal research underground laboratory in Germany. The granitic-monzonitic rocks are intensively faulted and fractured exhibiting predominant argillitic, minor propyllitic, alteration. Hydrotesting revealed transmissivityies and permeabilityies values common for crystalline rocks. Fault planes commonly outline normal faulting displacements, but also minor reverse faulting can be documented. At c. 410 m below surface deformation style and petrophysical properties and fracture density change significantly with the occurrence of subhorizontally foliated, partly mylonitic to ultramylonitic, granitic-granodioritic and metasedimentary rocks below the Tromm granites. We interpret these findings as a major tectonic contact between the Tromm pluton and the underlying metamorphic rocks. Regional structural data, a concave upward seismic reflector, and gravimetric data suggest a continuation of subhorizontal, possibly antiformal, metamorphic rocks of the Böllstein antiform (and/or the “Zwischenzone”) below the granites of the Tromm ridge. Further structural, geochemical, geochronological, and geophysical work will have to constrain this hypothesis.

01.06 Tectonic Systems – TSK Open Session

Variation of principial strain axis directions near first-order fault zones on the Island of Rhodes, Greece, and its importance for the interpretation of fault-slip data

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Kinematic analysis of small-scale shear faults is ubiquitously applied to infer principal strain directions in brittlely deformed terrains. Often, the directions vary greatly with position. In such cases, non-uniform principal strain directions are frequently interpreted as evidence for successive deformation phases. In the Cape Archangelos area, the pervasive coverage of multi-scale brittle faults lends itself to testing the validity of this practice. Here, kilometer-scale oblique normal faults form first-order faults regarding higher-order, meter- to decameter-scale shear faults. All faults affect Plio-Pleistocene marine strata and thus adhere to neo-tectonic deformation. This allows us to test to what extent principal strain axis orientations, inferred from the inversion of 365 higher-order shear faults, are influenced by their proximity to some 80 first-order normal faults at 14 stations. First-order normal faults form two sets, one striking NNE, the other NNW. As it is unlikely that the overall deformation regime changed during Plio-Pleistocene to Recent times, both sets formed under the same deformation regime. Based on the inversion of higher-order shear faults, principal strain axes indicate either overall N-S or E-W horizontal extension. Fault populations at each station are kinematically homogeneous. This is consistent with faulting during a single deformation regime. Moreover, half of the stations indicating approximately E-W extension are located on or close to first-order normal faults, whereas the other stations showing chiefly N-S extension are located up to hundreds of meters away from these faults. We conclude that the presence of first-order structural discontinuities can significantly influence principal strain axis directions.

04.07 Mineralogy of Secondary Raw Materials

Recovery model for the extraction of a high-grade Ti-fraction from processing residues

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Due to its high refractive index, TiO_2 is widely used in coatings and paints. Globally, two major industrial processes are used to produce pure TiO_2 from primary titanium ores. For rutile, the chloride process is applied by mixing finely ground ore with coke and chlorine at temperatures up to 1200 °C. In this process, titanium is reduced and converted to volatile $TiCl_4$, enabling the removal of impurities and production of highly pure TiO_2. However, the process also generates significant residues, mainly consisting of unreacted materials as TiO2, coke and, SiO_2 polymorphs.

To recover the TiO_2 and coke from the stream, floating by water as dense media is used to produce a concentrate of acceptable Ti grade, though large amounts of impure middlings are also generated. These fine-grained middlings are commonly used as low-value filler in concrete applications (approx. €1/t).

In this study, we present a detailed quantitative mineralogical analysis of the middlings fraction using automated mineralogy (AM), X-ray diffraction (XRD), and X-ray fluorescence (XRF). The data show a correlation between TiO_2 content, density, and particle size. Laboratory air jet sieving allowed the separation of a 63–125 µm fraction containing TiO_2 at ore-grade levels. This simple but effective method demonstrates that low-value middlings can be upgraded to a high-value Ti resource (approx. €400/t).

This study highlights how combining mineralogical characterization with basic processing techniques can significantly improve the economic value of industrial residues.

01.07 Stratigraphy in Earth System Science: methods, applications and case studies

The semichatovae Transgression (basal upper Frasnian) in Morocco

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The semichatovae Transgression marks an episode of major eustatic sea level rise in the Upper Devonian. It is commonly described by the wide spread of the index conodont Palmatolepis semichatovae and has been proposed to define the boundary between the middle and upper Frasnian substages within Frasnian conodont zone 11. The index species is known from the Moroccan Meseta (Mrirt region) but so far absent from the cratonic northern Gondwana shelf (Anti-Atlas). There, the eustatic event has been roughly recognized based on lithological and geochemical changes, which indicate a drastic turnover of low-oxygen water masses. We attempt to provide conclusive evidence for the event and associated environmental changes in a transect from the Meseta to the eastern Anti-Atlas by applying multiple methods, such as geochemical proxies for detrital input and hypoxia, stable carbon isotopes, microfacies developments, and changes of conodont assemblages. Outcrops were chosen to represent different facies types, from pelagic carbonate platform to more argillaceous intrashelf basins. The goal is to provide additional information on both the timing and duration of the event, as well as the environmental impact it had on the Gondwana margin. New detailed bio- and chemostratigraphic data shall assist the ongoing search for formal substage definition and stratotype selection.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

"Minecraft vs. Reality – Rocks, Minerals, Ores and the Use of Natural Resources": Design, implementation and evaluation of an interactive tour at the Mineralogical Museum Würzburg

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This project presents the design, implementation, and evaluation of an educational museum tour titled “Minecraft vs. Reality – Rocks, Minerals, Ores, and the Use of Natural Resources”, developed for fifth-grade students at Bavarian secondary schools.

Geoscientific topics such as rocks, minerals, and natural resources are essential for understanding sustainability but are only briefly covered in early secondary education. This tour addresses that curricular gap through science communication in an informal learning environment. By drawing on the pop culture phenomenon Minecraft, it connects digital experiences with real-world geoscience, using the game’s popularity to spark curiosity and engagement.

The tour follows a learning-at-stations format, consisting of four hands-on stations where students explore minerals, rocks, ores, and their uses through original specimens, interactive tasks, and guided comparisons with the game's representations. Gamification elements support motivation and long-term learning.

To evaluate the program’s educational effectiveness, pre- and post-questionnaires were conducted with participating school classes. The study investigates students’ prior knowledge, misconceptions, and learning gains, while addressing research questions around motivation, conceptual understanding, and the corrective potential of informal learning experiences linked to digital media.

Although originally designed for school groups, the tour is adaptable for broader audiences during public events such as a family activity day. With minor adjustments, the format holds strong potential for outreach beyond the classroom and across different age groups, positioning the museum as an accessible and engaging site of geoscience education.

04.06 Coupled Fluid-Rock Deformation: Unraveling Multiscale THMC Dynamics for Fundamental Geological Processes and Societal Challenges

Unravelling mechanisms and timescales of amphibolite-facies hydration of mafic crust

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During the collision of continental plates, the presence of fluids can be crucial for the progress and outcome of specific metamorphic mineral reactions, mass transport or tectonic deformation. These fluid-mediated processes require the pre-existence or formation of fluid pathways. In this study, we examined the underlying mechanisms and timescales of amphibolitization of mafic crust. The initially dry and nearly impermeable Kråkeneset Gabbro in the Western Gneiss Region, Norway was hydrated and transformed into an amphibolite under amphibolite-facies conditions, while the amphibolitization process was triggered by fluid infiltration through a newly opened N–S striking fracture network and allowed the fluid to pervasively infiltrate the rock. We performed a detailed mineralogical, petrophysical and thermodynamic analysis of a sample profile perpendicular to a vein, which includes sample material from the fully reacted amphibolite, the transition zone and the most pristine gabbro. Petrological data and thermodynamic modelling show that the transition from gabbro to amphibolite was accompanied by densification and related porosity formation. We observe that the progress of the amphibolitization was controlled by fluid availability and that besides the uptake of H_2O, no significant mass exchanges were necessary for this transformation, at least down to the thin-section scale. To estimate the duration of the amphibolitization we set up a reactive transport model based on local equilibrium thermodynamics, mass balance and Darcy flow, which addresses the mineralogical and petrophysical changes of the rock along the sampled profile at constant ambient amphibolite-facies P–T conditions. Furthermore, we calculated the evolution of lithium concentrations and isotopic compositions along the profile to better determine the timescales of the fluid-rock interaction. Starting from a fully dry rock, the model calculated reaction-induced porosity, permeability, and fluid pressure evolution based on the local bulk composition and the evolving mineral paragenesis. We used measured lithium data and amphibole content as fitting parameters for additional consistency and robustness of the model. This case study demonstrates how variations in crustal properties affect the rates of fluid infiltration and reaction front propagation, and that fluid–rock interactions can be efficiently maintained in near impermeable, dry and mafic crust.

01.06 Tectonic Systems – TSK Open Session

Four large earthquakes in the last 1700 years on the Motagua Fault, Guatemala

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The sinistral strike-slip Motagua Fault in Guatemala is part of the North American-Caribbean plate boundary system. A magnitude 7.5 earthquake that occurred on the fault in 1976 caused 230 km of surface rupture, up to 3 m surface offset, and the demise of ca. 23,000 people. Knowledge of earlier large earthquakes on this fault is largely lacking, hampering our understanding of the tectonic regime and the associated hazards for a largely vulnerable population. We used historical archives, aerial and satellite imagery, shallow geophysics, drone lidar surveys, and field mapping to identify a site that holds a geological record of past movements of the fault. In a paleoseismological trench at La Laguna (Sanarate), we found evidence for four surface-rupturing earthquakes. A small bend in the fault trace causes localized oblique-slip motion on the fault, leading to vertically offset strata and colluvial wedge formation in the hanging wall. Radiocarbon dating, optically stimulated luminescence, and archaeological findings of Mayan ceramics and obsidian blades show that the earthquakes occurred in the last ca. 1700 years. This implies a recurrence interval of 400-500 years along this part of the plate boundary.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Detrital zircon geochronology and provenance in the Cambro-Ordovician sedimentary succession of the COSC-2 drillhole

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The COSC-2 drilling project recovered ~2276 m of continuous core through the thin-skinned thrust system of the Caledonian Orogen in Sweden. We present a detrital zircon geochronological study of its Palaeozoic sedimentary section, which comprises a continuous Lower Cambrian(?) through Lower Ordovician(?) autochtonous to parautochtonous succession, marked by variable detritus sources along the profile.

The >350 m-thick Lower Cambrian portion was initially sourced locally from the Transcandinavian Igneous Belt, with a gradual shift toward a Sveconorwegian provenance. The upper part of the autochthonous sequence, just below the Alum Shale Formation, is marked by a flux of late Neoproterozoic-Cambrian grains. The maximum depositional age of the uppermost Lower Cambrian strata is estimated at 530.5 ± 4 million years. Despite tectonic overprint in its shaly middle part, the Alum Shale Formation remains continuous, encompassing a complete Middle Cambrian to Lower Ordovician sequence. Above, in the parautochthonous succession, detritus again reflects Sveconorwegian sources, resembling the provenance of Ordovician greywackes in the Lower Allochthon.

Comparison of detrital zircon spectra from the Lower to Middle Cambrian strata across Baltica shows a consistent influx of late Neoproterozoic-Cambrian detritus. Statistical analyses indicate that in Central Scandinavia, the likely source of this zircon population is the southern Santacrucian Arc. This flux reflects arc magmatism tied to subduction of the Mirovoi Ocean beneath Baltica.

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04.04 Hydrogen in the energy transition –white to green hydrogen and subsurface storage

Natural hydrogen emanations in northern Bavaria – soil gas surveys across three fault systems

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Natural hydrogen (H2) is increasingly discussed as a potential contributor to a future sustainable energy system. We present the results of the first comprehensive soil gas survey targeting natural hydrogen seepage in Northern Bavaria, Germany. Our study focuses on three major fault zones: the Franconian Line, the Heustreu Fault Zone and the Staffelstein Fault, and investigates their role as potential migration pathways for natural hydrogen.

From 303 soil gas measurements, we identified several hydrogen hotspots with concentrations exceeding 1000 ppm at 1 metre depth. These anomalies show spatial correlations with known fault structures and reveal a heterogeneous hydrogen distribution, suggesting that only hydraulically active fault segments serve as effective conduits. Elevated hydrogen levels at distances from mapped fault traces may indicate lateral migration within aquifers or the influence of unmapped or inclined faults.

Although we considered potential hydrogen source rocks such as serpentinites and radiogenic granites, our findings suggest that structural permeability plays a more dominant role than proximity to source rocks. Weak correlations between hydrogen and carbon dioxide, along with a strong land use effect on CO_2, confirm that CO_2 is not a reliable hydrogen proxy. Low methane concentrations and noble gas measurements support a geogenic rather than microbial hydrogen origin.

Our results demonstrate the area's considerable potential for natural hydrogen exploration and highlight the need for further research. Such research should include hydrogeological investigations, soil gas surveys and geophysical studies to better understand the extent, origin, migration pathways and flux rates of natural hydrogen in the region.

05.04 & 06.05 Biogeochemistry, geomicrobiology, and biomineralogy

Hydrogeochemical study for the evaluation of potential water sources in the community of Palo Colorado, Guanajuato

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The project seeks to generate an overview of the water resources situation in the Palo Colorado community, Mexico. This community was chosen as the study site because it is located within a mining region with a high degree of marginalization, where further studies on water assessment and supply are necessary. The region was many abandoned mining projects, where the wastes and tailings were left exposed to weatherization. The abandoned sinkholes were later floded and used as water reservoirs for domestic and agricultural uses. Preliminary analyses show that the water from two of its main dams, “La Cruz Dam” and “Chica Dam”, is contaminated with potentially toxic elements (EPTs), such as Cr, Hg and Pb above the maximum permissible limits of the drinking water normativity. Furthermore, the presence of this heavy metals has been linked to health issues within the inhabitants of the community. The objective of the study is to diagnose and evaluate water quality, and the sustainable use of water resources, through hydrogeochemical studies to understand the mechanisms that govern the liberation, mobility and fate of the PTEs in order to develope a remediation strategy or water treatment solution.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Decoding hydrothermal alteration link to epithermal vein systems: Insights from the Pb-Zn-Ag Freiberg vein district, Germany

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The Freiberg district represents a key example of a Late Paleozoic epithermal precious and base metal deposit in Europe. Despite extensive research focusing on the ore-bearing vein infill, the nature and extent of hydrothermal alteration in the surrounding wall rocks remain poorly understood. This study presents new petrographic and mineral chemical data from altered host rocks adjacent to mineralized veins across different parts of the Freiberg district. The data are supplemented by Ar-Ar geochronology of muscovite (sericite), which has been identified in both the alteration halos and as part of vein assemblages. Our results reveal a complex alteration pattern involving sericitic, chloritic, and silicic overprints associated with the epithermal mineralization. The Ar-Ar dating of the coarse-grained muscovite within veins and fine-grained sericite in altered host rocks yielded ages between 316.7±3.2 Ma and 306.8±3.1 Ma. These values are older than the previously reported Rb-Sr age of 276±16 Ma on sphalerite but align well with field-based cross-cutting relationships and recent evidence for multiple rhyolitic magmatic pulses in the area (326–297 Ma). Some samples returned anomalously old ages, likely due to excess argon. The data support a multi-stage mineralization history and demonstrate the complex interplay between regional geodynamics, felsic magmatism, and hydrothermal processes in the Erzgebirge Metallogenic province.

08.02 Building Bridges – Erfahrungen aus der geowissenschaftlichen Praxis für den Karriereweg

Die Situation auf dem Geo-Arbeitsmarkt

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Der Arbeitsmarkt für Geowissenschaftlerinnen und Geowissenschaftler unterliegt dynamischen Entwicklungen ist und ist breit gefächert. Es bestehen Möglichkeiten in verschiedenen Bereichen zu arbeiten Umwelt – Baugrund – Geoenergie / Geothermie – Rohstoffe – Wasser. Die in diesen Bereichen tätigen Arbeitgeber gehen von sehr unterschiedlichen Voraussetzungen aus und haben diverse Erwartungen an Absolventinnen und Absolventen.

Studierende müssen sich möglichst frühzeitig bewusst werden, dass einerseits ein Studium nur eingeschränkt auf das Berufsleben vorbereitet und andererseits, dass nicht alle Studierenden an den Universitäten Anstellungen finden werden: Mehr als 90% aller Absolventinnen und Absolventen werden früher oder später einen Einstieg in die Industrie, ein Ingenieurbüro oder einen anderen Bereich suchen müssen.

Der Vortrag beleuchtet in Form einer Übersicht Anforderungen, die an Berufseinsteiger gestellt werden, gibt Tipps zur Ausrichtung des Studiums und zur Vorbereitung auf das Berufsleben.

08.02 Building Bridges – Erfahrungen aus der geowissenschaftlichen Praxis für den Karriereweg

Beispiele aus der Praxis

GÜNTHER-PLÖNES, ANDREAS
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Vertreter des BDG berichten aus ihrem beruflichen Alltag und vermitteln, welche Dinge für die geowissenschaftliche Arbeit außerhalb der Universität wichtig sind und welche Fähigkeiten man mitbringen sollte. Dabei wird auch ein Fokus daraufgelegt, was im Studium üblicherweise nicht vermittelt wird und wie man sich diese Kenntnisse erarbeiten kann.

Die Vortragenden möchten demonstrieren, dass man keine Scheu vor der Arbeit in Industrie und Ingenieurbüro haben soll und dass eine solche Arbeit viel Spaß und Erfüllung bieten kann.

Es besteht die Möglichkeit zum intensiven Austausch mit den Vortragenden.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Formation of Carbonaceous Chondrites in a Jupiter-Induced Pressure Bump

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Carbonaceous chondrites (CC) are some of the most primitive meteorites in our Solar System, and their parent bodies likely formed a few Myr after the formation of the Solar System began. CC contain three major components: refractory inclusions, chondrules, and CI chondrite-like matrix. Isotopic studies reveal that the relative abundances of these components correlate with the formation time of their parent bodies. It has been proposed that variations in these abundances reflect the trapping of refractory inclusions and chondrule precursors within pressure maxima in the protoplanetary disk, likely associated with the gap created during Jupiter's formation.

In this talk, we present Monte Carlo simulations of dust evolution to test whether CC parent bodies could have formed in the outer regions of a Jupiter-induced gap. Our model tracks the transport and collisional evolution of refractory inclusions, chondrules, and matrix-like grains during the late stages of disk evolution. We demonstrate that the observed correlation between the component abundances and the accretion time of the parent body is consistently reproduced if CC formed in a common region over an extended period.

01.06 Tectonic Systems – TSK Open Session

Stylolites and mid-ocean ridges: development and similar dynamic system roughening

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Mid-Ocean Ridges (MORs) and transform faults are a significant feature of the Earth's surface that develop due to accretion of new material in an extensional regime. On a much smaller scale, stylolites are a dissolution feature in rocks that develop during compression and form distinct teeth structures. We present a comparison between the two features and argue that transform faults in MOR are similar to the sides of stylolite teeth with both features representing kinematic faults (KFs). First, we present a numerical model of stylolite and MOR growth and show that in both cases KFs nucleate and grow spontaneously. Secondly, we use Family-Vicsek scaling technique of describing fractal self-affine interfaces, which have been used for stylolites, to characterize the pattern of MOR systems. Our results show that both systems have self-affine scaling characteristics with similar scaling regimes. Both show a larger roughness exponent at small scales, a smaller exponent at the intermediate scale followed by a flattening of the system at the largest scale. For stylolites the physical forces behind the scaling are the surface energy (small scale), the elastic energy (intermediate scale) followed by the system reaching the correlation length where growth stops. For MORs the physical forces behind the scaling are not yet clear. However, the self-affine scaling shows that transform faults at MORs do have a fractal spacing, rather than a preferred spacing. Our study offers a new perspective on natural roughening phenomena on various scales and a new view on the development of MORs.

10.01 Open Topic

Inventory and chronology of mass movements in the Black Forest

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As natural hazards, landslides cause significant economic and societal damage. In the context of climate change, both frequency and intensity of extreme rainfall events as key triggers of landslide are expected to increase. Due to its high local relief and the highest elevations within the German Central Uplands, the Black Forest is repeatedly affected by landslides. In order to a better assess the likelihood and impacts of future landslides, it is crucial to identify and analyze the triggers, spatial distribution and development of paleolandslides.

However, so far there is little knowledge about the occurrence and spatial extent, not to speak of age distributions of landslides in the Black Forest. Preliminary data suggest that the current geological and hazard maps provide an incomplete and imprecise representation of landslides in the Feldberg area. This implies that many more landslides may exist across the Black Forest than previously assumed, highlighting the need for improved mapping and analysis of past events.

The research project includes a GIS-based approach combined with detailed geomorphological field mapping for the development of a landslide inventory, as well as Terrestrial Cosmogenic Nuclide Dating and Schmidt-Hammer Exposure Dating for the age determination of paleolandslides. Two study areas are selected for cluster and trigger analysis, characterized by contrasting lithological settings and varying degrees of glacial influence.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Site Amplification Analysis to Support Seismic Microzonation in Aachen, Germany: Ambient Noise Observations Complemented by Numerical Simulations

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Accurate seismic hazard assessment in urban environments requires comprehensive knowledge of near-surface geological and geotechnical conditions, which significantly influence ground motion amplification. This study presents an integrated dataset to support seismic microzonation of the city of Aachen (Germany), focused on a 5 x 5 km^2 area targeted for its critical infrastructure and potential fault zones. The investigation incorporates 450 horizontal-to-vertical spectral ratio (HVSR) measurements, six microtremor array measurements (MAMs), six electrical resistivity tomography (ERT) profiles, and 175 geotechnical boreholes. These datasets enabled the spatial characterization of the fundamental frequency (f0), the site amplification effects, and the Vs30 values. Advanced interpretation methods were applied, including Rayleigh and Love wave dispersion analysis, Rayleigh-wave ellipticity, and horizontal-to-vertical time-frequency analysis (HVTFA). Furthermore, a two-dimensional numerical model of seismic wave propagation was developed along a southwest–northeast profile to simulate peak ground acceleration (PGA), identify amplification zones, and delineate subsurface stratigraphy and active fault geometry. The integration of ambient noise-based techniques with borehole and ERT data significantly improves the resolution of geological modeling in Aachen. The results provide essential input for future ground motion scenarios and contribute to the development of reliable urban seismic response models. This multidisciplinary approach supports risk-informed planning and enhances resilience in regions characterized by moderate seismicity.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Developing a Research Data Pipeline for Integrating and Processing High-Dimensional Geoscientific Data

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Technological and computational advancements have led to a significant increase in the volume and complexity of geoscientific research data. This provides new opportunities for data-driven methods, but also poses new challenges for research data management. It is not only the increasing demands of the data that make data management more difficult; recent techniques, particularly machine learning approaches, require re-evaluating data handling practices, as these not only place higher storage demands and processing power, but also involve more extensive data processing, resulting in more intricate data workflows. To address these challenges, we present a modular pipeline framework designed to automate the key stages of the research data lifecycle (acquisition, transformation, processing and storage) of heterogeneous geomorphological and geochronological research data across disciplinary boundaries. This approach not only focuses on data storage but also provides an end-to-end data pipeline that bridges the gap between fieldwork, laboratory analysis, and scientific evaluation. By automating data workflows, the pipeline enables seamless flow of heterogeneous data from acquisition into a relational database and its subsequent transfer to an analytical database optimised for multidimensional queries. This dual-database architecture enables scalable storage, reproducible workflows, and the automation of complex analyses, including statistical and machine learning modelling. A case study in Western Romania illustrates the application of our approach in an interdisciplinary geoarchaeological project, focusing on integrating diverse, high-dimensional sedimentological datasets. Our work shows that research data pipelines can be essential in promoting reproducibility and replication in geoscience.

04.04 Hydrogen in the energy transition – white to green hydrogen and subsurface storage

Serpentinization in the Münchberg Massif: New petrological and geochemical data

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During the serpentinization process of ultramafic rocks, hydrogen is generated. Since ultramafic rocks are often buried deep within the subsurface, it is difficult to study the genesis of hydrogen by serpentinization. The Münchberg Massif in northern Bavaria is a stack of nappes, one of which contains numerous serpentinite bodies. The exposure of these serpentinite bodies at the surface at several locations offers an excellent opportunity to study the serpentinization process of ultramafic rocks.

We present new petrological and chemical data of serpentinites from two locations in the Münchberg Massif: Peterleinstein in the west and Zell in the southeast. The petrological, mineralogical and geochemical composition of the serpentinites at both locations are slightly different. Thin section analyses show different degrees of serpentinization at Peterleinstein and Zell. While rocks at Peterleinstein are almost completely serpentinized, those at Zell still show a certain amount of relic minerals. X-ray diffraction analyses reveal several serpentine minerals in both locations but in different amounts with the dominant serpentine mineral antigorite in Zell and lizardite in Peterleinstein. Major and rare earth elements indicate that the serpentinites at Peterleinstein have a protolith of depleted harzburgitic composition, whereas the serpentinites at Zell have a harzburgitic to dunitic composition. Furthermore, major and trace elements indicate that the protoliths for Peterleinstein come from an abyssal setting and the protoliths for Zell are from a subduction zone setting. Therefore, we suppose that the protoliths for both locations may have been situated at distinct locations within or close to a subduction zone.

01.02 Anthropogenic geomorphology

Tracing the Anthropogenic Fingerprint: Sedimentological and Isotopic Insights into Vienna's Floodplain Archives

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Human impact has developed into a major external forcing control on Earth’s environmental and geological processes, yet our understanding of the magnitude of its impact and evolution, particularly in (peri-)urban settings, is still limited. This study investigates the anthropogenic impact of the metropolis Vienna on its peri-urban environment in floodplain archives of the Danube River. By applying sedimentological, geochronological and chemostratigraphic methods, we aim to characterise the interplay between upstream human interventions and local river dynamics, and to identify and evaluate the geological signal of the Great Acceleration since the 1950s downstream of Vienna.

The study area is located in the National Park Donau-Auen, where minimal direct human intervention allows quantifying the human stratigraphic fingerprint and testing event-based dating using (artificial) radionuclides in an alluvial setting. Flood deposit ages were successfully determined combining radiogenic nuclide concentrations (137Cs, 239Pu, 240Pu, 237Np, 233U, 236U), field sedimentological methods, and historical records. Preliminary results reveal three distinct sedimentation periods reflecting upstream human interventions. The first phase (1870 – 1954) aligns with extensive river channelization leading to rapid erosion of mid-channel bars and backwater aggradation. The second phase (1954 – 1991) shows laterally extensive and thick sandy flood deposits from fast and undamped sediment transport through the straightened riverbed during extreme events. The final phase (1991 – 2002) is characterized by the thick, silty, and seemingly structureless flood deposits, interpreted as remobilized sediment from barrier lakes since the construction of the nearby hydro-power station Freudenau in 1997.

10.01 Open Paleontology Session

Two – most difficult to access – Devonian Fossil-Lagerstätten with normally very rare echinozoans, here excellently preserved as natural archives, one with a possible attempt to escape obrution, the other wih indications of a very special way of life.

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Both Lagerstätten were discovered many years ago and the two most unusual echinoderms in each were described: in Lagerstätte (‘archive’) I the armoured holothurian Prokrustia; in Lagerstätte (‘archive’) II the ophiocistioid Rotasaccus. Both Lagerstätten are burial (obrution) deposits. Due to the rarity of their very special echinoderms they represent important ‘natural archives’.

Natural archive I: In layers of the higher Talacasto Fm. (Lower Devonian) in the Precordillera (western Argentina) numerous obbrution Lagerstätten with diverse, very well preserved echinoderms were found, in one of them numerous specimens of the large Prokrustia which is completely skeletonised with large plates. Possibly, by new analytical methods the still unknown pharyngeal ring typical of holothurians will be detected. Special geopetal positions of Prokrustia will be will be discussed as unsuccessful attempts of escape lethal obrution.

Natural archive II: In finely laminated layers of the Wiedenest-Fm. (upper Middle Devonian of the Sauerland, eastern Rhenish Massif) there are several layers with some almost complete holothurians, but above all with thousands of jaw apparatuses (‘lanterns’ as in echinoids, but with typical, serially arranged angular teeth, "goniodonts") of Rotasaccus (a genus of the very rare echinoderm group Ophiocistioidea). As in some holothurians, its body wall of Rotasaccus is skeletonised with microscopic wheels, the wall of its very large podia with sieve plates. New ideas about the way of life of Rotasaccus are being discussed. Further important structures could possibly be visualised by using newer analytical methods on skeletons that partly are still calcitic.

10.01 Open Paleontology Session

New insights into the aquatic microfauna of the Lower Devonian Rhynie and Windyfield chert: an old ecosystem revisited

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Investigating ecosystems of the past is understandably different from studying modern-day ones. Many properties of now-gone ecosystems can only be indirectly inferred, where in modern ecosystems observations or measurements would provide a direct access (though being less easy for hardly accessible ecosystems, e.g. in the deep sea). Indirect access to fossil ecosystems is provided by the life habits of the extinct organisms that have been living in these ecosystems, such as aspects of their feeding behaviour or their life history strategies. The life habits of an extinct organism can finally be inferred by reconstructing the functional morphology, based on the morphological details observed in fossils in comparison to modern counterparts. Such investigations gain precision when exceptionally well-preserved fossils are studied, like those of the Lower Devonian Rhynie and Windyfield chert. These deposits preserve a diverse range of representatives of Euarthropoda, partly with terrestrial, partly with aquatic, non-marine lifestyle. Among aquatic forms, especially crustacean fossils have become known, such as the famous Lepidocaris rhyniensis. The preservation of the crustacean fossils provides details of their feeding apparatus down to the sub-micron-range, including different types of setal structures. Based on these observations, we can infer that crustaceans in the Rhynie and Windyfield chert performed a variety of different life habits. The biota thus contained a rich and differentiated non-marine aquatic fauna already 400 million years ago.

10.01 Open Paleontology Session

Why the evolution and fossil record of life history traits of the group Euarthropda matters in modern-day biodiversity research

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Life history traits describe aspects of the investment strategies of organisms. These traits have changed and diversified over the course of evolution, but they can also react to short-term changes of the environment. Under the current human-induced climate change, life history traits of many animals have already reacted, long before a species starts to decline or even go extinct. Changes in life history are, therefore, important early indicators for biodiversity assessments. Yet, for evaluating such changes and their significance, these need to be set in a sound frame of life history traits in an evolutionary context. Fossils can add to this reconstruction of the evolution of life history traits by adding now extinct states, including transitory ones. Yet, the challenge is assessing these traits. Even for many extant species, life history traits are only incompletely known or difficult to access entirely. For fossils, getting this access is even more challenging. Here I present examples from the group Euarthropoda (e.g. beetles, spiders, centipedes, shrimps). The advantage of using these animals for this approach is their discontinuous, pseudo-discrete growth pattern: they have to moult in order to grow, due to their non-stretchable chitin cuticle. Therefore, they offer an independent ontogenetic factor not present in other animals: stages separated by moulting. I will discuss in how far we can recognise differences in observable life history traits, such as egg size, hatching size, size at metamorphosis, in fossil and extant species, and in how far selective pressures act on these.

08.02 Building Bridges – Erfahrungen aus der geowissenschaftlichen Praxis für den Karriereweg

„Teil der Lösung sein“ – die Zukunft gestalten in den Staatlichen Geologischen Diensten Deutschlands!

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Eine Energie-, Wärme- oder Rohstoffwende braucht Gestalter:innen aus den Geowissenschaften, die Verantwortung für die Zukunft in Deutschland übernehmen. Die Staatlichen Geologischen Dienste (SGD) zählen dabei mit über 1.000 Mitarbeitenden zu den bedeutendsten Arbeitgebern für Geowissenschaftler:innen in Deutschland.

Die fachlichen Aufgaben innerhalb der SGD sind äußerst vielfältig und umfassen sowohl wissenschaftlich-fachliche (z. B. Landesaufnahme, Forschungsbohrungen, 3D-Modellierung) als auch angewandt-geologische Themen (z. B. Hydrogeologie, Geothermie, Geogefahren).

Von der Forschung bis zur spezialisierten Begutachtung sind also alle geowissenschaftlichen Fachrichtungen gefragt, sodass sowohl Generalisten als auch Spezialisten ihren Platz finden. Das breite thematische Spektrum macht die SGD zu einem einzigartigen Arbeitgeber. Der öffentliche Dienst bietet zahlreiche Vorteile, darunter Fort- und Weiterbildungsmöglichkeiten, Bezüge gemäß Tarif- oder Beamtenrecht sowie eine gute Vereinbarkeit von Beruf und Familie.

Das Recruiting und die Entwicklungsmöglichkeiten im öffentlichen Dienst folgen allerdings besonderen Regeln, die nicht immer sofort ersichtlich sind und auch entmutigend wirken können. Die verschiedenen Beamtenlaufbahnen und Modelle für Tarifbeschäftigte mögen den Eindruck einer in sich geschlossenen Welt erwecken. Der Weg zu Stellen in den SGD gestaltet sich oft schwierig, da Stellenanzeigen auf den üblichen Plattformen fehlen und die Verfahrensdauer bei der Einstellung lang ist. Um zukünftige Herausforderungen zu bewältigen, ist also eine offensive Strategie der SGD zur Gewinnung von Fachkräften erforderlich.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

3D printed models as replacement for fragile fossils in travelling exhibitions

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Display of fossils in museum exhibitions bears a great value in teaching the public about various aspects of earth history. However, fossils integrated in exhibitions face the risk of being damaged, especially through frequent handling, as for example in travelling exhibitions. In addition, when on display for years, fossils are not easily accessible for research purposes.

The recently conceptualised and implemented travelling exhibition Molassic Park deals with the fossil record from the Miocene Upper Freshwater Molasse of southern Germany and its ecological interpretations. The included mammal remains are in most cases unique with two type specimens and are very fragile. In order to avoid damage and research-restriction effects, the curator decided on replacement by 3D printed models.

Ca. 30 fossils were surface-scanned with blue-light technology using the precision 3D hand scanner Space Spider of Artec 3D. Virtual 3D models were calculated in Artec Studio 17 and 3D printed with an FDM printer. In preparation for colouration with acrylic paint, visible extruded material steps were covered with beige acrylic paint thickened with aerosil.

We found that printed 3D models are a much more gentle alternative to the objects than making traditional moulds and casts, and visitors receive a realistic impression of the fossil evidence. Hence, printed 3D models are a suitable replacement of real fossils in travelling exhibitions.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Speaking Geology Together: Tools for Pan-European Harmonised Vocabulary Creation

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The creation of a harmonised pan European geological map requires the agreement on a common lithological vocabulary. In practice, these are specific lithological concepts, ideally defined according to established and widely recognised classification schemes, represented by standardised labels.

Launched in 2022, the Geological Service for Europe (GSEU) project aims, among other objectives, to develop detailed, multilingual vocabularies for describing lithology, anthropogenic deposits, and lithotectonic units. These vocabularies are curated by international teams of GSEU members from across Europe. The challenge in creating a vocabulary suitable for harmonised mapping lies in reconciling differing classification schemes, addressing obsolete or regionally specific terms, accommodating multiple hierarchical structures, and incorporating genetically related terms, qualifiers, and compound names.

These challenges can be addressed through software applications that support visualising the hierarchical structure of the vocabulary and facilitate collaborative discussion. We present Vivity, a lightweight visualisation tool designed to plot hierarchies. It accepts Excel files as input, generates a tree diagram, and allows the user to export the plot as a PNG or SVG file. Additionally, factsheets are developed to represent each concept on an individual page. Ideally, each factsheet will be accompanied by an illustration that visually supports the concept's definition and will be made available as a printable document. To achieve this, a Python script processes Excel files by converting them into JSON format, which is then used to generate LaTeX files and, ultimately, finalised PDF documents. Furthermore, the vocabularies are being tested against real-world use cases to ensure the concepts are practically applicable.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

KOmatiite METamorphic devolatilization and METal mobilization (KOMET2): Implications for orogenic gold deposit formation

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Orogenic gold deposits are extensively studied as they account for more than 25% of the global gold supply. These deposits are found along a crustal continuum, from granulite to prehnite-pumpellyite facies rocks. The metamorphic devolatilization of metasedimentary and metavolcanic rocks at the greenschist-amphibolite facies transition is widely acknowledged as the primary source of fluids and metals for orogenic gold deposits up to amphibolite facies. At temperature above 600°C, however, this model is challenged as fluids may induce partial melting of quartz-feldspath-bearing rocks, consuming the fluids and preventing formation of deposits. Recent modelling suggests that komatiite — a significant but overlooked lithological unit in Precambrian greenstone belts — may generate auriferous metamorphic fluids up to the granulite facies and contribute to orogenic gold deposit formation.

The aims of KOMET2 are to: 1) test the metamorphic devolatilization model applied to komatiite and investigate auriferous fluid production, 2) evaluate the contribution of komatiite devolatilization to orogenic gold deposit formation.

To achieve these aims, we will investigate metakomatiites in the Southern Cross and Kalgoorlie auriferous greenstone belts in the Yilgarn craton in Western Australia. By combining the mineralogy, whole rock geochemistry and thermodynamic P-T-X models of granulite to greenschist facies metakomatiite, we will characterize the behavior of metals, metalloids and ligands (e.g., As, Au, C, Co, Cu, Mo, Ni, Pt, S, Sb, Sn, Te) during prograde metamorphism and determine if an auriferous metamorphic fluid is produced. Orogenic gold deposits will be investigated to determine the link between metakomatiite devolatilization and ore formation.

04.04 Hydrogen in the energy transition –white to green hydrogen and subsurface storage

The role of cushion gas in hydrogen storage

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The global commitment to mitigate climate change necessitates a transition of energy systems from fossil fuels to renewable sources. However, renewable energy technologies—such as wind and solar—provide intermittent supplies of clean energy. To manage this variability and minimize curtailment, storing excess energy as hydrogen presents a promising solution.

A significant portion of the capital expenditure in subsurface hydrogen storage is attributed to the need for both working gas and cushion gas. Cushion gas refers to the volume of gas that remains permanently in the reservoir to maintain the pressure required for effective withdrawal of the working gas during injection–withdrawal cycles. Similar to CO_2 storage projects—where high upfront costs have been identified as a key barrier to implementation—hydrogen storage in porous media faces substantial capital costs. In fact, cushion gas can account for over 80% of total CAPEX in these systems [(1)], highlighting the critical need to reduce this cost.

In this presentation, I will introduce three strategies to reduce the cost of cushion gas in hydrogen storage. Firstly, I will propose rethinking cushion gas not as a sunk operational cost, but as a recoverable and strategic national energy reserve—transforming it into an investment in energy security. Secondly, I will explore the use of alternative cushion gases, such as CO_2, to reduce overall storage costs. This will include a novel strategy using a case study from the Southern North Sea basin. Finally, and drawing on insights from the EMStor project [(2)], I will present a phased, cost-efficient development model. This approach begins with a moderately sized storage project, pre-designed for future expansion, thereby encouraging long-term investment.

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The UK's largest inland hydrogen cluster East Midlands Hydrogen

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Hoher Hagen-Basalt (Dransfeld bei Göttingen): Struktur und Intrusionstyp

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Der Hohe Hagen-Basalt intrudierte im mittleren Miozän in ca 70 m mächtige oligozäne Sande und Tone. Nach bisherigem öfter zitierten Modell handelt es sich um einen dreiseitig von Störungen kontrollierten "Vulkanstumpf" von ca 150 m Durchmesser und unbekannter Tiefe unter einem postulierten Vulkanbau. Mit fortschreitendem Basaltabbau zeigte sich ein anderes Bild, das jetzt dargestellt wird durch Kombination einer Diplomkartierung mit kürzlich wiedergefundenen Tachymeter-Meßtischaufnahmen, alle aus der Endphase der Basaltgewinnung 1980–84.

Die detaillierte Kartierung der räumlichen Orientierung der Basaltsäulen zusammen mit der Raumlage aufgeschlossener Basalt-Sand-Kontakte zeigt die erwartete ideale Orientierung sodaß mit ihr auch die Lage unbekannter Kontakte gut bestimmbar erscheint. Die Intrusion hat danach die Form einer in NNE-SSW-Richtung gestreckten Schüssel mit einer flachen Sohle, ca 100 x 200 m messend, die mit wenigen Grad zum Fuß des Westhanges einfällt. Dort ist im Norden der Kontakt durch das tiefste Abbauniveau nicht mehr erreicht worden. Hier kann also der Förderkanal der Lopolith-förmigen Intrusion liegen.

Plattiger, wasserreicher Basalt des Kontakts zeigt oft ellipsoidische, extrem geplättete und gelängte Blasen. Die entsprechend des X-Linears abgeschätzten Fließrichtungen sind ebenfalls gut verträglich mit einem Förderzentrum am und unter dem nördlichen Fuß des Westhanges.

Ein N-S-streichender, vermutlich störungskontrollierter Förderkanal verlangt nach einem Nachweis von Störungsbewegungen im Tertiär, der mit bisher untersuchten stratigraphischen Indikatoren uneindeutig blieb. Die regionale Bedeutung eines kartierten synmagmatischer Vertikalversatz in einer N-S-Zone am SE-Rand der Intrusion ist offen.

Mit der Definition einer Lopolith-förmigen Intrusion und einem N-S-verlaufenden Fördergang reiht sich der Hohe Hagen nun in mehrere gleichartige benachbarte mittelmiozäne Basaltintrusionen ein.

01.21 Advances in Geochronology: from tradition to avant-garde

Dating of kaolinites by EPR to unravel the evolution of Amazonian laterite profiles

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Kaolinite is a finely divided phyllosilicate which is widespread at the Earths' surface. It is formed by intense weathering of aluminous silicates such as feldspars or micas and is extremely stable at Earth's surface temperature conditions. Electron paramagnetic resonance (EPR) spectroscopy dating of kaolinite is a promising geochronological method for this clay mineral which cannot be dated by conventional radiometric [1]. Combined to (U-Th)/He dating of iron oxides and oxyhydroxides, it thereby enables deep insights into past and current surface processes and paleoclimatic evolution.

In this contribution we give an overview on the EPR method and its challenges and we present kaolinite EPR data from 28 samples deriving from two deep lateritic profiles developed throughout the Cenozoic on top of Paleoproterozoic schists of the Guiana shield. Comparison with geochronological constraints from (U-Th)/He dating on iron oxides and oxyhydroxides [2] of the same profiles allows a contextualization and a discussion of the ages, which enables a deeper insight into the evolution of the lateritic profiles.

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01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

Probing the deep central European lithosphere: *In-situ* Sr isotope analysis of a sheared garnet peridotite xenolith

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Mantle xenoliths give insights into igneous processes in the lithospheric mantle. Although spinel peridotite xenoliths from the Central European Volcanic Province have been studied extensively, the deeper central European sub-continental lithospheric mantle remains poorly understood due to the rarity of xenoliths from greater depths. Notably, the Delitzsch carbonatite complex in Germany hosts alnöite dikes (melilite-bearing ultramafic lamprophyres) that contain garnet-peridotite xenoliths [1]. To better characterise the deep lithosphere beneath central Europe, we investigated the radiogenic Sr isotope composition of a sheared garnet peridotite that was entrained from a depth of 190 km (5.9 GPa) by a Delitzsch complex alnöite [2]. We performed *in-situ* Sr isotope analyses on clinopyroxenes using a 193 nm Excimer laser ablation system coupled with a Neoma MC-ICPMS/MS. The use of SF_6 in the Neoma reaction cell enables interference-free measurement of SrF^+ ions [3]. The analysed clinopyroxenes exhibit indistinguishable initial $^{87}Sr/^{86}Sr$ of 0.7051 ±16, which largely overlaps with the host alnöite (0.704 and 0.70336) [4,5]. The results are consistent with a scenario where refertilization of the lower lithosphere due to prolonged magmatic activity along with a shift to extensional tectonics during the Cretaceous triggered the destabilization and removal of the lower 50–70 km of northern Bohemian Massif lithosphere [2].

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01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

^{182}W and ^{142}Nd anomalies in 2.7 Ga old basalts indicate long-term preservation of distinct mantle heterogeneities

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The combined short-lived ^{146}Sm–^{142}Nd and ^{182}Hf–^{182}W radiogenic isotope systems provide critical insights into early Earth differentiation and long-term preservation of mantle heterogeneities. Although Archean rocks often display resolvable ^{142}Nd and ^{182}W anomalies, these signatures diminish with time due to convective homogenization of the mantle. Proposed origins for these anomalies include early silicate-silicate or metal-silicate differentiation, and heterogeneous incorporation of late-accreted material [e.g., 1–4]. To further investigate these processes, we obtained high-precision ^{182}W isotope data for the 2.7 Ga old Theo's Flow tholeiites. We show that, in addition to the previously reported ^{142}Nd excess [5], the Theo's Flow tholeiites also have a positive ^{182}W anomaly, indicating the survival of an early-formed mantle domain for nearly 1.8 Ga. The ^{142}Nd anomaly is best attributed to silicate differentiation at ~4.4 Ga, whereas the ^{182}W signature likely reflects incomplete mixing of late-accreted materials, consistent with a 'grainy' accretion scenario. Comparison with coeval komatiites from Boston Creek, which were derived from the same mantle plume [6], highlight spatial heterogeneity in the incorporation of late-accreted material at the single plume scale. These findings support inefficient mantle mixing during the Archean and are more consistent with a stagnant-lid tectonic regime than with modern-style plate tectonics.

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06.04 Stressors in Hydrogeology: Interactions and Impacts

Urban Rivers, Hidden Signals: Feeling the Pulse of Contaminants in Bank-Filtrated Water

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Bank filtration has been applied worldwide to extract raw river water after a passage through subsurface sediments. Commonly, this water is used as drinking water after proper treatment. However, river water, especially if urban structures are part of their catchment, is prone to anthropogenic impacts possibly leading to unwanted chemical substances and compounds in water. A wide range of impacting boundary conditions, e.g., high or extreme low river water levels affect the spatio-temporal evolution of the resulting concentrations in groundwater. In order to improve the understanding in the key impacts influencing the concentration behavior in the extracted water at bank filtration sites, the following steps are applied in this study using a highly urbanized site at Düsseldorf, North-Rhine Westphalia, Germany: Firstly, conceptual models are set-up based on delineation of widely known principles at comparable sites. On the basis of these conceptual models, in a second step hypotheses are made for the spatio-temporal behavior of hydraulic and hydrochemical parameters in the groundwater for a set of scenarios often occurring in river catchments. The resulting assumptions and signals expected from the conceptual models under certain conditions were compared to field data from the water supply company Stadtwerke Düsseldorf and City of Düsseldorf and later-on analyzed using a 2D-vertical numerical model. Finally, improvements in the understanding of the processes can be achieved. Besides this, understanding will help to improve observation information quality by reducing efforts in the same time.

02.01 The Tethys Ocean – the cradle of modern tropical life

Bringing together otolith and skeleton fossil record: the case of Old-World Cyprinodontiformes

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Toothcarps (Cyprinodontiformes) are a highly diverse group of freshwater fish found worldwide. Their fossil record known until now is particularly rich in Eurasia, with few examples from Africa, and spans from the Late Eocene to the Pliocene. Although not as diverse as their extant relatives, approximately 76 fossil species have been described, of which 16 (21 %) are based on skeletons with otoliths ("ear stone") *in situ*, 24 (32 %) are skeletons only, and 35 (46 %) are based solely on otoliths. Linking skeletal with otolith-based findings can only be done in rare cases where fossils are found with otoliths *in situ* and/or when information from extant relatives is available. However, the lack of otolith knowledge from extant families and fragmented data of the fossil record has hindered the integration of skeletal and otolith-based fossil record. By gathering new morphometric, meristic and osteological data from fossil and extant species, together with a literature review, we started to investigate the skeletal and otolith-based fossil species to better understand the evolutionary and biogeographic history of toothcarps. The newly produced and compiled data suggest that the fragmentation of the Tethys Sea and the formation of its related basins (Paratethys) together with the development of various lake systems during the Oligocene and Miocene appear to have promoted the diversification and expansion of Eurasian toothcarps. Furthermore, we found some evidence that representatives of African and East Asian families, whose fossil record is very poor (apart from one family), may also have been present in Eurasia during this time.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

The “Megatambichnus” riddle: Investigating possible producers of large vertebrate burrows from the Cisuralian Bromacker locality

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Fossoriality is common among land vertebrates and offers many ecological advantages. Evidence for burrowing lifestyles dates back to the Paleozoic era, but large tetrapod burrows are rare, and their producers remain largely unknown. One of the oldest known large vertebrate burrows (up to ~70 cm wide) comes from the Cisuralian Bromacker locality in Thuringia, central Germany. Recent excavations at the Bromacker site have uncovered new material of this trace fossil, previously informally named “Megatambichnus”, including ramps, horizontal tunnels, and terminal chambers. These structures display distinct scratch traces, often in sets of five. Such features allow for a confident classification of the trace fossils as tetrapod burrows. Here, we take advantage of the unique simultaneous occurrence of trace fossils and exceptional preserved skeletons at the Bromacker locality to correlate potential producers with the “Megatambichnus” burrows. For that, we introduce a new method comparing burrow dimensions with the body sizes and proportions of fossil taxa from the same locality. In addition, we investigate the potential fossorial adaptations of the taxa that fit the burrow dimensions, based on osteological features observed in modern fossorial tetrapods. Our results show that diadectids, such as Orobates pabsti and Diadectes absitus, and caseids, such as Martensius bromackerensis, match the burrow dimensions and show skeletal traits consistent with a fossorial lifestyle, making them reliable tracemaker candidates. Further morphometric analyses of the trace fossils and skeletons, combined with biomechanical and histological approaches, will be conducted to more precisely identify the producer.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Transparency and traceability in the Site Selection Procedure – The BGE Repository Search Navigator

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The Federal Company for Radioactive Waste Disposal (Bundesgesellschaft für Endlagerung –BGE) has the task of evaluating Germany's subsurface to find the location with the best possible safety for a deep geological repository for high-level radioactive waste. In this role, and during the current phase of the Site Selection Procedure, BGE collects and interprets data from existing sources in order to identify siting regions for surface-based exploration. In this contribution, we focus on methods to create transparency of the decision process in terms of the proposed siting regions, using the "BGE Repository Search Navigator" as a newly developed web application.

In order to achieve the goal of a transparent decision process, BGE started developing the BGE Repository Search Navigator in summer 2022. The navigator is an interactive, multimedia, and browser-based application for public information. The aim of the application is to make the process of narrowing down the sub-areas, published with the sub-areas interim report in 2020, to a few best-suited siting regions visible and comprehensible. The application provides information on the status of processing, the reasons for classifying an area from unsuitable to best suitability, and the general geology. BGE will publish preliminary working statuses annually to ensure that the work progress of BGE remains transparent to the public.

01.10 The co-evolution of the Earth and life from the early Archean until today

New U-Pb zircon ages of (reworked) tuffs from the Moodies Group of the Barberton Greenstone Belt (3.22 Ga) confirm an unusually high-resolution Paleoarchean sedimentary record

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Eleven new U-Pb LA-ICP-MS zircon ages of the Moodies Group of the Barberton Greenstone Belt from tuffs, felsic lava flows, and aquatically reworked tuffaceous siltstones confirm that this up to 3.7 km thick siliciclastic unit in dominantly coastal-plain and tidal facies was deposited within only a few million years while being deformed into tight, steeply plunging folds. LA-ICP-MS dating of the Moodies Group gradually reaches its limits because [(1)] analytical uncertainty approaches the time scale of the research questions, and [(2)] xenocrystic and reworked zircons in the tuffs are commonly hydrothermally altered and subjected to multiple metamorphic events, resulting in complex populations. A diachronous onset of Moodies deposition is not discernible. The onset (ca. 3224±3 Ma) is statistically indistinguishable from the end (ca. 3217±8 Ma) of Moodies deposition. Deformation began at ca. 3221±3 Ma and had ended prior to ca. 3210±10 Ma. The large granodioritic Lomati River Intrusive laccolith is likely of Moodies ages (ca. 3220±8 Ma) and was folded while still viscoplastic. Its syndepositional character at only ca. 1 km depth below the surface is consistent with a dike stockwork, extensive hydrothermal alteration, and the eruption of the basaltic Moodies Lava. Hydrothermal silicification of Moodies sandstones in its halo preserved a large microbial lagerstätte. Moodies stratigraphy thus appears to be dominated by rapid subsidence, balanced by high depositional rates and accompanied by significant mafic to felsic magmatism. Sediment in the central BGB was mainly sourced from the erosion of intermediate to felsic volcanics in the rising Onverwacht Anticline.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Teaching Bromacker: Using research at a world-class fossil site as outdoor classroom

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The involvement of the Paleontology and “Soft-Rock” groups at the Geosciences Department in the Bromacker project provided not only an excellent opportunity to conduct research but also to prominently incorporate the topic into the departmental teaching and training mandate. The perimontane Early Permian Tambach basin in the Thuringian Forest region, hosting the Bromacker site, offered numerous advantageous features: It could be reached from Jena within an hour’s driving time; had easy access by forest roads and trails; provided quarries, numerous good outcrops, several research drill cores, an active excavation site, and a museum; could be meaningfully visualized from the thin-section- to the drone imagery-scale; had no restrictions on sampling; offered diverse geoscience topics (vertebrate, invertebrate, and trace fossil paleontology, volcanology, tectonics, geophysics, sedimentology and stratigraphy, sedimentary petrography) at various levels; and was firmly embedded within established geotourism infrastructure and ecotourism public-outreach activities. The Jena subproject was led by four FSU faculty, one postdoc, and one PhD-student of complementary expertise, all with teaching interest and prior regional and thematic experience. Our investigations combined the Tambach Basin trace fossil and invertebrate inventory with its re-studied tectonic and sedimentary record into an integrated paleoenvironmental assessment that clarified the setting of the Bromacker fossil site with respect to paleogeography, hydrology, climate, vegetation, pedology, and weathering regime. Extensive classroom teaching, lab exercises, and field trips were accompanied by ca. 21 semester projects, B.Sc.- and M.Sc.-theses and a Ph.D.-dissertation. Many teaching activities extended beyond the academic realm to special-interest groups and the general public.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

Sediment deposition dynamics in a high-altitude lake system in the northern Ecuadorian Andes

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High-altitude lakes are sensitive archives of environmental change, yet remain understudied with respect to sediment deposition dynamics. In particular, the tropical Andes of Ecuador are globally-relevant biodiversity hotspots and carbon sinks, which are highly threatened by climate change and human impacts. To learn from the past, we study the depositional history of Lake Caricocha, a high-elevation caldera lake (> 3,700 m asl) located in the Mojanda Lake region, north of Quito, Ecuador. A 72 cm-long sediment core was recovered and analyzed using a multi-proxy approach, including visual core description of the lake sediment facies, X-ray fluorescence core scanning, magnetic susceptibility, C/N and grain-size analysis. Radiocarbon dating was combined with tephra analyses to provide viable sediment accumulation rates over the last three millennia. Granulometric and geochemical data were evaluated using multivariate statistical techniques, including cluster analysis, principal component analysis, and end-member modelling analysis, to infer sediment provenance and deposition dynamics within the lake-catchment system.

The record reveals three major stratigraphic units intercalated with at least eight tephra layers and a high-energy event layer. Our analysis separates detrital sediment input from sediment input by volcanic eruptions, post-eruption reworking or catchment erosion during extreme events that activate the few existing inflows. We discuss grain-size and geochemical data as key to understand and unmix the lake-internal deposition from terrestrial erosion dynamics. This study contributes to a growing understanding of sediment dynamics in tropical high-altitude lakes, and their potential implications for local water resource management.

01.29 Environmental Hazards and Risks

Discrete Earthquake Populations and Multi-Segment Power Law Scaling: A Framework for Lithospheric Seismicity

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The Gutenberg-Richter law, relating earthquake frequency to magnitude via a power-law, remains a cornerstone of seismology. It captures the scaling of brittle failure from microfracturing to plate-boundary rupture. However, earthquake catalogs are inherently discrete, and this discreteness is often neglected in modeling and hazard estimation.

Here, we construct idealized earthquake populations as finite sets of discrete events drawn from a bounded power-law distribution, defined by upper and lower magnitude limits and a fixed total number of events. This formulation introduces a well-defined event density and direct control over seismic moment release, enabling a more physically grounded and reproducible basis for synthetic catalog generation and hazard analysis.

We extend this with a three-segment, piecewise power-law model constrained by a Bayesian prior on the largest observed earthquake. The steep upper segment, covering only Mw > 9 events, is interpreted as representing the largest possible ruptures—likely limited to subduction megathrusts. The meaning of the intermediate and lower segments remains open, potentially reflecting geometric constraints, energy saturation, or deeper tectonic structure.

Even in the absence of full physical interpretation, the segmented model offers a tighter constraint on recurrence rates, particularly for large, rare events. This has direct implications for seismic hazard modeling and estimates of maximum credible earthquake size, making the framework both conceptually and practically valuable.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

EGU Geosciences Education Field Officers – Assessment of Workshops in Germany

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The European Geosciences Union (EGU) Education Committee (EC) launched the Geoscience Education Field Officers (GEFO) programme in 2019, primarily to support geoscience education in Europe. The EGU has provided ongoing support to the programme since that time. Germany was incorporated when the programme was expanded in May 2022.

To evaluate the programme, an online evaluation form is made available to attendees at the end of each workshop. This form is designed to facilitate the collection of data on the characteristics of participants (e.g. the educational establishments they work in, their gender, their role, how many years they have been teaching, their professional position, the level of school they work in, and the subjects they teach) and their perception of the usefulness of the workshop in relation to their teaching practice.

German teachers greatly appreciate the teacher training offered by the German GEFO. The characteristics of the workshops and the results of the evaluation forms will be presented.

01.10 The co-evolution of the Earth and life from the early Archean until today

Experimental and isotopic insights into the formation of Earth's first continents

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Deciphering the formation of Earth's earliest continental crust is central to understanding its geodynamic evolution and the establishment of long-term planetary habitability. Archean Tonalite-Trondhjemite-Granodiorites (TTGs) are the preserved remnants of juvenile crust, yet the composition of their protoliths and the tectonic settings in which they formed remain debated.

This talk presents an integrated approach combining titanium (Ti) stable isotopes and trace element systematics from natural samples with high-pressure/high-temperature experiments to constrain TTG petrogenesis. Titanium isotopes are an ideal tool for tracing continental crustformation due to their sensitivity to rutile, ilmenite, amphibole, and (to a lesser extent), clinopyroxene and garnet – the main phases involved in TTG petrogenesis via partial melting of metabasalts.

We focus on Eoarchean metabasalts and TTGs from the Isua supracrustal belt (ISB) in southwest Greenland. Isua metabasalts are enriched in MgO and depleted in Al_2O_3 and TiO_2 compared to modern oceanic basalts. Partial melting experiments conducted at 1–1.8 GPa on synthetic Isua-like metabasalts demonstrate that such high-Mg, low-Al basalts are suitable protoliths capable of producing TTG-like melts.

The resulting experimental melts and mineral phases allow quantification of trace element and Ti isotopic fractionation during partial melting of hydrated mafic crust. Such data is critical for use in thermodynamic modelling of crust formation. Ti isotope data from Archean rocks combined with thermodynamic modelling supports a two-stage model for Archean crust formation: [1] generation of primitive tonalitic melts via polybaric partial melting of low TiO_2 metabasalts (~0.8–1.8 GPa), followed by; [2] fractional crystallisation to yield more evolved TTGs with heavier Ti isotopic compositions. These Ti isotope trends, combined with major and trace element proxies, are consistent with melting under variable pressure–temperature conditions, possibly within a 'proto'-subduction zone environment.

Together, these results highlight the power of combining experimental petrology with novel isotopic tracers to reconstruct early crust-forming processes and assess their implications for Earth's early geochemical evolution and planetary habitability.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Seismic site characterization of the Wiechert earthquake station in Göttingen

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The Wiechert earthquake station in Göttingen is the oldest existing seismograph station in the world, recording earthquakes continuously since 1903. In 2003, the broadband seismometer station GTTG was installed as part of the German Regional Seismic Network (GRSN) in close vicinity of the old instruments.

An analysis of the recordings of regional earthquakes showed a strong amplification of the horizontal signals around 3 Hz. This finding indicates that softer surficial layers overlie the harder seismic bedrock at the site. In order to investigate and quantify this site effect in more detail, different geophysical measurements were performed.

Using 20 three-component sensors, H/V and Rayleigh wave ellipticity curves were obtained for each single sensor. Analyzing 2.5 hours of passive seismic array data, dispersion curves for Love and Rayleigh waves were retrieved.

The Mintrop ball, a steel sphere of about 4 tons, was dropped three times from a height of about 14 m to perform an active seismic experiment. Analyzing the signals as a refraction seismic measurement, a P-wave velocity of about 700 m/s was determined for the uppermost 12 m. Analyzing the array signals of the drops by appropriate methods, dispersion and ellipticity curves were also obtained.

The active and passive dispersion curves are in good agreement. An inversion of the measured curves indicates that a strong velocity contrast at a depth of about 55 m, where the S-wave velocity increases from about 600 to almost 2000 m/s, can explain the amplification peak at 3 Hz.

05.02 Understanding (geo)materials with advanced experimental and computational methods

Build your own Micro-XRD-XRF System

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We present an in-house built micro-focus X-ray setup for diffraction and fluorescence measurements. The complete system was assembled, commissioned and tested in the course of laboratory internships and bachelor education, providing first-hand experience to students in the design, construction of an experimental analytical device and its application to a scientific problem.

At the heart of the machine is a Ag micro-focus X-ray tube with a multi-layer optic that provides a focal spot of 50 µm at a distance of 200 mm with a photon flux of 106 photons/sec at 22 keV. XRD patterns are collected on a mar345 image plate detector. XRF spectra are recorded by a Ketek Si-drift detector with 30 mm^2 active area and a digital signal processing unit. Beam intensity is monitored by a Si-PIN diode. The sample is mounted on a Huber XYZ stage with one vertical rotation and a second long translational stage perpendicular to the beam. An optical microscope allows for observation of the sample. The whole system is operated using TANGO (www.tango-controls.org) and SARDANA (www.sardana-controls.org).

The performance is presented with three examples: i) quantitative measurements of reference material ii) destruction-free analysis of an unprepared grain of Mukundpura CM2-Chondrit providing spatially resolved semi-quantitative mineralogical and chemical information; iii) *in-situ* high-pressure measurements of the unit-cell volume of a spinel by XRD up to 15 GPa using a diamond anvil cell.

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01.15 Taping records of environmental and climatic changes throughout the Quaternary

A Gibraltar speleothem record of environment and regional climate for the last 200 ka

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We present results of our Gibraltar project which intends to provide a speleothem based palaeoclimatic framework for the western Mediterranean realm over the last half-million years. Gibraltar climate is influenced by the Mediterranean Sea and the Atlantic Ocean in a boundary area between polar and subtropical air masses. Speleothem proxy records from Gibraltar provide opportunities to improve understanding of the long-term interplay of climatic features of this key location at the southern limit of tracks presently taken by the North Atlantic depressions delivering rainfall to Europe.

Here we focus on a composite record based on five speleothems: two from near present sea level in Ragged Staff Cave and three from an altitude of 255 masl in St. Michaels Cave. The composite chronology is constrained by over 260 U-Th dates and reveals a near continuous δ^{13}Ccalcite, δ^{18}Ocalcite and trace element proxy record for the last 200 ka. Extensive cave monitoring results provide a robust foundation for palaeoclimate interpretations of the proxy data. The Gibraltar δ^{18}O record shows clear imprints of Alboran Sea SST for the last 200 ka and is strikingly similar to NGRIP but with a range of variation notably more subdued than other long speleothem records like Soreq or Hulu that appear to have insolation forcing of monsoon strength as their dominant control. We interpret the Gibraltar δ^{18}O record with respect to changes in cave temperatures, ocean δ^{18}O and isotopic disequilibrium during calcite deposition. The Gibraltar δ^{13}C record is interpreted as signaling changes in vegetation and water balance.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Pleistocene glacial history of the central and northern Black Forest, south-west Germany

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Previous work points to the temporary existence of a plateau icefield and numerous cirque glaciers in the northern and central Black Forest, south-west Germany, but the chronology of glaciation remains poorly constrained. This study examines the glacial record at the transition between the central and northern Black Forest. Cirque metrics extraction for palaeoclimatic inferences was undertaken with the ACME2 (Automated Cirque Metrics Extraction) toolbox (Li et al. 2024) for the Esri ArcGIS Desktop software. The strong negative correlation between the longitude of the cirque centroid point and the minimum elevation of the cirques suggests the main supply of moist air masses from the west and orographic effects. Glacio-geomorphological mapping involved both the interpretation of derivatives of a LiDAR (light detection and ranging)-based high-resolution digital elevation model (DEM) and extensive field surveys. The mapping of moraines largely confirmed earlier work. At the same time, however, revisiting the study region resulted in the identification of a large number of moraines that have not yet been described. Due to their freshness, the ice-marginal moraines in the study region are likely of Late Pleistocene age. To test this assumption, rock samples for beryllium-10 surface exposure dating have been collected from 70 large quartz-rich sandstone boulders on moraines.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

Successful Science Communication as a Human Dimension

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In a fast-paced world overflowing with news, with brutal competition for being first, it is a challenge to get one's own messages heard. Simple language, e.g. "mountain building" instead of "orogeny", is not enough.

The question of how (geo)science should be communicated has a clear answer: on a human level! The messenger is a human being with flesh and bones, senses and emotions. The listener also is a human being. This opens up numerous options to convey scientific discoveries. The 6 Ws (Who, When, What, Where, How and Why) are helpful, but not sufficient.

To communicate scientific findings, emotional "detours" are often the best pathway into the minds and hearts of listeners. It's not just new knowledge that fascinates; rather, the underlying conditions, seemingly unimportant circumstances, are also of interest: How did it happen? What was the weather like? How was the food?

A successful example is the book "Abenteuer Wissenschaft" (Böhlau 2020), where human needs and feelings are at the center of the book. How do geologists and geographers fare in the mountains of Afghanistan or in the Karakorum? How did the men on the frigate Novara experience and survive a typhoon in the ocean on Emperor Franz Joseph's birthday on August 18, 1858?

The BLOG Wissenschaftsgeschichte(n) (www.derstandard.at) brings together more than 60 articles on various aspects of the (geo)sciences. Unexpected interdisciplinary connections, or seemingly marginal, previously unnoticed detail on human fates characterize these thoroughly researched articles. It is this human-centered approach that attracts a wide community of readers.

05.04 & 06.05 Biogeochemistry, geomicrobiology, and biomineralogy

Holocene Floodplain Sediments: From depositional processes to biogeochemical pollutant turnover

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Aquifer sediments, formed under varying depositional conditions, exhibit significant heterogeneity in their sedimentary architecture causing variability in their hydraulic and biogeochemical properties. The spatial arrangement of these properties controls the net turnover of biogeochemically reactive and environmentally relevant solutes in floodplains. However, the interlinkage between reactive and hydraulic properties is still enigmatic. This study proposes using sedimentary facies analyses to reconstruct the paleoenvironmental conditions that control the abundance and spatial distribution of aquifer materials, their potential as electron donors, and their hydraulic conductivity. The approach is applied to a Holocene aquifer in the Ammer floodplain in South-West Germany, which consists mainly of organic-rich tufa successions with varying contents of total organic carbon (TOC), peat lenses, as well as of gravel- and clay layers. The spatial extent of sedimentary features and baseline reactive properties (TOC, hydraulic conductivity) were constrained by combining sedimentological observations and bulk geochemical analyses. Based on the insights gained from the paleoenvironmental reconstruction, a facies-based virtual aquifer resembling the sedimentological makeup of the Ammer floodplain was generated and used to perform flow and transport simulations, using exposure of groundwater to TOC as proxy for reactivity. The study demonstrates that the spatial arrangement of facies and their combined biogeochemical and hydraulic properties determine over which range of times the breakthrough of nitrate is to be expected, highlighting the importance of sedimentological insights for groundwater-quality projections.

08.01 Young Scientist Session

Spatial patterns of sediment phosphorus contents and release in a deep clearwater lake undergoing rapid eutrophication

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Eutrophication symptoms are increasingly observed in remote clearwater lakes. A notable example is Lake Stechlin, a deep, endorheic lake in north-eastern Germany. Between 2010 and 2020, the total phosphorus (TP) concentration in the lake increased from ~15 to over 60 µg L^{-1}, accompanied by a gradual decline in hypolimnetic oxygen concentration. We determined TP concentrations in sediments and soluble reactive phosphorus (SRP) fluxes across the sediment water interface at 54 sites in the lake to determine spatial patterns of sediment P and release dynamics. SRP fluxes strongly increased with depth across all three basins of the lake, despite considerable variation among sites. Littoral sediments played a significant role in the overall phosphorus (P) release, with higher average SRP fluxes observed in June (1.11 mg m^2/day) compared to October (0.75 mg m^2/day). In contrast, profundal sediments showed higher release rates in October, as anticipated. Notably, about 46 % of the surface sediment area is located in water depths of less than 20 meters, underscoring the importance of littoral sediment zones. Importantly, SRP fluxes from profundal sediment depended less on absolute water depth than on the position of the sampling site relative to the oxycline, which differed greatly among lake basins. Overall, our findings point to considerable spatial variability of SRP sediment concentrations and fluxes to the water column, underscoring the importance of considering littoral sediments, which are often overlooked when assessing P release dynamics in lakes.

08.01 Young Scientist Session

Geophysical investigation of hydrological and archaeological features at travertine site Alicún de las Torres, UNESCO Global Geopark Granada, Spain

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In the framework of an Arqus Alliance student winter-school in February 2025, geophysical measurements and training was performed at the UNESCO Global Geopark of Granada, in southern Spain. A unique feature in the area are immense palaeontological and archaeological records. The latter has culminated in so far 151 identified megalitic dolmen of copper age (Chalcolithic), forming a network in the Gor river valley, a deeply incised fluvial canyon tributary to the Fardes river.

A peripherical archaeological site is located at the Balneario Alicún de las Torres, a site where travertine limestone platforms and walls have formed by the rise and cooling of deep hydrothermal waters. The calcium carbonate and magnesium sulfate precipitation leads to the formation of naturally formed several meters high aqueducts. However, the origin of these aqueducts are prehistoric ground-level ditches that were used to convey water to a supposed nearby settlement. The dolmens in this area are located nearby the aqueducts, and several geophysical methods, Georadar, Geomagnetics and Geoelectrics have been used to shed light on the hydrological conditions and possible further archaeological remains.

Here we present the first results of these surveys. Geoelectrics revealed the limits between groundwater saturated sediments and dry limestone patches parallel to an old, abandoned travertine aqueduct. Localized high conductivity of the ground may be related to vains of hydrothermal water “leaking” from the aqueduct. Georadar revealed the possible location of another dolmen of similar size and geometry. Furthermore, we show localized magnetic anomalies for discussion of future continuation of this project.

10.01 Open Topic

The fossil record of cockroach oothecae

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Today, the insect group Dictyoptera includes cockroaches, termites and praying mantises with an almost worldwide distribution. The evolutionary origin of the ingroups is still debated, but there is no doubt that cockroach-like representatives of Dictyoptera (sensu lato) or ‘roachoids’ were already abundant in the Carboniferous more than 300 million years ago.

A special feature of extant species within Dictyoptera is their ability to form a special egg case, the so-called ootheca. According to current knowledge, this characteristic was probably not shown by Carboniferous early roachoids due to the morphology of their egg-laying structures. The first direct evidence of oothecae can be found in fossils from the Cretaceous in amber and limestone. Since this time, cockroaches have developed various strategies with regard to oothecae: Some groups simply drop their oothecae after producing them or carrying them for a while (oviparity), other groups keep the oothecae in a brood pouch just before the nymphs hatch (ovoviviparity), or even longer (viviparity). However, the evolution of these strategies is largely unknown, and oothecae are surprisingly rare in the fossil record.

We present different cases of fossil oothecae in amber and limestone from the Cretaceous, Eocene and Miocene. We discuss different types of oothecae and indications for their mode of oviposition. With these new finds we can provide further information for the evolutionary reconstruction of the reproductive strategies of Dictyoptera in the deep time.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Tracing the Origin of Water in Terrestrial Planets: Insights from the Ribbeck Aubrite

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The origin of water on terrestrial planets remains one of the unresolved questions in planetary science. Meteorites have been proposed as a potential source of water to terrestrial planets. Aubrites, one of the differentiated achondrites with their mineralogical similarity to enstatite chondrites, provide crucial constraints on the early stages of planetary accretion and differentiation, particularly concerning the evolution of water. In early 2024, asteroid 2024 BX1 was recovered shortly after its fall near Ribbeck, Germany, and was subsequently classified as an aubrite based on initial mineralogical and isotopic analyses.

We conducted a detailed investigation of the Ribbeck aubrite through a comparative analysis with other aubrite, focusing on the distribution and characterization of water. We employed infrared spectroscopy to investigate the vibrational properties, bonding environments, and distribution heterogeneities of hydrogen in specimens, complemented by chemical analyses using electron probe microanalysis. The results will show that infrared imaging reveals a heterogeneous distribution of OH vibrations, and broad absorption feature between 3200 and 3800 cm^{-1} indicates that water is not structurally incorporated into the primary silicate phases. Instead, hydrogen appears to be hosted predominantly within hydrous phases associated with melt inclusions.

Through this investigation, we deciphered the vibrational mechanisms and origins of hydrous phases in aubrites. Our findings will enhance the understanding of water evolution during the early accretion and differentiation processes of terrestrial planets and provide new insights into the origin of water on Earth.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Bromacker 2020-2025 – Combining scientific excavations with science communication

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The BMBF-funded project „Opening Science – New ways of science transfer using the example of the research project “Bromacker”” involved annual scientific excavations at the Lower Permian palaeontological Lagerstätte Bromacker near Tambach-Dietharz in the Thuringian Forest. Six excavation seasons were conducted between 2020 and 2025 resulting in more than 1,500 documented finds comprising sedimentary structures, plant remains and multiple invertebrate and vertebrate trace and body fossils. Among them were new finds of partial skeletons including diadectid, synapsid, and not yet identified small vertebrate specimens.

The documentation methods were enhanced due to combining field notes, photography, tachymeter measurements and drone flights. Novel excavation techniques for the Bromacker site were tested to better preserve and collect large brittle finds, such as vertebrate burrow structures.

The main goal of the BROMACKER project is to open science and processes to the public and make current and modern research visible to a broad audience. During the summer excavations at the Bromacker Lagerstätte, the research process was made accessible to the public through guided tours, on-site information areas, and active engagement by the excavation team. Media representatives were invited, and formats like family programs and social media outreach helped turn a hidden scientific undertaking into a shared experience, attracting over 2,300 visitors during 4 weeks in 2024 alone.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Paleoseismology in Germany and Adjacent Regions – Updating and Improving the PalSeisDB v2.0

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We present a comprehensive update and improvement to the Paleoseismic Database of Germany and Adjacent Regions (PalSeisDB v2.0), compiling a broad range of paleoseismic records for Germany and surrounding parts of Central Europe. It compiles previously published and partly unpublished findings of paleoseismic evidence, complementing the short timespan covered by the region's historical and instrumental earthquake catalog. Such limited coverage does not reflect the long seismic cycles characteristic of Central Europe. Hence, PalSeisDB was developed to document paleoseismic evidence, including data from trenches, soft-sediment deformation, and mass movements, thereby extending the earthquake record into pre-historic times documenting seismicity. This forms a key element for seismic hazard assessments. The first version of PalSeisDB provided evidence for multiple events in various locations within the region. Newly acquired information has now been integrated, revealing a broader distribution of paleoseismic features. We suspect that a considerable amount of evidence has not yet been discovered in detail, especially to characterize fault systems, which are often showing temporal and spatial clustering seismicity. In the updated version, paleoearthquakes have been evaluated and assigned to potential seismogenic sources, indicating seismic activity over geological timescales. The considerable increase in documented paleoseismic observations underlines the scientific importance of comprehending this study. Further developments for PalSeisDB include improving data structure, integrating historical seismic events with environmental earthquake effects, and implementing a public, web-based map interface. This updated resource aims to support ongoing research and facilitate collaboration among the geoscientific community, ultimately enhancing our understanding of seismic hazards in Central Europe.

03.08 Earth Surface Systems and tipping elements in a changing climate

Denudation, erosion and weathering rates from meteoric cosmogenic nuclides in the basaltic volcanic field of the Vogelsberg, Germany

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Accurate projections of climate tipping points require quantitative constraints on the nature and strength of feedbacks within the Earth's surface carbon cycle. Among these, silicate weathering constitutes a key negative feedback by consuming atmospheric CO_2 through mineral dissolution. However, the feedback's climatic sensitivity, expressed by the dependence of weathering rate on climate, remains poorly quantified. Basalt weathering plays an outstanding role in this process, due to basalt's high abundance of CO_2-sequestering elements. For instance, increased basalt weathering fluxes may have caused global Cenozoic cooling. Determining weathering rates is key to this quantification. However, the quartz-free nature of basalt precludes the use of common *in-situ* cosmogenic nuclide approaches. We thus use the ^{10}Bemeteoric/^{9}Be cosmogenic nuclide method that has emerged as a powerful tool to simultaneously capture both physical erosion and chemical weathering in basaltic landscapes over millennial timescales.

We applied the ^{10}Bemeteoric/^{9}Be method to determine catchment-averaged denudation rates on river bedload and river waters, and local soil weathering rates on weathering profiles in the Vogelsberg (Germany). Denudation rates are consistent (~50 t km^{-2} yr^{-1} in rivers, ~40 t km^{-2} yr^{-1} in soils) and align with rates from other temperate basaltic regions. Weathering rates and intensities are high compared to other lithologies, which underlines the high reactivity of basalt. This first application of the method in basalt demonstrates its ability to simultaneously quantify denudation and weathering from multiple sample types. Extending this approach to other climates will help establish a baseline for detecting nonlinear or tipping responses in Earth's surface carbon cycle.

02.01 The Tethys Ocean – the cradle of modern tropical life

Palaeobiogeographic implications in the co-fauna of the World's Largest Ammonite Parapuzosia (P.) seppenradensis (Landois, 1895)

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The world's largest ammonite, Parapuzosia (P.) seppenradensis (Landois, 1895), has fascinated the world ever since the discovery in 1895 of a specimen measuring 1.74 metres (m) in diameter near Seppenrade in Westfalia, Germany. Its co-fauna was describedin detail The species was also found in sections in Mexico and southern England. The high-resolution integrated stratigraphy allows for precise trans-Atlantic correlation of these occurrences, and the Tepeyac section in Mexico has become Associated Stratotype Section and Point for the base of the Campanian (Gale et al. 2023). It yields giant ammonites in original deposition context (Ifrim et al., 2021) together with a rich macrofossil assemblage (Ifrim and Stinnesbeck, 2021) which is correlated to other parts of the world by ammonoid and inoceramid stratigraphy and the stable carbon isotope curve. The ammonoids in the co-fauna of P.(P.) seppenradensis in Germany and Mexico show common and endemic species. They allow for the interpretation of partially unexpected paleobiogeographic relations.

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09.02 Museen als Fenster in der Forschung

The digital museum guide in the Jura-Museum: many-level insight into geoscience

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The Jura-Museum is housed in the Willibalds Castle high above Eichstätt. It housed famous fossils like the Juravenator and the Eichstätt specimen of Archaeopteryx. Monument protection for the renaissance castle, the construction phase Jura-Museum and even the interior inhibit major changes in the permanent exposition. A digital museum guide was therefore developed together with a local company. It is browser-based and like that independent of system software. It can be used with the visitors smart phone or with loan tablets provided by the museum. The visitors are guided digitally to specific exponates by the guide and there provided background information at many levels. Introductory texts are accomplished by visualization, learning games, background inforamtion and videos in a way that invites the visitors to visually explore the exponate further. In the system, existing content can be implemented from publication platforms upon the right of re-use, or own content can be included, e.g. videos from the research excavation of the museum. In addition, it allows to lower barriers for people with special needs like zooming in content, having read the texts and image descriptions. The digital museum guide is a modern accomplishment of the rather classical exposition at the Jura-Museum. It allows the transfer of knowledge including ongoing research to a broad variety of visitors with timely educational approaches

01.26 Alpine-Zagros-Himalayan Orogenic System: Case Studies

Linking Structural Restoration and Thermochronology to Decode the Deformation and Exhumation History in the Western Kohat Fold and Thrust Belt, Pakistan

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This research focuses on the northwestern segment of the Himalayan foreland belt in Pakistan, the Kohat Fold and Thrust Belt (KFTB), where the style and sequence of deformation since the Miocene differ significantly from the rest of the Himalayas (Robinson et al., 2023; Ghani et al., 2018). Sequentially restored balanced cross-sections, integrated with apatite (U-Th-Sm)/He (AHe) thermochronology, are employed to jointly interpret the deformation history and exhumation pattern in the study region. The preliminary results show that the resetting age of AHe is late Miocene-Pliocene and Pleistocene in the northern and central KFTB respectively, while they are partially reset in the Khisor Ranges the western part of the Range front. In the Surghar Ranges (the central part of the Range front) the ages appear as reset in early Miocene time which is older than the previously reported AHe age (Ghani et al., 2021).

These patterns suggest out-of-sequence deformation and high exhumation in the northern and northwestern KFTB. The variation in low-temperature thermochronological ages along strike in the central KFTB is likely due to salt-tectonics activity in the eastern Kohat and limited toward the western KFTB. The age constraints in the Range front (from Salt Ranges to Khisor Ranges) suggest shallow burial in the east and west and deep burial in the northern segment of the range front (along the Surghar Thrust).

The ongoing apatite fission track thermochronology will provide additional constraints on the spatio-temporal evolution of the region

09.02 Museen als Fenster in der Forschung

MUSEUM MEETS SCIENCE: UNESCO World Heritage Upper Harz Water Management System – Landscape Change and Energy Use in the Harz in the context of the Anthropocene Discourse

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The dialogue between science and cultural institutions is becoming increasingly important in addressing environmental issues, such as landscape degradation, climate change, and energy use. In this context, the transdisciplinary LEHA-project "UNESCO World Heritage Upper Harz Water Management System: Landscape Change and Energy Use in the Harz in the Anthropocene – A Journey of Water from the Past into the Future" was carried out in collaboration between the Samson-Mining- Museum and the University of Göttingen.

In the Early Modern Period, the Upper Harz water management system represented the most significant energy supply system for mining world-wide. This research project aimed to present the energy system through selected exhibition objects in a media station, offering a novel interpretation in the light of the Anthropocene discourse. Focusing on the Sankt Andreasberg Mining District, the study explored the anthropogenic transformations of the landscape caused by mining activities. An interdisciplinary approach was employed, combining historical archives, 3D structure-from-motion photography, fieldwork, and a didactic framework rooted in the Sustainable Development Goals.

The project highlights both the sophisticated functionality and the historical development of this water-powered energy system, exploring its spatial and temporal dimensions above and below ground. At the same time, it situates the energy system within the broader context of Earth’s natural landscape evolution and the anthropogenic transformation considering social, cultural, political, and economic dimensions. It examines the local-to-global interconnections that link past environmental transformations with future sustainability challenges at an authentic place, the Samson Mine, where regenerative energy is still produced today.

01.02 Anthropogenic geomorphology

Mining Landscapes in Mountain Regions: The St. Andreasberg Mining District (Harz Mountains, Northern Germany) from an Anthropogeomorphological Perspective

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Human mining activities have been reshaping landscapes for millennia, but their pace and scale have accelerated substantially on a global level. As a result, mining has become a key indicator in the Anthropocene discourse. Moreover, increasingly complex landforms, shaped by both natural and anthropogenic forces, are emerging, resulting in hybrid landforms that necessitate a reevaluation of traditional geomorphological approaches. The study focuses on mining landscapes in mountain regions, which are under growing pressure due to increasing resource demands. Understanding past landscape development is crucial for addressing current and future socio-environmental challenges.

In this context, the Harz Mountains were selected as study area, as they represent one of the oldest and most significant historical mining regions in Central Europe. Using a multi-proxy environmental-historical approach, the study investigates when, how, and to what extent human activity has modified the relief landscape with a case study from the St. Andreasberg Mining District in the Oder and Sieber Valleys. An interdisciplinary conceptual approach was developed to address hybrid landform assemblages considering geological-geomorphological aspects in the light of the socio-cultural setting. The approach outlines the spatio-temporal interconnections between mining and its associated energy systems, the historical water management and charcoal production, and considers aspects such as the emergence of the global metal trade, economic and political systems as well as knowledge networks during the Early Modern Period. The study is part of the LEHA-project „UNESCO World Heritage Upper Harz Water Management: Landscape Change and Energy Use in the Harz in the Anthropocene“ financed by zukunft.niedersachsen.

01.06 Tectonic Systems – TSK Open Session

Unravelling the basin history of the northern Upper Rhine Graben using 3-D retro-deformation

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The Upper Rhine Graben (URG) represents a tectonically-complex section of the European Cenozoic rift system that crosses the European continent from N to S. However, the basin history remains unclear due to the heterogeneous development of subsidence rates together with phases of uplift and intricate changes of the local stress field.

This study represents an approach to unravel the basin evolution by retro-deforming a 3D geological dataset derived from interpretation of a 3-D seismic survey. The model covers an approximately 10 km x 30 km wide area between Darmstadt and Worms, in the northern part of the URG. The data were acquired for hydrocarbon exploration purposes and comprise 12 faults (mostly striking N-S and dipping with 55°E) and 9 seismic horizons, the latter range from the Base Iffezheim Formation (5 Ma) down to the Top of the crystalline basement. By backstripping and decompacting each horizon along complex fault patterns, we

Examine the effect of retro-deformation on fault plane geometry based on Allan maps,

Quantify subsidence rates across the study area derived from thickness changes

Understand the tectonic history and fault activity through analysis of the 3D retro-deformation.

Additionally, we attempt to estimate the potential reactivation of major faults using slip- and dilation tendency analysis. The results give first insights to the basin development of the northern Upper Rhine Graben, on which future studies can be built.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

From Fishpond to Farmland – The Transformation of Lake Lorsch

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As part of the project “The River Weschnitz Fluvioscape and its Interaction with the Lorsch Abbey”, a focal point is an artificial fish pond situated within the natural floodplain, used from 1474–1718/20. Located south of Lorsch in the present-day Hessian Ried, the pond—known as Lake Lorsch—is notable not only for its size, nearly four square kilometers, but also for the minimal construction required for its creation and maintenance. As Henselowsky et al. (2025) demonstrate, favorable environmental conditions—a high groundwater table, sedimentological sealing, and a location below the receiving water body, the River Weschnitz—enabled the project with little structural intervention.

