

# Pangeo / DEUQUA 2024

## Abstracts

23. – 27. September 2024



## CONVERGING SPHERES



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BÜRO FÜR GEOLOGIE UND HYDROGEOLOGIE  
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Program Overview

	Monday	Tuesday	Wednesday	Thursday
	Pangeo	Pangeo    DEUQUA	Pangeo    DEUQUA	Pangeo    DEUQUA
8:30	8:00: Full day field trips 1,2,4,5	Conference opening	Workshop presentations: Earth surface dynamics	Workshop presentations: Glacial erosion and deposition
8:50				
9:00	Thermochron workshop	Coffee break	Workshop presentations: Combined workshop earth's spheres and regional geology	Coffee break
10:00 - 10:30				
10:30 - 12:30	Teachers' workshop	Lunch break	Workshop presentations: Mineral raw materials and energy transition	Coffee break
12:30 - 14:00	Workshop keynote lectures			
14:00 - 16:00		Coffee break	Session: Regionale Quartär- und angewandte Geologie	Session: Regionale Quartär- und angewandte Geologie
16:00 - 16:30	Workshop keynote lecture: Glacial erosion and deposition			
16:30 - 17:30	ÖMG: Award ceremony	DEUQUA: General assembly	Field trip 6	
18:00	Ice breaker	Conference dinner		Public evening lecture: The large cave systems of the Eastern Alps
19:00				

Rooms

Third floor    A3.001    C 3.006    HS 435    HS 434    HS 431

Ground floor    Audimax    Blauer Hörsaal    Foyer    Mensa

## MONDAY, 23. September

**12:00– 13:00 LUNCH BREAK**

**14:00 – 14:30 COFFEE BREAK**

### Pre-conference workshops

#### **Thermochron Workshop, 9:00 – 18:00, A3.001**

Led by: **Bjarne Friedrichs, Bianca Heberer, Nicolas Villamizar, Christoph von Hagke**

Contents:

- Theoretical Introduction (Basics and Applications of Low-Temperature Thermochronology)
- Sample Preparation (Crystal Selection and Documentation for (U-Th)/He Dating)
- Lab Tour (Demonstration and Explanation of (U-Th)/He Analytical Routines)
- Thermal History Modeling (Fundamentals and Exercises using Synthetic and Natural Data)

9:00 – 10:30	Theoretical Introduction <b>(Christoph von Hagke)</b>	
10:30 – 10:45	additional Coffee Break	
10:45 – 12:00	Sample Preparation <b>(Bianca Heberer)</b>	Lab Tour <b>(Bjarne Friedrichs)</b>
12:00 – 13:00	<b>LUNCH BREAK</b>	
13:00 – 14:15	Lab Tour <b>(Bjarne Friedrichs)</b>	Sample Preparation <b>(Bianca Heberer)</b>
14:15 – 14:30	<b>COFFEE BREAK (Foyer)</b>	
14:30 – 16:30	Thermal History Modeling <b>(Nicolas Villamizar, Bianca Heberer)</b>	
16:30 – 16:45	additional Coffee Break	
16:45 – 18:00	Case Studies / Wrap-Up / Questions (all)	

Our room is equipped with 12 computers where the software for the Thermal History Modeling exercise is already installed. If you prefer working with your own device, please make sure to have [HeFTy](#) and [QTQt](#) installed.

Presentation slides, hand-outs and additional materials will be distributed digitally during the workshop. If you want to do the Sample Preparation exercise with your own heavy mineral separates and/or get an expert opinion on them, please feel free to bring a few.

If you are not registered yet but still want to attend the workshop and/or have any remaining questions, please do not hesitate to contact us via [bjarne.friedrichs@plus.ac.at](mailto:bjarne.friedrichs@plus.ac.at).

Language: English, free of charge, coffee breaks included

## Teachers' Workshop, 10:00 – 17:00, C 3.006

### **Why geology is needed in the classroom** (in German)

Led by: **Bernhard Hubmann**

The workshop is aimed equally at biology and geography teachers from all school types and at colleagues from geological subjects who are interested in teaching earth science topics. The program consists of lectures, the opportunity to try out teaching materials yourself and, above all, sufficient time and space for discussion.

<b>Hilberg, Sylke</b>	Geologie begreifen – digitale Lernspiele und analoge Modelle für den Geologie - Unterricht
<b>Unger, Clara-Louisa</b>	Erdwissenschaften und Schulbücher
<b>Nievoll, Gabriel</b>	"Die unsichtbaren Schätze im Klassenzimmer: Kritische Rohstoffe für eine nachhaltige und digitale Welt"
<b>Sachsenhofer, Reinhard</b>	Fluch und Segen: Wie GeowissenschaftlerInnen zur Energiewende beitragen
<b>Riedl &amp; Gulas-Wöhri</b>	Young European GeoExplorer
<b>Moser, Bernd</b>	„Es sind die G´schichten, Herr Professor... “ – Erfahrungen und Erkenntnisse aus 22 Jahren Edelsteinkunde-Unterricht im Fachbereich „Schmuck Metall Design“ an der HTL Ortweinschule Graz.
<b>Hubmann &amp; Krenn</b>	Die Grazer Perspektive auf das Lehramtsstudium Biologie und Umweltkunde: wie sieht die Ausbildung aus und wie „ticken“ die Studierenden?

**Conclusion:** Discussion on the forthcoming reduction of Earth Science issues in teacher training programs.

Language: German, free of charge, coffee break included

Discussion on the forthcoming reduction of Earth Science issues in teacher training programs.

Participation in the teacher workshop is free of charge. Please select the appropriate option when registering at [www.pangeo-deuqua2024.at](http://www.pangeo-deuqua2024.at), language: German, coffee breaks included

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## Ice Breaker (19:00, Mensa)

We look forward to welcoming you to our Ice Breaker at 7 pm on Monday evening at the conference venue. The cost is included in the conference registration fee, and no extra registration is required.

## TUESDAY, 24. September

10:00 – 10:30 COFFEE BREAK

12:30 – 14:00 LUNCH BREAK

16:00 – 16:30 COFFEE BREAK

### **Pangeo-DEUQUA Opening (8:30 – 8:45, Audimax)**

Words of welcome

### **ÖGG Award Ceremony (8:50 – 10:00, Audimax)**

- Ehrenmitgliedschaft (honary membership) to **Dirk van Husen** and **Reinhard Sachsenhofer**
- Otto Ampferer-Preis 2024 to **Simon Schorn**
- Hans Höfer von Heimhalt-Preis 2024 to **Georg Erharder** with short presentation on his research: *"Geology and Engineering: A Two-Way Road of Innovation and Discovery"*
- Eduard Sueß Medaille to **Franz Neubauer**: *"Mit Eduard Sueß In Gebirgen unterwegs"* and laudatory speech by Wolfgang Frisch

### **Pangeo Plenary Session (10:30 – 18:00, Audimax)**

Impulse talks by invited speakers. Talks are related to the different workshop topics on Wednesday.

**Arne Ramisch**, Universität Innsbruck: Tracing Elements to Landscapes: Core Scanning and the Dynamics of Earth's Surface

**Andreas Wölfler**, University of Hannover: Tectonics and landscape evolution in the Gurktal Alps: New data, models and open questions

**Jochen Kolb**, Karlsruher Institut für Technologie: Lithium resources in geothermal brines of the Upper Rhine Graben and possible extraction technologies

**Alissa Kotovsky** (Utrecht University), Caroline E. Seyler, James D. Kirkpatrick: How 'refrigeration weakening' drives catastrophic subduction initiation

**Jan Piotrowski**, Aarhus University: Water at the ice-bed interface and below: processes, sediments and landforms

**Gaudenz Deplazes**, Nagra: Tracing glacial erosion in Quaternary sediments of Northern Switzerland

### **ÖMG Award Ceremony (17:30 – 18:30, Audimax)**

Felix Machatschki Preis to **Simon Schorn** with short presentation in his research: *"In the wake of giants: Building upon the legacy of Otto Ampferer & Felix Machatschki"*

## DEUQUA Sessions (9:00 - 17:30, Blue lecture hall and Foyer)

### Terrestrial records of paleoenvironments and -climates (Blue lecture hall)

(9:00 – 12:30)

Chaired by Tobias Sprafke, Stephanie Neuhuber, Michael Zech & Philipp Schulte

#### 9:00 – 10:00 Terrestrial records of paleoenvironments and -climates I

<b>Zeeden et al.</b>	Reconstructing past climate from Loess-Palaeosol Sequences: Challenges of calibration functions
<b>Böse et al.</b>	The challenge to decipher Late Pleistocene to Holocene geomorphological processes in the Taiwanese mountains
<b>Novak, Andrej</b>	From seasons to centuries: activity of sedimentary processes on alpine alluvial fans (Planica Valley, NW Slovenia)
<b>Sauer, Daniela</b>	When and why did floodplain sediments in Mongolia start to accumulate?