Later anthropogenic modifications—particularly post-use terraforming—have obscured original features such as inflow and outflow channels, hatching ponds, and bank reinforcements. The initial phase of this study therefore focuses on identifying and isolating these later impacts, especially dense drainage networks and current turf and agricultural use, to better reconstruct the late medieval fluvial landscape.

Geophysical methods (ERT, EMI and core analysis) have confirmed the presence of structures derived from historical cartography and archival documentation. Nonetheless, sedimentological evidence is limited: lacustrine horizons are absent, phosphorus levels only slightly elevated, and fine-grained fluvial deposits minimal. This reflects the lake’s unique operational history; archival records show it was periodically and deliberately drained, sometimes remaining dry for months or years. While intended to boost nutrient availability and fish productivity, this practice prevented the long term development of lacustrine soils and stratigraphy in general.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Raman investigations of suspected airburst glasses from the Atacama Desert: Evidence for natural chemical vapour deposition of MoS2

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Airbursts of extraterrestrial projectiles likely occurred frequently throughout the geological past but are rarely available in the geological record to study. Interestingly, natural glasses from Pica in northern Chile (Pica glass) possibly formed during a natural airburst event [1] and could be samples to study such an airburst. The origin of Pica glass, however, is controversial, with pyrometamorphic processes also proposed for their formation [2]. To shed light on the geological origin of Pica glass, we analysed its atomic structure and dynamics using Raman spectroscopy. Raman measurements were performed on thin sections of Pica glass samples, targeting both the glass matrix and crystalline inclusions. The Raman scattering collected from the matrix resembles that of an amorphous SiO_4 network containing significant amounts of broken Si-O-Si linkages, likely caused by alkali and/or alkali earth elements acting as network modifiers. Furthermore, distinct peak pairs at ~383/407 cm^{-1} and ~385/406 cm^{-1} were identified, corresponding to multilayer and bilayer molybdenum disulfide (MoS2), respectively. These MoS_2 nanostructures are known from chemical vapour deposition experiments in which volatile MoO_3 reacts with S_2 gas [3]. The MoS_2 structures in Pica glasses are therefore interpreted to have formed by condensation of MoS_2 onto Pica glass melts – resembling deposition in a vapour plume. Preliminary EMP data show correlated, heterogeneous Mo and S concentrations in the glass matrix. Our results support the hypothesis that Pica glass formed by an atmospheric airburst event.

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Plenary Lecture: Anne Jantschke "Living Minerals: How Microalgae Build Carbonates and Adapt to a Changing Environment"

Living Minerals: How Microalgae Build Carbonates and Adapt to a Changing Environment

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For decades, scientists have been fascinated by how the tiniest organisms construct the most intricately ornamented biomaterials. Biomineralization – the formation of inorganic structures by living organisms – is interesting not only because of its biological control and sophisticated biochemistry, but also because it is essential to advance our understanding of geochemical cycling of elements, climate change and reconstruction, and offers a huge potential for developing sustainable materials.

While diatoms and coccolithophores have long served as models in microalgal biomineralization research, the mechanisms underlying mineral formation in calcareous dinoflagellates remain largely unexplored. Our research addresses this knowledge gap by establishing calcareous dinoflagellates as a model system for extracellular calcite morphogenesis. We recently proposed a novel biomineralization model involving an intracellular MgCaP-rich amorphous precursor phase, which offers new insights into biomineral construction in these organisms.

To unravel the interplay between organic and inorganic components, we combine advanced microscopy (e.g., cryo-EM), spectroscopy (e.g., solid-state NMR, Raman imaging), and molecular biology approaches (e.g., transcriptomics/genomics). This integrative strategy allows us to probe biomineralization processes in their native state and link molecular mechanisms to larger-scale mineral architectures and material properties. By bridging cellular processes with environmental and materials science perspectives, our goal is to advance both the understanding of biomineralization under changing environmental conditions and its translation into innovative bio-inspired technologies.

01.02 Anthropogenic geomorphology

Quantifying human impact during industrialisation on the evolutionary trajectory of Vosgian streams (NE France): the value of documentary archives

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Since the Industrial Revolution, European rivers have faced increasing anthropogenic pressure through channelisation, rectification, and the construction of dams and weirs. The Vosges Mountains (NE France), a densely populated low-mountain range, exemplify this anthropisation, with approximately 5,000 hydraulic structures (HS), primarily levees and weirs, built across its main streams. Unlike major rivers like the Rhine, the edification periods of HS in smaller catchments remains largely unknown yet, hindering the reconstruction of environmental and human impact timelines.

This study investigates the spatio-temporal development of anthropogenic influence on three major streams in the southern Vosges—Fecht, Vologne, and Moselotte—focusing on morphodynamic changes since the late 18th century. We used extensive archival resources from the “Ponts et Chaussées” administration, including construction requests, plans, and reports from the 18th to 20th centuries. We first mapped existing HS to create an updated database, then dated their construction and, in some cases, deconstruction. We also reconstructed the diachronic evolution of the channel pattern, using an 1866 topographic map and orthophotos from 1951 and 2018.

Our analysis provides a first quantification of human influence, revealing that 12 % (Fecht), 31 % (Moselotte), and 56 % (Vologne) of current weirs could be dated—mostly to the mid-19th century. We also identified a strong correlation between HS construction and channel simplification. Despite archival limitations (e.g., loss or unavailability of documents), this study demonstrates the value of historical records in understanding long-term human impacts on river systems, offering insights that usefully complement field observations and investigations.

01.11 Micropalaeontology – Advancements and Perspectives in Multiproxy Studies

The Role of Applied Micropaleontology in Integrating Geological and Geophysical Data for the Exploration and Development of South Caspian Oil and Gas Fields

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The South Caspian is one of the largest oil and gas-producing regions in the Caspian Sea, containing most offshore fields and major prospective reserves of Azerbaijan, Turkmenistan, and Iran. Effective development and exploration of these resources require a detailed understanding of Quaternary sea bottom sediments—their composition, microfauna, stratigraphy, thickness, and physical properties. This is essential not only for improving geological exploration efficiency and safety but also for solving engineering and geological challenges associated with field development.

This study presents results from a comprehensive analysis of data obtained from offshore wells in the South Caspian. We integrated geological and geophysical datasets, including seismic surveys, lithological descriptions, and paleontological studies.

Our findings are of practical importance for addressing geological and geoengineering tasks in the region, which are complicated by features such as mud volcanoes and active sedimentary dynamics. By analyzing the upper sedimentary layers, we gained critical insights into the geological structure, sedimentary architecture, and dynamic processes shaping the region’s offshore fields.

The research underscores the value of applied micropaleontology in synthesizing diverse data to develop a detailed understanding of subsurface conditions. This approach enhances exploration strategies and supports the safe and efficient development of offshore oil and gas fields in the Caspian Basin.

01.05 From mantle to crust: following melt evolution from source through the lithosphere

Boron isotopic signature of obducted mantle rocks at Indian-Eurasian convergent plate margin

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The Indus Suture Zone (ISZ) in north western Himalayas is major tectonic suture dividing the Indian plate from Kohistan Island Arc (KIA) and Eurasian plates. It coincides with the subduction zone where the Tethys oceanic lithosphere subducted beneath KIA and Eurasia causing the obduction of several bodies of Tethyan upper mantle along ISZ, two prominent among them are Jijal Complex and Sapat Complex. Mantle peridotites of these complexes individually lie at a distance of ~ 80 km and consist of harzburgites, pyroxenites, dunites and serpentinites.

In order to understand the effects of subduction and fluid rock interaction we measured the boron isotopic signatures of Jijal and Sapat mantle rocks through LA-ICPMS at FIERCE. Whole rock $\delta^{11}B$ was analyzed on nano-powder pressed pellets and mineral δ11B of olivine and pyroxene were obtained *in-situ* on polished thin sections. The whole rock $\delta^{11}B$ of Jijal ultramafics ranges from -4.32 to 6.43 ‰ with average $\delta^{11}B$ of 0.36 ‰. On the contrary, the Sapat ultramafics show higher average $\delta^{11}B$ of 2.80 ‰ and range of -0.13 ‰ to 7.66 ‰. The results from both mantle sections are significantly higher than the depleted mantle $\delta^{11}B$ value of -7.1 ‰. The difference between boron isotopic signature of Jijal and Sapat complex suggests forearc position of the later and potentially different magma compositions. The overall higher values of both mantle bodies indicate towards a more enriched mantle component or the influence of slab derived fluids from subducted serpentinites.

01.06 Tectonic Systems – TSK Open Session

Detrital and metamorphic record of the Lebnitsa metasediment, Ograzhden Unit, Serbo-Macedonian Massif, SW Bulgaria

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The Serbo-Macedonian Massif consists of high-grade orthogneisses with lenses of amphibolites, eclogites, and paragneisses derived from Gondwana-affiliated protoliths. In the Ograzhden Unit, amphibolite-facies paragneisses represent a diverging sedimentary succession based on their detrital ages (Peytcheva et al., 2015, Geol. Balcanica 44, 51–84). Near the village of Lebnitsa, a metasediment succession occurs that is different from these paragneisses in composition and local preservation of cross-bedding. The metasediment comprises quartzite and mica-Al_2SiO_5-garnet-rich layers. These observations suggest a mature fluvial sediment protolith.

We analysed zircons to characterize the detrital age component and origin of the Lebnitsa metasediment. The zircon population indicates various age clusters, with major peaks at 530 Ma and 450 Ma. The Struma Diorite and Frolosh Formations could have been the source for the former peak (516–579 Ma, Zagorchev et al., 2011, Bulg. Geol. Soc. “Geosciences 2011”), whereas the 450 Ma cluster is representative of the post-Cadomian orthometamorphic basement (440–480 Ma) of the Ograzhden Unit (Peytcheva et al., 2015, Geol. Balcanica 44, 51–84). Unlike most of the Ograzhden paragneisses, no peaks younger than 425 Ma are present. The metamorphic assemblage and Quartz-in-Garnet Raman elastic barometry of the Lebnitsa metasediment suggest amphibolite-facies metamorphism. The tectonic foliation and lineation correspond to the ones observed in the surrounding basement, suggesting common tectonic history.

Based on the newly obtained data, we propose that the Lebnitsa metasediment represents a monocyclic cover deposited on the Ograzhden basement in post-Cadomian times and metamorphosed at the amphibolite facies conditions during the Alpine orogeny together with the surrounding basement.

01.06 Tectonic Systems – TSK Open Session

Alpine deformation of the Ograzhden basement, Serbo-Macedonian Massif

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The Ograzhden Unit, a part of the Serbo-Macedonian Massif (SMM), comprises a suite of ortho- and paragneisses with lenses of amphibolites, intruded by the Triassic Igralishte granite (Peytcheva et al., 2009, Geol. Balcanica 38, 5–14). The orthometamorphic suite, representing the bulk of the basement, consists of different migmatized granites to granodiorites and unmigmatized granites with ages from 440 to 480 Ma. Amphibolites have slightly younger ages of 430–440 Ma (Peytcheva et al., 2015, Geol. Balcanica 44, 51–84). An eclogite lens locally preserved in the amphibolites was reported to be recording a Variscan ultra-high pressure metamorphic event (Trapp et al., 2021, Terra Nova 33, 174–183).

Although Alpine Cretaceous amphibolite-facies imprint was reported from the Vertiskos unit in the Greek part of the SMM (Kilias et al., 1999, Int. J. Earth Sci. 88, 513–531), the Ograzhden Unit is considered to be largely unaffected by it (Kounov & Gerdjikov, 2024, Geol. Balcanica 53, 29–85). However, new data suggest that also the Ograzhden Unit, including the Igralishte pluton, was deformed under upper greenschist- to lower amphibolite-facies conditions. We present new data for the age of the Nikudin pluton (445 Ma), previously assumed to be of Triassic age like the Igralishte pluton. Both plutons record similar deformation patterns, and both plutons as well as their host rocks record top-to-SE shearing. Thus, we suggest a ductile Alpine deformation with top-to-E thrusting (rotated by later extension to top-to-SE), probably associated with thrusting of the Circum-Rhodope Belt onto the European margin in the Late Jurassic to Early Cretaceous.

08.01 Young Scientist Session

Bridging worlds: Taphonomy and paleobiogeographic significance of Late Neogene vertebrate assemblages from southeastern Costa Rica

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The formation of the Isthmus of Panama during the Late Pliocene was a pivotal event in shaping continental biodiversity in the Americas. However, our understanding of the resulting Great American Biotic Interchange (GABI) relies heavily on fossil assemblages from Central America, which remain poorly constrained in terms of composition, depositional context and geological age. This study investigates the host strata, taphonomy and paleoecological significance of vertebrate faunas from Pedro Creek near Santa Rita de Limoncito, southeastern Costa Rica, based on ongoing excavations, high-resolution sedimentological profiling, taphonomic assessment, and geochronological analyses. Most vertebrate remains in this locality occur in two thick, massive intraclast conglomerates interbedded with sandstones and mudrocks of the marginal-marine San Gerardo unit (Upper Miocene). The taphocoenoses are poorly sorted, comprising isolated, disarticulated or fragmentary, relatively unweathered fossils. Based on the Voorhies classification for alluvial vertebrate assemblages, most fossils correspond to Group 1 – bones that are most easily transported. A comparative sample of reworked fossils from the streambed reflects 95 % Group 1 and 5 % Group 2, indicating progressive hydraulic winnowing. The assemblages include elasmobranch teeth, crocodyliforms and testudines remains (jaw fragments and dermal plates), and a mixture of North American (camels, horses including Equus, gomphotherids) and South American taxa (giant armadillos like Scirrotherium, ground sloths). These findings indicate that the terrestrial vertebrate fossils from Santa Rita de Limoncito are allochthonous elements in fan-delta deposits and provide evidence of faunal exchange across Central America prior to full emergence of the isthmian land bridge.

05.01 Spectroscopic methods in modern geosciences

Inversely Zoned Chondrules: Clues to Early Solar System Formation

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Chondrules are among the oldest solid components of our solar system and provide important clues to its early development. Especially inversely zoned chondrules (IZ chondrules) have been little studied so far and could provide new insights into the formation processes of the solar nebula. In this study, we make additionally analyse to the chemical and structural composition of IZ chondrules using optical microscopy, scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX), backscattered electron imaging (BSE), electron backscatter diffraction (EBSD) and Raman spectroscopy. Our investigations show that IZ chondrules have a core of Mg-rich pyroxene surrounded by an olivine rim. The high Fe content of the olivines (Fa 39–41 %), which is significantly higher than that of other chondrites, is remarkable. The core consists of radially arranged pyroxene crystals, with Mg-rich olivines (Fa34) occasionally occurring in the interior. The textural and chemical zoning indicates that these chondrules were formed in the earliest stages of the solar system and differ from classical chondrules. The formation of the pyroxene core is probably due to a rapid cooling of the protoplanetary nebula (500-2500 K/h). This was followed by a reheating to 1600–1800 K, which formed the olivine mantle. Another possibility was a subtle change in the composition of the chondrule, which may cause a shift in the liquidus phases from low ca pyroxene to iron-containing olivine. These results provide new insights into the diversity of chondrule formation processes and contribute to a better understanding of the early evolution of our solar system.

03.02 Subsurface Storage of CO_2 – Applied Geoscientific Aspects

Evaluation of possible CO_2 reservoirs in Baden-Württemberg in light of the largest industrial emitters

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Baden-Württemberg, as one of the most important industrial states in Germany, has a high volume of unavoidable CO_2 emissions. These emissions may originate from the production of cement clinker, paper, and glass, as well as from waste incineration or agricultural activities. To maintain the current level of industrial performance while meeting the climate goals of the European Union and Germany, Carbon Capture and Storage (CCS) could be implemented. Baden-Württemberg has the potential to store CO_2 underground, and in several cases, large-scale emitters could be directly connected to CCS facilities, avoiding the costs and energy required to transport CO_2 to the North Sea. Our study integrates the geological characterization of potential CO_2 reservoirs in Baden-Württemberg, with particular emphasis on sealing rock formations with an assessment of the available and future pipeline network that links the largest emitters to the nearest reservoirs within the state.

03.02 Subsurface Storage of CO_2 – Applied Geoscientific Aspects

Sealing integrity and heterogeneity of possible seals and casing cements from Germany in context of CO_2 storage: effects of confining stress and time on permeability

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Carbon Capture and Storage (CCS) is increasingly utilized to achieve climate goals by reducing atmospheric carbon dioxide (CO_2) levels. The long-term security of CO_2 sequestration depends on the integrity of both the reservoir and the overlying sealing units. While reservoir properties have been well studied, the transmissive properties of multi-barrier sealing systems remain less well understood and heterogeneity is rarely captured. This study investigates the sealing properties of low-permeability lithologies and well-cement, a critical factor in assessing storage site integrity. Helium was used as the primary permeant for all samples, with CO_2 additionally tested on selected samples to evaluate permeant-specific effects. Klinkenberg-corrected permeability evolution was assessed under increasing and decreasing confining pressures, considering mineralogical influences. The pressure sensitivity coefficient (γ-values) was determined to quantify permeability changes at different confining stresses. To evaluate the time required for permeability stabilization under representative *in-situ* stress conditions, samples were subjected to 30 MPa confining pressure, corresponding to effective stresses at approximately 2 km depth, and measured daily for 5–8 days. The results indicate that ductile lithologies exhibit a permeability reduction of approximately one order of magnitude after 3-5 days, while casing cement permeability can decrease by two orders of magnitude in 3 days. These findings highlight the necessity of allowing caprock samples to equilibrate under targeted effective stresses for at least three days to obtain reliable permeability measurements.

10.01 Open Topic

Eggcelent strategies! Egg Production, Egg Morphology and Laying Behaviour of Insects preserved in Amber from the Cretaceous to the Miocene

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Extant insects are adapted to a wide range of habitats and lifestyles on account of numerous specific strategies. In addition to foraging, defence and camouflage, reproduction is one of the existential determinants. Within insects, not only mating strategies are diverse in order to increase the chances of survival of the offspring, but also all aspects regarding the egg: the production of eggs, morphology and laying behaviour.

The number of eggs in a clutch, their size, shape and surface structure as well as the placement of the egg and the parental care after laying are often very characteristic of certain insect groups or species. However, when an isolated egg or clutch is observed, it can be difficult to identify the specific producer, even in extant insects because necessary information is missing in the literature.

The identification of the producer of a fossilised egg is even more difficult, which is further aggravated by the fact that insect eggs are rarely found in the fossil record in general and in amber in particular. The reasons for the rarity of eggs lie in taphonomic aspects, which depend, among other things, on the delicacy of the eggs and hidden deposits under bark or under the ground that were inaccessible to resin.

We present insect eggs and clutches preserved in amber from the Cretaceous to the Miocene and discuss aspects of the evolution of egg production, egg laying and egg morphology strategies. We also illustrate how knowledge about fossil eggs in amber can be expanded.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

From Magmatic Unrest to Eruption: Insights from Diffusion Chronometry in Iceland and Hawai‘i

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Understanding when and how magmatic systems evolve toward eruption is key to forecasting and hazard mitigation. This study applies diffusion chronometry to two basaltic rift eruptions – the 2021 Fagradalsfjall eruption in SW Iceland [1] and the 1950 Mauna Loa SWRZ eruption in Hawai‘i [2] – to constrain the timing of magma mobilization, mush disaggregation, and eruption run-up.

At Fagradalsfjall – the first deep-sourced eruption on a mid-ocean ridge segment monitored with modern instrumentation – diffusion chronometry in olivine and plagioclase identifies three pre-eruptive phases: [(1)] a priming phase with long diffusion timescales indicating deep magmatic upheaval years before eruption, largely undetected geophysically; [(2)] a transition phase beginning ~1 year prior, coinciding with regional seismic and geodetic unrest; and [(3)] a run-up phase marked by steep gradients in both diffusion ages and seismicity, reflecting rapid magma ascent.

At Mauna Loa, diffusion chronometry of six olivine types reveals a shorter, yet similarly structured timeline: [(1)] a ~1.5-year priming phase, recorded by high-Fo olivine, intensifying in the final 8 months and preceding detectable seismicity by ~2 months; [(2)] a transition phase 6–4 months prior, marked by increased magma flux, mush disruption and seismic onset; and [(3)] a run-up phase starting ~2.5 months prior, involving more evolved olivines and culminating in a magnitude 6.4 earthquake days before eruption.

These case studies underscore the diagnostic value of diffusion chronometry in tracking the onset, escalation, and pace of pre-eruptive processes in basaltic systems.

References

[1] Kahl et al. (2023a) Geology 51, 184–188.

[2] Kahl et al. (2023b) Bulletin of Volcanology 85:75.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Amphibole megacrysts with cavities: rapid crystal growth at mantle depth during the 1951 eruption of Fogo (Cape Verdes)

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The late basanitic pyroclasts of the 1951 eruption at Fogo Island (Cape Verdes) contain ultramafic cumulate xenoliths and euhedral kaersutite megacrysts up to 12 cm in size. The megacrysts are characterized by abundant cavities that locally contain vesicular basaltic glass with small clinopyroxene phenocrysts. Some of these cavities are crystallographically oriented and remind of hopper textures. Micro-CT analyses reveal that the cavities are only in part interconnected and locally form funnel-like openings to the crystal surface. The kaersutite megacrysts also contain numerous pyrrhotite rods aligned perpendicular to the crystal surface, some pyrrhotite blebs, and locally stellate spinel aggregates. We interpret these structures to reflect rapid growth of the megacrysts in a volatile-rich silicate melt under the presence of a CO_2-H_2O-dominated fluid phase and abundant droplets of exsolved sulfide melt. Glass compositions within the cavities suggest that this melt was slightly more primitive than the erupted host melt. Barometric data based on clinopyroxene-melt equilibria within cavity glass, as well as kaersutite composition, indicate that megacrysts grew at pressures of 630–700 MPa, overlapping with a range of 620–640 MPa obtained for coevally erupted cumulate xenoliths, which is within the uppermost mantle. Possible cause for the rapid growth at such depths could be sudden liquidus increase due to H_2O loss of the host melt, following magma mixing or CO_2 flushing. We suggest that this occurred within a crystal mush where mobility of coexisting fluid and sulfide phase was limited.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

Educational programs for children at the Museum Mineralogia Munich: Exploring meteorites, volcanoes and the rock cycle

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The Museum Mineralogia München offers a varied and exciting educational program for children designed to arouse their curiosity about earth sciences and planetary phenomena. Building on the natural fascination that many children feel for space, meteorites and the moon, our interactive tours and workshops encourage hands-on learning and discovery.

The main themes of the program include [1] meteorites – rocks from outer space – where children learn about and explore different types such as stony, iron and stony-iron meteorites.

Children can also learn about [2] the dynamic rock cycle, how rocks are formed and transformed by volcanic activity, erosion and tectonic processes. Another popular museum program deals with [3] pebbles from the Isar and encourages children to classify different types of rock, consider where they originated and how they are composed.

A special highlight is the [4] gemstone workshop for young people, where they learn what gemstones there are, how they are composed, what makes real and fake gemstones, how and where they are mined and much more.

With these different interactive and age-appropriate activities, the Museum Mineralogia aims to spark an age-appropriate interest in earth sciences and planetary exploration and provide young visitors with a solid foundation for STEM observation, classification and scientific thinking.

05.01 Spectroscopic methods in modern geosciences

Geochemical Characterization of Lunar Meteorites via Raman Spectroscopy: Implications for Planetary Differentiation and Comparative Analysis

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Lunar meteorites are a key source of information for understanding the Moon's geochemical structure and evolutionary history. Unlike Apollo samples, they originate from diverse and often unsampled regions, offering broader insights into volcanic activity, impact events, and differentiation processes. Each meteorite type provides a unique glimpse into different lunar periods, contributing to a more comprehensive understanding of the Moon's evolution.

A crucial aspect of their study is the detailed investigation of mineral phases. Key questions include the growth history of minerals, chemical zoning, fluid inclusions, and overprinting by melts or impacts. Raman spectroscopy is employed for initial, non-destructive mineral identification. This is followed by electron microprobe analysis and scanning electron microscopy (SEM) for high-resolution compositional data.

The Mineralogical State Collection Munich (MSM) operates a dedicated Raman laboratory and maintains the MSM-MRD database, a growing reference for laboratory and *in-situ* spectroscopy. Lunar meteorites significantly contribute to this database, enhancing Raman spectral libraries essential for future space missions using remote sensing and *in-situ* analysis.

Beyond lunar samples, our research includes meteorites from Mars, Vesta, pallasites, and chondrites. These are compared with terrestrial analogs—such as mantle xenoliths and ophiolitic rocks—to better understand planetary differentiation and magmatic evolution. Lunar meteorites, in particular, offer a more representative view of the Moon's surface and chemistry than Apollo samples alone.

This work supports the advancement of planetary spectroscopy, contributing to the interpretation of spectroscopic data and preparing the ground for future robotic and human exploration missions.

01.25 Geochemical Databases and Data Analysis Tools

Unifying GeoReM and GEOROC: Toward a Modern, Interconnected Geochemical Database System

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The GEOROC (Geochemistry of Rocks of the Oceans and Continents) and GeoReM (Geological and Environmental Reference Materials) databases were established approximately 25 and 20 years ago, respectively, at the Max Planck Institute for Chemistry in Mainz as complementary geochemical resources. GEOROC aggregates geochemical data from primarily igneous and metamorphic rocks and minerals, while GeoReM focuses on geological, biological, and environmental reference materials. Initially, the two databases were cross-linked, allowing for the transfer of published reference materials from GEOROC datasets to GeoReM, however, this connection has lapsed for several years.

In 2021, GEOROC was transferred to the University of Göttingen under the Digital Geochemical Data Infrastructure (DIGIS) project, where its IT and data systems were significantly upgraded. In contrast, GeoReM continues to operate on an aging and vulnerable platform, which restricts automated data exchange and poses significant risks to its long-term availability. The potential loss of GeoReM would adversely affect global data acquisition and calibration in geoanalytical laboratories, leading to severe consequences for both the geochemical research and industry communities.

To address this, the DIGIS team and the International Association of Geoanalysts (IAG) have formed a partnership to redevelop GeoReM's IT infrastructure and integrate it into the DIGIS/GEOROC framework. Standardizing technical elements such as controlled vocabularies across both platforms will further enhance consistency and interoperability. This collaboration will restore the connection between GEOROC and GeoReM, ensuring their continued role as vital, interconnected resources for the international geochemical community.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Parallel histories? A comparative GIS-based study of peat subsidence in Donaumoos and Rhinluch

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Peatlands are important long-term carbon sinks that also contribute significantly to water regulation. However, over the past centuries, many Central European peatlands have been heavily modified by human activity. One key consequence of these interventions is peat subsidence resulting from drainage and surface lowering. Understanding the extent and development of this process is essential for reconstructing long-term changes in wetland landscapes.

This poster explores peat subsidence over the last 250 years in two lowland regions: the Donaumoos fen in Bavaria and the Rhinluch fen in Brandenburg. Both areas were subject to major drainage efforts and canal construction beginning in the 18th centuries. Based on old maps from different time periods, we trace spatial and temporal patterns of surface change and land transformation. Therefore, contour lines were vectorised and interpolated into DEMs. Due to further calculations peat subsidence rate could be indentified (and show transitions). Intersection of the peatsubsidence with the spatial density of the ditches indicate the most intensive time period of human intervention on the peatlands.

The analysis investigates whether and how the development of peat subsidence differs between the two regions. While both have been significantly shaped by human interventions, the cartographic data allow for a comparative perspective on the dynamics of peatland transformation. Moreover, this approach provides a basis for estimating historical carbon losses associated with peat degradation—an essential step for understanding long-term environmental impacts.

08.03 Tilly Edinger Symposium

New insights on Early Jurassic bivalves, pleurotomariid gastropods, and the Permian–Triassic mass extinction (PTME)

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Specimen-based palaeobiological research combined with cutting-edge methods and models helps better answering questions about evolution and biodiversity throughout Earth's history. New research on Lower Jurassic bivalves from Germany have revealed the oldest members of two bivalve families, the earliest evidence of sexual dimorphism in bivalves, and specialized drilling predatory behaviour by an extinct gastropod. Pleurotomariid gastropods, the extant clade with the longest fossil record and the most diverse Paleozoic gastropod group, which declined in diversity since the mid-Paleozoic, contrasting with the continued diversification of Gastropoda. New collections from the Carboniferous suggest pleurotomariids were not only diverse but also the most abundant gastropod clade in the Late Paleozoic. Taxonomic re-examination of type material and undescribed specimens in museums shows that nearly all Triassic pleurotomariid genera evolved after the Permian–Triassic mass extinction (PTME). Their slow recovery in the Triassic was disrupted by the Carnian Pluvial Episode, and they never regained Paleozoic diversity levels. A phylogeny of pleurotomariids (Ordovician–Recent), reconstructed using the Fossilized Birth-Death model, revealed no significant differences in evolutionary rates among branches or over time, suggesting that extinction and diversity decline were not driven by evolvability. The analysis also indicates that early ontogenetic shell characters are more conservative, challenging previous assumptions about phylogenetic value of shell characters. The PTME affected not only Pleurotomariida but the entire marine ecosystems, as evidenced by new fossil collections from Türkiye. The modelled trophic interactions across seven localities show that food webs did not collapse but restructured and became top-heavy (predator-dominated), especially in higher latitudes.

02.01 The Tethys Ocean – the cradle of modern tropical life

Inference of secondary extinctions in marine communities using food-web modelling across the Permian–Triassic mass extinction

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The Permian–Triassic mass extinction (PTME) is characterized by the highest extinction rates in marine communities in the entire Phaneozoic. As the event coincides with extreme environmental perturbations such as rapid global warming, most palaeobiological studies assume all extinctions during the PTME occurred as primary loss of taxa directly caused by physical environmental stress. However, secondary extinction cascades triggered by changes in ecological interactions can be as, if not more, important drivers of species loss. Herein, we modelled food webs of marine communities across the PTME using the most comprehensive occurrence dataset from the western Tethyan tropical deposits at Meishan, China, at a very high stratigraphical resolution to infer secondary extinctions. Using robustly inferred predator-prey networks for each time interval, we classified extinctions as secondary under the following conditions: i) a predator became extinct when prey diversity declined, ii) a primary consumer (e.g., filter feeders) became extinct following a decrease in primary productivity, iii) a species within the trophic network became extinct following either increased predation pressure (increased normalized out-degree) or a loss of resources (declined normalized in-degree). Based on these classifications, the majority of the extinctions can be attributed to secondary extinction due to perturbations in primary productivity or changes in trophic interactions. Modelling trophic interactions in these extinct communities reveals the importance of considering evidence for secondary extinctions to better understand the processes giving rise to biodiversity patterns in deep time.

03.04 All about carbonates

Fluid-driven carbonate diagenesis in the Central European Basin revealed by fluid inclusions and U–Pb carbonate geochronology

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A detailed diagenetic reconstruction of the Anisian Schaumkalk (c. 245 Ma) and the Oxfordian Korallenoolith (c. 163 Ma) in the Central European Basin was conducted by combining petrographic techniques (including cathodoluminescence microscopy) with fluid inclusion analysis and *in situ* U–Pb dating of carbonates. Pack- and grainstone lithofacies were sampled from outcrops and cores, representing the present-day range from surface exposures in Central Germany to maximum burial depth in North Germany. U–Pb dating of carbonate grains and cementations yielded ages in the range of 244–63 Ma that cluster in seven distinct age groups. The earliest age group of 244–232 Ma (I) is related to eogenetic modifications of carbonate mud and cements of the Schaumkalk in shallow burial depth. Cementation groups II–VII are related to basin-scale fluid migration as evidenced by fluid inclusions trapped at 90–310°C with salinities of 13–24 wt% NaCl+CaCl2. Trapping of highly saline basinal fluids in authigenic cementations at 239–237 Ma (II), 227–223 Ma (III), 202–189 Ma (IV), 170–156 Ma (V), 102–99 Ma (VI) and 64–63 Ma (VII) correspond to phases of structural reorganization and tectono-magmatic activity in the Central European Basin. Comparing the intense diagenetic overprint of the Schaumkalk (all age groups present) with the incipient diagenesis of the Korallenoolith (age groups V–VII present) highlights the importance of fluid-driven diagenetic alteration. This refers in particular to wide-spread neomorphism of carbonate matrix in the Schaumkalk that cannot be explained by burial diagenesis alone.

04.07 Mineralogy of Secondary Raw Materials

From waste to resource: mineralogical and chemical insights into incinerated sewage sludge ash (ISSA) as a secondary raw material

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This study focuses on the characterization and valorization of incinerated sewage sludge ash (ISSA) as a secondary raw material, with particular focus on its mineralogical properties and environmental behavior. Produced as a by-product of municipal wastewater treatment, ISSA presents complex potential both as a source of valuable elements such as phosphorus and selected critical raw materials and as a functional component in industrial material systems. A systematic mineralogical, chemical, and morphological analyses were performed on ISSA samples collected from a Polish wastewater treatment plant. Emphasis was placed on identifying stable and reactive mineral phases, evaluating phosphorus speciation, and assessing the material's suitability for further processing and application. In parallel, leaching experiments were conducted to ensure the material's safety in use. The results support the use of ISSA in material production pathways, especially in construction-related applications. Among them, the use of ISSA in cementitious materials was explored in line with circular economy principles, repurposing waste, reducing landfill dependency, and improving resource efficiency. In this context, the potential for passive CO_2 uptake through mineral carbonation was also examined, indicating a measurable contribution to carbon management in sustainable construction materials

06.04 Stressors in Hydrogeology: Interactions and Impacts

Antimony isotope fractionation trace drainage waters of an abandoned Zn-Fe-Pb mine deposit in the Harz Mountains, Germany

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Heavy metal contamination of abandoned mines affects natural ecosystems long after mining has ceased. Recent analytical developments have shown that Sb isotopes can be used as a powerful geochemical tool to trace sources and processes of contamination in regions affected by Sb mining [1]. However, despite its toxicity, the Sb cycle in aqueous systems apart from Sb-mine contaminated waters remains poorly understood.

To address this issue and better understand Sb isotope behavior in abandoned mines without a (known) occurrence of Sb mineralization, we investigated Sb isotopes in drainage waters of the Ernst-August Stollen in Bad Grund, Harz Mountains (Germany), which was famous for its Zn-Fe-Pb mineralization. The water samples distributed throughout the mine and (anthropogenic) floating iron at the separator basin were collected during winter and summer seasons in 2024. The variable Sb concentrations (0.1 to 0.9 µg/L) and Sb isotope compositions of 0.2 µm filtered water ($0.13 \leq \delta^{123}Sb \leq 0.50$ ‰) are most likely related to natural Sb weathering and adsorption processes at variable conductivity (635 to 5300 µS/cm). In contrast, the floating iron has high Sb concentrations (~30 µg/g) and a heavier Sb isotope composition (~1.3 ‰). This Sb isotope fractionation between floating iron and circumneutral drainage water may reflect a combination of adsorption, weathering and subsequent leaching processes.

Reference

[1] Wen et al. 2023 J. Hazard Mater. 446, 130622.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Plutonic nodules in the eruptive products of Pulvermaar in the Eifel volcanic field

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The eruptive products of the Pulvermaar in the West Eifel volcanic field contain nodules, which are rounded pieces of plutonic rocks coated by lava rims. The plutonic parts may represent disrupted fragments of a magma mush zone, and thus provide insights into magma mush processes at depth. Their bulk compositions are similar to those of the magmatic coating, indicating that the plutonic parts may have been formed by the slow cooling of previous magma pulses at depth. The plutonic parts are composed of coarse grained olivine, clinopyroxene, biotite and amphibole, which crystallised in this relative order. The modal abundance of minerals varies widely, ranging from pyroxenites containing only clinopyroxene and olivine to hornblendites composed mainly of amphibole and biotite. The lava coating cross-cuts all mineral phases and records the final stage of magma emplacement prior to eruption. The chilled magma consists of glass, bubbles and phenocrysts of olivine and clinoproxene, showing some overlap with the olivine and clinoproxene compositions in the plutonic part. Growth zoning, recording different stages of evolution, is present in olivine, clinopyroxene and amphibole. The compositions of the zones in olivine (Focore = 0.88, XCa = 0.004 and Forim = 0.84, XCa = 0.02) and clinopyroxene (Wo49-52En32-43Fs16-08 in different zones) represent growth in different magmatic environments. Preliminary modelling using MELTS is able to reproduce the observed crystallization sequence, but the pressure-temperature conditions of crystallization remain poorly constrained and require detailed experimental and thermobarometric studies, which are currently underway.

08.01 Young Scientist Session

Morphological diversity of mantis shrimp larvae in deep time

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FEUSTEL, FINN SIMO
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Larvae of mantis shrimps (Stomatopoda) exhibit a great morphological diversity, reflecting their numerous ecological roles in the plankton. From hatching from their eggs to their adult stage they develop through numerous stages, each separated by a moult. Due to their long time spent in the plankton, the larvae reach relatively large sizes, up to several tens of millimetres. The larvae play an important role as active predators of smaller plankton animals, but also as prey of immatures of large predatory fishes, such as tuna, therefore occupying a crucial role in the marine food web, possibly even having economical significance. Their strongly pronounced compound eyes and strongly modified major appendages enable them to efficiently catch prey in the pelagic zone, especially smaller soft-skinned organisms, such as small-sized adults or larvae of other crustaceans. As larvae they drift in the planktic realm of the ocean, before continuing in a more benthic existence after metamorphosing. Their presence in the fossil record has been demonstrated by fossil finds since the Jurassic. Still, such larvae are still rare as fossils, while adults and post-metamorphic immatures are much more common and also reach further back in time, into the Carboniferous. We present here a quantitative morphological comparison of feeding structures of mantis shrimp larvae over time, exploring in how far their ecological roles might have changed or been retained through time.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

The 1080 AD earthquake between Mainz and Speyer (Upper Rhine Graben, Germany) – archeoseismology allows relocating the epicentre

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The imposing Romanesque cathedral of Speyer (Upper Rhine Graben, Germany) was built as thr burial site of German emperors, consecrated in AD 1061. However, mere two decades later it was almost completely rebuilt, a very unusual step in the history of any church. We put forward the hypothesis that the cathedral was severely damaged by an earthquake making re-building necessary. We describe construction history, identify features of earthquke-induced damage, and describe engineering solutions to make the new building more resistant to seismic shaking. An intensity IX-X is assigned based on archeoseismological evidence. The AD 1080 earthquake, recorded in Mainz (ESI-2007 = VII-VIII), some 80 km to the north, was probably the culprit. We suggest to relocate the epicentre from the proximity of Mainz southward, towards Speyer, with an M6.5 magnitude. ShakeMap analysis supports lower intensity for Mainz and higher intensity for Speyer. Worms cathedral, located halfway between Mainz and Speyer, bears evidence for destructive earthquake with severely tilted walls, which necessitated the rebuilding of collapsed vaults. Damage to the choir and apsis are very similar to those of Speyer. Start of the construction is known to be some time before 1132-37 AD. Whether this was the same earthquake which damaged Speyer, needs further considerations. Archaeoseismology provides information about past earthquakes which lack proper historical documentation.

03.05 Advances in Paleoclimate Proxies and Their Applications

Mg Isotope fractionation in Glycymeris (Bivalvia) shells

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Over the past 50 million years, Cenozoic climate cooling has coincided with rising Mg/Ca ratios in seawater. However, the connection between this shift in seawater chemistry and climate change remains debated. Magnesium isotope ratios (δ^{26}Mg) in seawater could help differentiate between possible mechanisms, such as dolomitization, formation of authigenic clays, and variations in silicate and carbonate weathering rates. Past reconstructions of paleo-seawater δ^{26}Mg using foraminifera, corals, and carbonate muds have yielded inconsistent results. In this study, we evaluate bivalves from the genus Glycymeris as alternative archives for paleo-seawater δ^{26}Mg. These bivalves possess several advantages, including evolutionary stability, thick shells, and a fossil record extending back to the Lower Cretaceous—traits that suggest consistent isotopic fractionation over time. We analyzed Mg isotope compositions from the ventral shell margins of three modern Glycymeris species (G. bimaculata, G. nummaria, G. pilosa) from the Adriatic Sea. Our data show increasing isotopic fractionation with ontogenetic age and distinct intra-shell differences depending on sampling location (center vs. margin) at the same developmental stage. Our results show that variations in precipitation rates best explain this behavior of Mg isotopes. Unaltered isotope signatures in fossil shells can thus be clearly identified. This work suggests that the rate-dependence of δ^{26}Mg in Glycymeris can be exploited to derive paleo-seawater δ^{26}Mg.

08.01 Young Scientist Session

Preliminary results of integrating surficial geochemistry with geophysical models on the case study of Ransko Mt., Czech Republic

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Surficial geochemistry and geophysics are two valuable tools for exploration geologists. In particular, surficial geochemistry, based on the compositional analysis of plant samples, has proven to be an indicator of lithological differences where outcrops are scarce or unavailable. Geophysical methods, such as electromagnetic surveys, offer a non-invasive means of measuring proxies of subsurface lithology. However, interpreting geophysical data requires inversion to produce 3D models, a process that can be improved by incorporating geological knowledge into the inversion algorithms. This knowledge-driven approach can also be supported by the geochemistry of plants.

This study uses data from a test site within the Horizon Europe SEMACRET project, which is located in an orthomagmatic intrusion featuring mineralisations. Data collection aimed to investigate the effectiveness of surficial geochemistry and electromagnetic surveys in detecting shallow and deep-seated mineralisations. The results show that geophysical data inversion and plant geochemistry provide complementary insights into the bedrock, offering a more robust proxy for lithological interpretation together. This study explores the potential of combining surficial geochemistry with geophysical models (resistivity and chargeability), and we present preliminary results from this investigation. This integrated approach has significant implications for exploration geology, exploiting techniques which are applicable even when sample numbers are comparatively low, which would otherwise inhibit classical machine learning-driven prospectivity modelling.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Holocene floodplain stratigraphy reflecting natural and anthropogenic induced sediment dynamics in a mining-affected catchment in the Eastern Harz Mts., Germany

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The formation of fine-grained overbank deposits is, among other factors, linked to human-induced land cover changes and water management, such as mill dams, ponds and ditches. Therefore, floodplain sediments and architecture can provide information about past sediment dynamics. In former mining areas, the variability of risk element concentrations with the sediment depth is a valuable proxy for environmental conditions and anthropogenic impacts.

The study area is the 180 km^2 large upper and middle catchment of the Selke River, which is well-known for mining activities since the 13th century. The Selke River is a typical river at the transition between the uplands of the Harz mountain range and the loess-dominated lowlands.

Based on archaeological and historical records, sites for drill core drilling and soil profiles were identified, representing floodplain characteristics upstream, in between, and downstream of known mining and smelting sites. The sampled sediments are analysed for grain size, radiocarbon ages from charcoal fragments, elemental concentrations, and slag.

Initial results indicate at least a biphasic nature of the overbank deposits, reflecting the onset of mining/smelting activities in the study area. In particular, changes in the risk element concentrations, the presence of slag fragments and their properties characterise anthropogenically affected sediments. The first radiocarbon ages date the earliest anthropogenically affected (e.g. polluted) sediments to the 10th to 11th century. In addition, variations in the risk element concentrations both vertically and horizontally within the cross-sections indicate intercalation with different phases of erosion and aggradation. Distinct changes in the grain size distribution support this complex floodplain architecture.

08.02 Building Bridges – Erfahrungen aus der geowissenschaftlichen Praxis für den Karriereweg

From the University to the Job Market

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Our session focusses on the onboarding process of geoscience students to the job market, particularly focusing on young professionals in fields such as engineering, consulting and public service.

Key sections include:

Career Choices: It discusses the importance of finding a balance between financial compensation and meaningful work. It encourages individuals to explore various sectors such as geo-engineering offices, government agencies and industries.

Employment Statistics: There are charts presenting data on employment categories, such as the number of students, unemployed individuals, and various job sectors. Additionally, it includes salary data for entry-level positions in geo-engineering offices, broken down by gender and years of experience.

Personal Transformation: The session reflects on the live-work balance changes coming with starting a new job, including lifestyle adjustments and the development of a professional identity.

First Job Experience: We address the challenges and emotions associated with starting a new job, such as excitement, uncertainty and the need to adapt to a new work environment.

Advice for New Professionals: We also emphasizes the importance of preparation, self-reflection and adaptability during the initial stages of a career.

Overall, the session will serve as a guide for recent graduates navigating their entry into the professional world, providing insights into career options, salary expectations and the personal changes that accompany this transition.

02.01 The Tethys Ocean – the cradle of modern tropical life

Tethyan biodiversity hotspots at the community level

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Areas of high biodiversity have shifted from the Mediterranean Tethys to the Coral Triangle in the western Pacific throughout the Cenozoic—a phenomenon often linked to plate tectonics shaping habitat heterogeneity. We use assemblage-level data from the Paleobiology Database to document spatiotemporal changes in alpha diversity of marine benthic communities, analyzing over 10,000 collections with at least 30 counted individuals.

Applying both traditional diversity metrics and rank-abundance distribution models, we observe a consistent trend of increasing alpha diversity toward the present and a growing proportion of complex benthic communities over time. Strong correlations between local and regional diversity measures suggest that regional species pools fundamentally structure local community diversity.

Despite potential lithification biases, environmental setting—particularly clastic-influenced reef environments—best explains the preserved spatial distribution of hotspots. Within the Tethys Ocean, biodiversity hotspots consistently occurred away from the equator, primarily along its northwestern margin near the modern Mediterranean, with occasional additional centers in South China, India, and Sinai.

Remarkably, the last time an area corresponding to today's Indo-Australian Archipelago was a hotspot of local richness was during the Middle Triassic, approximately 245 million years ago. This implies that the modern Coral Triangle is at a truly exceptional place, whereas the western Tethys region served as a stable marine biodiversity hotspot for nearly 200 million years.

01.20 Process oriented microfabric characterisation of geomaterials

Implications of crystallographic preferred orientations in quartz mylonites

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Quartz crystallographic preferred orientations (CPO), often reduced to solely inspecting the (0001) polefigure, are frequently used to deduce finite strain type, shear sense and deformation temperature of deformed rocks. While the direct dependency of CPO and deformation temperature can actually be rejected (Kilian & Heilbronner, 2017), a so-called opening-angle thermometer is still commonly applied. Using various datasets of natural quartz mylonites formed under different metamorphic conditions, we strongly suggest that a finite, steady-state quartz CPO is the result of mostly two independent, texture-forming deformation processes, dislocation glide (strain-dependent) and dynamic recrystallization by oriented nucleation and growth (stress-dependent). Those processes occur simultaneously and their relative contributions depend on factors such as strain rate, deformation temperature and grain boundary mobility, amongst others. In combination with flow kinematics, the contributions of both texture-forming processes determine the finite CPO. The quartz CPO features are at most only indirectly related to temperature and should not be applied as a thermometer. However, a useful application of quartz CPO includes usage as a simple proxy of rock rheology (i.e. flow at low or high stress conditions), mostly robust against post-kinematic annealing.

Reference

Kilian, R., Heilbronner, R., 2017, *https://doi.org/10.5194/se-8-1095-2017*

06.02 Recent advances in fossil imaging

Untangling soft-bodied preservation in the Miocene Öhningen Konservat-Lagerstätte

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The Miocene (Serravallian) Öhningen Maar in southern Germany is one of the most famous Konservat-Lagerstätten. In addition to its abundant plants and vertebrate fauna, the soft-bodied biota preserved in Öhningen is diverse, including various insects, aquatic arthropods, and arachnids. While the Öhningen Maar is often regarded as a single deposit in the literature, it is imperative to recognize that there are notable differences between the two separate outcrops. Not only are there variations in sedimentology, modes of preservation of the soft-bodied fossils, and fossil diversity at the outcrop scale, but these elements can also vary within a few centimetres of the same exposure. Part of this variation can be attributed to changing depositional environments and seasonality, but modern weathering and historical collections bias may also play significant roles. However, understanding the correlative nature of these proxies is in its infancy. Here we present new data from sedimentological, petrographic, paleontological, geochemical, and SEM-EDS analyses which showcase the importance of a multiproxy approach to the understanding of this convoluted deposit. The aim is to provide improved clarity onto the paleoecological and taphonomic questions that have plagued the Öhningen Maar for decades.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Sector-zoned radionuclide incorporation in natural calcite

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Deep geological repositories for radioactive waste necessitate safety evaluations, which encompass assessing the possible leakage of radionuclides from the waste containers into groundwater. In this context, the retention of radionuclides through water–mineral interactions is considered. Calcite is of significant importance in this regard, as it (re)crystallizes under relevant physico-chemical conditions in groundwater and can incorporate significant amounts of radioactive elements, such as trivalent actinides (Am, Cm). In contrast to laboratory experiments, which are conducted over short time periods and under controlled conditions, this study investigates radionuclide uptake during solid solution formation in natural systems. This approach offers the opportunity to evaluate the stability of solid solution phases over geological timescales.

To investigate the incorporation of trivalent actinides into calcite, as well as their analog element La, natural calcite samples were obtained from the Wenzel mine in the Black Forest, SW Germany. High-resolution LA-ICP-MS analyses reveal that the enrichment of La in specific sectors of the crystal can exceed that of other sectors by more than a factor of over 200. A mass balance of monovalent and trivalent ions within the different crystal sectors shows that the incorporation of La is not compensated by monovalent ion substitution. Our results suggest that trivalent ions are more likely compensated by vacancies on divalent ion sites on specific crystal faces. The study shows that calcite plays a significant role as a sink for trivalent actinides, but this role is highly specific and depends on the characteristics of the respective crystal surfaces.

03.05 Advances in Paleoclimate Proxies and Their Applications

Expansion and connection of Early Jurassic Ocean Anoxia: Constraints from U and Mo isotopes

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Reconstructing ancient ocean redox conditions is essential for understanding the link between marine anoxia and environmental changes. The Early Jurassic experienced significant oceanic redox fluctuations during the Pliensbachian/Toarcian event (Pl/To; ~184 Ma) and the more pronounced Toarcian Oceanic Anoxic Event (T-OAE; ~183 Ma). However, the expansion and connectivity of anoxic waters, e.g., in the European epicontinental seaways (EES), remain poorly understood. Here, we aim to apply U and Mo isotopes on carbonates and black shales that have become a powerful geochemical proxy for tracking redox changes at both local and global scales, combined with other redox-sensitive trace elements and REY, to unravel the oceanic redox evolution of the Early Jurassic.

Carbonate sediments investigated here are from Peniche (Portugal) and Toumliline (Morocco), covering both the Pl/To and T-OAE intervals. Shale-normalized rare earth element and yttrium patterns in the Peniche samples are characterized by negative Ce, positive Gd, and positive Y anomalies, indicating precipitation from open marine seawater. Recent data from near-contemporaneous Italian carbonate deposits suggest more extensive global seafloor anoxia during the T-OAE [1]. Our preliminary data, however, do not show negative U isotope shifts in the Peniche section suggesting that there was no global expansion of seafloor anoxia during either the Pl/To event or the T-OAE. Complementary U data of the Morocco section and coupled Mo-U isotope data from three different basins of the EES may clarify whether the redox shifts occurred contemporaneously and whether they represent a local or global phenomenon.

Reference

[1] Remírez et al. (2024), PNAS, 121(27)

04.07 Mineralogy of Secondary Raw Materials

Phosphogypsum as an alternative to FGD gypsum

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The University of Applied Sciences Nordhausen is currently conducting research projects on the topic of resource conservation. For example the separation of different materials with the aim of recycling or utilising them as a source of raw materials / secondary raw materials. The research concentrates on the gypsum recycling and the substitution of natural gypsum with gypsum from industrial productions. This problem is a particular issue in the southern Harz region, where the interests of big mining companies and nature conservation meet. With the end of coal-fired power generation, the German market will lose around 50 % of its gypsum, as this comes from flue gas desulphurisation. Unless other alternatives are found and utilised, the resulting deficit will probably have to be covered by mining natural gypsum. The current research project ‘PhosphoGypsum’ is investigating a quantitatively promising by-product of phosphoric acid production that requires qualitative optimisation. The aim is to develop a phosphogypsum available in Europe for industrial use and to analyse the existing opportunities, risks and challenges. Various treatment methods are to be implemented in the manufacturing process of the by-product in order to optimise the quality requirements of the material.

01.26 Alpine-Zagros-Himalayan Orogenic System: Case Studies

Along-strike variations of foreland thrusting in the Pamir

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The arcuate, northward convex Pamir mountains are fringed in the west and north by foreland fold-and-thrust belts forming the External Pamir (EP). In the west, the wide thrust belt occupies the entire Tajik Basin. Towards the northeast, it grades into a narrow, W-E-trending belt along the southern margin of the intermontane Alai Valley which separates the Pamir front from the Tian Shan in the north. In the westernmost Tarim Basin, the thrust belt widens again to form a pronounced northward salient. We present three cross sections to illustrate along-strike variations of the EP in topography, erosion level, stratigraphy, and structure. Possible variables that controlled structural styles and evolution include: [1] Basement rheology and structure: mechanical strength and buoyancy probably increase eastward from Pamir lithosphere forming a steeply dipping continental slab to the rigid Tarim basin. The basement beneath Alai makes a large antiform plunging west- and eastward towards the Tajik and Tarim basins. [2] Pre-Cenozoic structure: in the Tian Shan the Talas-Fergana fault is a major NW-SE-striking discontinuity that was already active in Paleozoic and Mesozoic time and probably links up with large faults in western Tarim. [3] Facies and thickness variations of Mesozoic and Cenozoic deposits: in Alai, multiple décollement levels in Cretaceous and Paleocene rocks favor short-wavelength folding. In W Tarim, few large thrusts splay from a single basal décollement in thick Paleocene gypsum. Cenozoic strata thicken markedly eastward. Mutual influence and feedback between these tectonic-stratigraphic parameters and variations in climate driving erosion intensity is probable.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Tectonics of the Leinetal Graben: unsolved questions

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The Leinetal Graben (LTG) is a key element of Germany´s post-Variscan fault network. It is part of the generally NNE-trending fault system running from the Upper Rhine Graben to the eastern border of the Lower Saxony Basin (LSB) and connects NW-SE-striking faults of the LSB with at least one regional fault in the Thuringian Syncline over a distance of some 50 km. This geometry suggests displacement transfer along the LTG. The link to the inverted LSB predicts two main phases of motion on the LTG faults: sinistral transtension during LSB opening (Triassic to Early Cretaceous) and dextral transpression during inversion (Late Cretaceous). Paleostress analysis (Sippel et al. 2008) does not contradict this model but has sparse observations from the LTG. The complicated western border of the LTG may record more strike-slip deformation while the eastern border is dominated by normal faulting. The role of Zechstein salt in the evolution of the LTG is unclear. Evacuation of thick, stratiform salt or collapse of a Triassic salt wall (Tanner et al. 2015) have been proposed, with minimal involvement of the basement. Concentrated brines drilled at about 400 m depth have been interpreted as revealing salt-intruded normal faults. The LTG is typically shown as part of the European Cenozoic Rift System, but may have remained inactive in Cenozoic time. Oligo-Miocene sediments and basalts are only present on the western shoulder but not within the LTG. The present topography of the graben may reflect river incision into soft Keuper and Lower Jurassic strata.

07.02 Geothermal energy — Potential and utilisation of geothermal energy resources for the heat transition

Numerical Assessment of Aquifer Thermal Energy Storage (ATES) in Deeper Siliciclastic Aquifers in Berlin from a Geochemical Perspective

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Germany's aquifers hold significant potential for geothermal applications at both shallow and greater depths. For the North German Basin, siliciclastic aquifers in the Lower Jurassic (Hettangian-Pliensbachian) and Upper Triassic (Rhaetian) formations are promising targets for deeper ATES systems. However, high-temperature ATES applications at greater depths remain rare, primarily due to high investment costs, operational uncertainties, and associated risks.

This study investigates fluid-mineral interactions in an anoxic siliciclastic aquifer (carbonate content <1 wt.%) of Hettangian age in Berlin, representative of the North German Basin. Numerical modelling was conducted, using the geochemical code PHREEQC, to study the impact of gas pressure and temperature on fluid-mineral equilibria. Specifically, the effects of groundwater temperature at constant partial gas pressures were analysed. Furthermore, the tendency for mineral precipitation/dissolution was evaluated under varying partial pressures of carbon dioxide and oxygen at selected temperatures (5°C–120°C), simulating the effects of carbon dioxide degassing and oxygen intrusion on the reservoir.

Using site specific mineralogical and geochemical composition, contour plots were generated to visualize precipitation and dissolution trends as functions of temperature and carbon dioxide or oxygen concentrations in the studied system. Results indicate [(1)] negligible pressure-dependent changes in the stability of iron (hydr-)oxide and carbonate mineral phases; [(2)] calcite precipitation at elevated temperatures due to changes in species activity and the temperature-dependent solubility constant of calcite, [(3)] Correcting hydrochemical field data is essential to match thermodynamic equilibrium conditions in the aquifer and significantly affects modelling results, especially with regard to iron speciation and iron mineral phase stability.

01.25 Geochemical Databases and Data Analysis Tools

The Significance of Geochemical Data Bases and the Impact of GEOROC and PetDB

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The GEOROC and PetDB databases have compiled peer-reviewed literature data on geochemical compositions of igneous rocks and minerals for >25 years (*https://georoc.eu/*; *https://search.earthchem.org/)*. While initially the focus lay on ocean island and mid-oceanic ridge basalts, respectively, both databases have widened their scope and now include the complete compositional range of igneous rock types as well as mantle xenoliths and minerals, comprising: 22 geological settings; 351 lithologies; 533 mineral species; and all common major, trace and rare earth elements, isotopic ratios as well as analytical ages. Today, the two databases contain >47 million single data values from ~27,000 publications, with 28,942,143 *in situ* and 18,330,454 bulk data points. Continued data curation of PetDB and GEOROC ensures that the databases continue to grow. The EarthChem Portal enables harmonized access, filtering and download from the combined databases (*http://portal.earthchem.org/*).

The comprehensive data collections offered by PetDB and GEOROC present a unique opportunity to the research community to undertake advanced analysis of large-scale regional and global datasets. New research questions have been tackled, making PetDB and GEOROC an essential tool for digital geochemistry. Both databases have accumulated more than 4,000 citations ranging from highly detailed, regional comparative research to machine learning studies using thousands of data points. We present a detailed analysis of the usage of GEOROC and PetDB data products to highlight the wide range of research topics that GEOROC and PetDB have supported, and the impact of global geochemical data compilations on past, present, and future trends in the Earth System Sciences.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

New predatory synapsid appendicular elements from the Bromacker locality (early Permian of Thuringia, Germany)

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New skeletal material from the early Permian Bromacker locality (Thuringia, Germany) adds critical information to our understanding of early synapsid diversity and anatomy. The first fossil bone ever discovered at Bromacker in 1974—specimen MNG 7744—was never formally described and only anecdotally identified as a potential diadectid skull element (pterygoid). To commemorate the 50th anniversary of this discovery, we reanalysed the partly embedded specimen using micro-CT imaging. The new data reveal that it is not cranial but postcranial in origin: the first known pelvis of Dimetrodon teutonis. During the 2020–2025 excavations, additional, yet undescribed skeletal material that can be referred to D. teutonis was discovered and includes a sacral vertebra, a second pelvis, as well as the first complete femora and ulna assignable to this species. The sacral vertebra also lacks the fusion known from Dimetrodon limbatus and giganhomogenes. We also report new material of the varanopid Tambacarnifex unguifalcatus, the apex predator of the Bromacker ecosystem. Although the postcranial skeleton of Tambacarnifex was previously known, a newly recovered femur is the first complete example. A humerus with incompletely ossified epiphyses, and a size less than 70% of the holotype, it represents the first juvenile varanopid from Bromacker. These finds provide new anatomical data for two key synapsid taxa and refine our understanding of the Bromacker predator guilds. They also demonstrate the value of modern imaging technologies for revisiting legacy specimens and reaffirm the Bromacker locality as a rich source of insight into early terrestrial vertebrate evolution.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Integrating facies and mineralogy: new Insights from the Opalinuston Formation in southern Germany

Kneuker, Tilo [1]
Mann, Thomas [1]
Dohrmann, Reiner [2]
Ufer, Kristian [1]
Blumenberg, Martin [1]
Erbacher, Jochen [1]
Bornemann, André [1]
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The Opalinuston Formation (OPA) is designated as host rock for the disposal of high-level radioactive waste in Switzerland. In southern Germany, it remains one of several potential candidates under investigation. For the present study, samples from the Mont Terri rock laboratory (Switzerland) and from the BGR project “Sequence Stratigraphy of the Aalenian in southern Germany” (SEPIA) were investigated using a facies-based approach including mineralogical and geochemical analyses. Particular emphasis was placed on the degree of ordering of the illite-smectite interstratified clay minerals (I-S), which are responsible for sorption of radionuclides and swelling properties.

The results support the classification of the OPA into several (sub-)facies types. The clay fraction present in the samples varies according to these facies types, consistent with variations in cation exchange capacity. For southern Germany, crystal structure-based Rietveld refinement indicates a proportion of illitic layers in the I-S averaging between 77 % and 83 % across all refinements and ordering types. No significant differences in the illite:smectite ratio of the I-S was observed between the two sites studied. However, a notable difference in the degree of ordering was identified. This variation can be attributed to differences in the burial history of the OPA at the two localities.

A preliminary comparison with results from the OPA in Switzerland reveals that the average proportion of illite layers in the I-S (approximately 77 % for Mont Terri) closely aligns with the results observed in southern Germany. Our ongoing effort is to compare these results with crystal-structure based Rietveld measurements from other claystone formations.

03.01 Recent Advances in the Geological Research of Marine Environments

Assessing the geochemical composition of the cold-water coral Enallopsammia rostrata as a proxy archive for the paleo-oceanographic evolution in the western Indian Ocean

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Cold-water corals (CWC) have been identified as a geochemical proxy archive for paleo-oceanographic reconstructions of intermediate water masses, due to their long lifespan (several hundred years) and their globally widespread occurrence. To date, the descriptions of CWC appearances in the Indian Ocean are only sparse and therefore require comprehensive geochemical investigations of these taxa within this region. In this study, we compare the spatial and temporal variations in the chemical composition to the structural and growth-related features of CWCs to assess their application as proxy archives to reconstruct recent changes in the intermediate water masses in the West Indian Ocean.

During research cruise SO306 with RV Sonne two living CWC colonies of Enallopsammia rostrata (Pourtalès, 1878) were collected in the northern part of the Mozambique Channel around the island of Mayotte. The corals originate from intermediate water depths (600 to 900 m) within the transition zone of South Indian Central Water (SICW) and the underlying Red Sea Water (RSW).

The chemical composition of different branches from each colony was analysed using EPMA mapping (Mg, Ca, S, Sr) and LA-ICP-MS line scans (Li, Mg, Ca, Sr, U). U/Th dating enable the determination of ages and growth rates of the individual colonial parts, allowing the sclerochronological alignment of the geochemical data. The obtained long-term (> 100 years) and spatially high-resolution data reveal pronounced cyclic variability in E/Ca ratios (e.g. Sr/Ca). However, using existing proxy calibrations along these data do not meet recorded environmental observations, emphasising the necessity for species-specific adjustments.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Experimental insights into liquid lines of descent of evolved high- and low-Si boninites from the Izu-Bonin-Mariana fore-arc

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The Izu-Bonin-Mariana (IBM) fore-arc is a rare example where flux melting of the refractory mantle and the generation and differentiation of boninitic melts can be investigated. A previous study proposed that IBM boninitic magmas were stored at very shallow depths (20–40 MPa) and temperatures > 1100 °C, based on orthopyroxene-liquid and olivine-liquid thermobarometry [(1)]. However, given the strongly hydrous nature of these boninitic magmas [(2)] (up to 3.2 wt% H_2O in quenched natural glasses), higher pressures seem likely. To constrain the liquid lines of descent and magma storage conditions of IBM boninites, we conducted equilibrium crystallization experiments on evolved high- and low-Si boninites using an internally heated pressure vessel (IHPV). Experiments were performed over a P-T range of 200–400 MPa and 1020–1220 °C with varying H_2O contents.

For the high-Si boninite, orthopyroxene is the liquidus phase. For the low-Si boninite, orthopyroxene is the liquidus phase at low water concentrations while olivine is the liquidus phase at high H_2O contents. Differentiation for both compositions proceeds with clinopyroxene and plagioclase crystallization. Residual melts follow calc-alkaline differentiation trends, evolving to high-Mg andesitic and dacitic compositions. Experimental results demonstrate that the liquid lines of descent of natural IBM boninitic glasses as well as mineral compositions can be reproduced at 200 MPa and bulk H_2O concentrations >2 wt%. We, therefore, conclude that natural boninitic magmas differentiated at higher pressures than previously estimated.

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04.06 Coupled Fluid-Rock Deformation: Unraveling Multiscale THMC Dynamics for Fundamental Geological Processes and Societal Challenges

Spatio-temporal characteristics of geological phenomena: Linking patterns to processes

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To predict and identify governing geological processes and their occurrence in space and time one needs to understand at what spatio-temporal scales they are active. The same goes for the design of experiments or numerical simulations and their up-scaling. If one chooses the wrong time window for an experiment, nothing may happen during that time.

Geological patterns in space and time are dependent on a number of processes that scale differently depending on whether or not they are linear or non-linear and on the involved constants (rate constants, diffusion constants). This is important for example for THMC processes in general, but also for the behavior of faults from the micro to macro scale or melt related processes in the Earth's lithosphere. Often the slowest process is dominating the time scale of pattern evolution, therefore cross-over points in space and time are of special interest, where the dominance of one process over another switches. Such cross-overs are critical points where the behavior of the system changes, especially when two processes are competing during pattern formation.

Here we explore five important processes namely elastic wave propagation, fluid or melt pressure diffusion, temperature diffusion, matter diffusion and reactions. For example, if a reactive fluid enters a fault, in a second the fluid pressure equilibrates on a m-scale, the temperature on a mm-scale and matter on the micro-meter scale. We will discuss examples of scaling relations with implications on how we can utilize such scaling phenomena for process understanding.

01.06 Tectonic Systems – TSK Open Session

The future of structural geology

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The theoretical root of structural geology is in continuum mechanics, founded by Euler (stress, 1776), Lagrange (strain, 1784), and Cauchy (1827). Compared with the principles of modern physics it is hopelessly obsolete. It completely ignores all the developments in physics after 1830, especially the rise of energetic thinking (starting 1840), physical work (Joule 1845), the First Law of thermodynamics (Mayer 1842), bonds in solids (Maxwell 1850), the mathematics of 3D space (Grassmann 1866), and others. It will be shown that Cauchy's derivation of the stress tensor is invalid, and that strain is physically meaningless (Koenemann 2008, 2014). Continuum mechanics is as obsolete as a trilobite. It fails completely and systematically for simple shear in the elastic (Poynting 1909), viscous (Nikuradse 1933), and plastic field (Koenemann 2008). This is particularly relevant for geologists trying to understand mylonites. Any attempt to tackle simple shear with a theory that is older than the discovery of bonds is a waste of time. Mathematics and physics provided the full set of necessary conceptual tools (thermodynamics, vector algebra) starting in 1901. A realistic grasp of elastic and plastic deformation satisfying modern standards is plainly impossible without solid training in mathematics (differential equations, linear algebra, vector algebra, potential theory), physics (thermodynamics in scalar [P, V, T] and vector field form [f, r, T]), and material science.

10.01 Open Topic

The late Viséan Chemnitz fossil site – a Carboniferous locality full of surprises

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Besides the Early Permian Fossil Forest, for which Chemnitz is known in the palaeontological literature worldwide, temporary outcrops in the north of the city have yielded a rich fauna and flora from the late Early Carboniferous. 19th- and early 20th-century sandpits and a motorway construction site in the early 2000s allowed for insights into the Ortelsdorf and Berthelsdorf Formations of the Hainichen basin (330 ± 4 Ma for the upper Ortelsdorf Fm). Characterised by loose sandstones, thin coal seams, carbonatic siltstones and locally thick conglomerates with large boulders, these formations document frequent changes of braided-river, swamp and alluvial plain conditions. The sandstones preserve a diverse flora consisting of mosses, horsetails, ferns, seedferns, and lycophytes, a terrestrial arthropod assemblage comprising myriapods, trigonotarbid and phalangiotarbid arachnids, scorpions, and Arthropleura, aquatic arthropods and vertebrates including chondrichthyans, possible actinopterygians, sarcopterygians, and Germany‘s oldest tetrapod. Most remarkably, the chondrichthyan record involves two types of shark egg capsules – Fayolia sterzeliana and Palaeoxyris sp. – which in places occur on the same bedding plane, and a xenacanth cephalic spine that probably derives from the producer of the Fayolia capsule. No further remains belonging to xenacanths or hybodonts correlative with the Palaeoxyris capsules have been found so far. Nonetheless, the Chemnitz locality represents the oldest record of chondrichthyan egg capsules worldwide and the only site where two types of capsules not only co-occur in the section, but actually are found on the same surface, indicating nearly synchronous deposition by two different groups of producers in the vegetated nearshore area.

01.21 Advances in Geochronology: from tradition to avant-garde

LA-ICP-MS measurement of U-Pb isotopes in magnetite of the Münchberg Massif: evidence for the serpentinization age of mantle material within the Prasinit-Phyllite Serie

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The Münchberg Massif consists of four metamorphic nappes, which show different metamorphic grades in inverse order. The lowermost nappe, the Prasinit-Phyllite-Serie, is of lowest metamorphic grade (greenschist facies) containing mainly phyllites and greenschists with intercalated serpentinite bodies. Serpentinization, a water-rock reaction, can generate molecular hydrogen (H_2), a potential energy carrier. These serpentinites, however, have received limited attention.

Hydrogen is a molecule with very low diameter, which might escape after serpentinization. Understanding the timing and conditions of serpentinization is thus essential for evaluating the preservation and potential of natural hydrogen accumulations. As part of the Prasinit-Phyllite-Serie, serpentinization could have happened at different stages: in the mantle during subduction, during obduction, or during the different stages of the uplift of the Franconian Line. To relate the serpentinization to any of these stages, the age of the newly formed minerals, such as serpentinite or magnetite, is of importance. Therefore, magnetite and some serpentine were analysed by Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) for their U, Th and Pb isotopic composition to constrain the timing of serpentinization.

Although the content of U, Th and Pb was low, the results of these measurements show a defined age range, which lies in the range of the ages of the Prasinit-Phyllite-Series and the Randamphibolite, which are supposed to be part of the Rheic Ocean (Koglin et al. 2018). Such ages older than the main stage of the Variscan Orogeny also indicate a serpentinization and hydrogen formation in the mantle beneath the Rheic Ocean.

01.02 Anthropogenic geomorphology

Shaping Wetlands: 250 Years of Human Impact in Two Contrasting Landscapes – A Comparative Analysis of the Rhinluch Peatlands and the Lower Havel River Floodplain

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Floodplains and peatlands across Central Europe have long been subject to human transformation. From early drainage efforts to large-scale engineering projects in the modern era, anthropogenic interventions have altered their hydrology, morphology, and ecological functions. Yet the nature, intensity, and consequences of these changes vary widely depending on local geomorphological and hydrological conditions. Understanding these differences is essential for assessing the long-term impacts of land use on wetland ecosystems and their geomorphological development.

This talk presents a comparative study of land use changes over the past 250 years in two distinct wetland regions of northeastern Germany: the peat-rich Rhinluch and the fluvial Lower Havel floodplain. Both areas have experienced extensive human interventions, including peat extraction, river regulation, mill and canal construction, settlement expansion, and deforestation. By analysing old maps from multiple time periods, we trace the spatial and temporal development of land use changes and their varying impacts on landscape form, surface hydrology, and sediment pathways.

The comparison highlights how geomorphological settings shape both the trajectory and consequences of land use transformation. While palynological studies, confirm considerable human impact in both regions, the old map analysis shows that the nature and focus of interventions differ, reflecting the contrasting characteristics of fen and fluvial environments. This regional perspective underlines the value of old map analysis for reconstructing long-term anthropogenic influences on geomorphic processes.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Rhenium complexes in supercritical fluids: implications for Re fractionation in porphyry Cu-Au-Mo-W deposits

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Most of the world's rhenium (~ 90 %) is obtained from molybdenite (MoS_2) of porphyry copper deposits. The highest Re contents in MoS2 were observed in the Cu-type deposits with smaller values in Cu-Au, Cu-Mo and Mo-W types deposits (Barton et al., 2020). The goal of this study is to determine the mechanisms leading to such fractionations.

To assess the role of salt and sulfur in the behavior of Re and the accompanying metals in supercritical fluids, we combined thermodynamic modeling with solubility experiments in aqueous salt-sulfur solutions at 400°C and 550 bar in the presence of pH, fS_2 and fO_2 mineral buffers. We measured the solubility of major ore minerals ($CuFeS_2$, MoS_2, ReS_2 and Au) in such fluids and critically revised the speciation models for those metals.

Our data show that Au and Cu form complexes with (HS)– and Cl– whereas Mo forms oxyanions and their ion pairs with K^+ that is typical for other similar chemically "hard" metals like W (Borchert et al., 2025). Re in its common oxidation state $^{+4}$ is expected to be a chemically "soft" metal and is likely transported by Cl- and S-type complexes.

Finally, we will present first results of complementary ab initio molecular dynamics simulations of Re speciation in aqueous fluids with different ligands, (OH)–, (HS)– and Cl–, and discuss structural parameters and the geometry of the hydrated complexes in solution.

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01.15 Taping records of environmental and climatic changes throughout the Quaternary

On the Complexity of River Terrace Formation: A High-Resolution Luminescence Chronology from the Fault-Controlled Guadix-Baza Basin (SE Spain)

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River terraces are key archives of landscape evolution, shaped by the interplay of climatic, tectonic, and geomorphic processes. While often treated as regionally synchronous responses to glacial-interglacial cycles, growing evidence suggests that their formation can be far more complex and spatially variable. This study contributes to the broader understanding of terrace genesis by presenting new data from the Guadix-Baza Basin in southeastern Spain—a region marked by active faulting, significant elevation contrasts, and a long history of fluvial reorganization.

Initially a closed intramontane basin, Guadix-Baza evolved into an open drainage system during the Middle to Late Pleistocene due to river capture. This transition, combined with sustained neotectonic activity—especially along the Baza Fault system—led to the formation of multiple, spatially discontinuous terrace levels. Traditionally, terrace chronologies have relied on single-point dating approaches. In contrast, our study employs high-resolution luminescence dating across a wide range of sites to reconstruct the temporal structure of terrace development.

The results reveal a non-uniform fluvial response that cannot be attributed to simple climatic or tectonic forcing alone. Instead, terrace formation reflects a complex mosaic of local controls, including differential uplift, sediment supply, and basin morphology. Apparent chronological inconsistencies between sites can be reconciled within a stratigraphically and tectonically informed model of landscape evolution. Our findings underscore the necessity of integrating detailed field observations with robust geochronological frameworks to adequately capture the complexity of river terrace formation.

03.05 Advances in Paleoclimate Proxies and Their Applications

A multi-proxy approach to decipher global sea-level and ice-volume dynamics during late Cenozoic “snapshot” intervals based on benthic foraminiferal cal-cite from ODP site 849

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The response of ice sheets and sea level to a warming climate is of global concern, with significant implications for human populations. To better understand these dynamics, especially during climates warmer than today, this project reconstructs sea-level and ice-sheet variability across six glacial-interglacial (G-IG) cycles of the late Cenozoic (~5 Ma), spanning the transition from the Pliocene greenhouse to the Pleistocene icehouse.

We use paired measurements of benthic foraminiferal $\delta^{18}O$ and Mg/Ca ratios to reconstruct bottom-water temperature (BWT) and derive seawater $\delta^{18}O$ ($\delta^{18}O_sw$), a proxy for global ice volume. While effective for interglacials, the Mg/Ca proxy likely overestimates glacial lowstands due to non-thermal effects. To improve reconstructions, we integrate carbonate clumped isotope (Δ_{47}) thermometry, a seawater chemistry-independent BWT proxy, using material from Eastern Equatorial Pacific ODP Site 849. Though analytically demanding, Δ_{47} offers a critical calibration check for Mg/Ca-derived BWTs.

Preliminary paired $\delta^{18}O$-Mg/Ca data from Oridorsalis umbonatus (3.35–2.0 Ma) at sub-millennial resolution reveal G-IG sea-level cycles with glacial lowstands lower than previous estimates. Δ_{47}-BWTs, available at lower resolution, broadly support the Mg/Ca-based reconstructions, reinforcing their validity despite limited precision and resolution.

Future work will refine the understanding of discrepancies between Mg/Ca- and Δ_{47}-derived BWTs, improving glacial sea-level estimates. This study aims to constrain sea-level variability rates and assess existing reconstructions, offering a more robust understanding of past ice-volume dynamics and informing projections of future sea-level rise.

03.06 Multiscale characterization of structure, flow and transport dynamics in fractured porous media and karst systems

openKARST: Assessing flooding dynamics in karst aquifers with a resolution-aware modeling tool

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We present a newly developed flow and transport simulator for karst systems, designed to model complex flow dynamics and tracer transport in large-scale networks. Based on the Saint-Venant equations, the simulator integrates advanced hydraulic modeling and particle tracking to investigate how conduit geometry and network structure influence flow and transport behavior. It supports both steady-state and transient conditions, under free-surface and pressurized flow. Turbulence is modeled via the Darcy-Weisbach equation with classical friction formulations, and validation includes analytical solutions and the extensive Ox Bel Ha cave system.

Using 3D lidar-derived geometries, we build high-resolution network models to study how geometric simplification, through resolution reduction, affects flooding signals. Downscaling reduces the number of conduits and averages properties such as diameter and roughness, which can mute or eliminate bottlenecks that control flow and hydraulic gradients. This leads to a more homogenized flow regime, altering the timing, magnitude, and spatial distribution of flooding.

These findings have direct climate relevance. As extreme rainfall events intensify under climate change, understanding karst aquifer responses becomes critical for flood prediction and water resource management. Simplified models may underestimate the role of geometric complexity in buffering or amplifying flood signals. Our work highlights the trade-offs between computational efficiency and predictive accuracy, emphasizing the need for resolution-aware modeling when assessing climate-driven impacts on vulnerable karst systems.

01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

Basaltic glasses in the lower mantle: trace elements as markers of changes in local structure

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Silicate melts play a key role in Earth's evolution, influencing differentiation and planetary cooling. Understanding their formation and properties in the lower mantle is essential but remains directly directly inaccessible.

This work investigates structural changes in the coordination environment of strontium and yttrium in silicate glasses at high pressure. Laser-heated DAC experiments with X-ray absorption spectroscopy were performed at ID24, ESRF. Spectra were obtained for two simplified basaltic glass compositions of in the systems Albite-Diopside and Anorthite-Diopside. In the AbDi-glass, part of Si was replaced by Ge [1]. Both contained Sr and Y at various levels.

EXAFS analysis showed a two-stage pressure response for both elements: initial bond lengthening and coordination increase up to ~20 GPa, then bond shortening and densification. In both glasses, the change in the trend of the Y–-O and Sr–-O distances at ~20 GPa, coincides with the stabilization of higher coordination states (CN = 7 for Y, CN = 8 for Sr). Bond valence analysis of the determined bond lengths confirms the coordination transitions upon compression. The results are consistent with molecular dynamics simulations for Ca and Mg in basaltic melts [2] and experimental high-P data for Sr in aluminosilicate glass [1]. These coordination changes may affect crystal–melt partitioning at depth [3], e.g., during magma ocean crystallization or near the core–mantle boundary.

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03.07 Risks from a Changing Cryosphere

Hydro-thermal contaminant mobilization from thawing permafrost in Alaska

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Thawing of permafrost in Alaska increases the risk of contaminant mobilisation into sensitive ecosystems and communities. Analysis of a contaminant site database reveals over 1,200 active contaminated sites on permafrost in Alaska—30% of which are military installations, containing up to 36 different pollutants. Hydrocarbons are the most abundant contaminants, followed by polycyclic aromatic hydrocarbons (PAHs) and other organic compounds. Though smaller but highly toxic groups of metals and pesticides can also be found on permafrost contaminant locations. Although many contaminants are poorly soluble, 40% of sites lie within 1 km of rivers or lakes, and over 70 % within 1 km of the ocean—placing aquatic and coastal systems at risk.

Using the hydro-thermal model CryoGridLite, we simulate the future lateral contaminant mobilisation and hazard (CMPH) potential under SSP1-2.6 and SSP5-8.5 climate scenarios. We find that the Contamination mobilisation potential and hazard (CMPH) is projected to double by mid century, and possible triple by 2100 under high emission scenarios. While southern Alaska shows the highest absolute mobilisation due to deeper thaw, the coastal Northern regions see the largest increases in CMPH due to larger increases in active layer thickness.

This study provides novel insights into thaw-induced contaminant release. Communities, particularly Indigenous populations living near the coast and relying on local water and food sources, may face increasing exposure.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Dating of Quaternary archives: advancements and perspectives for understanding environmental change

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Establishing robust and precise chronologies is fundamental to understanding environmental and climatic dynamics throughout the Quaternary period. Over the past decades, geochronological techniques – such as trapped charge dating (luminescence and electron spin resonance), cosmogenic nuclides, among others – have greatly advanced in terms of precision, accuracy, and broader applicability. These methods now provide crucial insights into the timing, duration, frequency, and intensity of Earth surface processes across a wide variety of environmental and geological settings. Such insights are essential for disentangling complex Earth system interactions and for contextualizing present-day climate trends within long-term natural variability. This contribution will focus on the advancements and practical applications of dating techniques in Quaternary archives. Special attention will be given to the role of trapped charge dating methods applied to diverse climatic and geomorphic settings. By aligning different chronological frameworks, more coherent and reliable reconstructions of past environmental change and landscape evolution can be developed. Ultimately, improved temporal frameworks enhance our ability to understand the mechanisms, thresholds, and feedbacks driving environmental change. This contribution aims to highlight current challenges, emerging tools, and future directions in Quaternary geochronology from selected case studies, underlining its central role in geosciences.

01.10 The co-evolution of the Earth and life from the early Archean until today

Reconstructing Paleoarchean marine environments: insights from REE and combined Hf-Nd isotopes in banded iron formations from the Daitari Greenstone Belt, India

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Banded Iron Formations (BIFs) are Precambrian marine chemical sediments that can be used as prime geochemical archives to reconstruct Earth's early ocean chemistry. The ~3.4-billion-year-old BIF in the Daitari Greenstone Belt, India, is one of the oldest so far known BIF that has only experienced greenschist-facies metamorphism [1] and provides a great opportunity to reconstruct Paleoarchean marine environments.

This study presents new major and trace element data, along with Nd and Hf isotopic compositions from BIF of individual Fe- and Si-rich layers. Exceptionally low concentrations of immobile elements indicate that the BIF are remarkably pure chemical precipitates without significant detrital contamination. Most samples exhibit shale-normalized rare earth element and yttrium (REYSN) patterns characteristic of Archean seawater, including positive LaSN, EuSN, and GdSN anomalies, super-chondritic Y/Ho ratios, an absence of negative CeSN anomalies, and enrichment of heavy REYSN over light REYSN. These features point to an anoxic, open-ocean depositional setting influenced by high-temperature submarine hydrothermal activity. Most BIF samples plot on ^{176}Lu–^{176}Hf and ^{147}Sm–^{143}Nd reference lines between 3.3 and 3.5 Ga, consistent with geological evidence [1]. Initial εNd values range from +1.7 at 3.5 Ga to +3.0 at 3.3 Ga and suggest that mantle-derived sources influenced ancient Daitari seawater. Extremely radiogenic εHf values (from +33.9 to +11.4) reflect either isotopic disturbance or incongruent weathering of emerged continental crust similar to what is observed from the Neoarchean onwards [2].

References

[1] Hofmann et al., 2022, Earth Sci. Rev. 228.

[2] Viehmann et al., 2014, Geology 42.

01.10 The co-evolution of the Earth and life from the early Archean until today

Tracking the Rise of Superchondritic Zr/Hf in Banded Iron Formations: A Novel Redox Tracer?

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PAKULLA, JOSUA J. [2]
MÜNKER, CARSTEN [2]
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The modern oceans' Zr/Hf ratio (150–3001) is significantly fractionated from the chondritic value (34.42). This deviation is driven by the higher particle reactivity of Hf relative to Zr, resulting in preferential sorption onto (oxide)-particles in estuaries. The ratio increases from the coastline towards the open ocean, leading to variability between water masses1. The short residence time of Hf and Zr makes this ratio a powerful tracer for ocean circulation patterns and sources affecting seawater.

The Zr/Hf of ancient seawater is poorly understood, but has great potential to extend this proxy as a paleoceanographic tracer. Banded iron formations (BIFs) may have preserved the Zr/Hf of ancient seawater and could serve as a seawater archive. We present high-precision Zr-Hf data of Precambrian BIFs complemented by available literature data to test this proxy as a paleoceanographic water mass tracer.

Archean BIFs display near-chondritic Zr/Hf, while super-chondritic ratios in individual BIF layers first appear ~2.51 Ga. The locations' averages predominantly remain near-chondritic until ~2.0 Ga, whereas younger BIFs show mostly super-chondritic ratios. The shift from chondritic towards super-chondritic Zr/Hf ratios of BIFs records changing conditions throughout the Precambrian seawater affecting the fractionation of Zr and Hf. Potential causes include increased occurrence of (Fe)-Mn(oxide)-particles and enhanced riverine discharge. Regional differences among coeval formations suggest varying depositional settings and distinct water mass circulation in the Precambrian ocean. The Zr/Hf ratio measured in BIFs potentially traces the occurrence of Mn-oxides, hence, oxygenated water masses.

References

[1] Godfrey et al., 1996, GCA 60

[2] Weyer et al., 2002, Chem.Geo. 187

09.02 Museen als Fenster in der Forschung

Between the laboratory and the public – the Mineralogical Museum Jena as a mediator

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There has been a mineralogical collection at the Friedrich Schiller University Jena for almost 250 years. It already existed before the start of teaching geoscientific issues. Today, it is more in demand than ever as a mediator between research activities in laboratories and the public. The museum serves as a showcase and explainer of scientific issues by using not only text but objects and is accepted by people of all ages because there is a low inhibition threshold for contact with science.

The Chair of General and Applied Mineralogy in Jena conducts research into mineralogical issues such as mining waste, the composition and thermodynamic and crystallographic changes of minerals and rocks in oxidation zones of ore deposits and their secondary formations. These are topics that may also concern and engage the general public in their private lives.

In addition to a permanent exhibition area special exhibitions are continuously presented twice a year. These are usually directly linked to research fields of the chair and always present the results of projects; Bachelor's and Master's theses are also included where possible. Some of the most recent exhibition themes were: Radiant beauties (here the focus was on primary and secondary uranium mineralization), Not all that glitters is gold (here the focus was on gold deposits and use of gold or substitute materials), From the depths to the light (primary and secondary ore minerals were the topic) and Raw materials – from cell phones to e-cars.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Fan morphodynamics under varying climatic and topographic gradients of the Chilean Andean forearc

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Mohren, Joel [1]
Quezada, Andres [2]
Schwarze, Pablo [3,4]
Walk, Janek [5]
Lehmkuhl, Frank [1]
Braun, Jean [6,7]
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Dry conditions in the Atacama and Andean forearc region, prevailing since the early Miocene, vary across geographic gradients and pluvial episodes. Areas of northern Chile experienced inherently different surface processes (e.g. evaporitic, periglacial, glacial), influencing fluvial system evolution and sediment signal propagation. We compare five Chilean alluvial fan sub-environments of varying aridity to assess sedimentary signal preservation. These sub-environments include 1) the hyper-arid, debris flow-dominated Chilean coastal fans that are largely incising and Late Quaternary in age; 2) the hyper-arid core Atacama with Quaternary fans impacted by evaporitic processes and paleolake level alterations; 3) the megascale Precordillera fans that date back to the Miocene; 4) fans in the arid transition from the upper Rio Loa valley to the High Andes that show evidence of periglacial processes and volcanic events; 5) finally, the semi-arid fans on the Altiplano of the western Andes that show evidence of Pleistocene glacio-fluvial aggradation and interfingering with lake sediments in addition to periglacial and volcanic events.

To investigate signal propagation, we assess the timing of terminal fan surface aggradation through terrestrial cosmogenic nuclides and luminescence dating, while documenting landscape processes. We also explore stratigraphic fan architecture, through numerical landscape evolution modeling, sedimentary bedding analysis, and ground-penetrating radar (GPR). Using this multi-method approach, we aim to disentangle how climatic and tectonic drivers shape sediment production and propagation in Andean forearc fan evolution. Results are preliminary, following multiple field campaigns, the latest in March 2025.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Saxo-Thuringia meets Bavaria: Paleozoic facies types in the light of current knowledge

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In the Saxo-Thuringian Zone (SXZ) of the Variscides, the strict bipartite subdivision of Paleozoic marine sediments date to the beginning of the last Century. This proposition based on the observation that early Paleozoic lithologies (Bavarian facies; ba) associated with the Münchberg Gneiss Complex in the hanging wall differ significantly from underlying lithologies of the same age. Sediments of the foot wall were ascribed as the (par-)autochthonous Thuringian facies (th) of the former Saxo-Thuringian basin. In such a view, continuous sedimentation of both facies types prevailed until the early Carboniferous (Visean, ~330 Ma). Only the crystalline pile of Münchberg and associated nappes (ba) of the former distal part of the Saxo-Thuringian basin are regarded as northwestward overthrusted allochthonous units. However, such a bipartite model is not able to explain the complex architecture of the SXZ. For example, Early Carboniferous (>340 Ma) Paleozoic nappes in the Vogtland (th), the Nossen-Willsdruff- and the Elbtalschiefergebirge (th+ba) are discordantly overlain by Visean synorogenic sediments (ba+th). The long-lasting (Early Devonian-Carboniferous) accretionary tectonics in the Erzgebirge-Fichtelgebirge Complex (EFC) also precedes the proposed end of continuous sedimentation in the SXZ. Medium- to high-pressure metasedimentary nappes of the EFC exhibit the distinctive geochemical signature of early Ordovician siliciclastic rocks (th). After a concise review of the sedimentary record of the Saxo-Thuringian Zone, we present a tectono-sedimentary model explaining the spatial distribution of the sediments with the formation of the vast Peri-Gondwana shelf eventually followed by prolonged continental accretionary tectonics during the collision of Gondwana with Laurussia.

04.02 Lithium Rescources

Characterization of spodumene concentrates – Implications for traceability

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Lithium-ion batteries are an important high-tech technology for the electrification of the transport sector and the transition to renewable energies. Depending on the battery type, elements such as cobalt, nickel, manganese or phosphate are required in different amounts, but lithium is not interchangeable in all of them. The raw materials for the lithium in these batteries are derived from brines as well as from mineral resources such as spodumene pegmatites, which occur almost worldwide and are mainly mined commercially in Australia, Canada and Brazil. The spodumene mineral concentrates produced there are traded globally, as the chemical processing into lithium carbonate or lithium monohydroxide does not often take place in the country of mining.

In this study, spodumene concentrates of different origin were used to investigate which methods are suitable to distinguish between the various deposits. The spodumene samples were analysed by optical microscopy and EDS measurements to characterise microstructure, inclusions and intergrowths. For trace element contents solution ICP-MS and for lithium isotope ratio MC-ICP-MS analyses were carried out.

The intergrowth differs mainly with regard to the presence or absence of locally very complex spodumene-quartz associations. Geochemical results show differences between the concentrates especially for trace elements such as Nb, Fe, or Ga. The lithium isotope ratio (δ7Li) varies from -1 to about 11 ‰. The results show that it is possible to differentiate between spodumene concentrates based on geochemical, mineralogical, and isotopic parameters. Thus, our data contribute to lithium fingerprinting as a proof of origin in mineral value chains.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Value element distribution in the Sangerhäuser Kupferschiefer – Insights from old drill cores

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Driven by the Critical Raw Materials Act and the associated search for raw materials in Germany, old Kupferschiefer mining districts are gaining the interest of research and exploration again. In the former Sangerhäuser district, the Kupferschiefer dips to the south and is dissected by faults separating different tectonic blocks. Consequently, the depth of the Kupferschiefer varies from bedrock outcrops immediately south of the Harz mountains to about 1000 m depth. Access to new sample material is difficult as the old mining fields are no longer accessible and have largely been flooded, but archived drill cores from before the 1960s exist.

Here, we report on examined drill cores from bore holes distributed over approximately 160 km^2. The data are used in order to better understand the lateral and vertical element distribution of critical elements such as vanadium, molybdenum, cobalt, nickel, and copper within the Kupferschiefer-type mineralisation. The element concentrations were determined using a portable X-ray fluorescence analyser.

The analyses of the drill cores clearly show that the mineralisation extends from the Kupferschiefer (T1) into the underlying footwall sandstone and the hangingwall Zechstein carbonate above. Based on preliminary data, the highest contents of copper are commonly found in the uppermost part of the sandstone or in the lowest parts of the Kupferschiefer. In some cases, however, the highest metal contents occur in the Zechstein carbonate. While vanadium appears to be mainly bound to the Kupferschiefer itself, measurable contents (<50 µg/g) of cobalt and nickel correspond mainly with areas of copper mineralisation.

01.06 Tectonic Systems – TSK Open Session

Predicting locations of fissure eruptions at the Fagradalsfjall and Sundhnúkur Volcanic Systems, Iceland

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In 2021, a period of volcanic unrest began on the Reykjanes Peninsula (Iceland). To date, eight eruptions have taken place with durations ranging from one day to half a year. The cumulative eruption volume is about 400 x 106 m^3 and covers an area of about 46 km^2. The eruptions can be divided into the Fagradalsfjall eruptions, directly fed by a deep-seated reservoir, and the Sundhnúkur eruptions, where the uprising magma is temporarily stored in a sill.

Magma travels in dykes, and breaks its way through the rock as long as the fluid pressure exceeds the host-rock strength. The earthquakes reflect this fracturing. Together with the inflation of the sill, earthquake swarms serve as predictors for imminent eruptions in the study area.

All the eruptions have taken place in the very close vicinity of the fishing town of Grindavík. One eruption started in the area protected by dams. Under the premise that magma transport can be traced by the earthquakes, I am improving the accuracy with which the location of the eruption site can be predicted.

I apply a fully automated and thus unbiased algorithm. The algorithm detects the number of clusters and assigns earthquakes from the subsequent time windows, according their spatial distribution, to the clusters. It then analyses the geometric properties of the clusters, ranks them and finally determines a location that presents the most likely eruption site for each time window. Finally, I compare the results with real world data and determine the applicability of my approach.

10.01 Open Topic

Iceland’s sizzling secret – an unusual sedimentary rock?

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NGUYEN-THANH, LAN [3]
SCHLOEMER, STEFAN [1]
BLUMENBERG, MARTIN [1]
SVENSSON, KRISTOFF [4]
KRUMBHOLZ, JOHANNA [5]
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Sedimentary rocks are rare in Iceland's predominantly magmatic landscape. We analyse a sedimentary rock from NW Iceland that exhibits remarkable behaviour: it releases large amounts of gas while immediately decomposing upon contact with water. The sample is brown, fine-grained, and has a low density. At high microscopic magnification, a planar texture is visible. Previous analysis concluded that the rock is x-ray amorphous and does not contain swelling clay minerals that would explain its behaviour.

New XRD analysis reveals that the material consists to 70 wt. % of illite and to 20 % wt. of illite-smecite mixed layer. In addition, it contains goethite, quartz, and, as confirmed by infrared (FTIR) analysis, organic material. These results are complemented and supported by Inductively coupled plasma mass spectrometry and scanning electron microscope analysis.

µCT measurements show no significant pore volume above 1 µm. Most likely, the gas is not only trapped in pore space between the clay particles, but also in the interlayers of the interstratified phases (illite-smectite). One of two independent analyses of the gas released during decomposition shows significantly elevated CO_2 concentrations compared with air and we identified organic molecules that hint to oil and plants.

To understand if the extraordinarily rapid decomposition can be solely attributed to the clay content, we investigate further using a wide range of analytical methods, e.g., porosimetry measurements and surface area determination by gas adsorption. We also aim to gain inside into the geothermal history and organic petrography of the rock by applying a Rock-Eval pyrolysis.

01.20 Process oriented microfabric characterisation of geomaterials

Deformation microstructures in serpentinites from the Atlantis Massif Oceanic Core Complex

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Oceanic core complexes are a common feature along slow-spreading mid-ocean ridges. Serpentinized mantle rocks are exposed at the seafloor in the footwall to large-scale detachment faults. While it is likely that the exposed and rotated footwall has experienced deformation, it is unclear how internal footwall deformation is accommodated by the ultramafic rocks. One example of such an oceanic core complex is the Atlantis Massif at the Mid-Atlantic ridge (30° N) drilled by International Ocean Discovery Program (IODP) Expedition 399. Site U1601 provides the unique opportunity to understand any deformation recorded in serpentinized mantle rocks over >1.2 km depth.

To better understand the depth distribution of deformation and the associated deformation mechanisms, we combine microstructure and crystallographic preferred orientation (CPO) analysis by means of Scanning Electron Microscopy techniques, Micro-X-ray Fluorescence Mapping and synchrotron high energy X-ray diffraction. Results show variable microstructures ranging from zoned mesh cells with no CPO, to foliated samples with a strong CPO of both serpentine and magnetite, to serpentinite samples exhibiting deformation microstructures like kinking, faulting and dissolution-precipitation. The origin of characteristic microstructures and CPOs, whether formed due to serpentinization, deformation, or mutual interaction, will be discussed.

03.07 Risks from a Changing Cryosphere

Permafrost landscapes in a changing climate – Rockslides and Thermokarst along the Forkastningsfjellet coastline

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SCHÜßLER, NICK [1]
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Accelerated climate warming in Arctic latitudes is leading to permafrost degradation, which is accompanied by rapidly changing landscapes. Thawing permafrost and thus related thermokarst processes have significant impacts on local ecosystems and existing infrastructure. Likewise, thawing permafrost threatens Arctic communities by increasing slope instability and potentially correlated displacement waves. However, scarce observational data limits our understanding of deep-seated landslide development in connection with fast thawing permafrost and thermokarst.

Forkastningsfjellet is a rapidly changing coastal mountain range, situated along the eastern margin of Isfjorden, Svalbard, which is affected by such thermokarst activity and rockslide driven coastline changes. Over the past 8 years, we have been documenting accelerating surface deformation and thermo-erosive activity, which in turn led to subsurface drainage, sinkhole and tunnel formation that lowered the stability of the permafrost bedrock of the cliff. The most recent rockslide in November 2022 was promoted by thawing of formerly ice-filled cracks and increasing pore water pressures within the strongly fractured bedrock. Due to continuing head scarp retrogression and ongoing gully formation along pre-existing zones of weakness, cliff collapse will most likely continue.

In order to achieve a better understanding of the process rates and the associated mass transfer, we use integrated, cross-platform datasets (drone imagery, satellite data, surface temperature measurements and differential GPS) to analyse the process dynamics, quantify rates of cliff top retreat and the correlated surface mass transfer. Our results are of fundamental importance for the understanding of future engineering geological hazard scenarios in Arctic coastal regions.

01.07 Stratigraphy in Earth System Science: methods, applications and case studies

Multi-method characterisation of Neoproterozoic and Upper Cambrian–Lower Ordovician low-grade metasedimentary rocks from Saxo-Thuringia

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WILLBOLD, MATTHIAS [2]
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Recent studies on the oldest sedimentary units of Saxo-Thuringia, comprising Neoproterozoic greywackes and Upper Cambrian–Lower Ordovician siliciclastic rocks, have demonstrated the necessity of reassessing the stratigraphic affiliation of certain units. In this context, it was first revealed that some Ordovician units had previously been erroneously assigned a Neoproterozoic age. A multi-method approach was applied to develop specific differentiation criteria based on petrographic, (isoptope-)geochemical and detrital zircon characteristics, which enable reliable differentiation between these units. Compared to the immature greywackes, the Lower Palaeozoic units are distinguished by a considerably increased maturity, which is manifest petrographically through the absence of feldspar and an elevated quartz content. Geochemically, the increased maturity of Upper Cambrian–Lower Ordovician units is further reflected by higher SiO_2, accompanied by significantly lower Al_2O_3, Na and Ca contents. The Lower Palaeozoic units can also unequivocally be distinguished from the older greywackes in terms of isotope geochemistry, due to their significantly higher 87Rb/86Sr ratios of >4. These characteristics are derived from the intensive weathering phase occurring during the Cambrian Period, which led to the reworking and resedimentation of the Neoproterozoic clastic material. The youngest detrital zircon U–Pb ages established an Upper Cambrian–Lower Ordovician maximum age for the Clanzschwitz Group (North Saxon Block) and the Seidewitz Formation (Elbe Zone), contrary to the previously assumed Neoproterozoic age of sedimentation.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Grain growth in an olivine-melt system: Convergence of Experiments and phase-field modeling

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MARXER, FELIX [2]
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The application of phase-field modeling to geological systems enables a quantitative investigation of how various boundary conditions influence texture evolution. This may be used to reconstruct the timescales of non-equilibrium solidification in magmatic rocks (e.g. through the use of crystal size distributions, CSD, and diffusion chronometry). In this study, we developed a multi-component solidification model tailored for magmatic systems accommodating an unlimited number of crystals with varying orientations and anisotropies. Thermodynamic data from the MELTS database in combination with a surface anisotropy model (using surface energies from the literature) were used to model the growth of multi-faceted crystals.. Experiments as well as numerical models to study the coarsening of olivine crystals in a melt were carried out at a high constant undercooling (ΔT = 250 K at 1247 °C for annealing times of 1h, 4 h,18 h, and 72 h). Average growth rates and interface mobility in the experiments and models were consistent with each other for a coarsening behavior governed by equations of diffusion-controlled growth: d ≈ Mt1/3, where d is an average diameter of crystals and M is a kinetic coefficient. From the kinetic coefficient an average diffusion coefficient of components can be evaluated as D ≈ 2 x 10-10 m^2/s. This value is similar to diffusivities expected for divalent cations in many basaltic melts, and somewhat faster than the diffusion rates expected for network formers such as Si.

09.02 Museen als Fenster in die Forschung

Caldera Connections: Engaging the Public with the Story of South Tyrol's Supervolcano

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An integrated outreach initiative focusing on the South Tyrolean Supervolcano successfully increased public awareness of one of Earth's largest and least known volcanic systems, especially among younger audiences. Combining geological research from the "Living with the Supervolcano" and "Caldera" research projects with creative educational strategies, we developed Caldera – Spurensuche im Supervulkan, an interactive exhibition showcasing the dynamic relationship between the ancient volcano and its surrounding ecosystems. This exhibition later evolved into a travelling format, incorporating themes of sustainability to further enhance its educational reach and expanded to include school workshops and interactive programming. A series of short videos exploring the supervolcano, the exhibition process, and fossil research techniques broadened the outreach. Artistic collaborations—such as Forest Futurism and 6_VOCI—offered further ways to explore geological narratives through creative expression. As a lasting outcome a children's book blended storytelling with nine geologically themed excursions to inspire families to explore the region through a scientific lens. Our initiative demonstrates how interdisciplinary collaboration can transform complex geoscientific topics into accessible, meaningful, and memorable public experiences.

02.01 The Tethys Ocean – the cradle of modern tropical life

Terrestrial floras during the Carnian Pluvial Episode in the Northwestern Tethys

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The Carnian Pluvial Episode (CPE) has been identified as a time of plant radiation and origination of new lineages, likely related to rapid changes from xerophytic to more hygrophytic floras. Increasing humidity, causally resulting from large igneous province volcanism, is considered the likely trigger for the observed changes in terrestrial ecosystems. Understanding the cause and effects of the CPE on the plant realm requires the study of well-preserved floras that are precisely aligned with the CPE. Some of the most iconic Carnian floras are located in the Alps, laying during the CPE in the northwestern margin of the Tethys. This includes the famous Lunz locality (Northern Calcareous Alps) with the so far most diverse and rich plant fossil assemblages, as well as the Raibl plant fossil assemblages (Carnic Alps) and Dibona and Monte Pora (Southern Alps). These successions did not only yield the oldest fossiliferous amber worldwide. Integrated studies of palynomorphs and macro-remains reveal a variety of different plant fossil assemblages from highly diverse ones dominated by ferns and cycadophytes to plant fossil assemblages almost exclusively composed of conifers that show a mixture of predominantly late Palaeozoic (Majonicaceae, Voltziaceae), Mesozoic (Cheirolepidiaceae), and extant (Araucariaceae, Pinaceae, and Podocarpaceae) conifer families.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Connecting fracture filling geochemistry and migration paths in deep granitoid rocks from the Bukov Underground research facility (URF)

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The predictability of transport pathways in potential host rock formations for deep geological disposal of nuclear waste is crucial, as it helps to understand contaminant mobility and importantly, retention processes and the mechanistical understanding causing these reactions. This is currently being investigated at the BUKOV Underground Research Facility in the Czech Republic. In the recent study by Kuva et al. 2025, transport pathways were intensively analyzed using a drill core sample, with extraction approved by SÚRAO (Radioactive Waste Repository Authority).

Their analysis revealed that the core was overprinted by a complex network of fractures and veins, and the surrounding rock exhibited noticable variations in porosity. Revisiting those samples, this study focuses on the trace element enrichment within multiple carbonate infills to better understand the genesis and retention capacity of these migration paths. Trace element analysis was conducted using μXRF and LA-ICP-MS. Cluster analysis enabled the identification of several precipitation events. Comparisons of selected areas using SEM-CL and SEM-EBSD demonstrated that, in these samples, carbonate trace element incorporation is primarily influenced by fluctuations in the initial solution composition.

By comparing our findings with the characteristics of the fracture network, we traced some of the investigated transport paths, allowing us to connect geochemical observations with the structure of migration pathways.

Reference

Kuva, Jukka; Jooshaki, Mohammad; Jolis, Ester; Sammaljärvi, Juuso; Siitari-Kauppi, Marja; Jankovský, Filip et al. (2025): Characterizing heterogeneous rocks in 3D with a multimodal deep learning approach – Implications for transport simulations. In: Tomography of Materials and Structures 7, S. 100055. DOI:10.1016/j.tmater.2025.100055.

01.20 Process oriented microfabric characterisation of geomaterials

Contact metamorphism-related deformation mechanisms of radiolarites and skarns at the Monte Capanne pluton, Elba Island, Italy

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During Late Miocene magmatic activity, Elba Island was intruded by multiple magmatic complexes. In the north-eastern part of Western Elba, the rocks have undergone pyroxene hornfels metamorphism and ductile deformation due to the intrusion and following uplift of the 6.9 Ma Mt. Capanne monzogranitic pluton. Objectives of this study are preliminary detailed microfabric analyses of a metalimestone (diopside-bearing marble), a metacalc-silicate (wollastonite-bearing skarn) and a metachert from the contact aureole at the Spartaia and Paolina beach to present a first insight into the contact metamorphism-related deformation mechanisms. X-ray diffraction, electron backscatter diffraction, scanning electron and optical cathodoluminescence microscopy were applied, to quantify microstructures and crystallographic preferred orientations (textures). It was found that the metalimestones and metachert show significant microstructural deformation and strong texture that is correlated to the intrusion, uplift and exhumation of the Mt. Capanne pluton. The metalimestones show intensive simple shear deformation by grain shape preferred orientations, deformation bands, twinning, recrystallisation and textures. Some of the deformation features in the skarn cannot only be correlated to the intruding pluton but also to the metamorphic reactions by growth of the thermometamorphic mineral wollastonite. The very fine-grained metachert shows a polygonal microstructure and a homogenous texture throughout the fold hinge and limbs. From these first results, further detailed studies can be deduced and defining now a systematic sampling considering e.g. sample orientation related to folds, the metamorphic gradient within the contact aureole and non-metamorphic pendants in Eastern Elba to refine the metamorphic and deformation history at different scales.

01.10 The co-evolution of the Earth and life from the early Archean until today

New age constraints for the Volyn biota

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The Volyn biota from the Precambrian Korosten pluton (Western Ukraine) represents an exceptional assemblage of (micro)fossils. Their significance lies in the extraordinary three- dimensional preservation as well as their unique mode of occurrence – found at depth of ≥100 m within miarolitic vacuoles in granitic pegmatites. Previously, we arrived at a minimum age of ~1.5 Ga for the Volyn biota, (Franz et al. doi.org/10.5194/bg-20-1901-2023), which was challenged by Popov (doi.org/10.3390/geosciences13100297). Head et al. (doi.org/10.5194/bg-21-1773-2024) doubted the fossil nature of the Volyn biota.

While confident in the classification as genuine fossils, we acknowledged that our minimum age estimate relies solely on one mineral (muscovite) and one isotope system (40Ar/39Ar; Franz et al. doi.org/10.5194/bg-21-4119-2024) and hence demands validation. Here, we present new geochronology data based on *in situ* Rb/Sr dating of igneous alkalifeldspar and Li-mica, post-igneous muscovite and hydrothermal buddingtonite together with *in situ* U/Pb dating of black opal (with organic matter). The latter acts as a cement within the pegmatites and therefore represents the latest mineral formation (see poster in session 01.21 Advances in Geochronology).

The Li-mica confirmed the previously known igneous event of ~1.7 Ga and records a hydrothermal event at ~1.5 Ga. The muscovite Rb-Sr data is in agreement with the previous 40Ar/39Ar age. Buddingtonite, which did not yield reliable 40Ar/39Ar ages, gave a reliable Rb/Sr isochron at ~520 Ma. Alkalifeldspar recorded the igneous event and several hydrothermal events at ~1.5 Ga, ~500 Ma, and ~200 Ma). Opal records the latter event and a Jurassic overprint at ~160 Ma.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Tracing provenances of Quaternary dust deposits in dammed valleys (vegas) on Lanzarote

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On Lanzarote (eastern Canary Islands), several valleys were dammed by volcanic activity during the Quaternary, creating closed sedimentary basins locally known as “vegas”. Since their formation, these basins have acted as natural sediment traps, preserving layered sequences of aeolian dust, volcanic material, and colluvial slope deposits. The sediments are characterized by an alternation of pale carbonate-enriched layers (PCLs) and reddish clay-enriched layers (RCLs), reflecting cyclic sedimentation patterns.

In this study, we apply principal component analysis (PCA) to geochemical (XRF) and mineralogical (XRD) data to differentiate sediment sources and assess the provenances of dust inputs. The PCA results show a clear geochemical and mineralogical pattern within the profiles, enabling interpretations of sediment origins and depositional dynamics. PC1 separates silty, quartz- and Zr-dominated dust from clay-rich inputs, linked to kaolinite, and basalt-derived material enriched in Fe, Ni, and Zn. These local materials are also separated from V and Rb by PC2. The distinct clustering of quartz, kaolinite, and K-feldspar points to contributions from multiple North African dust source areas. This geostatistical approach provide the basis for further investigating dust source areas and linking the findings to regional palaeoclimatic developments across the Canary–North Africa domain.

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

Deep learning approaches to trace fossil analysis

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Trace fossils are direct records of organism activity and are often abundant where body fossils are absent. Because the responsible tracemaker taxon often cannot be identified, trace fossils are named and classified in an independent parataxonomy called ichnotaxonomy. In vertebrate track ichnotaxonomy, only morphological features related to anatomy should be used, although behaviour, substrate properties and preservation also contribute to the shape of the track. Because of these multiple sources of variation, and the continuous rather than discrete nature of morphological features, ichnotaxonomy involves many subjective decisions that make rigorous quantitative analyses difficult.

Deep learning is a promising approach to the study of trace fossils and can be used to independently test ichnotaxonomy and its conclusions. Here I present a novel similarity learning approach where different models are trained on dinosaur tracks of the same morphotype and locality, modern bird tracks of known species, and/or synthetic data, with the aim of autonomously learning anatomically relevant features. New tracks can be plotted based on these features, revealing clusters that are conceptually similar to, but independent of, traditional ichnotaxa. The models suggest widespread oversplitting of dinosaur ichnotaxa and major inconsistencies in ichnotaxa definitions. They confirm that the dinosaurian ichnofauna of East Asia differs significantly from that of Europe and North America in the Lower Cretaceous. However, this difference does not appear to result from a geographic isolation of East Asia, as commonly assumed, but from the absence of an ecomorphotype in Europe and North America.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Evaluation of clinopyroxene-based thermobarometers for tholeiitic arc systems using experimental data and application to Mutnovsky volcano (Kamchatka)

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To date, reconstructing temperature and pressure conditions in magmatic systems remains challenging. Commonly used tools, such as thermobarometers, often suffer from imprecise underlying calibration datasets and erroneous application to natural samples resulting in significant uncertainties on obtained results. This study uses phase equilibria experiments on a primitive arc tholeiitic basalt from the Mutnovsky volcano in Kamchatka to evaluate the performance of different clinopyroxene-based thermobarometers in calc-alkaline and tholeiitic arc systems. Common application errors were evaluated using an improved analytical protocol for EPMA measurements (e.g. improving statistical errors by accounting for the number of individual measurement points which are averaged for P-T calculations, selecting matrix-matching calibration and reference standards, and investigating the occurrence of beam damage). Errors introduced during data processing were accounted for via clinopyroxene component calculations and measurements of H_2O contents of coexisting silicate glasses. Our results demonstrate that the performance of commonly-used clinopyroxene-based thermobarometers can substantially be improved by thoroughly addressing analytical and application-related uncertainties.

Subsequently, we applied our refined analytical approach to natural samples from Mutnovsky volcano. Calculated temperatures of clinopyroxene crystallization during pre-eruptive magma storage range from 1310 °C to 1440 °C and pressures from 0 to 500 MPa. Pressure estimates are in alignment with previous studies postulating a shallow magma chamber at ~1.5-3 km depth (≈ 40-80 MPa), although showing a distinctively higher variability. In contrast, temperatures are overestimated by the clinopyroxene-based thermobarometers as previous studies report onset of clinopyroxene crystallization around 1000 °C indicating a potential systematical error of the applied thermobarometers.

01.20 Process oriented microfabric characterisation of geomaterials

Importance of folding for the elastic anisotropy of foliated rocks in the NW-Tauern Window (Eastern Alps, Austria)

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Most rocks show direction-dependent seismic wave velocities, which are largely controlled by the content and CPO (crystallographic preferred orientation) of elastically anisotropic minerals, especially phyllosilicates. In order to unravel the effect of complex structural features like folding, re-folding and the scale difference between seismic experiments and lab measurements, we investigate polyphasely deformed phyllosilicate-rich samples from the NW-Tauern Window. Based on anisotropy and modeled seismic velocity data we evaluate the effect of folding and hence upscaling to a larger scale.

The CPO of millimeter-thick foliated sample cylinders was measured using high energy X-ray diffraction at the German and European Synchrotron Facilities (DESY, ESRF). Folding structures were quantified from thin sections, drill cores and field data. CPOs were then synthetically folded and weighted based on observed and hypothetical geometries. Overall seismic velocities were computed using µXRF-based modal composition, single crystal stiffness tensors and folding-derived CPOs and considered to be representative up to kilometer-scales.

Folding and crenulation reduce the Vp-anisotropy by approximately 40% at interlimb angles of 60° and 45°, respectively. Polyphase folding around parallel fold axes shows only a slight further reduction. Re-folding at distinctly different fold axis orientations leads to an elastic anisotropy reduction up to 80%. In our samples, only wide interlimb angles of >120° occur that reduce the Vp anisotropy by <20%. Shear wave splitting results in a reduction of <30%. Hence, folding may have a significant effect on the elastic anisotropy of foliated rocks and can be crucial for any interpretation of seismic data.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Reconstructing the past as a glimpse into a (potential) future: The impact of glacigenic processes on the long-term safety of radioactive waste repositories

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Long-term safety assessments for a deep geological repository for highly radioactive waste require evaluating potential future geological and climatic developments over the next one million years. Therefore, the impact of potential future cold stages and glaciations on the geological barrier needs to be considered. The glaciation of a repository site is likely to have the largest effect; however, repository sites located outside the maximum ice-sheet extent may also be affected. Relevant processes with potentially large impacts that can reach repository-relevant depths include glacigenic erosion, ice-load induced deformation, and permafrost formation. A sound understanding of the processes during past glaciations is key to assessing the potential impact of future glaciations, which may serve as analogues. We present examples from current case studies that use reconstructions and numerical modelling of Pleistocene processes to support long-term safety assessments. The first case study focuses on the incision of Pleistocene tunnel valleys in northern Germany. Based on zones of similar depth, the potential for future subglacial erosion is assessed (Breuer et al. 2023). The distribution and orientation of tunnel valleys are compared to the regional structural framework to understand the geological control on subglacial incision (Lang et al. 2025). The second case study presents a numerical model of the response of salt structures to ice-sheet loading (Lang & Hampel 2023), offering new insights into the controlling factors of ice-salt interactions.

References

Breuer et al. (2023) DOI: *https://doi.org/10.5194/egqsj-72-113-2023*

Lang & Hampel (2023) DOI: *https://doi.org/10.1007/s00531-023-02295-5*

Lang et al. (2025) DOI: *https://doi.org/10.1111/bor.12694*

06.04 Stressors in Hydrogeology: Interactions and Impacts

Old drainage tunnels – new, innovative water reservoirs? Hydrogeological investigations and modeling for a potential analysis

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Mineral resources and water have been uniquely interwoven in the Harz Mountains region. For centuries, the waters of the Harz powered mine drainage systems and were channeled through an ingenious network of drainage tunnels. Today, the Harz region has great importance for supra-regional drinking water supply. With climate change, extreme hydro-meteorological events are putting increasing pressure on existing water infrastructures. The Ernst-August-Stollen (EAS), a 40 km long drainage tunnel in the Upper Harz, offers potential for underground storage and other water management uses. In the EAGruMo project (Ernst-August-Grubenwassermonitoring) we aim to assess this potential by understanding the hydrogeological system of the EAS, estimating water residence times in the Paleozoic fractured aquifers, and quantifying water flow rates. Methodologically, we employ stable water isotopes, conduct tracer tests, and perform hydrological investigations (field studies, modeling) to gain a deeper process understanding of water dynamics. These hydrogeological investigations are complemented by the continuous monitoring of water quality and quantity, in order to evaluate the suitability of the tunnel system for water management uses, taking into account local geological and hydraulic conditions. The insights will not only benefit the Harz region but can serve as a model for other post-mining regions facing similar water management challenges under changing climatic conditions.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

Potential to reconstruct paleoenvironmental changes using lake sediments from Lago della Maddalena, northern Maritime Alps

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High-mountain regions are highly sensitive to climate change, but there is limited understanding on how landscapes will respond to climate and land-use change, e.g., land abandonment due to rural-urban migration. In our study, we explore the potential of using lake sediments of Lago della Maddalena to serve as a high-resolution archive of Late Holocene paleoenvironmental changes. The study site is located at ~1974 m a.s.l. in the northern Maritime Alps (Italy), a climatically sensitive transition zone between Mediterranean and continental influences. The lake provides a valuable sedimentary record for identifying naturally and anthropogenically induced environmental dynamics in grazing-induced treeline settings. We aim to identify distinct sedimentary environments, material sources, and underlying patterns.

A multi-proxy approach was applied to two short sediment cores using visual lithofacies descriptions, C/N, macrocharcoal analysis, and micro-XRF core scanning. Principal component and cluster analyses of centered log-ratio transformed XRF data revealed four distinct geochemical units, indicating shifts in sediment provenance and depositional processes. The sediment composition suggests alternating phases of increased clastic input and carbonate-rich conditions. C/N ratio points to a predominance of terrestrial organic matter. Low charcoal content suggests that fire plays a minor role in the catchment area.

We discuss challenges of disentangling proxy data from broader paleoenvironmental signals, especially in contexts where climate, land-use, and geological processes interact. This work provides a methodological basis for future studies seeking to better resolve the timing and drivers of ongoing environmental change in the southwestern Alps.

10.01 Open Topic

Extinct detritivorous mites and a bradytelic bristly millipede together frozen in time.

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Fossiliferous tree resin, known as amber resin, is a unique material that offers the rare opportunity to observe organisms from deep time, sometimes preserved in exceptional quality. Thanks to the quick encapsulation of the animals, it facilitates the unique preservation of past ecological interactions, offering a glimpse into how past ecosystems looked like up to 100 million years ago. We here investigated a syninclusion preserved in Eocene Baltic amber (~40 mya) in which two astigmatan mite specimens and a bristly millipede were fossilised in close proximity. The two mites are identified to be adult representatives of Glaesacarus rhombeus, one of them female. This is a species of mites that is frequently found in Baltic and Rovno amber, considered to be now extinct. The bristly millipede is also a female adult, identified as a representative of Polyxenus, exhibiting remarkable morphological similarities to the extant species Polyxenus lagurus; indicating that they have probably been thriving since the Eocene. This syninclusion provides an interesting interaction, with one of the mites seemingly surrounded by the defensive setae of the millipede, but it also provides clues on the shared microhabitat of these two groups in Eocene forests. The striking persistence of morphological traits in representatives of Polyxenus over 40 million years suggests a stable ecological niche and effective adaptive strategies, highlighting the evolutionary stability, resilience, and long-term success of the group. Although the two lineages here represented used to share the same habitat in deep time, despite being commonly entrapped, they displayed different evolutionary trajectories.

02.01 The Tethys Ocean – the cradle of modern tropical life

Palynological insights into the Carnian Pluvial Episode (CPE) in Switzerland

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The Carnian Pluvial Episode (CPE), dated to 234-232 Ma, marks a major climatic disruption during the Late Triassic, interrupting the prevailing arid conditions in the paleotropics with increased humidity. The CPE coincided with key evolutionary events in the marine and terrestrial realms. In the Central European Basin, this shift is recorded by a rise in siliciclastic sedimentation, notably in the Ergolz Member ('Schilfsandstein') of the Klettgau Formation. We present palynological and bulk organic carbon isotope data from the Bözberg core, in northern Switzerland. Palynological data indicate an organic matter input predominantly of terrestrial origin, with well-preserved assemblages. Althought spore diversity is low, sporomorphs offer valuable insights into regional paleoenvironmental changes. Qualitative and quantitative analyses reveal a shift from xerophytic to hygrophytic assembalges, accompanied by an increase in spore abundance, suppporting evidence for changing climatic conditions during the CPE in this region. A notable feature is the occurence of Aulisporites astigmosus, a taxon associated with humid intervals during the CPE in Tethyan records (Baranyi et al., 2018).

Reference

Baranyi, V., Miller, S. V., Ruffell, A., Hounslow, W., M. & Kürschner, M. W. 2018: A continental record of the Carnian Pluvial Episode (CPE) from the Mercia Mudstone Group (UK): palynology and climatic implications, Journal of the Geological Society, 176, 149-166.

07.02 Geothermal energy – Potential and utilisation of geothermal energy resources for the heat transition

Understanding controls on temperature anomalies in the Wörth area of the Upper Rhine Graben by integrating static and dynamic data at the regional scales

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The Upper Rhine Graben (URG), located in southwestern Germany, is well-known for its exceptional geothermal potential. As part of the European Cenozoic Rift System, it is characterized by complex fault-fracture networks that facilitate deep fluid flow leading to zones of pronounced heat anomaly, with geothermal gradients up to 100 °C/km. The geothermal site Wörth am Rhein of URG is an important target for deep geothermal energy production due to its high subsurface temperatures (> 160 °C) in the sedimentary aquifers as Muschelkalk and/or Buntsandstein, which can be used for industrial heating purposes. This type of geothermal play system is catalogued as non-magmatic, convection-dominated, fault-controlled. Recently published work suggests that the URG is characterized by large confined convection cells associated with hydraulically active fault zones.

Therefore, it is of paramount importance to understand, on a regional scale, the main factors and mechanisms that control the distribution of the thermal field in this type of geothermal play. Hence, in order to minimize the associated exploration risks, it is necessary to develop 2D/3D thermal-hydraulic (TH) models on a regional scale that combine existing static and dynamic data with robust numerical modeling following a stepwise complication approach. This integrated procedure provides valuable insights into the geothermal potential of the Wörth area and provides a framework for similar studies in other geothermal regions with similar geological settings. The results of this work contribute to the development of more efficient and sustainable geothermal energy development strategies and support the transition to renewable energy sources.

04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

Analysis of the mechanical properties of agglomerates produced under alternating conditions for the reuse of by-products from metallurgical processes

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By-products such as slag, sludge and fine dust from various iron and steel industries and foundries have high value due to their potential to recover iron and iron oxides as metallic iron, which can reduce the amount of waste sent to landfills and environmental pollution. In this study, different fine dusts and sludge were processed into agglomerates using a suitable reductant and formed via stamp pressing under varying contents and conditions. Instead of cement-based binders, biogenic alternatives such as potato starch, wheat starch and molasses oil were employed, and their influence on the mechanical properties of the agglomerates was examined, with the main emphasis on the cold compressive strength. Additionally, various amounts of fibrous materials were added to improve mechanical performance.

To optimize the mechanical properties, multiple recipes were systematically tested under different compaction pressures, binder compositions and curing conditions. The influence of fibre content and pressing parameters as well as curing time and temperature was evaluated to identify optimal combinations. The results show that biogenic binders, especially starch-based ones, in combination with fibre additives and an optimised curing, significantly enhanced the cold compressive strength of the agglomerates. The findings contribute to the development of sustainable, high-performance agglomerates suitable for industrial reuse and lay the foundation for further upscaling and application in metallurgical processes.

10.01 Open Paleontology Session

(Re)discovery of an echinoderm fossil lagerstätte in the Lower Devonian of the Precordillera of the Andes, Argentina

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While prospecting in the foothills of the Andes in 1894, near San José de Jáchal (San Juan Province, Argentina), German palaeontologist Wilhelm [Guillermo] Bodenbender discovered a rich fauna of Early Devonian echinoderms at a place called Quebrada de las Aguaditas, after an earthquake. Despite some preliminary notes (Kayser 1897, Ruedemann 1916), it was not described in detail until a century later (Haude 1995), revealing a particularly diverse and remarkably well-preserved assemblage, including asteroids, crinoids, holothurians, ophiuroids and stylophorans. Despite several field campaigns, Bodenbender's original site has not been found. However, the exploitation of equivalent levels in a neighbouring locality (Loma de los Piojos) has yielded very abundant and comparable faunas, perfectly stratigraphically calibrated (upper part of the Talacasto Formation, Upper Lochkovian to Lower Emsian; Wenger et al. 2025). The exceptional preservation of numerous complete and articulated echinoderm remains indicates rapid burial, probably linked to storm/obrution deposits. This interpretation has recently been confirmed by sedimentological and ichnological analysis of the Loma de los Piojos section (Wenger et al. 2025). The echinoderms of the Talacasto Formation show strong affinities with other high-latitude peri-Gondwanan assemblages (Malvinocaffre Province), particularly with those found in South Africa and Brazil, but also with faunas from more distant regions, such as Australia.

01.02 Anthropogenic geomorphology

Geomorphological footprint in the Anthropocene: Landform transformation as a driver of changed process-response characteristics

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Pastoralism and agriculture are one of the main drivers of land cover change and affect various components by influencing the process-response characteristics of ecological and geomorphological systems. Agrarian societies established in different ecozones at different times. Phases of increased human impact in Europe are the Greco-Roman period and the late Middle Ages. Significant land cover changes on a global scale established with the onset of colonialism. The extent of global human impact increased during the industrialization and accelerated rapidly after the WW II. The transformation of landforms was paralleled by interferences into most geomorphological systems. The rapid growth of the population and of urban areas resulted in an increasing need of raw materials and in the need to transport large quantities of materials. These interferences were associated with the extension of complex infrastructural measures. Particularly noteworthy in this context are interferences into the fluvial system such as measures for navigability and flood protection along rivers such as those along the Rhine River, but also changes of landforms due to mining and the diversion of rivers which resulted in new unforeseen hazards during extreme rainfall events such as the Ahr and Inde River flooding in July 2021. The examples show that human interferences on landforms and environment are acting largely through the areal extent of land use, infrastructure, urbanization, industrialization and mining and by the acceleration and modification of geomorphic processes which in turn result in multifold feedback loops and complex response in different geomorphic systems.

01.25 Geochemical Databases and Data Analysis Tools

Standing on Shaky Grounds: On the Resilience of Geochemical Databases

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Geochemists today can look back on 25 years of online access to large-scale, global geochemical databases that have inspired and supported hundreds of scientific studies, generating new knowledge, and even leading to entirely new methods of geochemical data analytics that were not possible in times when individual researchers needed to spend years to compile their comprehensive syntheses of literature data. Geochemical databases provide easy access to millions of geochemical measurements for the global research community, but they do not come for free. They require dedicated, stable funding that supports the human and technical infrastructure to operate reliable, trusted data services in the long term. Currently, these databases are funded through research grants from federal agencies. Grants needs to be recompeted every 3 to 5 years and may not be renewed. Funding gaps are possible (and have happened), generating substantial challenges for uninterrupted maintenance and access of the geochemical databases

Long-term sustainability of databases such as PetDB/EarthChem and GEOROC/DIGIS is a problem that the geochemistry community needs to address jointly and on a global scale to ensure future availability of what has become a fundamental research infrastructure. An alliance of international geochemical data providers and members of the OneGeochemistry initiative (*https://onegeochemistry.org*) recently issued a Call to Action to engage the community broadly – researchers, scientific societies, research institutions, data providers – to develop a shared vision and agree on a roadmap for sustainable access to geochemical data. This presentation will provide an overview and updates the campaign to ensure access to geochemical data.

06.01-b Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

EarthChem & Astromat: Aligning Research Data Infrastructure for Samples from the Deep Earth to Outer Space

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PROFETA, LUCY
MAYS, JENNIFER
JI, PENG
DANNINGER, GRIFFIN
CELNICK, MOLLIE
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The data facilities EarthChem and Astromat (Astromaterials Data System) deliver similar but distinct services for the curation and management of laboratory analytical data generated by the study of material samples. EarthChem, developed and operated since 2006 with funding from the US NSF, focuses on geochemical data of terrestrial samples, while Astromat – started in 2019 with NASA funding – is NASA's primary archive for astromaterials samples data. Both facilities operate data repositories that curate, publish, and preserve sample-based data and maintain synthesis databases that aggregate and harmonize published data into 'science-ready' collections that enable large-scale data analytics.

While the two data facilities differ in scope and funding level, there is wide overlap in the requirements for and design of system architecture, metadata schemas, vocabularies, data curation workflows, policies, and functionality of software applications leading to substantial synergies and economies of scale in the operation of the data systems. The development of the Astromat Data Archive and the Astromat Synthesis has provided an opportunity to modernize EarthChem's system architecture and software ecosystem. Astromat's new cloud-based repository platform, the new architecture of the synthesis database, and the design of user interfaces were adopted and adapted for EarthChem. New curation workflows and tools are also shared by both systems. Metadata schemas and vocabularies are kept in sync to the degree possible, advancing consistent data best practices and standards in geochemistry more broadly. Common data curation procedures and policies make it easier to maintain compliance with repository standards and obtain certification by CoreTrustSeal.

01.07 Stratigraphy in Earth System Science: methods, applications and case studies

A Baltoscandian view of the biotic radiations related to the Darriwilian shift into the Ordovician icehouse

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STOUGE, SVEND [5]
LINDSKOG, ANDERS [6]
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ZHANG, ZHUTONG [7,8]
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Geoscientists documented the Great Ordovician Biodiversification Event (GOBE) within various clades. This has led to a discussion of mechanisms controlling the ecosystem changes that pushed a distinct Darriwilian peak in global biodiversity. A complex interplay of factors such as the highest dispersal of continental plates and the largest tropical shelf areas during the Palaeozoic, a very intense volcanic activity, extra-terrestrial dust input related to an asteroid breakup (L-chondrite parent body, LCPB), increased faunal interactions and competition in complex ecosystems presumably played a major role. However, scientists widely agree that global climate cooling was probably the major trigger for the GOBE.

Our high resolution $\delta^{18}O$ and $\delta^{13}C$ study together with a bed-by-bed appraisal of conodont species richness in the Hällekis quarry at Kinnekulle (southern Sweden), displays a rising curve up through the Lenodus antivariabilis conodont zone (CZ). This is followed by a peak in the lowermost Lenodus variabilis CZ a plateau and a two-phased drop in richness in the upper variabilis CZ. Our $\delta^{18}O$ record supports the results of a microfacies-derived sea level curve, indicating that the studied interval was mainly deposited during colder climates. The richness plateau and extinction pulse occurred when sea level was at its lowest. The suggestion that the LCPB disruption caused an enhanced flux of micro-meteorites to Earth around 467 Ma, triggering climate cooling and intensifying the GOBE, is heavily debated since the inferred LCPB level occurs within an overall period of cooling.

07.02 Geothermal energy — Potential and utilisation of geothermal energy resources for the heat transition

Geothermal exploration in Göttingen: 20 Years of multi-horizon targets and implementation barriers

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Göttingen is located at the eastern margin of the of N-S trending Leinetal Graben, which developed within ~ 1500 m of Permian-Mesozoic cover rocks. Potential geothermal horizons for heat extraction and/or storage in medium-depth geothermal systems include Zechstein salt and dolomite layers, Middle Buntsandstein strata, and karstified Muschelkalk carbonates. Strategies for the geothermal exploitation of the meta-sedimentary rocks of the Variscan fold-and-thrust belt, which are expected to underlie the sedimentary cover, have been developed based on analogue studies in the Harz Mountains.

A multi-target approach is proposed for Göttingen, integrating both shallow and medium-deep geothermal systems, in coordination with existing surface heating and cooling infrastructure. Feasibility studies to date have relied primarily on detailed geological surface maps and two intersecting seismic lines, approximately 10 and 11 km in length, recorded in 2015. These seismic profiles supplement the very limited well data available for the sedimentary cover. The geological interpretation of the seismic data remains highly uncertain, however, because of the scarcity of well data, significant lithological thickness variations within the graben, and intense faulting and halokinesis in its central part. A scientific exploration well is essential as the next step to reduce exploration risk, particularly in terms of economic feasibility. Simultaneously, only optimally designed transformation strategies for energy supply and surface infrastructure will enable the successful implementation of multiple geothermal systems.

01.06 Tectonic Systems – TSK Open Session

Tectono-topographic response to stress changes induced by aseismic ridge subduction: Insights from analytical and 2-D finite element models

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The subduction of aseismic oceanic ridges at convergent plate margins causes a reduction in submarine margin relief, which alters the balance of topographic and tectonic stresses. The stress changes increase the compression of the upper plate and may hence be relevant for understanding surface uplift and mountain building in response to ridge subduction. However, the detailed effects of relief changes and other parameters affecting the upper-plate force balance at subduction zones remain to be explored. Here we use analytical and two-dimensional finite-element models to investigate the effects of relief changes and additional parameters that may change during ridge subduction, including the initial trench depth, the slab dip angle, the slab curvature, and the submarine surface slope angle.

Our modeling results show that the compression caused by a decrease in submarine margin relief depends not only on the total relief change but also on the initial trench depth before ridge subduction and the geometry of the subducting slab. In addition, changes in the submarine surface slope angle during ridge subduction alter the compression of the upper-plate and may affect the total amount of surface uplift. Additional finite-element models with a setup of adjusted to the subduction of the Cocos Ridge (Central America) indicate that surface uplift in response to a reduction in submarine margin relief explains up to 50 % of the high topography in Costa Rica.

01.10 The co-evolution of the Earth and life from the early Archean until today

Micro- and nanoscale observations on anhydrite formation at surface conditions

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The evolution of hyper-arid surface environments on Earth and Mars is strongly linked to the occurrence of three calcium sulfates minerals: gypsum ($CaSO4 \cdot 2H_2O$), bassanite ($CaSO4 \cdot 0.5H_2O$), and anhydrite ($CaSO4$) [1,2]. While the formation mechanism of the first, gypsum, is well understood, though do the crystallisation pathway and the required (paleo-)environmental conditions for the formation of the water-free sulfate, anhydrite, still depict a conundrum.

To date, there exists no model that can reliably predict how anhydrite forms at earth's surface conditions. While thermodynamics favour its occurrence, it is hardly achieved on laboratory time scales at conditions fitting either the Atacama Desert on Earth or the surface of Mars.

Considering recent transmission electron microscopy findings [3] advocating for a complex, non-classical nucleation mechanism for all calcium sulfates, we present analyses of natural samples from different facies of the Atacama Desert, i.e. aeolian deposits, (sub-)surface nodules and selenites, to identify key features that promote the nucleation and growth of anhydrite under planetary surface conditions.

Additionally, alternative pathways for anhydrite nucleation facilitated by metabolic products of biological organisms (e.g. fungi, lichen, cyanobacteria) found in soils of the Atacama [4] will be discussed.

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01.20 Process oriented microfabric characterisation of geomaterials

A microstructural record of brittle-ductile clinopyroxene deformation in the lower crust

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In the mafic lower crust, clinopyroxene and plagioclase are among the main rock-forming minerals. Both are considered to be strong and to deform by brittle mechanisms at dry lower crustal conditions. However, at fluid-present high-pressure conditions both are highly reactive, transforming to omphacite, (clino-)zoisite and garnet, thus forming weaker eclogite.

Recent studies have focussed on plagioclase breakdown reactions and their effect on rock weakening. However, field observations on Holsnøy, Norway, indicate ductile deformation of coarse-grained clinopyroxene in the mafic lower crust, reflected by bending of the granulitic foliation. This study focusses on the strain accommodating processes of the granulitic clinopyroxene at an early stage of eclogitisation. Representative samples of deformed weakly eclogitised granulite were analysed using scanning electron microscope, electron back-scattered diffraction, and electron probe micro analysis.

Microstructural analysis revealed the formation of garnet-lamellae along the clinopyroxene-cleavage. Initial bending of this anisotropic clinopyroxene is accommodated by the development of micro-en-echelon cracks at a high angle to the cleavage. Micro-cracks are traced by garnet with similar composition as the lamellae, suggesting that both formed at identical conditions. With ongoing strain, cracks start to link and evolve into micro-shear zones, systematically widening with strain. This leads to the nucleation of amphibole and a second clinopyroxene with higher magnesium-concentration, facilitating further macroscopic bending of the clinopyroxene. Late static eclogitic overprint suggests that micro-shear zones form at an early deformation stage. Our investigations show the complex interplay of brittle and ductile processes on a microscopic scale during macroscopically ductile flow.

03.05 Advances in Paleoclimate Proxies and Their Applications

Changes in the diversity of the Paleogene greenhouse vegetation at the southern edge of the proto-North Sea

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The Paleogene succession of the Helmstedt Lignite Mining District in Northern Germany includes records of coastal peat mires from the latest Paleocene to the middle Eocene. Due to an interaction between changes in sea level, salt withdrawal in the subsurface and climate-related changes in runoff from the hinterland the area was subject to frequent changes between marine and terrestrial conditions, including peat formation. In an almost continuous section, the effects of long-term changes and short-term perturbations of the climate on the diversity and composition of plant communities can be traced by using pollen and spores as proxies. High-resolution C-isotope analyses allowed for precisely locating important short- and long-term climate events within the lower Eocene greenhouse, such as the Paleocene Eocene Thermal Maximum (PETM) and the Early Eocene Climatic Optimum (EECO). Here we present high-resolution palynological data from the lower Eocene Schöningen Formation at Schöningen to compare the wetland vegetation before, during and after these events. The focus is on the identification of short-term pulses versus long-term sustainable changes in composition and diversity of the vegetation. However, a climatic influence and the corresponding response of the ecosystems cannot simply be revealed from the microflora as documented in the studied succession. When interpreting the palynomorph record it is necessary to distinguish between changes in the vegetation that were controlled by climate or those controlled by other factors such as, for example, natural succession due to peat aggradation.

Plenary Lecture: Martin Lercher "Night Science: the creative side of the scientific process"

Night Science: the creative side of the scientific process

LERCHER, MARTIN

Heinrich Heine University, Germany

The formal scientific method tells you how to rigorously and objectively test a hypothesis. But where do hypotheses come from in the first place? Posing fruitful new questions, generating ideas for novel hypotheses, and devising innovative experimental technologies all require scientific creativity. Compared to the executive “day science” process, the creative “Night Science” process requires a different mindset. It builds on a different set of thinking tools, such as an open mindset, anthropomorphic language, embracing contradictions, and importing ideas across fields.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

Integrating Quantitative Provanance Analysis and Geomorphology to Unveil Controls on Sediment Generation and Flux in Hillslope Catchments

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Quantitative Provenance Analysis (QPA) and Geomorphology provide complementary yet traditionally decoupled insights into sediment generation. QPA reconstructs lithological sources from detrital compositions, while geomorphology quantifies sediment erosion, transport pathways and morphometric controls. Their integration defines Sediment Generation as an emerging process-based discipline that seeks to quantify how sediments with specific compositional and textural properties are produced from source rocks under variable tectonic, climatic and morphodynamic conditions.

Studies of tectonically active catchments in Colombia and southern Italy reveal that sediment production and flux is nonlineraly controlled by both lithological properties, such as erodibility and textural inheritance, and morphometric parameters like slope, structural connectivity and sediment routing potential. Weathering rates and both steady-state and episodic erosional processes like landsliding and rock falls, controlled by hillslope morphology, directly affect sediment compositions including bulk geochemistry, clay mineralogy and geochemistry, sand petrography and detrital geochronology.

Numerical integration of morphometric parameters and derived indices, such as the index of connectivity and global erodibility index, with basic sediment generation models based on endmember mixing enables the quantification of lithological and morphometric controls. The relative contributions of heterogeneous parent rocks to sand, silt and clay grain sizes are primarily governed by lithological characteristics. However, these controls may be overridden by morphometric features and local drainage configuration.

The interdisciplinary QPA-geomorphology approach permits high-resolution sediment budgets, advances predictive sediment modeling, and redefines our understanding of anthropogenic disruptions such as deforestation and hydroelectric damming. It further offers a critical advancement for unraveling source-to-sink dynamics in both recent and ancient sedimentary systems.

07.02 Geothermal energy – Potential and utilisation of geothermal energy resources for the heat transition

The Bavarian Petrophysics-Database

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POLEDNIA, JOANA
SCHUH, MAX
SÁNCHEZ-LEÓN, EMILIO
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The Bavarian Geological Survey is developing a comprehensive petrophysical database for characterization of the underground potential. It includes thermal, hydraulic, elasto-mechanical, and electromagnetic rock properties, from samples from our drill core repository, containing more than 90,000 m core/cuttings material.

A standardized internal lab workflow allows for the determination of several parameters in a single sample, including thermal conductivity and diffusivity (under dry and saturated conditions), bulk and grain density, porosity, and magnetic susceptibility. Selected samples are further analyzed for ultrasonic velocities, uniaxial compression, mineralogy (XRD), and geochemistry (XRF).

Currently, the database features over 6,500 samples from 70 drill cores, representing more than 280 geological (sub-)units and 70 lithological types described with different levels of detail and ranging from 0.2 to 5,400 m depth. All data must fulfill five minimum criteria and are georeferenced for 3D geological modeling at different scales. For these models, two distinct data generalization approaches are used: a “Top-to-Bottom” approach for rapid estimation using medians for lithologies and geological units, and a “Bottom-to-Top” weighted averaging, which accounts for the lithological/geological heterogeneity of each model layer.

The database plays a key role in current LfU projects, especially in geothermal reservoir modelling in the Bavarian Molasse basin. Its usage extends to research on CO_2 capture and storage, search for a radioactive waste repository, as well as hydrogen production and storage. Public data access to this database via the “UmweltAtlas Bayern” online platform is under development in accordance with the German law (Geologiedatengesetz, 2020).

01.21 Advances in Geochronology: from tradition to avant-garde

In-situ Rb-Sr dating using LA-MC-ICP-MS/MS: the effect of YO+ and ZrO+ interferences and their correction.

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The ^{87}Rb-^{87}Sr system is a versatile chronological tool and geochemical tracer. Unlike Rb-Sr measurements by thermal ionization mass spectrometry, *in-situ* laser ablation (LA) mass spectrometry offers high sample throughput and minimizes sample destruction. This method, however, is compromised by the presence of multiple isobaric interferences on Sr isotopes. This problem can be overcome using multi-collector inductively-coupled-plasma mass spectrometers (MC-ICP-MS) equipped with the recently developed pre-cell mass filter and collision/reaction cell (CRC), such as the Thermo ScientificTM NeomaTM MS/MS-MC-ICP-MS. This instrument allows the simultaneous measurements of on-mass and mass-shifted Rb and Sr isotopes using SF6 reaction-gas [1–4]. Here we show, however, that for Y- and Zr-bearing phases, $^{89}Y^{16}O^{+}$, $^{90}Zr^{16}O^{+}$, and 91Zr16O+ can form in the CRC, when O_2/H_2O enters the CRC either from impurities in the reaction gas or molecules that formed in the plasma. These oxides interfere with ^{86}SrF+, 87SrFy, and ^{88}SrF+, respectively, and cause systematic errors on measured ^{87}Rb/^{86}Sr and ^{87}Sr/^{86}Sr ratios. To correct for these effects, we synthesized glasses, doped with Rb, Sr, Y and Zr. The glasses can be used to correct for YO^{+}- and ZrO^{+}-induced systematic errors on measured ^{87}Rb/^{86}Sr and ^{87}Sr/^{86}Sr ratios. The effects of these interferences and their correction, using our synthesized glasses, on *in-situ* Rb-Sr dating using LA-MC-ICP-MS/MS will be discussed at the meeting.

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[4] Huang et al. (2025), Spectrochim. Acta B 224, 107117

10.01 Open Paleontology Session

Soldier beetle larvae are much more common in the fossil record than previously anticipated

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Solider beetles (Cantharidae) are relatively well known in the fossil record. Yet, not many fossil larvae of this group have been reported, despite the importance of this developmental phase. The larval phase of solider beetles is different from that of many other beetles, as in some species the early larvae ("pre-larvae") differ from the later larvae. Therefore, the development of Cantharidae is possibly associated to hypermetamorphosis, a developmental pattern with early larvae being different in morphology and fulfilling different ecological functions than the later larvae. This type of differentiation between life stages has been thought to be a driving force in the evolution of beetles and other holometabolans (wasps, butterflies, etc.). Details of the evolution of this developmental pattern should therefore be informative for improving our understanding of evolutionary response to ecological selective pressures, and fossils could provide details for a well-resolved reconstruction. Unfortunately, so far only three fossil larvae of Cantharidae have been reported. Here we add 44 new specimens from Baltic and Kachin (Myanmar/Burma) amber and one new adult specimen in Baltic amber. Together with fossil and extant specimens from the literature we assembled a dataset of over 300 specimens, immatures and adults. Shape analyses and measurements were performed to investigate the change over time (evolution) of the change over time (ontogeny) on a quantitative level. Our results indicate a higher diversity of extant forms of Cantharidae, but also fossil morphologies could be recognised that are absent in the modern-day fauna, indicating certain losses of diversity.

10.01 Open Topic

New click beetle larvae from about 100 million years ago and possible niche differentiation of predatory larvae in the past

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Reports of beetle larvae in amber are relatively rare, compared to the size of the group Coleoptera. Yet, to understand an ecosystem such larvae are quite important, due to their long interaction time with the environment, their enormous biomass, and their highly diverse morphologies coupled to myriads of ecological functions. We here report 16 new fossil beetle larvae of Elateridae, the group of click beetles, preserved in Cretaceous Kachin amber (Myanmar/Burma). The morphology of the new specimens stands out by the head having a prominent fronto-clypeus dorsally and the mouthparts forming a special maxillo-labial complex. The posterior end of the specimens bears paired projections and a prominent anal opening ventrally. The morphology of the larvae, especially of the toothed sickle-shaped mandibles, indicates a predatory lifestyle. We performed a quantitative comparison of the newly reported fossil beetle larvae and fossil and extant lacewing larvae using a shape analysis. The latter seem to have occurred in the same habitat and both appear to have been predatory. The lacewing larvae seem to have been quite dominating, possibly competing with the beetle larvae for resources. Our results indicate a morphological and also ecological differentiation between the two groups. This outcome shows how functions in a shared habitat can differ in animals of similar size. Furthermore, we discuss the functional aspects of mandibles and stylets (special mouthparts of lacewings) and compare them between the new fossil beetle larvae and the fossil larvae of lacewings.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

From Field to Future: How Out-of-Classroom Experiences Shape Geoscience Trajectories

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Black, Alan
Hu, Shunfu
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The availability of geological science courses in secondary and tertiary education is inconsistent across the world. This is leading to decreasing enrollment in the geosciences in universities, the closure of geology departments in universities facing budgetary crises, and subsequent shortages in qualified workers for some geoscience industries. To counter this decline, schools and universities without a formal degree program in geosciences can develop and offer out-of-classroom learning experiences that showcase the field of geosciences and the range of potential careers. We developed and studied an extracurricular program that provided geoscience research experiences, field excursions, technical training, and career seminars to a group of 22 early undergraduate students at a university that lacks departments of geological, marine, or atmospheric sciences. The program ran for multiple years, with students having the option to participate in the activities that best fit their schedule and interests. We interviewed individual students at multiple times during the program using questions that examined how the program was shaping the students' education and career goals. Transcribed interviews were coded to examine program influence on learning and geoscience career motivation. A key finding was that meaningful relationships—both peer-to-peer and with faculty mentors—boosted students' confidence in pursuing geoscience careers. This research identifies evidence-based strategies for crafting immersive experiences that deepen student connection to geosciences beyond traditional classroom boundaries.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Metal (re)distribution in and around the Kupferschiefer-type mineralization, Röhrigschacht Wettelrode (Saxony-Anhalt)

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The Kupferschiefer-type mineralisation of the Southern Permian basin in Poland and Germany represents the largest base metal mineralisation and resource in Europe. Outstanding scientific questions still to be solved include the spatial zoning of metals within some of the deposits and the mineralogical host phases of specific trace elements (e.g. Co, Se, Mo, V) that had been extracted in the past and still contribute to the economic potential of the mineralisation. This study investigates samples associated with the Kupferschiefer-type mineralisation of the Rotliegend sandstone, the basal black shale (T1) of the Zechstein, and Zechstein carbonates. The three lithotypes were continuously sampled along vertical profiles from underground exposures in the Röhrigschacht of the Sangerhausen mining district. Thin sections of the samples were examined by µXRF to obtain element distribution maps. Mineral assemblages and ore textures were determined by reflected light microscopy, BSE-imaging and EDS. The investigations confirm the classical base metal zoning from bottom to top: copper-lead-zinc, typical for the Sangerhausen district, but also reveal anomalous elemental distributions that deviate from expected patterns. In addition to common sulfide minerals (e.g., pyrite, chalcopyrite, bornite, galena, sphalerite), Pb- and Cu-chloride minerals of presently unclear origin were identified as carriers of value trace metals. Moreover, mineralised faults and the brittle-ductile deformation of ore minerals indicate the post-ore tectonic influence of the Upper Cretaceous Harz mountains uplift affecting the Wettelrode deposit. These findings provide new insights into the mineralogical complexity and the metallogenic processes of the Kupferschiefer-type mineralisation.

08.01 Young Scientist Session

Spatial patterns of surface temperature are controlled by soil physical properties across geomorphological units in a European alpine meadow.

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Understanding drivers of spatial patterns in soil surface temperature is essential to assess ecosystem vulnerability to climate change, particularly in alpine landscapes characterized by pronounced microclimatic heterogeneity that arise from complex topography, elevation gradients, and pedogenic processes. However, the role of underlying soil properties in modulating surface temperature dynamics remains poorly understood. This study investigates diurnal and nocturnal surface temperature patterns across geomorphological units in a European alpine meadow, emphasizing the roles of soil chemical and physical properties.

An intensive three-day field campaign was conducted in July 2024 near Pansier in the French Alps. Surface and subsurface soil temperature and moisture were recorded at 24 locations across five geomorphological units defined based on their solar radiation input and slope position: moraine ridge, moraine slope, alluvial plain, scree footslope, and scree slope. Soil profiles down to ~40 cm were sampled and analyzed for physical properties such as texture, bulk density, rock fragment content, and chemical properties such has soil organic carbon (SOC), total nitrogen (TN), and soil pH.

Distinct surface temperature patterns emerged for each geomorphological unit, with scree slopes exhibiting notable nocturnal variability and pronounced warming. Overall temperature patterns were associated with soil physical properties, especially sand and rock fragment content, rather than chemical properties. This finding was reinforced by the limited improvement in predictive models when chemical properties were included. Our study suggests soil physical properties play a dominant role in regulating surface thermal behavior in European alpine landscapes, and therefore should be preferentially considered in microclimate-based vulnerability assessments.

06.01-b Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

One platform cannot solve everything: FID GEO's Collaborative Approach to Open Science

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The Fachinformationsdienst für Geowissenschaften (FID GEO) is a DFG funded initiative that has been supporting the geoscience community for nearly a decade. It provides publication services through its partner domain repositories GFZ Data Services (for research data and software) and GEO-LEOe-docs (for text publications). FID GEO promotes digital transformation and Open Science practices through workshops, publications, conference contributions and engagement in thematic events. Its activities are aligned with international developments, striving to synchronize national progress with global standards and best practices for data management and distribution. Collaboration is a cornerstone of FID GEO's work.

For many years, researchers have expressed a strong desire for a 'single source' platform to manage growing datasets, publications and projects. And yet, the complexity of existing infrastructures is often overwhelming. A one-size-fits-all solution is neither technically feasible nor sustainably maintainable. Instead, widespread implementations of machine-readable (meta)data standards offer a path forward, enabling links between distributed data systems and the persistent identification of authors and institutions. Competing infrastructures, limited funding, and overlapping goals further complicate the landscape. FID GEO addresses these challenges through collaboration and guidance, helping researchers navigate this complex landscape and demonstrating practical ways to make scientific outputs visible, reusable and aligned with the FAIR and Open Science principles.

This presentation will share best practices, lessons learned, and future directions for fostering a collaborative and open research environment. FID GEO envisions a geoscience community empowered by shared data and collaborative infrastructures, better equipped to address pressing global challenges.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

The transition from miaskitic to agpaitic magmas – case study Serra de Monchique, Portugal

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The peralkaline F-rich igneous pluton of the Serra de Monchique complex in southern Portugal shows various REE- and HFSE-bearing mineral assemblages in variously evolved and hydrothermally overprinted rock units. Based on mineral compositions and field relations, the differentiation history of the complex will be elucidated with special focus on partitioning of halogens, REEs and HFSEs.

The complex consists of two main units: an inner core unit of homogeneous nepheline to sodalite syenite and an outer roof unit of heterogeneous nepheline and sodalite to quartz-(monzo)syenites and breccias. Faults separate the two main units. The complex is crosscut by lamprophyric and phonolitic dyke rocks.

Alkali feldspar, nepheline and sodalite are the dominant felsic minerals in all units. Plagioclase occurs sparsely. Clinopyroxene following the diopside-aegirine trend (Di80Hd12Ae05 – Di02Hd09Ae89) is the dominant mafic mineral together with biotite, locally occurring amphibole, magnetite and ilmenite. Titanite (up to 0.158 LREE3+ apfu) and fluorapatite (Fap49Hap47Clap04 – Fap100Hap0Clap0 with up to 0.664 LREE3+ apfu) occur as accessory phases throughout the complex, whereas fluorite and zircon occur as traces. Late magmatic phases include HFSE-bearing silicates of the wöhlerite- and rinkite-groups, documenting a transition from miaskitic to agpaitic phase assemblages during differentiation.

Alteration by hydrothermal fluids affected the whole complex. Aqueous fluids resulted in significant growth of zeolites, carbonate-bearing fluids formed calcite and cancrinite, mostly at the expense of nepheline. Breakdown of HFSE- and F-bearing silicates by carbonate-bearing fluids led to the growth of secondary fluorite, calcite and zircon, whereas breakdown of titanite caused formation of calcite and anatase.

01.12 Coastal dynamics in different timescales: from seconds to millennia

3D Mesh Analysis of Coastal Boulder Deposits in Southern Peloponnese: Investigation of a Possible Tsunamigenic Origin

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Coastal boulder deposits (CBD) along the Greek coastlines have long been considered indicators of past extreme-wave events, such as tsunamis. In this study, we aim to refine previous volume and mass estimates of CBD and reassess their possible tsunamigenic origin. To achieve this, CBDs were analyzed using advanced calculations for hydrodynamic conditions, that not solely focus on masses, but include LiDAR-scanned geometrical shapes and variations of coefficients that rely on their physical properties.

Therefore, we studied CDB near the Bay of Vatika by using built-in smartphone LiDAR sensors. In combination with rock density analysis, their masses were obtained. The CBD are distributed along a ~600 m-long coastal stretch. The largest boulders (≥38 t) are located on bedrock near the shore. Smaller boulders (>100 kg) are located up to ~200 m inland, partly embedded in sandy sediments and covered by vegetation, and were found up to 6-7m above sea level. It is indicated that the sandy sediments underneath boulders were transported as suspended load and deposited alongside them. Orientations of >330 measured CDB's longest axes dominated in NNW-SSE direction. Rock pools indicate overturning during transport, imbrications and accumulations in clusters indicate extreme-wave events as transport mode. OSL analysis is intended to provide a chronology and confirm prior age estimations for the CBDs (~910–1150 yrs. BP).

With reference to the existing literature, we found that former volume analyses on CBDs in the study areas significantly overestimated the masses, thus we provide new data to refine calculated wave parameters and tsunami wave heights.

02.01 The Tethys Ocean – the cradle of modern tropical life

Crickites – investigation of a unique extinction taxon of Palaeozoic goniatites (Ammonoidea)

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The extraordinary genus Crickites is chronologically restricted to the uppermost Frasnian (Upper Devonian, UD I–L), occurring exclusively during the Upper Kellwasser Crisis, often in large numbers and with remarkable body size (> 40 cm). Morphological features place it within the Gephuroceratidae, distinguished particularly by its characteristic suture with a high ventrolateral saddle. Unlike most other representatives of this family, which exhibit biconvex growth lines, Crickites – along with its much thinner sister genus Clauseniceras – is characterized by exclusively convex growth lines. Additionally, the conch is unusually wide and becomes progressively wider through ontogeny. Crickites ranks among the largest known ammonoids of the Devonian, thriving during a time of severe ecological changes now recognized as one of the major mass extinction events in Earth's history. This apparent paradox of a global spreading followed by rapid extinction, raises significant evolutionary and palaeoecological questions. The genus shows a wide distribution, from Cr. lindneri in the Canning Basin (NW Australia), to Cr. holzapfeli in the Rhenish Mountains (Germany), and supposed Cr. rickardi in the Appalachians (North America). A major challenge, however true for all gephuroceratids, is the unresolved taxonomy and systematic classification. Contributing factors include a historically fragmented and inconsistent research history, the loss of type material, and the lack of precise diagnoses. To date, it remains unclear how many and which species are validly assigned to Crickites. Therefore, this study provides the first comprehensive revision of this important yet poorly understood fossil group.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Geoscientific characterization of flat bedded rock salt as part of the German Repository Site Selection Act – Part II “Thuringian Basin”

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According to the Repository Site Selection Act (Standortauswahlgesetz – StandAG), the German Site Selection Procedure is an iterative process and consists of three phases with increasing levels of detail in which the assessed area is continuously reduced during the process. Starting with an empty, so-called “white map of Germany,” BGE (implementer of the German Site Selection Procedure) completed Step 1 of Phase I in September 2020 with the submission of the Sub-areas Interim Report (BGE 2020/88), where BGE identified 90 individual sub-areas (in claystone, rock salt, and crystalline rock).

In Step 2 of Phase I, BGE aims to localize siting regions within the 90 sub-areas by applying preliminary safety assessments and other scientific criteria. Within the preliminary safety assessments, subsurface data are interpreted and the results documented. The workflow comprises the detailed characterization and interpretation with a focus on the host rock formation that acts as the main geological barrier but also considers the surrounding rock formations.

Part II of this contribution describes the integration of different data for a geological interpretation of individual criteria in the preliminary safety assessments using the Zechstein rocks salts of the Thuringian Basin as an example. The assessment of the spatial geometry (thickness of the main geological barrier and minimum depth) as well as the internal configuration of the rock salt are important features that were combined in the categorizations for the Thuringian Basin, which were published as a preliminary working status in 2024.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Centennial provenance variability during the last glacial maximum revealed by heavy mineral analysis of loess deposits

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Loess-Paleosol-Sequences (LPS) are important sedimentary archives that enable to infer climatological parameters during the Quaternary at high temporal resolution. Three isochronous, central European LPS sites were investigated by means of heavy mineral, single-grain sedimentary provenance analysis using an automated, correlative workflow guided by machine learning. The goals of this study are [1] to investigate if regional differences exists between the LPS in terms of heavy mineral composition [2] if local sources can be disentangled from regional ones and [3] if short-lived processes affecting the source-to-sink system are detectable.

The LPS compose a transect from SW to NE Germany. Synchronicity was controlled by presence of the Eltville tephra (ca. 23.2 – 25.6 ka) and/or precise OSL age modeling, confirming sedimentation during the last glacial maximum.

120 silt-sized heavy mineral aliquots were analyzed by microscopy, Raman-spectroscopy and electron microprobe, resulting in a correlated dataset of grain parameters (size, roundness, color, etc.), mineralogy and chemical composition for each grain analyzed.

First results show that the LPS are differentiated based on heavy mineral composition, supporting a Southern, Alpine and Northern, Fennoscandian provenance. Heavy mineral ratios and garnet chemistry reveal abrupt, centennial changes in the Southern and Northern LPS. This points to re-organization of the sediment routing system in the Rhine flood plain at the Southern site. While at the Northern site the advancement of the Scandinavian Ice Sheet probably perturbs the westerlies resulting in short-lived phases of increased deflation from the East.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Joint Research Data Infrastructures to foster interoperability and future sample retrieval

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Until very recently, the word "archive" has often been associated with the connotation of a dark, dusty storage room with odd objects poorly maintained. Changing this perception and transforming an archive into a vivid, well-curated collection of samples for research, is a worthwhile effort that increases the value of each sample.

The Helmholtz Centres GEOMAR and Alfred Wegener Institute jointly develop research data infrastructure to keep track of the physical objects AND their associated data, using the open-source system LinkAhead. It hosts metadata of various sample types, such as biological and geological samples, taken at sea, on land and during ice expeditions. It ensures the unique identification of each sample and allows registration of persistant identifiers e.g. International Generic Sample Number IGSN as DOI via DataCite. Other export options serve for publications, to provide metadata to overarching platforms like the Marine Data Portal, and a link to the Nagoya documentation. Furthermore, a sample storage management with individual loan requests and lending documentation is incorporated.

In both Institutes, the database tool is in use as separate instances but with a common kernel, to allow for close collaboration and future joint developments. With these services to Earth and Environment researchers, we expand the F.A.I.R. data principles to the original physical material – make samples findable and facilitate their reuse – and want to encourage other dusty old archives to join the future of Geosciences.

04.07 Mineralogy of Secondary Raw Materials

Weathering products of scheelite and wolframite as a function of environmental pH

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Tungsten is considered to be inert to weathering and benign if released to the environment. The main tungsten ore minerals, scheelite and wolframite, seem to be weathering very slowly or not at all. In our research in the oxidation zone of the Ochtiná W-Mo deposit (eastern Slovakia), we observe complete weathering of the W minerals and release of W into the environment as a function of pH. The primary ores consist of quartz, pyrite, scheelite, and wolframite. The secondary minerals are iron oxides, identified as goethite by Raman spectroscopy. Some of the iron oxides have the morphology typical of schwertmannite. These Fe oxides contain 0-5 wt.% WO3 and are products of weathering of the primary W minerals under mildly acidic conditions. Their textures change if the primary mineral was pyrite, wolframite, or scheelite. High porosity in the weathered W minerals suggest release of material, especially of W, into water percolating through the oxidation zone. X-ray absorption spectroscopy shows that W is adsorbed on the Fe oxides. In some samples, the weathering assemblage includes tungstite, hydrotungstite, W-bearing jarosite, goyazite, and baryte. Among these minerals, especially jarosite is an indicator of strongly acidic conditions. The occurrence of either Fe oxides or W oxides can be rationalized by calculation of their solubility curves as a function of pH. The solubility of Fe oxides attains its minimum at circumneutral conditions whereas that of the W oxides in strongly acidic media. This study explains the behavior of W in mining waste.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

The role of the seismic time model in the verification of depth modelling approaches in the North German Basin (TUNB Velo 2.0)

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JAHNKE, CHRISTOPH
OBST, KARSTEN

Geological Survey of Mecklenburg-Western Pomerania

As part of the TUNB Velo 2.0 project, a new seismic model in the time domain was developed for the northeastern part of the North German Basin – as a supplement to the existing depth model of Mecklenburg-Western Pomerania (Obst et al. 2024). The time model is based on interpreted and reinterpreted 2D seismic profiles from the 1960s to 1990s and opens up new possibilities for identifying structural features that were less pronounced at depth due to the inhomogeneity of the velocity field as well as the presence of salt bodies and fault zones with potentially anomalous velocities.

Since existing archive data was mainly used to build both models, primary data that was not available for deep modelling could also be taken into account for time modelling in some areas. The subsequent comparison and mutual conversion between time and depth models based on a harmonized 3D velocity field enabled us to check and to refine the existing depth model.

The time model therefore proved to be not only an intermediate step in the modelling process, but also an independent instrument for validation and regional analysis that significantly improves the reliability of geological reconstructions in the basin. In addition, this methodological approach can also serve as a practical tool for quality assurance of geological models in other regions with heterogeneous data.

Reference

Obst, K., Brandes, J., Matting, S., Wojatschke, J. & Deutschmann, A. (2024): Das 3D-Untergrundmodell des Landes Mecklenburg-Vorpommern: Datengrundlagen, Modellierungsergebnisse und Anwendungsmöglichkeiten. – SDGG 100: 59-92. DOI: 10.1127/sdgg/100/2024/59

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Vanadium Enrichment and Exsolution Microtextures in Fe-Ti Oxides from Mafic Intrusions in Québec, Canada

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Magmatic Fe-Ti oxide deposits are an important source of Vanadium, yet the mechanisms controlling V enrichment and redistribution remain debated. This study investigates vanadium-bearing titanomagnetite from two contrasting mafic intrusions in Québec, Canada: the layered Lac Doré Complex and the massif-type Lac Saint Jean Anorthositic Suite.

Both intrusions reveal complex lamellar exsolution textures, including trellis-, sandwich- and cloth-textured ilmenite intergrowths. These structures reflect two distinct exsolution pathways that operated under different thermal and redox conditions. Coarse ilmenite lamellae with trellis and sandwich intergrowths formed through high-temperature oxy-exsolution under super-solvus conditions, where magnetite became progressively oxidized. In contrast, subsolvus re-equilibration at lower temperatures produced typically cloth-textured ulvöspinel, which was subsequently replaced by fine-grained ilmenite during continuous cooling.

Electron microprobe and LA-ICP-MS analyses reveal systematic variations in TiO_2, FeO, and Fe_2O_3 contents in titanomagnetite, reflecting magmatic differentiation and variable redox conditions. Vanadium distribution is closely linked to the ratio of Fe^{2+}/Fe^{3+}, with V preferentially incorporated as V^{3+} under moderately oxidizing conditions via coupled substitution with Fe^{3+} in octahedral magnetite sites.

During exsolution processes, vanadium becomes locally redistributed between magnetite and ilmenite lamellae. The observed textures provide a spatial record of this redistribution and demonstrate that both magmatic and postmagmatic processes influence vanadium partitioning between mineral phases. These findings have direct implications for the formation and economic assessment of vanadium-bearing Fe–Ti oxide layers in mafic systems.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Late Cretaceous thick-skinned basement thrusting and associated thin-skinned fold-thrust-belt evolution in a plate's interior – an example from Gardelegen-Haldensleben Basement Thrust System

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Fold-and-thrust belts and foreland basin deformation are typically associated to orogenic systems along plate margins, where contraction and shortening is transferred to the foreland. In contrast the Late Cretaceous "hercynian" intraplate contraction affected large areas of the Central European lithosphere far away from the next adjacent plate margins. Shortening resulted in the inversion of basins and (half-)grabens, but also the formation of large basement-cored uplifts and crustal-scale thrusts occurred. Due to crustal scale thrusting and lithospheric folding foreland basins developed, which resemble structures typically known from foreland fold-and-thrust belts all over the world.

This contribution deals with the Gardelegen-Haldensleben Basement Thrust System in Central Germany. In this region two major basement thrusts formed and syntectonic sedimentary basins evolved in their northern foreland. Due to the existence of mechanically weak strata these foreland basins were deformed in parts by thin-skinned "fold-and-thrust belt style". To unravel the evolution of thick-skinned and thin-skinned thrusts we used classical cross-section balancing methods of equal bed-length and areas, in parts supported by recently reprocessed seismic reflection data. Timing constraints and estimates of uplift and shortening were deviated from the correlation of boreholes, which penetrated the pre- and syntectonic strata.

Our results show that synchronously with thrusting wide areas in the foreland of the Gardelegen-Haldensleben Basement Thrust System were still affected by subsidence of the North German Basin, superimposed by foreland basin formation and successively growth and tilted Late Cretaceous strata. With the onset of Latest Cretaceous (Maastrichtian), uplift ceased and basin fill overlap earlier basement structures.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Sedimentology and integrated stratigraphy of the Opalinuston-Formation in Southern Germany

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ERBACHER, JOCHEN [1,3]
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The Opalinuston-Formation in Southern Germany comprises a thick sequence of Middle Jurassic silty claystones. In parts of Bavaria and Baden-Württemberg, the formation has been designated as a sub-area by the Federal company for radioactive waste disposal (BGE), indicating that favorable geological conditions for the final disposal of high-level radioactive waste can be expected there. However, state-of-the-art sedimentological and stratigraphic data for the complete formation is typically lacking. This contribution provides new and coherent data on the geological variability of the Opalinuston-Formation in Southern Germany based on four drill cores that penetrated through the entire formation. Cores were examined in high resolution using a combination of classic core description techniques, non-destructive analytical tools such as XRF core scanner and high-frequency sampling for a precise stratigraphic classification and geochemical-mineralogical characterization. Particularly with respect to changes in grain size, clay mineralogy and sedimentary facies, results exhibit both, notable variability but also similarities between sites, and in comparison to observations from Switzerland. Such sedimentological and stratigraphic patterns can be explained by the interplay of a complex, bottom-current dominated depositional environment, and differential subsidence, leading to relative-sea-level changes on a sub-basin scale. In summary, this contribution highlights the geological variability of the Opalinuston-Formation in Southern Germany and beyond, and discusses the possibilities of a sequence stratigraphic approach to accelerate exploration efforts of siting regions in claystone formations in order to rapidly identify the most suitable parts for the final disposal of high-level radioactive waste.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

Cultivating Geoscience Literacy – What does it take?

MANNING, CHERYL

Earth Systems Science Education Research and Consulting, United States of America

Geosciences are essential for managing mineral, energy, and water resources; developing infrastructure; mitigating natural hazards; and understanding climate systems. Despite their foundational importance to economic prosperity and planetary stewardship, most people lack geoscience literacy, hindering informed decision-making on critical issues.

Supporting geoscience-literate societies requires three components: teachers with deep geoscience knowledge, education research supporting instructional improvement, and leaders who prioritize geoscience education through adequate resources and time allocation. Geoscience learning ecosystems (GLE) offer potential solutions by engaging local communities in sustainable programs that promote literacy and inspire learning while leveraging existing social systems to accelerate geoscience solutions.

Limited research has examined learning ecosystem applications in geosciences. This presentation outlines emerging GLE theory and research methodologies, illustrated through a mixed-methods case study of Earth science (ES) teachers implementing Next Generation Science Standards (NGSS).

The study investigated ES teachers in an NGSS-adopted state lacking cohesive implementation plans, addressing three objectives: identifying attributes preparing teachers for NGSS sustainability standards, understanding how teachers' experiences, science belonging, knowledge, and ecological worldview influence instruction, and describing teachers' support networks.

Survey data from 245 ES teachers underwent path analysis, revealing that teachers' degree credentials predicted their sense of belonging in science, which subsequently influenced content knowledge, worldview, and place-based instructional strategy usage. Follow-up interviews with survey participants explored support networks utilized when teaching ES, providing insights into effective GLE development and implementation strategies for enhancing geoscience education.