#### 10:30 – 11:30 Terrestrial records of paleoenvironments and -climates II

<b>Stojakowits et al.</b>	Environments during the Late Middle Pleistocene in the Heidelberg Basin, Upper Rhine Graben (Germany)
<b>Labahn et al.</b>	Cyclicity patterns within Quaternary vega formation on the eastern Canary Islands
<b>Mayr et al.</b>	A composite geochemical record based on X-ray fluorescence scanning and radiocarbon dating for the Upper Palaeolithic site Kammern-Grubgraben (Austria)
<b>Vinnepand et al.</b>	Lake Bosumtwi – A million year record of hydro-climate oscillations in West Africa

#### 11:30 – 12:30 Terrestrial records of paleoenvironments and -climates III

<b>Prochnow et al.</b>	A 7500 year long, 30-yr-resolution $\delta^2\text{H}$ record from Moossee, Switzerland, indicates strong influence of solar activity on paleohydrology
<b>Oehler et al.</b>	Central European LGM temperatures revealed using an innovative luminescence approach
<b>Rettig et al.</b>	Glacier evolution in the Valsugana (south-eastern European Alps) during the Last Glacial Maximum and the Late Glacial
<b>Asch et al.</b>	The International Quaternary Map of Europe and Adjacent Areas: Based on a plethora of detailed regional mapping results

#### 14:00 – 16:00 POSTER SESSION (Foyer)

##### Terrestrial records of paleoenvironments and -climates (thematically listed)

<b>Otto et al.</b>	Reconstructing past glacier extents in the Chilean Altiplano (18.5°-19° S) - Regional patterns and paleoclimatic implications
<b>Griesmeier, Le Heron</b>	What happened after the Last Glacial Maximum in the Sölk Valleys (Styria, Austria)?
<b>Winsemann et al.</b>	Entangled external and internal controls on periglacial alluvial fan evolution: the Late Pleistocene Senne and Heller fans in the Münsterland Embayment and Elbe Valley (Germany)
<b>Eder et al.</b>	The sedimentological anatomy of a landslide in Embach, Salzburg.
<b>Marburg et al.</b>	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
<b>Kögler et al.</b>	Pleistocene river terrace development in the Baza Basin, Spain: Processes and chronology
<b>Meng et al.</b>	Holocene mollusc faunas in a northern German lowland river system of the Baltic Sea region (Peene River, Mecklenburg-Western Pomerania)
<b>Wrozyzna et al.</b>	Middle to late Holocene climatic changes in the Dominican Republic, Caribbean Region, deduced from ostracode and coral stable oxygen and carbon isotope values.
<b>Biermanns</b>	Adiabatic winds, put into mathematical formulas

### Regional Quaternary and applied geology (in alphabetical order)

<b>Asch, Kristine</b>	IQUAME 2500 - The International Quaternary Map of Europe and Adjacent Areas, scale 1:2,5 million: Hands-on Harmonisation and Review of the Austrian and German part
<b>Rother et al.</b>	Die Forschungsbohrungen Concordia-See und Königsau (ehemaliger Ascherslebener See, Sachsen-Anhalt): Neue Multiproxy-Analysen zur detaillierten Gliederung der Weichsel-Kaltzeit
<b>Weidenfeller et al.</b>	Integrated geological map of the East Eifel Volcanic Field (EEVF)

### Anthropogenic impact on the development of landscapes

<b>Boettcher et al.</b>	The search for environmental changes in the tropical Lago Enriquillo (Dominican Republic) using multi-isotope (H, C, N, O, S) partitioning
<b>Koukal et al.</b>	FT-IR microplastics identification in natural sediments of Austria and the Republic of Korea – introduction and first results
<b>Pauly et al.</b>	OSL dating of Holocene fluvial sediments of the Wiesent River in the Northern Franconian Alb (Bavaria, Germany)
<b>Schneider et al.</b>	Anthropogene Kleinreliefformen als Relikte früherer Landnutzung – Großflächige Kartierung aus digitalen Geländemodellen
<b>Wulf et al.</b>	Preliminary geochemical results from a gravity core from Stechlinsee in northeastern Germany

**16:30 – 17:30 Keynotes Workshop: Glacial erosion and deposition** (see Pangeo plenary Session)

**DEUQUA General Assembly (17:30 – 19:00 Blue lecture hall)**

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### Conference Dinner (19:00, Mensa)

The conference dinner will take place at 7 pm at the conference venue on Tuesday evening. The cost (including drinks) is €45,00. Please register with the conference registration.



## WEDNESDAY, 25. September

10:00 – 10:30 COFFEE BREAK

12:30 – 14:00 LUNCH BREAK

16:00 – 16:30 COFFEE BREAK

### Full-day Workshops (8.30 – 18:00, various lecture rooms)

A special issue of the [Austrian Journal of Earth Sciences – Home \(ajes.at\)](http://ajes.at) is planned. Article contributions from the presented studies and workshop results are highly welcome.

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#### Workshop Earth Surface Dynamics (8:30 – 18:00, HS 434)

Responsible organizers: Michael Strasser, Jörg Robl, Sylke Hilberg

The morning of the workshop will be dedicated to the presentation of the submitted studies and the discussion of the research results. In the afternoon, under the motto "Bringing together early career scientists and established researchers", we will work in break-out groups on research questions in the field of Earth surface dynamics. In addition to the joint scientific work, we would like to emphasize the mentoring and networking of early career scientists. The break-out groups will be composed of established researchers and early career scientists, so that the combined expertise can be used to solve specific scientific questions and problems.

The 25 contributions to the workshop are thematically divided into the three thematic blocks "*Mass movements*", "*Water, weathering and fluxes*" and "*Landscape evolution*" and will be presented in the form of posters. Each of these blocks will be opened with a 12 (+3) minute keynote lecture. In the following short impulse presentations (3 minutes), the poster contributions will be briefly presented (2-5 slides) with selected highlights. We will allocate 1.5 hours in the morning for the subsequent poster session. We encourage the participants of the afternoon workshop to include the poster contributions and to ensure a lively exchange between the groups.

#### BLOCK 1 | Mass movements (Keynote talk: Patrick Oswald)

Oswald et al.	New perspectives on volume and emplacement dynamics of the Kölfels rockslide deposits by combined geophysical–geological studies
Westreicher et al.	Multiple Datierung eines Holozänen Bergsturzes am Stöttlbach in der Mieminger Kette (Nördliche Kalkalpen, Tirol)
Ortler et al.	Signals of two earthquakes at Lake Altaussee (Salzkammergut, Austria)
Uhlir	Exceptional gravitational mass movements within the Austrian UNESCO Geoparks
Fink et al.	Recent sediment dynamics in the landslide-debris flow complex of the Sattelkar, Obersulzbachtal, Hohe Tauern
Haunsperger et al.	3D modeling of topographic stress in alpine landscapes: the competition between relief formation and destruction
Hergarten	A modified Voellmy rheology for modeling rapid mass movements

**BLOCK 2 | Water, weathering, and fluxes (Keynote talk: Benedikt Pleyer)**

<b>Pleyer et al.</b>	Chemical erosion and dissolved load of a calcareous torrential catchment in the northern Alps
<b>Schultz &amp; Bufer</b>	Weathering fluxes under moderate erosion rates – the case of the Black Forest, Germany
<b>Hilberg &amp; Hauser</b>	Grubenwässer der Altbergbaue im Geopark Erz der Alpen
<b>Winkler et al.</b>	Das Abflussverhalten von Blockgletschern und übergeordneter alpiner Einzugsgebiete – ein Blick in die Zukunft
<b>Vremec et al.</b>	Trend analysis of Alpine Spring discharge in Austria: Interplay between climate and catchment characteristics
<b>Höfer-Öllinger</b>	25 Jahre Quartär- und Hydrogeologie des Nordöstlichen Flachgaus
<b>Tenczer et al.</b>	Alpine soils from the Rieding valley: geochemical, mineralogical and granulometric analysis
<b>Kahre &amp; Otto</b>	Sediment core analysis of glacial lakes Löbbensee and Salzbodensee, Hohe Tauern, Austria

**BLOCK 3 | Long term landscape evolution (Keynote talk: Maud Meijers)**

<b>Meijers et al.</b>	Quantifying surface elevations in deep time through stable isotope paleoaltimetry
<b>Stuwe et al.</b>	Surface uplift of the Eastern Alps - much faster than we thought?
<b>Robl et al.</b>	Old orogen - young topography: lithology governs landscape evolution in the uplifting Bohemian Massif
<b>Ranftl et al.</b>	Miocene and Quaternary sediments in the Wachau region, revisited
<b>Brisson et al.</b>	Using low temperature thermochronometers for model selection: an approach for choose the best geometry for the Eastern Alps
<b>Rau et al.</b>	Investigating the Influence of Uplift on the Central European Drainage Pattern using a Landscape Evolution Model
<b>Dremel et al.</b>	Old Orogens - Young Topography: Exploring the Effects of Continental Rifting on Erosional Dynamics and Topographic Development
<b>HAMPL et al.</b>	Uranium-, vanadium- and chromium-bearing reduction spheroids in karst bauxite of the Unterlaussa mining district (Upper Austria)
<b>Eichkitz et al.</b>	Geoelektrik und Sub-Bottom Profiling an der Grenzmur im Bereich Bad Radkersburg
<b>Nuss et al.</b>	Holocene Coastal Dynamics in the Eastern Gulf of Thailand

## Combined Workshop Earth's Spheres (Crust, Mantle & Core) and Regional Geology (8:30 – 18:00, HS C 3.006)

Responsible organizers: Bernhard Grasemann, Christoph von Hagke, Walter Kurz, Bianca Heberer