07.02 Geothermal energy — Potential and utilisation of geothermal energy resources for the heat transition

Modeling complex reservoir architecture and connectivity in channel belt sandstones: The case study of the Rhaetian Distributive Fluvial System in the North German Basin

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Fluvial geothermal reservoirs are often characterized by complex and heterogeneous reservoir geometries and sandstone-body connectivities. One particular example is the Rhaetian Distributive Fluvial System (RDFS), whose channel belt reservoirs represent key targets of medium-deep geothermal energy exploration. By combining a data- and a model-based approach, we recreate for the first time the depositional environment of Rhaetian Lower Exter Formation in the Darss area, located in Northeast Germany. In this region, high sandstone thicknesses can be found in distributary channel belt reservoirs, which consist of different morphological elements of meandering fluvial channels. The lateral and vertical distribution of channel vs. overbank facies is realistically modeled by the process-based and stochastic simulation software FLUMY™, creating a heterogeneous 3D reservoir model of the study area. Additionally, existing well data is integrated in the user-defined multi-sequence scenario to hard condition the simulation. Further, we propose a multistage workflow, featuring the pre-processing, the hard conditioned simulation and finally the post-processing. The detailed facies-classification of the wells and the consequently developed 3D reservoir model allows for a better in-depth understanding of channel belt reservoirs of the RFDS concerning lateral distribution of sand-prone facies and sandstone-body connectivity.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Introducing DFG-research project RO 7078/2-1: Late Pleistocene dune archives spanning from the Canary to the Tyrrhenian Basin – Paleoenvironmental reconstruction via dust imprint from source areas in northern Africa

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Saharan dust input is a well-known phenomenon worldwide but especially concerning landscapes around the Mediterranean Sea and on the Canary Islands since the largest dust source areas on earth are located in the northern African continent. Its effects have been imprinted in several geoarchives and are especially well known from aeolianite archives. These coastal dune archives typically form in dependence of changes in sea level and are comprised of pale coloured carbonate sands, intercalated by reddish silty layers, which we call paleo surfaces. They were heavily influenced by, among others, dust imprint from the northern African continent. The aim of our research project is hence to conduct detailed analyses on those layers to reconstruct local and supraregional environmental conditions during the last glacial.

In view of the good temporal resolution over the last glacial our sites on Lanzarote (Canary Islands), Cabo Roig (SE-Spain), Formentera and Eivissa (Balearic Islands) and Sardinia offer best conditions to answer the following research questions, building on each other: (i) What are site-specific characteristics of the dust enriched layers and what information about the local environmental conditions are stored within our geoarchive? (ii) Are there differences or systematical similarities in terms of quantities and admixture of dust material when comparing the different paleo surfaces within a single site/profile? (iii) Can we identify distinct source areas of dust as well as dominating dust pathways ? (iv) Are we able to correlate the different sites from the Canary to the Tyrrhenian basin and what supraregional patterns are deducible?

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Geoscientific characterization of claystone as part of the German Repository Site Selection Act – “Sub-area Upper Cretaceous (East)”

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According to the Repository Site Selection Act (Standortauswahlgesetz – StandAG), the German Site Selection Procedure is an iterative process and consists of three phases with increasing levels of detail in which the assessed area is continuously reduced during the process. Starting with an empty, so-called “white map of Germany,” BGE (implementer of the German Site Selection Procedure) completed Step 1 of Phase I in September 2020 with the submission of the Sub-areas Interim Report (BGE 2020/88), where BGE identified 90 individual sub-areas (in claystone, rock salt, and crystalline rock).

In Step 2 of Phase I, BGE aims to localize siting regions within the 90 sub-areas by applying preliminary safety assessments and other scientific criteria. Within the preliminary safety assessments, subsurface data are interpreted and the results documented. The workflow comprises the detailed characterization and interpretation with focus on the host rock formation that acts as the main geological barrier but also considers the surrounding rock formations.

The claystone succession of the “Upper Cretaceous” in eastern Germany has been designated as claystone sub-area. Based on borehole data and a published petrographical study, the sequence was characterized lithologically in order to define a succession with a barrier function within the stratigraphic sequence. The thickness of the actual barrier was important for the categorization of the sub-area. This poster explains the results that were already published as a preliminary working status in 2024.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

The exceptional vertebrate burrow record of the early Permian Bromacker locality

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Burrows are crucial for the survival of vertebrates, providing shelter from unfavourable climate and predators, but also forming a safe space for feeding, breeding, hibernation, or aestivation. Nevertheless, the origin and early evolution of fossoriality is scarcely investigated. The early Permian Bromacker locality (Tambach Formation, Germany) is worldwide known for its exceptional vertebrate skeletal and footprint record. Nevertheless, vertebrate burrows were only briefly reported so far. New excavations in the frame of the BMBF-funded Bromacker project (2020–2025) yielded an unexpectedly large amount of potential vertebrate burrows of different size and morphology. Large-sized (about 30–40 cm wide), low-dipping burrows ending in oval chambers with dense concentrations of broad scratch traces at the bottom and at the sides, were found in high concentrations in fine-grained and cross-stratified sandstone layers. Some of the burrow infills contain tetrapod remains, including Diadectes, Orobates, and Martensius. Somewhat smaller (about 12 cm wide), long, low-dipping burrows ending in pentagonal chambers, characterise the fluvial sandstones at the bottom and at the top of the succession. Furthermore, small (about 5 cm wide), low-dipping burrows displaying branching, thin scratch traces and large quadrangular chambers, were found in the cross-stratified sandstone at the top of the succession. A further type of small (about 3-5 cm wide), simply built burrows, vertical or slightly dipping, characterise the laminated mudstone facies. This exceptional abundance and diversity of potential vertebrate burrows makes the Bromacker locality a key area for studying the early evolution of fossoriality, likely linked to survival strategies during early Permian global warming.

03.08 Earth Surface Systems and tipping elements in a changing climate

Spatial analysis of dolines as microclimatic refugia in the Berchtesgaden National Park

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Climate change is already causing species to relocate in the Alpine region. To counteract current and future habitat loss, microclimatic refugia can play a crucial role. In this context, dolines are potentially valuable refugia. To assess their occurrence and distribution and thus support further research in their microclimatic potential, reliable mapping is required.

In this study, the fill-sink method for automated doline mapping was applied to a digital terrain model (DTM) of the Berchtesgaden National Park, which also provided the data. The results were compared with manual mapping. Additionally, the spatial distribution of dolines under the influence of topography (elevation, slope, exposition) was investigated to evaluate their microclimatic relevance.

The results show that the overlap between the two methods is small. A central problem of the method may be that it often combines several individual dolines into one higher ranked sink, likely due to the heterogeneous relief in the region. Nevertheless, the automated method identified margins of uvalas that align with historical maps. Based on manually mapped doline distribution only, we find a clustering of dolines at elevations between 2000 and 2200 m a.s.l, in low slope inclinations and on north-facing slopes.

Overall, reliable automated doline mapping needs to be adapted for regions with more complex relief. However, since other karst features with potential microclimatic importance were identified, the broader applicability of the fill-sink method should be further investigated beyond doline mapping. The current manually mapped distribution of dolines suggests future relevance for cold-adapted species and therefore requires further research.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Bubble Genesis: Experimental Investigation of Vesicle Formation and Evolution in Hydrous Phonolitic Melts

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The eruption behavior of volcanic systems is governed by the separation of an H_2O fluid phase from a supersaturated hydrous melt during magma ascent. Vesicle number density (VND, mm-3) is a key parameter used to quantify the efficiency of this fluid-melt separation. While VND typically increases with decompression rate due to nucleation-driven vesicle formation—making it a potential proxy for magma ascent velocity—recent studies suggest that spinodal decomposition, which produces decompression rate-independent VND, may dominate in hydrous alkali-rich melts.

We conducted super liquidus decompression experiments on phonolitic melts under H_2O-saturated and undersaturated conditions, across decompression rates of 0.064–1.7 MPa/s. The samples show consistently high initial logVNDs of ~5.5, regardless of decompression rate, with uniform vesicle diameters of 2–8 µm, supporting spinodal decomposition as the vesicle formation mechanism. As vesicle coalescence begins and progresses, vesicle sizes increase up to ~500 µm and VND decreases significantly, becoming dependent on decompression rate and final pressure. The lowest logVNDs of 0.5–0.8 occur at the slowest rates, while the highest coalesced VNDs with 3.1–3.7 are observed at the fastest rates.

This transition—from a high-VND, decompression rate-independent regime to a coalescence-driven, rate-dependent regime—marks a critical shift in vesiculation dynamics. It reflects a development from a closed, potentially explosive system to a more open, outgassing system favoring effusive eruption. These findings offer vital insights into how degassing processes may influence eruption style and contribute to improved volcanic hazard assessment.

01.21 Advances in Geochronology: from tradition to avant-garde

Uranium incorporation in garnet

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MILLONIG, LEO [1]
KUTZSCHBACH, MARTIN [1]
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Uranium contents in natural garnet are typically in the range of 1–50 µg/g in andraditic garnet found in alkali-magmatic rocks and skarns, but are orders of magnitude lower in metamorphic almandine–pyrope with typically 1–100 ng/g. Nonetheless, the instrumental setup at FIERCE coupling laser-ablation with a modern MC-ICPMS system enables us to routinely extract U–Pb ages even from samples of the latter group at a geologically meaningful level of precision. However, limited knowledge of the mechanisms and systematics of U incorporation into garnet hamper the processes of sample selection and data interpretation for garnet petrochronology.

We find that U is predominantly incorporated into both andraditic and almandine–pyrope garnet in its tetravalent form and that it strongly favours the dodecahedral X site of garnet. The elbrusite substitution, which includes hexavalent U does not operate at the trace-element level of U in natural garnet. Instead, the incorporation of tetravalent U into the dodecahedral X-site dominates and is charge balanced through tetrahedral ferric Fe and/or through divalent cations in the Y-site. Many andradite samples show oscillatory zoning with a covariation of U, Th and the light REE, demonstrating that incorporation of the lanthanides and actinides may be controlled by the same crystal chemical mechanisms. Some samples additionally show clear sector zoning in U (and Th and Ce) with a 20–50 % enrichment of U in the {211} sectors compared to the {110} sectors, demonstrating a control of crystal growth rate on U incorporation.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Importance of the Lower Permian Fossillagerstätte Bromacker near Tambach-Dietharz in the Thuringian Forest (Germany, Tambach Formation) – Results of the first international research project (1992 – 2010)

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Our understanding of the evolution of the earliest amniotes during the time span 320 to 270 million years ago on the Pangaea supercontinent is known from only very rare fossil localities, most of which are in North America. The fossil locality Bromacker (Bromacker Quarry) in the Lower Permian Tambach Formation near Tambach-Dietharz, central Germany, has developed after discovering of first bone 1974 until 2010 to be the most important and productive fossil locality for Lower Permian, terrestrially adapted tetrapods outside USA.

Scientific results emerged in 20 years of international collaboration between Dr. Thomas Martens (MNG, Gotha) Dr. David Berman und Amy Henrici (Pittsburgh, USA) Prof. Stuart Sumida (San Bernardino, USA) Prof. Jozef Klembara (Bratislava, Slovakia) Dr. David Eberth (Royal Tyrrell Museum, Drumheller, Kanada) and Prof. Robert Reisz (University of Toronto, Kanada).

We discovered first examples of Seymouridae (Seymouria sanjuanensis), Diadectidae (Diadectes absitus and Orobates pabsti), Protorothyrididae (Thuringothyris mahlendorffae), Bolosauridae (Eudibamus cursoris), Sphenacodontidae (Dimetrodon teutonis) and Varanopidae (Tambacarnifex unguifalcatus) in the Lower Permian of Europe or outside of USA and some new species/genera of Mikrosauria (Tambaroter corrolli), Trematopidae (Tambachia trogallas and Rotaryus gothae), Amphibamidae (Georgenthalia clavinasica) and Caseidae (Martensius bromackerensis).

The Bromacker produces the best preserved terrestrial vertebrate fossils from the Lower Permian time period (about 290 million years ago). Significantly, the locality provides the example of strictly terrestrial amniote ecosystem. Thus, the herbivores and carnivores coexisted in a natural community as early as the Lower Permian.

08.01 Young Scientist Session

Manual for geosciences outreach on social media: the case of Divulgación Terróloga

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Social media has become a key bridge between the scientific community and the broader public. Early Career Researchers (ECRs) in Latin America have increasingly embraced digital platforms to engage non-specialist audiences with geoscience content, especially during the COVID-19 pandemic. One such initiative is Divulgación Terróloga, a non-profit, self-funded science communication project launched on June 11, 2019, by Mexican ECRs. The project aims to communicate Earth system processes clearly and accurately in Spanish through Facebook and Instagram. Our content covers all Earth spheres topics and features regular posts that promote the visibility of geosciences and the scientific work of mainly ECRs. The section "Miércoles de Jóvenes Investigadores" (Young Researchers Wednesday) highlights the research of students and early-career scientists, while the section "Geocientíficos en Acción" (Geoscientists in Action) focuses on geoscientists working beyond academia. We also conduct interviews with established researchers to highlight diverse career paths. In this presentation, we share the scope, challenges, and impacts of running Divulgación Terróloga. By April 23, 2025, we have published ~360 posts, reached ~2200 people per post on average, and grown a following of over 5300, with our most popular post reaching nearly 60,000 views. The audience is gender-balanced (49% women, 51% men) and spans Latin America, the U.S., and Europe. Our posts have been translated automatically into English, French, and German. This talk aims to highlight the power of social media in promoting geoscience education, increasing the visibility of minorities in science, and building international networks in outreach.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Half-precession cycles and orbital-scale hydroclimate variability in the low-latitude Atlantic over the past 1.3 million years: connecting oceanic and continental records

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Zeeden, Christian [1]
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Over the past 1.3 million years, about forty glacial-interglacial cycles occurred, linked to orbital-scale variability. In tropical regions, short-term periodicities such as half-precession (HP) cycles (~12–8 kyr) offer insights into tropical responses to abrupt climate shifts and the interplay between orbital and millennial-scale events. Yet, their expression remains unclear due to limited long-term tropical records. We present a new inorganic geochemical record from ODP Site 663 (1°N, Gulf of Guinea) spanning ~1.3 million years. We aim to detect HP cycles and understand the possible drivers and their hydroclimate effects on the continent. Preliminary results suggest enhanced aeolian input during glacial periods, likely driven by Sahara expansion and intensified Harmattan winds. In contrast, interglacials show increased fluvial input probably driven by a northward migration of the Intertropical Convergence Zone and an intensified West African Monsoon. Spectral analyses reveal that HP cycles are mainly expressed during interglacials with high planetary eccentricity. These intervals also coincide with the highest recurrence of millennial-scale events, suggesting a modulation of tropical hydroclimate by orbital-scale insolation forcing. Our findings emphasize the role of tropical processes in modulating millennial-scale climate variability, a mechanism traditionally attributed to high-latitude dynamics. Our findings align with HP signals in Lake Bosumtwi (Ghana) between ~650–550 ka BP (MIS 13–11) and hydroclimate variability during MIS 5 in Lake Petén Itzá, Fúquene, and Chalco. Together, these records underscore the critical role of low-latitude processes in shaping global climate variability and offer new perspectives on tropical hydroclimate mechanisms across glacial-interglacial timescales.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

In-situ generation of rhyolitic melts in a basaltic crystal mush below Cordón Caulle volcano (Chile) – an experimental study

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The Cordón Caulle volcano in the Southern Andean Volcanic Zone in Chile represents an ideal setting to study magmatic processes within an active arc system. Rhyolitic lavas erupted in 2011-2012 host crystal-rich basaltic enclaves which have been interpreted as pieces of an active crystal mush. Interstitial glasses of these mush fragments are compositionally very similar to their host rhyolitic magmas suggesting that a basaltic crystal mush represents the source of the rhyolitic melts, thereby offering a rare possiblity to investigate an active mush system.

In this study, we experimentally test this petrogenetic model by performing partial melting experiments on natural rock powders of basaltic enclave samples employing bulk water contents of 0.5–1.0 wt.%. Experiments were run at 150 MPa in internally heated pressure vessels (IHPV) at temperatures between 750 and 1000 °C and fO2 buffered between NNO-1 and NNO. Our experimental setup is specifically designed to simulate a crystallisation-driven differentiation mechanism applicable to an *in-situ* evolving crystal mush, representing a mixture between fractional and equilibrium crystallisation regimes, where the "reactive magmatic system" is continously changing during progressive cooling.

Experimental residual melts define distinct differentiation trends and show a close compositional match with bulk rocks as well as groundmass glasses of the rhyolitic lavas strongly supporting a petrogenetical link between basaltic mush enclaves and host ryholites. Consequently, the generation of highly-evolved liquids in a cooling basaltic crystal mush combined with an efficient residual melt extraction mechanism represents a possible differentiation scenario for the Cordón Caulle volcano and similar volcanic systems.

01.20 Process oriented microfabric characterisation of geomaterials

The Role of Antigorite's Anisotropic Thermal Conductivity in Slab Thermal Evolution

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Antigorite is a phyllosilicate exhibits a marked mechanical anisotropy: the crystals are relatively stiff along the foliation plane (001), while being very compressible along the [001] crystallographic direction. Moreover, under shear deformation, antigorite develops a strong crystallographic preferred orientation (CPO) with the [001] direction oriented perpendicularly to the shear plane. Given its mechanical anisotropy, antigorite crystals hosted in subducting slabs are predicted to align their [001] direction perpendicular to the slab dip. Other physical properties of antigorite might show similar anisotropic behavior. Lattice thermal conductivity Λ, for example, is closely related to the elastic stiffness of a mineral. For this reason, we measured the in-plane Λ[010], and cross-plane Λ[001] thermal conductivities of antigorite using the Time-Domain Thermo-Reflectance (TDTR) technique[1]. We found that Λ[001] is ~2-3 times lower than Λ[010], even at the high-P,T conditions of subducting slabs. To investigate the large-scale effects of antigorite's anisotropic Λ we designed a finite difference heat diffusion model of a 2D vertically subducting slab, in which we prescribed the presence of a 3-km-thick layer of serpentinite. This insulating layer hinders the propagation of thermal energy toward the cold core of the slab. This effect would reduce the stability field of hydrous phases in the external part of the slab, thus promoting dehydration embrittlement. Furthermore, the presence of antigorite in pre-existing faults can trap the frictional heating inside shear zone, thus favouring the onset of thermal runaway. Potentially antigorite is a key mineral for the development of double seismic zones (DSZs).

04.01 Prospection and extraction of critical and strategic raw materials in Europe

Where Are We Heading Regarding Mining in Germany?

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The first round of the Critical Raw Materials Act (CRMA) has concluded, and Germany is wondering why so few projects from the Federal Republic made it onto the CRMA list. If we aim to achieve greater independence from foreign-sourced raw materials, it is essential to have a precise inventory of our domestic resources and to actively promote them within industry. Critical raw materials—such as lithium, rare earth elements, cobalt and semiconductor-grade silicon—are the backbone of Germany's advanced manufacturing sectors (including automotive, renewable energy, electronics and defense). They are indispensable for meeting our climate targets, sustaining high-tech production and maintaining global competitiveness.

Furthermore, the state mining authorities (Oberbergämter) must be staffed with sufficient personnel to evaluate and approve German projects within the prescribed timeframe. At present, approvals still take decades; the CRMA, however, mandates that permitting procedures be completed within 27 months.

We must also raise public awareness about raw materials and their origin, rebuilding social acceptance of domestic mining within civil society. At the same time, we need to encourage the next generation to enter the mining industry and make careers as mining engineers or resource geologists attractive again. Resource consciousness begins in school and should be fostered there and in the media.

Only with a positive attitude towards our domestic raw materials, responsible mining under the highest standards of nature protection and social considerations as well as aceptance, can we create transparent supply chains within Germany and Europe.

07.03 Quantifying surface and near-surface dynamics with remote sensing and geophysics

Unravelling the key mechanisms and chronology of zebra stripe formation in the Atacama Desert (N Chile)

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García, Juan Luis [3]
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The Atacama Desert in northern Chile is one of the most arid regions on Earth, with an extremely hyperarid core receiving less than 2 mm of rainfall per year. In this virtually waterless world, mechanisms and rates of geomorphic processes are so far poorly understood. New detailed field data and monitoring of local conditions are hence much needed, and would ultimately provide valuable insights into geomorphic processes under extreme hyperaridity. The DFG-funded project “Key mechanisms and chronology of geomorphological processes in hyperarid landscapes” (ref. no. AG 432/1-1, MA 5768/6-1) aims to fill this knowledge gap by studying processes, drivers and time scales of hillslope sediment production and transport in hyperarid landscapes. Specifically, it aims at investigating the so-called zebra stripes, arguably the most enigmatic and widespread hillslope landform in the central Atacama Desert. Zebra stripes cover slopes between the coastal range and the pre-Andean cordilleras and are defined as contour-parallel, thin lateral bands of loose angular gravels resting on hillslopes between 4° and 30°. Backed by geomorphological and geochronological investigations from recent years, the new project will focus on repeated field geomorphological investigations at zebra stripe key sites by (i) conducting on-site monitoring of local environmental conditions and processes; and (ii) obtaining both relative and absolute chronological information on zebra stripe formation time scales utilising rock surface luminescence and terrestrial cosmogenic nuclide dating techniques. This contribution introduces the project and presents first data of monitoring and dating results.

01.06 Tectonic Systems – TSK Open Session

3D structural, thermal and rheological modelling of the Central Andes

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Understanding the coupled multi-scale geodynamic processes related to the subduction of the oceanic Nazca Plate beneath the South American Plate is one pre-requisite to better assess seismic hazards in the region. It is essential to identify all relevant forces within the system, such as negative buoyancy of the subducting slab or mechanical coupling between the Andean domain and the Pampean foreland, to analyze tectonic processes like subduction or strain transfer and localization. We approach this by initially investigating the present-day physical state of the subsurface, including first-order variations in pressure caused by mean lithostatic stress, temperature, and rock composition as constrained by multi-disciplinary observations.

For this we build data-based 3D lithospheric models to characterize the system's response to these forces, with particular attention to the rheological behavior dictated by rock composition, temperature, and pressure. By employing an integrated methodology combining seismic velocity conversions with gravity modelling (IGMAS+), we create refined 3D models of the crust and lithosphere that capture structural, thermal, and rheological properties of the subsurface, as these exert significant control on spatial variations in lithospheric strength and deformation behavior.

Datasets such as surface heat flow, earthquake catalogues, as well as geodetic observations can then be used to validate the models and shed light onto the underlying geophysical processes active in the region.

01.06 Tectonic Systems – TSK Open Session

The role of thermal anomalies in the breakup evolution along the conjugate margins of the Fram Strait

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JOCHMANN, MALTE [3,4]
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The Eurekan Belt is an intraplate orogen that extends for nearly 2000 kilometres across the Arctic Realm and is closely linked to large-scale transform faults. After orogenic movements ceased, the Eurekan Belt became dissected, the affected margins of Greenland and the Barents Sea became passive and the Arctic-North Atlantic gateway, the Fram Strait, opened.

To obtain information on the thermal imprint of rifting and continental breakup processes along a sheared margin, we investigated highly mature sedimentary rocks exposed along both of the conjugate margins using apatite fission track and (U-Th)/He thermochronology.

Our data suggest that a large transform fault system played a major role in the development of the Eurekan Belt and the subsequent formation of the Barents and Greenland margins: along segments of the transform fault system heating occurred prior to and during the Eurekan Orogeny. Heat transfer may have caused or contributed to lithospheric weak zones which focussed deformation during the intraplate orogeny. Movements along the transform fault system continued after the end of the Eurekan Orogeny and caused further structural weakening of pre-existing fault zones. These were utilised during the final continental breakup leading to the opening of the Fram Strait.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Hidden under the ice: unravelling the tectonomorphic history of the Bellingshausen Sea Sector, West Antarctica

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Röhnert, Daniela [1]
Sahragard Sohi, Mohammad [1]
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Monien, Patrick [1]
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The Bellingshausen Sea sector is largely covered by the West Antarctic Ice Sheet, which impedes direct geological investigations. The rift-related structures of the West Antarctic Rift System presumably control the course of ice streams. In turn, the glacially eroded troughs provide pathways for warm oceanic deep water, which causes basal melting of the overlying ice.

During Polarstern cruise PS134 we collected rock samples from onshore nunataks and clastic sediments from glacial outlets. We apply petrographic analyses and radiometric dating on apatite and zircon to characterize the source area hidden beneath the ice and to investigate the thermotectonic evolution of the Bellingshausen sector.

Our data will provide insights into the geological units present under the ice as well as information on the timing of activity, mode, and kinematic relationships of the rift branches of the West Antarctic Rift System in the Bellingshausen Sea sector. These new data allow to refine palaeotopographic models of West Antarctica, which will provide boundary conditions for understanding and modelling the onset of the glaciation of West Antarctica. Combined with offshore seismic and sedimentological information, the new data will also allow to visualize onshore and offshore denudation and burial over time, which will contribute to understanding source-sink relationships, drainage patterns and the regional long-term landscape evolution.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

U-Pb-Hf zircon geochronology of metasedimentary and meta-igneous basement rocks of the Odenwald Crystalline Complex– implications for pre-Variscan geodynamic evolution of Central Europe

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The Mid-German Crystalline Zone (MGCZ) plays a key role to unravel the complex pre- to syn-Variscan tectono-magmatic evolution in central Europe from the Neoproterozoic to the late Carboniferous. The most complete record of this evolution is preserved in basement rocks of the Bergsträsser Odenwald, even though highly ambivalent. While a large number of (isotope) geochemical and geochronological data and geodynamic models exist for the Variscan evolution of the Bergsträsser Odenwald (between 360 and 320 Ma), information about pre-Variscan events is scarce, although lately published zircon ages constrain pieces of Cadomian basement and Silurian intrusiva. Our new results of zircon U-Pb dating confirm these findings, but additionally point to a widespread occurrence of pre-Variscan intrusive rocks in the Bergsträsser Odenwald, which are known so far in this extent only from the Böllstein Odenwald.

Detrital zircon grains reveal different age spectra, pointing to a wide range of source areas and supply routes of the detritus from source to sink. Some age spectra correlate well with published data from other units of the MGCZ or the Saxo-Thuringian Zone, whereas others are completely different, and unique for the Odenwald. Maximum depositional ages range from the Neoproterozoic (c. 550 Ma) to Early Variscan (c. 355 Ma) and indicate that the Odenwald basement preserves different periods of sediment deposition and a prolonged geodynamic evolution, much longer and complex than previously thought. Our new results have consequences for the interpretation of the evolution of the MGCZ and adjacent areas within the Central European Variscides.

01.07 Stratigraphy in Earth System Science: methods, applications and case studies

Revising the stratigraphy of the oldest rocks of the Elbtalschiefergebirge (Elbe Zone, Saxo-Thuringia) based on the discovery of trace fossils

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Ediacaran glacial deposits have been described in recent years from several peri-Gondwana units, including the Weesenstein Group of the Elbtalschiefergebirge (Elbe Zone, Saxo-Thuringia) (e.g. Linnemann et al. 2018, Int. J. Earth Sci., 107, 885-911). These sedimentary rocks with only low-grade metamorphic overprint have been considered the oldest rocks of the region. The Weesenstein Group comprises two formations, following Linnemann et al. (2018): the older (but see below) Seidewitz Formation overlain with gradual transition by the Müglitz Formation. The former comprises quartzite and quartz schist horizons and a thick quartzite unit, named the Purpurberg Quartzite, interpreted to be a glacio-eustatic controlled low-stand deposit. The Müglitz Formation comprises mainly greywacke, partly pebble bearing, of the Weesenstein diamictite; the latter has been interpreted to belong to the Ediacaran glaciomarine diamictites of Cadomia. The stratigraphic concept, however, has recently been put into question based on the findings of a low-diversity trace fossil assemblage in the Purpurberg Quartzite, indicating a Palaeozoic, most likely Early Ordovician age, and evidence for an inverted stratigraphic order of the two formations (Meinhold et al., 2025, Geol. Mag., 162, e10). Palaeoenvironmental models of glacio-eustatic controlled deposition of the Purpurberg Quartzite of the Seidewitz Formation due to sea-level fall during an Ediacaran glaciation need to be abandoned. Both the age (Ediacaran or Palaeozoic?) of the Müglitz Formation and the nature of its contact with the Seidewitz Formation, are in need of further study. The term Weesenstein Group requires a revision, adjusting for the new stratigraphic concept of the area.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

A new 3D model of the base Quaternary for northwestern Lower Saxony (Germany)

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The base Quaternary in northwestern Lower Saxony is characterised by an undulating surface that is intersected by a complex network of buried tunnel valleys. Their development is mainly associated with the Elsterian glacial stage. The Quaternary sediments contain minable sand and gravel deposits, and host most of the groundwater reservoirs. The incision depth of tunnel valleys is a relevant parameter for the countrywide ongoing search for a suitable site for radioactive waste storage. To date, comprehensive information for the base Quaternary in Lower Saxony is available from a 30-year-old contour map, but more recent data are available. Thus, a revision of the base Quaternary as a 3D geological model is essential to support strategies for sustainable resource extraction and land use.

The new 3D model covers approximately 11,800 km^2. It has been compiled in Aspen SKUA® and is based on a broad dataset: The existing contour map of the base Quaternary has been combined with more recent data, especially seismic data (2D/3D) and extensive borehole data. Additionally, we considered information from geological cross sections and regional 3D models. Several previously unknown tunnel valleys were discovered. Seismic data proved to be extremely valuable to map their course and geometry over tens of kilometres. Our model indicates that erosion depths may reach up to -415 m NHN, which is more than 50 m deeper than previously assumed.

The 3D model will be available via the NIBIS® mapserver (*https://nibis.lbeg.de/cardomap3*). Work on the 3D model will be continued for other parts of Lower Saxony.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

From the Permian to the Digital Age: Science Communication via Instagram in the BROMACKER Project

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In an age shaped by digital media and rapid information exchange, science communication is adapting to new tools and audiences. The BROMACKER—a multidisciplinary research project focused on a 290-million-year-old fossil site in Thuringia, Germany—is using social media to make its research more visible and accessible. Through the Instagram channel @bromacker_chroniken, the team shares fieldwork, fossil discoveries, as well as paleontological and geological insights in formats tailored to a broad, non-specialist audience.

This contribution explores how visual storytelling, authentic glimpses into fieldwork, and easy-to-understand explanations can help open up scientific research beyond academic circles. Using concrete examples, it illustrates how humor, visuals, and accessible language turn complex science into something people can relate to and respond to. At the same time, it also reflects on the opportunities and limitations of using social media to communicate evolving research via social media.

By embedding outreach into the scientific routine, @bromacker_chroniken demonstrates how digital media can enrich science communication, spark curiosity, and strengthen the relevance of research in society today.

09.01 Open Educational Resources (OER) in Geosciences: From Basics to Practice

Teaching materials for geoscience classes

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There is an urgent need to include Earth system sciences in the school curricula in order to enable the next generation to understand the basics of the Earth as a dynamic system and its global problems such as climate change or the sustainable use of georesources. In order to support school and student training but also for people who are generally interested in natural sciences and in particular in geoscience, I have created a whole series of websites and educational videos over the last four years, which are part of my collection of teaching materials that can be found on the DGGV website. Educational videos on my YouTube channel "Lehrvideos System Erde" (Educational videos on the Earth System) are integrated into the web pages. All texts, images and movie clips used in the videos can be downloaded free of charge and for free use. This web-based teaching material is particularly suitable for teachers in schools, but is also intended for students and interested laypeople.

The series is under construction, with 20 websites and videos completed so far. The chapters are currently available in English and German; Spanish will be added as a third language soon. The 20 completed chapters cover the structure of the Earth, isostasy, the development of the oceanic crust and lithospheric mantle, divergent plate boundaries, transform faults, the Earth´s magnetic field, and the geometry of plate movements. More websites and videos will follow soon.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

YouTube channel “Educational videos on the Earth System”

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The YouTube channel “Lehrvideos System Erde” (Educational videos on the Earth System) went online in April 2024. It provides educational videos about the Earth system. The videos are currently available in English and German. Spanish as a third language will be added soon. The series is under construction, with 20 videos completed so far. The length of the videos is between 6 and 15 minutes. Thematically, they cover the basics of geodynamics. More videos will be added soon. All videos are provided together with a website with the same content, where all descriptions and images or animations used in the videos are available for free download. The website is available through the German Geological Society (DGGV, German version *https://www.dggv.de/das-system-erde/themen-zum-system-erde/*, English version *https://www.dggv.de/en/the-earth-system/themes-system-earth/*) with links given below each video on the Youtube channel.

The videos are aimed specifically at teachers in schools, but also at students, at universities, and interested laypeople. Tests in school education settings by individual teachers have revealed that they are a useful and welcome aid for teachers in their classrooms. After one year, the YouTube channel has meanwhile 230 subscribers and more than 10.000 views. The website associated with the YouTube channel had more than 15,000 visitors. I hope that the interest in the channel and website will grow further and I would be happy if the information about this channel would be distributed.

01.10 The co-evolution of the Earth and life from the early Archean until today

Changes in continental weathering and the marine redox state in the wake of the GOE: insights from the lower Pretoria Group (Transvaal Basin, South Africa)

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The sedimentary rocks of the lower Pretoria Group record the first appearance of oxygen in Earth's atmosphere and surface environments during the ca. 2.32 Ga Great Oxidation Event (GOE). While the change of ocean water redox-conditions during the GOE has been extensively investigated, the link between fluctuations in continental weathering patterns and their impact on the marine realm during this critical time interval in Earth's history is less known. The black shales of the 2.32–2.25 Ga Timeball Hill Formation (TBH), deposited directly after the onset of atmospheric oxidation during the GOE, denoted by the disappearance of mass-independent fractionation of S-isotopes in the underlying Rooihoogte Formation, bear the potential to provide a better understanding of these processes.

Here, we report newly obtained major and trace element data of the EBA-1 drill core, covering the Rooihoogte, the Timeball Hill (including the Rietfonteindam Diamictite) and the Boshoek formations, at very high-spatial resolution, providing detailed insights into the continental weathering conditions and associated changes in the marine environment. While the Rooihoogte and lower TBH formations display intense weathering on the continents under warm climates, the weathering intensity massively decreased through the upper TBH, suggesting strong atmospheric cooling, terminating in the deposition of the Rietfonteindam Diamictite, which corresponds to a major glaciation. The overlying Boshoek Formation records a renewed increase in weathering intensity due to climatic warming. These fluctuations in weathering conditions were accompanied by changes in nutrient fluxes, which in turn influenced the oceanic redox conditions on a basin-wide if not global scale.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Getting ready for PalaeOpen: Multi-proxy data synthesis of Holocene vegetation and fire dynamics in the tropical Andes

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Tropical high mountain ecosystems, including páramo grasslands, are highly vulnerable to climate change and important providers of biodiversity, carbon storage and water regulation. Paleoecological reconstructions that rely on environmental proxies such as pollen, charcoal or fungal spores preserved in lake sediments offer valuable insights into how ecosystems have responded to past climate changes and human activities. The Holocene, a relatively stable interglacial with significant human impact, serves as a key interval for investigating vegetation, climate and fire regime dynamics.

This study as a test case for the new EU COST Action PaleoOpen (*https://www.cost.eu/actions/CA23116/*), explores the potential of using the open-access and community-curated Neotoma palaeoecological database to integrate multiple local proxy datasets into cross-regional reconstructions of vegetation and fire dynamics in the montane forest and páramo ecosystems in the Ecuadorian and Colombian Andes.

We find that Holocene vegetational dynamics exhibit regionally divergent trends between Ecuador and Colombia, contradicting the initial hypothesis of coherent cross-regional climate signals within the tropical Andes. These results suggest either diverging regional climatic trajectories, potentially driven by Intertropical Convergence Zone (ITCZ) and El Niño-Southern Oscillation (ENSO) variability, or limitations due to insufficient spatiotemporal data coverage and high topographic complexity within the Andean region. Some fluctuations likely reflect diverse anthropogenic land use. These results highlight the need for enhanced spatial data coverage, alongside temporally and taxonomically harmonized datasets (a key challenge for PaleoOpen) to provide a better understanding of tropical high mountain ecosystem dynamics – essential for developing effective conservation and adaptation strategies facing accelerating climate change.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Magmatic versus metasomatic origin of HFSE- and REE-enriched peridotite-melilitolite-foidolite-carbonatite complexes – a melt inclusion study from Gardiner (Greenland) and Kovdor (Russia)

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In some composite alkaline complexes, large amounts of ultramafic rocks occur together with melilitolites, carbonatites and other alkaline silicate rocks. These rock associations are of significant economic interest due to their common enrichment in critical and strategic elements like Ti, P, HFSE, or REEs. Key examples for such systems are the Gardiner (Greenland) and Kovdor (Russia) complexes. The timing of enrichment of HFSE during the evolution of these two complexes is still under debate. Carbonatites at Kovdor (Russia) are HFSE-mineralized, with only minor HFSE-phases in the associated silicate rocks. In contrast, melilitolites from Gardiner show ore-grade enrichment of perovskite, while the associated carbonatites are barren.

Previous work assumed similar parental melts due to similar homogenization temperatures and daughter mineral assemblages in olivine-hosted melt inclusions from ultramafic rocks. However, it was recently shown that dunites, peridotites, pyroxenites, and melilitolites from Gardiner represent orthomagmatic cumulate rocks, whereas some of the dunites and melilitolites at Kovdor are rather of metasomatic origin.

To reconcile these different origins, compositions and homogenization temperatures of crystallized melt inclusions from dunites, pyroxenites, and melilitolites are revisited in detail. Subtle differences in temperature and the abundance of carbonates and HFSE-phases in olivine-hosted melt inclusions from peridotites may display the metasomatic evolution. The comparison between the Gardiner and Kovdor complex will shed light on the nature of these rocks at variable evolutionary stages and the subsequent ore forming processes.

04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

Materialographic preparation of geological and mineralogical samples

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Materialographic sample preparation is essential for the reliable qualitative and quantitative analysis of geological and mineralogical samples. The aim of this presentation is to present optimized preparation methods for rocks, ores, minerals, fossils and material from tailings piles, which is becoming increasingly important in a world with fewer resources. The methods described include precise separation with different machines and cutting wheels adapted to the sample hardness and structure, whereby gentle sample treatment is necessary, especially in the case of porous, brittle or powdery samples. For tailings pile material, which often has heterogeneous compositions, high porosity and variable grain sizes, special mounting and impregnation techniques are recommended to ensure representative and artifact-free sample preparation.

Mounting is preferably done with low-viscosity epoxy resins under vacuum to completely fill pores and cracks and stabilize powder mixtures. Alternatively, warm-curing or light-curing mounting agents are used. The subsequent grinding and polishing processes are carried out with modern, semi-automatic and fully automatic grinding and polishing machines. Various abrasives and polishing agents, especially diamond and silicon carbide discs, are selected depending on the sample material and preparation target. Thin sections are produced by multi-stage grinding to final thicknesses of 20 to 30 µm, whereby precise control of flatness and thickness is essential.

The techniques presented enable high reproducibility, a significant reduction of preparation artifacts and excellent surface quality. This increases the informative value of light and scanning electron microscopy as well as analytical investigations. Targeted sample preparation is therefore a basic prerequisite for reliable geoscientific analyses, especially with regard to sustainable raw material extraction from secondary sources such as tailings piles.

04.01 Prospection and extraction of critical and strategic raw materials in Europe

The ICE-SRM EU activities to support the CRMA implementation

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The EU Critical Raw Materials Act (CRMA) was adopted in 2024 and first reporting is due in 2026, where applicable using the United Nations Framework Classification (UNFC). The European International Centre of Excellence for sustainable Resource Management (ICE-SRM EU), established within the Geological Service for Europe (GSEU) project as a capacity building and promotion centre in support to UNFC and UNRMS (United Nations Resource Management System) started its activities in capacity building, networking and promotion of UNFC to support its implementation and use according to the CRMA.

01.21 Advances in Geochronology: from tradition to avant-garde

LA-ICPMS U-Pb dating of polymetamorphic garnet and its inclusions from the Adula nappe, Central Alps

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The Adula nappe, Lepontine Alps, Switzerland and Italy, was shaped in a south-dipping subduction zone during the Alpine orogenic cycle. It comprises crustal gneisses, metasediments, and mica schists, as well as eclogites, amphibolites and peridotites. Rocks from the Adula nappe record a gradual increase in pressure and temperature from north to south with high-pressure (HP) metamorphism followed by low-pressure (LP)/high–temperature (HT) conditions. HP metamorphism and the subsequent LP-HT overprint are considered to reflect a single P–T evolution. However, geochronological data from the Adula nappe indicate Variscan and Alpine metamorphism. The P–T conditions recorded by the Adula nappe are thus attributed to Variscan-Alpine polymetamorphism and a polyphase Alpine deformation history, which obscured the mineral equilibria developed during each high-grade event.

In this contribution, we investigate the U-Pb systematics of polymetamorphic garnet from the Adula Nappe by LA-ICPMS. We furthermore explore the U-Pb dates of U-rich inclusions in garnet to constrain their entrapment and formation history and thereby complementing the age information obtained from garnet. The location of the laser spots analyses is guided by BSE imaging, which resolves different garnet growth zones.

Our preliminary results indicate a plethora of internal garnet textures, that document the fragmentation of Variscan garnet and subsequent Alpine overgrowth, amongst others. Moreover, U-Pb dating of the accessory phases in garnet reveals that Variscan garnet also contains Alpine-aged inclusions.

05.03 Archaeometry – Geosciences4Humanities

Historical Plaster Formulations and Their Influence on Crystallographic Microstructure

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Historical plaster formulations offer valuable insights into advanced engineering in pre-modern cultures. This study examines two such gypsum-based recipes: Gach-e Koshteh from 14th-century Iran and Gesso Sottile from 15th-century Italy, both of which have unique characteristics and were essential for artistic and architectural decoration. By replicating these recipes in a laboratory setting, we demonstrate how traditional masters manipulated gypsum microstructure without additives to optimize the surface and mechanical properties of plaster for specific functional and artistic purposes.

The Koshteh recipe involves intensive kneading during plaster hydration, which retards setting and produces a platelet-like crystal morphology with alignment of the {010} faces, resulting in a hydrophilic surface ideal for water-based wall paintings. Sottile, in contrast, relies on slow recrystallization in excess water, generating loosely packed, needle-like crystals with reduced wettability—suitable for oil-based painting and gilding.

Using wide-angle X-ray scattering (WAXS), atomic force microscopy (AFM), and scanning electron microscopy (SEM), we reveal that the Koshteh recipe yields a denser, better-packed plaster with enhanced wettability, while the Sottile recipe forms larger, more loosely arranged crystals and a more hydrophobic surface. These findings underscore the ingenuity of historical materials engineering and offer valuable insights for modern conservation and sustainable restoration practices. [1]

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04.07 Mineralogy of Secondary Raw Materials

Characterisation of printed circuit boards and particle based simulation for recycling purposes

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Printed circuit boards (PCBs) play a crucial role in recycling of WEEEs (waste from electronical and electronic equipment), containing valuable elements like copper, gold, nickel, palladium and many others. While e.g. copper and gold are being recycled via well-established pyrometallurgical routes (Hagelüken, 2006), others are lost in the waste stream. Additionally, hazardous contents like flame retardants and persistent organic compounds comprise further issues for recyclers. In an attempt to contribute to the improvement of recycling rates, we used a combination of different analytical tools to investigate unpopulated PCBs, such as Computer Tomography (CT), SEM-based image analysis (i.e. automated mineralogy, AM), X-ray diffraction and wet chemical methods in order to perform a case study eventually including the usage of heavy liquid separation, a new type of eddy current separator and hydrometallurgical techniques. Furthermore, we trained a particle-based separation model (PSM, Pereira et al. 2021), which has successfully been applied to primary raw materials, to predict the probabilities of individual particles reporting to different processing products. Our results indicate that PSMs are valuable tools to predict recycling efforts, we suggest to use rather 3D-methods (e.g. CT) for complex particle shapes rather than 2D-techniques (e.g. AM) to obtain particle data necessary for simulations.

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01.10 The co-evolution of the Earth and life from the early Archean until today

Kinetic stability of ATP – a proxy for habitality?!

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Extremophiles thrive in hostile environments on Earth, such as hydrothermal vents on the ocean floor. These organisms developed a number of adaptations that allow them to survive in conditions of extreme temperature, up to 122 °C, and pressure, up to 125 MPa. A critical factor in their survival is the stability of adenosine triphosphate (ATP), an essential energy carrier whose hydrolysis could limit metabolic processes under extreme conditions. This remarkable adaptability of extremophiles has led to a growing interest in studying them, particularly with regard to exploring the potential for extraterrestrial life in our solar system.

In situ Raman spectroscopy, combined with a hydrothermal diamond anvil cell (HDAC) and a gas-pressurized autoclave, was used to study the hydrolysis of ATP in aqueous solutions at temperatures of 80 °C, 100 °C, and 120 °C and pressures up to 1670 MPa. The results indicated that ATP undergoes rapid hydrolysis at elevated temperatures, with rate constants of 4.34×10^{-3} s^{-1} at pH 3 and 2.91×10^{-3} s^{-1} at pH 7 at 120 °C, corresponding to half-lives of only a few minutes. An effect of pressure on ATP hydrolysis was observed, with hydrolysis rates increasing almost tenfold as pressure increased from 365 MPa to 1670 MPa at 100 °C. The influence of Na^+, Ca^{2+} and Mg^{2+} was investigated. It was found that while Na^+ and Ca^{2+} have a negligible effect, Mg^{2+} significantly reduces the hydrolysis rate up to 30 % at 80 °C and 50 % at 120 °C, thereby kinetically stabilizing ATP under extreme conditions.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

From Pleistocene gravels to Anthroposphere flooding: The July 2021 flood at Erftstadt-Blessem in a long-term context

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Severe flooding in July 2021 exposed Pleistocene Rhine River gravels (upper terrace) overlain by Erft River floodplain deposits near Erftstadt-Blessem, Germany. Though now inaccessible, the site provided an opportunity to investigate fluvial sculpting caused by natural fluvial processes and human interference. Preliminary cosmogenic burial dating places the Rhine gravels to 900–1100 ka, covered by <35 ka clayey sediments of a buried channel (optically stimulated luminescence, OSL, from quartz). Further OSL ages of ~1 ka in a sandy lens and ~0.4 ka in reworked floodplain loess represent early, anthropogenically-induced sediment redistribution.

Historical maps depict a pre-19th century Erft meander close to our site and the buried channel. Despite subsequent anthropogenic channelisation, the 2021 flood caused backward erosion that mirrored this earlier routing. Striking geomorphological features (theatre-shaped gully heads, pipes) formed, potentially resembling plunge pool and seepage erosion (sapping), as typically occurring where discharge meets sudden elevation changes and lithological contrasts are sharp, such as found at our site.

To evaluate the role of such exotic erosional processes in landform formation, we conducted structural and morphometric analyses using Structure-from-Motion Multi-View Stereo (SfM-MVS) photogrammetry. Several gullies display features characteristic of sapping-dominated landscapes. At least one pipe could have predated the 2021 flood, as indicated by internal manganese incrustations; fallout radionuclide analyses are underway to test soil particle transport through these pipes.

This multi-method study aims to enhance our understanding of Quaternary fluvial dynamics and anthropogenic impacts in the Rhine-Erft region, and how both contributed to the specific post-flood erosional patterns found at Erftstadt-Blessem.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Where Researchers Meet the Public: A New Conception of Science Communication in Practice

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The multidisciplinary research project " Opening science: new ways of knowledge transfer using the example of the research project BROMACKER" (2020–2025) aims to rethink science communication . The focus is on the development of dialog-based approaches to communicate scientific work related to the unique Bromacker fossil site in Thuringia, Germany. In the past years, over 30 diverse outreach formats — digital, analogue, creative, and research-oriented — have been developed and implemented to engage a broad public. Opening up the excavation site to the general public and providing an insight into the everyday work of the researchers during the excavation was the annual highlight of the communication measures. Evaluation results confirm the project's success: 95% of visitors would recommend the experience, and direct interaction with researchers was seen as very valuable. Project members also reported enhanced communication skills, great appreciation from the visitors and a deeper awareness of the societal relevance of their research. This project demonstrates how science communication can succeed when structurally integrated, politically supported, and creatively implemented. It offers a transferable model for geoscientific and interdisciplinary research communication efforts. The results underline the importance of sustainable strategies, target group-specific formats and a culture of openness – locally embedded, but with a national impact.

08.01 Young Scientist Session

New Horizons of Exceptionally Well-preserved Plant Fossils from the Upper Triassic of the Transantarctic Mountains

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The Transantarctic Basin preserves up to 4 km of Palaeozoic and Mesozoic sedimentary rocks, rich in fossil plants. Permian and Triassic floras are especially well represented, with both silicified and cuticle-bearing remains enabling detailed studies of high-latitude Gondwanan ecosystems. During the 13th GANOVEX Expedition (2018/2019), new Triassic plant-fossil sites were discovered in the Prince Albert Mountains. The most diverse site, an unnamed nunatak west of Timber Peak, yielded five Dicroidium species, Pteruchus africanus pollen organs, Heidiphyllum elongatum, and Dejerseya lobata leaves. Another horizon at the same site contained abundant cuticles of a single Dicroidium species with needle-like leaflets. Southeast of Timber Peak along the edge of the Polar Plateau, plant fossils include altered Heidiphyllum remains and a dense accumulation of two foliage types—needle-like Dicroidium and narrow-leaved Linguifolium—with dispersed seeds (Feruglioa, Carpolithus) and a small Pteruchus species. A third, species-rich assemblage was found in Southern Vicotria Land at Benson Knob in the Ricker Hills, with four Dicroidium species and minor amounts of Heidiphyllum and horsetails. These new discoveries expand known Triassic floral diversity in the Transantarctic Mountains. Particularly, the species-poor deposits offer valuable insights into organ associations, contributing to whole-plant reconstructions. Together, these findings contribute to a deeper understanding of Mesozoic polar forests in Gondwana.

08.01 Young Scientist Session

Insightful observations from the Hamama polymetallic gold prospect, Arabian–Nubian Shield, Egypt

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The Arabian Nubian Shield is the largest Neoproterozoic juvenile crust on Earth, formed by the closure of the Mozambique ocean during the Pan-African Orogeny which gave rise to the formation of the supercontinent Gondwana. There is a broad consensus that the tectonic processes related to the assembly of Gondwana led to the formation of the numerous gold deposits distributed in the shield. Later in Cenozoic, the shield was dissected by the Oligo-Miocene Red Sea rift into two parts, which are the Nubian Shield which extends through Egypt, Sudan, Eritrea, and Ethiopia and on the other side the Arabian Shield covering large parts of Jordan, Saudi Arabia, and Yemen. The gold deposits include Au-bearing volcanogenic massive sulfide (VMS), orogenic gold, intrusion related gold and rare, but significant deposits described as epithermal gold deposits .

Hamama polymetallic gold prospect in Egypt has been intermittently investigated since 1970s and is traditionally known as Au-bearing VMS. Recent field mapping and extensive drilling by Aton Resources Inc. revealed that the metals are hosted in a horizon termed silica-carbonate-barite (SCB), which is surrounded by 695 Ma submarine metavolcanics. This horizon extends for about 3.2 km in NE-ENE direction, has a thickness of 15 to 40 meters and is intersected in drillholes at an average depth of about 120m. They estimated the inferred gold and silver resources from the Hamama West prospect at about 230 and 7,836 koz., respectively. Previously, and until recently, the SCB was believed to be a part of the Neoproterozoic submarine environment. The main debate has mainly revolved around its nature, whether it is an exhalative sedimentary rock or a felsic volcanic that suffered carbonatization.

We conducted two field trips and obtained representative borehole specimens to apply a more detailed work. We discovered that the SCB is a previously unreported sedimentary formation of Late Cretaceous entrapped between the Neoproterozoic metavolcanic piles. The conspicuous time gap was affirmed by field relations, first-time observed fossils and petrographic characters that aligns with the newly proposed model. The presentend findings argue against the deposition of Au in the shield merley in Precambrian.

01.20 Process oriented microfabric characterisation of geomaterials

Microstructural Evolution of High- and Low-Strain Serpentinites from the Zermatt-Saas Meta-Ophiolite: Insights into Antigorite and Olivine Deformation at Intermediate-Depth Seismicity Depths

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Serpentinites are key players in subduction zones due to their unique mechanical behavior, which affects tectonic and seismic activity along the subduction interface. A persistent question is the mismatch between experimentally deformed serpentinites—typically showing brittle or brittle-ductile features—and naturally deformed ones, which display dominantly ductile microstructures. Debate also continues over whether deformation in antigorite-bearing rocks is driven by crystal plasticity, dissolution-precipitation, or both. Additionally, few studies have addressed deformation in hydrated or partially dehydrated serpentinites (with metamorphic olivine and clinopyroxene) at (ultra)high-pressure conditions.

To explore these issues, we analyzed a strain gradient zone within the Zermatt-Saas meta-ophiolite, focusing on antigorite and olivine deformation under conditions relevant to intermediate-depth earthquakes and mantle wedge exhumation. Low-strain samples show olivine-diopside veins from brucite-antigorite dehydration, with weak antigorite CPOs and evidence of twinning. Deformation localizes around olivine veins, where olivine shows a B-type CPO but no internal strain. With higher strain, antigorite forms a strong foliation, its CPO intensifies, and olivine experiences folding, boudinage, and CPO strengthening. High-strain zones exhibit mylonitic fabrics, intense antigorite foliation, and transposed olivine veins forming isoclinal folds. S-C’ foliations and pressure shadows develop with fine-grained olivine fibers and olivine-diopside mixtures.

These observations reveal a transition from brittle-ductile to fully ductile deformation in fluid-rich serpentinites, governed by both dissolution-precipitation and dislocation creep. This study offers rare insights into the deformation behavior of serpentinites at depth.

03.05 Advances in Paleoclimate Proxies and Their Applications

Testing the accuracy of palaeo-CO_2 estimates from the Franks leaf gas exchange model

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In light of anthropogenic climate change, the use of palaeo-CO_2 proxies to reconstruct past atmospheric pCO_2 is essential for understanding the impact of CO_2 variations on the Earth's climate. The mechanistic leaf gas exchange model of Franks et al. (2014) utilises the relationship between atmospheric pCO_2 and chemical and morphological traits of leaf fossils to reconstruct pCO_2. While the model has shown promising results, its broader applicability remains unclear, particularly whether there are consistent off-sets in pCO_2 estimates among major plant clades. Here, we evaluate the performance of the model across different phylogenetic groups (five ferns, six gymnosperms, five angiosperms), with generic input values and recommended adjustments to isotopic values, assimilation rates and the scaling of stomatal conductance. Results show species-specific variations with generic values; a clade-level bias is therefore unlikely. As a consequence, the correction factors to remove a phylogenetic effect from isotopic values do not show improvements across plant groups. Adjustments to the assimilation rate based on phylogeny, habit and habitat result in less species-specific variation and in an improvement in pCO_2 estimates. While the minor change in the scaling value of stomatal conductance for woody angiosperms results in inconsiderable differences in accuracy, precision decreases due to higher error rates. Overall, the results of this study show that the Franks model has a strong potential for reconstructing past atmospheric pCO_2 when applied in a multitaxon framework, especially with recommended assimilation rate values.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

The hydrothermal Bonanza-grade native Ag deposit Elizabeth Hill (Western Australia): an As-depleted five-element endmember or just supergene enrichment?

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Novel petrographic, mineral chemical and microthermometric data combined with hydrothermal allanite U-Pb ages of the unusual high-grade Elizabeth Hill hydrothermal native Ag vein-type deposit in Western Australia reveal similarities to five element veins. Mineralized veins are hosted by fault-controlled quartz-carbonate breccias in Archean basement rocks of the West Pilbara Craton tied to basement contact with the layered ultramafic-mafic Munni Munni Complex hosting stratiform magmatic sulfides. Unconformity-based Fortescue Group siliciclastic-volcanic cover rocks are partly eroded. Host rocks close to the mineralization are silicified, calcified and chloritized. Pre-existing magmatic sulfides comprise chalcopyrite-pyrrhotite-pentlandite and are intersected by veins of stage I characterized by sphalerite-chalcopyrite-galena with minor pyrite, pyrrhotite and gersdorffite, and stage II Ag mineralization hosting argentopentlandite-acanthite-native Ag. Supergene remobilization of stage I and II minerals produced multiple generations of native Ag encompassing wires, veins and Ag-Hg amalgam ≤35.7 wt.% Hg. Chalcopyrite and acanthite allomorphs indicate high temperatures for stage I >557 °C and II >179 °C. Two phase (vapor-liquid) inclusions of stage I record the ternary $CaCl_2$-NaCl-H_2O system with salinities of 8.1–16.6 wt.% (CaCl2+NaCl) and Th of 107–147 °C, which are interpreted as a signature of retrograde re-equilibration. Two allanite age groups (2400–2370 and 2050–1990 Ma) coincide with episodes of craton-wide hydrothermal activity and orogenic and epithermal Au vein formation. Compared to most five-element veins, Ni, Co and As are rare; hence, Elizabeth Hill may represent an As-depleted, native Ag-dominated, Kongsberg-type five-element deposit. Repeated supergene Ag enrichment probably involved reactivation of the hosting fault system and long-term weathering.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Development of a 3D geological and hydrostratigraphic model of the Agourai plateau (Morocco): insights into karst aquifer dynamics and structural framework

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A comprehensive understanding of reservoir architecture in complex karst environments requires the integration of geological and hydrogeological data within three-dimensional modelling frameworks. This study presents the first 3D geological and hydrostratigraphic model of the Agourai Plateau in Morocco, developed using the Groundwater Modeling System (GMS). The model integrates a diverse set of datasets, including borehole logs, geological maps, geophysical interpretations, structural network analyses, and piezometric measurements.

This integrated modelling approach delineates the spatial extent of geological units and refines the structural framework of the study area, capturing the complexity of the karst system. Notably, the incorporation of piezometric data into the solid model enhanced the traditional geological model, enabling the generation of detailed piezometric surfaces and high-resolution hydraulic cross-sections. The model identifies eight distinct geological units, from the basement rock to the overlying aquifer formations, with the total groundwater storage volume of the karst aquifer estimated at 36.3×10^9 m^3.

In addition to mapping the distribution of major faults that control groundwater dynamics, the model provides new insights into subsurface flow patterns and highlights the role of abandoned quarry zones in influencing the aquifer system. This regional-scale model demonstrates the potential of integrated 3D modelling as a decision-support tool for the sustainable management and protection of groundwater resources in vulnerable karst regions

01.12 Coastal dynamics in different timescales: from seconds to millennia

Geoarchaeology of Leuke Akte Roman Harbour and submerged Church remains by technology technic for heritage protected methods in Ras El Hekma area, NWcoastofEgypt

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Ras El Hekma area located in the Mediterranean sea, this area seems as triangle head land extending into the Mediterranean sea for about 15 km ,It lies West of Alexandria City for about 220 km, and some 70 km East Marsa Matruh city. Some historical writers like Fourtau, 1914 and Ball, 1942 show that Leuke Akte harbour was situated in the eastern of Ras El Hekma area.

This place was mentioned by that name by Scylax, Strabo, Ptolemy, and in the Book of Stadiums. As for the portolan from the beginning of the twelfth century, they mention it by the names: Rase El Kanayis, the red head according to Keith. As for Piri Reis, or “the Reis on (the Turkish)he calls it the head of the churches and advises ships to use it to protect themselves from the winds coming from the land. The name Leuca means “act.” White Land or White Coast or White Head.

The underwater archaeological survey in this bay resulted in the discovery of a group of amphorae and metal and stone anchors extending Chronologically, from the first century BC to the seventh century AD, indicating the intensity of navigational activity in the region.

This study aims to define geomorphological characteristics and geoarchaeological evidence of the Leuke Akte ancient harbor, and to study effect of Holocene sea level change on the study area.

This study depends on detailed geo-archaelogical and geo-morphological surveying and mapping, coring of sediment samples, interpretation of multi-dates RS images and GIS techniques.

01.26 Alpine-Zagros-Himalayan Orogenic System: Case Studies

Sedimentological and structural evidence for an Eocene start of Tian Shan mountain uplift in the Ili Basin (southeastern Kazakhstan)

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The India-Asia collision, which started about 50 Ma ago, resulted not only in mountain building in the Himalayas. Recently about 50% of the total India-Asia convergence is accommodated in the Tian Shan orogenic system, far “behind” the collision zone. The start of uplift of the Tian Shan ranges is strongly debated. Most estimations, based on thermochronology, range from Oligocene to Late Miocene. The intermontane Ili Basin in southeastern Kazakhstan accommodates continuously clastic continental sediments since the Paleogene, recording the uplift history of the Tian Shan mountains. The basin is subdivided by young basement uplifts, providing good outcrops of the basin fill. The study of numerous sections revealed growth strata and progressive unconformities in different stratigraphic levels, specific for particular basement anticlines. First indications of deformation were observed already in late Eocene units. Uplift of basement anticlines and activity of thrust faults was interrupted by periods of tectonic quiescence and continuous deposition. Alluvial fan progradation documents uplift in the hinterland. Large alluvial fans were active during different periods, some disappeared and became reactivated. The basin fill documents asynchrony of growth strata, unconformities and alluvial fan progradation, proving spatially and temporally differentiated tectonic uplift throughout the Ili Basin. We explain the varying activity of structures by strain partitioning at major strike-slip faults or temporary locking of thrusts by the load of the hanging wall, possibly caused by low erosion rates during arid climate.

01.20 Process oriented microfabric characterisation of geomaterials

Granite Fabrics and Paleostress: An Integrated Structural Approach to Felsic Plutonites

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The weak anisotropic fabrics of granites can be used to reconstruct emplacement and strain conditions to infer the paleostress field during their development. For that purpose, case studies commonly analyse the anisotropy of magnetic susceptibility (AMS) or the crystallographic preferred orientations (CPOs) of rock-forming minerals. Here, we present a systematic investigation of a range of granitoids from Germany, integrating AMS data with CPOs of feldspar and quartz (EBSD) and universal-stage measurements of microfracture orientations. Primary magmatic fabrics, as defined by AMS and feldspar CPOs, exhibit local variability in orientation and range between prolate and oblate shapes. In contrast, late- to post-magmatic fabrics are revealed through fluid inclusion planes (FIPs) and quartz CPOs. While c-axis distributions in low-strain samples are typically weak and irregular, distributions of the rhomb-faces consistently display orthotropic symmetry, characteristic of stress-induced Dauphiné twinning. These patterns, previously proposed as potential paleostress indicators, align systematically with FIP orientations, which are independently known to record coaxial strain at low differential stresses. Remarkably, both rhomb-face distributions and FIP orientations are spatially consistent across several kilometres, highlighting their potential as mappable late- to post-magmatic paleostress indicators. We discuss the implications of these findings for regional paleostress interpretations and the role of late-magmatic fluid migration pathways during the structural evolution of granites.

01.10 The co-evolution of the Earth and life from the early Archean until today

Fluid-Mediated Metamorphism in Ultramafic Rocks from the Isua Supracrustal Belt: Evidence Against UHP Conditions

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The Eoarchean Isua supracrustal belt (ISB) in southern West Greenland contains one of Earth's oldest rock records. Its tectono-metamorphic evolution remains debated, particularly regarding timing and peak conditions in mafic to ultramafic lithologies. Phase equilibria modelling suggested homogeneous peak metamorphic conditions (550-600 °C; 0.8–1.0 GPa), though recent studies of a dunite lens suggested ultra-high pressure (UHP) to prograde low-pressure deserpentinization.

This study examines metamorphism in ultramafic rocks from lens B in the northwestern ISB, analyzing four samples from rim to center using EPMA, SEM, EBSD, ICP-MS and thermodynamic modelling.

The lens rim shows strong foliation with antigorite (XMg=0.91) + magnesite + magnetite ± ilmenite. The center shows decreased deformation with antigorite (XMg=0.98) + fosterite (XMg=0.97) + magnesite + magnetite ± Ti-chondrodite/Ti-clinohumite.

We found Ti-clinohumite being replaced by Ti-chondrodite, indicating cooling at lower pressures. The presence of carbonate without brucite or talc emphasizes CO_2's role in phase relations. Thermodynamic modelling shows antigorite stability is CO_2-dependent, limiting antigorite + magnesite stability to pressures < 1 GPa at $XCO_2 > 0.005$. EBSD analysis shows olivine deformation preceded antigorite growth, supported by magnetite, magnesite and Ti-humite phases associated with olivine breakdown.

This study suggests the lens exhibits a fluid-mediated reaction front achievable at homogeneous amphibolite-facies conditions, rather than requiring UHP conditions or deserpentinization.

04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

Deeper understanding of metal oxide reduction through mechanochemical ball milling

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The reduction of metal oxides is crucial for the extraction of metals from their ores, a fundamental process in metallurgy. Growing demands within a rapidly transforming environment requires the development of innovative and sustainable solutions.[1] Mechanochemistry offers a solvent-free, energy-efficient route to materials processing, aligning with green chemistry principles.[2] By employing mechanical forces to induce chemical transformations, mechanochemical ball milling enables alternative reaction pathways, kinetics and alternative products.[3]

In this study, the mechanochemical reduction of metal oxides (e.g., Co_3O_4) is investigated through *ex situ* and perspectively *in situ* X-ray powder diffraction.[4, 5] A systematic study will explore the influence of metallic reductants (e.g., Mg, Al), gas atmospheres (e.g., H_2, NH_3), milling parameters (ball-to-powder-ratio, ball size, frequency), and jar/ball materials (e.g., steel, ZrO_2) on reaction mechanisms, phase evolution, and product properties. Metallic cobalt in both its cubic and hexagonal phases was successfully synthesized via ball milling, without the need for elevated temperatures or hazardous reducing agents such as hydrazine

This research advances the fundamental understanding of reaction mechanisms in mechanochemistry and supports the sustainable material processing. The results will contribute to critical topics such as green synthesis, recycling processes, and environmental aspects of material production. It addresses challenges at the interface of applied mineralogy, crystallography, materials science, and engineering.

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01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

A comprehensive trace element and radiogenic isotope dataset allows new insights into the petrogenesis of Quaternary Eifel Volcanism

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Lavas from the Quaternary East and West Eifel volcanic fields in western Germany are among the youngest volcanic products of the Central European Volcanic Province (CEVP). In a comprehensive approach, we report Sr-Nd-Pb-Os isotope as well as major and trace element data for 59 samples covering Quaternary Eifel volcanism. In accord with previous studies, all lavas are SiO2-undersaturated including primitive basanites, melilitites, and nephelinites as well as phonolites. In the West Eifel Field (WEVF), Sr–Nd–Pb compositions of the younger ONB-suite lavas are similar to FOZO or the EAR. Conversely, older (700 to 80 ka) F-suite lavas in the WEVF and from the entire East Eifel Field (EEVF) tap a more enriched mantle component, as illustrated by more radiogenic Sr isotope compositions and variable Pb isotope compositions. Radiogenic isotope compositions of F-suite and EEVF lavas require the admixture of melts from lithospheric mantle sources. Elevated Nb/Ta and Lu/Hf in combination with variable Os isotope compositions indicate residual carbonated eclogite components as a possible source of CO_2 in the lavas. The presence of a mantle plume can neither be confirmed nor excluded based on geochemical data alone. However, the absence of W isotope anomalies together with only moderately elevated He isotope compositions argue against a deep-rooted plume beneath the Eifel volcanic fields. Collectively, plume-like melt pulses that partially tap carbonated eclogite domains and interact to variable extents with the lithospheric mantle provide a viable model for the compositional spread of volcanism in the Eifel and elsewhere in the CEVP.

05.01 Spectroscopic methods in modern geosciences

Luminescence techniques applied to gemstone research

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Luminescence is a generic term that describes the ability of gemstones and other materials to emit light after energetic excitation of valence electrons. Corresponding to the various types of excitation, and depending on either spontaneous or stimulated energetic recovery from the excited to the ground state, there exist a fairly diverse range of luminescence phenomena and techniques. Current gemstone analysis is dominated by the use of photoluminescence (PL; excitation with light) and cathodoluminescence (CL; excitation with electrons), even though other techniques such as ionoluminescence are increasingly applied.

Luminescence is first commonly used to image internal textures of gems. Minute lateral concentrations variations in trace elements and/or structural defects result in luminescence-distribution patterns that are most sensitive in giving hints to primary growth (such as used in distinguishing naturally and lab-grown diamond) and secondary alteration processes (such as used in revealing diffusion enhancement). Second, spectroscopic analysis of the emission facilitates sound interpretation of the luminescence's origin and assists in understanding reasons for internal textures. Hyperspectral mapping represents a combination of the two approaches.

This keynote lecture attempts to summarise luminescence current applications in gemstone analysis. In an introduction, also some terminology issues (ambiguous use of "persistent luminescence" and "afterglow"; luminescence versus fluorescence) will be discussed. Presented research examples include the application of excitation spectroscopy in unravelling diffusion treatment, the use of hyperspectral mapping to estimate self-irradiation damage, non-destructive gem analysis in historic objects of art, and changes in PL spectra resulting from heat treatment of gems.

10.01 Open Paleontology Session

Anatomy, Biology and Ecology of a silicified Claytosmunda (Osmundaceae) Rhizome from Antarctica

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Osmundaceae is the only extant family of the Osmundales, the most basal order of leptosporangiate ferns. Claytosmunda beardmorensis from the Upper Triassic of Antarctica, one of the earliest representatives of the crown group Osmundaceae was first described in 1978. However, the unusual growth habit and ecology of the species have never been described in detail and some important anatomical characters were left unknown. We present new information on the species based on a detailed study of a second, better-preserved silicified rhizome collected from the type locality at Fremouw Peak.

Stem and petiole anatomy, growth habit and associated remains were analysed through acetate peels of serial section surfaces. A digital three-dimensional model showing the arrangement and growth trajectory of stems within the specimen was created from vectorized section surfaces using 3d modelling software. A morphological phylogenetic analysis of the crown-group Osmundaceae was conducted with the new anatomical information.

Unknown morphological characters were clarified and inaccurate information emended. The digital 3d model shows numerous branching, semi-erect stems within the rhizome that are arranged in a funnel-shape. The phylogenetic analysis shows that C. beardmorensis occupies a basal position within Claytosmunda and is more closely related to the genus Osmundastrum than previously assumed.

Several autochthonous and allochthonous remains of other organisms were found within the specimen. Represented groups include arthropods, fungi and several different seed plants. Noteworthy are locally abundant sporangial remains with patch-shaped annuli, presumably belonging to the host plant, as well as arbuscular mycorrhizal fungi in the host plant roots.

02.01 The Tethys Ocean – the cradle of modern tropical life

What is a species? A new machine learning approach bridging taxonomic concepts in biology and palaeontology

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Despite over 250 years of species descriptions since Linnaeus, the challenge of accurately delimiting species remains unresolved – particularly between fossil and living taxa, where data types and availability differ greatly. This has resulted in multiple competing species concepts and complicated biodiversity comparisons across time.

I present preliminary results from a project developing a novel machine learning framework for species delimitation that integrates image data from extant species – where boundaries are molecularly established – with related fossil species. Our study focuses on the renowned Plio-Pleistocene Viviparus beds of paleo-lake Slavonia (SE Europe), which preserve an iconic viviparid species flock. Since the 19th century, over 40 morphospecies have been described from these deposits, many serving as key biostratigraphic markers. The striking morphological diversification spans from small, smooth-shelled forms to large, highly ornamented shells. As a baseline for morphological diversity, we use a modern viviparid species flock from long-lived lakes Yunnan (China), exhibiting a similar range of variation.

To delineate species, we train a Siamese Convolutional Neural Network, which can learn from relatively small, labelled datasets, generalize to previously unseen classes, and perform classification with minimal retraining. A specific aim is to assess how varying degrees of fossil preservation affect model performance, offering potential for broader paleontological applications. Ultimately, we seek to reconstruct biodiversity patterns across geological time, infer diversification dynamics within the Slavonian viviparids, and critically evaluate the biostratigraphic utility of traditional morphospecies. Our novel system should be readily transferable towards a variety of species groups.

04.01 Prospection and extraction of critical and strategic raw materials in Europe

Inclusive Resource Management: Youth as Catalysts for Just and Sustainable Governance

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As Chair of the UNECE Resource Management Young Member Group (RMYMG), I will present the group's work in promoting inclusive resource management through youth engagement, intergenerational dialogue, and equitable participation in decision-making processes. Operating under the Expert Group on Resource Management, the RMYMG brings together young professionals from diverse backgrounds to contribute to the development and implementation of the United Nations Framework Classification for Resources (UNFC) and the United Nations Resource Management System (UNRMS).

This presentation will focus on how inclusive approaches can strengthen the social license, legitimacy, and long-term sustainability of resource systems. Drawing on our recent activities, including engagement at COP29, collaboration with global partners, and contributions to capacity-building efforts, I will highlight the importance of integrating underrepresented voices, particularly youth, local communities, and stakeholders from the Global South, into resource governance frameworks.

Inclusive resource management is not only a matter of fairness, but a strategic imperative for ensuring that resource development supports broader societal goals such as climate action, just transitions, and sustainable development. By fostering diversity of thought and experience, we can design systems that are more adaptable, transparent, and future-oriented.

The RMYMG aims to serve as a catalyst for inclusive dialogue and action, bridging generational and institutional gaps. This intervention invites stakeholders to engage with us in rethinking resource governance in a way that is participatory, just, and aligned with global sustainability objectives.

04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

The Lithium deposit at Polokhiv, Ukraine

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The strategic importance of lithium (Li) as a critical raw material for the global energy transition has tremendously increased in recent years. Several Li-bearing ore deposits have been identified in Ukraine, predominantly within the Ukrainian Shield and commonly associated with rare-metal pegmatites. The Polokhiv deposit, located in the central part of Ukraine within the Korsun-Novomyrhorod pluton, remains underexplored. To date, three ore zones have been delineated. Lithium mineralization at Polokhiv hosted in fine-grained microcline-petalite-albite metasomatites, with petalite accounting for estimated 95 wt.% of the total Li content.

Previous studies identified three morphological and textural generations of petalite. Generation I comprises coarse-grained crystals (up to 4 cm) intergrown with albite and microcline in an albite-microcline-petalite pegmatite. Generation II consist of micro-grained quartz-petalite aggregates that replace primary albite and microcline; symplectitic intergrowth of petalite with albite relics are also observed. Generation III is characterized by thin veinlets of petalite crosscutting the newly formed porphyry-like microcline. Preliminary tests have confirmed the potential suitability of using these ores for Li extraction.

Open questions concerning the genesis of the Li resources of Polokhiv deposit and the mechanisms of Li incorporation into ore- and rock-forming minerals will be addressed within a German-Ukrainian research collaboration between the Technische Universität Berlin and the National Academy of Science of Ukraine. Resolving these issues is essential for improving quantification of Li resources and for the development of efficient and sustainable Li extraction strategies.

07.02 Geothermal energy – Potential and utilisation of geothermal energy resources for the heat transition

Structural and thermo-hydraulic-chemical effects on geothermal energy extraction from complexly deformed carbonate reservoirs: Insights from Kohlenkalk in Weisweiler, North Rhine-Westfalia (NRW)

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Kohlenkalk, a lower-Carboniferous carbonate, is targeted for geothermal exploration in Weisweiler, NRW. In the area, both the NNW-directed Variscan shortening and the Tertiary WSW-ENE Lower Rhine Graben extension significantly affected Kohlenkalk, creating structures on the m- to km-scale that likely control geothermal fluid pathways. To understand these controls, we have classified and characterised structural elements of Kohlenkalk outcrops into fluid conduits (bedding characteristics, joints, fractures, karsts, fold hinge collapse zones) and barriers (clay smears on flexural slip folds and normal/thrust faults). Our data allow the definition of Hydraulic Flow Units (HFU) within the deformed Kohlenkalk sequence in Weisweiler and thus the identification of the most likely geothermal flow pathways.

To assess the sensitivity of these flow pathways to changes in the chemistry of the geothermal fluid, we performed a series of flowthrough experiments on Kohlenkalk sub-members. 4D microCT and post-mortem SEM data, as well as ion chromatography analyses on pore fluids yielded a time-resolved sequence of evolving transport properties, host rock mineralogy, and pore morphology under geothermal conditions.

Our two-pronged investigation combines field- and laboratory data to contribute additional insights on the multi-scale thermo-hydraulic-chemical behaviour of Kohlenkalk in Weisweiler. The dataset is ready to be utilised by digital modelling, which will improve exploration accuracy, reduce risks, and ensure the long-term sustainability of geothermal energy production in carbonates.

03.05 Advances in Paleoclimate Proxies and Their Applications

How seasonality drives interglacial permafrost thaw: Insights from speleothems and climate modelling

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Various proxy records have suggested widespread permafrost degradation in northern high latitudes during interglacial warm climates, including the mid Holocene (MH, 6000 years before present) and the last interglacial (LIG, 127 ka BP), and linked this to substantially warmer high-latitude climates compared to the pre-industrial period (PI). However, most Earth system models suggest only modest warming or even slight cooling in terms of annual mean surface temperatures during these interglacials. Here, we combine paleo permafrost reconstructions derived from speleothem and pollen records with paleoclimate simulations of the AWI-ESM-2.5 climate model and the CryoGridLite permafrost model to investigate the ground thermal regime and freeze-thaw dynamics in northern high-latitude land areas during the MH and the LIG. The simulated paleo permafrost extents are broadly in agreement with proxy contrainsts from speleothems. The simulations further revealed that not only changes in mean temperatures, but also the enhanced seasonal temperature amplitude due to a different orbital forcing have driven permafrost and ground ice dynamics during past interglacial climates. Our results provide an additional explanation of reconstructed periods of marked permafrost degradation in the past, which was driven by deep surficial thaw during summer, while colder winters allowed for permafrost persistence in greater depths. Our findings suggest that past interglacial climates have limited suitability as analogues for future permafrost thaw trajectories, as rising mean temperatures paralleled by decreasing seasonal amplitudes expose the northern permafrost region to magnitudes of thaw that are likely unprecedented since at least Marine Isotope Stage 11c (about 400 ka BP).

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Characterization of Active Tectonics and their influence on Landscape evolution in the Lower Rhine Graben (LRG), Western Germany- a morphotectonic approach

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Morphotectonic methods are commonly used to study landform evolution in regions with strong tectonic activity, like active plate boundaries. However, these methods are less often applied in low-strain but tectonically active intraplate areas such as the Lower Rhine Graben (LRG), even though the region has a history of recent and historical earthquakes. This study investigates how ongoing tectonic processes affect the landscape in the LRG. Using a 1-meter resolution LiDAR data, we applied GIS techniques, Topotoolbox (Schwanghart and Kuhn, 2010), and the SLiX model (Piacentini et al., 2020) to analyze lineaments, knickpoints, and key morphometric indices. These indices include the stream length-gradient index, hypsometric integral, basin asymmetry factor, valley floor width-to-height ratio, basin shape index, and transverse topographic symmetry factor. This study generated 53 knickpoints, and rose diagrams reveal identical trends between lineaments and existing faults. Further results show spatial correlation between anomalous indices' values, and knickpoints with existing fault structures and the generated lineaments. We interpreted the close location (< 600 m) of knickpoints to nearby fault structures, and their spreads at varied elevations to indicate 1) a passive or active tectonic control on landforms, 2) the influence of Variscan orogeny and glacial retreat on base-level changes in LRG, respectively. Finally, we used the Index of Relative Active Tectonism (IRAT), which averages all indices, to classify the region’s tectonic activity as moderate. Consequently, it was concluded that although the LRG is not highly deformed, moderate tectonic processes continue to shape its landscape.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Thermal-geological data for the safety analyses of repository systems in sedimentary host rocks of Germany

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Understanding the temperature field is essential for conducting safety analyses during site selection for a repository of heat-generating radioactive waste in Germany. The initial temperature distribution in the respective host rock determines the repository design. This information is also important for analysing possible future developments of repository systems regarding the safe confinement of radioactive nuclides. In the BGE-funded project ThermoBase, BGR and GFZ are collaborating to characterize the subsurface thermal conditions in regions with sedimentary host rocks, such as rock salt and claystone.

BGR carries out stochastic analyses of the influence of parameter variations on the temperature in the host rock and the overburden. Numerical repository system models of varying complexity are used for the safety-related assessment of the influence of the variance of thermal rock properties and boundary conditions on the temperature development in the final repository. First analyses provide insights into the effects of parameter variation on the thermal field.

GFZ is developing detailed 3D geological models for transient conductive temperature and heat flow simulations. New measurements of rock thermal properties are being conducted on core sections in the laboratory and derived from high-resolution geophysical logs. First results provide insights into the spatial variability of the thermal field and its implications for repository planning.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

Adding value to cosmogenic nuclide analyses: multi-metric approaches to studying landscape evolution

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Chemical and physical weathering and subsequent erosion from hillslopes provide the raw materials for river transport and deposition. As such, active channel sediments and sedimentary archives such as alluvial terraces contain within them a record of catchment-wide weathering and erosion processes. Cosmogenic nuclides are regularly called on to measure denudation rates, which represent the sum these processes. However, in rapidly evolving landscapes cosmogenic nuclides provide insights into catchment-averaged weathering and erosion processes only over relatively short timescales. For example, in the Southern Alps of New Zealand, denudation rates can exceed 10mm/yr, implying cosmogenic nuclide averaging timescales of less than a century. Similarly, sediment yields also provide a geologically near-instantaneous picture of catchment-wide denudation. An interesting problem then arises in which it becomes challenging to separate the effects of long-term geologic drivers of weathering and erosion such as ongoing rapid uplift from those of recent low frequency/high magnitude geologic events or anthropogenic activity. In these rapidly evolving settings, soil profiles, sedimentary deposits and geomorphic form can be useful archives to disentangle these confounding factors. We combine cosmogenic nuclides with; elemental mass balance, grain size, U/Pb, and landscape morphology to interrogate the drivers (e.g., uplift) and constrain the rates of weathering and erosion across Aotearoa, New Zealand.

02.01 The Tethys Ocean – the cradle of modern tropical life

The composition of the Tethyan plankton in the Triassic

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Triassic plankton already resembled modern communities to a considerable degree. After the end-Permian extinction, primary producers rebounded quickly: acritarchs and prasinophytes dominate Early Triassic successions, and the first calcareous nannoliths, including true coccoliths, appear by the late Norian to Rhaetian in the western Tethys and British Columbia. Calcispheres may record encysting algae, while oberhauserellid foraminifers are considered precursors of planktonic globigerinids. Unambiguous dinoflagellate cysts emerge in Middle Triassic strata of Western Australia.

Zooplankton diversified at the same pace. Radiolarians regained pre-extinction richness by the Anisian and Ladinian, with spectacular faunas in the Buchenstein Formation of the Dolomites. Planktonic crinoids, documented by masses of micro-ossicles from the Cassian Formation, formed a conspicuous suspension-feeding tier. Meroplankton was equally abundant: protoconchs show that most Cassian gastropods produced planktotrophic larvae, and echinoderms with similar larval strategies (holothurians, echinoids, ophiuroids) are widespread from Ladinian time onward, even though pluteus or auricularia ossicles are only sporadically preserved. Throughout the period, prolific ammonite populations imply a constant flux of cephalopod paralarvae that nourished higher trophic levels.

Far from being radiolarian-only, Triassic plankton already contained most of the elements that later structured Mesozoic, and ultimately modern, marine food webs.

06.01-b Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Advancing Earth System Sciences to FAIRness and Openness: the NFDI4Earth Commitment

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In the evolving landscape of geosciences, the need for findable, accessible, interoperable, and reusable as well as open (FAIR and Open) data has never been more important. The NFDI4Earth FAIRness and Openness Commitment (the NFDI4Earth Commitment, *https://doi.org/10.5281/zenodo.10123880*) invites the Earth System Sciences (ESS) community to take a step towards a more collaborative and impactful scientific future through their endorsement.

The principles of FAIR and Open data advance research data management (RDM) practices, e.g., using domain-specific research data infrastructures. Good RDM practices are crucial to ensure that data-driven methods are reproducible, robust, and transparent. The NFDI4Earth Commitment has been published in 2024 as the common vision of NFDI4Earth (*https://nfdi4earth.de*). It provides values and practical guidance to start a conversation on advancing FAIR and Open data practices in ESS. Signatories demonstrate that they strive to adhere to the commitment's values and to implement better RDM practices. ESS institutions and organisations as well as individual researchers can endorse and sign the NFDI4Earth Commitment.

We present how the endorsement of the NFDI4Earth Commitment can spark attention of individuals and initiate actions in organisations. For example, academic societies may take an endorsement as an opportunity to evaluate how they can support FAIR and Open data practices in the ESS in their role as platforms for discourse and policy setting, and as journal publishers. Through the Commitment, NFDI4Earth aims to drive progress in the Earth sciences and address global challenges. Join us in shaping the future of our field by signing today.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Petrographic analyses of a new mafic maar-diatreme volcano in the Seidewitztal near Pirna (Saxony)

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Investigations of core material from a borehole that was drilled in the Elbe Zone south of Dresden suggest the existence of a unique volcanic structure. It is situated in a complex geological area with units of different ages, e.g. Neoproterozoic greywackes of the Weesenstein Group, metamorphosed Palaeozoic sediments and igneous rocks of the Elbtalschiefergebirge and sediments of the North Bohemian Cretaceous Basin.

The borehole gives insight into a 50 m thick succession of a volcanic breccia underneath a few metres of Quaternary fluvial gravel. The colour varies between greenish-grey at the uppermost part to greenish-black down to the final depth of 55.3 m. Clast analyses allow to classify the rock as bomb-bearing lapillistone. Besides pyroclasts of different modal composition and texture, xenoliths occur representing ultramafic mantle xenoliths and diverse crustal fragments. Notable are amphibole megacrysts up to 10 cm in size.

Among the juvenile components, it can be distinguished between dominating scoria lapilli and subordinate crystallized melt fragments, which contain olivine, clinopyroxene, sometimes plagioclase in a glassy, partly altered groundmass (mesostasis). The mafic clasts are accompanied by xenoliths of greywacke, gneiss, granite and claystone with foraminifera of supposed Upper Cretaceous age. Such mixture suggests a Strombolian eruption of an alkaline basalt magma, accompanied by phreatomagmatic pulses. The mineralogical variation of the juvenile components hints to different magma batches in a complex feeding systems for this monogenetic volcano. A Tertiary age can be assumed which is common for the Lusatian Volcanic Field further east.