Understanding the spatial and temporal evolution of the system Earth requires studying geologic processes based on knowledge of composition, rheology, and thermal structure of crust and mantle, as well as feedback processes between the different spheres of the Earth. To do this, regional geological studies are essential. This workshop aims to bring together multidisciplinary research contributions that explore the structure and dynamics of lithospheric and asthenospheric upper mantle across a range of tectonic settings (e.g., subduction zones, transform faults, rifts, orogens) and length scales using techniques and datasets from various fields, including but not limited to tectonics, seismology, physical and numerical modelling, geochronology, petrology, and mineralogy. During the workshop we will discuss these topics at posters, in interactive longer as well as short presentations (PICOs) and breakout sessions.

### BLOCK 1 (8:30 – 10:00) Petrology & Geochronology (Chairs: W. Kurz & C. von Hagke)

Talk 1 & 2 (12+3 minutes)

<b>Hollinetz et al.</b>	Not sexy, but still dateable: Unravelling the P-T-t-d evolution of low-grade Permian metasediments using xenotime geochronology (Austroalpine Unit, Eastern Alps)
<b>Költringer et al.</b>	The Sankt Leonhard nappe: HP-UHT metamorphic rocks within the Gföhl Nappe System, where and how to draw the nappe boundary

### Picos à 2 minutes, followed by posters:

<b>Sawasdee et al.</b>	Geochronology, Geochemistry and Petrology of Metabasites and Metadacites from the Nan Suture Zone, Northern Thailand
<b>Santitharangkun et al.</b>	Petrology and Geochronology of Igneous and Metamorphic Rocks from the Inthanon Zone: Implications for the Tectonic Evolution of Northwestern Thailand
<b>Fehleisen et al.</b>	Petrology and geochemistry of the Belhelvie and Arnage-Haddo House gabbro intrusions and their contact aureoles - Aberdeenshire, Scotland
<b>Raso et al.</b>	Diabases are petrologists' best friends: quantitative P-T constraints on the Eoalpine metamorphic gradient in the Ötztal nappe using diabase dikes
<b>Karner-Rühl et al.</b>	Pre-Alpine Metamorphism in Alpine low-grade metamorphic units in the Eastern Alps
<b>Arnold et al.</b>	Petrographie exotischer Gerölle aus dem Helvetikum im Gschliefgraben (OÖ)
<b>Haas et al.</b>	Provenance of the Permo-Mesozoic cover sediments of the Seckau-Schladming nappe system revealed by detrital zircons
<b>Haas et al.</b>	Unravelling the pre-Alpine evolution of Alpine basement units by U-Pb zircon geochronology – a case study of the Austroalpine Schladming nappe system
<b>Heberer et al.</b>	Deciphering the 4-D evolution along and across the Insubric Line using a multi-method geo- and thermochronological approach

### BLOCK 2 (10:30 - 12:30), Tectonics and Structural Geology 1 (Chairs: B. Grasemann & B. Heberer)

Talk 1 – 4 (12+3 minutes)

<b>DeFelipe et al.</b>	Alpine deformation mechanisms along central and north Iberia Peninsula: a wide-angle seismic cross-section
<b>Villamizar-Escalante et al.</b>	Slab length and slab tearing control asymmetric exhumation of the Calabrian Arc
<b>Sieberer et al.</b>	Control of lateral strength variations on deformation of the Adriatic plate: insights from lithospheric-scale analogue models
<b>Hinsch et al.</b>	Geometrical kinematical forward modelling of stages in easternmost Alps development

**Picos à 2 minutes, followed by posters:**

<b>Ortner et al.</b>	Thrusts and unconformities in tectonic maps: The Trattberg thrust and the Trattberg fault system
<b>Iglseeder et al.</b>	Initial exhumation of the Upper Austroalpine Unit along the Walchen Shear Zone (Styria, Austria)
<b>Neubauer et al.</b>	Controls of the collisional architecture in an evaporite-bearing fold-thrust wedge: the central Northern Calcareous Alps
<b>Louis et al.</b>	Low-temperature thermochronology and vitrinite reflectance data reveal long-wavelength exhumation of the Molasse basin
<b>Pengg et al.</b>	Petrophysical and sedimentological characterization of fault rocks from the Vienna Basin: Implications for induced seismicity and fault reactivation
<b>DeFelipe et al.</b>	Characterizing gravimetric and magnetic anomalies in the South of Salamanca (Spain): implications on the tectonic structure and Sn-W mineralizations
<b>von Hagke et al.</b>	Triangle Zones as Mechanical Gages for Fold-Thrust-Belts
<b>Barjaktarović et al.</b>	Inner Dinarides revisited: Opening and closure of a Neotethys branch in Western Serbia
<b>Guo et al.</b>	Cenozoic tectonic evolution of the West Qinling and its effects on the Cenozoic climate evolution, NE Tibetan Plateau

**BLOCK 3 (14:00 – 16:00), Tectonics and Structural Geology 2**

**(Chairs: B. Grasemann and Christoph von Hagke**

Talk 1 – 4 (12 +3 minutes)

<b>Neubauer</b>	Tectonic models for the Austroalpine structure in Eastern Alps: nomenclature matters
<b>Hinterwirth et al.</b>	Re-interpretation of the TRANSALP seismic section in the light of a new tectonic subdivision of the western Northern Calcareous Alps
<b>Pomella et al.</b>	The Subpenninic units in the southwestern Tauern Window
<b>Brandner</b>	Permotrias-Paläogeographie der westlichen Nördlichen Kalkalpen und deren Zwangspunkte bei Deckenüberschiebungen und Seitenverschiebungen.

**Poster session and plenum discussion**

**BLOCK 4 (16:30 – 18:00), Paleontology & Stratigraphy & Mapping**

**(Chairs: W. Kurz and B. Heberer)**

Talk 1 – 4 (12+3 minutes)

<b>Harzhauser et al.</b>	The Neogene of the Vienna Basin between geodynamics and global climate
<b>Mrdak et al.</b>	Enigmatic traces of volcanism in the Rhaetian of a far-travelled Late Triassic Hallstatt nappe in northern Montenegro
<b>Kranner et al.</b>	Continuative foraminiferal research using the Enhanced Benthic Foraminifera Oxygen Index
<b>Haider</b>	Tethys Research Data Repository – an approach to provide sustainable and readable valuable geoscientific data for further research

**Picos à 2 minutes, followed by posters:**

<b>Neubauer</b>	Facies analysis in a poorly exposed siliciclastic area: the Upper Cretaceous basal Gosau Conglomerate at Gaisberg, Austria
<b>Hofmayer et al.</b>	Revision of the „Robulus-Schlier“ in Austria – A stratigraphic enigma in the North Alpine Foreland Basin

<b>Diersche</b>	Blassangerl-Hundstodscharte Fm - a new Lower to Middle Miocene lignite formation from the Steinernes Meer, NCA/Tirol, Germany and Austria
<b>Diersche et al.</b>	The Ledererkar Formation: a new Late Jurassic Formation with type-locality in the Steinernes Meer (Northern Calcareous Alps)
<b>Hofmayer et al.</b>	A new vertebrate fossil in Upper Austria – Preparation, 3D Modelling and Regional Geology
<b>Andreea et al.</b>	Jurassic to Early Cretaceous history of the obducted Mirdita ophiolites in Albania: new insights based on a Late Jurassic – Early Cretaceous sedimentary succession above the from Mali I Shejtit
<b>Hintersberger et al.</b>	EAGLe = Erstellung der Allgemeinen Geologischen Legende für Österreich im Maßstab 1:50.000

## Mineral Raw Materials, and Energy Transition (8:30 – 18:00, HS 435)

Responsible organizers: David Misch, Frank Melcher

The workshop Mineral Resources and Energy Transition will address aspects of the sustainable use of geoenergy (e.g. geothermal energy production, natural hydrogen), energy storage (e.g. hydrogen, green methane, thermal energy), carbon capture and storage (CCS) and the production of mineral resources in connection with the technologies needed for the energy transition (photovoltaics, wind energy, battery systems). There will be a combination of keynote speeches (morning), a classical poster session (afternoon) and open discussions (morning/afternoon). The results of the workshop will be summarized by the co-chairs in a final presentation on the last day of the conference. A short summary of the workshop will be distributed among the workshop participants.

### BLOCK 1 (08:30 - 10:00) Mineral Resources & Geoenergy,

#### Impulse talks 1

08:30 – 08:40 Opening, Talk 1 – 4 (15+5 minutes)

<b>Melcher</b>	The Critical Raw Materials Act: what does it mean for domestic production?
<b>Bertrandsson Erlandsson et al.</b>	The Eastern Alpine metallogenic province: a resource of critical and strategic elements?
<b>Hölzel</b>	Geoenergie – Ziele, Potentiale und Forschung in Österreich
<b>Kulich &amp; Ott</b>	CO2 storage options in Austria & current developments

### BLOCK 2 (10:30 - 12:30) Mineral Resources & Geoenergy,

#### Impulse talks 2

10:30 - 10:40, Block 1 recap, Talk 5 – 7 (15+5 minutes)