08.01 Young Scientist Session

Swift heavy ion induced amorphization in zircon as part of various experimental series

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To investigate the irradiation-induced structural damage in zircon, that may potentially influence dating methods, we exposed zircon samples to swift heavy ions in two different experimental series. To quantify the impact of increasing irradiation, the first series involved irradiation with gold ions (Au79+) at an energy of 8.6 MeV/u, with target fluences of 1e11, 2e11, 5e11, 1e12, and 5e12 ions/cm^2 at atmospheric pressure and 25 °C on disc-sliced zircon. Since the second series of experiments focused on the influence of pressure as an additional factor, we used a Paris-Edinburgh press combined with a modified (toroidal) large-volume diamond anvil cell (DAC) with diamond windows, which enabled the irradiation of entire zircon grain samples of larger sizes, approximately 2–3 mm. One of these samples was irradiated with uranium ions (U^{92+}) at an energy of 480 MeV/u and a pressure of 1.5 GPa at 25 °C.

Using confocal Raman spectroscopy, the focus was on the changes in the FWHM of the v3(SiO_4) Raman band at approximately 1008 cm^{-1} as an indicator of structural damage. The peak position exhibited shifts towards lower wavenumbers, and increased peak widths correlated with increasing fluence, showing a strong relationship between ion irradiation and the degree of amorphization. Maps of the samples of the second series show a linear shift of up to 4 cm^{-1} that is localized exclusively along the irradiation path. However, to more accurately determine the influence of pressure, further analytical methods, such as TEM and EBSD, are still necessary.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Holocene climatic change on the Arabian Peninsula: a high-resolution record from the Layla Lakes, central Saudi Arabia

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The Layla Lakes are a series of karst lakes located in central Saudi Arabia (300 km S of Riyadh). Their sediments were exposed in the 1980s due to groundwater drawdown. These finely laminated lacustrine sediments likely consist of seasonally alternating carbonate and sulfate layers and preserve a high-resolution archive of Holocene environmental variability in central Saudi Arabia.

Two sedimentary successions capture the transition from a more humid early Holocene to increasingly arid conditions after ~4000 cal BP. The humid phase (7500–6200 cal BP) is characterised by laminated micritic carbonates with the average sedimentation rate ~2.7 mm/year and alternating loosely and tightly packed layers. Loosely packed layers are rich in biogenic compounds, whereas tightly packed layers lack visible biological content. This alternation likely reflects summer–winter seasonality, forming seasonal laminae. Fossil-rich layers were potentially formed during summer, and biogenically poor layers during winter.

The arid phase (4400–2600 cal BP) is marked by a higher sedimentation rate ~5.1 mm/year with alternating thick gypsum and thin carbonate layers, and pollen assemblages typical of semi-desert vegetation. Gypsum layers are devoid of organic remains and likely formed during hot, dry summers with intense evaporation, whereas carbonate layers contain biogenic material (ostracods, algae, diatoms, and gastropod fragments) and may reflect cooler, wetter winters. This seasonal deposition regime appears to have persisted until recent times.

These sedimentary patterns reflect a long-term Holocene shift toward increased aridity and seasonality. Additionally, the rhythmic recurrence of carbonate and sulfate layers and variations in fossil content indicate sub-Milankovitch (centennial-scale) climatic cyclicity.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Natural amphibole and biotite crystals as potential reference materials for *in-situ* Fe isotope analysis

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The *in-situ* analysis of stable isotope ratios, e.g. $^{7}Li/^{6}Li$, $^{56}Fe/^{54}Fe$, in natural and experimental samples has become an indispensable tool for investigating inter-mineral, intra-mineral, and mineral–melt isotope fractionation processes, such as diffusion, equilibrium isotope exchange, or crystal growth / dissolution. A pre-requisite for reliable high-precision measurements of those isotope ratios, however, is the availability of suitable solid reference materials that serve as bracketing standards during the *in-situ* analyses. Here, we have investigated a series of mm-sized natural amphibole and biotite crystals using both, solution-based MC-ICP-MS and fs-LA-MC-ICP-MS, in order to assess their suitability to serve as reference materials for *in-situ* $\delta^{56}Fe$ measurements. These crystals have previously been employed to establish $Fe^{2+}/\Sigma Fe$ analyses by electron microprobe using the flank method [1]. The amphibole candidates are classified as hastingsite (Amp-11), pargasite (Amp-12, Amp-40), or tremolite (Amp-15), showing FeOT contents between 4.2 and 12.7 wt %. The four biotite candidates (Bt-18, Bt-25, Bt-26, Bt-41) display FeOT concentrations between 8.2 and 28.6 wt % [1]. The results of our *in-situ* $\delta^{56}Fe$ analyses by fs-LA-MC-ICP-MS indicate that the investigated biotite crystals are sufficiently homogeneous, and the *in-situ* data are in good agreement with the Fe isotopic compositions obtained by solution-based MC-ICP-MS within analytical uncertainty. Regarding the amphibole crystals, the *in-situ* and solution-based Fe isotope measurements reveal that only Amp-11 and Amp-40 represent promising candidates for serving as reference materials. In contrast to this, Amp-15 shows significant internal inhomogeneity and Amp^{-12} displays large crystal-to-crystal variations in $\delta^{56}Fe$.

Reference

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01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Ecohydrological changes and potential Salmon habitat suitability since pre-industrial times at the Mulde River (Germany)

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Channel patterns and river connectivity are widely recognized to be an integral descriptive parameter for the geomorphic behaviour and ecohydrological properties of rivers. They are sensitively affected by climate and land-use changes and, in turn, can indicate the habitat suitability for the aquatic fauna, i.a. expressed by the diversity of channel width, flow velocity and depositional regimes. Both, habitat potential and the overall river connectivity are additionally influenced by barriers such as weirs and dams, at least since Medieval times. Here we present the results of a multi-temporal study investigating river morphology, river connectivity and floodplain land use in the Mulde River system. The study is motivated by the local extinction of the Atlantic Salmon (Salmo salar) within the last two centuries and low-success reintroduction endeavours. In order to test for a relation to water body structures, we make use of old maps (‘Sächsische Meilenblätter’, 1780–1821; ‘Von Deckersche Quadratmeilenblätter’, 1816-1821) to pinpoint (i) historical barriers and (ii) historical floodplain land use as a pollution proxy that may have affected migratory fish populations. Furthermore, we (iii) evaluate anthropogenic changes in channel patterns assuming that these also influence salmon habitat suitability. Preliminary results point to a negative relation between an increasing number of cumulative barriers, increased floodplain land use and the occurrence of salmon populations during the past. Sinuous and meandering channel patterns correspond with higher probabilities of salmon occurrence.

01.10 The co-evolution of the Earth and life from the early Archean until today

Archean to Proterozoic siliciclastic rocks display bulk silicate Earth-like $\mu^{182}W$ and $\mu^{142}Nd$ compositions

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Short-lived isotope systems such as ^{182}Hf-^{182}W (t1/2 = 8.9Ma) and ^{146}Sm-^{142}Nd (t1/2 ≈ 100 Ma) are pivotal tools in understanding Hadean and early Archean geodynamic processes, including core formation, silicate differentiation, and crust formation. However, there is no consensus on the average crustal composition of ^{182}W and ^{142}Nd, because excesses, deficits, and bulk silicate Earth (BSE)-like $\mu^{182}W$ and μ142Nd values have been interpreted as regional rather than global average crustal compositions [1, 2].

To resolve this discrepancy, we analysed the $\mu^{182}W$ and $\mu^{142}Nd$ composition of Archean to Proterozoic (3.2 Ga to 1.2 Ga) siliciclastic rocks from the Kaapvaal Craton (South Africa) and the Yangtze Block (South China). These sedimentary rocks, integrating isotope signals from broad source regions, best represent the average upper continental crust composition. Trace element ratios (e.g., W/Th, La/Yb, Th/Sc) and long-lived radiogenic isotope compositions ($^{143}Nd/^{144}Nd$, $^{176}Hf/^{177}Hf$) infer a mixture of dominantly felsic, but also mafic juvenile igneous source rocks. Except for one shale with ^{182}W deficits, all samples exhibit BSE-like $\mu^{182}W$ and $\mu^{142}Nd$ values. Consequently, our $\mu^{182}W$ and μ142Nd data set represents the best current estimate for the composition of the upper continental crust between 3.2 and 1.2 Ga. The absence of resolvable $\mu^{182}W$ and $\mu^{142}Nd$ anomalies also constrains the corresponding mantle source compositions. This suggests that anomalous $\mu^{182}W$ and $\mu^{142}Nd$ compositions [1,3] likely originated from locally restricted and isolated mantle sources.

References

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[3] Willbold et al. 2011; Nature

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Gold mobility in subduction zone, the slab perspective

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Arc environments are Au-endowed and it has been long hypothesized that Au mobilization during slab dehydration could affect mantle composition and arc Au-fertility. Here, we determine Au-mobility during prograde high pressure-low temperature metamorphism of both metavolcanic and metasedimentary rocks from the islands of Santorini, Ios, Naxos and Syros (Greece). These have sustained peak metamorphism from greenschist to upper-blueschist/eclogite facies, allowing determination of large-scale Au-mobility within the subduction zone. Gold is significantly mobilized by fluids at the blueschist-eclogite facies. Mélange zones at the slab-mantle interface provide a unique opportunity to understand the fate of Au in the mantle. In these zones Au shows heterogeneous concentration but is not enriched, implying only partial retention in the mélange and efficient Au mobilization across slab-mantle interface. Furthermore, mélange zones contribute to the slab component inherent to arc magmatism and their intrinsically complex lithology as well as heterogenous Au concentration appears to play a role on arc magmatism Au-fertility.

08.01 Young Scientist Session

Deciphering the evolution of sea urchins through the Devonian and Carboniferous: recent advances and open questions

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Sea urchins (phylum Echinodermata, class Echinoidea) have an excellent fossil record throughout the Mesozoic and Cenozoic, but their evolutionary history in the Paleozoic is much less understood. A first diversity maximum of Paleozoic (stem-group) echinoids in the Mississippian has long been recognized, and Mississippian forms are taxonomically and morphologically distinct from their Devonian predecessors. Recent work has shown that Famennian echinoids are more similar to Carboniferous forms than to those of the pre-Famennian Devonian, implying faunal turnover around the Frasnian-Famennian boundary. Ongoing research by the author on Devonian and Mississippian echinoids from Germany and Belgium confirms that the family Lepidocentridae, after attaining its maximum diversity in the Frasnian, likely disappeared at the end of the Frasnian, while the Famennian saw the first appearance of the important Late Paleozoic families Lepidesthidae, Proterocidaridae and Archaeocidaridae. New material also confirms an Early Devonian origin of the family Palaechinidae which, after a long ghost lineage spanning most of the Devonian, would become the primary driver of echinoid diversity increase in the Mississippian. Recent research based on large datasets of museum specimens has underscored the impacts of taphonomic and sampling biases as well as the legacy of scientific colonialism on perceived patterns of paleobiodiversity and paleobiogeography in Paleozoic echinoids. To overcome these challenges and identify genuine diversity patterns, detailed and targeted systematic work based on articulated and disarticulated material must be combined with improved understanding of Paleozoic echinoid phylogeny, paleobiology and habitat preferences.

10.01 Open Topic

The story of research on Devonian echinoids from the Rhenish Massif: how historical circumstances created a mess

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Research on sea urchins from the Rhenish Massif began in the 19th and early 20th century with description of several species from the Middle Devonian of the Eifel synclines. While some of the type specimens were stored in collections in Germany, others were eventually sold to the US. During World War II, several important specimens in the collections in Göttingen and Munich were destroyed, and with the German partition after the war, specimens stored in East Berlin became inaccessible to researchers from West Germany. Subsequently, when West German researchers J. Haffer and S. Jentsch attempted to revise the genus Lepidocentrus, they were limited by the lack of available material and synonymized the species L. lenneanus, whose type material had been lost, with L. muelleri, and assigned a newly found specimen from the Sauerland to L. rhenanus, whose holotype was unavailable to them. Current re-investigation by the authors shows that L. lenneanus and L. muelleri are distinct, and the assignment of the Sauerland specimen to L. rhenanus is a mistake that resulted in researchers overlooking that L. rhenanus and L. muelleri may be conspecific. Another species from the Sauerland was described by East German researcher H. Nestler in 1982 as Palaechinus praematurus and placed in the family Palaechinidae, which is confirmed by newly found material. This species is very significant, proving a pre-Carboniferous origin of the family, but surprisingly, Nestler's work was never recognized or cited by later authors, presumably because it was simply unknown to other researchers.

05.04 & 06.05 Biogeochemistry, geomicrobiology, and biomineralogy

3D shapes of magnetite nanocrystals from magnetotactic bacteria: clues to crystal growth processes

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Cells of magnetotactic bacteria (MTB) typically contain single crystals of magnetite that have strain-specific and distinct morphologies. Crystal habits deviate from the equilibrium form, the octahedron; categories including ‘cubooctahedral’, ‘prismatic’ and ‘bullet-shaped’ are widely used in the MTB literature [1]. These morphologies have been used as biomarkers, can affect the magnetic properties of the crystals and cells [2], and may offer insight into the genetic background of control over crystal growth. However, the exact morphologies of the magnetite nanocrystals have not been systematically determined.

We performed electron tomography (ET) by obtaining tilt series of high-angle annular dark-field (HAADF) images in a scanning transmission electron microscope (STEM), since the HAADF image contrast is not affected by diffraction and is directly proportional to specimen thickness. Magnetite shapes were characterized in various MTB strains containing octahedral, ‘prismatic’, ‘ladyfinger’- and ‘bullet-shaped’ particles. While the crystals of the first two types were bound by well-defined, indexable facets, the latter two types had irregular surfaces consisting of short segments of low-index faces. A common feature of all magnetite types was a pervasive presence of voids inside the nanocystals, suggesting a growth process dominated by particle attachment. ‘Non-classical’ crystal growth by the attachment and recrystallization of precursor nanoparticles is well known in several mineral systems; however, it is surprising that euhedral, single magnetite crystals form in this way. Provided that our interpretation of the growth process is correct, the current view of the genetic control over magnetite formation in MTB might need to be revised [3].

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05.01 Spectroscopic methods in modern geosciences

Simultaneous high pressure high temperature X-ray emission and diffraction at ID27, ESRF, revisiting the spin transition of magnesiosiderite

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The recent upgrade of ID27 at the ESRF, included a portable Von-Hámos X-ray emission spectrometer for simultaneous x-ray emission spectroscopy (XES) that can be used in parallel to x-ray diffraction (XRD) experiments in diamond anvil cells (DAC), with and without laser-heating of the sample. This combined setup, built within the framework of the BMBF-funded ‘NanoExtrem-2’ project, will facilitate in-depth studies of structural and electronic properties under extreme conditions.

To test the XES-XRD setup, DAC experiments were conducted on a magnesiosiderite [$(Mg_{0.43}Fe_{0.55}Mn_{0.2})CO_3$] up to 50 GPa. Si(111) and Si(110) analyser crystals were successfully used for measurements of the Kβ1,3 emission spectrum. The experiments demonstrated that Kβ1,3 can be acquired within 90 min at photon flux of 1012 photons/s, using a 23.5 keV beam. At this energy XRD patterns with a maximum scattering vector Q = 6 $Å^{-1}$ could be collected within 30 sec. Reducing the energy to 15.6 keV enabled acquisition of Kβ1,3 in just 30 min at the same photon flux, resulting in a threefold improvement in XES intensity. At this energy, XRD patterns with a maximum scattering vector of Q=3.3 $Å^{-1}$ could be collected in 30 seconds.

These results highlighted the potential of ID27 for advanced studies of materials under extreme conditions, paving the way for novel insights into the relation between electronic state and bulk structure of many sample systems that have emission lines at energies ≥ 7 keV.

Acknowledgements

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01.08 Applications and Advancements in Sedimentary Provenance Analysis

Probing the metamorphic record using detrital rutile

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Much of what is currently known about early Earth has been recovered from detrital minerals, most notably through detrital zircon studies. But while zircon mostly records high-temperature magma formation, crustal growth and recycling, other minerals must be investigated to study the metamorphic record. Rutile, one of a range of different heavy minerals, can be used as a fingerprint for deep-crustal metamorphic processes, becoming progressively more stable under (ultra)high-pressure (UHP) and HT metamorphic conditions. Since rutile can be dated using the U-Pb method and Zr is incorporated as a function of temperature, rutile has been extensively used to trace metamorphic temperatures during metamorphism. However, extracting barometric or grade information from rutile remains one of the main challenges. Also, a more detailed assessment of rutile stability and chemistry at LT-HP conditions was lacking. Titanite, as a Ti-bearing phase, is often present at blueschist facies while rutile can be absent. To investigate this, rutile and titanite from metamafic rocks formed under HT-LP and LT-HP metamorphic conditions were studied. Rutile is found stable at HP and also at <2 kbar, lower than the constraints suggested by experiments for rutile stability, because of the release of excess Ti from Ti-amphiboles. Using Nb/V as a pressure proxy distinguishes rutile grains formed at LP from those formed at eclogitic pressures. Together with recent advances in using H_2O concentrations in rutile (Lueder et al., 2024), rutile chemistry can unlock the potential of using detrital rutile to investigate the tectonometamorphic evolution of the crust.

04.07 Mineralogy of Secondary Raw Materials

Application of natural pozzolanic material from South America-Peru as SCM

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A naturally occurring pozzolanic material from Peru was characterized comprehensively to evaluate its suitability as a supplementary cementitious material. The objective was to determine the mineralogical and chemical composition of the material.

The material was processed into powder samples for X-ray diffraction (XRD) and fused beads for X-ray fluorescence (XRF) analysis.

XRD results revealed the presence of sanidine, plagioclase, and cristobalite, indicative of a volcanic, magmatic origin. Minor variations in peak distributions across measurements confirmed the material's consistent mineralogy.

XRF analysis showed a chemical composition of approximately 74 wt% SiO_2, 14 wt% Al_2O_3, 4 wt% K_2O, and 4 wt% Na_2O, with trace amounts of CaO, Fe_2O_3, and MgO, and a loss on ignition of 0.1%.

Further investigations, including scanning electron microscopy (SEM), Blaine tests (EN DIN 196-6), Frattini tests (EN DIN 196-7) and isoperibolic calorimetry, are planned to assess precisely the material's pozzolanic reactivity. Preliminary results suggest promising potential for application in the construction industry.

03.05 Advances in Paleoclimate Proxies and Their Applications

Quantification of oxygen-17 fractionation during phosphoric acid digestion: Implications for $\Delta'^{17}O$ in carbonates

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The application of the triple oxygen isotope systematics ($\Delta'^{17}O$) to carbonates has emerged as a powerful tool for reconstructing past hydroclimate dynamics and tracing the long-term oxygen and carbon cycles. Over the past decade, a wide range of analytical techniques has been developed to determine the $\Delta'^{17}O$ value of carbonates. Most methodologies involve phosphoric acid digestion, a process introducing systematic oxygen isotope fractionation that varies with carbonate mineralogy. While oxygen-18 fractionation during acid digestion is well known, the corresponding effects on oxygen-17 remain poorly constrained for many carbonate phases. This unknown factor, is likely to contribute to interlaboratory variability in measured carbonate $\Delta'^{17}O$ values, limiting the reliability of cross-study comparisons and raising concerns about the accuracy of reported $\Delta'^{17}O$ values, particularly when mixed carbonate phases are involved. In this study, we characterize the oxygen-17 acid fractionation factor $\theta(CO_2\text{–acid/}CaCO_3)$ for a range of carbonate minerals, including calcite, aragonite, dolomite, and witherite. Instead of relying on quantitative fluorination, we apply a new technique to determine the oxygen isotope composition of the carbonate phases. This method combines high-temperature conversion elemental analysis (TC/EA) with high-voltage glow discharge to achieve quantitative oxygen extraction from carbonate as CO and its subsequent conversion to CO_2. We compare the $\delta^{18}O$ and $\Delta'^{17}O$ values of the resulting CO_2 with those obtained via carbonate acid digestion at different temperatures. All measurements were performed using laser absorption spectroscopy (TILDAS). The results of this study will provide critical reference data to improve standardization, interlaboratory reproducibility and interpretation of carbonate $\Delta'^{17}O$ values.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Oxygen isotope exchange between suspected airburst glasses and air

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Airbursts of extraterrestrial objects were likely common in the geological past but left few traces in the rock record. Three occurrences of texturally similar, vesicular natural glasses – Pica glass (Chile), Edeowie glass (Australia), and Dakhleh glass (Egypt), here termed PED glasses – may have formed during airburst events [e.g., 1] or, alternatively, through combustion metamorphism [e.g., 2]. Silicate melts can exchange oxygen isotopes with air if exposed to high temperatures for sufficient time, e.g., 50 % exchange at T > 1500 °C within 15 s [1], as observed in irghizites – a type of impact glass formed in an impact-generated vapour plume. To investigate the formation conditions of PED glasses, we therefore analysed their triple oxygen isotope compositions, and compared these with a broad suite of natural glasses. The data show that PED glasses contain several tens of atom percent atmosphere-derived oxygen. Similarly, paralavas from the Canadian Arctic – melts formed via the combustion of bituminous shales and coal seams – also incorporate significant amounts of atmospheric oxygen. In contrast, tektites, basaltic glasses from subaerial eruptions, impact melts, and desert fulgurites show no detectable atmosphere-derived oxygen. Additionally, trinitite, the glass formed by the low-altitude (30 m) nuclear airburst in 1945, does not contain measurable atmospheric oxygen either. These results confirm that PED glasses formed under exceptionally high-temperature conditions, exhibiting a common formation mechanism – either similar to irghizites but not to trinitite or, alternatively, to paralavas.

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06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Bridging Analog and Digital: Tools and Interfaces from TUNB Project

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Present-day challenges in geothermal research, sustainable exploration, and energy storage require detailed information on the geological setting of the deep subsurface, which should be at the same time easily accessible and understandable. Generalized vertical profiles serve as essential tools for using this information during various project phases, from initial planning to geological interpretation or resource estimation.

Our study presents one approach to developing such profiles for representative subareas (TK25, TK50) in sedimentary basins in Saxony-Anhalt. Stratigraphy, temperature, and lithofacies are systematically compiled in comprehensive data sets based on borehole data, historical maps, literature values, and recently published 3D parametrized volume models of the TUNB project.

To ensure broad accessibility and practical usability, an interactive map is implemented, serving both as a visualization tool and a simplified, user-friendly database. Users can select an area to view column profiles displaying stratigraphy, temperature gradients, and lithofacies distribution. Planned features include statistical summaries and an optional expansion with block diagrams highlighting geological features.

Our approach offers an efficient framework for utilizing and providing different types of geological data. It supports future research and other geological activities, and is adaptable to other regions and data types.

01.03 Chaotic rocks – characteristics, formation and geodynamic significance

Signatures of changing deformation rate dynamics in deforming rocks: Examples from the exhumed Slow Earthquake Zone of New Caledonia

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It is now recognized that there must be a wealth of interaction between processes of vastly different strain rates. One “type” example of a deformation phenomenon encompassing deformation of different rates are Slow Earthquakes (SEs). In SEs, slip occurs more slowly than in regular earthquakes, but significantly faster than can be attributed to normal plate motion. SEs have been shown to be closely associated with a range of deformation processes active at different deformation rates. Although SEs are abundant, their geophysically observed characteristics cannot be reconciled with current understanding of how rocks deform: New evidence of slip processes need to be discovered in the geological record.

Rock outcrops from an example of exhumed subducted crust in New Caledonia are interpreted to contain zones of former SEs. Microstructural characterization combining EBSD and EDS analyses deciphers controlling deformation processes, while phase petrology is used to evaluate stages of fluid ingress, production or egress. Based on our observations, we interpret that several deformation processes directly associated with the presence and movement of fluids governed rock behaviour. Relatively “slow” dissolution-precipitation creep is the main “background” deformation process responsible for the shape- and crystallographic-preferred orientations, in-grain compositional variations and grain boundary alignment. Fast brittle, hydrofracturing and local granular flow is enabled by episodic high fluid pressures induced by mineral dehydration reactions. These transient deformation processes act at much faster strain rates but occur for only short time periods.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

High strain melt transfer: signatures and implications

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We present microstructural and outcrop-scale evidence for melt migration pathways that formed during deformation within high-strain zones cutting through both partially molten (supra-solidus) and solid (sub-solidus) rocks. High-strain zones with more than 10% undeformed felsic or leucocratic material are easily recognized as melt pathways, especially in supra-solidus rocks. However, identifying similar pathways in sub-solidus rocks—or those with very low melt content (1–2%)—is more difficult, as they often lack visible felsic components at the outcrop scale and closely resemble typical mylonite zones, leading to frequent misinterpretation.

Even where large volumes of melt once moved through these zones, direct microstructural evidence can be subtle or only detectable under the microscope. When melt-rock interaction is more intense, textural signs may remain faint, but geochemical signatures can be detected at both the micro- and macro-scale. In these settings, melt tends to flow through porous, high-strain networks in a highly reactive manner, producing complex reaction fronts.

We urge geologists to carefully assess whether deformation occurred in the presence of melt, even in zones that appear solid-state. This distinction is critical because: [1] rocks deformed with even small amounts of melt are significantly weaker than those in the solid state; [2] melt-rock interactions can lead to metasomatism; and [3] these zones can channel and sustain prolonged melt movement, contributing to large-scale chemical differentiation of the crust.

01.24 Fieldwork as common playground: the importance of geological survey to unravel Earth processes

New field evidence from the eastern margin of the Lepontine Dome: structural constraints for its exhumation

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The eastern margin of the Lepontine Dome represents an area of particular interest to understand the geodynamic evolution of the Central Alps. Here, the stack of the lower Penninic units underwent a syn- to post-nappe emplacement regional Barrovian metamorphism and was then exhumed forming a dome-like structure. This vertical ascension up to the present-day crustal levels was coeval with the intrusion and exhumation of the Gruf-Bergell system along the Insubric Line and was plausibly affected by buoyancy forces driven by a hot thermal perturbation. The uplift of these units involved the structurally higher Briançonnais Tambò and Suretta nappes, that, unlike the Lepontine Dome, did not experience a regional Alpine Barrovian metamorphism. Focusing on the contact between Adula and Tambò nappes, a transition from ductile to brittle deformation behaviour can be observed in the field, along with several kinematic indicators that point to a top to North-NorthEast directed shearing of the southern portion of the Tambò Nappe. The Forcola Line, that separates Adula and Tambò nappes across the Swiss-Italian border, represents the major tectonic lineament that express a syn-collisional orogen-parallel extension within a predominantly brittle regime, active since the Oligocene and directly related to the ascension of the dome. Within this intricated scenario we present several field evidence that will help to shed light on the geodynamic setting and evolution of this area, focusing on the structural relationships between Adula, Tambò and Gruf units and on the role of rigid bodies in the deformation and related metamorphism of the Tambò Nappe.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Invertebrates from the Lower Permian Bromacker site

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The present study describes former and new findings of invertebrates from the Tambach Sandstone Member (Tambach Formation, Rotliegend Group; early Permian) at the Bromacker early tetrapod fossil site near the town Tambach-Dietharz (Thuringian Forest Basin, Free State of Thuringia, central Germany). The Lower Permian of Central Europe is mainly represented by continental sediments, deposited close to the Central Pangaean Mountains on the supercontinent Pangaea. Sand- and siltstones of several fossil sites in the Tambach Formation contain a characteristic fauna and flora, indicating extreme environments caused by a continental near-equatorial climate. During our project “Bromacker”, which runs from 2020 – 2025, we excavated fossils of invertebrates accompanied by vertebrates, plants and ichnofossils within the context of our annual field campaigns at the Bromacker site. The low diverse fauna of invertebrates belongs to the groups of conchostracans, insects, diplopods and Hydromedusae, each containing only 2-4 species, which all need revised descriptions. All these invertebrate fossils are preserved as imprints, no body fossils have been found so far. Most common are conchostracans, whereas insects and diplopods are much rarer. Hydromedusae are less frequent and occur within the Tambach sandstone layers but not within the siltstones of the Bromacker horizon. The invertebrates, dominated by arthropods, are representatives of a typical terrestrial fauna which indicates full continental environments in a strongly seasonal climate causing fluctuating wet and dry conditions with non-permanent ponds and floddings.

01.11 Micropalaeontology – Advancements and Perspectives in Multiproxy Studies

Ostracods from the Layla Lakes in Saudi-Arabia – first results

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The former Layla Lake Area in Saudi Arabia were covered by a couple of lakes which dried up until the 1980th, caused by man-made irrigation processes. The running DFG founded project „Zwischen der Westwindzone und der Innertropischen Konvergenzzone: ein hochaufgelöstes Paläoklima- und Paläoumweltarchiv holozäner Sedimente der Layla-Seen in Saudi Arabien“ investigates the lake sediments by applying a multi proxy approach to reconstruct the lake history and link it to climate changes during the Holocene. The applied methods include sedimentology, geochemistry, hydrology, diatoms, palynology and micropalaentology. Here we present the results of the ostracod analysis of the master section L-2-1. We identified at least four species (Pseudocandona spp., Cyprideis torosa, Darwinula stevensoni and Heterocypris salina), which indicate different water qualities, probably based on changing water levels and development of a phytal zone. Additionally, we used the ostracod valves of two selected species for stable isotopes analyses. Although the pollen association indicates the increasing aridisation of the Arabian peninsula during the late Holocene, the ostracod assemblages do not follow this trend and point to a water column which seems to be independent from the general climate trends. More intense investigations of the population structure the detailed ostracod shell features and a comparison with the four other sections of the Layla Lakes are needed for further details and will be carried out in near future.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Induced seismicity in Germany during the last decade – an overview and update

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The Federal Seismic Survey at BGR evaluates seismic events in Germany and neighbouring countries on a daily basis. The results are supplemented by the outcomes of the seismological agencies of the federal states of Germany and German universities and stored in an event database and in the German earthquake catalogue.

The events are classified as natural earthquakes, induced earthquakes or explosions (mostly quarry blasts). A considerable number of the events are induced earthquakes. They originate from stress changes due to human activities in the subsurface. The main causes of the induced events are coal mining, potash salt mining, natural gas extraction and geothermal energy production.

We describe the characteristics of the associated seismicity for the different mining regions in Germany. In contrast to natural seismicity which originates in long-term processes, the number and strength of induced seismicity is strongly dependent on rather short-term temporal and spatial changes.

The seismicity in coal mining regions, e.g., decreased coinciding with the shutdown of coal mining, whereas seismic activity in geothermal or natural gas fields show different behavior, increasing or decreasing depending on the location. Additionally, the latter both types of induced seismicity show remarkable peculiarities in their temporal behavior.

We show the temporal course of induced seismicity over the last 10 years in dependence on the distinct extraction types and compare it with the previous decades. In addition, we also investigate the magnitude-frequency relationship and the energy release of the induced earthquakes and compare the parameters with those of the natural seismicicity.

03.04 All about carbonates

Nanoscale processes in crustal carbonate fault zones

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Determining fault rheology is vital for assessing earthquake hazards, yet the mechanisms controlling fault strength, slip behaviour, and healing remain uncertain, especially in fluid-rich carbonate systems. Advances in high-resolution microscopy and isotope geochemistry reveal that crustal carbonate fault zone deformation occurs at the nanoscale, significantly impacting fault rheology throughout the seismic cycle. We integrate natural fault observations from Greece with high-velocity rotary-shear experiments to investigate nanoscale transformations in carbonate gouges. Under fluid-rich conditions and using ^{18}O-enriched tracer fluids, experiments show near-instantaneous calcite decarbonation during slip, producing transient phases like CaO, amorphous carbon, and nanocrystalline calcite. These products govern fault strength evolution, enabling dynamic weakening independent of conventional frictional mechanisms. Natural mirror slip surfaces also display nanoscale coatings of amorphous carbon and secondary calcite nanograins, indicating similar processes occur in nature. Nanostructural evidence reveals a shift in deformation mechanisms, from grain-boundary sliding to crystal-plastic flow and dynamic recrystallisation, driving cyclic grain size reduction and strengthening. We propose that triboelectrochemical processes, triggered by slip-induced electrical potentials, may facilitate CO_2 reduction and amorphous carbon formation. These findings challenge traditional fault models by showing that weakening and healing are largely governed by chemically driven nanoscale phase changes, not just mechanical abrasion. Together, these nanoscale processes explain the formation of ultra-smooth fault surfaces and influence both co- and post-seismic fault behaviour. Our results emphasise the critical role of fluids and transient phases in seismic mechanics and advocate for integrating nano-analytics with geochemistry to better understand earthquake processes in carbonate-rich faults.

08.03 Tilly Edinger Symposium

Integrative approaches to fossil cephalopod macroevolution

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Cephalopods are among the most iconic taxonomic groups for palaeontological research due to their excellent fossil record and high evolutionary rates. However, despite their historical relevance, phylogenetic studies have been lagging behind when compared to other fossil groups. Only recent years have seen an increase in these studies, with the application of modern quantitative methods such as Bayesian inference and particularly the fossilised birth-death model. This has allowed a clearer understanding of the evolutionary history of different groups of fossil cephalopods. Building upon this, it is also necessary to expand research efforts into novel, as well as traditional directions. For example, comparative phylogenetic tools allow to target specific characters for ancestral state reconstructions or their rate of changes across the tree. This can be used for geochemical proxy data, allowing to link population-level palaeoenvironmental conditions with macroevolutionary patterns, for which the term “phylogeochemistry” was recently established. Other studies have provided new insights into biomineralization strategies, microstructures and chemical composition of fossil cephalopods, as well as improved knowledge on the 3D morphology of internal shell structures. Last but not least, core taxonomic work remains crucial, as it forms the basis of palaeobiological research, but many uncertainties and problems persist. All previous aspects provide information that can be fed back into morphological character matrices or further explore cephalopod macroevolutionary patterns through downstream analyses. In conclusion, fossil cephalopods can serve as an excellent example how diverse tools allow for an integrative perspective on the evolution and palaeobiology of a clade.

03.05 Advances in Paleoclimate Proxies and Their Applications

Phylogeochemistry – the what, how and why

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Biodiversity dynamics in deep time are influenced by climatic changes. However, linking these two aspects is challenging. At a basic level, a phylogenetic tree can be directly compared to global averages of a palaeoclimate proxy of interest. This approach is only qualitative and neglects regional climate differences. In a recent article, we introduced the concept of phylogeochemistry, which links the – typically distant – topics of geochemical proxy data and comparative phylogenetics. As a case study, we applied this technique to main and trace element concentrations in belemnite rostra, showing how and at what rates these proxies change through time with respect to macroevolutionary links. Here, we introduce phylogeochemistry more broadly, explaining the motivation and background, and provide a brief overview of the methodology and potential research questions. Specifically, in a phylogenetic tree, each tip (representing, e.g., a species or population) can be associated with proxy data (e.g., oxygen isotope ratios used for the reconstruction of palaeo-seawater temperatures). Phylogenetic comparative methods can then be used to reconstruct ancestral states at internal nodes or the rate of changes. Potential applications include, e.g., testing whether temperature affects extinction rates, whether distinct warm- or cold-water clades can be identified. Due to the flexible probabilistic framework, the models can be specifically tailored to the research objectives at hand. We further discuss challenges and caveats that need to be considered in study design. Last but not least, phylogeochemistry calls for closer collaborations between geochemists and palaeobiologists for the best results.

01.04 Latest Achievements in Scientific Ocean and Continental Drilling

Two atypical overdeepening-fills from the Lake Constance area

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During the Pleistocene epoch the Alpine scenery with its surroundings was repeatedly reshaped by glacial activity. Subglacial erosion led to basin-shaped structures, so-called ‘overdeepenings’ (OD), embedded in bedrock. Their sedimentary fillings are important archives for understanding glacial history and the glacial impact on environmental transformation. Some of these infills are composed of multiple cycles representing separate glaciations.

Numerous well investigated cores in the Northern Alpine Foreland led to the recognition of typical fining-upward OD-fill sequences – characterized by glaciolacustrine deposits overlying glacially originated diamicts at the basal unconformity. These fining-upward sequences typically start with glacitectonites that regularly transition into coarse-grained, sand-dominated, and finally fine-grained basin fills, and can occur as several unconformably stacked units.

In the ICDP-DOVE framework, two new cored profiles were recovered north of Lake Constance (drill sites Gaisbeuren and Lichtenegg). These consist of OD-fills that are not typical for the Alpine Foreland, because they are almost entirely composed of diamictic deposits. While these deposits show some variations in concentration and size of clasts, well sorted lacustrine sediments are missing. Potential reasons for the atypical character of these OD-fills are to be discussed.

04.01 Prospection and extraction of critical and strategic raw materials in Europe

Acceptance of Plant-Based Geochemical Exploration and applicability: Lessons from SEMACRET

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This study presents findings concerning plant-based geochemical exploration from the SEMACRET project, which investigated identifying sources and deposits of orthomagmatic critical raw materials (CRMs), including Ti, V, Ni, Co, Cr, Cu, and PGM. Our research demonstrates that plant geochemistry effectively reflects underlying geology across diverse ecosystems, as well as exploration targets such as sub-outcropping ores and subtle lithological variations, including different types of mafic rocks.

Through community engagement, we found that local stakeholders generally accept plant-based geochemical exploration, perceiving it as a low-impact and environmentally benign activity. While concerns about potential mining activities may persist, this method was recognized as non-intrusive and potentially beneficial for addressing environmental research questions beyond exploration.

This contribution summarizes the key takeaways from community events and interactions regarding surficial geochemistry, and contextualizes the effectiveness of plant-based exploration for identifying sub-outcropping mineralizations in European ecosystems from a geologist's point of view. A crucial aspect of conducting surficial geochemistry was found to be the timely and transparent communication with local stakeholders about the sampling methods and objectives, which helped to establish trust and acceptance.

The lessons learned from SEMACRET, scientificallly and during interaction with stakeholders, will inform the development of exploration strategies for the DeepBEAT project, which focuses on sustainable deep exploration in Europe.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Constraining the earthquake recurrence intervals of the Periadriatic Fault using ESR dating and numerical modeling

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Both electron spin resonance (ESR) and optically stimulated luminescence (OSL) are dating methods that have been used to date surface-rupturing earthquakes along faults using gouges. Laboratory shear experiments have demonstrated that a complete resetting of ESR and OSL signals can be achieved by shear heating during faulting. However, ages obtained using OSL/ESR from fault gouges indicate overestimation of up to 2–3 orders of magnitude compared to the last known historical earthquakes along the faults. A possible explanation for this discrepancy is the incomplete signal resetting during faulting events.

In this study, we evaluate the conditions for partial thermal resetting of quartz ESR signals (Quartz – Al center) in fault gouge samples from the Periadriatic Fault (PAF) System in the Eastern Alps. The PAF is one of the largest post-collisional faults in the Alps, mainly active during late Oligocene–Miocene times, contributing to lateral extrusion towards the east. The seismic activity of the PAF has been debated but recent studies indicate that the fault hosted surface-rupturing earthquakes during the Quaternary.

Apparent ESR ages and signal thermal stability parameters were integrated to model the possible partial signal resetting conditions of the gouges due to seismic activity. Maximum shear heating temperatures were integrated using Raman spectroscopy of carbonaceous matter in the gouges. Our findings show that for the PAF the possible reset conditions are met at earthquake recurrence intervals in the order of 1–100 ka with shear heating temperatures below 350 °C.

06.02 Recent advances in fossil imaging

Virtual sectioning: a micro-CT and point counting workflow for non-destructive organism quantification

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A common method to assess the inner structure of a fossil, a litho- or a bioclasts are thin sections. However, producing thin sections requires the destruction of the examined object, rendering it unavailable for subsequent studies. Moreover, the number of sections that can be obtained from one sample or object is limited, making quantitative analyses difficult.

Herein, we introduce an advanced methodological solution for this issue. A methodological combination of virtual micro-CT cross-sections with a modified point counting approach allows for straightforward and non-destructive identification and quantification of the examined sample.

We demonstrate the benefits of this method through a pilot study examining the quantitative biological composition of calcareous rhodolith matrices from the Arctic Svalbard archipelago. These calcareous matrices can be composed of one or more crustose coralline algal taxa, as well as a mixed assemblage of various invertebrate encrusters. Due to their unique skeletal structure, these biological components can usually be clearly identified in micro-CT scans.

Virtual cross cutting of scanned matrices, quantification of their taxonomic compositions via point counting and subsequent analyses via binomial regression models revealed bathymetrically influenced proportional differences of the rhodoliths.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Ostracoda as proxies of anthropogenic impacts in fluvial systems – new actualistic studies and perspectives from Central Germany

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Ostracoda (Crustacea) are widely used and approved proxies for lacustrine palaeoenvironments, but are rarely applied for characterising river sediments. Their densities are generally lower in rivers and overbank sediments, the latter often show dissolution of the calcitic ostracod shells. We think, however, that ostracods have a much higher potential for palaeoecological analysis of river sediments, especially when combined with molluscs, but this needs additional research. For further exploring their potential, we analysed recent ostracod associations from several river systems in Germany: The Saale and its tributaries around Jena (37 samples), streams in the Thuringian Forest (26), as well as two smaller rivers in southwestern Germany; Echaz and Eger (18). Almost all samples contained ostracods, most of them in high numbers, allowing detailed statistical analyses. We found 32 ostracod species in total. Most abundant are Candona candida, Cavernocypris subterranea, Cypria ophthalmica, Eucypris pigra, Ilyocypris inermis, I. bradyi, Limnocythere inopinata Prionocypris zenkeri, Psychrodromus olivaceus and Potamocypris zschockei. Water quality assessment based on recent or fossil associations, similar to the saprobia index, is possible and can be improved by combining ostracod with mollusc data. Water turbulence, phytal zones and non-permanent water cover are indicated. Special attention has to be paid to taphonomical effects, like transport, disarticulation, fragmentation, abrasion and dissolution.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Molluscs and Ostracods as Bioindicators in Holocene Floodplain Sediments of the Rivers Echaz and Eger (Southern Germany)

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The floodplains of the rivers Echaz (3rd order tributary of the Rhine) and Eger (3rd order tributary of the Danube) in southern Germany were both heavily anthropogenically modified from the Middle Ages to early Modern times. Water pollution from the larger cities and the usage of water meadows are two important examples of human activities that are visible in the sediment, which ostracods and molluscs can provide more information about.

Actualistic studies of ostracods in central European rivers have confirmed that they are good indicators for documenting water turbulence and phytal zones as well as non-permanent water covers. With fossil assemblages thereby also the spatial extent of water bodies can be assessed. Water pollution by organic substances or heavy metals may be indicated and assessed by oxygen or heavy metal sensitive species. The frequency of aquatic and terrestrial gastropods, bivalves, and macrobotanical remains provide further information about the floodplain development, the palaeoenvironment, and the past land use.

In both colluvial and overbank deposits, taphonomic effects play an important role in the distribution of micro- and macrofossils. Transport can be detected by, e.g. disarticulation, fragmentation or abrasion of ostracod carapaces and mollusc shells. Although the springs of both Echaz and Eger derive from the Swabian Jura and are characterized by calcareous water, the overbank sediments often show dissolution, especially the thinner ostracod valves. Local changes in dissolution patterns can, however, also be used to indicate groundwater levels or the spatial location or proximity of a water body.

05.04 Biogeochemistry, geomicrobiology, and biomineralogy

Organic Matter Dynamics and Microbial-Mineral Interaction across Aridity Gradients in the Atacama Desert

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The Atacama Desert in Northern Chile, one of the driest places on Earth, provides a unique setting for studying organic matter preservation and microbial resilience in extreme aridity. Our project investigates the relationships among organic compounds, microbial communities, and mineral substrates across aridity gradients from the Coastal Cordillera via the hyperarid core to the foothills of the Andes. Its focus is on investigating surface crust formation, organic matter dynamics within these crusts, and the role of lithobiotic and endolithic communities in stabilising soil through interactions with mineral matrices. We combined gas chromatography-mass spectrometry (GC-MS) and scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy (EDX) to analyse lipid biomarkers and microorganisms, biofilms, and biominerals, respectively. First results reveal that surface crusts from areas receiving more than 5 mm of annual rainfall show a much higher diversity and concentration of sterols and fatty acids compared to areas with less than 2 mm of rainfall, reflecting differences in biological diversity, crust composition, and organic degradation. Halite crusts display lower lipid contents than adjacent soil crusts. Samples from the hyperarid core exhibit abundant aromatic hydrocarbons, suggesting atmospheric input and microbial degradation. SEM images reveal close microbial-mineral interactions and their agglutinating effect on mineral particles. Integrating biomarker data with mineral and microbial analyses aims at unravelling how biogeochemical processes, past hydrological episodes, and microbial activity simultaneously shaped the desert landscape, contributing to a broader understanding of carbon dynamics in extreme environments.

05.02 Understanding (geo)materials with advanced experimental and computational methods

CO_2-neutral and -negative Mg-binders based on olivine

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The production of ordinary portland cement releases large amounts of CO_2 by burning of fossil fuels and by decarbonation of limestone, in which CO_2 is chemically bound as $CaCO_3$. The burning process leads to decomposition of $CaCO_3$, where CO_2 is released and CaO is part of the clinker.

For this new building material, olivine is used as raw material instead. In this study, the Mg-end-member forsterite, Mg_2SiO_4, is used as model system to describe the hydration of olivine, which naturally occurs as a Mg-rich solid solution. Forsterite is able to react with water, forming serpentine, $Mg_3Si_2O_5(OH)_4$, and brucite, $Mg(OH)_2$. This reaction is known as serpentinization and lasts long time scales during geological processes, but can be accelerated by an activation process [1] for technical applications.

The activation process consists of two steps. First step is autoclavation of forsterite, which corresponds to serpentinization. Serpentine and brucite are thermally activated in second step. Annealing these hydrate phases leads to thermal decomposition, where H_2O is partially released and a reactive amorphous magnesium silicate phase is formed. The activation process is low in energy consumption and does not release chemically bound CO_2.

The activated magnesium silicate phase reacts with water forming a M-S-H phase. M-S-H has only low crystallinity [2]. Furthermore, this binder shows the possibility of CO_2 uptake by mineral carbonation, creating a CO_2-negative building material.

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07.03 Quantifying surface and near-surface dynamics with remote sensing and geophysics

Linking Geophysical Signatures to Iron Mineral Dissolution in Acidified Aquifer Sands

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The real-time monitoring of mineral dissolution processes would constitute a much-needed advancement in remediation strategies at contaminated aquifers. Recent advances in applied geophysical techniques have highlighted the potential of methods such as spectral induced polarization (SIP) for monitoring subsurface (bio)geochemical processes non-invasively. SIP's unique ability to trace geochemical changes stems from its capability to detect changes in the charge storage properties at the mineral-fluid interface in porous media. The unique link between geo-electrical and geochemical processes makes SIP a valuable tool for monitoring changes in redox-active minerals such as oxides and reduced minerals such as iron sulfides. Here, we present results from a flow-through column experiment, where we triggered the dissolution of naturally occurring reduced iron (sulfide) phases by infiltrating 0.01 M HCl into aquifer sand collected from the Fuhrberger Feld Aquifer (Hannover, Germany). We integrated our geochemical investigation with geophysical measurements collected over both space and time. We further developed a reactive transport model to simulate coupled chemical and physical processes. Our model, calibrated using observed breakthrough curves, accounted for both the dissolution of iron sulfides and the protonation of residual mineral surfaces under acidic conditions. The incorporation of mineral dissolution as well as protonation of the residual mineral surface at lower pH in our reactive transport model reveled a strong linear correlation between the dissolution front arrival time and the timing of a measured anomaly in the SIP signal. These results underscore the potential of SIP as a powerful tool for subsurface process monitoring and predictive environmental modeling.

01.05 From mantle to crust: following melt evolution from source through the lithosphere

How can we chemically analyse fluids *in situ* around mineral inclusions in gem-quality diamonds?

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Diamonds crystallize from fluids or melts circulating in the Earth's mantle. Direct analysis of these fluids is possible when they remain entrapped during diamond growth, a rare feature in gem-quality stones. We present a three-step approach to analyse thin silicic fluid films (≤ 5 µm; cf. Nimis et al., 2016) surrounding mineral inclusions in gem-quality diamonds using slow LA-ICPMS depth profiling.

Non-destructive characterization: FTIR and Raman spectroscopy are used to classify diamonds and identify mineral and fluid inclusions. Confocal micro-Raman mapping reveals a heterogeneous 3D distribution of fluid films containing Si2O(OH)6 and Si(OH)4 around mineral inclusions.

Laser ablation time estimation: LA drilling experiments on a diamond fragment helped to determine the ablation rate. Combined with the inclusion depth, this allows estimation of the time needed to reach a mineral inclusion at a constant LA repetition rate.

Targeted LA-ICPMS depth profiling: A photo of the marked diamond, showing both the diamond surface and the inclusion in focus, is overlaid on the live image, enabling accurate targeting of the mineral inclusion during LA-ICPMS analysis. Slow ablation (~2 Hz) resolves distinct chemical signals. Fluid-mobile (e.g., Ba, Sr) and mineral-specific elements (e.g., Mg, Fe for olivine) are used to differentiate between fluid, host diamond, and mineral inclusion in a single depth profile.

Despite limitations from pit tailing, graphitization, depth-dependent ablation rates, and biased inclusion depth estimates (diamond’s high refractive index), we successfully analysed two samples. These results allow comparison of entrapped fluids with previously studied High-Density-Fluids (HDFs) from fibrous diamonds using trace element ratios.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Permeability evolution during cyclic loading at different temperatures using the Thermo-Triaxial device

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The study of the long-term evolution of permeability of crystalline rocks under different high-pressure/temperature conditions is important for various geological underground projects, including the safety disposal of nuclear waste. As one of the specific objectives of the AMPEDEK project, this work focuses not only on studying the thermo-hydro-mechanical response of a representative granitic rock sample from the German crystalline basement under different high-pressure/temperature conditions, but also on analyzing the dynamics of permeability through long-term flow-through experiments.

The experiments were conducted using the Thermo-Triaxial device, which was designed to perform triaxial tests under high pressure/temperature. Cylindrical plugs were tested under different combinations of vertical and lateral stresses at three temperatures (30, 60, and 90 °C). Matrix permeability and the resulting deformation of the plugs were continuously monitored throughout the entire experiment (12 days).

At 30 °C and 60 °C, permeability exhibited minor and reversible changes during one or two load–unload cycles, indicating limited alteration of the rock structure under these conditions. In contrast, at 90 °C, a pronounced and irreversible decrease in permeability—by more than two orders of magnitude—was observed during the first load cycle, suggesting permanent structural changes or clogging effects within the pore network. During the second cycle at 90 °C, the permeability behavior resembled the reversible trends observed at the lower temperatures.

Permeability changes can be categorized into two types based on the prevailing stress conditions: [1] instantaneous changes resulting from the modification of the mean stress, and [2] gradual changes attributed to time-dependent deformation (creep-effect).

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Monomineralic magnetite layers in the Bushveld Upper Zone formed by sinking Fe-rich immiscible melts

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Monomineralic magnetite layers (MMLs) in mafic layered intrusions are a key global source of iron (Fe) and the primary suppliers of titanium (Ti) and vanadium (V). However, their formation mechanisms remain poorly understood. In this study, we examined drill core samples of Magnetite Layer 21 from the Upper Zone of the Bushveld Complex through detailed textural and mineralogical analyses. Petrographic observations reveal abundant plagioclase xenoliths and narrow plagioclase-rich layers within the magnetite layers. At the contacts between magnetite and plagioclase-rich layers, various symplectites (comprising olivine, plagioclase, amphibole, and biotite) and overgrowth rims (olivine and amphibole) rooted in Fe-Ti oxide grains are observed. Microprobe analyses indicate that the composition of primo plagioclase remains nearly constant (~An#54–56), while plagioclase in symplectites is significantly more anorthitic (~An#70–90). The Mg# of olivine and amphibole decreases from the rims toward the symplectites along the growth direction. Mass balance calculations suggest that these symplectites formed through reactions between primo plagioclase and Fe-rich immiscible melts. The presence of such melts is further supported by chilled margins within Magnetite Layer 21 and at its base, where fine-grained primo plagioclase with extremely anorthitic compositions (~An#90), extremely Fe-rich olivine (~Mg#30–35), and euhedral apatite assemblages are found. Based on mineral textures and compositions, we propose a new formation model for MMLs, in which Magnetite Layer 21 formed from Fe-rich immiscible melts that sank following the onset of immiscibility.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Multi-scale, open-system magmatic and sub-solidus processes contribute to the chemical and isotopic characteristics of a shallow crustal magma reservoir: a plutonic perspective

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Plutonic bodies are solidified magma reservoirs, and their chemical and isotopic characteristics represent the integration of magmatic and sub- solidus processes operating across spatial and temporal scales during pluton construction, crystallization, and cooling. Disentangling these processes and understanding where chemical and isotopic signatures were acquired requires the combination of multiple tools trac-ing processes at different time and length scales.

Here, we combine whole rock and mineral major, trace element, and isotopic compositions with high-precision U-Pb ID-TIMS zircon geochronology to evaluate differentiation processes and their timescales in the bimodal (gabbro and granite), shallow crustal Guadalupe Igneous Complex, Sierra Nevada, USA.

We show that the complex was constructed in ~300 kyr. Pluton-wide $\delta^{18}O$(whole-rock), $\delta^{18}O$(zircon), and Sr- Nd isotopic ranges are too large to be explained by *in situ*, closed- system differentiation, instead requiring open- system behavior at all scales. Low $\delta^{18}O$(whole-rock) and $\delta^{18}O$(zircon) values indicate assimilation of hydrothermally altered marine host rocks during ascent and/or emplacement. *In-situ* differentiation processes operated on a smaller scale (meters to tens of meters) for at least ~200 kyr via [1] percolation and segregation of chemically and isotopically diverse silicic interstitial melt from a heterogeneous gabbro mush; [2] crystal accumulation; and [3] sub- solidus, high- temperature, hydrothermal alteration at the shallow roof of the complex to modify the chemi-cal and isotopic characteristics.

Whole-rock and mineral chemistry in combination with geochronology allows deciphering open-system differentiation processes at the outcrop to pluton scale from magmatic to sub-solidus temperatures over time scales of hundreds of thousands to millions of years.

05.01 Spectroscopic methods in modern geosciences

Fe3+/FeT ratios in amphibole minerals determined by single-crystal synchrotron Mössbauer spectroscopy: a tool to understand the redox state of arc magmas

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Amphibole is an important fractionating phase during calc-alkaline differentiation in arc magmas. Through the presence of both ferric (Fe^{3+}) and ferrous (Fe^{2+}) iron in its crystal structure, amphibole has the potential to provide constraints on variations in Fe^{3+}/FeT ratios and thus magmatic oxygen fugacity (fO_2) of the melt from which it crystallized.

We present major element compositions (electron microprobe), hydrogen isotopes and H_2O contents (secondary ion mass spectrometry), and Fe^{3+}/FeT ratios (single-crystal synchrotron Mössbauer spectroscopy; SMS) of volcanic amphiboles, which crystallized from magmas recording a wide range of fO2 (ΔNNO = -1.0 to + 3.0, log units relative to the Ni-NiO buffer). These high spatial-resolution analytical techniques are applied to the same area on each grain thus allowing to correlate data sets and avoid averaging inclusions and intra-grain compositional heterogeneity present in many natural amphiboles.

Amphibole Fe^{3+}/FeT ratios increase with increasing fO_2 varying from 0.14 to 0.67 over the investigated fO_2 range thus amphiboles may be useful monitors of magmatic oxygen fugacity. However, individual volcanic amphiboles can experience extreme dehydrogenation and associated sub-solidus Fe oxidation (e.g., with Fe^{3+}/FeT ratios of up to 0.86, low H_2O: 0.17±0.01 wt. % and extreme δD: 421±4 ‰ relative to SMOW), which likely occurred during shallow crustal storage. It is therefore important to combine the aforementioned high-spatial resolution and high-precision analytical techniques to distinguish primary magmatic from secondary amphibole Fe^{3+}/FeT ratios to interpret Fe^{3+}/FeT ratios correctly in the context of magmatic fO_2 .

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Facies Characterization and Stratigraphic Evolution of Atypical Upper Maastrichtian Shallow-Marine Deposits of the Reitbrook Formation, North German Basin

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The youngest Maastrichtian sedimentary unit in the North German Basin (NGB) is represented by the Reitbrook Formation. Historically significant as a hydrocarbon target, these marine deposits are currently under evaluation for mid-depth geothermal potential. Yet, they remain poorly characterized, with limited understanding of lithofacies variability, depositional environments, and stratigraphic evolution.

This contribution presents preliminary results from a comprehensive sedimentological study of a 140-meter-thick core section of Upper Maastrichtian beds, recovered from the central-northern sector of the NGB in Lower Saxony. Emphasis is placed on lithofacies analysis and the identification of depositional sequences, complemented by existing petrophysical data to assess vertical variations in reservoir quality.

Two lithofacies associations dominate throughout the succession: i) whitish, frequently flint-bearing, sandy marlstones, containing considerable amount of terrigenous component, likely deposited in inner to mid-shelf settings; and ii) glauconite-rich and siliciclastic-dominated “greensand” beds deposited in a nearshore environment, showing high porosity and permeability values. Both associations differ markedly from the classic bioclastic limestones of the Reitbrook Formation described in the literature, have not been previously documented, and are thus interpreted as proximal equivalents.

Sedimentary sequences of various orders are identified within the succession. Particularly, its basal portion comprises stacked small-scale sequences, typically within a 20-meter thickness, characterized by variations in sandy marlstone thickness and flint content, and bounded by glauconite-rich clastic beds. These cycles likely reflect the interplay between sea-level fluctuations and/or episodic pulses of sediment influx. Overall, the succession displays a pronounced regressive trend, with nearshore greensands increasingly dominating upward, correlating with enhanced reservoir potential.

01.26 Alpine-Zagros-Himalayan Orogenic System: Case Studies

Asymmetric Exhumation Across the Western Himalayan Syntaxis: Implications for the Tectonic Evolution of Orogenic Wedge

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The western Himalayan fold-and-thrust belt exhibits variable fault kinematics and exhumation patterns. Our thermochronological (AHe) data reveal a broad zone of consistent cooling ages (~4–6 Ma) across the Potwar Plateau and Salt Range. This spatially uniform pattern suggests a temporally limited phase but spatially extended region of synchronous exhumation. We interpret this as deformation localized along a low-friction salt detachment enabling wedge translation on the emergent SRT/HFT without significant internal reorganization. In contrast, the eastern flank of the syntaxis (Kashmir Himalaya) exhibits significantly younger and spatially variable AHe ages (~0.9–7 Ma), with young ages (0.9-3.5 Ma) concentrated in the frontal and rear ends, and older ages in the center. This spatial and temporal variability in exhumation, interpreted along with the geological, geophysical, and geomorphic evidence, suggest that orogenic wedge is segmented, where exhumation is driven by rock displacement along active roof backthrusts in the frontal zone, and internally by out-of-sequence faulting facilitated by focused erosion and reactivation of inherited basement structures. Based on our analyses, we propose that exhumation in the Kashmir Himalayas occurs via distributed, diachronous uplift, reflecting a mechanically heterogeneous and internally reorganized orogenic wedge.This contrasts with the synchronous and spatially uniform exhumation pattern in the western limb. These contrasting patterns and wedge behaviors suggest an asymmetric structural architecture and differing thicknesses of sedimentary parts (salt vs. clastic) in the foreland, modulated by feedback between erosion, fault kinematics, and wedge strength. Understanding this coupling is crucial for unraveling young orogenic wedge evolution and assessing seismic hazard risk.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Permian Feeding Remains: A Study of Bromalites from Bromacker (Thuringia, Germany)

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Bromalites — fossilised digested remains — are of high scientific value as they offer insights into the behavioural ecology and physiology of extinct organisms, including evidence of predator-prey interactions. These remains can be preserved either internally within body fossils (e.g., oralites, gastrolites, cololites) or externally, as separate entities (e.g., coprolites, regurgitalites). They are exceptionally rare, especially from Palaeozoic terrestrial deposits. The early Permian Bromacker locality in central Germany (Tambach Formation) yields outstanding fossilised vertebrate traces associated with skeletal remains. Here, we describe the first two bromalites from the Bromacker locality, identified as a regurgitalite (fossilised vomit) and a coprolite (fossilised faeces). Elemental mapping reveals differences of phosphorous concentration between the two bromalites, allowing a clear distinction between coprolitic and regurgitated remains. While the coprolite contains cranial and post-cranial elements of the small trematopid temnospondyl Rotaryus gothae, the regurgitalite preserves skeletal remains assignable to at least four different taxa: Eudibamus cursoris, Thuringothyris mahlendorffae, a diadectid and a dissorophoid. Based on their size and content, we hypothesise that these bromalites were most likely produced by a terrestrial apex predator, such as the sphenacodontid Dimetrodon teutonis or the varanopid Tambacarnifex unguifalcatus, previously recorded from the Bromacker locality. These findings provide new insights into the behavioural ecology and trophic structure of the Bromacker ecosystem and of terrestrial tetrapod ecosystems in general.

01.11 Micropalaeontology – Advancements and Perspectives in Multiproxy Studies

Combining ‘modern’ techniques and micro- and macropalaeontology—What can they contribute?

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The increased use of X-ray computed tomography and comparable analysis and documentation techniques in geosciences and biosciences over the past 20 years has not stopped at macro- and micropalaeontological objects. Combining modified (or rarely used) micropalaeontological processing techniques with other analysis (SEM, X-ray CT, UV-light documenting etc.) on microfossils (e.g. isolated skeletal elements of invertebrates and vertebrates) and macrofossils (e.g. articulated material from fossil lagerstätten), the overall results on biodiversity and palaeobiological are often comprehensive and outstanding.

In the keynote, the author will present and illustrate this with a few examples. Diversity in the selection and application of different methods and techniques is the key to promising and innovative new results.

Plenary Lecture: Tony Reimann "Earth-Evolution at the Dry Limit – new insights from a geo-bio collaborative research project"

Earth-Evolution at the Dry Limit – new insights from a geo-bio collaborative research project

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The availability of water influences the evolution of life as well as the evolution of the Earth's land surface. Until recently, the role of geomorphological and biological (geo-bio) processes including their interactions and co-evolution have been poorly understood for extremely water-limited (hyper-arid) environments. This emerging field lies at the nexus of weathering, soil (crust) formation and erosion but also involves landform evolution, which creates barriers or corridors for life across varied geological time scales. To facilitate interdisciplinary research at this geo-bio interface, we established the DFG funded Collaborative Research Centre CRC1211 (Earth–Evolution at the Dry Limit, funded since 07/2016). The natural laboratories we use for this work are the hyper-arid cores of the Atacama and Namib deserts with the main objective to gain improved understanding of the geo- and biosphere evolution in hyper-arid environments and to evaluate interactions between these spheres. We hypothesize that phases or events of higher water-availability (by fog, dew or rain) are the key drivers of geo-bio co-evolution. Furthermore, we hypothesize that barriers of geological, geomorphological, and climatic origin are the main controls on present-day biodiversity at various hierarchies including ecosystem dynamics. To test both hypotheses, we apply state-of-the-art methods from (phylo-) genetics, molecular biology, biogeography, ecology, soil sciences, geomorphology, meteorology, (palaeo-) climatology, (isotope-) geochemistry and geochronology to shed new light on the trajectories and thresholds of the evolution and isolation of life. New results of this research endeavour will be presented during the lecture.

05.04 & 06.05 Biogeochemistry, geomicrobiology, and biomineralogy

Fracture-filling calcite from the deep continental crust – an archive for microbial lipid biomarkers

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A significant fraction of Earth's prokaryotic biomass is produced in the continental deep biosphere, but the exact size, diversity and evolution of this important habitat is still incompletely understood. In several studies, we targeted ancient microbial activity in the deep subsurface by analyzing inter alia the lipid biomarker content of fracture calcites. We detected fatty acids (mainly straight-chained and branched C12:0 to C20:0) of biological origin in calcites from various fracture systems of the continental crust (Fennoscandian and Greenlandic shields), including a broad depth interval (down to 1000 m) and different precipitation ages (back to 410 Ma; e.g., Drake et al., 2015, 2021, 2023, 2024). In locations where calcite co-occurred with pyrite, different branched C15:0 and C17:0 acids were found (e.g., Drake et al., 2018, 2021, 2023, 2024), which represent biomarkers of sulfate reducers. In addition, α,ω-diacids of unknown source were sometimes present. Based on our results, it seems that fatty acids are well preserved in facture calcites from the deep continental subsurface over long geological time scales. Such enhanced preservation likely derives from the physicochemical properties of the carboxyl groups of the fatty acids, matching those of Ca^{2+}-ions on the calcite surface (e.g., Suess, 1970; Zullig and Morse, 1988). In addition, fatty acids and diacids may also serve as an initial nucleation site for calcite precipitation in the fractures, thereby being entrapped in the mineral lattice. Fracture calcite from the deep continental subsurface may therefore constitute an important archive for lipid biomarkers of ancient subsurface microorganisms.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Experimental Insights of the Pyrite to Magnetite Transformation at hydrothermal conditions

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Hydrothermal deposits are formed by the precipitation of minerals from hot aqueous fluids circulating within the Earth's crust and are often associated with magmatic activity, e.g. VMS deposits on mid-oceanic-ridges. These deposits typically contain a variable amount of pyrite along with other metal-bearing sulfides. During hydrothermal alteration, interactions between sulfides and fluids can cause the formation of magnetite, thus indicating changes in fluid chemistry during the reaction. However, the conditions and replacement mechanism of this reaction remain ambiguous and need further evaluation. Therefore, we conducted experiments to analyse the conditions of this alteration and to constrain the lost of trace-elements into the hydrothermal fluid during pyrite replacement in a temporal evolution.

As starting material, equal mass amounts of natural pyrite (Panasqueira, Portugal) and deionised-water were filled into gold capsules and were exposed to hydrothermal conditions in an autoclave at 400 °C and 500 bar. We conducted the experiments for 3, 5, 7, 11, 14 and 21 days, followed by EDX, EMPA, ICP-OES and XRD. The first indications of magnetite formation were detected after 14 days characterised by a decrease of Fe-content in the fluid compared to the 7 days run and the detection of Fe-oxides by EDX. We assume that the Fe-concentration in the fluid stabilises at thermodynamic equilibrium. Analysis of the trace-element content in the fluid and on pristine and altered pyrites will constrain the trace-element release or partitioning at all time-steps.

Thanks for support to Maria Kokh, Wolfgang Morgenroth, Antje Musiol, Hans-Peter Nablein, Valby van Schijndel, Christian Schmidt.

01.01 Multidisciplinary perspectives on solar system formation and evolution

A New Laboratory for Investigating High-Temperature Planetary Processes at the Max Planck Institute for Solar System Research

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High-temperature evaporation under high-vacuum conditions has been a critical factor in shaping planetary bodies during their early evolution, as well as in impact events and volcanic degassing on airless worlds such as Jupiter's moon Io, Earth's Moon, and Mercury. These processes have a major impact on the distribution and depletion of volatile and moderately volatile elements, yet the exact mechanisms and environmental parameters remain insufficiently understood. Observations from NASA's MESSENGER mission to Mercury, for example, revealed surface features called hollows—irregularly shaped depressions up to 80 meters deep and several kilometers wide. The bright halos around these hollows and their morphology suggest an ongoing formation process driven by volatile loss. MESSENGER also identified bright regions (faculae) interpreted as pyroclastic deposits, analogous to dark mantle deposits on the Moon, indicating gas-driven volcanic eruptions whose volatile components remain largely unknown. Gaining a better understanding of the volatile species and mechanisms responsible for both hollow formation and explosive volcanism is crucial for constraining Mercury's volatile history. To investigate these phenomena, we have developed a new laboratory facility designed for *in-situ* detection of volatiles under high-vacuum conditions at temperatures up to 2000 °C. In this contribution, we introduce the new experimental setup and share preliminary findings.

04.07 Mineralogy of Secondary Raw Materials

The “Theisenschlamm” Challenge: Exploring the potential and limitations of valorizing a stockpiled flue dust sludge by blending it with other environmentally toxic waste streams.

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"Theisenschlamm" is a geochemically complex industrial residue resulting from the historical smelting of Kupferschiefer ores in the Mansfeld region (Germany). Produced as flue dust during copper extraction and later fed into lead smelting, this fine-grained slurry was stockpiled after the closure of the lead smelter in the 1970s. By 1990, following the termination of regional mining and metallurgical operations, 220,000 tons were safely stored in a engineered tailings facility.

The material is enriched in Pb, Zn, and Cu, and contains critical trace metals such as Re, Ag, and Ge. It consists of sulfide, sulfate, and silicate phases embedded in a carbon-rich matrix with harmful organic compounds, including biphenyls and dibenzofurans. These characteristics make “Theisenschlamm” both a valuable secondary resource and a complex environmental legacy.

Previous recovery efforts failed due to technical and economic limitations. As part of the FINEST project, a novel recycling concept has been developed, based on detailed geochemical and mineralogical insights. The approach integrates plasma furnace-based pyrometallurgy with waste stream management. Central is the co-treatment of "Theisenschlamm" with precipitates from local wastewater treatment. The process yields a metal-rich concentrate and a geochemically stable, non-classified slag suitable for reuse or disposal without long-term monitoring.

This contribution presents the geochemical basis for material selection, mass balance constraints, and the behavior of key elements during processing, offering insights into the possibilities and boundaries of resource recovery from complex legacy wastes.

The project FINEST is funded by the Investment and Networking Fund of the Helmholtz Association under grant agreement no. KA2-HSC-10.

01.25 Geochemical Databases and Data Analysis Tools

GeoReM – A Cornerstone of Geoanalytical Quality: Honouring Klaus Peter Jochum and Advancing Toward a Sustainable, Modern Database Infrastructure

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GeoReM, the database for geological and environmental reference materials, was established in 2005 by Klaus Peter Jochum (1944–2024) and maintained by him and dedicated colleagues at the Max Planck Institute for Chemistry in Mainz. His commitment to metrology and reference material quality made GeoReM a cornerstone in geoanalytical research. To ensure its long-term sustainability, the International Association of Geoanalysts (IAG) and the DIGIS team at the University of Göttingen have initiated the integration of GeoReM into the DIGIS GEOROC database infrastructure. This contribution describes our roadmap towards establishung a new and updated IT infrastructure for restoring full interoperability between GeoReM and GEOROC, provided that funding will be provided.

This integration secures the preservation and continued curation of existing data while laying the groundwork for substantial technical and scientific enhancements. Planned developments include an expert user interface via API access, automated monitoring of data quality, and advanced filtering and screening capabilities based on analytical criteria. Statistical modules will enable method-specific outlier detection and robust interpretation of analytical data.

Restoring interoperability eventually also with other geoscientific and environmental databases, is a central goal. In parallel, quality-controlled datasets of recommended values for a wide range of reference materials will be provided for seamless integration into laboratory software via API. Another innovation will be a metadata-driven ‘expert quality control index’ for published data sets using GeoReM standards.

These efforts will ensure GeoReM remains a dynamic, quality-assured resource for future geoanalytical applications.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Subsurface uncertainties and the screening of areas for a deep geological repository for high-level radioactive waste in Germany

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In the current phase of the German Site Selection Procedure for a deep geological repository, large areas of Germany's subsurface are being screened in order to identify the most-suited regions. The portfolio of host rocks includes claystone, rock salt, and crystalline rocks. These geological formations can exhibit significantly different properties and key subsurface uncertainties relevant to a geological repository.

Additionally, in alignment with the regulations, only existing subsurface data are used during this screening phase, i.e., data acquired for other purposes, such as hydrocarbon, potash exploration, etc. Hence, the available dataset is heterogeneous, both in terms of data types and in terms of geographical distribution.

The estimation of the subsurface uncertainties is relevant for the robustness evaluation during the safety assessment. Consequently, the uncertainty estimation concept includes methods tailored for the specific requirements.

For large areas with heterogeneous data, a semi-quantitative method for a consistent and efficient assessment of the subsurface uncertainties was developed. This method estimates a "degree of confidence", which represents the reliability of given statements concerning the interpretation of the subsurface. The "degree of confidence" will be assessed for all investigated sub-areas in claystone, rock salt (stratiform), and crystalline host rock. It comprises the combination of data quality and quantity, on the one hand, and the geological complexity, on the other. This contribution gives an insight into the method and the preliminary results.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Geoscientific characterization of flat bedded rock salt as part of the German Repository Site Selection Act – Part I "Methods and work status"

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According to the Repository Site Selection Act (Standortauswahlgesetz – StandAG), the German Site Selection Procedure is an iterative process and consists of three phases with increasing levels of detail in which the assessed area is continuously reduced during the process. Starting with an empty, so-called "white map of Germany," BGE (implementer of the German Site Selection Procedure) completed Step 1 of Phase I in September 2020 with the submission of the Sub-areas Interim Report (BGE 2020/88), where BGE identified 90 individual sub-areas (in claystone, rock salt, and crystalline rock).

In Step 2 of Phase I, BGE aims to localize siting regions within the 90 sub-areas by applying preliminary safety assessments and other scientific criteria. Within the preliminary safety assessments, subsurface data are interpreted and the results documented. The workflow comprises the detailed characterization and interpretation with a focus on the host rock formation that acts as the main geological barrier but also considers the surrounding rock formations.

Part I of this contribution describes important methods and criteria that are used to characterize sub-areas related to flat bedded rocks salts. Preliminary results are presented.

BGE (2020/88): Sub-areas Interim Report pursuant to Section 13 StandAG. Bundesgesellschaft für Endlagerung mbH (BGE). Peine: Bundesgesellschaft für Endlagerung mbH (BGE).

03.02 Subsurface Storage of CO_2 – Applied Geoscientific Aspects

Evaluating Reservoir and Seal Integrity in the San Juan Basin for Carbon Capture and Storage (CCS)

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The San Juan Basin located in the Four Corners region of the southwestern United States, has long been recognized as a prolific hydrocarbon province, with decades of oil and gas production contributing to a well-understood subsurface geology. With growing global interest in CO_2 capture and storage (CCS) as a strategy to reduce greenhouse gas emissions, this study evaluates basin potential for long-term geological storage.

We focus on Mesozoic reservoir units—particularly those historically associated with conventional and unconventional hydrocarbon production. This work assesses the reservoir quality, seal integrity, and structural configuration of the basin through analysis of well logs, 2D/3D seismic data, and existing geologic studies. Criteria for site selection and potential risk factors for leakage were also examined.

The Entrada Formation, composed of Middle Jurassic sandstones, was identified as a particularly promising reservoir, with thicknesses up to 250 ft, porosities reaching 25%, and permeabilities ranging from 180 to 450 mD. The overlying Todilto Formation, consisting of limestone and evaporites, serves as an effective local seal. Additionally, regional sealing units such as the Mancos Shale and Lewis Shale enhance long-term CO_2 storage. These findings support the viability of the San Juan Basin as a CO_2 storage site, especially in proximity to industrial emission sources such as thermal power plants.

03.05 Advances in Paleoclimate Proxies and Their Applications

Quantifying glacial-interglacial climate shifts in the Armenian highlands using landsnail shells – a multi-proxy approach combining mutual climatic range analysis and shell isotope transfer functions

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Subfossil gastropod assemblages in geological deposits can be used to reconstruct past environmental and climatic conditions. We present new results from loess-palaeosol sequences in the Armenian highlands that provide insights into multiple glacial-interglacial transitions across the past 400 ka. Hereby our main aim was to reconstruct quantitative information that can serve as reference data e.g. for cross-validating earth system models. Our approach combines stable oxygen isotope ($\delta^{18}O$) analysis of snail shells with the ecological interpretation of species assemblages. The latter includes mutual climatic range analysis, supported by climatic niche modelling based on modern species distribution data. The gastropod assemblages showed distinct variations within the sequences, indicating different ecosystem characteristics and associated climatic conditions. We observed a significant relationship between specific ecological groups of gastropods and oxygen isotope signals in the shells. Predominantly xerophilous assemblages linked to stadial phases showed more negative $\delta^{18}O_{shell}$ signals, while mesophilous assemblages linked to warmer phases corresponded to more positive signals. $\delta^{18}O_{shell}$ signals provide valuable information on the isotopic composition of ingested precipitation, which in the studied region is strongly related to average temperatures. Temperature estimation based on transfer functions indicated a difference of 5.4°C between stadial and interglacial phases. Climatic range modelling turned out to be suitable for precipitation reconstruction, pointing to mean annual precipitation amounts centering around 425+-75 mm during glacial and 775+-75 mm during interglacial phases. This study provides new evidence-based palaeoclimate data for the Caucasus region highlighting the potential of snail shells as a quantitative proxy for palaeoclimate reconstruction.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Retention capacity of lanthanides, thorium and uranium in calcitic fracture mineralisation of granitic rocks

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The safety assessment of a repository system for radioactive waste in crystalline rock depends to a large extent on the the fracture system and its properties. Calcite is the most common fracture mineralisation at many crystalline sites in terms of radionuclide retention potential. The aim of the planned work is to investigate calcite fracture mineralisation in crystalline rocks of the Odenwald Crystalline Complex with regard to their ability to retain radionuclides. The investigations will focus on radionuclide retention by incorporation, i.e. substitution of radionuclides in the calcite crystal lattice. Since it is not possible to study radionuclide retention in natural calcite fracture mineralisation, natural analogues are used for these studies. Due to similar chemical behaviour, the lanthanides (REE) can be considered as analogues for the trivalent actinides, and Th and U as analogues for the tetravalent actinides. By [1] analysing the concentrations of REE, Th and U in calcite and in the hydrothermal fluids or deep (palaeo-) groundwater from which the calcites were precipitated, and [2] investigating the physico-chemical formation conditions (e.g. temperature, pressure, pH) by fluid inclusion analyses, it is possible to estimate to what extent and under what conditions the formation of calcite can contribute to the binding of radionuclides in fracture mineralisation.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

A tephrochronological framework for glacial lake outburst flood deposits in the Channeled Scablands, U.S. Pacific Northwest

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The largest known freshwater floods in Earth's history scoured the northwestern USA during the late Pleistocene, following the catastrophic drainage of glacial Lake Missoula. These glacial lake outburst floods, involving as much as 2500 km^3 of water, covered over 7,500 km^2, leaving behind a dramatic landscape of erosional features and extensive sedimentary deposits. Concurrently, eruptions from Cascade volcanoes, primarily Mount St. Helens (MSH) and Glacier Peak, blanketed the region with volcanic ash. Remarkably, some of these tephra layers were preserved within and overlying the flood sediment sequences, providing a rare opportunity to investigate the timing and extent of glacial lake outburst floods.

We present new geochemical fingerprints of tephra layers using electron microprobe analysis, comparing them to reference samples from proximal deposits of MSH, and well-characterised deposits from Glacier Peak and Mount Mazama. Our new analyses of 37 tephra layers spread across 10 different sites within the U.S. Pacific Northwest, confirm previous results from fewer sites that these floods occurred during the eruptive phase known as MSH Set S. Notably, the ~16 ka So and Sg tephras are preserved as a distinct couplet within the flood sediments. In contrast, the ~13.5 ka Glacier Peak G and B tephras, which lie above the flood deposits, post-date the floods. These findings constrain these floods to have commenced prior to ~16 ka but ending before ~13.5 ka and highlight the value of geochemical tephra analysis across multiple flood sediment sequences for refining the chronology of major Pleistocene glacial lake outburst flood events.

01.06 Tectonic Systems – TSK Open Session

Resolving the sinkhole conundrum of the Chicxulub impact crater, Yucatán Peninsula, Mexico, using scaled physical experiments

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Karst-induced sinkholes in Pliocene strata, the youngest sequence of Tertiary rocks covering the 66 Ma Chicxulub meteorite impact crater, form a semicircle that is congruent with the underlying crater margin as imaged by gravity anomalies. The causal relationship between the crater margin and the formation of the sinkholes has remained elusive since the discovery of the Chicxulub crater more than 30 years ago. Ground water flow of the northwestern Yucatán aquifer calls for the presence of prominent structural discontinuities in Tertiary strata above the buried crater margin, which likely control sinkhole formation. Based on the analysis of high-resolution satellite scenes, we mapped the ellipticity and respective long axes of some 6500 sinkholes. Assuming that the long axes represent traces of subsurface dilation fractures and, thus, orientations of maximum principal stresses, the angular departures of these stresses from the uniform regional trend point to local stress perturbations above the crater margin. The patterns of these perturbations agree with experimentally produced ones observed in scaled numerical and physical models, in which model craters are embedded in elastic materials and subjected to uniaxial compression. Moreover, concentric fractures preferentially form at model crater margins in physical experiments simulating cratering-induced crustal relaxation on the order of hundreds of thousands of years. We conclude that the localization of sinkholes in Pliocene strata above the Chicxulub crater rim is the combined result of the concentration of ambient stresses at the crater rim and the consequent reactivation of concentric fractures and their propagation into the overlying Tertiary strata.

01.06 Tectonic Systems – TSK Open Session

The Kynsikangas shear zone, Southern Finland: paleotectonic role, kinematic partitioning and structural evidence for slow fault slip in the lower continental crust

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Detailed field-based structural examination of the Kynsikangas shear zone (KSZ), a prominent structural discontinuity of the Svecofennian Province, allows us to better understand the rheological and kinematic behaviour of localized shearing in the lower continental crust. The analysis of deformation kinematics and mineral shape fabrics on multiple scales revealed that the KSZ formed by pure shear-dominated, left-lateral transpression under NW-SE shortening. A pronounced scale-dependent heterogeneity in the geometry and intensity of mineral shape fabrics as well as in the deformation kinematics are structural hall marks of the KSZ. An important result of our analysis is that small-scale kinematic indicators may not portray the regional sense-of-shear and, thus, questions their use for identifying shear zone kinematics in general. Furthermore, the ubiquitous presence of mesoscopic shear bands and S-C fabrics, both interpreted as precursor structures of scaly fabrics, known from active crustal shear zones, may constitute slip transients in a frictional-viscous material. Thus, the KSZ features structural evidence for slow-slip seismic events. In terms of paleotectonic significance, the KSZ is likely structurally linked and kinematically compatible with a major shear zone, the Kolinummi reverse shear zone, to the South of the KSZ. The KSZ can, therefore, be considered part of a network of crustal shear zones pervading lithotectonic terranes that amalgamated during the Svecofennian orogeny. Due to its distinct kinematics and orientation, the KSZ most likely served as a tectonic transfer zone among mostly easterly striking oblique reverse shear zones during later stages of the Svecofennian orogeny.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

From spatio-temporal patterns of river incision rates to Quaternary uplift history of the Variscan Rhenish/Ardenne Massif (N. Europe)

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The Rhenish/Ardenne Massif (RAM) is one the most “emblematic” Variscan structures located north of the Alps. Intraplate uplift affected the RAM during the Plio-Quaternary along with other Palaeozoic massifs located in the alpine foreland. However, its cause(s), shape and rates are still poorly understood and therefore remain debated. This was, until recently, mainly due to a lack of reliable ages for uplift markers, such as the Quaternary terrace staircases along deeply incised valleys of the Rhine, Moselle and Meuse as well as their main intra-massif tributaries. Several studies based on numerical dating methods (i.e., cosmogenic nuclides, ESR, OSL…) have shed new light on these questions by assigning numerical age estimates on key levels of fluvial terraces or cave levels related to phases of regional base-level stability.

This contribution compiles all chronological data produced over the last twenty years. Plio-Quaternary incision rates are accordingly reconstructed. A similar trend is reported throughout the RAM with a peak of incision occurring during the Early or Middle Pleistocene and matching the main massif-wide geomorphological marker. However, age control reveals a significant time lag (>250 ka) between the south-eastern and north-western RAM margins. High incision rates onset is consistently older along the Rhine/Moselle and tributaries than along the Meuse and tributaries. This key finding is well in line with the hypothesis arguing for a wave of uplift migrating northward throughout the RAM. It also supports regional tectonic causes for uplift (i.e., upper-crustal stress transfer from the Alps to their foreland) rather than more local ones.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Relationships between trace element composition in various quartz-bearing bedrocks (Vosgian Strengbach catchment, E. France) and Electron Spin Resonance (ESR)/Optically Stimulated Luminescence (OSL) properties

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Quartz Optically Stimulated Luminescence (OSL) and Electron Spin Resonance (ESR) offer valuable quantitative tools both for dating a wide array of Quaternary deposits but also for understanding sediment provenance and dynamics. However, the variability of quartz sensitivity remains an issue, attributed either to (i) the intrinsic properties of source bedrock, (ii) processes during sediment transport and deposition, or (iii) both. This study tackles this key question by investigating quartz from magmatic, metamorphic, and sedimentary formations in the Strengbach catchment (Vosges Massif, France).

Using a combination of ESR, OSL, and LA-ICPMS trace element analyses, our study reveals significant relationships between quartz OSL/ESR sensitivities and source bedrock characteristics, such as lithology, crystallization conditions, and deformation histories. ESR Ti-centre and OSL signals are notably influenced by trace elements like Al, Li, and Ti. Samples that underwent high pressure during metamorphism along with those located in the tectonic shear zone show both lowest OSL and ESR intensities, while higher sensitivities are observed in plutonic rocks and sandstones. This suggests that (i) pressure can be one of the prevailing factors driving changes in OSL/ESR sensitivities (ii) enhanced OSL sensitivity in mature and recycled sediments underscores the impact of sedimentary transport and reworking. As preliminary results of along-stream, *in situ* measured OSL signal intensity show no spatial pattern, further investigations are required to explore this topic. Our results highlight the need for careful interpretation of ESR and OSL signals, both for dating or sourcing, particularly in sediments derived from metamorphic terrains.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Influences of workflow choices on 3D seismic interpretation

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Seismic interpretation is inherently subjective, yet it underpins critical decisions concerning various uses of the subsurface—from the oil industry to the emerging challenges of the energy transition, including projects such as carbon storage and nuclear waste disposal. It serves as the fundamental building blocks (bricks) for constructing 3D models of the subsurface, shaping how it is visualised, modelled and understood. This study investigates how different interpreters, applying their own workflows to the same 3D seismic dataset, produce interpretations that diverge and converge and what these patterns reveal about the workflows. Two interpreters with similar levels of experience were independently tasked with generating a 3D interpretation of a salt body, selected horizons, and faults using the same seismic volume. Each interpreter's workflow was documented, including their use of tools, attribute analysis, and decision-making rationale.