<b>Angerer et al.</b>	Geological Surveys as multiplier for domestic exploration incentives – Austria's response to the Critical Raw Materials Act
<b>Nachtmann</b>	Fossil Energy Sources in Light of the Energy Transition
<b>Conradi et al.</b>	Aquifer Thermal Energy Storage (ATES) – Review of Principles, Significance and Feasibility of ATES Applications in Neogene Strata from the Vienna Basin

11:40 - 12:30 Open discussion and wrap-up of morning session (Blocks 1+2)

### BLOCK 3 (13:30 – 14:45) Mineral Resources & Geoenergy,

Poster session (5 min slots per poster, listed in alphabetical order)

<b>Akhverdiev et al.</b>	Methodical seismic inversion techniques for quantitative interpretation in the Libyan Murzug basin
<b>Altenberger et al.</b>	Innovative stream sediment analysis for tungsten exploration: A case study in the Rauris Valley (Salzburg, Austria)

<b>Arató et al.</b>	Fingerprinting natural graphite deposits
<b>Bakker et al.</b>	The origin of sparry magnesite deposits of Brumado (Bahia, Brazil) - evidence from fluid inclusions
<b>Bokelmann et al.</b>	Passive seismic imaging for geothermal reservoirs: the Schwechat depression under Eastern Vienna
<b>Efendiyev et al.</b>	Geomechanical modeling of well sections based on the results of complex geophysical and geological-technological studies during the drilling process
<b>Geringer et al.</b>	Polyphase deformation of the Graz Paleozoic recorded in the Pb-, Zn-, Ba- and Ag-bearing Arzberg deposit
<b>Gopon et al.</b>	Precious and critical metal potential of historic Cu-Au-As mine waste in the Eastern Alps
<b>Jud et al.</b>	Seismische Exploration für tiefe Geothermie in Braunau– Akquisition und Processing einer kabellosen 2D-Vibro-Seismik mit STRYDE Nodes.
<b>Sachsenhofer et al.</b>	From peat facies to oil quality: Investigations in the Barito Basin (Indonesia)
<b>Safaei et al.</b>	CO2 Storage Potential of Low-rank and Medium-rank coal deposits from Austria and Kazakhstan
<b>Shi et al.</b>	Unraveling the micromechanical response to mudstone compaction: A combined approach of nanoindentation mapping and machine learning data analysis
<b>Skerbisch et al.</b>	Comprehensive characterization of rock salt from the Haselgebirge Formation: Insights for cavern storage of hydrogen
<b>Weitz et al.</b>	Geochemical characterization of the Göstling formation in the Scheiblingbachgraben: Implications for climate change and hydrocarbon potential

**BLOCK 4 (14:45 – 16:30) Mineral Resources & Geoenergy,  
Open discussion and wrap-up of the workshop**

**Glacial erosion and deposition (8:30 – 12:30, Audimax)**

**Responsible organizers: Lukas Gegg, Jörg Lang**

This workshop will focus on aspects of erosion and deposition by (paleo)glaciers, their interactions with the landscape, and their traces in the geological record. The workshop starts with a brief introduction by Gaudenz Deplazes & Jan Piotrowski. It will be divided into 3 thematic blocks, each comprising 5 short presentations of 3 minutes each (max. 2 slides) and around 90 minutes discussion time at the posters in front of the lecture hall. The workshop ends with a final discussion in the plenum (~60 min).

**BLOCK 1: Regional scale**

<b>Cohen-Corticchiato et al.</b>	Erosion and sediment transport by subglacial water in the Rhine glacier during the LGM
<b>Kamleitner et al.</b>	Alpce - ongoing compilation of geochronological & geo(morpho)logical constraints on Alpine paleoglacier evolution
<b>Firla et al.</b>	The timing of the infilling of glacially overdeepened structures from the northern Alpine foreland in the context of tunnel valleys from the Fennoscandian ice shield
<b>Jungdal-Olesen et al.</b>	Modelling tunnel valley erosion in northern Germany during the first icesheet advance (Elsterian, MIS 12) – a conceptual model and preliminary
<b>Lang et al.</b>	Structural control on tunnel-valley incision: Fact or fiction?