The resulting interpretations will be compared using spatial juxtaposition, geospatial feature quantification, and heat maps. Preliminary results indicate that while some consistent interpretational patterns are emerging, notable variations are observed in fault positioning and the complexity of the salt body. These differences correlate with specific workflow choices such as sampling density preferences, attribute usage, and assumptions. Our findings demonstrate that interpretation outcomes are shaped not only by the data but also by the interpreter’s methodological framing.

By better understanding the sources and consequences of interpretation uncertainty, we can improve the reliability of 3D subsurface models, contributing to more robust and transparent geological assessments for critical subsurface applications.

08.01 Young Scientist Session

Experimental investigation of first-order kinematics and fault patterns in upper crust affected by sequential phases of variable shortening directions

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Obliquely convergent plate margins and continental collision zones, such as the Andes and Tibet, respectively, are often characterized by crustal-scale, rhomb-shaped basins enveloped by transpression zones. The geometries and sizes of such basins, typically evident as low-strain upper-crustal domains, and their transpressive margins are highly variable. Using two-layer analogue experiments, crudely scaled to length and strength of viscous lower and brittle upper continental crust, and horizontally shortened by an inclined piston, we explored the deformation patterns of model upper crust. Specifically, we were interested in the evolution of displacement vector fields, vertical-axis rotations and strain gradients, collectively monitored by digital image correlation, resulting from consecutive phases of shortening with variable directions. In all experiments, we observed the formation of high-amplitude ramp anticlines at the piston, followed respectively by a distinct zone of rhomb-shaped deformation domains and a low-strain zone of rather distributed deformation. As somewhat expected, orthogonal shortening tended to generate symmetric deformation domains enveloped by conjugate model transpression zones, increasing in spacing with distance to the piston. By contrast, highly oblique convergence of the piston generated transpression zones, the geometry and kinematics of which adhered to sets of Riedel shears. Most importantly, the geometry of deformation domains and deformation kinematics change according to the sequence of imposed shortening directions. An added value of the experiments is that one of the lateral margins is unconstrained, allowing shortened material to escape laterally, thereby mimicking indenter tectonics.

01.02 Anthropogenic geomorphology

Anthropocene and magnitude of geomorphological changes in the urbanization process in the metropolis of São Paulo, Brazil

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Research conducted over the last 30 years has explored the potential of Geomorphology and its emerging subfield, Anthropogenic Geomorphology, in discriminating the origin and magnitude of changes in geomorphological systems over centuries-old time intervals, particularly related to the Great Acceleration stage. The main type of intervention considered was the urbanization of the metropolitan region of São Paulo, in terms of direct interventions and their effects, considering as main references the typical fluvial geomorphological systems of plateaus in the humid tropical environment of southeastern Brazil: river basins, fluvial-lacustrine systems, fluvial channels, floodplains and fluvial terraces. The types of geoindicators used in this methodology were morphological-morphometric, surface materials and process indicators, which revealed significant discriminatory potential in relation to the origin of the changes and their magnitude. In terms of magnitude, the changes observed were compatible with the phases of geomorphological adjustments of the inputs of matter and energy generated by tectonic actions and climate change. Changes were identified in the geoindicators of river channels, such as: decrease of 30% to 47% in the length of channels, increase of 420% in the cross-section area of channels, increase of up to 2233% in the magnitude of extreme flows and loss of floodplain area of up to 99%, among other robust results revealing the high magnitude of direct interventions and their effects. The researches also revealed relevant results for the dimensioning of the magnitude of losses of ecosystem services of river plains in the metropolis of São Paulo.

01.20 Process oriented microfabric characterisation of geomaterials

Strain localization at eclogite-facies conditions induced by syn-metamorphic strength inversion

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In convergent settings, continental and/or oceanic mafic rocks are subducted to great depths where they experience high pressures and temperatures and transform to eclogite. Accompanied mineral transformations subsequently result in mechanical changes and in density variations. In the last decades, numerous studies targeted eclogite and aimed at quantifying its mechanical behavior as well as characterizing strain weakening processes, yet the mechanisms driving strain localization remain unclear. We combine field, microstructural, petrographic and geochemical data to investigate the origin of strain localization at eclogite-facies conditions. Our study examines a shear zone containing two distinct eclogite-facies assemblages. The host-rock eclogite is composed of clinopyroxene, garnet, zoisite, amphibole, quartz, kyanite, and rutile, within which sigmoidal enclaves are enriched in zoisite, hornblende, and garnet. Protolith assemblage calculations suggests these enclaves originated as plagioclase-rich gabbro cumulates and were initially weaker than the surrounding gabbro. However, their sigmoidal geometry within ultramylonitic eclogite implies they were stronger during shear zone evolution. The ultramylonitic eclogite shows a fabric dominated by euhedral clinopyroxene, with grain boundary melt traces and junctions indicating deformation via melt-assisted grain boundary sliding. In contrast, enclave microstructures are dominated by elongated zoisite and amphibole aggregates that deform through dislocation creep and diffusion-mediated grain growth. These findings indicate a strength inversion during high-pressure metamorphism where initially weaker enclaves became stronger, concentrating stress at lithological boundaries and thus promoting strain localization in the weaker eclogitic matrix. Our results underscore the significance of compositional heterogeneities on strain localization at high pressures.

01.29 Environmental Hazards and Risks

Debris Flow Frequency in a Changing Climate: Evaluating Trigger Conditions using a downscaled Regional Climate Model

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Debris flows occur as one of the most significant natural hazards in high mountain regions worldwide, and play a substantial role within the sediment budget. Despite their importance, it remains unclear how their frequency may evolve under changing climatic conditions. Long-term and comprehensive records are essential to detect significant changes in their activity over time. However, such multi-decadal datasets are scarce. As debris flows are predominantly triggered by high-intensity rainfall, the identification of (potential) trigger events from precipitation data presents an alternative, at least for transport-limited debris flow systems with sufficient sediment availability. Due to the lack of long-term precipitation records with sufficient temporal resolution, we employed dynamical downscaling of a Regional Climate Model (RCM) based on the Advanced Weather Research and Forecasting model (WRF). This approach produced a high-resolution dataset with 2x2 km spatial and 15-minute temporal resolution, enabling the analysis of intense rainfall events back to 1850.

We applied this approach to the Horlachtal catchment in Tyrol, Austria, where we have elaborated a debris flow inventory from remote sensing and lichenometric dating that spans the past 170 years. This integrated approach allows us to assess changes in debris flow frequency and their climatic drivers since the end of the Little Ice Age. As the RCM dataset covers much of the Central Alps, the analyses can be extended to other regions, offering broader insights into the development of debris flow frequencies in a changing climate.

05.03 Archaeometry – Geosciences4Humanities

An approach to uniformly describing lead isotope data in archaeology: The TerraLID metadata profile

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Lead isotopes became an important method in archaeology for reconstructing the raw material provenance of, among others, non-ferrous metals, glass, and pigments. The reliability of interpretations drawn from lead isotope data essentially relies on an as complete as possible data collection from items with known raw material provenance as well as sufficient contextual information to take geological and archaeological aspect into account. Currently, combining reference data from different publications is time-consuming to impossible due to a large variety of metadata, their different levels of detail, their sometimes ambiguous definition, and imprecise information.

A core element of TerraLID, the research data infrastructure for lead isotope data in archaeology, is a metadata profile that aims to overcome the above-mentioned challenges by providing a uniform way for the description of lead isotope data and their contextual information. Developed by the TerraLID editors, representatives of the scientific community, its draft is currently available to the entire community for feedback to ensure that it will be as widely applicable as possible. As part of this feedback process, the scope of the metadata profile will be presented before some aspects will be discussed in more detail with the aim to stimulate discussion and feedback on its compatibility with current data handling workflows of the session participants.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Structure of the TerraLID metadata profile for lead isotope data in archaeology

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The application of lead isotope ratios especially on non-ferrous artefacts evolved into the default method for the reconstruction of their raw material provenance. A pre-requisite for this method is the collection of data with known raw material provenance to which the artefact's signature can be compared to. Unfortunately, the compilation and re-use of these data from literature is often hampered, among others, by the metadata's large variety and different levels of detail. This does not only result in a time-consuming data compilation process but also limits, e.g., the implementation of machine learning approaches or large-scale meta studies.

The aim of TerraLID is to overcome the current state by developing a research data infrastructure through which lead isotope data can be published, stored, and accessed. It is complemented by a web application to work with such data, an online textbook which provides open educational materials on the topic, and a toolbox to facilitate re-use of the tools and templates developed for TerraLID. At the core of the data infrastructure is the TerraLID metadata profile to uniformly describe lead isotope data and contextual information. The TerraLID editors as community-representatives guided the development of this metadata profile and the entire community is currently invited to provide feedback on its draft. This contribution presents the structure of the metadata profile and how it connects to other metadata schemata and profiles.

05.02 Understanding (geo)materials with advanced experimental and computational methods

Microplastic Deposition and Transport in a Human-Impacted Stream: Insights from Geomorphic Sinks and Sediment Analogues

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Understanding microplastic dynamics in fluvial systems is key for identifying pollution source and potential long-term sink remediation. While many studies rely on controlled experiments (e.g., columns, flumes, tanks), to understand the behavior of this pervasive anthropogenic particle, *in-situ* investigations remain limited. This research investigates the deposition and transport behavior of microplastics in relation to natural sediments within a small (ca. 7 km) highly anthropogenised stream near Vienna, Austria, serving as a natural field laboratory.

In April 2025, 18 sediment and 7 water samples were collected from diverse geomorphic sinks—such as bars, backwaters, and areas affected by infrastructure. Water sampling was performed using a 150 µm plankton net (30 cm diameter) to capture surface and suspended fractions. A follow-up sampling campaign is planned after a major rainfall event to evaluate sediment reactivation and the potential remobilization of microplastics from these sinks.

Hydrodynamic parameters were measured, and approximately 60 large wood (LW) deposits were mapped and characterized to assess their role in altering flow patterns and sediment connectivity. Microplastics particle shape, size and estimated density will be compared to natural sediments through grain size distribution and total organic content.

Extraction and identification methods include sieving, density separation (1.45 g/cm^3), Fenton oxidation, and non-FPA FTIR mapping for polymer identification.

This research explores to what extent microplastics behave analogously to natural sediments in riverine depositional environments. The findings aim to improve our understanding of microplastic behavior in real-world geomorphic contexts and contribute to broader discussions on sediment dynamics in human-impacted river systems.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Dating zircon inclusions in sanidine-megacrysts from core to rim documents growth over hundreds of thousand years at super-solidus conditions

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We present *in-situ* U-Pb and U-Th ages of zircon inclusions from core to rim in a single 8 cm-large K-Feldspar megacryst from the 32.9 ka dacite dome eruption of Taápaca volcanic complex (Central Andes, Chile). These large sanidine crystals formed in a rhyodacite magma and erupted in a hybrid dacite after magma mixing just prior to ascent. Zircon in the core (n = 13) are in U-Th secular equilibrium with U-Pb dates of 530±35 to 950±35 ka. Zircons in the mantle (n = 10) are again in U- Th secular equilibrium with U-Pb ages of 333±13 to 480±43 ka. Only four zircons yielded U-Th isochron ages of 302 (+55/-36) to 339 (+70/-42) ka (n = 4). Rim-hosted zircons (n = 16) are all significantly younger with U-Th ages of 58 (+12/-11) to 251 (+112/-54) ka. Thus, zircon continuously crystallized and became successively trapped during sanidine growth in the rhyodacite host magma over several hundreds of thousands of years (from 920 ky to 25 ky before eruption), with a maximum individual zircon growth time of 30–50 ky. These results agree with Ba-diffusion timescales for the host K-feldspar and other megacrysts from the same dome eruption. Our combined results indicate at least 500 ky of megacrystic growth at magmatic conditions of 740 to 820 °C and 1 to 2 kbar (thermobarometry on amphibole inclusions in the sanidine) and protracted “hot” magma storage at upper crustal levels in continental arc settings

04.06 Coupled Fluid-Rock Deformation: Unraveling Multiscale THMC Dynamics for Fundamental Geological Processes and Societal Challenges

Experimental and numerical studies on fluid–granite interaction for chemical stimulation in Enhanced Geothermal Systems (EGS)

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Porosity generation and permeability maintenance in low-porosity rock systems are crucial for Enhanced Geothermal Systems (EGS), as they enable efficient fluid flow and transport while enhancing heat exchange in low-permeability reservoirs. In EGS, reactive transport processes, triggered by chemical stimulation, drive dynamic changes in mineral composition and petrophysical properties. However, the parameters that control the efficiency of chemical stimulation of granitic rocks are incompletely understood and experimental studies are still scarce.

In this study, we investigate reactive transport processes by performing batch and flow-through experiments, analyzing the interactions of granites with acidic F-bearing aqueous fluids under simulated geothermal reservoir conditions. Our experiments aim to understand and quantify the reaction-induced porosity and permeability increase of low-porosity granite systems using fluid compositions relevant for the chemical stimulation of EGS.

We used X-ray powder diffraction (XRD) and scanning electron microscopy (SEM) to characterize and quantify mineralogical changes while assessing the microstructural evolution of granites exposed to reactive fluids.

Our first experiments have demonstrated that significant porosity is created through chemical stimulation of low-permeability granite, driven by preferential dissolution of feldspar and mica in the host rock and the precipitation of amorphous silica and denser F-bearing phases that pseudomorphically replace the original mineral assemblages.

The chemical stimulation in the laboratory can be reproduced by reactive transport modeling. Our one-dimensional (1D) numerical model with different experimental parameters aim to recreate results from experiments, providing insights into the evolution of the system’s composition and petrophysical properties and predicting the potential for EGS reservoir development.

01.06 Tectonic Systems – TSK Open Session

A four-dimensional approach to understand the Miocene deformation of the western Tauern Window (European Eastern Alps)

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The nappes of the Tauern Window (TW) in the European Eastern Alps were formed by the southward subduction of the European plate beneath the Adriatic plate. These nappes were stacked during the Late Eocene and refolded during the Miocene due to the northward push of the Dolomites Indenter. This study focuses on the Miocene deformation history of the western TW using 2-D, 3-D, and 4-D approaches, while we concentrate only on the core of the western TW. We first restore a N-S oriented cross-section along the trace of the Brenner Base Tunnel using published zircon fission-track and P-T data. Restoration reveals two deformation phases: upright folding of the nappe stack began to wane around 17 Ma, followed by thrusting of the entire nappe stack along the Sub-Tauern ramp. The hanging-wall nappes experienced 25-48% thinning due to W–E extension. Subsequently, we restore the western TW in 4-D using the same method as for our 2-D reconstruction. We displace the nappe stack downwards along the Sub-Tauern ramp, followed by unfolding under high-temperature conditions. We found that 21 – 23 Ma ago, indentation began in N to NE direction, which was followed by anticlockwise rotation during the Miocene, resulting in a NNW-NW indentation direction. During indentation, the lower crust of the Dolomites Indenter probably detached in the vicinity of the TRANSALP section. Volumetric differences of the gneiss cores are most likely primary and not due to lateral extrusion.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Neotectonics and Morphotectonics of the southern eastern Upper Rhine Graben – the Cenozoic tectonic history of the Northern Markgräflerland, Germany

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The Upper Rhine Graben (URG) is the central segment of the European Cenozoic Rift System. The present-day stress field is characterised by an approximately NW–SE orientation of the principle stress axis σ1, which is responsible for sinistral transtensional conditions that affect the URG system. In the southern eastern segment of the URG, seismic activity indicates that neotectonic processes are ongoing, shaping the present-day relief. This study focusses on neotectonics, tectonic geomorphology and the tectonic evolution of this region since the onset of the main URG rifting in the Early Oligocene. We combined remote sensing, fieldwork and geophysical measurements (GPR, ERT). Our analysis reveals that kilometre-sized fault-blocks of the Variscan basement tilt northeasterly. This can be inferred from the asymmetrical hillshape of the fault blocks, which are characterised by southward-shifted crestlines and larger local catchments on the northern with respect to the southern hillslopes. Triangular facets are aligned along both NW–SE and NE–SW trending valley sides in the Variscan basement. They are most notable at the western entrance of the Lower Münstertal near Staufen indicating active normal faulting. Riedel-shear fault patterns, bent and shifted creek beds as well as fault scarps in alluvial deposits of the Staufen Bay prove neotectonic activity of the eastern URG boundary fault. Faults have been (re-)activated with different kinematics at different times due to repeated changes of the regional stress field since the onset of the main rift phase of the URG in Early Oligocene.

02.01 The Tethys Ocean – the cradle of modern tropical life

Isolated marine reptile teeth from the Lower Jurassic Posidonia Shale Formation of Schandelah, northern Germany – Description, classification and implications for biodiversity

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The author presents a detailed description and depiction of 13 tooth morphotypes, based on isolated marine reptile teeth from the Lower Toarcian Posidonia Shale Formation (PSF) of Schandelah, Lower Saxony, northern Germany. These morphotypes are compared to selected reference specimens from the collections of the Staatliches Museum für Naturkunde, Stuttgart, Germany, as well as the Staatliches Naturhistorisches Museum, Braunschweig, Germany, with the purpose of systematic assignment. This comparison process shows that most of the isolated teeth belong to thalattosuchian crocodylomorphs, which is surprising, as most non-tooth marine reptile fossils from the Schandelah quarry belong to ichthyosaurians. Even with this disparity in tooth distribution between morphotypes, the isolated teeth can be assigned to all five ichthyosaur genera (Stenopterygius, Hauffiopteryx, Eurhinosaurus, Temnodontosaurus, and Suevoleviathan) known from the PSF, three thalattosuchians (Macrospondylus bollensis, Pelagosaurus typus, and Mystriosaurus laurillardi), and tentatively one pliosauroid (Rhomaleosaurus zetlandicus). Stratigraphic distribution of the isolated teeth points to all groups of marine reptiles having been present throughout the entire section of the PSF exposed at the Schandelah quarry. The thalattosuchian teeth yield the most reliable data on stratigraphic range, as they make up the bulk of all isolated teeth. Finally, new additions to the north German PSF faunal assemblage can be made, as certain tooth morphotypes are the first evidence for the presence of the ichthyosaurian genus Suevoleviathan, the thalattosuchian M. laurillardi, and the pliosauroid R. zetlandicus.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Geological 3D modelling and data management for the Lausitz: a transboundary approach

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Over the past 150 years, lignite mining in the Lausitz has created a cultural landscape under intensive human control. With the implementation of the Act to Reduce and End Coal-Fired Power Generation (KVBG), the region now faces a range of geotechnical, hydrogeological, hydrological and energy-related challenges that demand renewed attention.

The deposits within the Lausitz are characterised by thick Cenozoic sequences, which locally up to 350 m thick, rest on a pre-Tertiary bedrock surface dipping northward. These strata were formed through an interplay of repeated marine transgressions and regressions, marsh formation, and terrestrial sedimentation processes. Following Quaternary glacial systems produced heterogenic sedimentary systems with interglacial layers. Particularly, deeply eroded channels and extensive glacial deformation zones lead to highly complex geological units.

The aim of the Project is to provide a detailed 3D model of the geological situation within the Lusatian area, independent of national borders and associated political responsibilities. The model will incorporate detailed stratigraphic, lithological and structural parameters of the Cenozoic deposits. In the current phase of the project, the focus is on developing the methodological approach, data management, statistical analysis and technical data processing.

Ultimately, the 3D model will cover both active and former opencast mining fields, as well as the previously underrepresented areas in between them. It will provide a spatially resolved representation of the Quaternary and Tertiary successions, serving as a fundamental tool for subsequent modelling-such as groundwater flow simulations for transboundary groundwater management in Saxony and Brandenburg, shallow geothermal energy assessments, and addressing further geotechnical issues.

03.05 Advances in Paleoclimate Proxies and Their Applications

What has driven a late Miocene drop in clumped isotope temperatures of detrital calcite in Himalayan river systems?

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Variations in the composition and texture of detrital records preserved in the Himalayan foreland basin and the Indus and Bengal fans, potentially records stages in evolution of the orogen, the Indian Summer Monsoon climate, and regional ecology. However, interpreting these records is challenging, as sediment properties are influenced by changing provenance, hydrological sorting, weathering intensity, incorporation of mineral and organic matter, and post-depositional alteration. To address some of these complexities, we analyzed the mineralogy and clumped isotope compositions of detrital carbonates from modern Ganga River sediments and from early Miocene to Holocene Bengal Fan turbidite deposits. We show that variations in clumped and oxygen isotope values of detrital calcite in Himalayan river sediments reflect mixing between Himalayan-derived lithic carbonates and authigenic calcite precipitated within the river system. Clumped isotope temperature values and calcite-to-dolomite ratios in Bengal-Fan turbidite deposits drop in the late Miocene, indicating an increase in the relative contribution of authigenic calcite. This shift cannot be explained by a decrease in source temperatures, as it would imply unrealistically high-temperature lithic or authigenic calcite formation during the Miocene. Nor can it be attributed to intensified weathering, given that turbidite K/Si* values (proxy for weathering intensity) remain stable since the mid-Miocene. We therefore suggest that these trends are primarily driven by a change in the abundancies of both calcite and dolomite in Himalayan derived sediments. Specifically, we propose that this observation reflects a Late Miocene Himalaya-wide shift in provenance of detrital carbonate, from calcite-rich (dolomite-poor) Tethyan- and Greater-Himalaya to calcite-poor (dolomite-rich) Lesser Himalaya terrains.

04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

High-Throughput Automated Platform for *In-Situ* Monitoring of $CaSO_4$ Formation

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Capturing short-lived intermediate phases during crystallization is critical to understanding and improving the sustainability of mineral processing, but conventional *ex situ* methods often miss these transient species. We present a novel automated flow-through synthesis platform that enables simultaneous *in-situ* X-ray diffraction/scattering and Raman spectroscopy measurements to investigate crystallization processes in real time. This setup captures transient reaction intermediates and tracks crystallization mechanisms during wet-chemical reactions, providing direct insight into dissolution–reprecipitation pathways and amorphous phase transitions.

Using calcium sulfate ($CaSO_4$) as a model system, we demonstrate how the platform reveals complex crystallization dynamics: real-time monitoring of gypsum-to-bassanite conversion in a hypersaline solution captured intermediate nanoparticle formation and a clear dissolution–reprecipitation mechanism. By enabling such controlled synthesis and monitoring, the method supports sustainable mineral use and the potential recycling of calcium sulfate materials through optimized reaction pathways.

The modular design of our platform —incorporating a glass capillary flow cell and peristaltic pumps for continuous circulation—minimizes contamination and allows uninterrupted *in-situ* analysis, with all components programmed via a Python-based control system for improved reproducibility. This high level of automation also opens opportunities for self-optimization of syntheses via machine learning algorithms. While demonstrated on calcium sulfate, the versatile system is readily extendable to other material classes including polyoxometalates (POMs), metal–organic frameworks (MOFs), and covalent organic frameworks (COFs).

05.02 Understanding (geo)materials with advanced experimental and computational methods

Beneficiation of BOF-slags by mineral processing for enhanced application in road construction

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Blast oxygen furnace slag (BOF) is one major by-product of steel production by Linz-Donawitz process. It is produced in the converter during the refining from pig iron to crude steel. At HKM steel plant approximately 430.000 t of BOF slag is produced ongoing the production of 4.3 Mio. t of steel, annually. Nowadays 30.000 t of the slag is used as high-quality asphalt chippings. BOF consists in general of Ca-silicates, Ca-ferrites and Fe-oxides. The slags show further a wide variety in specific gravity due the randomized distribution of macro porosity and heavy steel particles.

One limiting factor for this application is the homogeneous specific gravity of the material, which is crucial because it controls the asphalt recipes. However, bituminous binder is one major cost factor during asphalt production.

In this study, we present a combination of analytical procedures to investigate the distribution of pores and steel pebbles in slag particles to evaluate the particle specific gravity. Based on the analytical results, a beneficiation scheme by mineral processing is presented to separate heavier from lighter particles. As an established method of gravity concentration, jigging is used as a reference. In addition, the application of sensor-based sorting using X-ray transmission technology is presented for density-based separation.

By the application of the presented processing scheme, the BOF slag´s variability in density can be reduced to a tenth of its original deviation. Thus, the presented beneficiation scheme is capable to improve BOF slag valorization due to improved value.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

Hydrological Engineering Modeling (HEC-HMS) for Abu Galum Protected Area

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Abu Galum Reserve is located in the northeastern part of South Sinai near the Gulf of Aqaba. It has a total area of about 500 km^2 and is made up of granite mountains that end abruptly on a narrow coastal plain. The area also includes canyons, flood fans, coastal lagoons, and marshes. The study area suffers from the dangers and problems caused by torrential rains, which affect human activities, as the study area is characterized by drought and lack of water, but the sudden and heavy rainfall causes torrential torrents that leave sabotage and destruction. This paper aims to assess the risk of flash floods by using the engineering hydrological model (HEC-HMS), to calculate the torrent hydrograph curve and estimate the amount of torrential flow and its flow rates, thus calculating the depth of rain for different return periods up to 100 years.

10.01 Open Paleontology Session

Late Miocene hipparionine fossils from the Dhok Pathan Formation of Pakistan

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Here, we have provided a detailed taxonomic description of equid fossils first time from Markhal, Chakwal District and Sulaiman Range, Sakhi Sarwar, Dera Ghazi Khan District in Punjab, Pakistan. The dental remains of hipparionins have been recovered from six which are Dhok Pathan Type Locality, Ochri, Gujjar Mehra, Molair Patti, Markhal, and Gharbin. These localities are dated to the Late Miocene to Early Pliocene period (10.2–3.4 Ma). The specimens described here contain both upper and lower dentitions belonging to two genera, Cormohipparion and Sivalhippus. During the Late Miocene, the palaeoenvironment of the Siwaliks is currently hypothesised to have had open habitats with a warm, arid environment. However, the presence of three-toed hipparionin equids suggests a wide range of complex paleoenvironmental conditions varying from grasslands to forest habitats. Furthermore, our study reveals complex dental structures in the extinct hipparionin species from the Siwaliks, indicating a dietary transition from C3 to C4 diet from browsing to grazing during the Late Miocene epoch.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

New geological map data for Düsseldorf and adjacent areas (North Rhine-Westphalia, Germany)

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Geological mapping in the vicinity of Düsseldorf, Germany, has been carried out systematically for over 100 years, starting with a mapping campaign by the Prussian Geological Survey in the 1920s. Today, geological mapping is performed by the Geological Survey of North Rhine-Westphalia and published at a scale of 1 : 50 000. In addition, 3D models are created from the collected data and all data are made available to the public via online portals free of charge.

We present new geological map data for the surface and at major sedimentary hiatuses for Düsseldorf and adjacent areas. The map of the surface geology allows a detailed representation of Pleistocene to Holocene sedimentary processes. While fluvial sediments of the Rhine River predominate in the Rhenish lowlands, the hilly landscape of the Bergisches Land is widely characterized by aeolian sediments of the Quaternary cold phases. The geological map of the pre-Quaternary surface provides a detailed depiction of Oligocene marine sedimentation. The geology of the top of the pre-Permian bedrock depicts marine to paralic sedimentation in the Devonian and Carboniferous. Furthermore, it clearly shows the tectonic structures that were created during Variscan orogenic folding and post-orogenic normal faulting. In addition to these map layers, cross sections were created for depths of up to 3000 meters. A spacing of only 2 km between these cross sections allows detailed three-dimensional imaging of the subsurface.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Metamorphic mobilization of tin in the Erzgebirge

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Primary tin (Sn) deposits are commonly associated with highly fractionated, reduced granites derived from melting of evolved crustal rocks. While extreme fractionation is necessary to generate Sn-granites from low-Sn siliciclastic sediments (~5–10 ppm Sn), melting of Sn-enriched source rocks can yield Sn-rich magmas with minimal fractionation. We present an example of Sn-rich mica schists from the Bockau area, Western Erzgebirge that underwent metamorphic Sn enrichment prior to post-orogenic Sn-granite intrusion[2]. Strata-bound Sn mineralization in the schists average 50–200 µg/g, with local concentrations up to 1 wt%. Microfabric analysis shows that Sn mobilization was linked to progressive deformation. Tin occurs in prograde minerals—biotite and garnet—as structurally bound Sn and as cassiterite (SnO_2) inclusions. A second phase of Sn mobilization is represented as secondary cassiterite inclusions during the retrogression of biotite to chlorite. Comparative whole-rock geochemical analysis of the protoliths[1], Sn-rich non-retrogressed, and retrogressed schists reveal continuous Si addition throughout metamorphism and significant Fe and Sn enrichment during prograde metamorphism, accompanied by depletion of K, Rb, Ba and a relative decrease in the immobile elements, Al, Ti and Zr. Additionally, Li, B concentrations increased during the prograde and retrograde stages, respectively.

References

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07.02 Geothermal energy — Potential and utilisation of geothermal energy resources for the heat transition

Permeability and reservoir temperature correlation in Upper Jurassic carbonates in southern Bavaria and implications for diagenesis and exploration

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Upper Jurassic Carbonates ("Malm") are the most widely used hydrothermal reservoir in Germany. Located in the North Alpine Foreland Basin, reservoir temperature gradients vary with values below 24 K/km and up to 43 K/km. The lowest values are present within a large negative anomaly around the city of Wasserburg in eastern Bavaria – so far, a largely underexplored region.

The diagenetic history of the reservoir is complex, with indications of syn-sedimentary emergence, Cretaceous burial, subsequent local exhumation, and rapid burial during the alpine orogeny (Tertiary) to depth of up to 5.000 m. Widespread dolomitization occurred in several phases. Fluid inclusions of authigenic carbonates revealed temperatures far exceeding today's values.

Until now, a correlation between permeability and reservoir pressure, approximately related to depth, was used to predict flow rates of geothermal projects. However, this was not viable for the region of the large negative temperature anomaly. Here, the correlation of permeability with reservoir temperature yields a significantly better fit. The trend deduced can also be used in adjoining areas, although the difference to the pressure correlation is less obvious here.

The relation of reservoir permeability to present-day temperatures indicates the formation of authigenic minerals during much higher palaeo-temperatures did not affect the reservoir properties significantly. Therefore, the current temperature field is likely to have been stable since a long time. Due to the new correlation, a higher reservoir permeability than previously can be predicted for the currently underexplored region, where higher flowrates may compensate for the relatively low temperatures.

09.02 Museen als Fenster in der Forschung

Insights into the Black Forest collection of the State Museum of Natural History Karlsruhe

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The mineralogical and petrographic collection of the State Museum of Natural History Karlsruhe (SMNK) houses a broad collection of specimens from mineral deposits of the Black Forest. This collection includes specimens dating back to the 18th century, from the private collections of Margravine Karoline Luise, as well as specimens from the geological survey of the Grand Duchy of Baden, which was the first comprehensive geological survey of Baden, and was probably incorporated into the well-known Prussian geological survey. Expanded by ongoing collecting activities, the Black Forest collection provides historical documentation of mining in the Black Forest, as well as an important geological archive. With current considerations on the security of raw materials supply in Germany and efforts to resume mining in Baden (e.g., the Käfersteige mine near Pforzheim), the collection is also relevant outside of fundamental research efforts. Here we provide insights into the current collection management strategies, as well as digitalization efforts and digital availability of the collection.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

The influence of halogens on amphibole stability – an experimental approach

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Amphibole represents an important rock forming mineral commonly occurring in calc-alkaline and alkaline igneous rock and its complex crystal structure allows the incorporation of a wide variety of major and trace elements. However, despite the crucial role of amphibole in magmatic systems, the effects of various parameters on amphibole crystallisation systematics are still poorly constrained. In particular, data on the influence of halogens on amphibole stability and composition are scarce although the replacement of (OH) by halogens (e.g. Cl and F) on the W site is commonly observed in natural amphiboles. Thus, in this study, we investigate the systematic influence of halogens on amphibole stability under magmatic conditions.

For this purpose, we ran high-pressure and high-temperature phase equilibria experiments in internal heated pressure vessels (IHPV). As starting material, we used a synthetic powder mixture, based on a natural basalt from the Adamello Batholith in Northern Italy, systematically spiked with Cl and F contents ranging from 0.5 to 1.5 wt.%. The experiments were performed under H_2O-rich fluid-present conditions at 200 MPa with temperatures ranging from 1000 to 950 °C and fO_2 buffered at NNO+2.3.

Our data reveal that halogens affect the crystallisation systematic of amphibole, where the presence of Cl and F show distinctively different effects on phase equilibria (i.e. stabilisation of amphibole by F and destabilisation in the case of Cl). Consequently, currently existing tools to predict the stability and crystallisation conditions of amphibole in magmatic systems (e.g. geothermobarometers) need to be used cautiously when dealing with halogen-bearing magmas.

08.01 Young Scientist Session

Mineral authigenesis in pyroclastically embedded plants: insights and questions from the Permian of central Germany

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The Chemnitz Fossil Forest represents the most completely preserved Permian ecosystem, buried 291 myr ago in the phreatomagmatic ashes of the Zeisigwald Tuff (Leukersdorf Formation, Chemnitz Basin, central Germany). Its fossils provide cell-scale insights into the anatomy and ecology of past life but also stand out for their unusual mineralogy, e.g., fluoritized wood. Another barely reflected feature are isometric crystal casts <1 mm in diameter that occur in the outer tissues and the adjacent rhyolitic tuff of the petrified stems. These clay-filled casts exhibit hexagonal and octagonal outlines when cut and are discussed to reflect early-diagenetic garnet formation and alteration due to high fluid pressure and metasomatosis in the ash. We discuss the formation of these casts based on reviewing previous studies and own preliminary XRD, SEM, and electron-microbe analyses and CL spectroscopy. In sum, these structures formed shortly during and after burial, as indicated by surrounding, plastically displaced tissues and well-preserved cells and intracellular fungi in the non-compacted trunks – evidence for a rapid, early-diagenetic silicification. The preferred occurrence in plants rich in parenchyma, the preservation of thermally labile tissues, uncharred wood and the silica CL prove that water and temperatures <250°C impacted authigenesis. The cast fill results from hydrothermal alteration and consists of kaolinite and iron-oxide-hydroxide aggregates that are dissected by xenotime veins. Mg and Ca contents are low (<2wt%). The results indicate the former presence of euhedral cubic minerals, whose formation and alteration resulted from burial in ‘cool’ ashes of a highly evolved magma and subsequent authigenesis.

01.24 Fieldwork as common playground: the importance of geological survey to unravel Earth processes

Multi-methods integration for accurate and fast multi-scale geological mapping: 2D and 3D

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Cartographic surveying relies on an iterative methodology of continuous and reciprocal validation between discrete field observations and continuous spatial representations—such as digital stereo and mono photogrammetry, orthomosaics, hillshades, and satellite radar interferometry—derived from Earth Observation (EO) techniques. Today, EO methods offer such high spatial resolution that they may seem to reduce the need for fieldwork. At the same time, advances in high-performance tablets and dedicated software are transforming classical field practices. These digital tools can replace traditional “paper and pencil” methods and allow geologists to consult and analyze EO data directly in the field. This integration enhances the efficiency and responsiveness of the iterative process required for fast and accurate field-based cartography.

Over the past five years, we have mapped approximately 840 km^2 at a 1:10 000 scale as part of the Geological Atlas of Switzerland. This extensive effort has involved detailed geological, geomorphological, and phenomena mapping across diverse terrains. In this contribution, we present best practices developed through this work to support efficient, accurate, and modern mapping workflows. Our experience shows how the combination of fieldwork, high-resolution EO data, and advanced digital tools results in more reliable cartographic products.

07.04 Challenges in geoscientific applications

Mainstreaming and Upscaling Fluvial Nature-Based Solutions in Europe: Bridging Science, Society, and Policy

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Nature-Based Solutions (NbS) are increasingly recognized as effective and sustainable approaches to address complex water-related challenges such as flood risk, biodiversity loss, and water quality degradation. By leveraging natural processes and ecosystem functions, NbS offer resilient, adaptive, and often cost-effective alternatives or complements to traditional grey infrastructure. In Northwest Europe, interest in NbS is growing, yet widespread implementation is hindered by institutional inertia, limited metrics for co-benefits, and a lack of standardized assessment methods.

This contribution discusses key challenges and opportunities for mainstreaming and upscaling NbS, drawing on a broad base of literature and practical experiences. It emphasizes the need for clear definitions, objective comparison frameworks, and stronger integration of co-benefit valuation into decision-making processes. Tools such as the IUCN Global Standard for NbS offer valuable guidance, yet often require adaptation for specific regional and project contexts.

Insights from the EU-INTERREG ResiRiver project, which includes nine pilot sites across Belgium, France, Germany, Ireland, and the Netherlands, illustrate both the potential and practical limitations of implementing NbS across varying river types and governance settings. ResiRiver demonstrates how self-assessment tools, stakeholder engagement, and targeted communication strategies—such as policy briefs and virtual excursions—can support more effective adoption.

Achieving large-scale implementation of NbS requires a combination of technical innovation, institutional commitment, and knowledge exchange. Strengthening scientific evidence, improving outcome-based monitoring, and fostering international collaboration will be key to realizing the full potential of NbS in river basin management.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Velocity modelling across borders: Insights from the TUNB Velo 2.0 project

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During the TUNB Velo 2.0 project, the State Geological Surveys of Schleswig Holstein, Lower Saxony, Mecklenburg Western Pomerania, Brandenburg and Saxony-Anhalt together with the Federal Institute for Geoscience and Natural Resources (BGR) developed a large-scale seismic velocity model for the North German Basin. The structural model of the previous TUNB project formed the basis for modelling. However, the project partners did not use a consistent classification of geological layers when assigning the interval velocities. Furthermore, different methods were used for creating the volume model and its parametrization. Additionally, input datasets for the velocities varied between project partners. All these differences necessitate the harmonization of the velocities at the borders to have a consistent regional model. The harmonisation methods were tested in a pilot region and differ for each border. Velocities were mainly consistent between Lower Saxony and Schleswig-Holstein because we used the same regional velocity model as a basis. With Mecklenburg Western Pomerania, the theoretical surface velocities and gradients were interpolated to harmonize the interval velocities. For Brandenburg and Saxony-Anhalt, a weighted interpolation of the interval velocities in a buffer zone was applied.

On the poster, we present an overview of the harmonization strategies applied along the borders between Lower Saxony and its neighbours. We highlight different border-specific approaches and illustrate how we achieved regional consistency despite varying methodologies and datasets. Selected results from the pilot region demonstrate the effectiveness of the applied methods and their impact on building a coherent velocity model for the North German Basin.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

TUNB Velo 2.0: Large-scale velocity modelling of the North German Basin – Results from Lower Saxony

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During the TUNB Velo 2.0 project, the Geological Surveys of the North German Federal States and the Federal Institute for Geosciences and Natural Resources (BGR) developed a seismic velocity model of the North German Basin. It is based on the TUNB structural model from the previous TUNB project, which covers 13 stratigraphic units from Zechstein to Tertiary, numerous salt structures and faults.

For Lower Saxony, the modelling was done in Aspen SKUA®. A volume model was derived from the structural model and parameterized with seismic velocities. The regional velocity approach is based on Jaritz et al. (1991), where the interval velocities of the stratigraphic units can be derived from their theoretical surface velocities and gradients (V0-K method).

The resulting regional velocity model of the TUNB Velo 2.0 project covers almost all of Lower Saxony, with the exception of the southernmost areas where the availability of seismic data is limited. At the LBEG, 75% of the 3D and 83% of the 2D seismic data is available only in time domain. With the velocity model now available, time domain seismic data can be converted to depth domain for its use in structural modelling. In the talk, we will present modelling results, show uncertainty considerations and the usage of this regional velocity model to convert seismic data.

Reference

Jaritz W., Best G., Hildebrand G., Jürgens U. (1991) Regionale Analyse der seismischen Geschwindigkeiten in Nordwestdeutschland. Geol Jahrb 45:23–57

06.04 Stressors in Hydrogeology: Interactions and Impacts

Advancing Tracer Techniques: Comparative Analysis of Solute, Particulate, and Microbial Transport in Field Experiments

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Karst aquifers are particularly susceptible to contamination due to their high permeability and limited natural attenuation capacity. Conventional delineation of karst catchments and flow pathways has largely relied on solute tracer experiments. While effective for identifying groundwater connections, such tracers do not adequately reflect the transport dynamics of particulate contaminants, including colloids and microorganisms, which are increasingly relevant in assessing groundwater vulnerability.

Over the past years, a comprehensive series of tracer experiments has been conducted at a karst spring in southwestern Germany. These tests employed a diverse set of tracer substances, including fluorescent dyes, organic micropollutants, silica microspheres, and microplastic particles. Most recently, the tracer suite was extended to include non-pathogenic microorganisms to more closely mimic pathogen transport behavior. The comparative analysis revealed high overall transport velocities with predominantly conservative transport behavior. Only slight variations in transport velocities among the different tracer types regardless of transport length were detected. However, notable discrepancies in tracer recovery rates point at distinct retention and removal mechanisms acting on the particulate tracers. These findings underscore the complexity of particle transport in karst systems and highlight the limitations of traditional tracer approaches.

The study further emphasizes the need for methodological advancements—particularly in tracer selection and analytical techniques—to improve of tracer tests involving particulate and biological agents. Future research should focus on optimizing the design of such experiments, including the development of standardized microbial tracers and the integration of advanced detection methods.

01.20 Process oriented microfabric characterisation of geomaterials

Magnetite microstructure in oceanic serpentinites

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Magnetite frequently forms during low-temperature serpentinization of mantle rocks and is hence a common mineral in serpentinites at oceanic core complexes. Deformation of serpentinites is considered a crucial ingredient in many geodynamic processes and yet poorly understood. Here we explore magnetite microstructures in order to test their suitability to track deformation in serpentinites.

The Atlantis Massif at the mid-Atlantic ridge is an oceanic core complex where a ~1.25 km long core (U1601C) was drilled during IODP Expedition 399. Shipboard data of recovered samples show strong variations in macroscopic parameters such as alignment, thickness and spatial distribution of magnetite aggregates. Using electron backscatter diffraction (EBSD), we analyse how microstructural parameters such as grain size, grain shape and alignment and crystallographic preferred orientation (CPO) link to the macroscopic parameters .

Four representative samples with a distinct macroscopic foliation intensity have been chosen and large area ESBD/EDX maps produced at 0.2/0.5 µm step size. Grain size is mostly <10 µm equivalent diameter. Long axes of individual grains tend to be (sub)parallel to the long axes of larger magnetite aggregates, irrespective of whether aggregates contribute to the main foliation or not. Magnetite CPO strength is variably strong and dominated by CSL3 twinning.

We will discuss the relation between macroscopic and microstructural parameters with regard to the development of the magnetite foliation and its possible relation to deformation.

05.04 Biogeochemistry, geomicrobiology, and biomineralogy

Building the Las Cruces Gossan (SW Spain), Part I – Establishing a Geomicrobiological Model System

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Stoll, Justus [2]
Rey-Samper, J. Javier [3]
Tornos, Fernando [4]
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The Las Cruces gossan (Seville, Iberian Pyrite Belt, Spain) hosts a large cementation zone with abundant copper sulfides. Previous studies proposed that microbial sulfate reduction in the subsurface may have contributed to the secondary formation of these minerals[1,2]. Here, we experimentally evaluated this hypothesis by investigating the potential role of sulfate reducing bacteria (SRB) in copper sulfide mineralization processes under conditions relevant to the Las Cruces gossan. More specifically, we established a geomicrobiological model system emulating the Las Cruces gossan subsurface environment. First, we exposed microbial enrichment cultures from sites characterized by moderate environmental conditions to 12.7 mg/L Cu at 40 °C for four weeks. Subsequent 16S rRNA sequencing revealed an increased relative abundance of several SRB (e.g. Desulfosporosinus, Desulfovibrio & Desulfitobacterium), which are also present in the Las Cruces gossan today[2]. In further enrichments, different incubation temperatures and Cu concentrations were tested (see also abstract by Stoll et al.). We found that the SRB tolerated Cu concentrations of up to 38 mg/L at 40 °C. Subsequent SEM-EDS analysis revealed mineral-encrusted cell-like structures, together with colocalizations of Cu and S at or near these structures, potentially suggesting microbially mediated copper sulfide formation during the experiments. Although the observed mineralization could not be attributed to specific SRB, the results of our study lend support to the hypothesized microbial origin of copper sulfides in the Las Cruces gossan.

References

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[2] Tornos et al. (2018) Geology 47 (2): 143–146.

08.01 Young Scientist Session

Limnic herpetofaunas of the Permian late-icehouse tropics: Insights from the Lochbrunnen Lake Unit (Oberhof, central Germany)

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The Lochbrunnen Lake Unit (Oberhof Formation, Thuringian-Forest Basin) represents one of the youngest perennial-lake deposits of the European Permian and is key to understanding limnic ecosystem evolution in tropical Pangea. Based on two excavations, 126 temnospindyl specimens were anatomically documented, biometrically analyzed, taxonomically identified, and their embedding pelites lithologically and taphonomically characterized on a millimeter scale.

Most amphibians—mainly the branchiosaurids Apateon flagrifer and Melanerpeton arnhardti (90–95%) and the eryopid larvae of Onchiodon sp. (5–10%)—are preserved as articulated impressions with skin shadows, occurring in profundal and subordinate littoral facies. Five taphotypes reflect different preservation modes, often linked to microbial mats, anoxia, and sediment dynamics. Dorsoventral orientation predominates, while lateral burial is rare. The lake ecosystem comprised a full trophic web: microbial mats and algae (Perissothallus) as producers; bivalves, conchostracans, crustaceans, branchiosaurids, and Onchiodon larvae as consumers; and xenacanthid sharks and adult Onchiodon as top predators. The dominance of small branchiosaurids indicates ecological instability related to increasing aridification. Under these conditions, A. flagrifer appears as a generalist, while M. arnhardti shows possible adaptations (e.g., sclerotic rings, basibranchial morphology) to living in deep or oxygen-poor waters. Exceptional preservation of the amphibians likely resulted from anoxic events, microbial coverage, and rapid burial. The results document the various taphonomic pathways of amphibians in lakes and enlighten the impacts of late-icehouse environmental changes on low-latitude lake ecosystems.

06.04 Stressors in Hydrogeology: Interactions and Impacts

Constraining groundwater recharge estimates with gravity measurements

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Measuring gravity over time provides direct information about subsurface mass changes and, consequently, changes in groundwater storage. Gravity residuals can be used to estimate the specific yield of aquifers or to calibrate hydrogeological models.

As part of our research project, a high-precision absolute gravimeter will be developed for field applications. The absolute gravimeter is expected to offer significant advantages over existing high-precision instruments, such as a simple setup and low drift. In parallel, we will build a mesh-based physical hydrogeological model simulating both unsaturated and saturated zone processes in a study area experiencing declining groundwater levels. Mass changes in each mesh cell lead to gravity changes, which can be calculated by accounting for local subsurface properties. Model parameters will be constrained by fitting the modeled gravity response to the observed data. While previous studies have successfully calibrated saturated zone models using gravity data, including the unsaturated zone will improve the accuracy of subsurface mass change estimates and enhance the understanding of processes such as groundwater recharge. A comparison with repeated measurements of surface nuclear magnetic resonance will further assess the method's validity for capturing unsaturated zone processes.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Spatiotemporal dynamics of floodplain patterns during the last 400 years south of Leipzig – A regional scale analysis

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The Elster-Pleiße floodplain south of Leipzig has undergone significant hydromorphological changes over the past centuries, influenced by both natural processes and anthropogenic interventions. This study employs high-resolution LiDAR-based fluvial-geomorphological mapping (1x1 m resolution) and old maps analyses to reconstruct past river dynamics and identify shifts in channel morphology. Geomorphological mapping reveals an earlier, more dynamic floodplain characterized by meandering and anabranching channels, which transitioned into a system of stabilized, largely immobile watercourses. Comparative analyses of old maps spanning from the 16th to the 20th century indicate a gradual reduction in river sinuosity and lateral migration, coinciding with increasing human modifications such as mill races, timber rafting canals, and flood protection measures. Key transformations include the straightening of channels, floodplain aggradation, and the impact of open-cast lignite mining in recent centuries. The study highlights the complex interplay of climatic fluctuations, sedimentary processes, and anthropogenic activities in shaping the floodplain's evolution.

Understanding these long-term dynamics provides crucial insights for contemporary river restoration and flood management strategies.

04.02 Lithium Rescources

Lithium – European Perspective to 2030 and beyond

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E-mobility and the green energy transition (wind, solar energy storage) in general represent the largest growth areas for lithium-ion batteries. In 2030, more than 90% of the demand for lithium will come from this sector. Due to its properties, lithium cannot be substituted in the mass market of LIB in the near future and all types of currently available cathode technologies contain lithium. The EU voted to ban new ICE vehicles from 2035 onwards, which will be one of the major challenges for the industry and their supply chain. However, global economic developments have led some governments to questions these ambitious targets. Nonetheless, demand for lithium and other battery raw materials is expected to increase rapidly in the coming years, as the green transition is inevitable. Currently the EU is heavily dependent on imports for either batteries or raw materials (i.e. precursor materials) for this industry with China being in a very strong position across all of these materials. In order to reduce these dependencies the EU has put the EU Critical Raw Materials Act (CRMA) in place with very ambitious goals and targets for mining, processing, recycling and import diversification. In this presentation, the current global and European market situation (supply chains) of lithium as well as production potentials will be discussed. Furthermore, implications of the newly announced CRMA strategic projects, the German Raw Materials Fund, Battery Regulation and ESG concerns as well as other regulatory measures on the market development will be addressed.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Development of a Cross-Border 3D Geological Model for the Lausitz: Methodology and Applications

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Intensive lignite mining in the Lausitz region has significantly influenced both the environment and local communities over the past 150 years, shaping a unique cultural landscape. The region now faces a range of complex challenges – geotechnical, hydrogeological, hydrological, and energy-related – that affect not only human settlements but also the natural ecosystem. The Lausitz deposits are characterised by Cenozoic sequences resting on a northward-dipping pre-Tertiary bedrock. Tertiary strata were shaped by repeated marine transgressions interacting with paralic and terrestrial systems. Overlain by Quaternary glacial and interglacial deposits associated with eroding channels and extensive glacial deformation zones.

The study area covers an area of 11,500 km^2 (7,450 km^2 Brandenburg and 4,050 km^2 Saxony) and represents a sediment thickness of up to 350 m. The aim of the Project is to provide a detailed 3D model of the geological situation independent of national borders and associated political responsibilities. It will provide a spatially resolved representation of the Quaternary and Tertiary successions, serving as a fundamental tool for subsequent modelling – such as groundwater flow simulations for transboundary groundwater management in Saxony and Brandenburg.

In the current phase of the project, the focus is on developing the methodological approach, data management, statistical analysis and technical data processing. Integrating data from various sources to create accurate representations of geological formations. More than 178,000 boreholes are currently available for quantification and qualification, supported by layer information including lithological parameters and stratigraphic interpretation. Existing geological model approaches will be updated and optimized for further processing.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Phase relations in alkaline and carbonatitic rocks from northern Tanzania

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Due to low-degree partial melting of metasomatized mantle sources, the northern Tanzanian segment of the East African Rift hosts volcanoes that produced diverse rock series, ranging from basaltic to trachytic, and from nephelinitic ±melilititic to phonolitic compositions. Some of the latter group also produced carbonatites (Oldoinyo Lengai, Kerimasi, Mosonik, Shombole), while others (Sadiman and Burko) did not.

We present a petrological study of alkaline silicate rocks and associated carbonatites from Kerimasi, Mosonik, and Shombole, and compare them with the nearby Sadiman, Burko, and Oldoinyo Lengai volcanoes. The silicate rocks include olivine-melilitites, various nephelinites and phonolites, and their plutonic counterparts. Whole-rock XMg (Mg/(Mg+Fe)) values decrease from ~0.7 in melilitites via 0.6–0.5 in nephelinites to <0.2 in phonolites, indicating progressive magma evolution. Simultaneously, CaO, FeO, TiO_2, and P_2O_5 decrease, while alkalis, Al_2O_3, and SiO_2 increase; in some cases, peralkaline compositions ((Na+K)/Al >1) are reached. Mineral assemblages change from åkermanite +forsterite +perovskite +Fe-Ti oxides in primitive rocks, via diopside +andradite +nepheline in intermediate rocks, to aegirine-augite +nepheline +alkali feldspar +titanite ±sodalite-aenigmatite-eudialyte in evolved rocks. Carbonatites are mostly calciocarbonatites that differ in amount and composition of silicate phases. Apatite, magnetite, mica, and clinopyroxene are present in all volcanoes. Olivine, monticellite, perovskite, periclase occur only at Kerimasi, while Mosonik and Shombole typically contain nepheline, titanite, K-feldspar.

These textural, chemical, and mineralogical variations reflect different storage conditions, cooling histories, as well as heterogeneous mantle sources and partial melting processes, which we aim to constrain by estimating temperature, pressure, redox state, silica activity, and CaO activity.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

CT-based re-evaluation of the anatomy and phylogeny of the trematopid temnospondyl Rotaryus gothae

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Trematopids are a monophyletic group of Permo-Carboniferous dissorophoid temnospondyls from North America and Europe. These anamniotes were well adapted for a terrestrial lifestyle, but most species are only known from a single specimen. The scarcity of well-preserved fossils, combined with anatomical variation among taxa, poses significant challenges for resolving trematopid taxonomy and relationships. This study re-evaluates Rotaryus gothae, a trematopid from the lower Permian Bromacker locality in central Germany, using computed tomography (CT) and 3D digital segmentation. This detailed examination revealed previously obscured anatomical features and led to the identification of novel characters. Notable findings include the presence of an internarial fenestra and new insights into the mandibular and palatal anatomy, including new information on the dentition. Furthermore, a comprehensive set of postcranial elements was uncovered, including a previously unknown, nearly complete and articulated right hindlimb. These discoveries provide valuable new insights into the locomotor morphology and functional anatomy of Rotaryus gothae. Bayesian and parsimony analyses were conducted using two matrices, respectively. The results support the trematopid identification ofRotaryus, but it acts as a wildcard taxon with varying phylogenetic positions depending on dataset and method used. Furthermore, the broader relationships within Olsoniformes remain unresolved. This new data has led to a better anatomical understanding of Rotaryus but also highlights the difficulties posed by limited specimen availability and high morphological variability. This study underscores the necessity of re-evaluating early tetrapods with modern tools to refine unresolved phylogenetic questions and provide a foundation for future investigations.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Seismic microzonation of Carora, Venezuela

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Carora is located in western Venezuela on the edge of the Carora Basin, on Quaternary sediments over Cretaceous and Tertiary rocks in a region with intermediate seismicity. Carora has experienced medium seismic damage (MCS= VII), such as in the M6.9 El Tocuyo earthquake (1950). Some potential seismic sources affecting Carora are Burbusay fault and the Mesa de Aregue fault, this one 20 km to the north.

Geophysical data obtained in Carora include ambient noise measurements which were analyzed using Rayleigh wave ellipticity curve inversion. Three seismic microzones were defined based on results from ReMi (Refraction Microtremor) and topographic analysis for Vs30 and depth determination (H) to a seismic basement with Vs > 1200 m/s. Microzone 1 corresponds to formations with Vs30 > 400 m/s (a Class C site) and H < 80 m. Microzone 2 comprises sediments with Vs30 of 200–400 m/s (a Class D site) and H < 110 m, and microzone 3 comprises sediments with Vs30 of 200–400 m/s (a Class D site) and H of 110–230 m.

Probabilistic Seismic Hazard Assessment (PHSA) was conducted based on the geographic location, Vs30, and basement depths. Faults and sectors of intermediate seismicity within a 2º radius (222 km) of the center of Carora were considered. Three NGA-2013-2014 attenuation relationships were used to calculate rock and site spectral responses at 21 structural periods, for 4 seismic return periods. Then site spectra were smoothed for engineering purpose. Results lead to specified spectra limited by 85 % of building code values.

02.01 The Tethys Ocean – the cradle of modern tropical life

The Tethys – a mosaic of biodiversity hotspots

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Today biodiversity hotspots cluster mainly in the tropics. The high diversity in tropical floral and faunal communities is regarded as a product of low extinction (“museum”) and relative higher origination rates (“cradle”) due to higher molecular evolution compared to higher latitudes.

The Tethys Ocean reigned an extensive tropical area for a major part of the Phanerozoic. Sediments deposited in this tropical ocean and the fossils included are a treasure trove for palaeontologists. They allow glimpses into past biodiversity hotspots, into past faunal and floral communities and into centers of evolution.

Although the Tethyan realm is primarily known for exquisite marine fossil records, here the focus is on the vegetation of the surrounding continents. Plant macrofossil sites adjacent to the Tethys testify not only the early evolution of typical Mesozoic plant groups in the late Permian (Corystospermales, Bennettitales, and the conifer family Podocarpaceae in Jordan) but also the radiation of some of these groups in the Anisian and Carnian deposits of Austria and northern Italy. In contrast to the plant macrofossil sites surrounding the Tethys, plant microfossils are transported into the Tethys by rivers and deposited in marine sediments. These document for example plant survival during the Permian–Triassic mass extinction in South China or the Middle to Late Triassic biogeographical differentiation of the flora.

03.04 All about carbonates

From water multilayers to ice on calcite (10.4)

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Calcite, the most abundant carbonate mineral in Earth's crust, plays an important role in processes such as the global carbon cycle and biomineralization. To get a deeper understanding of these processes the interaction between water and the most stable calcite (10.4) surface on the nanometer scale is of central importance.

Previously, water coverages ranging from single molecules up to one monolayer were imaged with atomic force microscopy in an ultra-high-vacuum environment. [1] [2] These studies are expanded by several studies of bulk water at ambient conditions. [3] However, the intermediate coverages region of a few multilayers was poorly studied.

We employ atomic force microscopy to follow the growth of water layers at low temperatures. High-resolution imaging reveals, that the first few layers have different superstructures. Depending on temperature and pressure, we observe the formation of amorphous or crystalline ice clusters on top of these layers.

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04.07 Mineralogy of Secondary Raw Materials

Efficient recovery of critical elements by creating artificial minerals in slags

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The scarcity of raw materials, especially rare earths, lithium, tantalum and vanadium, is a significant risk factor in today's society. Geological reserves of these elements are not sufficient to meet future demand. By recovering these elements from material waste streams, an independent second source of raw materials can be created. Such a second source can be created by capturing the critical elements in a phase with good separation properties through the production of engineered artificial minerals (so-called EnAMs). This approach can be used for the recovery of critical elements from slags resulting from pyrometallurgical processing.

In addition to industrial slags (e.g. Umicore), synthetically produced slags were also studied to investigate the crystallization behavior of Li, Ta and V and to identify potential EnAMs. Specific modifications (chemistry, heat supply, atmosphere) have been used to study how critical elements are incorporated into artificial phases during slag solidification. The example of Li shows that different EnAMs (LiAlO2 and LiMnO2) can act as potential sources of recovery. Preliminary investigations have shown that the formation of LiAlO2 can be inhibited by other phases. For instance, due to the increasing use of lithium-manganese rich cathode material, additionally manganese enters the system, resulting in the preferred formation of spinels (MgAl2O4) instead of LiAlO2. As aluminum can largely be eliminated via mechanical processing, in this study, LiMnO2 was investigated as a potential main EnAM for the recovery of lithium. Since manganese is highly redox-sensitive, the investigation of speciation changes in the high temperature range of slag is important.

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

An unusual invertebrate trace fossil from the Thuringian Rotliegend

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Recently, a trace fossil of unusual morphology was found in the Cabarz quarry in the Thuringian Forest near Bad Tabarz (Thuringia, central Germany). The specimen was collected at the base of Floor 2B of the quarry exposing rocks of the Lower Goldlauter Formation (Lower Rotliegend, early Permian). The trace fossil is preserved as epi-/hyporeliefs on two siltstone slabs representing part and counterpart. The siltstone surface is of greyish-red colour and shows rain drop marks. The deposit is interpreted as floodplain facies. The trace fossil is discussed to be composed of a central crawling track of the invertebrate body and, along with it, impressions of walking legs on both sides. In the concave epirelief, the crawling track exhibits a string-of-pearls-like structure. Compared to literature, morphological similar impressions of walking legs and the pearl-like central track were known from Diplichnites and Imponoglyphus, respectively. Both ichnogenera have been reported from the study area before. Combining these characteristics in a single trace corresponds morphologically to Glaciichnium, which is currently interpreted to represent locomotion traces of isopods or caddisfly larvae. Glaciichnium-like traces are hitherto unknown from the Thuringian Rotliegend. The inferred locomotion, combining pulsating crawling (Imponoglyphus) and walking (Diplichnites), suggests a behaviour that has not yet been described from any other invertebrate trace fossil from the Thuringian Rotliegend and therefore seems to be rare in the study area.

09.02 Museen als Fenster in die Forschung

An early Permian xenacanthid fragment from Thuringia

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During a palaeontological excavation in the Thuringian Forest near the town of Oberhof (Free State of Thuringia, Central Germany), a fragment of a xenacanthid shark skeleton was recovered. The new fossil finding belongs stratigraphically to the Lower Protriton-Horizon of the Lower Oberhof Formation (Lower Rotliegend, early Permian) in the Thuringian Forest Basin. This xenacanthid is preserved on a grey coloured, lacustrine siltstone that measures 7 cm in length and 13 cm in height; a smaller counterpart of the rock slab is preserved as well. The brown coloured remnants of the xenacanthid skeleton include hemal, neural, basal spinae, dorsal radialia, parts of the pelvic fin, and modified scales of the lateral line organ. Compared to literature, lateral lines appear to be rarely preserved in xenacanthid fossils.

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

Procolophonichnium tracks from the middle to late Permian of central Germany

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In this study we compare footprints and trackways of small reptiles assigned to the ichnotaxon Procolophonichnium from two central German study areas: [1] the middle to late Permian Mammendorf quarry close to Magdeburg and [2] the late Permian Kupferschiefer mining area of the Sangerhausen Depression, Saxony-Anhalt. This material is compared to finds from the late Permian Cornberg Sandstone, Hesse and the Early Triassic tracksite of Britten, Saarland. Furthermore, the uppermost Rotliegend to basal Zechstein deposits exposed near Morungen close to Sangerhausen were studied in detail to clarify the depositional environment of the associated footprint finds. In terms of imprint proportions, morphology and size, the Procolophonichnium from the Sangerhausen area is similar to the Mammendorf Procolophonichnium specimens but different from the Cornberg and Britten samples. The trackway patterns of most Mammendorf specimens differ notably from the rest of the sample in their high (normalized) pace length and gauge width, implying a track producer with a different walking style. According to our documentation of the inactive quarry Morungen, the abundant Procolophonichnium finds from nearby spoil tips come from fluvial units that overlie the marine Zechstein conglomerate and underlie a sandy black shale, which is interpreted as the deep-water equivalent of the third cycle of the Kupferschiefer in the typical Zechstein basin facies. Consequently, the track-bearing sandstones are terrestrial equivalents of the lower part of the marine Kupferschiefer. The occurrence of footprints made by non-marine reptiles is probably related to the temporary persistence of an island in the rapidly flooded Zechstein Sea.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Geoscientific characterization of claystone as part of the German Repository Site Selection Act – “Sub-area Opalinuston Formation”

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According to the Repository Site Selection Act (Standortauswahlgesetz – StandAG), the German Site Selection Procedure is an iterative process and consists of three phases with increasing levels of detail in which the assessed area is continuously reduced during the process. Starting with an empty, so-called “white map of Germany”, BGE (implementer of the German Site Selection Procedure) completed Step 1 of Phase I in September 2020 with the submission of the Sub-areas Interim Report (BGE 2020/88), where BGE identified 90 individual sub-areas (in claystone, rock salt, and crystalline rock).

In Step 2 of Phase I, BGE aims to localize siting regions within the 90 sub-areas by applying preliminary safety assessments and other scientific criteria. Within the preliminary safety assessments, subsurface data are interpreted and the results documented. The workflow comprises the detailed characterization and interpretation with a focus on the host rock formation that acts as the main geological barrier but also considers the surrounding rock formations.

The claystone succession of the “Opalinuston Formation” in southern Germany has been designated as claystone sub-area. Based on borehole data, the sequence was mapped and described in vertical and lateral extend. This information was used to assess, for example, the thickness of the barrier and the maximum depth of the top of the Opalinuston Formation, which led to the categorization of parts of the sub-area in the first two steps of the preliminary representative safety analysis. This poster explains the results that were already published as a preliminary working status in 2024.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Geoscientific characterization of claystone as part of the German Repository Site Selection Act – "Methods and work status"

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According to the Repository Site Selection Act (Standortauswahlgesetz – StandAG), the German Site Selection Procedure is an iterative process and consists of three phases with increasing levels of detail in which the assessed area is continuously reduced during the process. Starting with an empty, so-called "white map of Germany," BGE (implementer of the German Site Selection Procedure) completed Step 1 of Phase I in September 2020 with the submission of the Sub-areas Interim Report (BGE 2020/88), where BGE identified 90 individual sub-areas (in claystone, rock salt, and crystalline rock).

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Part I of this contribution describes important methods that are used to characterize and assess the claystone successions present in the different sub-areas.

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StandAG: Standortauswahlgesetz vom 5. Mai 2017 (BGBl. I S. 1074), das zuletzt durch Artikel 8 des Gesetzes vom 22. März 2023 (BGBl. 2023 I Nr. 88) geändert worden ist.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Chemical discrimination of rutile from different metamorphic source rocks: Dealing with hierarchical data structures in Random Forest classification

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Rutile provides a wealth of petrochronological information in metamorphic geology and due to its high stability during processes of the sedimentary cycle, rutile takes a special position in sedimentary provenance analysis. Besides being one of the classical minerals datable using the U–Pb system, rutile incorporates a broad range of trace elements, many of those being incompatible in most of the common metamorphic minerals. Although a large number of multivariate statistical tools including machine-learning approaches is available, current rutile discrimination schemes suffer from focusing on uni- and bivariate approaches, leading to large compositional overlaps. Here we compiled a dataset of 2,335 rutile trace-element analyses (1,605 new analyses and 730 from Lueder et al. (2024))) from 110 metamorphic rock samples of 48 localities covering a wide range of pressure–temperature conditions. After showing that the subsampling and testing strategy of the classical random forest algorithm (Breiman, 2001) is inappropriate for such hierarchical data structures, we introduce a modified version (hierarchical random forest) which provides realistic and generalized error estimates, improving hyperparameter tuning and performance. By applying this concept, we present a novel and multivariate rutile discrimination scheme, using the concentrations of 16 elements. The model correctly predicts the source rock composition (felsic versus mafic) in ~89 % of the cases and the metamorphic gradient (≤350 °C/GPa versus >350 °C/GPa) in ~84 %. Combined with U–Pb dating, this enables to gain time-resolved insights into the geodynamic evolution of the hinterland, taking rutile provenance analysis to the next level.

05.02 Understanding (geo)materials with advanced experimental and computational methods

Search for novel photovoltaic absorber materials: Kesterite and Briartite

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Photovoltaics is one of the most easily implementable renewable energy source. Highly efficient thin-film solar cells use chalcogenides such as $Cu(In,Ga)Se_2$ or halide perovskites like $(Cs,FA,Ma)Pb(I,Br)_3$ as absorbers. Since the availability of indium as well as the limited stability of halide perovskites is an object of concern regarding large scale production of solar cells, the search for novel absorber materials with long term stability is an ongoing challenge.

We studied the chalcogenides Kesterite (Cu_2ZnSnS_4) and Briartite (Cu_2ZnGeS_4) as promising candidates for photovoltaic applications. These semiconductors show a high absorption coefficient of solar radiation and long term stability. Kesterite-based thin film solar cells already reach power conversion efficiencies > 12% [1].

To understand the materials' optoelectronic properties, deep insights into the structural properties are crucial. Both compounds crystallize in the tetragonal Kesterite structure, which is characterized by a network of corner sharing tetrahedra. Additionally Briartite shows an orthorhombic modification (Wurtz-Kesterite structure). The symmetry reduction is caused by a distortion of the coordination tetrahedra.

We investigated the structural and optoelectronic properties of Kesterite and Briartite using powder samples synthesized by solid state reaction. The formation of different Briartite modifications depends heavily on the sulfur pressure, tailored during the synthesis. The challenge in structural analysis is the differentiation of the electronic similar elements Cu, Zn and Ge. We solved this problem by applying neutron diffraction as well as multiple energy anomalous diffraction.

The presentation will give an overview of structure-property relations of these promising photovoltaic absorber materials.

Reference

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01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Lithium bearing silicates in Upper Permian salt rocks of the Morsleben site (Germany)

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Li can be detected in salt rocks, although no known naturally formed salt mineral incorporates Li in the crystal lattice [1]. Very low Li concentrations (few µg/g) are related to fluid inclusions, but higher concentrations must originate from other sources, e.g. phyllosilicates [1, 2]. To verify the Li-hosted minerals, samples from the upper Staßfurt-Formation (Deckanhydrit, z2DA) to the lower Leine-Formation (Grauer Salzton, z3GT; Leinekarbonat, z3LK; Hauptanhydrit, z3HA) were investigated. The succession contains salt clays, anhydrite and carbonate bearing salt rocks of the Upper Permian (Zechstein) from the Morsleben site (Germany).

The samples were investigated using ICP-OES, ICP-MS, XRD, SEM and thin section microscopy.

The z2DA shows Li concentrations of ca. 4 µg/g to 159 µg/g. The sample with the highest Li content consists of quartz, illite-muscovite, chlorite (clinochlore), halite, anhydrite, magnesite, kaolinite, koenenite, biotite and hydrotalcite. The z3GT is composed of quartz, illite-muscovite, halite, sylvite, anhydrite, carnallite, hydrotalcite, chlorite (clinochlore), anatase, biotite and tourmaline, with a Li content of 146 to 154 µg/g. In the z3LK, the Li content varies from 11 to 46 µg/g and in the z3HA from 5 to 116 µg/g. Al, K and Rb show positive relations to Li in all samples.

In the z2DA, Li probably originates from illite-muscovite, in the z3GT probably from illite-muscovite and a Li-bearing variety of a tourmaline (elbaite). The Li content of these minerals will be verified in future work.

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01.09 HEATin ´EUROPE during the Carboniferous and Permian: causes and effects

Oxygen isotopes in cherts from the Rhenish Massif record paleo-heat flow and burial rates

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Oxygen isotopes in sedimentary rocks have long been used to reconstruct paleo-surface temperatures. Chert, a microcrystalline form of SiO_2, has also been explored as a paleotemperature proxy, but the factors controlling its isotopic composition remained uncertain. A recent numerical model of silica diagenesis has now linked chert oxygen-isotope ratios directly to paleo-heat flow, opening new opportunities for its application [1].

Diagenetic chert forms when amorphous silica (opal-A) dissolves and reprecipitates, passing through an opal-CT intermediate before becoming microcrystalline quartz. The oxygen-isotope ratios ($\delta^{18}O$, $\Delta'^{17}O$) in the resulting chert capture the temperature and fluid composition at the depth of the opal-CT to quartz transition. By simulating that diagenetic transition, the new model relates $\delta^{18}O_{chert}$ and $\Delta'^{17}O_{chert}$ to burial temperatures, pore fluid alteration and heat flow.

We use the model to reconstruct paleo-heat flow during prograde silica phase transformation and derive burial rates and pore fluid alteration across the Rhenohercynian basin. Our data reveal paleo-heat flow in the order of 50 to 70 mW m^{-2}, agreeing with a previous model [2] and high burial rates in the east of up to 80 m Myr^{-1}, agreeing with the thickness of overlying turbidites. Burial rates and clay mineral content coincide with ^{18}O-depleted compositions of cherts, i.e compositions in three isotope space that deviate from the expected temperature-equilibrium. This dataset lays the foundation for a new tool to study the thermal- and burial histories of sedimentary basins.

References

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01.10 The co-evolution of the Earth and life from the early Archean until today

Evidence for serpentinization in the Columbia Hills, Gusev Crater, Mars adds to their habitability

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Mars Exploration Rover Spirit landed in Gusev crater on Mars in 2004. The crater was selected as the landing site because delta-like deposits at the mouth of a large inflow channel, Ma'adim Vallis, suggest that it once held a lake. However, Spirit landed on top of lava flows obscuring any potential lake sediments. The Columbia Hills are located near the center of the crater and are embayed by these lava flows, thus representing older material. Though not lake deposits, the hills reveal evidence for substantial aqueous alteration including fine-grained, layered outcrop containing the iron hydroxide goethite at the West Spur (Morris et al. 2006) the Comanche outcrop containing ~26% magnesium/iron carbonate (Morris et al. 2010) and opaline silica deposits (Squyres et al. 2008) indicating an ancient hot spring (Ruff and Farmer 2016) in the Inner Basin. The hot spring deposits resemble biosignatures found in hot springs on Earth (Ruff and Farmer 2016). Here we present evidence that the mineralogy at the West Spur as maeasured with Spirit's Mössbauer (Morris et al. 2006) and miniature Thermal Emission Spectrometer (mini-TES; Ruff et al. 2006; Wang et al. 2006) is consistent with serpentinization. Furthermore, serpentinization at West Spur, carbonates at the Comanche outcrop and the opaline silica hotspring deposits in the Inner Basin can be linked via an evolving aqueous fluid. The process of serpentinization adds to the Columbia Hills' habitability because it can result in the formation of organic molecules via Fischer-Tropsch synthesis, and release hydrogen, which could support microbial metabolisms.

04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

Reactivity and Characterization of Activated Clays for Low-Carbon Cement Applications

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With the planned phase-out of coal in Germany by 2030, fly ash—a widely used supplementary cementitious material (SCM)—will no longer be available. Among potential alternatives, activated clays have emerged as one of the most promising candidates due to their high pozzolanic potential upon activation. Structural damage enhances the reactivity of clays, enabling the silicon and aluminum components to participate in the formation of calcium aluminate silicate hydrate (C-A-S-H) phases in the presence of cement and water.

In this study, the phase composition and chemical properties of various clays were characterized via X-ray diffraction (XRD) and X-ray fluorescence spectroscopy (XRF) to determine the phase content and the silicon-to-aluminum (Si:Al) ratio, a key parameter governing pozzolanic reactivity. While most previous studies have focused on high-purity clays[1], this work also investigates clay mixtures, comparing their behavior in cementitious systems to pure clays.

The activation process includes thermal treatment in a muffle furnace or mechanical treatment via grinding, both aimed at destroying the clay mineral structure. To optimize the thermal activation, decomposition temperatures were determined using differential scanning calorimetry and thermogravimetric analysis (DSC-TG). The pozzolanic reactivity of the activated materials was evaluated through isoperibolic heat flow calorimetry and the Frattini test according to DIN EN 196-5.

The results indicate that when the Si:Al ratio is nearly 2:1, the reactivity and hydration behavior of clay mixtures closely match those of pure clays, highlighting the potential of using mixed or impure clays as viable SCMs.

Reference

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01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Variscan tectonics of the Elbtalschiefergebirge, Saxo-Thuringian Zone – Evidence for two consecutive burial-exhumation cycles

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The Elbe Zone serves as an example for the intricate architecture of the Central European Variscides. In the Elbtalschiefergebirge, remnants of a heterogeneously deformed and metamorphosed nappe complex are juxtaposed with the crystalline blocks of the Lausitz and the Erzgebirge. The preserved Paleozoic lithologies contain the record of the Variscan orogeny postdating marine sedimentation on a vast Peri-Gondwana shelf. However, the relationship between sedimentation, magmatism and Variscan tectonics remains contentious. Here, we present a tectonic model for the Elbtalschiefergebirge that is characterized by two consecutive burial-exhumation cycles. Late Devonian marine facies differentiation and bimodal magmatism marks the onset of the Variscan Orogeny. These sedimentary to volcanoclastic successions were then affected by low-grade regional metamorphism, followed by nappe stacking. The deposition of Early Carboniferous synorogenic marine sediments on top of the exhumed crustal pile marks the transition into the second cycle, which is characterized by renewed burial and subsequent heterogeneous dextral transpressional deformation of the Elbe Zone. Shearing at the northeastern boundary of the Elbtalschiefergebirge is accompanied by a prograde high-temperature metamorphic overprint, probably associated with the emplacement of the synkinematic Meissen granitoids. Shearing in the southwest resulted in the formation of the brittle-ductile to brittle Mid-Saxon Shear Zone, which is related to the final exhumation of the Erzgebirge complex into upper crustal levels. The end of the pervasive dextral strike-slip activity is marked by the intrusions of the undeformed Markersbach-Granite and Late Carboniferous rhyolite dykes as well as by the unconformable deposition of Permo-Carboniferous sediments of the Döhlen Basin.

01.29 Environmental Hazards and Risks

Multi-regional landslide susceptibility mapping in the Federal Republic of Germany

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The geological surveys of the federal states play a vital role in mitigating the impacts of landslides and safeguarding communities in Germany.

However, certain decisions require a cross-border approach to geohazard assessment, like the landslide susceptibility assessment (1:250 000 scale) that the Federal Company for Radioactive Waste Disposal commissioned. They requested it for areas, in which favorable geological conditions for the safe final disposal of high-level radioactive waste can be expected. To facilitate this we will homogenize state inventories and data from publications supported by state geological surveys (SGDs).

We will distinguish rockfall, translational, and rotational landslides in rule-based simplification steps. We will select specific methodology for each landslide type based on its causes, available information and best practices developed on the state level. For rockfall, we will estimate runout zones with the shadow angle method and identify source areas based on a critical slope angle, both derived from a digital elevation model (DEM) and calibrated against the landslide inventory. Translational landslides will be assessed using the infinite slope method, incorporating a nationwide soil map and a DEM. Geotechnical paramaters will be inferred via a pedotransfer function from the soil data, acknowledging associated uncertainties.

Rotational landslides will be evaluated with the Analytical Hierarchy Process to quantify regional expert knowledge from multiple parameters, because they are the least generalizable type. The available data will be used to define trivial areas. We aim to collaborate with SGDs and local experts to ensure technically sound and regionally adapted methodologies are used.

01.29 Environmental Hazards and Risks

Multi-regional sinkhole susceptibility mapping in the Federal Republic of Germany

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The Federal Company for Radioactive Waste Disposal (BGE) commissioned us to assess sinkhole susceptibility (1:250 000 scale) in areas relevant to the search for a final nuclear waste repository. In these areas favorable geological conditions for the safe final disposal of high-level radioactive waste can be expected. Each German geological survey contributes to geohazard mitigation within its respective federal states, addressing hazards such as sinkholes. To support this effort they document karst features in regional inventories. Our proposed work will be underpinned by these homogenized state inventories supplemented by data from selected publications with a connection to the geological surveys. Key parameters will be the general geological map of the Federal Republic of Germany (GUEK250), and the geological map of the Federal Republic of Germany (GK1000). These maps are supplemented with information from the borehole map of Germany and the geological 3D model of the deep subsurface in the North German basin (TUNB).

We differentiate between carbonate, sulphate and chloride karst. Each entry in the harmonized inventory is assigned a classification based on its karst type. Using geological maps, borehole information and TUNB we plan to derive binary maps showing the availability of soluble rocks for each karst type. These maps in combination with the karst type specific inventory allow us to delineate karst prone areas in Germany susceptible to sinkhole formation. Regional datasets will be used for validation through comparative analysis. To take into account regional variability we want to engage with local geological professionals from across Germany.

03.04 All about carbonates

Six Ca-Mg-Fe Carbonate Reference Materials for *In-Situ* Analysis of Oxygen and Carbon Isotope Ratios

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di Rocco, Tommaso [4]
Vennemann, Torsten [5]
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Glodny, Johannes [1]
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Six Ca-Mg-Fe carbonate reference materials (RMs) were characterized for oxygen and carbon isotope ratios analyses by Secondary Ion Mass Spectrometry (SIMS). This new suite includes four dolomites with Fe# ranging from 0.0004 to 0.3429, one magnesite with Fe# = 0.0099 and one siderite with Fe# = 0.6152. The six samples were split into between 128 to 2048 metrologically identical aliquots, each containing roughly 100 mg of material. We performed a detailed characterization on split materials for their major and minor chemical element composition using EPMA and their mineralogical composition using XRD. The oxygen and carbon isotope reference values were also determined in multiple gas-source isotope ratio mass spectrometry laboratories while the homogeneity of the oxygen and carbon isotope ratios at the sub-nanogram test portion mass were assessed using SIMS. The repeatability of our SIMS measurements varied from ± 0.15 to ± 0.31‰ (1s) for $\delta^{18}O$ and from ± 0.29 to ± 0.71‰ (1s) for $\delta^{13}C$. Significant compositional SIMS matrix effects were observed across the dolomite-ankerite and magnesite-siderite solid-solution series in the investigated compositional range. This confirms the need of multiple matrix-matched RMs spanning a wide chemical range in order to get accurate SIMS isotope ratios in minerals that form theses solid-solutions.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Publishing Geological Subsurface Models via OGC API

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The open geospatial consortium (OGC) provides standards to store and transport geospatial data. A new family of standards around the OGC API seeks to replace the well established standard WFS (Web feature service), WMS (Web map service) or WCS (Web coverage service) for transporting geospatial data. The old standards were designed nearly 20 years ago. They are based on XML and define a now outdated interface to interact with geospatial data.

At the same time new kinds of geospatial data evolved. The new OGC API standard defines a shared, extensible REST interface based on JSON endpoints for managing geospatial data. The OGC API unifies the various W*S and extends them with support for new kinds of geospatial data. The standard consists of various parts and pieces that can be combined as required by specific usecases.

As part of this talk I want to demonstrate how to use various parts of the OGC API to share geological subsurface models to different shareholders for visualisation and modelling purposes. Finally I want to outline various limitations of the current set of OGC API standards for describing and transporting geological subsurface models.

06.04 Stressors in Hydrogeology: Interactions and Impacts

Statistical Assessment of Water Quality in Mexico's Contaminated Purisima Dam

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Mexico's Purisima Reservoir is a significant aquatic ecosystem and a designated protected natural area. To comprehensively understand its environmental health, a recent study evaluated the reservoir's water quality and contamination through an integrated scientific approach. This involved analyzing water and sediment samples for metal/metalloid content and physicochemical properties. Data processing utilized WAWQI, PAST 4.03, JMP15.2, and QGIs 3.26.3. Primary elements found in the reservoir's water (0.002–0.1 mgL^{-1}) included

cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), and arsenic (As). Strong associations ($p < 0.05$) emerged between several element pairs: Pb and As; Cr with Hg and Pb; Hg with Pb and zinc (Zn) and Cd and Pb. Sediment analysis at 25 reference points concurrently showed arsenic (As) as the contaminant most enriched, largely due to anthropogenic mining and mineralization. Other elements generally mirrored natural crustal rock concentrations. We categorized the Purisima Reservoir's water quality as "poor," but biomonitoring revealed it to be "moderately polluted." This research offers vital insights into the environmental health of the reservoir, providing essential guidelines for preventive and corrective measures to manage and conserve this critical water resource.

01.09 HEATin ´EUROPE during the Carboniferous and Permian: causes and effects

Carboniferous-Permian magmatism in the UK

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The UK preserves a diverse record of Carboniferous to Permian magmatism that occurs in a lower plate setting, relative to the southwards-dipping latest Devonian Rheic-Rhenohercynian suture zone, that is seismically imaged offshore to the south of SW England. The classical model of foreland-propagating thrust systems, immediately following the closure of the Rhenohercynian Ocean, is not consistent with the widespread occurrence of Early Carboniferous syn-rift mafic magmatism immediately north of the suture that persists to Scotland.

The SW England Permian magmatic province includes the Cornubian and Haig Fras batholiths and associated mafic igneous rocks developed over a 20 Ma period in Early Permian. These developed in a post-Variscan extensional regime that brought about exhumation and thinning of the lower plate during reactivation of the Rhenohercynian suture zone (Cornubian Batholith) and Bristol Channel Fault Zone (Haig Fras Batholith). Decompression melting of the mantle during lithospheric extension is the most likely cause but lithospheric delamination cannot be excluded.

North of the Variscan Front, latest Carboniferous to Early Permian magmatism was renewed following Variscan intraplate shortening. Most occurrences are consistent with decompressive melting during N-S extension and/or localised extension during movements on wrench faults.

The overall record of Carboniferous and Permian magmatism across the UK does can be explained by extensional tectonics and decompression melting of lithospheric ± asthenospheric mantle plus, possibly, lithospheric delamination below SW England. Whilst mantle plume involvement has been invoked for magmatism in some areas, it is not required to explain heat flow and magmatic activity.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Smart 3D Infrastructure for Geoscience Innovation at LBEG

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3D Infrastructure is a key area of work at the LBEG (State Authority for Mining, Energy and Geology, Lower Saxony), encompassing the technical support required for 3D modeling, including software provision, data management, tool development, and visualization systems. It supports the creation, processing, and publication of three dimensional geodata.

The various software needed for the 3D modelling are procured, internally distributed and carefully maintained. In-house developments supplement standard software by adding functionalities tailored to LBEG's use cases—such as generating geological cross sections, well generator for borehole data, and data conversions. A 3D printer is available to create realistic and demonstrable 3D models which could then be displayed at events and exhibitions.

The 3D models created by the (hydro-)geologists are made available to both professionals and the general public through the web-based NIBIS3D Viewer. This platform hosts geological and hydrogeological models at state, regional, and local levels, accompanied by metadata, reports, and other relevant documentation. Additionally, the potential of virtual and augmented reality is actively explored and utilized wherever applicable.

Numerous ongoing projects with external partners enable knowledge exchange and cooperation. The GEVISGEO3D project, for instance, extends LBEG's infrastructure by hosting two new web instances for the states of Schleswig-Holstein and Hamburg.

Regular interaction with geological surveys of other federal states, through working groups and discussion forums, ensures alignment with current developments in the field of 3D geoscience.

05.02 Understanding (geo)materials with advanced experimental and computational methods

In situ characterization techniques:advances and challenges

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Advanced characterization techniques are essential for gaining insights into the structural and chemical evolution of functional materials under reaction conditions [1]. *In situ* and operando methods have become increasingly important to overcome the limitations of traditional *ex situ* analysis conducted before and after reaction. However, there are many pitfalls one can encounter when conducting non-ambient experiments with elevated temperature, pressure, and humidity. This study highlights the necessity for interdisciplinary knowledge, such as surface and bulk chemistry, nano-size effects, fluid and gas dynamics, and flow-pressure relationships, to effectively plan and execute operando experiments through various application examples in heterogeneous catalysis. What remains non-trivial is the assessment and handling of the complexities associated with the use of corrosive or reductive/oxidative gas atmospheres.

This study presents the development of in-house operando X-ray powder diffraction (XRPD) and quasi-*in situ* X-ray photoelectron spectroscopy (XPS) setups for monitoring inorganic catalyst precursors under non-ambient conditions, including elevated temperatures, reaction gas environments, under pressure, or in a protective atmosphere. Operando XRPD enables real-time tracking of structural transformations, while quasi-in situ XPS provides surface-sensitive chemical state interpretation. Together, these techniques offer a comprehensive understanding of catalyst behavior under realistic reaction conditions and demonstrate the feasibility and value of in-house instrumentation for catalytic research.

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01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

From carbonation in the forearc mantle to carbonate melting in the upper mantle

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Listvenites (carbonate+quartz) and soapstones (carbonate+talc) form by metasomatic transformation of variably serpentinized peridotites in the forearc mantle due to extensive reaction with CO_2-bearing aqueous fluids released from the subducting slab[1]. This COH-fluid/rock interaction plays a critical role in regulating deep carbon fluxes. Evidence for effective CO_2 storage includes: (1) naturally occurring, nearly fully carbonated peridotites; (2) high-pressure experiments that replicate fluid–rock interactions under subduction zone conditions; and (3) thermodynamic models simulating fluid infiltration. Fluid-driven carbonation sequesters large amounts of CO_2 since soapstones and listvenites commonly contain > 20 wt% and > 30 wt% CO_2, respectively. Although volumetrically rare rock types, they occur in many ophiolites throughout much of the geological record[1]. In this presentation, the formation of listvenites and soapstones within the forearc as a relevant sink for CO_2 will be examplified.

Further, the stability of carbonates within the subducting slab and more generally within the upper mantle will be considered from recent experimental results on the anhydrous Ca-Mg-carbonate system. At 6 and 9 GPa, Ca-Mg-carbonates undergo incongruent melting producing dolomitic melt and periclase for temperatures above ~1250 °C [2,3]. At such high pressures, magnesite is expected to be the predominant carbonate phase. Magnesite does not melt, even in the presence of hydrous fluid or under hot subduction geotherms. [4].

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04.06 Coupled Fluid-Rock Deformation: Unraveling Multiscale THMC Dynamics for Fundamental Geological Processes and Societal Challenges

Use of Physics-Based Machine Learning Surrogate Models for Optimal Sensor Placement

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The forcing exerted over subsurface reservoir during operations to extract geothermal heat causes changes in, for instance, the subsurface pressure and temperature state, which can lead to induced seismicity. Therefore, an appropriate consideration of the expected measurable response of the reservoir is needed to design reliable monitoring systems. Computer assisted simulations of thermo-hydraulic-mechanical (THM) processes in fractured reservoirs allow to get a prognosis of the reservoir state and its evolution during operations and to consequently get the expected seismic event number and ground motion amplitudes as design monitoring criteria. The caveat is that an optimal strategy requires a large number of simulations to testing possible monitoring configurations, which makes the usage of full order models unfeasible because of the high associated computational cost. To bypass this barrier, we explore the use of physics-based machine learning surrogate models using the non-intrusive reduced basis method, to obtain fast and accurate solutions. We showcase this methodology for the construction of reliable surrogate models for a reservoir in the transition between convection and conduction dominated heat transfer, which is representative for a wide range of common conditions encountered in geological reservoirs. We especially highlight the differences, to entirely data-driven approaches. We finally illustrate the integration process into algorithms for optimal sensor placements, and how application specific-constraints can be considered.

07.02 Geothermal energy – Potential and utilisation of geothermal energy resources for the heat transition

Reuse of old deep wells in Brandenburg, North German Basin – potential and challenges (Transgeo Project)

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The ongoing structural transformation from the hydrocarbon industry to sustainable green energy is one of Europe's current challenges. In Germany, there are about 15,000 boreholes with depths ≥ 400 m (deep wells). Transgeo, a transnational project (EU Interreg program), aims at identifying the potential of such boreholes for geothermal energy production in Germany (+4 other countries). A central aspect of the project is the collection of data from deep wells. This data is then entered into databases and fed into a web-based IT-tool to demonstrate the potential of deep wells for geothermal energy production to future investors. The reuse of old wells, especially former oil or gas wells, is particularly attractive as it can reduce the costs of otherwise very expensive geothermal drilling while utilizing existing infrastructure. The deep wells in the eastern part of the North German Basin are mostly several decades old. As the former GDR was seeking economic independence, considerable effort was put into exploring and mapping national raw material deposits. Therefore, numerous comprehensive studies and data collections are still available in the archives. Analyses of samples taken, measured parameters, etc., are invaluable. The important parameters are not only temperature, porosity, and permeability in identified pay zones within formations of interest, but also technical data on well construction. Once abandoned, detailed information on the location of cement bridges and geological background information or technical problems during or after the drilling process becomes important when considering reuse or planning a new drilling.

08.01 Young Scientist Session

Archaeogeophysical and satellite image investigation of Early Bronze- and Iron Age water management structures at Bisya, Oman

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Aubrey, Laurent [3]
Jean, Mathilde [4]
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Studies of the location, function, and chronology of ancient hydraulic systems are crucial to understanding human adaptation to arid lands. Integrated archaeogeophysics are essential methods to document these buried, little visible and very extended structures. Such systems for water catchment and management (e.g., aflaj) were likely used for irrigation and made it possible to maintain sustainable occupation from the earliest oasis sites until recent times.

Here we report on archaeogeophysical field investigation that was carried out near Bisya, Oman, where two major wadis converge in a plain that had been a fertile oasis at least since the Bronze and Iron ages until the Islamic period. The first implementation, extent and chronology of such water management system is still little known, as well as the functional purpose of different identified round structures, especially in relation to the known decline in water abundancy in various historical periods.

At Al-Dhabi site, a discovery of ditches was made with Geomagnetics and Georadar, later confirmed by excavations. At Fell site, a channel could be identified by Georadar. Geomagnetics revealed the existence of an elongated structure with one circular side, further connected channels and a second area twice encircled by magnetic anomalies. At Salut site, Geomagnetics confirmed the existence of ditches, that surround the elliptical structure, and a strong anomaly indicates the location of the central well. All anomalies are related to the contrast between the formerly water-logged fine sediments in the channels and ditches, the bulding material of deteriorated mud bricks and calcrete rocks.

04.04 Hydrogen in the energy transition – white to green hydrogen and subsurface storage

Apparent and phase diffusion coefficients for H2 geological storage scenarios using a modified Maxwell-Stefan method

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Geological storage of hydrogen (H_2) is a promising strategy for large-scale energy storage, crucial for integrating intermittent renewable energy sources. Diffusion is a key mechanism governing the long-term containment security and potential migration of stored H_2 within subsurface formations. This study presents analytical assessment and its validation with experimentally measured values of H_2 diffusion coefficient in porous media under conditions relevant to geological storage, specifically using parameters inspired by the Ketzin pilot site for town-gas and CO_2 storage. We employ an enhanced diffusion model based on the Maxwell-Stefan (MS) formulation, coupled with correlations for fluid and rock properties (Peng-Robinson EOS, Chung viscosity, extended Henry's law, Sharqawy brine density, Meyer-Elshahaby brine viscosity). The model calculates the apparent diffusion coefficient (Dapp) considering bulk gas, Knudsen diffusion, dissolved phase, and potential minor sorptive transport, including fracture contributions. Dapp(H_2) was calculated for representative Ketzin reservoir (sandstone) and caprock (claystone) conditions under varying gas saturations, yielding values consistent with expected experimental ranges (e.g., 10^{-9} to 10^{-8} m_2/s for wet sandstone, 10^{-10} to $10^{-9}m^2$/s for wet caprock). Phase diffusion analysis revealed significant composition dependence of Fickian coefficients. Results consistently identified water saturation (Sw), tortuosity (τ), constrictivity (χ), and gas phase accessibility (α) as the most influential parameters controlling Dapp(H_2). Monte Carlo simulations, incorporating parameter uncertainty based on plausible Ketzin parameters, indicated a potential variability in Dapp(H_2) spanning approximately two orders of magnitude, underscoring the need for accurate site characterization. Spearman rank correlation analysis confirmed the high impact of Sw, τ, χ, and α on Dapp(H_2) uncertainty.

03.08 Earth Surface Systems and tipping elements in a changing climate

Did Mid-Pleistocene biome shifts cause gully erosion in eastern South Africa?

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Pleistocene climate change affects landscape stability in many ways and is reflected in sedimentary archives through phases of erosion, deposition and soil formation. Vegetation dynamics play a mediating role here: while established vegetation stabilizes the landscape when it's within its climatic optimum, climate-induced vegetation shifts are characterized by ecological stress, turnover and the establishment of new vegetation forms, which promotes a phase of erosion. The landscape archive of Jojosi, KwaZulu-Natal, South Africa, is an exceptional site to better understand these dynamics. The site lies on the boundary between savanna and grassland, where a succession of sedimentary bodies indicates repeated phases of gully cut-and-fills since the Mid-Pleistocene.

We report on the results of several field campaigns in which we have stratigraphically correlated the Jojosi badlands, characterized them using geochemical and spectral properties, dated them using feldspar luminescence and measured their current erosion dynamics with UAV photogrammetry. Building on this, we used geostatistical models based on paleoclimate models to simulate the development of vegetation over the last 800,000 years. According to these models, the environmental conditions of the site oscillated back and forth between grassland and savannah over several climate cycles. The results suggest that past climate changes influenced the growing season length and fire regime, leading to non-linear, altitudinal shifts of the tree line, which promoted erosion and is reflected in the sedimentary succession. Our findings from the past allow to inform the future by inferencing our model to near-future climate scenarios to estimate related erosion risk.

01.10 The co-evolution of the Earth and life from the early Archean until today

Origins of Primordial Monazite in Archean Metapelites from the Isua Supracrustal Belt, Greenland

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We are exploring the origin of some of Earth's oldest monazites discovered in the Isua supracrustal belt (ISB). Monazite, crucial for light rare earth elements Th and U, is widespread in low Ca granites and metapelites. Its formation depends on the Al/Ca ratio of the host rock and ceases below a critical threshold and is potentially preceded by allanite at lower metamorphic grades.

Modern geological settings often feature rocks with high Al/Ca ratios suitable for monazite formation. In contrast, Archean rocks, typically basaltic to ultramafic, generally have low Al/Ca ratios, prohibiting monazite growth. However, during crustal differentiation, some rocks exceeded this threshold, enabling initial monazite formation, though specifics remain uncertain. Our study presents evidence of early monazite formation in the ISB.

Focusing on a "metapelitic" rock with garnet porphyroblasts, hosting two generations of monazite, we find older monazites in garnet cores dating to ~3.6 Ga, placing them among the oldest monazites known to date, while younger ones in garnet rims and matrix date to ~2.7 Ga.

The absence of other monazite occurrences in Isua and the *in situ* formation of both generations suggest a metamorphic origin rather than detrital. These rocks, with a pelitic bulk composition, represent some of the oldest preserved clastic sedimentary rocks, sourced from ultramafic, mafic, and felsic igneous rocks or reflecting metasomatic alterations of basaltic rocks.

The presence of ~3.6 Ga monazite establishes a minimum age for the high Al/Ca composition essential for monazite growth in Isua's Archean crust, supporting interpretations of late Eoarchean metamorphism.

01.21 Advances in Geochronology: from tradition to avant-garde

Age and genesis of Neoachean ruby deposit from Greenland

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The Fiskenæsset Complex of Greenland with an inferred metamorphic age of 2.7–2.5 Ga hosts one of the oldest ruby deposits in the world, named Bjørnesund. Although it was discovered at the end of 1970s, the exact time of formation and genesis of this deposit are still poorly known.

Ruby mineralization occurs in mica shists hosted by anorthosites of the Fiskenæsset Complex. *In situ* SIMS U-Pb dating of rare rutile inclusions within ruby crystals yielded concordant ages averaging 2482 ± 37 Ma (95% confidence; n = 4; mean square of weighted deviates = 0.45), which to the best of our knowledge is the first U-Pb age for rocks from this area. Applied geothermobarometric methods indicated that the formation of ruby-bearing rocks occurred at temperatures of ~710–730°C based on Zr-in-rutile thermometry and at maximum pressure of 400 MPa. Trace element ratios within ruby such as Ga/Mg, Cr/Ga, Fe/Ti, and FeO-Cr_2O_3-MgO-V_2O_3 (wt.%) vs. FeO + TiO_2 + Ga_2O_3(wt.%) commonly used as proxies to identify corundum origins correspond to a metamorphic signature. It implies that formation of this ruby deposit may be linked to regional metamorphism during the Neoarchean which overprinted the Fiskenæsset anorthosite complex.

01.05 From mantle to crust: following melt evolution from source through the lithosphere

Growth and chemical evolution of the Kohistan-Ladakh Arc crust, Northern Pakistan, Western Himalayas

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The 55 km-thick Kohistan-Ladakh Arc (Northern Pakistan) was an intra-oceanic arc for 120 Ma prior to becoming an Andean-type continental arc from 50 to 40 Ma. We present new geochemical data from the Kohistan-Ladakh Arc and use existing geochemical and geochronological literature data from this arc to constrain the growth and chemical evolution of the arc crust. The ultramafic to mafic lower crust of the Kohistan-Ladakh Arc is older than their intermediate to felsic middle to upper crust. Olivine, clinopyroxene, anorthite and amphibole fractionated from basaltic magmas to form the intermediate to felsic plutons of the Kohistan Batholith. The middle to upper crust of the Kohistan-Ladakh Arc has higher Th/La and lower 143Nd/144Nd ratios than the older lower crust. The later intermediate to felsic plutons of this arc formed by fractional crystallisation of basaltic magmas and were more influenced by slab sediment melts than crustal contamination. The 150 Ma Matum Das Pluton and Hunza Formation were cogenetic. The 67-65 Ma plutonic rocks of the eastern Kohistan Batholith are genetically related to the 65-60 Ma Teru Formation and Dir Group. The high (Dy/Yb)N ratios of some of the mafic plutonic rocks imply deeper melting of the Kohistan-Ladakh sub-arc mantle once the arc had attained a thickness of >42 km Late Cretaceous. The older volcanic and plutonic rocks in the Kohistan-Ladakh Arc resemble those of the active Izu-Bonin-Mariana and Tonga intra-oceanic arcs, whereas the younger igneous rocks are more similar to those in the active Cascade continental arc.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Investigating volatile depletion processes using Te isotope fractionations in iron meteorites

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Magmatic iron meteorites sample the metal cores of differentiated planetesimals, and are classified into distinct chemical groups by their markedly different contents of the moderately volatile elements (MVE) Ge and Ga. The variable MVE depletions may be inherited from an iron parent body's precursor materials or are the result of secondary losses associated with parent body accretion, differentiation, and disruption. To better understand the origin of these MVE depletions, we obtained mass-dependent Te isotopic data, using a ^{123}Te–^{125}Te double-spike and MC-ICP-MS, for metal and troilite samples from several magmatic irons (IC, IIF, IIIAB, and IVA). The Te concentrations vary by two orders of magnitude among the investigated samples and follow the volatile depletion trends defined by the less volatile Ge and Ga. In all samples, Te is predominantly hosted in troilite, with troilite-metal partitioning coefficients of ≈100. As such, the Te isotope composition of troilite can be taken as a proxy for that of the bulk iron meteorite and, by inference, the bulk core. Despite large differences in Te concentration, the troilites investigated in this study show only limited mass-dependent Te isotope variations and fall within the range of compositions observed among carbonaceous chondrites. Of note, all troilites investigated thus far are isotopically lighter than CI chondrites. Together these observations suggest that any MVE loss from the iron parent bodies did not induce large Te isotope fractionations and that the precursor material of these bodies was already somewhat MVE-depleted compared to CI chondrites.

01.06 Tectonic Systems – TSK Open Session

Hydroxyl in eclogitic garnet, orthopyroxene and oriented inclusion-bearing clinopyroxene, western Norway

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Ten eclogites from the Caledonide orogen in western Norway, whose mineral chemistry records metamorphic conditions of up to 850 °C and 5.5 GPa, were investigated quantitatively for structural hydroxyl (OH). Each rock sample contains clinopyroxene with oriented inclusions of either quartz, albite or quartz + pargasite. Five orthopyroxene-bearing eclogites have relatively homogeneous amounts of structural OH in garnet (13–32 μg g^{-1} H_2O equivalent), clinopyroxene (119–174 μg g^{-1}) and orthopyroxene (4–17 μg g^{-1}). In contrast, the other five orthopyroxene-free eclogites have variable amounts of OH and it ranges in garnet from 8 to 306 μg g^{-1} and in clinopyroxene from 58 to 711 μg g^{-1}. Apart from extreme values, the OH content of clinopyroxene in these eclogites is significantly lower than in comparable ultra-high-pressure metamorphic samples, such as metasomatised and pristine eclogite xenoliths from the lithospheric mantle underneath several cratons and coesite- and quartz-eclogites from the Erzgebirge and the Kokchetav massifs. The low structural OH contents, the deficiency of molecular water and the evidence for the preservation of diffusion-sensitive mineral chemistry arising from metamorphism well beyond the stability field of amphibole suggest that oriented inclusions of quartz + pargasite were formed isochemically during eclogite-facies decompression.

01.04 Latest Achievements in Scientific Ocean and Continental Drilling

A glimpse into the West Antarctic environment before glaciation

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Zundel, Maximilian [1]
Mark, Chris [2]
Chew, David [3]
Millar, Ian [4]
Najman, Yani [5]
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The Amundsen Sea Embayment of West Antarctica is today the site of pronounced glacial retreat and mass loss. Very little information is available on how the area looked like before the onset of large-scale continental glaciation, and on which morphologic boundary conditions finally led to the onset of glaciation. Here we report data from the first drilling campaign on the Amundsen Sea continental shelf, using the MeBo drilling system. We obtained coarse-grained sediments deposited during the Eocene, shortly before major ice sheet buildup. Our findings reveal the Eocene as a transition period from >40 million years of relative tectonic quiescence toward reactivation of the West Antarctic Rift System, coinciding with incipient volcanism, rise of the Transantarctic Mountains, and renewed sedimentation under temperate climate conditions. The recovered sediments were deposited in a coastal-estuarine swamp environment at the outlet of a >1500-km-long transcontinental river system, draining from the rising Transantarctic Mountains into the Amundsen Sea. Much of West Antarctica hence lied above sea level, but low topographic relief combined with low elevation inhibited widespread ice sheet formation.

07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Use of catalogues of paleo, historical and recent seismicity for the estimation of seismic hazard in codes for earthquake-resistant building in Germany

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Specific seismic hazard maps and detailed procedures for the calculation of seismic hazard are the basis of codes and rules which determine the construction and the operation of ordinary buildings and industrial facilities to withstand relevant seismic loads. The paper will primarily address the data foundations which are used to calculate seismic hazard, especially catalogues of paleo seismic data, historical seismicity and modern earthquake monitoring as well as further important input parameters. In Germany, Eurocode 8 and its German National Annex are used for most ordinary buildings. It contains a regional map of probabilistic hazard of Germany and a map of the geological underground classes to be used for local seismic hazard assessment. Earthquakes up to about 500 years return period are considered. On the basis of Eurocode 8, a related rule was developed to be used in case of chemical industry facilities. For nuclear installations there is a rule of the German Nuclear Technical Committee called KTA 2201.1 (‚Kerntechnische Anleitung'). The specific requirements include the consideration of earthquakes with return periods of up to 100.000 years and the evaluation of local paleoseismic data. Long return periods are attributed to rarely occurring strong earthquakes and lead to higher levels of seismic hazard. Additionally, a code for different kinds of dam structures is used in Germany (DIN19700). Is is related to Eurocode 8 but requires longer return periods up to 10.000 years. Finally, the present requirements in the German selection process for a repository of high-level nuclear waste are summarized.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Planetesimal formation in the inner and outer disk: Evidence from ungrouped iron meteorites

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Isotope anomalies in meteorites reveal a fundamental dichotomy between non-carbonaceous (NC) and carbonaceous (CC) materials [1]. This dichotomy is recognized in both early- and late-formed planetesimals, but whether these formed from the same or distinct materials remains uncertain. To address this, we analyzed Fe and Ni isotopes in a large suite of ungrouped iron meteorites representing ~22 parent bodies. These samples, previously characterized for Mo and W isotopes, derive from early-formed differentiated bodies of NC [9] or CC (16) affinity [2].

Our new Fe and Ni isotope data show that early- and late-formed NC and CC planetesimals span similar isotopic ranges as their respective chondrites. This indicates that bodies in each reservoir accreted from similar dust mixtures, either in long-lived disk structures or in different sub-reservoirs containing the same materials. Among CC bodies, two findings stand out. First, many ungrouped irons match the isotopic composition of late-formed CR chondrites, suggesting the CR reservoir formed early and remained isolated throughout disk evolution. Second, CI chondrites are the only CC meteorites whose isotopic composition is absent among differentiated meteorites, implying planetesimals with this signature formed late by a distinct mechanism [3] and/or in a separate reservoir [4].

References

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04.05 Applied and Technical Mineralogy: promoting sustainable solutions through deeper understanding of materials and material processing

Effect of thermal treatment on phase composition and pozzolanic reactivity of a natrolite-rich rock

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The Fohberg phonolite, Kaiserstuhl Volcanic Complex (SW Germany), is a zeolite-bearing subvolcanic rock used as raw material for blended cement manufacturing. Rock-forming zeolites are of the natrolite group (natrolite, Ntr, and gonnardite, Gon) which amount to 45-50 wt.% of the bulk rock. The natrolite/gonnardite ratio, determined by powder X-ray diffraction (pXRD) and expressed as xGon = Gon/(Ntr+Gon), varies between 0.1 and 0.2 but may reach > 0.3 in exceptional cases. During industrial processing, the crushed rock is tempered in a rotary kiln at about 400 °C to enhance pozzolanic reactivity.

In-situ pXRD experiments (Bruker D6 Phaser equipped with Anton Paar BTS 500 heating stage) up to 460 °C were conducted to unravel mineralogical changes of the material during processing, and to detect structural changes of the zeolite constituents. Natrolite starts to convert to metanatrolite during heating at 380 °C; the phase transition is fully reversible. Gonnardite shows a strong, gradual decrease of the a-lattice parameter during heating, and becomes irreversibly unstable at 380 °C. The disappearance of gonnardite is accompanied by an increase of amorphous content of the sample. Structural changes are reflected by a distinct mass loss between 330 and 400 °C, related to zeolite dehydration. The other phonolite phases remain unaffected.

To test the pozzolanic reactivity, untempered and tempered phonolite samples with variable xGon were blended with a commercial CEM I 42,5 R reference cement. Indicators of reactivity are compressive strength and $Ca(OH)_2$ consumption (Frattini's test). Results of the tests are shown and related to the pXRD experiments.

01.05 From mantle to crust: following melt evolution from source through the lithosphere

Geochemical variations in phonolite by interaction with sedimentary country rock (Kaiserstuhl Volcanic Complex, Germany)

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The contact zones of two Miocene subvolcanic phonolite intrusions towards underlying sedimentary country rock within the Kaiserstuhl Volcanic Complex, SW Germany, are exposed in drill cores. The phonolites form fine- to medium grained and homogeneous intrusive bodies. The dominant primary minerals are foids, sanidine, aegirine-augite, wollastonite; common accessories are andradite, fluorapatite, titanite and götzenite. Postmagmatic alteration transformed all foids to zeolites (Spürgin et al. 2019). The country rock consists of finely laminated, dark claystones with variable carbonate content and intercalated, thin sulphate beds. It belongs to the Oligocene Wittelsheim Formation, which was deposited in shallow lakes during the subsidence of the Upper Rhine Graben. At the contact to phonolite, brittle and ductile deformation structures developed on the cm- to dm-scale during emplacement. Furthermore, centimeter-wide magmatic veins were injected close to the contact, and crosscutting veins containing zeolites, calcite and fluorite penetrate phonolite and claystone.

Phonolites become obviously porphyric close to the country rock. Several major and trace elements show depletion in proximity to the contact (e.g., Na_2O, Al_2O_3, SiO_2, Zr, Ba), whereas others are enriched compared to the general phonolite chemistry (e.g., CO_2, MgO, Sr). Transition zones extend several meters from the contact into the phonolites.

Wall rock interaction, manifested by mineralogy and texture, is capable to alter the chemical composition of phonolitic magmas. However, exchange processes during magma emplacement work only in a zone of a few meters, which is thin compared to the intrusion sizes of several hundred meters.

Reference

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10.01 Open Paleontology Session

Palynological and mesofossil analyses of an Edmontosaurus bonebed from the Late Cretaceous Lance Formation: Paleoecological insights

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The fossiliferous strata of the Maastrichtian-aged Lance Formation in Wyoming, although broadly coeval with the better-known Hell Creek Formation, remain comparatively understudied. A detailed examination of a recently discovered Edmontosaurus annectens bonebed in the Lance Formation opened a new window into the last Cretaceous terrestrial ecosystems of present-day North America. This locality, which yielded a wealth of vertebrate remains but also macro-, meso-, and micro-palaeobotanical remains, now serves as a focal point for renewed paleoecological analysis of the Lance Formation. This study presents palynological and mesofossil data from sediments associated with the Edmontosaurus bonebed, with particular emphasis on a peculiar aquatic palynoflora. Notably high abundances of Azolla, an ecologically restricted aquatic fern, were recovered from multiple stratigraphic levels within and surrounding the bonebed horizon. The presence of Azolla megaspores, along with other freshwater-indicative palynomorphs such as Pediastrum, Botryococcus, and Gunnera, supports deposition in a freshwater floodplain setting with densely vegetated still-water bodies. Moreover, the concentration of Azolla and associated aquatic palynoflora in and around the bonebed horizon may offer new insights into the paleoecology of Edmontosaurus, including potential habitat preferences and feeding behaviors. Stratigraphic analysis of the floral assemblages below, within, and above the bonebed also suggests notable shifts in plant community composition over time, possibly linked to environmental changes in the latest Maastrichtian. This integrated paleoecological and palynological perspective enhances our understanding of the Lance Formation ecosystems, and underscores the importance of expanding research beyond more extensively studied rock units like the Hell Creek Formation.

08.01 Young Scientist Session

Hellgrammites and their relatives in the deep past – the fossil record of megalopteran larvae (Insecta)

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Dobsonflies, fishflies, and alderflies are all representatives of the group Megaloptera. Today, the group Megaloptera comprises around 400 formally described species, making it one of the smaller ingroups of Holometabola, the group of “flying insects” characterised by a strongly expressed metamorphosis. Like most holometabolans, megalopterans spend the majority of their lives as immatures, also known as larvae. These larvae are aquatic and predatory; some of these are very large and known as “hellgrammites”. The fossil record of megalopteran larvae is relatively poor, reaching back into the Triassic. On a qualitative level, the fossil larvae strongly resemble their modern counterparts. We report new finds such as Triassic sedimentary fossils and fossils in amber from the Cretaceous and Eocene. Together with the already known specimens, we compared the fossils to their modern counterparts, using quantitative morphology of different body regions. For further comparison, we also included larvae of other holometabolan lineages with similar life habits. Especially larvae of Gyrinidae, the group of whirligig beetles, are similar to megalopteran larvae in many aspects: the body is rather elongate, the mouthparts are prominent and forward-protruding, the trunk region has a pair of elongate gills on most segments. The analysis revealed that at least some of the fossil megalopteran larvae had morphologies not present in the modern fauna, indicating a certain loss of diversity over time.

04.07 Mineralogy of Secondary Raw Materials

Towards solution-driven recycling of gypsum

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Gypsum ($CaSO_4 \cdot 2H_2O$) is a crucial mineral across sectors such as construction, agriculture, and biomedicine. Despite its potentially full recyclability, a shortage looms due to limited mining in Europe and decreasing production of flue gas desulfurization (FGD) gypsum, a byproduct of coal power plants. With current EU consumption at 24 MT/a (17 MT mined, 7 MT FGD), a deficit of 10–35 MT/a is projected by the 2030s as $CaSO_4$ becomes a critical raw material [1]. Meanwhile, substantial $CaSO_4$ waste is produced in various industries (e.g., phosphogypsum, red gypsum), but its recycling remains limited (10% in Germany, 5 % in the EU) due to contamination and separation challenges.

This contribution introduces a sustainable, efficient wet-chemical method for converting gypsum to bassanite ($CaSO_4 \cdot 0.5H_2O$), and thus recycling gypsum, under mild conditions (T < 100 °C) using reusable high-salinity aqueous solutions (brines with c[NaCl] > 4 M) [2]. The optimal conversion conditions (T > 80°C, c[NaCl] > 4 M) enable rapid (<5 min) and reversible transformation. Upon cooling, gypsum re-forms, offering a temperature-dependent control over phase transition. Unlike conventional thermal dehydration (150–200 °C), this approach promotes the dissolution of gypsum, allowing contaminants to be separated via selective precipitation or adsorption. Additionally, the wet-chemical process facilitates the physical removal of impurities from gypsum matrices, making it advantageous for recycling gypsum waste from sources such as demolition or urban mining, where it is often mixed with other materials.

References

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07.01 From paleoseismic trenches to seismic building codes and safety analyses for nuclear installations in Germany: progress in seismic hazard assessment

Paleoseismic investigations in the Lower Rhine Graben (LRG): Challenges and insights from a densely populated, tectonically active intraplate region

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Assessing seismic hazard in tectonically active intraplate regions with slow slip rates (<0.1 mm/yr) is particularly challenging, especially when such regions are densely populated and extensively anthropogenically modified. Fault activity often remains undetected due to long recurrence intervals, limited surface expressions, and widespread anthropogenic overprinting. The Lower Rhine Graben (LRG), part of the European Cenozoic Rift System, exemplifies these conditions. In addition to its current low to moderate seismicity, the LRG region has experienced damaging historical earthquakes (e.g., Düren 1756, ML 6.4; Roermond 1992, ML 5.9), underscoring its seismic potential.

In this context, we conducted five paleoseismic investigations within the LRG to access direct geological records of past surface-rupturing events and fault kinematics. We focused on its most seismically active and structurally segmented subregions: the Roer Valley Graben and the Erft Block. The investigated fault segments include the Feldbiss Fault, Sandgewand Fault, Birkesdorfer Fault, Rurrand Fault, and the Louise Sprung.

All sites provide evidence of Late Pleistocene to Holocene surface-rupturing events, with single-event displacements of up to 70 cm and estimated magnitudes up to M 6.3. The faults are characterized by steeply dipping planes (70 – 80°), pure dip-slip kinematics, low slip rates (< 0.03 mm/yr), and show indications of hydraulic activity. At the Rurrand Fault and Louise Sprung, we observed induced aseismic creep linked to groundwater extraction, highlighting the need to distinguish natural from anthropogenic deformation.

Our results demonstrate the seismic potential of these faults and underline the importance of integrating paleoseismic data into regional seismic hazard assessments.

05.01 Spectroscopic methods in modern geosciences

Microstructural characterization of varieties of serpentine group minerals in natural heterogeneous samples using Raman spectroscopy – A case study from the Erzgebirge (Saxony, Germany)

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Serpentinites, formed through hydration of ultramafic rocks, have long been known to play a pivotal role in rock-water interaction accompanying plate-tectonic processes along divergent and convergent margins. Lately, they have attracted growing geoscientific interest due to their role in hydrogen generation and carbon sequestration by mineral carbonation. Serpentine group minerals, as their main constituents, occur naturally in three main varieties: antigorite, lizardite, and chrysotile. Traditionally identified by X-ray diffraction (XRD) and electron microscopy, homogeneous serpentines can also be effectively distinguished using Raman spectroscopy based on characteristic spectra. A critical question remains: Can Raman spectroscopy offer clear identification of serpentine varieties in natural, heterogeneous serpentinites?

For this study we applied Raman spectroscopy to serpentinites from Zöblitz in the Erzgebirge (Saxony). The serpentinites are hosted in quartzofeldspathic gneisses that underwent high-pressure metamorphism during the Variscan orogeny. They show a range of macroscopic textures, from garnet-bearing, highly serpentinized peridotites with isotropic matrices to decimeter-scale banded serpentinites. Raman spectra were collected through spatial mapping both in low (200–1350 cm^{-1}) and high (3200–3950 cm^{-1}) wavenumber regions on polished thin sections. The mapped areas were also examined using polarization microscopy.

Data processing involved analyzing peak parameters (peak position, full width at half maximum) and comparing spectra to reference data using classical least squares (CLS) fitting. The domains investigated, pre-characterized by polarization microscopy, showed clear microstructural heterogeneities linked to optical and morphological differences, all reflected in distinct Raman spectra. Comparing characteristic peak parameters, CLS fitting, and polarization microscopy enabled confident identification of the main serpentine varieties.

01.07 Stratigraphy in Earth System Science: methods, applications and case studies

First results of the „Forschungsbohrung Krefeld“

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As part of the Geothermal Master Plan of North Rhine-Westphalia, the Geological Survey of NRW carried out a nearly 1000 Meters deep drilling in the city centre of Krefeld. Since detailed geological data of the deeper subsurface was sparse in the area, cores were recovered for the entire Palaeozoic interval of the drilling. The primary objective was to fully penetrate the Mississippian (Carboniferous) sedimentary succession of the Kohlenkalk Group and to characterize the geothermal potential of this reservoir.

The borehole intersected a complex sedimentary succession. Particular focus is placed on the lithological and facies variability of the carbonate platform facies of the Kohlenkalk Group, which comprises alternating layers of mostly limestone and dolomite. We present first results based on core descriptions, geophysical well logging, and biostratigraphic analyses which allow a refined stratigraphic subdivision of the sedimentary succession. In addition, the overlying Tertiary and Quaternary deposits provide important insights into the more recent geological development of the Lower Rhine Embayment.

The data obtained from the well contribute essential geoscientific information for the better understanding of the geological setting, for the advancement of regional 3D geological models and for assessing the geothermal potential of deeper subsurface formations. The borehole thus represents a key stratigraphic reference point for future geological modelling, resource assessment, and site planning in support of the energy transition in North Rhine-Westphalia.

01.06 Tectonic Systems – TSK Open Session

Understanding the Stability of Thrust Sheets Supporting Kilauea's Submarine Flank: Insights from Direct Shear Experiments

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The south flank of Kilauea volcano (Hawaii, USA) is actively moving seaward at rates of up to ~10 cm/year along a basal décollement. This movement is accompanied by earthquakes and landslides. The Hilina Slump is located on top of the mobile flank and has not yet failed catastrophically as seen elsewhere on the Hawaiian Islands. It is thought that stacked thrust sheets at the toe of the submarine flank act as a buttress, helping to stabilize the active slump. The mechanical properties of the slump and thrust sheets are poorly understood but may significantly influence their deformation behavior and the overall stability of Kilauea's flank. To better understand these systems, we conducted direct shear experiments on samples collected from submarine exposures of both the thrust sheets and the Hilina Slump. Our results reveal both velocity-weakening and velocity-strengthening frictional behavior, depending on sliding velocity. Velocity-strengthening occurs predominantly at low velocities. Intact samples are stronger and tend to exhibit more velocity-strengthening behavior, whereas powdered samples, representative of pre-existing fault zones, are weaker and show more velocity-weakening behavior. This suggests that fault zones could experience unstable sliding. Additionally, altered surface sediments from the Hilina Slump show stick-slip behavior. Overall, the variable material behavior across the submarine flank may explain the range of deformation structures and slip styles observed at Kilauea.

10.01 Open Paleontology Session

Lignite-bearing strata from Central Mongolia reveals a unique Early Cretaceous paleoenvironment

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Early Cretaceous terrestrial environments from inner paleo-Asia are poorly studied. Here we report new data from the Tevshiin Govi opencast lignite mine (TSG; Choir-Nyalga Basin; Aptian-Albian) from central Mongolia. The TSG contains a thick, lignite-rich succession assigned to the Khukhteeg Formation, which bears an exceptionally well-preserved fossil flora composed of various pine and redwood species as well as representatives of extinct seed plants. In order to reconstruct the conditions during peat formation, we used a combined approach including coal petrology and palynology, complemented by geochemical measurements (TOC, TS, δ^{13}Corg) and brGDGT-based palaeothermometry. The investigated lignites show maceral compositions with high amounts of mineral detritus, which are dominated by huminite. Calculated maceral indices are indicating a topogenous mire setting. The variability of the GWIAC indicates regular flooding of the peat. The stratigraphic trend in δ^{13}Corg covaries with fusinite content, suggesting that short-lived events such as peat fires had a pronounced effect on the δ^{13}Corg signature. Palynological observations show a strong dominance of pollen produced by Cupressaceae and Pinaceae, which is in accordance with the macrofossil findings. No angiosperm pollen was observed. The brGDGT data exhibit mean annual air temperatures of around 10°C (± 3°C), which is slightly cooler than previously thought. Overall, the TSG site reveals a paleoenvironment that was mainly forested with conifers with an understory of pteridophytes and strongly influenced by fluvial processes. During phases of peat formation, the environment was either covered by water or regularly flooded. Overall low inertinite contents reveal varying intensities of peat fires.

05.04 Biogeochemistry, geomicrobiology, and biomineralogy

Building the Las Cruces Gossan (SW Spain), Part II – Could Microbes have formed Sulfides in the shallow Subsurface?

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Schlund, Laura M. [1,2]
Rey-Samper, J. Javier [3]
Tornos, Fernando [4]
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Microbial sulfate reduction (MSR) may have played a major role in the formation of secondary copper sulfides such as covellite (CuS) and chalcocite (Cu2S) in the cementation zone of the Las Cruces gossan (Seville, Iberian Pyrite Belt, Spain)[1,2]. However, the formation of copper sulfides by MSR under conditions relevant to the Las Cruces gossan (e.g. hydrochemistry, temperature, pH) has not been experimentally evaluated yet. Using an established geomicrobiological model system for the Las Cruces gossan (see abstract by Schlund et al.), we explored MSR by tracking electron acceptor turnover (e.g. sulfate, phosphate) in incubation experiments over five weeks and by analysing yielded solid phases with SEM-EDS. Our data demonstrate significant MSR between 30–50 °C and even at high Cu concentrations (38 mg/L). Sulfate turnover increased with temperature (10 mmol/L at 30 °C, 17.3 mmol/L at 50 °C) and was highest in high-Cu experiments (20.1 mmol/L). Decreasing sulfate concentrations were accompanied by increasing phosphate concentrations and rising pH (4.5 to 7–8.5). SEM-EDS revealed the presence of copper sulfides in the experimental products, partially associated with Corg – similar to findings from the Las Cruces gossan[2]. Taken together, our results support the hypothesis that Cu sulfides in the cementation zone of the Las Cruces gossan formed secondarily, driven by MSR. Moreover, our study contributes to a better understanding of the deep biosphere – including potential ore forming geomicrobiological processes in the shallow subsurface.

References

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06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Application of Self-Organizing Maps (SOM) to 3D Geophysical Inversion Models in the DroneSOM Project

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The DroneSOM project, co-funded by EIT RawMaterials, aims to develop an integrated approach to geophysical data acquisition and interpretation for mineral exploration. Drones are used to collect gravity and electromagnetic data, that is subsequently analyzed using specialized software. The three-year project is coordinated by the Geological Survey of Finland (GTK) and carried out in partnership with RADAI Oy, the Technical University of Denmark (DTU), and Beak Consultants GmbH. It comprises six work packages that include field measurements at various sites in Finland, Germany, and Sweden, as well as data integration and interpretation.

This contribution focuses on the application of Self-Organizing Maps (SOM) for the analysis of three-dimensional geophysical voxel data derived from 3D inversion of the surface-based measurements. The methodology involves preprocessing and normalization of the input data, SOM-based clustering, and subsequent evaluation and validation using sensitivity analyses, boxplots to assess data distribution within the resulting clusters, and evaluate spatial correlation with existing geological knowledge.

Results from the application of this method to a test site in Finland are presented. The analysis demonstrates how 3D-inverted geophysical data can be structured and visualized using 3D SOM to reveal geological patterns. The combination of 3D data processing and unsupervised machine learning enables the interpretation of subsurface structures and opens new perspectives for geoscientific data analysis.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Telling Bromacker time: Time-series analysis of redbed cores from the Early Permian of the Tambach Basin, Thuringian Forest, Germany

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Research boreholes Fb Altenbergen 01/2022 and Fb Tambach-Dietharz 01/2023 from the perimontane Tambach Basin (Artinskian; 290.1–279.3 Ma) flank the Bromacker excavation site with 2.6 and 1.5 km distance and recovered 250 and 200 m, respectively, of excellent core in fluvial (channel, overbank, floodplain) and conglomeratic alluvial facies. High-resolution analysis of climate-relevant proxies was based on color (CIEL*a*b color space), volume-specific magnetic susceptibility, and carbonate content (of Fb Altenbergen, 92.33 – 198.59 m; 33 cm spacing), supported by gamma-ray logs. Lithologies and measurements readily correlate with each other over the 4 km distance, with the Bromacker site approximately midway. A time-series analysis (spectral analysis, Fourier analysis; multi-taper method) based on the proxy measurement series (with and without conglomerate) shows numerous cycles. The dynamic-chaotic fluvial environment and the climate-independent weathering of the lithic, Fe-rich minerals of proximal volcanic provenance primarily affect high-frequency "short" cycles. Low-frequency “long” cycles, in contrast, consistently show a high statistical significance. We interpret them to represent periodic climatic changes with stronger bioturbation and soil formation, correlated to warmer periods of higher precipitation. Using the frequency-ratio method, cycles compare well to Early Permian orbital (Milankovic) cycles of known astrochronological periods, best to the long eccentricity cycle of 405 ka in the Permian. Fb Altenbergen 01/2022 thus appears to represent a stratigraphic record of ca. 2.13 Ma, Fb Tambach-Dietharz of ca. 2.16 Ma, and a mean sedimentation rate of ca. 12 and 10 cm / ka, respectively, for both compacted and decompacted profiles.

03.04 All about carbonates

On the formation and persistence of ikaite

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Ikaite ($CaCO_3 \cdot 6H_2O$) is a metastable mineral, occurs in cold regions of Earth, and readily transforms into more stable minerals such as calcite or vaterite. The conditions for formation and transformation of ikaite, however, are insufficiently explored. Important implications of the occurrence of ikaite, such as its potentially large effect on the polar carbon cycle or its applicability as low temperature proxy, therefore, cannot be assessed adequately.

To contribute to a better understanding, three key aspects of ikaite formation and transformation were investigated: i) the effect of the presence of mineral surfaces on ikaite nucleation, ii) the effect of increasing temperatures (T = 0–20 °C) on ikaite stability in aqueous solutions, iii) the effect of phosphate on ikaite growth.

Our experiments revealed that mineral surfaces can significantly promote nucleation of ikaite vs. calcite and vaterite. Furthermore, the persistence of ikaite is reduced by the temperature dependent increase of vaterite and calcite precipitation. Inhibition of these minerals, therefore, is inevitable for an increased ikaite persistence. No significant incorporation of aqueous phosphate (an effective calcite inhibitor) into growing ikaite was detected.

The findings agree with an ikaite formation mechanism via an assembling of aqueous $CaCO_3$ complexes. Ikaite nucleation per se is possible at increased temperatures, if solution supersaturation and inhibitor concentration are sufficiently high. In natural environments, however, occurrence of such conditions becomes less likely with increasing temperature.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Paleogeographic and -environmental evolution of the Early Permian Tambach Basin

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The Bromacker Project investigates the “Ursaurier” vertebrate lagerstätte of the same name in Early Permian redbeds of the Tambach Formation. Its geologic-paleontologic subproject aims to contribute key parameters such as paleoecology, -climate, -geography, and depositional environments to the reconstruction of the Tambach Basin. Two new, fully cored research boreholes, combined with facies-oriented geologic mapping, the analysis of legacy cores, large-scale outcrop 3-D documentation and -interpretation utilizing UAVs, as well as paleocurrent analysis and sandstone petrography allowed detailed insights in the paleogeography, depositional environments and paleoecology.

The basal Bielstein Conglomerate Member was deposited on a fluvial braidplain, sourced from the deeply dissected Oberhof Porphyry Complex (OPC) to the east. Transport occurred towards the west-southwest, beyond the limits of the current Tambach Basin area. The transition into the Tambach Sandstone Member is gradual in the southern part of the basin with little changes in provenance and fluvial style, suggesting the continued existence of topographic relief within the OPC. In the northern part of the basin, a rapid change towards floodplain deposits, rarely interbedded with OPC-sourced conglomeratic channels and fine-grained sandstones, was sourced from metamorphic rocks to the west and a reduced relief. This trend is terminated by fluvial-fan conglomerates from the northwest which are present throughout the basin and sourced from the Mid German Crystalline High, documenting its uplift

The results show a rather small, dynamic basin dominated by fluvial systems with rapid spatial and temporal changes in depositional environments and numerous habitats for the Bromacker ecosystem populations.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Assessing Fault Reactivation Using Slip and Dilation Tendency

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Understanding the reactivation potential of geological fault zones in the deep subsurface is crucial for evaluating the feasibility of subsurface uses, such as CO_2 and hydrogen storage, geothermal energy, and radioactive waste disposal. This study investigates the reactivation potential of faults across Germany, using fault-specific datasets (e.g., fault traces, 3D models, or focal mechanism solutions) to demonstrate different application procedures. We considered the parameters of slip tendency (ST) and dilation tendency (DT), where ST quantifies the tendency of fault reactivation by shear under a given stress field, and DT indicates the tendency of a fault to open, thus acting as a fluid migration pathway.

For a first approximation of present-day stress conditions, we used data from a 3D geomechanical numerical model by Ahlers et al. (2022), which covers the onshore and parts of the offshore regions of Germany. From our perspective, ST and DT are robust and computationally efficient parameters that can be reliably derived from fault data in various formats. This study presents the methodology for calculating these parameters and discusses the strengths and limitations of the input data.

The results contribute to a better understanding of fault behaviour under current stress conditions and may support a first approximation of geological suitability for subsurface applications. However, further refinement of the stress model would be essential to achieve more reliable and site-specific results.

10.01 Open Paleontology Session

Revisiting Hybodus and Mesozoic hybodontiform evolution

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Understanding the evolution of hybodontiforms, a diverse group of shark-like chondrichthyans ranging from the Late Devonian to the Late Cretaceous, is challenging, as most species are only known from their teeth. The genus Hybodus, established in the 19th century based on both dental and skeletal material from the Early Jurassic Lias Group (UK), has traditionally been regarded as one of the most speciose hybodontiforms, encompassing numerous nominal species from across the globe and spanning a stratigraphic range from the Early Permian to the Late Cretaceous. However, recent research has revealed that Hybodus, as historically defined, represents an unnatural assemblage of unrelated species characterized by unspecialized multicuspid teeth. Here, we present preliminary results from an ongoing study of abundant, largely undescribed fossil material referred to Hybodus, including articulated and whole-bodied specimens from some of the world's most productive Jurassic vertebrate sites. Our findings provide evidence for restricting Hybodus to its type species, H. reticulatus from the Early Jurassic Lias Group, and further bolster the hypothesis that Jurassic hybodontids were ecological generalists exhibiting an arrested evolutionary trajectory.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

Orogen-scale erosional patterns from sediment fingerprinting and unmixing modeling of Alpine river sediments

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Clastic sediments and sedimentary rocks are almost always complex mixtures of detritus supplied by several different source rocks. Modern sedimentary provenance analysis should aim not only to identify these source rocks, but also to quantify the (relative) contribution of the different sources through space and time. This is often challenging because of limited and incomplete databases, overlapping or unknown source fingerprints, and a general lack of awareness of the proper statistical tools and procedures.

In this contribution, we highlight the use and advantages of statistically robust fingerprinting (i.e., establishing endmember compositional signals of source rocks) and (un)mixing modeling (i.e., quantitatively reconstructing relative source contributions in a mixed sediment) on a large orogenic scale, the European Alps. Multiple provenance proxies (sediment petrography, heavy mineral analysis, bulk geochemistry, zircon fission track dating, and zircon U-Pb dating) are used to define compositional endmembers of the main Alpine source rocks and regions. Unmixing modeling is used to identify and quantify the contribution of the endmember sources to mixed sediment carried by the main large Alpine rivers (the Adige, Dora Baltea, Drau, Enns, Inn, Mur, Rhine, Rhone, and Salzach rivers). In a second step, the same methodology is applied to Oligocene and Miocene fluvial and shallow marine sedimentary rocks from the Alpine foreland basin. The data is interpreted in the context of changing fluvial network architecture and erosional patterns in response to climatic and tectonic changes in the orogen, but also in terms of compositional bias, such as contrasting mineral fertility and diagenesis.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

The first 150 years of Bromacker discoveries: a model of cooperation in modes of research, funding, outreach, and science communication

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The Lower Permian Bromacker locality preserves what may legitimately be argued as the most well-preserved terrestrial vertebrate tetrapods of their age in the world. It is within outcrops of the Tambach Formation in the midregion of the Thuringian Forest, approximately 1.5 km north of the village of Tambach-Dietharz and 20 km south of the town of Gotha in formerly eastern, now central, Germany. Over fifty years of excavation, sedimentological and paleoecological research have demonstrated the Bromacker to be an internally drained paleograben showing evidence of being the earliest modern type terrestrial foodweb, predating those of the Mesozoic by minimally 50 million years or more. The locality has been mined intermittently for sandstone for over 150 years, and became initially famous for its preservation of footprints, first studied by Wilhelm Pabst from 1887–1908. In 1974 Thomas Martens discovered the first vertebrate skeletal fossils, and continued to work the quarry from 1975–1992, and in 1993, Martens initiated a remarkable international collaborative effort. The Bromacker is significant in its collaborative and cooperative approaches in almost all aspects, from research, to funding, to outreach, to dissemination. Initially teams from the United States joined Martens and his German crews; later to be joined by colleagues from Slovakia, Canada, and the United Kingdom. Likewise, funding came from German and American institutions, as well as National Geographic and NATO. Education, scientific communication, and outreach have ranged from academic publications to interpretive multilingual signage to popular media to cooperative support from the surrounding villages, businesses, and cities.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Between nature and humans: charcoal analysis for the reconstruction of fire activity in Bispingen during the early Eemian Interglacial and its context in a regional comparison

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Understanding the role of fire in past interglacial ecosystems is crucial for interpreting long-term vegetation dynamics and early human-environment interactions. Here, we investigate macroscopic charcoal (150–500 µm and >500 µm size fractions) preserved in palaeolake sediments from Bispingen (Lower Saxony, Germany), which cover the entire Eemian Interglacial (marine isotope stage (MIS) 5e; ~125.000 years before present). The goal of this study is to reconstruct local fire activity during the early Eemian and assess whether its causes were natural or anthropogenic, including potential links to early hominin presence. Results will be compared with other Eemian sites in Central Europe, particularly Neumark-Nord, to contextualize the findings both regionally and palaeoecologically (e.g. through comparison with existing pollen data).

Samples were taken continuously at 2-cm intervals from the early Eemian part of the palaeolake sediment succession and subsequently wet-sieved into different size fractions. The extracted charcoal fragments were counted and morphologically assessed using a digital microscope. Preliminary results show a low abundance of macroscopic charcoal, especially of the smaller size fraction, suggesting that fires were not widespread near the palaeolake. Dominant charcoal morphotypes are yet to be identified. Special attention is thereby given to methodological consistency, including challenges related to charcoal distribution across size fractions and morphological variability. Influx per year and cm2 is calculated, allowing the comparison to other Central European sites.

Overall, the results of this study contribute to the broader understanding of fire as an ecological, climatic and potentially cultural driver during the Eemian Interglacial.

01.06 Tectonic Systems – TSK Open Session

Plate boundary-parallel extension causes basin formation on the Island of Rhodes, Greece

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Crust underlying the Island of Rhodes is part of the forearc of the eastern Hellenic subduction zone. Deformation of the forearc rocks appears to be influenced by oblique plate convergence, subduction roll-back and horizontal-axis rotation, the relative importance of these processes is not well known. The southeast coast of Rhodes hosts Pliocene to Pleistocene marine strata, attributed to fault-controlled basin formation. However, it is poorly understood how faulting is intertwined with deposition of marine strata and how basin formation relates to the first-order tectonic processes. To examine these relationships in detail, the Lardos area was selected, due to its excellent exposure of marine sedimentary strata and fault scarps. Neotectonic deformation on multiple scales was assessed employing satellite- and drone-based imagery, differential GPS as well as lithological and structural mapping. Collectively, these observations point to the following sequence of tectono-sedimentary stages of basin formation: Normal faulting initiated the Pre-Pleistocene graben formation. Based on the occurrence of the sedimentary breccia along the fault scarps and displaced Pleistocene marine terraces, graben-bounding normal faults continued to be active during and after the Pleistocene. Faulting affected Pre-Pleistocene carbonate rocks and the unconformably overlying Pleistocene marine sedimentary strata. During uplift of the southeast coast of Rhodes, marine terraces formed and reshaped the paleo relief. Graben formation can be attributed to overall ENE-WSW, i.e., plate boundary-parallel, extension of the forearc rocks. This extension direction can be explained by increasing crustal stretching along the forearc as a consequence of progressive tightening of the curved Hellenic subduction zone.

01.24 Fieldwork as common playground: the importance of geological survey to unravel Earth processes

A study of the crystalline basement of the Cima Lunga unit (Lepontine Dome, Swiss Central Alps)

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The Cima Lunga is a crystalline basement unit located in the Lepontine dome (Swiss Central Alps). It is formed by paragneisses, orthogneisses, layers of calcschists and marbles, and boudins of mafic and ultramafic rocks. These latter preserve the record of Alpine (ultra)high-pressure conditions and have been the object of numerous studies in the past years.

The presence of such diverse lithologies lead previous authors to suggest that the Cima Lunga is a subduction channel tectonic mélange. However, recent field studies redefined its internal structure and relationships with the nappes tectonically above and below. The Cima Lunga unit is sandwiched within the upper levels of the Simano and below the Maggia nappes. The deformation within the unit is intense, especially around the mafic and ultramafic bodies enclosed within the paragneisses, and can be explained by shearing affecting the whole unit. In the field, layers of orthogneisses, calcschists, and marbles extend over kilometers, suggesting that these lithotypes cannot be fragments derived from the adjacent Simano.

In this contribution we present a comprehensive map of the Cima Lunga unit. This map is the result of extensive fieldwork performed for the realization of the new Swiss National Maps 1:25.000 (fieldwork at scale 1:10.000) and of the new Tectonic Map of Switzerland 1:500.000. We present within the map a compilation of literature results comprising calculation of pressure and temperature conditions as well as age data. We highlight the spatial distribution of these data, which is fundamental for the comprehension of such an intensely deformed unit.

01.29 Environmental Hazards and Risks

A Hybrid Ensemble Framework for Landslide Susceptibility Mapping: Integrating Spatial Clustering and Multi-Scale Terrain Features

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This study presented a hybrid machine learning framework for high-resolution landslide susceptibility mapping in the Svaneti region of the Georgian Greater Caucasus, a steep alpine environment prone to frequent mass movements. The objective was to enhance predictive accuracy and spatial generalization of susceptibility maps by integrating geomorphological knowledge with data-driven modeling.

We combined geostatistical, geomorphometric, and spectral terrain features, including slope derivatives and multi-scale gray-level co-occurrence matrix texture extracted from diverse raster sources. These were systematically preprocessed and complemented by spatial clustering, which segmented the landscape into zones with internally coherent terrain characteristics using tree-based projections, dimensionality reduction, and spatially-aware k-means.

Supervised classification leveraged a binary landslide inventory aligned to the feature grid. Class imbalance was addressed through stratified undersampling. Base classifiers, including extreme gradient boosting, random forests, k-nearest neighbors, and a multi-layer perceptron neural network, were tuned using Bayesian optimization and combined into a stacked ensemble with extreme gradient boosting as the meta-learner. The final model yielded high cross-validated performance (AUC = 0.98, balanced accuracy = 0.95).

The resulting susceptibility map showed good spatial agreement with known events and provided a detailed zonation of hazard potential. Despite a high recall (0.98) for landslide prediction, the low precision (0.13) and moderate Cohen’s Kappa (0.21) reflected challenges posed by extreme class imbalance and spatial noise in event inventories. Overall, the proposed framework demonstrated strong potential for integrating spatially-informed clustering with ensemble learning to enhance landslide susceptibility mapping in complex mountainous regions and supported scalable, region-specific hazard assessment.

03.06 Multiscale characterization of structure, flow and transport dynamics in fractured porous media and karst systems

Coupled Thermal and Hydraulic Effects in Low-Permeability Barriers: Insights from the HotBENT *In-Situ* Experiment

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The HotBENT experiment at the Grimsel Test Site investigates the coupled thermal and hydraulic behaviour of a bentonite barrier subjected to high temperatures. The setup includes four electric heaters embedded in a bentonite buffer, with temperatures reaching up to 200 °C. Four “enhanced geosphere pressurization boreholes” using natural Grimsel groundwater support and enhance hydration of the bentonite buffer via surrounding fractured granite. This configuration induces complex interactions between drying, vapour transport, and re-saturation processes.

We present results from 3D fully coupled thermo-hydraulic simulations conducted using OpenGeoSys. The model incorporates temperature-dependent transport properties, bentonite-specific retention behaviour, and hydration from the surrounding granite. Although fractures are not explicitly represented, the surrounding rock acts as a boundary condition influencing water inflow into the bentonite.

Experimental data are used for calibration and validation. The study highlights how temperature gradients affect saturation, vapour movement, and pressure development in low-permeability media. We also discuss numerical challenges related to material nonlinearity and boundary implementation.

These results enhance our understanding of thermo-hydraulic behaviour in engineered barriers and their interaction with fractured host rocks — even when treated as continuous domains — supporting predictive modelling efforts in subsurface systems.

03.05 Advances in Paleoclimate Proxies and Their Applications

Beyond δ-values: Examples from triple magnesium- and triple silicon isotopes

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Triple metal(oid) isotope systems can provide valuable insights into underlying fractionation mechanisms. However, the limited isotopic variability and the precision constraints of MC-ICP-MS analyses often hinder the resolution of differences in three-isotope space. As a result, correlated isotope ratios are typically used only as quality indicators for δ-value measurements.

In this study, I introduce a straightforward method to reduce uncertainty in triple isotope slope measurements using MC-ICP-MS. This approach is applied to Mg isotopes in carbonates, demonstrating improved precision. Additionally, two case studies of Si isotopes show that differences between equilibrium and kinetic fractionation slopes -on the order of ~10 ppm per ‰- can be resolved by enhancing the spatial resolution or simply by high-precision solution analyses for fractionations of approximately 3 ‰.

These advances in resolving triple isotope variations open new avenues for the application of metal(oid) isotopes as proxies in paleoenvironmental reconstructions.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Characterization and timing of diagenetically altered sedimentary gypsum in Luneburg and Othfresen (Northern Germany) by using modern OSL, petrographic and geochemical investigations

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Gypsum of cap rocks from Upper Permian (Zechstein) salt structures in Luneburg and Othfresen, both Northern Germany, were investigated for geochronological, mineralogical-geochemical, stable isotopic ($\delta^{34}S$ and $\delta^{18}O$ of the SO_4^{2-} ion $\delta^{18}O$ of the hydration water of gypsum) and petrographic characteristics. Cap rocks are formed during salt diapirism and groundwater contact (dissolution, re-precipitation, transition of evaporite minerals). For dating the precipitation of gypsum, Optical Stimulated Luminescence (OSL) was used [1].

First uncorrected age estimates range from 0.4 ka ± 0.3 ka to 7.1 ka ± 2.8 ka for the Luneburg samples and for the gypsum pit Othfresen, respectively. The age estimates represent the lower detection limit of the method for these samples. Some individual subsamples yield uncorrected age estimates from 14.4 ka ± 2.8 ka to 114 ka ± 25 ka for Luneburg samples and 9.3 ka ± 5.0 ka up to > 394 ka for Othfresen gypsum. Age estimates of these subsamples could be part of an unbleachable OSL-component or it could reflect the timing of different solution/ precipitation phases of gypsum crystals during alteration.

$\delta^{34}S$- and $\delta^{18}O$- values of the sulfate ion average 11.5 ‰ (VCDT) and 12.1 ‰ (VSMOW), representing a typical Upper Permian Zechstein signature. In contrast, $\delta^{18}O$- values of bulk gypsum average 5.8 ‰ (VSMOW), indicating the influence of isotopically light hydration water from the transformation of Permian anhydrite to gypsum. These results are in line with the young ages derived from OSL and the petrographic observations.

Reference

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03.01 Recent Advances in the Geological Research of Marine Environments

Implications of declining rhodolith growth in a warming Arctic: a century-scale perspective

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Crustose coralline algae (CCA) precipitate high-Mg calcite, contributing to carbonate sediment budgets and benthic habitat complexity. Rhodoliths formed by CCA are key bioconstructors in high-latitude photic zones, playing a role analogous to coral reefs in tropical systems, albeit with markedly slower accretion rates—on the order of micrometers per year. Their sensitivity to environmental change makes them valuable archives for assessing long-term climatic and oceanographic variability, but also challenges their future role as calcifying ecosystem engineers.

This study integrates historical temperature records with a temporally explicit model to reconstruct rhodolith growth trends over ~90 years in Arctic waters. Our results reveal a significant inverse relationship between summer seawater temperatures and rhodolith accretion at 11 and 27 m depths, with an average decline in growth of 8.9 µm per °C (95% CI: 1.32–16.60 µm $°C^{-1}$; $p < 0.05$). At 46 m depth and under mesophotic conditions, no significant trend was observed. These findings suggest that increasing ocean temperatures—potentially compounded by acidification and turbidity—are suppressing the calcification rates of CCA beyond their thermal optimum, thus reducing their net carbonate production.

Given the global distribution and ecological importance of CCA-generated rhodolith beds, our findings highlight a geologically significant reduction in biogenic carbonate formation in polar regions. This decline not only alters present-day benthic systems but also has implications for interpreting past climate signals recorded in high-latitude carbonate deposits.

03.02 Subsurface Storage of CO_2 – Applied Geoscientific Aspects

Identifying Blue Carbon sources – Organic signatures of Zostera Marina meadows near Poel Island (SW Baltic Sea)

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Sandy proximal sediments underlying Zostera marina meadows near Poel Island (SW Baltic Sea) were cored to a depth of ~ 60 cm and studied for the nature and amount of particulate organic carbon. Special emphasis was placed on the questions (i) whether seagrass coverage would lead to an enhanced C sequestration in this high-energy depositional setting, and (ii) whether the organic matter stored in these sediments has a seagrass origin or derives from other, marine or terrestrial sources. We observed that the C sequestration in the rhizosphere of seagrass vegetated areas is currently very low and similar to unvegetated areas. However, our analyses of selected lipid biomarkers (sterols, ω-hydroxyacids, and α,β-dihydroxyacids), scanning electron microscopy, ^{14}C age dating, and a 'heavy' $\delta^{13}C$-value clearly identified a layer enriched in fossil seagrass biomass that has been buried about 2,500 years ago. This material now resides at a depth of 40 – 60 cm as a several cm thick organic-rich layer and contains most of the organic carbon stored in the uppermost ~ 0.5 m of the sediments near Poel Island. Thus, event-driven burial of seagrass biomass may provide a critical pathway for enabling Blue Carbon storage over relevant (103 yrs-) timespans in coarse-grained proximal sediments.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Tracing Earth's Missing Non-Meteoritic Building Materials Through Isotopic Signatures

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Planetary bodies exhibit distinct nucleosynthetic isotope signatures that provide insights into the origin of their building blocks [1]. The isotopic composition of Earth and Mars align with nucleosynthetic isotope anomaly trends defined by non-carbonaceous (NC) meteorites, indicating that the terrestrial planets primarily accreted from inner solar system material [2,3]. Furthermore, Earth's isotopic composition consistently occupies an endmember position within the NC trends. For anomalies in s-process elements this endmember position is absolute, indicating that Earth incorporated a component not represented among known meteorites—an s-process-rich material likely formed in the innermost Solar System and now missing from the meteoritic record.

To investigate the nature of this component, we analyzed fine-grained, matrix-rich fractions from primitive NC chondrites that formed under varying redox conditions and at different heliocentric distances. Our data show that the Ti isotopic composition of these fine fractions deviate from the composition of their bulk host meteorites and are shifted toward—or even beyond—Earth's isotopic composition. First Zr isotope data from one matrix-enriched fraction indicate that this material is s-process enriched, consistent with an origin in the inner Solar System. This component may represent a missing building block of Earth, heterogeneously distributed within the NC reservoir and selectively preserved in fine-grained material, even if diluted or absent in bulk chondrites.

References

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[2] Burkhardt et al. (2021), Sci. Adv. 7, eabj7601.

[3] Mezger et al. (2020), Space. Sci, Rev., 216 :27

05.02 Understanding (geo)materials with advanced experimental and computational methods

Atomic-Scale Investigation of Thermal Conductivity in Lower Mantle Minerals

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Constraining heat transport across the core-mantle boundary (CMB) is key to understanding Earth's thermal evolution and the operation of the geodynamo. This work focuses on the lattice thermal conductivity of the three dominant minerals in the lower mantle—periclase, bridgmanite, and post-bridgmanite—under relevant pressure-temperature-composition conditions. We apply three complementary atomistic simulation methods: the Boltzmann Transport Equation (BTE), Green-Kubo Molecular Dynamics (GKMD), and Non-Equilibrium Molecular Dynamics (NEMD), to study thermal transport up to 150 GPa and 4000 K. The methodology allows cross-validation and provides insights into the role of anharmonicity and length/time scale effects at deep Earth conditions.

Preliminary results for periclase show consistent trends across all three methods and align well with existing data, including the impact of isotopic substitution. For post-bridgmanite, thermal conductivity has been evaluated using both BTE and GKMD over a range of pressures and temperatures, offering initial insight into its anisotropic transport behavior and confirming method consistency. This work lays the foundation for further studies on how compositional variations—such as Fe/Al substitution and spin-state transitions—affect thermal conductivity in deep mantle minerals.

07.03 Quantifying surface and near-surface dynamics with remote sensing and geophysics

Controls on valley-floor width in the western Andes

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River valley floors are low-relief, confined landscapes that temporarily store sediment moving from mountains to lowlands. This transient storage affects sediment budgets, global element cycles, and the preservation of environmental signals. However, the factors controlling valley-floor width remain poorly understood, preventing landscape evolution models from reproducing and forecasting those diverse landforms. In this study, we analyze valley-floor width and four potential controlling factors—river discharge, tectonic uplift, lithology, and lateral sediment supply from hillslopes—across ~126,000 locations in 84 catchments along the western Andes (5°–40°S). Using a random forest regression model, we identify river discharge as the dominant control on valley width, followed by lateral sediment supply, tectonic uplift, and erodibility. When organizing the data by catchment and elevation, correlation analyses reveal that discharge has greater influence at lower elevations, while uplift plays a stronger role at higher altitudes. A comparison with a theoretical model—predicting steady-state valley width based on discharge, uplift, and sediment supply—shows over 95% agreement, reinforcing the significance of these parameters. Discrepancies between model predictions and observed data mostly occur in transient stream segments, where dynamic processes are not captured by the model. Overall, our findings improve understanding of valley floor formation and sediment storage and aid in interpreting past climate and tectonic activity through valley morphology.

01.25 Geochemical Databases and Data Analysis Tools

Data Quality Insights from the World's Largest Geochemical Rock Database

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The GEOROC database (Geochemistry of Rocks of the Oceans and Continents) was born in 1999 at the Max Planck Institute in Mainz (Germany) under the leadership of A. W. Hofmann and B. Sarbas. For 25 years, GEOROC has served the geochemical community and now has more than 685,000+ sample records for whole rock, glass and mineral analyses. Since 2021 the database has been curated and further developed as part of the DIGIS project from its new home at the University of Göttingen, and now also offers a data repository service.

In the era of AI, chatbots and scraping algorithms, geochemical data can be scraped from the internet into un-curated piles and fed to generalized data analysis models. In this context, the greatest strength of our well-curated expert reviewed data products that can give users the necessary critical metadata to scrutinize analytical data and their quality for tracing geochemical transport processes on global to micron scales. In this talk, we dive deep into the lessons we have learned and the tools we are developing using GEOROC as a case study: Where do errors occur during compositional data publication, how we can identify the type and source of errors? Quality control of long-tail analytical data is of general concern, and our approaches may be applicable to other fields of Earth System Science as well.

03.04 All about carbonates

Carbonate modification after extreme stress loading

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Carbonates, which are highly-relevant for lithosphere-biosphere-atmosphere interactions, are prone to modification – especially after being affected by high stresses and strains. Modification of carbonates after extreme stress loading during hypervelocity impact from Ries impact breccias is presented in this study. In calcite aggregates, new grains formed on the expense of partly preserved shocked host grains. The shocked host grains contain e-, f- and r- twins as well as a-type lamellae and have a high Grain Orientation Spread (GOS) of up to 8° (GOS is the mean misorientation angle between all pixels of one grain and the mean orientation of the grain). The new grains, in contrast, do not contain twins and the GOS is generally <1°. Their crystallographic orientation is close to that of the various twins or the host grain. We propose that the new grains have formed from the back-transformation of a transient high-pressure phase formed upon shock. The calcite aggregates show a zonation with variations in MnO- and MgO-contents (0–1.6 and 0–0.4, respectively), which is preserved in the new grains (i.e., the zonation is cross-cut by grain boundaries). This indicates that diffusional processes were relatively minor, which is consistent with fast transformation processes. Heating experiments of shocked carbonates indicates that temperatures after shock were <400°C, as at these temperatures the twinned microstructure is markedly modified. The study of modification processes of highly strained carbonate in impact breccias yields valuable insights into fast transformations in the carbonate system.

01.21 Advances in Geochronology: from tradition to avant-garde

How nature freezes life at cell scale: novel approach reveals 200-myr history of plant silicification

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Fossils that provide three-dimensional anatomical detail are among the most spectacular and significant archives of past life. However, the duration and speed of tissue mineralization often remain obscure, as do the sources of the fossilizing agents. We present a novel approach to reconstruct the deep-time 3D silicification of plant tissues, using Late Pennsylvanian fossil wood from fluvial red beds of the Kyffhäuser (Siebigerode Formation, Saale Basin, central Germany). Methods applied include fossil-wood histology, sediment petrography, cathodoluminescence (CL), scanning-electron microscopy, Raman spectroscopy, electron-probe and fluid-inclusion microanalysis, LA-ICP-MS *in-situ* U-Pb dating and Si isotopy of silicified fossil wood. The results reveal a 200-myr history of mineralization that occurred in concert with regional basin evolution. Accordingly, initial permineralization through amorphous silica is dated to 304±10 Ma and sourced from pyroclasts related to syndepositional, late-Variscan volcanism. This stage was followed by the opal-quartz transformation during subsidence until c. 290 Ma (early Permian). Around 260 Ma, hydrothermal quartz-hematite mineralization impacted the woods following middle–late Permian inversion. Blocky quartz sourced from basinal brines crystallized in the fossil trunks during maximum burial between 180–160 Ma (Late Jurassic), at 3.5–5.0 km depth and 160–240°C. The youngest mineralization found in the trunks dates to 115 Ma (Early Cretaceous) and resulted from regionally traceable, hydrothermal quartz-baryte-calcite mineralization in the course of inversion in the Central European Basin System. These outcomes not only break new ground in understanding cell-scale fossilization but also reveal silicified plants as promising tools for reconstructing basin evolution and regional mineralization.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Loess in northern Pakistan: Current Understanding, Knowledge Gaps, and New Field Observations

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The topic of loess (and other Late Quaternary palaeoclimate archives) in Pakistan has not been discussed much during the last decades. (Muhs, 2018) states that the extent of loess in Pakistan remains only vaguely understood, a situation that has not significantly changed. Several loess areas are reported from the Peshwar Basin, specifically the area around Nowshera west of the confluence of the Kabul and Indus Rivers, the Haro River Loess-Palaeosol deposits, and the area of Islamabad. Also Smalley et al., (2016) highlight the absence of a systematic loess study for Pakistan and emphasize that, for the Indian (sub)continent “the conditions appear to be perfect for the formation of large deposits”.

In this contribution, we summarize literature, and present observations form a recent field excursion. We consider both aeolian loess and redeposited loess-like fluviolacustrine sediments to be present in much larger areas than previously reported. We hypothesize that an aeolian sediment flux into the landscape was repeatedly intercalated by fluviolacustrine sediments of similar silt grain size. The aeolian sedimentation proceeded into mountain regions north of the basins, but preservation of fine material in sparse. At several places, loess is intercalated with (unrounded) slope deposits and fluvial deposits.

01.13 Sedimentary basins as multi-proxy and multi-process recorders

The Influence of the Digul Fault on the Formation and Evolution of the South Papua Sedimentary Basin in the Context of the Extension of the North Australian Basin

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South Papua is a complex geological region, particularly due to its position as a structural extension of the North Australian sedimentary basin. In this region, the Southern Papua Basin developed along with

intensive tectonic activity, one of which is the influence of the Digul Fault.

This study aims to evaluate the relationship between the fault system and the formation and evolution of basin stratigraphy in the Asmat region and its surroundings. Based on the interpretation of regional geological, lithological, and geophysical data, it is known that the Digul fault acts as the main structural boundary that controls sedimentation from the Miocene to the Recent. This fault activity triggered the formation of graben and half-graben systems that accommodated the accumulation of clastic and carbonate sediments in fluvial to deltaic environments.

This study also indicates that the existence of these structures can influence the potential for hydrocarbon traps and active tectonic dynamics in South Papua.

04.02 Lithium Rescources

Lithium Exploration Potential of Pakistan: A Concept Note

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Pakistan hosts diverse mineral domains with notable potential for lithium (Li) occurrences across multiple geological settings. In the northern regions, Li-bearing pegmatites and feldspar-rich granites are widespread, particularly along the Himalayan pegmatite belt that extends from Afghanistan through Pakistan to Bhutan. Two prominent sub-belts, Nuristan and Hindukush, contain rare-metal pegmatites associated with two-mica granites enriched in Li, Ta, Nb, Be, Sn, and Cs. In the Hindukush, the Garam Chashma and Miniki Gol granites are comparable to the Laghman Intrusive Complex in Afghanistan, showing significant Li enrichment (27.5–469 ppm) in non-pegmatitic samples and elevated concentrations of Be, Cs, Nb, and Ta.

To the east, pegmatites hosting Li-tourmaline (Elbaite) and Lepidolite occur in areas such as Shengus, Braldu, Haramosh, Kashmal, and Shigar valleys of Gilgit-Baltistan, and the Neelum, Muzaffarabad, and Kara valleys of Kashmir. Additional pathfinder minerals including pollucite, cleavelandite, aquamarine, beryllonite, and columbite in the Shigar and Rondu districts further support the Li-fertility of these pegmatites. Geochemical signatures of Shigar pegmatites—enriched in F, Rb, and Nb but depleted in Mg, Ti, Ba, Fe, Sr, and Zr—indicate advanced fractionation and lithium enrichment.

Two-mica granites of the Peshawar Plain Alkaline Igneous Province (PPAIP) also warrant exploration for Li-bearing pegmatites. Beyond hard rock deposits, the presence of lithium-rich hectorite in the clay formations of the Salt Range and potential lithium brines in closed-basin lakes such as Hamun-i-Lora, Hamun-i-Mushkhel, and the Rann of Kach highlight Pakistan’s multifaceted lithium resource potential.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Talc-carbonate-alteration of the Chromitiferous Harzburgite unit of the Uitkomst Complex, Nkomati Ni-Cu-Cr-PGE Mine, South Africa

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The Nkomati Ni-Cu-Cr-PGE Mine of the Uitkomst Complex in the Mpumalanga Province was the main primary nickel producer in South Africa until 2021, when the open-pit operation was placed on care and maintenance. The nickel demand generated by the EV battery market and the long-term increase of the Ni price may be reason to consider further detailed study of the petrology and alteration processes of the complex.

The lower three rock units of the about 2057.6 ± 0.7 Ma old (Maier et al. 2018) mafic to ultramafic complex contain Ni-Cu-PGE sulphide and chromite mineralisation. From bottom to top they are intensely saussuritizised, amphibolitised, serpentinised, talcified, and carbonatised. The original igneous cumulate mineral assemblage determines the composition of the alteration minerals, which in turn challenge ore processing of the unit. However, a positive correlation between the degree of alteration and increasing grade and aggregate size of the ore is obvious.

The formation of talc-carbonate schist is regarded as the ultimate stage of ultramafic rock alteration under the influence of a H_2O- and CO_2-rich fluid phase derived from pelitic and dolomite country rocks. These were strongly contact metamorphosed and partially assimilated by the ultramafic magma. Carbonate devolatisation provided the CO_2 for continuous talc-carbonate-alteration, from a late-magmatic to a hydrothermal stage. Pseudosections of CO_2 fraction vs. temperature phase diagrams allow the estimation of a formation temperature of about 500°C for the main part of the alteration paragenesis. The formation of the talc-carbonate-pyrite schist is regarded as a retrograde alteration process of serpentinised harzburgites.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

3D modeling of salt dome structures – a case study in the Pricaspian Basin (Central Asia)

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The Pricaspian Basin represents an approximately 600 km wide (east-west) structure at the northern edge of the Caspian Sea. Isolated from the Paleo-Tethys by carbonate massives, this structure was filled with up to 4.5 km thick Permian (Kungurian and Roadian (Kazanian)) evaporite rocks and covered mainly by clastic sediments in post-Roadian times. From the late Permian and intensifying in the Triassic, halokinesis led to the rise of salt diapirs, which highly deformed the salt successions. This diapirism continued in a later movement phase between the Jurassic and the Neogene resulting in more than 1.500 salt dome structures known in the Pricaspian Basin. These salt dome structures are of economic interest, e.g. for gas, oil, potash, and borate.

With the help of seismic investigations, as well as lithological and chemical analyses from drilling results, a 3D model of a potash deposit was created. This 3D model represents a case study of a complex tectonic and halokinetic genesis within a salt diapir of the Pricaspian Basin.

02.01 The Tethys Ocean – the cradle of modern tropical life

Late Miocene land vertebrate faunas from the Eastern Paratethys area: Geochronology, Climate Evolution, Biotic record

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The Late Miocene record of the continental vertebrates has a rich record in the north of the Eastern Paratethys. The territories of Romania, Moldova, Ukraine and Southern Russia provide continental and partially marine deposits rich in marine and terrestrial faunas. Previous extensive studies dated the ages of these deposits from the Sarmatian s.l. to Maeotian (11-6 Ma). In most cases, the ages of sites have broad ranges, significantly limiting paleobiogeographic, -geographic, -environmental, and -climatic reconstructions and analyses.

In the framework of a research project, our team reassessed the ages of the known sites and documented new ones from Moldova and Romania with vertebrate faunas using a broad range of multidisciplinary up-to-date methods of geological sciences. They include sedimentological description, magnetostratigraphy, micropaleontology, mollusc biostratigraphy, dating using autogenic nuclides and vertebrate paleontology. The sections represent mostly fluvial deposits of the Balta Formation, but they also include deposits from the shore and/or deltaic environments.

Our studies allowed to estimate more precisely the ages of the sites ranging from the Bessarabian to Maeotian ages. Further, the dating using autogenic nuclides allowed to establish a geochronological model for our sites independent from the marine biozones and mammalian MN units.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

The Nantois section at the westernmost part of the Eurasian loess belt – First multi-proxy precipitation estimates for the Saalian and Eemian and geomorphological/sedimentological inferences

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Changes in continental precipitation patterns may drastically reshape landscapes and living-environments of humans in terms of geomorphological settings and sedimentological regimes. Dust based quaternary sediment archives like widespread loess-palaeosol-sequences (LPS) record climatic changes and provide key geomorphological and sedimentological information. These records are also essential for comprehending precipitation changes across continents and associated terrestrial system responses. Currently, precipitation quantities strongly vary along a W-E gradients across Europe, but this pattern is likely to have changed dramatically in the past – especially when the Nordic ice-sheets started to grow upon their massive extend during their glacial maxima. Here we present first precipitation estimates considering a suite of established chemical ($\delta^{13}C$ of the total organic carbon) and magnetic measures for the Nantois section (northern Brittany, France) covering the Saalian (penultimate glaciation) with its cold and harsh conditions and the Eemian (last interglacial), when the climate was globally warmer than today. We discuss our sedimentological results considering the special geomorphological setting of the Nantois section and its role regarding the reaction to dry-moister cycles. Based on this, we demonstrate the advantage of combining sedimentological and geomorphological perspectives when aiming at a more holistic landscape understanding.

05.04 & 06.05 Biogeochemistry, geomicrobiology, and biomineralogy

Genes to make a calcite spicule: Innovation and functional diversification in calcareous sponges

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A key innovation in the evolution of calcareous sponges was the ability to form calcite spicules. Several genes involved in this process have been characterized in the model organism Sycon ciliatum. These genes are expressed in active sclerocytes during different stages of spicule formation and are, in some cases, specific to certain spicule types. Many lack clear orthologs in other sponge classes, suggesting they represent genetic innovations dating back to the last common ancestor of extant Calcarea.

Here, we investigate the evolution of key biomineralization genes in Calcarea using genomic, transcriptomic, and proteomic data from both major subclasses, Calcinea and Calcaronea. Our results reveal that several of these genes are orthologous within Calcarea and absent from other sponge lineages. These findings support the growing body of evidence that spicule formation evolved multiple times independently in different sponge classes. Within Calcarea, gene innovation followed by duplication and neofunctionalization has refined the biomineralization toolkit, giving rise to spicule-type-specific functions.

01.27 The BROMACKER project: A novel combination of multidisciplinary research and science communication in a UNESCO Geopark

Digital curation and new ways of science transfer in the BROMACKER paleo-science communication project

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In the BROMACKER research project, the public is to be involved in this multidisciplinary and integrative research project through innovative communication and mediation measures in parallel to the scientific knowledge gained. This is achieved through a new, interdisciplinary transfer and communication approach: the opening up and presentation of real research processes so that the public can gain insights into the scientific process and the advancing findings during the course of the project. One highlight is the annual excavation in the middle of the Thuringian Forest, where early tetrapods, invertebrates, plants and traces of their lives and environment are excavated. At the same time, innovative communication measures are being tested and established with the participation of researchers. As the first digital curator at the Museum für Naturkunde Berlin, I will tell you about the exciting journey through the various formats and locations in which we have brought BROMACKER closer to the public: 360°-videos, virtual reality, augmented reality, planetarium, interactive online exhibition, social media. What do you do as a digital curator in the middle of a pandemic when there are no research results yet and research is only just beginning? It was important to us that the teams worked on an interdisciplinary basis and that the researchers themselves were involved in creating the media, sometimes having to improvise and learning many new things in the process. The ‘first-hand’ participation enriched the formats and the media products became very authentic as a result. It wasn't always easy, but it was worth it!

Plenary: AG Verbundprojekte des DVGeo "Zukunftsforschung in den Geowissenschaften: wie weiter? Eine interaktive Diskussion"

Zukunftsforschung in den Geowissenschaften: wie weiter? Eine interaktive Diskussion

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Wie können die Geowissenschaften die großen Fragen unserer Zeit in koordinierten Forschungsprojekten angehen? Welche Forschungsfragen wollen wir angehen? Welche großen Beobachtungsinfrastrukturen benötigen wir? Welche geologische Beiträge sind zur Lösung der großen globalen Krisen Klimawandel und Biodiversitätsverlust möglich? Wie können Georessourcen und der Untergrund verantwortungsvoll genutzt werden? Was beschreibt die Dynamik von Kippunkten im Erdsystem? Gibt es Leben auf anderen Planeten?

Zu diesen und vielen anderen Themen hat die “Arbeitsgemeinschaft Verbundprojekte” des Dachverbandes der Geowissenschaften dieses Jahr ein White Paper veröffentlicht. In der Plenarsitzung werden wir das White Paper in Erinnerung rufen sowie Impulse und Hinweise die Umsetzung erfolgreicher Verbundprojekte geben. Mit den Teilnehmern der Plenarsitzung werden wir in Echtzeit digitales Feedback einholen. Wir werden fragen: Was fehlt der deutschen Geowissenschaftlichen Gemeinschaft, um mehr inter- und transdisziplinäre Verbundprojekte durchzuführen? Diese sollen nicht nur die vielseitigen Wechselwirkungen zwischen den Komponenten des Erdsystems thematisieren, sondern auch die Sichtbarkeit der Geowissenschaften erhöhen?

Wir bitten alle Teilnehmenden, ihr Smartphone mit Internetverbindung bereit zu halten.

Link zu der AG Verbundprojekte: *https://www.dvgeo.org/ueber-uns/gremien-1/ag-verbundprojekte*

Link zu dem White Paper:
https://www.dvgeo.org/fileadmin/user_upload/News_2025/250120_DVGeo_Whitepaper-Zukunftsforschung.pdf

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

The osteology of the Mediterranean and African dwarf goby Corcyrogobius (Teleostei: Gobiidae) – Testing the limits of µCT-Scanning

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Within the past decade, Micro-CT-Scanning and 3D-Rendering have become established methods in palaeontology for both actualistic and fossil studies. While this non-destructive procedure has yielded impressive, species-identifying traits for many fossil and recent organisms, we asked whether it could also accurately reconstruct the delicate skeletons of one of Earth's smallest vertebrates: dwarf gobies. The material presented here includes the three species of Corcyrogobius Miller, 1972, rare cryptobenthic dwarf gobies of the Adriatic Sea and West African coasts. The specimens, ranging in size between 12 and 25 mm, come from the collection of the British Museum of Natural History, London (BMNH), and the Zoological State Collection, Munich (ZSM). They were micro-CT-scanned, visualized using Amira 3D-rendering and compared with x-ray images and isolated otoliths (hearing stones). Despite common artifacts and dislocations due to scanning errors, the scans revealed a surprising amount of intricate detail. The taxonomically important otoliths could be rendered with high resolution. Even closely overlapping bones, such as gill covers (opercle, subopercle), could be separated using Amira's segmentation tool. Moreover, previously unknown differences between the three species were detected in the jaw bones, pelvis and vertebral column. A frequently encountered downside was the sometimes poor resolution of the scans and, as a result, of the segmented bones. Additionally, the program had difficulties distinguishing weakly ossified bones from soft tissue.

At this small scale, Micro-CT-scanning presents challenges and may produce misleading results. Nevertheless, our work with Corcyrogobius demonstrates that even miniature vertebrates can be successfully analyzed using this technique.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

WBGeo: A modular workbench to streamline geoscientific workflows

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Structural geological modeling is often an integral part of larger geoscientific workflows. However, when creating these workflows, challenges arise not only in constructing models but also in the knowledge and availability of software, coding skills (especially for open-source solutions), and expertise across multiple domains. These hurdles hinder the exploration and comparison of various methods, compelling users to develop workflows tailored to specific scenarios that frequently require manual adjustments—making them difficult to reuse and labor-intensive.

To address these issues, we present a workbench for digital geosystems that employs a component and connector software architecture alongside both textual and graphical domain-specific languages (DSLs) to establish a modular framework. Within this framework, we define fixed interface formats for each workflow step, allowing components responsible for specific tasks to be interchangeable.

This design enhances workflow creation accessibility while promoting comparability and reusability. New components can be easily integrated into the workflow as long as they adhere to the established interface formats.

The current version of our workbench focuses on workflows spanning structural geological modeling, meshing, and numerical process simulations. Additionally, it incorporates integrated visualization capabilities in extended reality (XR), virtual reality (VR), and augmented reality (AR) for each step of the workflow.

We will showcase the software architecture and DSL system through a series of simple models with an emphasis on structural geological modeling.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

Sedimentological analysis and single-grain luminescence dating of glaciotectonic complexes and tunnel-valley fills in northwestern Germany

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The exact number, extent, and chronology of Middle Pleistocene ice advances into northern Central Europe are still debated. To gain insight into the timing of the Elsterian to Saalian ice advances, 25 samples for feldspar single-grain luminescence dating were taken from five different Saalian ice-marginal positions and Elsterian tunnel-valley fills in northwestern Germany. The sampled Elsterian glacigenic sediments comprise subaqueous fans and deltas that were deposited in glacial lakes and underfilled tunnel valleys during ice-margin retreat. The preliminary luminescence ages indicate a correlation with Marine Isotope Stage (MIS) 12. However, the sampled sediments are partly in saturation. This is likely due to subglacial erosion of older sediments. The analyzed Saalian deposits mainly consist of glaciofluvial fans, characterized by sandy sheetflood deposits, alternating with coarser-grained, multilateral, or multistorey channel bodies. Preliminary luminescence ages suggest several ice advances during MIS 8 and MIS 6.

01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

Highly siderophile element and Re-Os systematics of peridotite xenoliths and basalts from Isla Floreana, Galápagos

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Hot spot volcanism may reflect both contributions from sublithospheric and lithospheric mantle sources. In addition to lithophile radiogenic isotopes, Re-Os isotopic data may aid in understanding the contributions from different sources. The Galápagos archipelago is the manifestation of a long-lived mantle plume. Its source reservoirs are well characterized in terms of lithophile radiogenic isotopes, major and trace elements. A distinctive feature of the Galápagos mantle source is the presence of a strongly incompatible element-depleted component that mixes in three directions with an EM1-like plume signature and a HIMU-like endmember expressed in lavas from Floreana. However, Re-Os-systematics of Galápagos, are limited by very few basalt samples. In this contribution, we present highly siderophile element (HSE) and Re-Os isotopic data of 19 ultramafic xenoliths and 2 basalts from Isla Floreana in the southern Galápagos Archipelago.

HSE patterns in the xenoliths reveal two distinct groups: some exhibit high Pd/Ir and Pt/Ir, similar to ultramafic cumulates from ophiolites, whereas other xenoliths display low Pd/Ir and Pt/Ir, consistent with typical mantle xenoliths. Measured 187Os/188Os vary between 0.1265 and 0.1372 and overlap with data on basalts from Isla Floreana (0.130 to 0.140) and Isla Fernandina (0.132) (Gibson et al. 2016, EPSL 449, 345-359), where the plume centre is currently located. Cumulate xenoliths and their 187/188 Os mostly reflect the slightly suprachondritic values of the lavas, while other xenoliths with lower 187/188 Os are of lithospheric origin.

09.02 Museen als Fenster in der Forschung

DuDoku: An Open-Source Android App to Simplify Image Documentation in Museum Digitalization

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Image documentation is a crucial component of digitalizing museum collections — and serves as a vital bridge between scholarly research and public engagement. However, capturing images with conventional cameras can be logistically challenging due to bulky equipment and the need for technical expertise. A particularly tedious and error-prone task is renaming image files according to the inventory numbers of the objects, in order to correctly link each photograph with its corresponding dataset. This manual process adds inefficiency to an already demanding workflow.

To address these challenges, we developed DuDoku, an open-source Android camera application designed to simplify and accelerate image documentation. The app enables users to input the inventory number at the moment of capture, automatically assigning it as the image filename. Input can be done manually via touchscreen or by scanning barcodes or QR codes, when available.

As smartphone photography is part of everyday experience for most users, no specialized skills are required fort he use of the app. When connected to a cloud storage service, DuDoku supports a fast, mobile, and lightweight workflow. It reduces post-processing workload, improves accuracy, and provides a scalable solution for large-scale, *in situ* digitalization of museum collections.

In this presentation, we will outline how DuDoku has been integrated into the documentation workflow at Museum Wiesbaden. We will share results from over a year of active use, highlighting measurable improvements in the speed, accuracy, and overall efficiency of our digitalization processes.

09.01 Workshop "Open Educational Resources (OER) in Geosciences: From Basics to Practice"

Open Educational Resources (OER) in Geosciences: From Basics to Practice

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Open Educational Resources (OER) are becoming increasingly relevant in higher education, yet many educators and researchers are still unfamiliar with how to use and publish them effectively. This interactive workshop provides a structured introduction to OER, guiding participants from the fundamentals to discipline-specific applications in geosciences and geography education.

In the first part, participants will learn about the principles of OER, licensing models, and the benefits of open educational practices. Building on this foundation, the second part will focus on subject-specific platforms where high-quality OER materials can be found and published. Through hands-on activities, participants will explore how to create and share their own open resources, gaining practical experience in developing accessible and reusable educational materials.

The workshop is designed to be interactive, combining theoretical input with practical exercises. By actively engaging in OER development, participants will learn how to curate their own discipline-specific material collections. This process will also contribute to establishing a Community of Practice for geosciences educators, fostering collaboration and the exchange of open teaching resources.

This session is aimed at educators, researchers, and instructional designers in geosciences and geography education who are interested in leveraging OER for innovative and sustainable teaching practices.

01.11 Micropalaeontology – Advancements and Perspectives in Multiproxy Studies

Comparing the Past and the Present: Ostracod Associations from a Recent and an Early Holocene Tufa Stream in Thuringia, Central Europe

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We compare ostracod communities from two tufa-bearing freshwater environments near Jena (Thuringia, Central Germany): a modern spring-fed stream in the Pennickental and an early Holocene tufa sequence in the Plinz valley. Both sites represent low-order fluvial systems influenced by carbonate-rich groundwater, but they differ in their underlying lithologies, with dominating Muschelkalk at Pennickental and Buntsandstein at Plinz. In total, 19 ostracod species were recorded in the modern stream, whereas the fossil association consists of 11 species.

The early Holocene Plinz profile reveals a succession of three faunal zones reflecting changing aquatic habitats: (1) a plant-rich, fast-flowing brook with cold, oligotrophic water; (2) a shallow pond behind a tufa barrier with stable, nutrient-richer conditions; and (3) a spring-proximal shallow stream. Dominant species include Candona weltneri and Cavernocypris subterranea, indicating cold climate and changing habitat conditions after the Pleistocene-Holocene transition.

The modern Pennickental assemblages are structured by habitat type: spring ponds, waterfalls, ponded zones, and cascading streams. Flow-adapted and eurythermal species such as Eucypris pigra and Ilyocypris inermis dominate. Cluster and PCA analyses suggest temperature, current velocity, groundwater chemistry (especially alkalinity and sulfate), and vegetation cover are key environmental drivers. Species-environment relationships are consistent between fossil and modern datasets, supporting the ecological stability of many non-marine ostracods over millennial timescales. Nevertheless, different recent and fossil ostracod associations point to changing environments by climatic and anthropogenic factors. Our results demonstrate how modern analogues can refine paleoecological interpretations and provide insights into freshwater responses to past climate transitions.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

The superposition of fault networks around the Asse salt structure as a proxy for the regional tectonic evolution – insights from 3D seismic data

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The salt-cored Asse-anticline is located in the Subhercynian Basin and was formed during the Late Cretaceous phase of tectonic shortening. The salt anticline contains a former salt mine, in which low- and intermediate-level radioactive waste was disposed during the 1970s. During more than hundred years of mine history and the planning for the retrieval of the radioactive waste in the last 15 years, a large amount of geological and geophysical data were acquired. The interpretation of a 3D seismic data set in combination with new well data recently provided insights into the local structural framework.

We discovered that the Asse salt anticline developed around an intersection of two systems of normal faults formed prior to the Late Cretaceous. The NW-SE trending fault system strikes parallel to the anticline and is located in the vicinity of its crest. Another E-W-trending fault network crosses the eastern part of the anticline and causes an along-strike change of its geometry. Although the exact timing of the faults is unclear, they indicate two separate phases of tectonic extension. During the subsequent phase of tectonic compression, the normal faults in the anticlinal flanks partly became inverted.

The structural trends of the normal faults are also recognized in the intra-salt layers. Here, the dominant trend of the fold axes is NW-SE, which is interrupted by E-W-striking folds in the Eastern part of the salt mine. Thus, we suggest that salt deformation is mostly a relict of the extensional phases and was only partly overprinted by tectonic shortening.

01.20 Process oriented microfabric characterisation of geomaterials

The effect of fluorine on rim growth rates in the ternary CaO-MgO-SiO_2 system

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An increase in fluorine concentration significantly enhances rim growth rates between periclase and wollastonite, as previously reported by Franke and Joachim-Mrosko (2022). However, the mechanisms responsible for this acceleration, as well as the quantitative relationship between volatile content and rim growth dynamics, remain only partially understood. A more detailed understanding of these processes is critical for our understanding of the role of volatiles in metamorphic and metasomatic reactions.

To address this, we conducted high-p-T experiments at 1000 °C and 1.5 GPa for 20 minutes, with fluorine contents ranging from 1 to 2 wt%. For example, at 1 wt% fluorine, rim growth reached an overall thickness of approximately 50 µm. Building on a previous study (Franke and Joachim-Mrosko, 2022), our preliminary results suggest a linear increase in rim growth rate between 0 and 1 wt% fluorine. However, at fluorine concentrations exceeding 1 wt%, the slope of this linear trend seems to suddenly decrease. Moreover, fluorine is observed to accumulate at the rim–wollastonite interface, indicating a coupled transport of fluorine and MgO.

The reduced growth rate above 1 wt% fluorine may be attributed to a microstructural transition from a layered to a more lamellar rim microstructure, which likely modifies grain and phase boundary properties and thus affects rim growth kinetics.

Reference

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01.04 Latest Achievements in Scientific Ocean and Continental Drilling

Stepwise synchronization of Antarctic and global climate since 1.5 Ma – implications for the carbon cycle

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As an integral part of Earth's climate system, the Antarctic Ice Sheet (AIS) impacts global sea level and interacts with Southern Ocean climate on a variety of timescales. A lack of long and continuous records of AIS variability on orbital timescales, however, has challenged our understanding of the complex interplay between the AIS, ocean, atmosphere, and biogeochemical cycles and its contribution to the evolution of Plio-Pleistocene climate. Here we sediment records from Iceberg Alley Site U1537 (IODP Expedition 382) from the Antarctic Zone of the Southern Ocean in combination with climate and ice-sheet model simulations to show that key components started to synchronize with orbitally-paced global climate change since ~1.5 million years ago (Ma), 0.3 Ma before the Mid-Pleistocene Transition (MPT) started. Since ~1.5 Ma, productivity (upwelling) and dust proxies of Site U1537 covaried on orbital time. From ~1.5–~0.9 Ma, Southern Hemisphere sea-ice increase was accompanied by a similar long-term decrease in sea-surface temperature. During that period, Antarctic ice volume also increased. Since ~0.9 Ma, all climate components show increased synchronization with global climate on orbital time scales. Since the Mid-Brunhes event (~0.45 Ma), all components of the Antarctic climate and ice-sheet system were locked into an orbital rhythm with high-amplitude, glacial-to interglacial variability. The weak response to orbital forcing prior to 1.5 Ma indicates sensitivity thresholds for the Southern Ocean and the AIS. Specifically, the sea-ice increase and sea-surface temperature decrease in combination with AIS growth increasingly regulated the carbon cycle across the MPT.

09.03 What Do We Know About Learning and Teaching Geosciences? – Geoscience Education Research and Outreach

Experiences from education and public outreach in the National Geopark GrenzWelten. How to make climate change and relevant UNESCO SDG topics exciting

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The IPCC Sixth Assessment Report summarises the knowledge of climate change and defines in the Synthesis Report future climate change scenarios, risks and short- and long-term climatic responses. Of key relevance is the interdependence of climate, ecosystems, biodiversity and human societies.

17 Sustainable Development Goals (SDGs) defined by UNESCO aim at peace and prosperity and concentrate on climate change at the same time. The mission of National Geoparks exhibits substantial overlap with many SDGs, for example education (SDG 4), clean water (SDG 6), climate action (SDG 13) and life below water (SDG 14) and on land (SDG 15). In that regard the contribution of geoscience is twofold and covers research and outreach to the public.

School plays a vital role in climate change education although the lack of geoscience content has been recognized as limiting factor. Our National Geoparks have the potential to bridge this gap by providing a variety of attractive activities and educational services. One initiative of Geopark GrenzWelten is the newly designed Climate and Building Stone Korbach City Tour which conveys regional geology and climate change of Earth during 350 million years. Building stones represent exciting low-hanging fruit which help to explain not only regional geology but also highlight the value of domestic resources and to help explain natural vs anthropogenic climate change. The tour presents a fresh view on Zechstein carbonates, Buntsandstein clastics and Neogene volcanics and is offered as post-conference field trip.

07.02 Geothermal energy – Potential and utilisation of geothermal energy resources for the heat transition

Action Plan Deep Geothermal Energy: How Brandenburg will enhance the availability and quality of geological data for deep geothermal exploration

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Geothermal energy is a crucial part for the energy transition towards renewables and highly in demand by municipal energy providers to supply energy via their district heating networks. The North German Basin in Brandenburg was explored heavily during the 1960–1980s for hydrocarbons. Despite the amount of vintage hydrocarbon exploration data such as seismic surveys or borehole logs, most data can only be accessed at the GeoArchiv at the Landesamt für Bergbau, Geologie und Rohstoffe (Geological Survey Brandenburg). The majority of the vintage data is not yet digitized.

The Geological Survey and the Ministry for Economic Affairs, Labour, Energy and Climate Action agreed on an Action Plan (Aktionsplan Tiefengeothermie) to kick start geothermal exploration in the federal state of Brandenburg. Until 2028 Brandenburg invests heavily in

(I) its IT infrastructure to convey digitized data to stakeholders and consultants but also in providing direct downloads for open data according to the Geology Data Act (Geologiedatengesetz),

(II) digitizing vintages exploration data as well as homogenize and enhance selected data by reprocessing or vectorization,

(III) identifying and closing data gaps by state funded exploration applying geophysical exploration methods and

(IV) providing new open data by a state funding drilling campaign including petrophysical, mechanical and chemical data on selected reservoir horizons within the North German Basin.

The Action Plan will be supported by ongoing public outreach to inform stakeholders or investors within Brandenburg as well as the general public in the areas targeted for exploration.

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Harmonizing a 3D velocity field between Mecklenburg-Western Pomerania and Brandenburg: Insights from the TUNB velo 2.0 project

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As part of the transnational TUNB velo 2.0 initiative, the Geological Surveys of Mecklenburg-Western Pomerania and Brandenburg contribute to the development of a 3D seismic velocity model of the North German Basin. Building on the 3D geological framework established in the predecessor TUNB project, which spans from the Cenozoic to the base of the Zechstein, this new phase involves transforming surface-based models into voxel models parameterized with seismic velocity data.

The seismic velocity data used for model parameterization stem from extensive hydrocarbon exploration campaigns conducted in both federal states between the 1960s and 1990s. Although the primary focus was on deep Permian reservoirs, data were systematically collected for Mesozoic formations as well. The dataset includes a substantial number of check-shot surveys and vertical seismic profiles (VSPs) from over 250 well, regional velocity models, stacking and migration velocities.

In a pilot region in Northwestern Brandenburg (Southwestern Mecklenburg–Western Pomerania) a concept was developed to revitalize the historical data with modern methods and cross-border harmonization was achieved in TUNB velo 2.0 showing promising results for a seamless 3D velocity field.

10.01 Open Topic

Geoparks – linking geosciences, nature and society for a sustainable future

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Geoparks are an important link between science and the public. In the guise of geotourism, they not only strengthen sustainable regional development, but also offer an interesting encounters with geology and the profound history of our planet. Geoparks enable universal access to the earth as a habitat and thus strengthen respect for nature in society.

The concept of Geoparks is designed to captivate, interest and educate people from different backgrounds. From an early age, visitors can immerse themselves in the history of the earth in a playful way with information boards, information points and games. Geoparks also offer a wide range of activities for adults: numerous geosites, guided tours, themed cycling and hiking trails and more, deepen the understanding of the environment and geology among interested locals and tourists. In this context, the Geoparks also play a decisive role, as they maintain, protect and preserve the geological heritage in the spirit of international research with their regional network.

In addition to its status as an extracurricular educational site, the Geopark Ries educational network for example enables "Geopark Ries Schools" to implement projects directly in exchange with teachers and pupils. There are teaching materials on the Ries event, projects for the preservation of intangible cultural heritage and a series of events “From science to the classroom” in cooperation with universities.

Geoparks therefore play an important role in raising public awareness of the relationship between geology, nature and people, thereby laying a solid foundation for a sustainable future.

05.03 Archaeometry – Geosciences4Humanities

Towards a better understanding of the past: Investigating the sea spray effect in modern coastal environments

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Stable isotope analyses of archaeological finds from coastal environments have been shown to be influenced by sea spray. Sea spray consists of aerosols derived from seawater that may contain various ions, potentially resulting in a marine-like isotope signature in terrestrial organisms. This so-called sea spray effect can hamper or even falsify the reconstruction of the diet or provenance, for example when investigating archaeological human skeletal remains. The magnitude of the sea spray effect and the underlying mechanisms are still unknown. In order to quantify the present-day local sea spray effect on several isotope systems ($\delta^{13}C$, $\delta^{18}O$, $\delta^{34}S$, $^{87}Sr/^{86}Sr$) at different sites close to the North and Baltic Sea, modern environmental samples are investigated. This will help us to understand the effect of sea spray on biochemical pathways in plants and the isotope signature of organisms feeding on them. Preliminary results show seasonal and regional variations in the local sea spray effect in plants. This suggests that a varying sea spray effect should also be expected in prehistoric samples from different archaeological sites. Investigating modern environmental samples of known origin will provide a better understanding of the local sea spray effect and enable the correction of the isotope fingerprints of (local) archaeological remains (e.g., animals, humans) against the regional sea spray effect. This will result in a more correct diet or provenance reconstruction and, thus, a better understanding of the past.

03.01 Recent Advances in the Geological Research of Marine Environments

Stable antimony isotope composition of hydrogenetic ferromanganese crusts

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Marine hydrogenetic iron and manganese deposits have been shown to be excellent geochemical archives of seawater chemistry. The behavior of Sb in marine environments and their interactions with marine ferromanganese (oxy)hydroxides, however, are still poorly constrained.

In this study, we report trace element concentrations and the Sb isotope composition in marine Cenozoic hydrogenetic ferromanganese crusts from the southern Central Pacific.

Antimony concentrations are enriched by a factor of approx. 3.4 × 105 compared to ambient seawater concentrations and is mostly of authigenic nature with minimal detrital input. Antimony behaves similarly to particle-reactive Zr (R2 = 0.5) and Hf (R2 = 0.6) in the hydrogenetic ferromanganese crusts, indicating Sb enrichment by surface precipitation onto ferromanganese colloid particles without significant desorption. The Sb isotope fractionation factor varies between 0.00 and 0.36‰ for the fractionation between Sb in hydrogenetic ferromanganese crusts and Pacific seawater [1]. The range in Sb isotope compositions (δ^{123}Sb = 0.37 – 0.73‰) in the hydrogenetic crusts may be explained by shifts towards heavier values with higher growth rates or different Sb isotope compositions of seawater during the growth of the crusts. Isotopic Sb fractionation in hydrogenetic ferromanganese crusts may be caused by an interplay of factors (e.g. redox transformation, Rayleigh distillation, and biologically controlled mechanisms).

The results of this study build toward a more comprehensive picture of the Sb isotope system in marine system and highlight the potential of Sb as a deep-time tracer of marine redox conditions.

Reference

[1] Rouxel et al. (2003) Chem Geol. 200, 25 – 40

06.03 3D Geological Modelling: Methods, Applications, and Regional Insights

Modern Geological Modeling: from Geostatistics to Machine Learning (and, of course, AI)

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Geological modeling is central to understanding the subsurface—whether for resource exploration, groundwater management, geothermal energy, or assessing geological risks. These models aim to integrate diverse and often sparse data into coherent representations of subsurface structures and properties.

Traditionally, geostatistics has provided a powerful framework to create geological models and to handle spatial uncertainty, allowing interpolation and simulation of rock properties based on limited observations.

However, as geological settings grow in complexity and data volumes increase, classical approaches reach their limits. Recent advances in computational geometry offer new possibilities: they enable compact, low-dimensional representations of complex geological structures that remain interpretable and physically plausible. These representations are particularly well-suited for integration with geophysical inversion methods and allow for efficient probabilistic workflows with meaningful uncertainty quantification.

In this talk, we explore the evolution from traditional geostatistical techniques to modern approaches in geological modeling, including the use of machine learning and AI. We highlight how large-scale pre-trained models—such as foundation models and LLMs—can provide a path to include contextual understanding. Through examples from joint geological-geophysical modeling and inversion, we illustrate how these novel tools offer not only technical improvements but also a conceptual shift in the use of geological models as scientific tools to understand the subsurface.

04.02 Lithium Rescources

Altmark Lithium Extraction – Redevelopment of a Historic Brine Resource in Support of EU Raw Material Goals

WENKE, AXEL

Neptune Energy, Germany

The Altmark gas field in Saxony-Anhalt, Germany, Europe's second-largest onshore gas field, hosts a lithium-rich deep formation brine previously investigated during the 1970s and 1980s. A first Direct Lithium Extraction (DLE) pilot plant was constructed during the late GDR period but never commercialized due to political and market shifts.

With the increasing urgency to develop domestic sources of critical raw materials under the EU Critical Raw Materials Act (CRMA), the redevelopment of this historic resource has resumed. The brine reservoir, hosted in the Permian Rotliegend formations, holds average lithium concentrations of >400 mg/l, with peak values of up to 600 mg/l. The estimated in-place resource of 40–50 million tonnes LCE could support sustained production of up to 25 ktpa over multiple decades.

Following renewed exploration and permitting, Germany's first lithium-from-brine production license was granted in early 2024. Recent pilot tests using ion exchange DLE technology have successfully produced battery-grade lithium carbonate from brine co-produced during gas extraction. A feasibility study is underway, demonstrator production targeted for 2027/28 and early commercial operations by 2029/2030.

Altmark Lithium Extraction demonstrates how legacy hydrocarbon assets can contribute to Europe's raw material security. The project integrates decades of subsurface data with current UNFC-aligned classification efforts to ensure transparent and traceable resource reporting in line with emerging CRMA implementation frameworks.

05.03 Archaeometry – Geosciences4Humanities

Material analyses of Pre-Columbian metal artwork from Costa Rica: Aspects of technology, provenance and regionality

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The wealth of Pre-Columbian gold, guanín (an argentiferous gold-copper alloy, also called tumbaga) and copper objects found in Costa Rica and the country's abundant ore deposits suggest a rich tradition of local metal artwork manufacturing. However, since the majority of artefacts was unearthed by illicit digging during large-scale infrastructure and construction projects in the 19th century (primarily of railways and banana plantations), their find context, dating and often also true origin usually are unknown. These circumstances severely limit understanding of e.g., the chronological and regional development of metal use and the differentiation of imports from possible local production, rendering technological and geochemical studies of the objects themselves a major source of insight into these open questions.

Here, we present a study of Pre-Columbian objects of different stylistic and material types, which were found in Costa Rica and are hosted in the collections of the Museo Nacional de Costa Rica (MNCR) and the Museo del Jade in San José/Costa Rica, and the Ethnologisches Museum Berlin. The main element composition of the objects was determined non-destructively by (near) surface analysis performed with portable X-ray fluorescence spectrometry, and their manufacturing techniques were investigated by digital microscopy. Furthermore, detailed metallographic, compositional and isotopic analyses will be carried out on fragments sampled from 30 metal objects from the MNCR. By comparison with data of Pre-Columbian metal objects from neighbouring regions, we discuss craftsmanship techniques, gold-copper supply and technological choices in artefact production, and their possible correlation with areas of origin or different workshops.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

The AMPEDEK project: Geochemical, Petrophysical and Rock Mechanical Characterization of the Crystalline Basement in Germany for High-Level Radioactive Waste Disposal

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RAMÍREZ, ÁNGEL

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The long-term and safe disposal of high-level radioactive waste remains a major concern in both scientific and public discussions. In Germany, the Federal Company for Radioactive Waste Disposal (BGE) is responsible for selecting a suitable repository. In the first phase of the site selection process, the BGE defined several sub-areas, seven of which lie within the crystalline basement. However, many of these areas lack detailed information on the mineralogical, geochemical, petrophysical, and mechanical properties of the crystalline rocks, limiting the ability to assess their suitability. To address this gap, the AMPEDEK project aims to build a comprehensive reference database for crystalline basement rocks in Germany. In the initial project phase, data from over 40 published sources were compiled and integrated. Subsequently, around 650 cylindrical plugs from drill cores and outcrops were systematically analysed for petrophysical, mechanical, thermal, and geochemical properties. Triaxial tests and thermal conductivity measurements were conducted at elevated temperatures (up to 275 °C) and pressures (up to 30 MPa) to simulate reservoir conditions. The resulting database comprises ~25,700 data points for up to 34 rock properties derived from over 8,200 samples across more than 3,400 locations in eight federal states. The results reveal a wide range and variability in rock properties, reflecting the geological complexity of Germany's crystalline basement. Lithology-specific trends in density, magnetic susceptibility, and thermal conductivity were observed. HT/HP experiments show significant changes in permeability and thermal properties with increasing temperature and pressure, underlining the need for site-specific characterization.

01.07 Stratigraphy in Earth System Science: methods, applications and case studies

Cyclostratigraphy in deep time: lessons from Devonian strata in the Rhenish Massif

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Over the past decades, cyclostratigraphy has been used to refine the Cenozoic timescale, and evidence for astronomical forcing of major climatic events has been identified in numerous records. Progress also has been made in the Mesozoic, although the absence of astronomical solutions complicates this effort. The next frontier for cyclostratigraphy is the Paleozoic. This talk will outline some of the challenges of cyclostratigraphy in deep time, using examples from the Late Devonian of the German Rhenish Massif. The Late Devonian saw repeated occurrences of widespread anoxia, some of which were associated with mass extinctions. The recurrent nature of these anoxic events suggests that astronomical forcing could have played a role in their initiation. Investigating this hypothesis requires an integrated stratigraphic approach. The cyclic deep-marine successions of the Rhenish Massif have been studied for over a century. This research history has culminated in many well-described outcrops with detailed litho-, bio-, and chemostratigraphy, ideal for cyclostratigraphy. Analysis of three sections that record the Kellwasser, Annulata, Dasberg, and Hangenberg biotic crises supports the hypothesis that these events were at least partially controlled by astronomical forcing. Furthermore, we show that cyclostratigraphy can be used to refine the Devonian timescale – if a consensus based on astrochronologies from various sites can be reached. With more and more cyclostratigraphic works being published, an astrochronological framework for the Late Devonian is starting to emerge, and the Rhenish Massif will be a key region to further develop this framework in the coming years.

06.01 Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

Hands-on presentations of 3D geomodels in Augmented Reality – Ways to bring your models to GST[AR] and thus to everyone

WIECZORECK, BJÖRN

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Communicating the nuances of (possibly complex) 3D geological concepts via geomodels is a difficult task. No matter if you are introducing students to the numerous variants of earth's volcanoes at school, teach about different types of fault zones at university, or present your latest subsurface model to colleagues at a conference: The best way for them to explore and understand such a model is by observing and directly manipulating it themselves in 3D space (compared to 2D illustrations or animations).

This is often easier said than done because proprietary formats and software, or hard to meet hardware requirements make it cumbersome or even impossible to efficiently share 3D geomodels with a wider audience. As a mobile app, GST[AR] runs on commonly used hardware without the need for complex setups and thus aims to improve that situation by lowering the barrier of entry.

With this poster we want to shortly explain what GST[AR] does and how the underlying data structure looks like. To make GST[AR] available to a large user-base, workflows and tools will be presented that enable geomodellers to make their own subsurface models accessible via the app. Furthermore the poster will act as a firsthand example of how easy it is to give conference attendees direct access to these 3D models on their own device by making use of QR codes.

01.21 Advances in Geochronology: from tradition to avant-garde

Some Observations Concerning U-Pb Data Quality Based on the G-Chron Proficiency Testing Scheme

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Starting in 2019, the International Association of Geoanalysts has run a Proficiency Testing programme designed to aid geochronology laboratories test their U-Pb zircon data for unsuspected bias. Test samples are dispatched world-wide to roughly 70 laboratories at roughly 2-year intervals. To date, three such rounds have been completed; this talk will provide some insights based the results that have been reported. The three zircon materials that have been distributed range in age from Late Archean to Mesozoic, with each material having its U-Pb homogeneity tested using the Potsdam SIMS instrument. Subsequently the target 206Pb/238U and 207Pb/206Pb values were defined by the results pooled from between three and seven ID-TIMS laboratories. From the rank distribution plots from the 70-odd laboratories it can be seen that roughly 20 % of those reporting have significant biases in their reported 206Pb/238U values. Likewise, for the two older samples it is also apparent that around 20 % of the reported 207Pb/206Pb results differ substantially from the ID-TIMS-defined target values. Another important observation is that the bias from the target values correlates poorly with the reported analytical uncertainties. A further surprise from the submitted data is that quadrupole ICPMS instruments generally report more precise results as compared to sector instruments.

01.17 Understanding Magmatic Systems: From Mush to Magma and Beyond

Measurements of $Fe^{2+}/\sum Fe$ in natural and experimental silicate glasses by EPMA: further developments of the flank method

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The redox state of mantle-derived primary magmas and their derivative liquids has been extensively studied over the past decades, yet remains a challenging topic. Insights into magma redox conditions are primarily derived from analyses of iron speciation in pillow glasses or mineral phases. Among the various techniques available to determine Fe^{3+}/Fe^{2+} ratios, the EPMA-based flank method stands out for offering high spatial resolution and accuracy at relatively low cost. Nevertheless, its routine application is still limited by the requirement of well-calibrated standards and a precision that is generally lower than that of XANES or Mössbauer spectroscopy.

In this contribution, we present further improvements of the flank method approach using a JEOL JXA-iHP200F EPMA. To address this, we synthesized a set of new dry and H_2O-bearing basaltic to andesitic glass standards ranging in $Fe^{2+}/\sum Fe$ from ~0 to 1. In addition, we used natural boninitic and fore-arc basaltic pillow glasses (IODP EXP 352) as well as Shatsky Rise pillow glasses to test the beam stability of different sample types and investigate their performance.

We demonstrate that, while dry basaltic glasses can endure high beam energies, hydrous glasses only endure about a tenth of beam energies before alteration. The precision in $Fe^{2+}/\sum Fe$ ratio obtained for dry basaltic glasses (~ ±0.05) is significantly lower compared to hydrous glasses (~ ±0.12) due to their higher stability allowing longer measurement times and stronger beam currents. Our flank method results for dry basaltic glasses generally agree with previously obtained XANES data of the same samples.

10.01 Open Topic

Bloom Taxa and Analogous Morphological Diversification after the K-Pg Boundary

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citizen scientist, Germany

Despite distinct evolutionary origins, the gastropod Araeodactylus and Perissoptera lineages show striking morphological parallels, suggesting convergence in ecological roles and locomotion strategies after the K-Pg boundary.

Araeodactylus, known from Paleogene strata, likely originated in the Late Cretaceous and is linked to “Chenopus buchii” Münster, 1839 sensu lato, with a possible Jurassic ancestor in Bicorempterus Gründel, 2001. Key morphological features include a teleoconch with spiral lines, a single apertural digit, and a straight to slightly bent rostrum.

On the other hand, Perissoptera likely descends from the Jurassic Pietteia Cossmann, 1904, both characterized by axial teleoconch ornamentation and a similar single apertural digit, which evolved in Perissoptera into a wing-like structure by the Maastrichtian.

Post-K-Pg, both lineages developed broad wing-like extensions. These may have functioned as protective feeding chambers, as in Xenophoridae, or supported locomotion—hydrodynamic gliding or swimming—as proposed by Savazzi, 1991, aligning with the diverse movement strategies seen generally in Stromboidea. While the Araeodactylus group and the broad-winged members of the Perissoptera group fully vanished in the Paleogene, various genera of the Perissoptera group survived and are now known as the family Rostellariidae.

Conclusion:

Despite originating separately, Araeodactylus and Perissoptera lineages demonstrate strikingly parallel evolutionary stories shaped by mass extinction at the K-Pg boundary, adaptive radiation, and eventual climate-induced collapse in the Oligocene.

Reference

Savazzi, E. (1991). Constructional morphology of strombid gastropods. Lethaia 24(3): 311–331.

01.12 Coastal dynamics in different timescales: from seconds to millennia

A Barrier-Lagoon Record of Sea-Level Change During the Late Pleistocene in Northeastern Oman

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Understanding past climate dynamics is critical for improving projections of future climate change (IPCC, 2022). The Last Interglacial period (126–115 ka), characterized by elevated global temperatures and sea levels, serves as a valuable analog for anticipating future climate scenarios. While this period has been extensively studied in some areas, the Arabian Peninsula and adjacent Indian Ocean region remain comparatively underexplored (Rovere et al., 2023). Coastal sediments at Ras ar Ru'ays in northeastern Oman, situated 1–3 meters above present sea level, are likely linked to the Last Interglacial (Decker et al., 2024) and offer promising insights into past sea-level behavior. This study examines these deposits, which consist of interbedded sand and silt layers and a shelly coastal bar. A total of six sedimentary profiles and nine thin sections were investigated, both in the field and through micro facies analysis, to characterize lithofacies, diagenetic features, and depositional settings. Stratigraphic cycles were identified from the profiles to assess the role of climatic and sea-level fluctuations. Results indicate that the outcrop represents a barrier-lagoon system, an environment shaped by dynamic coastal processes and variable energy conditions tied to changes in sea level and climate.

01.14 „Geomorphology and sedimentology beyond boundaries“ – towards integrating geomorphology and sedimentary system science

Capturing or Shredding Milankovitch Climate Cyclicity within Death Valley Alluvial Fans

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The distribution of grain size in sedimentary fans is commonly used as a record of past climate fluctuations. The fidelity of this record can, however, be affected by several processes such as highly condensed stratigraphy or strong autogenic geomorphic processes that tend to ‘shred’ the climate signal. In this study, we use a coupled FastScape erosional–depositional landscape evolution model with a gravel grain-size model to identify the environmental and geomorphic conditions that optimize the generation and preservation of climate-driven grain-size signals. Our results indicate that such signals are most reliably recorded in low-bypass, transient, and topographically constrained alluvial fans.

To illustrate this, we apply an optimization approach to a gravel fining dataset, catchment wide erosion rates, and topographic profiles from two alluvial fans in Death Valley described in D’Arcy et al. (2017). These fans were interpreted as preserving climate signals tied to Milankovitch-scale rainfall variability despite some channel incision on a neighbouring fan surface (D’Arcy et al, 2017). Our analysis suggests that these systems are near-optimally configured for archiving climatic fluctuations. The methodological framework we present can be used to inform the design of future grain-size data collection strategies and offers a tool for assessing the potential of other fan systems to preserve paleoclimate signals in their depositional stratigraphy.

Reference

D’Arcy, M. et al. (2017). Sedimentology, 64(2), 388–424

01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

Magnetic mineralogy of the Laacher See deposits: Indicators of fractionation processes and emplacement conditions

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BERCKHAN, JOHANNA

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The eruption history and geochemistry of the Laacher See tephra 12.9 ka ago are well-documented. This study is the first to investigate the magnetic properties of the approximately 55 m thick tephra deposits south of the vent. The goal is to establish a relationship between magnetic properties, magma fractionation processes, and emplacement conditions. Magnetic susceptibility, its field- and temperature-dependence, and natural remanent magnetization were measured, and the petrography of the opaque phases was studied. Magnetic susceptibility increases significantly with stratigraphic height, starting from very low values in the lowest deposits. This trend is also seen in remanent and total magnetization, due to an increase in the number and size of titanomagnetite grains in ash and pumice lapilli. The increase in crystal content is attributed to the highly zoned magma reservoir of the Laacher See volcano, resulting from fractional crystallization. Post-eruption, the tephra deposits represent the inverse magma column, with less fractionated crystals at the top. Field- dependence measurements of magnetic susceptibility reveal three zones with slight field dependence (up to 10 %) and a zone without field dependence in between. These four zones are also observed in temperature-dependent magnetic susceptibility. Heating curves typically show Curie temperatures between 480 °C and 530 °C, while cooling curves show significantly lower Curie temperatures (up to 200 °C), likely due to cation ordering effects. Total magnetization values provide new insights into the magnetic anomaly field in the Laacher See region, suggesting previous models overestimated magnetization by up to two orders of magnitude at depth.

01.05 From mantle to crust: following melt and fluid evolution from source through the lithosphere

Across-Arc Molybdenum Isotopes Variations in the Kamchatka Subduction Zone System

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Molybdenum (Mo) isotopes are emerging as a valuable tracer of magmatic processes across diverse geological settings. Here we present Mo isotope data from the Kamchatka arc in the NW Pacific, spanning basaltic lavas along a SE – NW transect from the volcanic front to the back-arc. Most of the studied volcanic centres are situated above the subducting Hawaii–Emperor Seamount Chain.

Our results reveal systematic variations in $\delta^{98}/^{95}$Mo correlated with trace element ratios (Ce/Pb, Ce/Mo, Nb/Zr, La/Sm) and ^{143}Nd/^{144}Nd across the arc. Lavas from the arc front exhibit higher $\delta^{98}/^{95}$Mo and lower Ce/Pb, Ce/Mo, Nb/Zr, and La/Sm compared to back-arc lavas. As a subducted sediment contribution can be ruled out, we interpret these trends as reflecting a change in mantle source composition from arc front to back arc.

At the arc front, high $\delta^{98}/^{95}$Mo and low Ce/Pb and Ce/Mo point to a dominant slab-derived fluid component. In contrast, back-arc lavas show signatures more typical of an enriched mantle, with mantle-like Ce/Pb and Ce/Mo, and elevated Nb/Zr and La/Sm. Notably, the combined $\delta^{98}/^{95}$Mo, Nd, and Pb isotope signatures of back-arc lavas closely resemble those of modern Hawaiian ocean island basalts.

These observations suggest that the back-arc mantle may have been modified by an enriched asthenospheric component akin to that beneath Hawaii, potentially introduced by the subducted Hawaii–Emperor Seamount Chain.

09.02 Museen als Fenster in die Forschung

PAINTING THE PAST: BRINGING 500 MILLION YEARS OF MADYGEN BACK TO LIFE

WINKLER, ALINA

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In southwestern Kyrgyzstan, a complexly folded landscape provides an exceptional opportunity to study geological and biological evolution throughout the Phanerozoic in a one-day walk. Situated between the Southern Tian Shan and the Fergana Basin, the Madygen region offers an almost continuous stratigraphic record from the Cambrian to the present. While the Paleozoic and Cenozoic sequences are predominantly marine, the Mesozoic strata reflect extended continental environments.

To promote scientific research, education, and geotourism in this developing country, the Madygen area aspires to become a certified UNESCO Global Geopark. Madygen's great potential for paleobiological research also offers an ideal setting for science communication. A new series of paleoart brings to life the diverse fossil flora and fauna, as well as the manifold habitats across the Phanerozoic.

The local Madygen Formation, a lacustrine Middle to Late Triassic fossil conservation Lagerstätte, impresses with its exceptional quality and quantity of paleontological finds. To date, over 30,000 fossils—including at least 500 insect species, twelve endemic vertebrate species, and numerous ichnofossils—have been recovered from these strata (Voigt et al., 2017).

But Madygen's geological and paleontological richness extends far beyond the Triassic. The area's diverse Cambrian fauna includes stem-group cnidarians and mollusks, brachiopods and trilobites, and many newly described taxa (Geyer et al., 2015). Prominently red Cretaceous strata with large ichnofossils transition into Paleogene marine sediments, which represent unique paleogeographic realms containing oysters and other mollusks, chondrichthyan and fish fossils, and various microfossils (e.g., Trubin et al., 2025).

02.02 Trace fossils as indicators for the ecology, function, physiology and behaviour of fossil organisms and their evolution in the context of palaeoenvironmental change

EXCEPTIONALLY LARGE FOSSIL BURROWS FROM CRETACEOUS DEPOSITS OF THE SOUTHERN FERGANA BASIN (SW KYRGYZSTAN) AND THEIR PALEOENVIRONMENTAL IMPLICATIONS

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In the Southern Fergana Basin (southwestern Kyrgyzstan), strikingly red siliciclastic Cretaceous strata contrast sharply with surrounding lithologies, including older Triassic to Jurassic terrestrial, and younger Paleogene marine sediments within the Madygen Geopark area (Trubin et al., 2025). These Cretaceous deposits are associated with marginal marine settings, reflecting the marine transition of this complex and long-lived basin and its connection to the Peritethys (Getman et al., 2015).

These Cretaceous deposits lack body fossils and diagnostic sedimentary structures, hindering precise stratigraphic and paleoenvironmental interpretations. However, previously undescribed, exceptionally large ichnofossils, interpreted as burrows, offer rare insights into the Cretaceous of the Southern Fergana Basin. At three sites within the Madygen Geopark area, these structures are remarkable in size, density, and abundance, making them the only known evidence of macrobiotic activity from this time in the region. Despite the absence of body fossils, the burrows preserve sufficient morphological detail to suggest functional significance and potential tracemakers.

Their presence provides a valuable proxy for reconstructing local paleoenvironmental conditions during the Cretaceous and help interpret the extent of the shifting habitat. Moreover, the ichnofossils contribute to the broader understanding of large fossil burrows—an ichnological group often difficult to interpret due to the lack of modern analogs (Bromley et al., 1975). To support further analysis, the ichnofossils were documented using photogrammetry, and selected samples were examined via scanning electron microscopy (SEM). We suggest that the burrows have been produced by crustaceans, as they show strong similarity to the ichnogenus Camborygma (Hasiotis and Mitchell, 1993).

01.10 The co-evolution of the Earth and life from the early Archean until today

The suitability of ca 3.25 Ga banded iron formations from the Fig Tree Group (Barberton Greenstone Belt, South Africa) as archives for Palaeoarchaean seawater chemistry

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Banded iron formations (BIFs) are authigenic marine sedimentary rocks that may record the chemical composition of ancient seawater and are widely used as geochemical archives to reconstruct Precambrian marine environments. In this regard, the approximately 3.25 Ga old BIFs of the Fig Tree Group, Barberton Greenstone Belt, have been shown to be prime recorders for Palaeoarchaean marine environmental conditions and seawater chemistry during the early stage of Kaapvaal Craton formation [1, 2].

To further evaluate the suitability of this BIF and its individual mineral phases as geochemical archives, we present trace and major element concentrations of 13 layers dominated by magnetite, chert, and siderite from the BARB 4 drill core. Immobile element (Zr, Th) concentrations vary over four orders of magnitude between the samples. In combination with non-seawater-like shale-normalised (subscript SN) rare earth element and yttrium (REY) patterns, this indicates variable degrees of detrital contamination. However, cherts and two of the magnetite samples show typical Archaean seawater-like signatures with positive LaSN GdSN, and YSN anomalies as well as a depletion of light REY relative to heavy REYSN, indicating a seawater-derived origin. The lack of a negative CeSN anomaly and positive EuSN anomalies indicate anoxic environmental conditions and contributions of high-temperature hydrothermal fluids, respectively.

Our results show that chert in BIF is the most reliable mineral phase for obtaining information to reconstruct BIF depositional environments through deep time.

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04.01 Prospection and extraction of critical and strategic raw materials in Europe

Actions and actors in the geosciences for greater CRM resilience in Europe?

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Societal needs, as well as trade distortions and political paradigm shifts, increasingly emphasize the need to ensure greater resilience in access to and supply of raw materials in Europe. The Critical Raw Materials Act is one-step in this direction. Actions and actors must flesh out the legal framework. In the geosciences, this requires a variety of actors and public and private sector actions to create the basis for fundamental information. The high investment required to develop a discovery into a deposit through to a mine must be underpinned by high quality and available technical data. From universities to exploration companies, from geological monitoring organizations to mining companies, all have important roles to play in developing reliable and ecologically and environmentally sustainable solutions. Insights are derived from specific case studies and used to develop viable solutions. In order to improve the availability of raw materials in Europe in a timely manner, the national exploration programs in the first cycle will focus on selected areas with high potential for selected raw materials. Exploration campaigns can then concentrate on the most promising areas. By concentrating on potential development areas and providing easily understandable, comprehensive reports (e.g. according to PERC and UNFC), the application process for development and approval for operation can also be improved.

03.04 All about carbonates

Denudation and weathering rates of carbonate landscapes from new cosmogenic methods

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Karst landscapes provide vital services to humans, but the rates and controls of carbonate rock weathering and erosion, in sum termed denudation (D), are not well constrained. To address this gap, we adapted a framework using the cosmogenic meteoric10Be/9Be ratio. Radioactive 10Beryllium (Be) traces atmospheric input, while stable 9Be indicates weathering. This method can be performed on water, soil, sediment, or travertine, does not rely on specific minerals like quartz or calcite, and D can be partitioned into weathering and erosion rates. Extensive testing showed that the method is suitable for both pure limestone and mixed carbonate-siliciclastic settings.

We employed the 10Be/9Be method to the temperate limestone-rich French Jura Mountains, obtaining rates of catchment-wide D (from sediment) and point source D (from soil). Average D range from 300–500 t/km^2/yr, with denudation primarily driven by weathering (W/D > 0.92), and a non-negligible contribution to weathering from deep (below soil). These rates are consistent within a factor of two when compared to decadal-scale D derived from combined suspended and dissolved fluxes, underscoring the substantial potential of this method for Earth surface research in karst landscapes.

On a global scale, our data provide the first cosmogenic nuclide-based denudation rates for the mean annual precipitation (MAP) range of 1,200–1,700 mm/yr under dense vegetation cover. At similar MAPs, our rates exceed previous rates derived from e.g. *in situ* 36 Cl measured in calcite from less vegetated sites. Altogether, global D patterns suggest a control of precipitation on D and/or W that may be modulated by vegetation cover.

04.03 Understanding Metal Enrichment Processes – Advances in the Genesis, Evolution, and Geodynamics of Ore Deposits

Organic Matter Alteration in Kupferschiefer: The Role of NSO Compounds during Mineralization

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The Late Permian Kupferschiefer in north-central Europe is one of the world's most significant sediment-hosted stratabound copper (SSC) deposits, with mining of copper and other base metals dating back to the Middle Age (Borg, 2012; Paul, 2006).

Organic matter (OM) is thought to play a key role in the mineralization process, as previous studies have indicated pronounced alteration patterns in bulk parameters and non-polar biomarkers in mineralized rocks, using conventional analytical methods. However, subtle changes in organic composition may remain undetected using these approaches. Moreover, the exact mechanisms governing OM transformations during mineralization remain unresolved (e.g. Bechtel et al., 2002). Poetz et al. (2022) expanded the traditional approach by integrating polar compounds containing nitrogen, sulfur and oxygen (NSO) using high-resolution mass spectrometry (FT-ICR-MS), as these compounds are more reactive than hydrocarbons. They observed alteration of the oxygen containing compounds that correlated with the metal content but did not find significant differences in NSO compound composition between Cu mineralized rocks and Zn-Pb mineralized rocks. Building on this, we have analyzed samples with varying degrees of mineralization and thermal overprint by combining bulk and molecular parameters obtained through conventional analytical methods (GC-MS, GC-IRMS, ICP-MS, and Rock-Eval pyrolysis) with FT-ICR-MS data, aiming to provide a more comprehensive understanding of OM alteration and its dynamics during mineralization. Preliminary data suggest next to an enhanced OM alteration in the highly mineralized sample, an enhanced aromaticity which may resulted from oxidative processes.

03.08 Earth Surface Systems and tipping elements in a changing climate

Critical turning points in the geomorphological evolution of the Guadix-Baza Basin (Geopark Granada, Spain) during the middle to late Quaternary

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Within the last 600 ka, the Guadix-Baza Basin underwent a number of significant geomorphological phases during its transformation from a flat endorheic basin towards the today´s deeply dissected erosion scenery.

Some of these phases represent turning points that introduced an entirely different geomorphic process structure such as the complex multi-phase capture of the basin. Other phases are characterized by unprecedented process intensities that, however, are leveled by opposing feedback-mechanisms such as incision and aggradation within dimensions of several tens of meters. Beside climate impact and the progressive down-cutting of the erosion base at the basin outlet, likewise tectonics exerted noticeable effects on prevalent geomorphic processes. Therefore, identifying causal factors remains a demanding task considering, furthermore, that climate archives are rare within the basin.

Here we present several examples in which way fluvial system behavior responded to certain external and internal impacts. Due to extensive geomorphological mapping and a hitherto unknown density of luminescence dating, we are able to provide a detailed picture of the fluvial evolution of the basin.

01.05 From mantle to crust: following melt evolution from source through the lithosphere

Geochemical Evolution of Age-Progressive Magmatic Centres in the Northern Aegean Arc

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Over the past 32 million years, slab rollback and trench retreat in the Aegean region have led to back-arc extension and southward migration of the subduction zone. Consequently, several age-progressive plutonic centres with associated volcanism formed over a ~300 km distance. This study compiles new and existing geochemical data from igneous rocks of the four oldest magmatic centres in northern Greece: Leptokaria/Kassiteres (~32 Ma), Maronia (~29 Ma), Samothraki (~23–16 Ma), and Limnos (~22–19 Ma).

Major and trace element data reveal significant compositional diversity among the magmatic units. Maronia, Samothraki, and Limnos exhibit shoshonitic compositions characterized by strong enrichment in incompatible elements, whereas Leptokaria/Kassiteres is dominated by a high-K calc-alkaline series with more moderate incompatible element enrichment.

Isotopic data indicate that the two oldest centres, Leptokaria/Kassiteres and Maronia, have less radiogenic Sr and more radiogenic Nd signatures than the younger shoshonites from Samothraki and Limnos. In addition, the shoshonitic rocks display higher La/Yb ratios than the calc-alkaline samples, with the highest values observed in the Limnos and Samothraki samples.

High P/Nd and Ba/La ratios in the shoshonites are consistent with a lower degree of partial melting, however, suggest an additional influence from a mantle source enriched by subducted P- and Ba-rich sediments. Nd/Sr and Hf/Nd ratios, together with isotopic signatures, indicate that sediment–mantle mixing played a major role before partial melting. The observed geochemical and isotopic diversity along the arc is likely the result of mixing of variable sediment with the mantle, possibly in the form of a heterogeneous peridotite–sediment mélange.

03.04 All about carbonates

Cluster-mediated formation of amorphous calcium carbonate: compositional gatekeepers, bindings partners of biomineralization proteins, and agents in spinodal demixing

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Which mechanisms underlie the formation of amorphous calcium carbonate, and how do organic compounds and foreign ions — such as biomineralization proteins or Magnesium — impact these processes? In addressing these outstanding questions, we conducted a comprehensive set of studies, adopting a molecular perspective. A particular emphasis has been placed on so-called prenucleation clusters and their as-yet elusive impact on calcium carbonate formation. These dynamic clusters, composed of interconnected chains of carbonato-calcium units, have been interpreted as proto-nucleation germs, a nonclassical crystallization species that remains debated. The present study demonstrates their role as compositional gatekeepers of the later ACC phase for organic inclusions and foreign elements, e.g., giving rise to notably low Mg distribution coefficients. In addition, we show distinct interaction with characteristic low-complexity repeat regions typical for biomineralization proteins, revealing clusters as putative binding partners, thereby deorphanising a wide range of biomineralization proteins. From a synthetic perspective, these coordination polymers can thus undergo supramolecular interactions, which breaks new ground for further expansion towards phase separation pathways uncommon for ionic and sparingly soluble mineral systems. With controlled fast flow chemistry, which ensures turbulent mixing, we even achieve spinodal demixing on larger scales, forming characteristic nanosized bicontinuous networks in various cluster-forming inorganic systems. The presented results emphasize the chemical nature of these pre-critical solution species, particularly their specific molecular interaction with organic compounds and their capability to generate supramolecular assemblies.

01.01 Multidisciplinary perspectives on solar system formation and evolution

Germanium isotopes reveal distinct processes of moderately volatile element depletion among planetesimals

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The depletion of moderately volatile elements (MVEs) is a key characteristic of planetary materials, but the origins of these depletions are unclear. To investigate the relative importance of nebular vs. planetary volatile depletion processes, we studied the mass-dependent isotopic composition of the MVE Ge in chondrites and iron meteorites. Chondrites exhibit Ge isotope fractionations which correlate with matrix mass fraction and Ge depletion. This indicates mixing between volatile-rich, isotopically heavy matrix and a volatile-poor, isotopically light chondrule component. Despite much larger Ge depletions, iron meteorites exhibit a similar range of Ge isotope fractionations as chondrites. Specifically, the strongly depleted IVA/IVB irons have lighter Ge isotope compositions than CI chondrites, while there rarely are iron groups with heavier compositions. These observations indicate that the MVE depletions among irons cannot simply result from degassing of CI-like starting materials. Instead, these systematics likely reflect two stages of MVE depletion. The first stage took place in the solar nebula and, like for the chondrites, involved mixing of volatile-rich and volatile-poor precursor components. The second stage occurred on the iron parent bodies and likely involved degassing from molten iron cores, after collisional disruption of the parent bodies. While for most irons the Ge elemental depletion mostly occurred during this second stage, these losses do not appear to have induced large Ge isotope fractionations. As such, an iron parent bodies' Ge isotopic composition largely reflects that of its precursor material. Thus, both primordial nebular and secondary planetary volatile loss shaped the MVE budgets of differentiated planetesimals.

01.06 Tectonic Systems – TSK Open Session

Slip histories of normal faults and landscape evolution in the European Alps

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The European Alps are dissected by north-south trending normal fault systems which are the surface expression of orogen-parallel extension during convergence between European and Adriatic plates. However, the slip rate and time when normal faulting proceeded remain debated. Here I present thermochronological data and thermokinematic modelling on the most prominent normal faults of the European Alps, the Simplon, Brenner, and Katschberg normal fault. This allows us to constrain the time when they were active as well as their fault slip rates. Our results indicate that east-west extension in the Eastern Alps decreases towards the east in concert with decreasing north-south extension.

To the east of the Katschberg fault, the topography comprises a low-relief surface at an elevation of 2000-2200 m which has been formed in the Early Miocene. To decipher the exhumation history of this remarkable landscape we employ thermochronology on elevation profiles in this area and we compare the results to our profiles from the Ötztal which has one of the highest topographies of the European Alps.

In the last part I will compare the long-term erosion rates derived above to erosion rates on a millennial time scale derived by cosmogenic nuclides. Cosmogenic nuclides also allow us to calculate exposure ages, e.g. from glacially polished quartz veins. Our exposure ages on quartz veins are in concert with the model predictions for the timing of ice retreat after the last glacial maximum.

04.07 Mineralogy of Secondary Raw Materials

Time-resolved hydrate phase evolution and pozzolanic reactivity of OPC mixtures, considering different modifications of leached spodumene

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During lithium extraction from spodumene, leached spodumene concentrate (LSC) is generated as a mineral by-product. Previous studies have indicated its promising pozzolanic potential, suggesting its suitability as a supplementary cementitious material (SCM) [1]. This study investigates the influence of the two leached spodumene (LS) modifications in LSC on the evolution of hydration phases and pozzolanic reactivity in cementitious systems. Two LSC samples with differing proportions of hexagonal leached spodumene (H-LS) and tetragonal leached spodumene (T-LS) were selected and incorporated into blended cement mixtures at 10, 20, and 30 wt.%, hydrated for 28 days. The change of mineral phases with reaction was followed by X-ray diffraction (XRD). Subsequent Rietveld analysis was performed to quantify the phases after different reaction times. Additionally, thermogravimetric analysis coupled with differential scanning calorimetry (TG-DSC) and isothermal calorimetry measurements were conducted to gain further insights into the hydration behavior and reaction kinetics. For comparison, synthetic reference phases (α-, β-, and γ-spodumene as well as H-LS and T-LS) were produced and characterized concerning their pozzolanic activity. The results reveal no significant differences in the hydration behavior of the two LSC samples, indicating that both H-LS and T-LS exhibit comparable pozzolanic reactivity. Overall, the ratio of H-LS to T-LS appears to have only a minor influence on the hydration performance and reactivity.

Reference

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06.01-b Data Management, Research Data Infrastructures, AI-Applications and 3D Visualization Techniques: Meeting Today's and Future Needs in Geosciences

A Data-Driven Approach to Identifying Optimal Direct Air Capture Deployment Sites in Germany

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Direct Air Capture (DAC) is a carbon dioxide removal (CDR) technology that extracts atmospheric CO_2 for storage or utilization. This study presents a data-driven approach to identify optimal DAC deployment sites in Germany, focusing on the North German Basin (NGB), a region with promising geological CO_2 storage capacity. Building on 92 identified storage traps, we integrate K-means clustering machine learning algorithm to evaluate surface conditions using both environmental and infrastructural datasets.

Criteria were selected from the literature and divided into onshore and offshore constraints, including factors such as population density, protected areas, pipeline access, seismic activity, and shipping routes. Spatial data processing involved aggregating raster inputs into 100 m^2 grid cells and calculating distance maps from key infrastructure and risk zones. All the features were homogenized in the same format to process it through K-means algorithm.

K-means clustering, supported by the Elbow method, grouped potential DAC sites based on geospatial similarities. Cluster results were compared using a 5-level suitability ranking system (J-scores), which assigned scores based on site characteristics and normalized them for comparability. The resulting surface suitability map highlights high-priority regions. The developed methodology can then be used for larger geological regions for which 5-level ranking suitability ranking system is not feasible. This methodology offers a scalable, machine learning-supported framework for DAC site selection that integrates geospatial, environmental, and infrastructure criteria. It serves as a valuable tool for planners, industrial operators and stakeholders aiming to strategically implement DAC. The method is transferable to other regions with appropriate data availability.

04.01 Prospection and extraction of critical and strategic raw materials in Europe

Assessment of uncertainty to achieve CRMA goals of rare earth mining in Europe

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Metallic and mineral raw materials demand is expected to significantly increase globally due to transition towards low carbon technologies and population growth. To meet its carbon emission reduction targets (net zero by 2045), the German Government aims to further expand technologies such as wind energy and electric vehicles, increasing the need for critical raw materials, including rare earth elements (REE). For that, the German Government aims to increase the amount of EVs on its roads from 1 million in 2021 to 15 million in 2030. Furthermore, it aims to increase onshore wind energy capacity from 56 GW to 115 GW and offshore capacity from 7 GW to 30 GW between 2020 and 2030. In order to achieve the goals, investments in REE mining and processing should be supported, along with the research on recycling and substitution. Since Germany and the EU27 rely on imports from countries with high market concentration, a resilient and sustainable REE supply is essential to avoid supply disruptions.

This study examines company announcements to assess whether the CRMA benchmarks are feasible for REE mining. We use the uncertainty of raw material projections to estimate the reasonability of CRMA to achieve 10% REE from mining in EU27 by 2030. Our results indicate that the achievement of the CRMA benchmark w.r.t. REE mined from EU27 deposits is not feasible in the given timeframe, but expected demand may be covered at a later stage if assumed results from scoping studies would turn out to become reserves.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Geological and Mineralogical Exploration of Basement Rocks in the Xarardheere Area, Mudug Region, Somalia

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This study investigates the geological and mineralogical characteristics of basement rocks in the Xarardheere area, central Mudug Region, Somalia. The region is part of the Precambrian crystalline basement of East Africa, yet remains poorly studied. Through detailed field mapping, petrographic analysis, and mineralogical investigations, the study identifies key lithologies including granitic gneisses, amphibolites, and mica schists. Petrographic observations under polarized light revealed mineral assemblages dominated by quartz, feldspars, biotite, and hornblende, with accessory minerals such as zircon and opaque phases. Textural relationships suggest multiple deformation and metamorphic events, supported by observed foliation, folding, and mineral alignment. X-ray diffraction (XRD) analysis provided further confirmation of mineral phases and detected alteration zones, possibly linked to fluid-rock interactions. The findings contribute valuable data to the understanding of Somalia's Precambrian basement and offer insights into its tectonometamorphic evolution. This research establishes a foundation for future work in geochronology, structural geology, and mineral resource assessment, particularly in an area with limited previous study. The outcomes hold significance for regional geological correlation and potential applications in mineral exploration and geotechnical development.

03.05 Advances in Paleoclimate Proxies and Their Applications

Ancient atmospheric triple oxygen isotope signatures preserved in fossilized cosmic spherules constrain paleo-CO_2 levels

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Iron-rich I-type cosmic spherules — micrometeorites formed by the complete melting and oxidation of extraterrestrial Fe, Ni metal particles — incorporate oxygen from the Earth's atmosphere. As a result, they can be used to assess the triple oxygen isotope composition of atmospheric O_2, offering insights into CO_2 levels and global primary production [1,2]. When recovered from sedimentary rocks, these spherules can preserve a record of atmospheric conditions dating back billions of years. To date, no published triple oxygen (and triple iron) isotope data exist for fossil I-type cosmic spherules. This study aims to address this gap as we establish using fossil I-type cosmic spherules as an archive of Earth's atmospheric oxygen isotope composition and by quantifying associated CO_2 levels during key geologic periods. We analyzed a collection of fossil I-type cosmic spherules extracted from Phanerozoic sedimentary rocks, focusing on both triple oxygen and triple iron isotope compositions. This approach allowed us to reconstruct the triple oxygen isotope anomalies in past atmospheric O_2 and to assess the potential terrestrial alteration of these spherules. Our data reveal moderate ancient CO_2 levels during the Miocene (~8.5 Ma) and late Cretaceous (~87 Ma). We also demonstrate the competitive precision of using I-type cosmic spherules for paleo-CO_2 determination. Additionally, our work indicates that morphologically intact spherules can be isotopically altered by terrestrial processes, underscoring the need for rigorous sample screening.

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01.21 Advances in Geochronology: from tradition to avant-garde

Radiometric age dating of black opal (Volyn, Ukraine)

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Opal ($SiO2 \bullet nH_2O$) is one of the few non-crystalline minerals. Due to its amorphous nature, high porosity, arrangement in spheres of silica nanograins, and elevated H_2O content, it poses significant challenges for radiometric dating. Consequently, opal has rarely been used as material for dating purposes, although it occurs relative widespread in both sedimentary and hydrothermal environments. Here we present results of U-Pb dating of black opal (pigmented by organic matter), which occurs in miarolitic pockets of pegmatitic rocks within the Precambrian Korosten Pluton (Western Ukraine). The opal formation age is of particular interest, as these pockets also host the Volyn biota (Franz et al. 2023, doi.org/10.5194/bg-20-1901-2023, see talk in session 01.10).

U-Pb dating was carried out by LA-ICP-SF-MS at KIT (Karlsruhe) on three different samples, using an ELEMENT XR (Thermo-Scientific) coupled to a 193 nm Excimer laser. Opal from a Li-mica-rich domain, with very low common Pb content, yielded a Triassic age of 201+8/−14 Ma, reflecting the minimum time of opal formation. In contrast, opal from alkali-feldspar-rich domains, which is always enriched in common Pb, yield Jurassic lower intercept ages of 168±6 Ma and 156±5 Ma, perhaps dating fluid infiltration. An altered opal crust gave a (sub)recent age, suggesting Pb-loss during a very recent hydrothermal overprint. The results show that LA-ICP-MS techniques provide a potential tool to place new constraints on the timing opal formation, fluid infiltration and alteration, and to gain new information about the late-stage hydrothermal evolution of the Eastern European platform.

01.06 Tectonic Systems – TSK Open Session

Authigenic monazite-xenotime-rutile-zircon growth in white-mica schist – complex fluid-rock interaction at 530 Ma, Espinhaço Range, Brazil

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Petrographic observations, mineral-geochemical data and results of *in situ* U-Pb dating and Nd isotope analyses provide evidence not only for authigenic growth of zircon, xenotime, rutile and monazite in white-mica schist at ca. 530 Ma, but also for the preservation of detrital grains of zircon, rutile and monazite that crystallized between ~3100 and 1150 Ma. The authigenic character is indicated by zircon outgrowths closely intergrown with xenotime and rutile crystals, and by a U-Pb lower intercept age of 530 ± 5 Ma, estimated for xenotime and monazite rims. The zircon outgrowths occur where detrital zircon faces are dissolved in contact with Fe-Mg-rich phengitic muscovite, suggesting the involvement of an aqueous fluid enriched in K-Mg-Fe-Al-Ti-P near the thermal peak at 510 °C. In contrast, authigenic monazite rims overgrowing rounded cores were formed during the retrograde evolution, as indicated by their local occurrence in assemblage with kaolinite and extreme geochemical compositions. The monazite rims show very low U contents (4–14 ppm), extremely high Th/U ratios (up to 1670), and nearly identical 143Nd/144Ndt (0.51184 ± 0.00006), values that markedly differ from the detrital cores (143Nd/144Ndt=0.51000±0.00050; U=162–16418 ppm; Th/U=2.6–153). The high Th/U ratios point to the involvement of an oxidizing fluid, in line with late goethite formation. Monazite microstructures, results of geothermobarometry, and Nd isotope characteristics point to a chain of processes, from partial dissolution of detrital monazite, through REE transport and Nd isotope homogenization in an aqueous fluid, to monazite-rim growth at T = 280 °C and P < 3 kbar.

05.03 Archaeometry – Geosciences4Humanities

Synchrotron Radiation and Mobile Technology for Cultural Heritage: New Perspectives with PETRA III, PETRA IV and ENCI

ZERBE, KATRIN

DESY, Germany

Cultural heritage research is undergoing a transformation—driven by cutting-edge facilities like PETRA III at DESY. This keynote presents recent advances in non-destructive analysis of archaeological and historical artefacts using synchrotron radiation.

PETRA III enables ultra-precise imaging and spectroscopy, already providing new insights into the material composition, manufacturing techniques, and provenance of objects such as ancient cuneiform tablets and complex painted surfaces.

Looking ahead, PETRA IV will offer nanometer-scale resolution, allowing researchers to visualize fine pigment distributions, organic binders, and microstructural ageing processes—opening up new dimensions for archaeometry and conservation science.

These stationary large-scale infrastructures are complemented by ENCI, a mobile high-resolution CT scanner developed with the “Understanding Written Artefacts” cluster. ENCI allows *in-situ* 3D imaging of fragile objects, such as sealed tablets, in museums or excavation sites—without transport or damage—and has been successfully deployed in Paris and Ankara.

Together, these technologies signal a shift from isolated analyses toward data-driven, integrated approaches to cultural heritage research and preservation.

01.18 Regional Geology – the wider Göttingen area, Germany and beyond

Unravelling provenance and diagenetic evolution of an Upper Rotliegend conglomerate: A single clast perspective from the Schadewalde 2/75 borehole, Saxony-Anhalt, Germany

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The polymict Upper Rotliegend conglomerate of the Schadewalde 2/75 borehole, Saxony-Anhalt (Germany) represents a high-resolution archive of erosion and sediment supply along the northeastern Permian Saale Basin. The clasts are embedded in a matrix-rich, poorly sorted conglomerate, representing proximal alluvial fan deposits of the Upper Rotliegend (Havel Subgroup). Microscopic investigations of core samples from the 1407–1440 m depth interval, reveals a broad spectrum of clast lithologies, including milky quartz, various plutonic, volcanic, and metamorphic rock fragments. This lithological diversity suggests a heterogeneous provenance and reflects a complex depositional history. Our study focusses on characterising the range of clast composition and textures to unravel the provenance.

Although the dataset is still in progress, a coarse graphically textured pegmatitic biotite quartz-monzonite to monzodiorite clast already illustrates the informative potential of individual grains. Microscopic investigation reveals graphic intergrowth of quartz and K-feldspar, perthitic K-feldspar, altered plagioclase, chloritised biotite, and late diagenetic chlorite-filled micro-fractures. These microstructures suggest crystallisation from a volatile-rich melt upon slow cooling, followed by potential greenschist-facies deformation, and/or hydrothermal alteration, predating erosion, transport, and deposition of the clast. Subsequent diagenetic fluid overpressures may have triggered micro-hydrofractures during basin subsidence, facilitating chlorite precipitation. Although representing only a single clast, its characteristics suggest a nearby Permian exposure of highly evolved granitic plutons, providing insights into the source area, basin-margin transport, and alluvial-fan processes. However, its provenance assignment remains tentative, as it cannot yet be considered representative for the entire conglomerate.

03.06 Multiscale characterization of structure, flow and transport dynamics in fractured porous media and karst systems

Effects of Thermoelasticity induced Aperture Variation on Performances of Enhanced Geothermal System

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LIU, QUAN [2]
LI, KE [3]
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Geothermal energy, as one of the renewable energy types, has great potential to balance the variable energy supply from photovoltaic and wind energy types. This, however, requires the development of an Enhanced Geothermal System (EGS). Injecting cold water into deep geo-reservoirs induces thermoelastic deformation and changes the fracture apertures, which may significantly affect the EGS lifetime and energy performance. In this case, this study develops a fully coupled thermal-hydraulic-mechanical model to investigate the impacts of temperature, pressure, and aperture heterogeneity on the alterations of fracture aperture. Then, considering the reservoir lifespan, the research takes a further step into the influence of heterogeneous aperture variation on EGS production temperature and long-term energy performance. Results show that aperture significantly varies once a temperature breakthrough occurs in the production well for both homogeneous and heterogeneous aperture fields. The thermoelasticity-induced aperture variations enhance water flow rate, leading to a considerable increase in reservoir heat production rate, but a shorter EGS lifespan. Furthermore, temperature variation shows a more substantial influence on aperture alteration compared to pressure change. Additionally, a sensitivity analysis indicates that the 30-year total energy output is proportional to the injection/production pressures and injection temperatures. However, the fracture with either excessively large or small initial apertures leads to worse EGS energy performance.

01.08 Applications and Advancements in Sedimentary Provenance Analysis

The North German Basin – A story told by zircon of drill core G1/86

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Zircon from North German drill cores represent an important archive for reconstructing sedimentary processes. In this study, we analyzed magmatic zircons from rhyolites (Lower Permian) and detrital zircon grains from the Upper Rotliegend II strata (Upper Permian) in the southern North German Basin, using a multi-proxy approach that includes morphology, trace element composition, U–Pb geochronology, and Lu–Hf isotopic data. The dataset allow us to trace sedimentary fluxes and provenance pathways within the basin. Understanding the evolution of such an extensive sedimentary system is essential, considering the basin's significance in reconstructing sediment dynamics within a supercontinent configuration.

We dated a rhyolite marking the base of the succession to 296±2 Ma. This volcanic unit is overlain by fine-grained sandstones. Detrital zircon grains from these sandstones exhibit a progressive change in roundness—from predominantly angular to mostly rounded—across all age groups, indicating varying degrees of sedimentary reworking. U–Pb dating of zircons from the lower core sections reveals major age populations corresponding to the Permian, Carboniferous, and Cambrian periods, alongside minor contributions from the Neo-, Meso-, and Paleoproterozoic eras. These age spectra reflect the tectonothermal imprints of the Cadomian and Variscan orogenies and sediment recycling linked to the evolution of the Rheic Ocean. In contrast, the upper core shows an influx of Meso- to Paleoproterozoic material, likely sourced from Baltica. This compositional and morphological diversity highlights the complexity of sedimentary processes in the Central German Basin and points to a dynamic interplay between recycled detritus and input from exposed crystalline bedrock.

01.23 Fluvial Anthropospheres – Exploring Central European Floodplain Transformations

Great transitions in Donaumoos land reclamation (Bavaria, Germany) since the late 18th century – a palaeohydrological and historical perspective

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Köhler, Anne [1]
Seeburg, Vera [2]
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Systematic human intervention in wetlands has been taking place in central Europe for several centuries. The Donaumoos fen in Upper Bavaria, Germany, has been cultivated since 1788, resulting in the permanent loss of its natural state. The adjacent Danube River was straightened during the same period. This study presents a quantitative reconstruction over a 235-year-long time frame of the development of the natural Donaumoos fen and Danube River into a human-dominated landscape (anthroposphere). The selected quantitative proxies for the change in the socio-ecological system are the Donaumoos drainage ditch lengths and changes in Danube surface water area traced through the analysis of old maps. A multi-temporal series of old maps are used to document land reclamation in the Donaumoos and hydro-engineering activities in the Danube floodplain. A comparison of the quantitative data on the development of drainage ditch lengths with the state of research from written sources leads to the discovery of potential great transitions in floodplain and peatland changes and associated human drivers as well as consequences for society in the region. One phase of great transition with far-reaching human interventions spanned 1788 to 1794 and a second phase ran from 1907 to 1959. However, the phases of substantial transitions with river straightening, land reclamation and colonization were embedded in multi-decadal intervals of setbacks and socio-ecological stagnation. Regarding the future, an updated economic and ecological understanding of resources is difficult to implement for the Donaumoos because socio-ecological path dependencies present challenges for the sustainable development of the Donaumoos.

01.29 Environmental Hazards and Risks

Fluvial deposits of the Ahr River reveal recurring high-magnitude flood events during the last 1500 years

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WESTERMANN, HENRIETTE [2]
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Floods are one of the most critical environmental threats in Central Europe. They are responsible for more than half of the economic damage caused by environmental hazards in Germany. The magnitude of the 2021 Ahr flash flood has far exceeded the values of previous flood hazard forecasts. This was due to significantly underestimated hazard assessments, as the former hydrological models considered exclusively instrumental discharge records. Due to the recording interval being too short, previous high-magnitude flood events were not considered in flood hazard assessments. Historical flood events from written sources were also not included in the official flood hazard assessment. In this study, we show the importance of geomorphological records from Ahr flood deposits for reconstructing past high-magnitude flood events. Our analysis shows that centennial to millennial-scale high-energy flood deposits are not the exception but the rule. In addition to the catastrophic flash flood of 2021, the historically documented flash floods of 1910 and 1804 were geomorphologically proven as well as a previously unknown flash flood event from the approx. 6th century AD. The results document the high potential of floodplain archives for reconstructing high-magnitude flood events in Central European rivers, allowing a systematic reassessment in terms of occurrence and frequency of high-magnitude flood events.

08.03 Tilly Edinger Symposium

Deconstructed Forests of the Past: What Types of Wood and Fungi did Beetle Larvae Feed upon Based on Amber Inclusions?

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The composition of today's forests is shaped by multiple factors: climate zones with specific temperature and precipitation patterns, altitude, soil composition, natural disturbances, and anthropogenic influence all affect forest structure and biodiversity. In warm, humid climates, wood decomposition is rapid, driven by fungi and microorganisms; however, this process slows in drier and cooler conditions. Insect larvae also play key roles in this breakdown, fragmenting plant material and promoting forest floor humification through their frass.

This ecological function has remained the same over millions of years. Fossilized resins—ambers—offer unique insights into ancient forest ecosystems. Amber often preserves insect larvae, especially beetle larvae that lived in or near resin-producing trees. Beetle larvae feeding on hardwood, softwood, fungus-infested wood, and directly on spores and hyphae appear widespread in amber deposits from diverse regions. They must have helped recycle nutrients and supported decomposition in past forests.

To infer these ancient ecological relationships, I analyze larval morphology. Mouthparts are especially informative: chisel-like mandibles point to hardwood borers, while brushes or setose structures indicate fungal feeders. Body shape also provides insights—flattened forms suggest life under bark or on exposed surfaces under strong environmental pressures, while cylindrical shapes imply life within soft or decaying substrates. This presentation showcases a diverse array of insect larvae from ambers of various origins and ages, using morphological and shape analyses to reconstruct their ecological roles and feeding strategies, supported by a range of methodologies. The new findings deepen understanding of ancient forest ecosystems.

10.01 Open Paleontology Session

Fossil Fungi-feeding Beetle Larvae in Deep Time

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Many beetle larvae are common feeders on fungi and molds, and this mycophagous lifestyle is likely ancestral for several beetle lineages. The ecological roles of these beetles are often reflected in their vernacular names, such as handsome fungus beetles, hairy fungus beetles, and silken fungus beetles. Some species display specialized feeding behaviors, including burrowing into fungal fruiting bodies or fungus-infested wood.

Immature stages of handsome fungus beetles, minute bark beetles, and pleasing fungus beetles often possess distinctive setiferous (bristle-bearing) processes, likely linked to their ecological adaptations. These structures may aid in camouflage, defense, or even spore dispersal. In fact, the use of body processes for cloaking is not unique to beetles; it also occurs in other insects, such as some lacewing larvae. Larvae of handsome fungus beetles, for example, may cloak themselves with debris, fungal hyphae, or plant material. In a remarkable case of parental investment, females of Endomychus biguttatus wrap fungal hyphae around their eggs, offering them physical protection.

Despite the ecological importance and widespread occurrence of these larvae, their fossil record remains poorly explored. Reports of fossilized larvae have been limited and sporadic. Our study significantly expands this record by documenting new larval specimens preserved in amber from multiple deposits, spanning several geological periods and diverse geographic regions. These findings provide valuable insights into the deep evolutionary history and ecological continuity of fungus-associated beetle larvae.

03.04 All about carbonates

Interfacial and Intercalated Carbonates: From Catalytic Interfaces to tuneable Layered Materials

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Carbonates, in both their crystalline and amorphous forms, have been shown to play multifaceted roles across geological and synthetic environments. In this contribution, recent insights are presented into high-temperature interfacial carbonates (HT-CO_3) within CuO-ZnO-based catalyst systems, where carbonate species are retained after calcination and act as molecular anchors at metal oxide interfaces. Through the combination of vibrational spectroscopy and first-principles modelling, their strong binding energies have been determined, and their essential role in suppressing thermal sintering has been demonstrated. The concept of carbonate functionality is further extended to layered double hydroxides (LDHs) — synthetic analogues to natural hydrotalcite-like phases — in which carbonate ions are incorporated as interlayer anions to modulate material stability, reactivity, and ion-exchange capacity. By comparing these two chemically and structurally distinct systems, the versatility of carbonate species is emphasized, both in dynamic catalytic settings and in tuneable layered solids. A broader understanding of carbonate behaviour at the molecular scale is thereby contributed, with implications for geochemistry, nanomaterials design, and carbon management strategies.

01.15 Taping records of environmental and climatic changes throughout the Quaternary

The lacustrine sediment sequence from Rodderberg near Bonn (Germany) challenges numerical dating of the Middle Pleistocene

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While the marine realm provides quasi-continuous sediment records back into the Tertiary, terrestrial environmental and climatic archives are more complex, fragmentary and commonly short, i.e. they often provide evidence of just one interglacial. Sediment sequences comprising several glacial-interglacial cycles in superposition are exceptions and often encountered in crater basins. The sediment sequence from Rodderberg near Bonn, a paleolake record from a closed crater basin, provides such a record with several organic-rich (interglacial) intervals. A total of 86 luminescence ages was determined for numerical dating at two different laboratories. Furthermore, tephrochronology provides key markers, while cyclostratigraphy, applying the global marine stable isotope stack (LR05), expands this chronological approach. It is hypothesized that the archive spans the past 440 ka. However, the results obtained are of a surprising nature and will prompt further investigation.

The detection of sedimentological and elemental signatures from depositional records with high spatial resolution has become a standard since the advent of sediment scanning techniques. The example of Rodderberg is provided to demonstrate the potential of such high-resolution proxy data. However, correlating these natural archives in space and time requires reliable age/depth models, which are only available for the last two glacial-interglacial cycles. For older records of the entire Middle Pleistocene, the chronologies remain as running targets. In order to resolve the existing inconsistencies between sites and regions, further efforts are required to enhance numerical dating techniques. This can be achieved by extending the temporal range of luminescence dating and by refining radiometric dating methodologies.

01.05 From mantle to crust: following melt evolution from source through the lithosphere

Petrogenesis and tectonic setting of gabbroic rock at Shakha Rash Mountain within Zagros belt, northeastern Iraq

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Mafic rocks are dominant rocks in Shakha Rash Mountain, Shakha Rash occurs in the middle of Bulfat complex, which represents a part of in Zagros suture zone (ZSZ), northeastern Iraq. Gabbro, olivine gabbro, pyroxene hornblende gabbro and alkali gabbro are the main rock types of mafic rocks cropping out in the area. These rocks even its different variety rock types, its showing different granularity from fine to coarse texture. These mafic rocks are calc-alkaline affinity high aluminum basalt. Compared with the primordial mantle, they are enriched in Large Ion Lithophile Elements (LILE) and Light Rare Earth Elements (LREE) over High Field Strength Elements (HFSE) and Heavy Rare Earth Elements (HREE) close to oceanic arc basalt (OAB). Their enrichment in the LREE relative to HREE is relatively low fractionation (LaN/YbN) (1.64-3.31, ave. ~2.39) chondrite), with Eu anomalies changed from weakness negative to positive. This feature together with relative depletion of Nb, Pr, Nd, Zr, Hf and Ti but Cs, Ba, K, U and LREE enrichment. From trace element indicate that these rocks associated with volcanic arc basalt (VAB), this volcanic arc formed as a result of enclosed of Neo-Tethys. Trace and rare earth elements show that these rocks crystallized from magma melted from spinel lherzolite, by patch partial melting.

01.28 Geosciences for the safe disposal of radioactive waste– long-term safety, host rock characterisation and analogue studies

Geoscientific characterization of claystone as part of the German Repository Site Selection Act – “Sub-areas of the Lower Marine Molasse”

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According to the Repository Site Selection Act (Standortauswahlgesetz – StandAG), the German Site Selection Procedure is an iterative process and consists of three phases with increasing levels of detail in which the assessed area is continuously reduced during the process. Starting with an empty, so-called “white map of Germany,” BGE (implementer of the German Site Selection Procedure) completed Step 1 of Phase I in September 2020 with the submission of the Sub-areas Interim Report (BGE 2020/88), where BGE identified 90 individual sub-areas.

In Step 2 of Phase I, BGE aims to localize siting regions within the 90 sub-areas by applying preliminary safety assessments and other scientific criteria. Within the preliminary safety assessments, subsurface data are interpreted and the results documented. The workflow comprises the detailed characterization and interpretation with a focus on the host rock formation that acts as the main geological barrier but also considers the surrounding rock formations.

The claystone successions of the “younger” and “older” Lower Marine Molasse have been designated as claystone sub-areas. Based on mainly borehole data, the sequences were characterized lithologically in order to define a succession with a barrier function within the stratigraphic sequence. Also, the spatial geometry of the barrier (such as the thickness of the barrier and maximum depth of the top of the barrier) are important features that are used for the assessment and categorization of the sub-areas. The results for both sub-areas were already published as a preliminary working status of the preliminary representative safety analyses in 2024.

05.01 Spectroscopic methods in modern geosciences

Importance of creating a Database for Space Exploration

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Raman spectroscopy is a vital tool for analyzing the mineralogical and chemical composition of lunar rocks, providing rapid, non-destructive identification of minerals, volatiles, and potential biomarkers. Despite its importance, lunar research is hindered by the absence of a centralized, standardized Raman spectral database for lunar samples, complicating both Earth-based studies and future *in-situ* lunar exploration. This proposal advocates for the creation of a comprehensive Raman spectroscopy database specifically tailored to lunar geology. The envisioned database would compile spectral signatures from recent lunar meteorite analyses, analog materials, and minerals, enriched with detailed metadata such as instrument parameters, environmental conditions, and mineralogical context. Standardizing data across different instruments would enable robust cross-calibration, enhancing the accuracy of portable Raman spectrometers used by astronauts during lunar missions. This resource would support real-time decision-making, such as identifying valuable samples or detecting hydration features without needing Earth-based confirmation. A key innovation is the database's optimization for machine learning applications, allowing handheld devices to compensate for lower resolution and field limitations by leveraging high-quality spectral libraries. Adaptive algorithms could further refine analyses by accounting for lunar-specific conditions, such as regolith interference or low gravity effects. For space agencies, the database would streamline mission planning, inform instrument design, and foster global collaboration through open-access data sharing. Additionally, it would benefit terrestrial research and education, uniting expertise in planetary science, spectroscopy, and data science to transform lunar exploration and deliver faster, more reliable geological insights.

01.06 Tectonic Systems – TSK Open Session

Dynamics of large and hot subduction-accretion complexes: insights from fossil and active systems

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The dynamics of subduction zones are influenced by the sediment supply to the trench, which determines whether the margin is erosive (low supply) or accretive (high supply). At present, trench-fill thicknesses ≥1 km promote accretion, which can lead to the construction of a crustal-scale accretionary complex. Here we discuss the dynamics of very large subduction-accretion complexes that encompass the entire upper plate. The formation of such large complexes due to high sediment supply to the periphery of Gondwana during the Cambrian and Ordovician has been inferred from Cenerian basement units within and outside the Alps. The units record Ordovician metamorphism and anatexis of metagreywackes and metapelites that host elongated sheets of peraluminous orthogneisses and banded amphibolites, indicating a peraluminous magmatic arc situated in a large, cratonized subduction-accretion complex. However, the formation and cratonization of such hot complexes has not been evaluated in mechanical terms and the relevance of some field constraints, including a prevalence of strike slip faulting and lack of late- to post-Cenerian uplift, have remained uncertain. We therefore corroborate the existing model by mechanical considerations and insights from active systems. We discuss the requirements for the formation of hot subduction-accretion complexes and address how high sediment supply affect the upper-plate stress conditions, fault kinematics, rock uplift, and development of topography.