## BLOCK 2: Landform scale

<b>Fiebig et al.</b>	End moraine system of Lake Altaussee.
<b>Schmalfuss et al.</b>	The paleolake deposits of Bad Aussee (Austria): New insights into pre-LGM inner-alpine landscape dynamics of the Eastern Alps
<b>Kettler et al.</b>	Unravelling the maximum extent of Middle Pleistocene Glaciation in the Ybbstal Alps, Austria
<b>Pomper et al.</b>	Overdeepening-fill profiles in southwestern Germany
<b>Breuer et al.</b>	Sedimentary Architecture of a Pleistocene Tunnel-Valley Fill from 3D Seismic Data in the German North Sea
<b>Hofmann &amp; Kox</b>	Extent and dynamics of the last glaciation in Kellwassertal, Harz Mountains, central Europe

## BLOCK 3: Grain scale

<b>Reitner &amp; Menzies</b>	Subglacial deformation, till formation and deformable bed conditions: The Late Pleistocene sequence of Einödgraben (Aurach, Kitzbühel Alps, Austria)
<b>Heninger</b>	Bringing Order to Chaos: Micromorphological Analysis of Late Palaeozoic Glacial Diamictites
<b>Piotrowski et al.</b>	Response of till to subglacial shear stress simulated in ring-shear experiments derived from X-ray computed microtomography
<b>Schuster et al.</b>	Quantitative CT scan analysis: an innovative tool for interpreting ice-contact sediments from overdeepened basins of the northern Alpine foreland
<b>Gegg et al.</b>	A geotechnical view on glacial sediment profiles

## Pangeo Session (14:00 –18:00, HS 431)

### Analytical Advances

Chairpersons: **Christoph Hauzenberger, Bjarne Friedrichs**

Earth Sciences rely on data generated by a wide range of analytical methods, with a continuous development of new instruments and applications. This session comprises five oral presentations (12 + 3 minutes) with an analytical focus with plenty of room for additional discussions and laboratory tours according to participants' interests afterwards.

<b>Degenhart et al.</b>	Micro-computer-tomographic mineralogical and textural evaluations of Egyptian Blue Spheres
<b>Auer et al.</b>	New multiproxy approaches in paleoenvironmental reconstruction – An example from a Late Miocene upwelling cell in the northwestern Indian Ocean
<b>Santitharangkun et al.</b>	EPMA and LA-ICP-MS monazite dating in the Western Gneiss Belt, Northern Thailand: An Over 200-Ma Spread of Dates
<b>Altenberger et al.</b>	Simplifying LA-ICP-MS data processing and interference correction using the non-commercial G.O.Joe software tool
<b>Friedrichs et al.</b>	Development of an analytical protocol for solution ICP-MS analysis in (U-Th)/He thermochronometry

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## Pangeo-DEUQUA Session (14:00 – 17:30, Audimax)

### Regionale Quartär- und angewandte Geologie (in German)

Chaired by Christian Hoselmann, Michael Hermann Konrad & Henrik Rother

Session of the German state offices (Landesämter) and Austrian state geological services (Landesgeologie).

#### 14:00 – 16:00 Regionale Quartär- und angewandte Geologie I

<b>Börner et al.</b>	Aktueller Stand und Methoden der Bohrungsaufnahme im Quartär Mecklenburg-Vorpommerns
<b>Meinsen et al.</b>	Heterogener und tiefer als zuvor bekannt – aktueller Stand der Neumodellierung der Quartärbasis in Niedersachsen (Norddeutschland)
<b>Endtmann et al.</b>	Die Forschungsbohrung Klosterrohrbach in der Helme-Niederung (Sachsen-Anhalt) – Interdisziplinäre Untersuchungen an Sedimenten aus dem obersten Mittelpleistozän.
<b>Posch-Trözmüller et al.</b>	Fremddatenmanagement an der GeoSphere Austria
<b>Melzner et al.</b>	Ein GIS basiertes Dokumentations- und Kommunikationstool für Gemeinden im Katastrophenfall
<b>Linner et al.</b>	Hierarchische Liste der Gesteinsbegriffe der GeoSphere Austria – Standard für geologische Aufnahmen, Lithologie und Generallegende

#### 16:30 – 17:30 Regionale Quartär- und angewandte Geologie II

<b>Jawecki et al.</b>	Landesgeologie Wien im U-Bahn-Bau: Geologie in Prognose und Ausführung
<b>Vigl, Eva</b>	Rutschung Hochreute in Hörbranz/Vorarlberg
<b>Konrad, H. M.</b>	Muren, Rutschungen, Felsstürze – der Landesgeologe im Katastropheneinsatz

### Public Evening lecture (19:00, Audimax)

*The large cave systems of the Eastern Alps – Archives of landscape evolution (in German)*

By **Lukas Plan (Naturhistorisches Museum Wien)**

The karst plateaus of the Eastern Alps contain about 15,000 caves, some of which are over 100 km long and/or 1 km deep. The talk will give an overview of these caves and what they tell us about the post Miocene landscape evolution.



## THURSDAY, 26. September

**10:00 - 10:30 COFFEE BREAK**

### **Pangeo Discussion Session (8.30 – 11.30, Audimax)**

Presentation of workshop results, discussion

### **DEUQUA Session (8:30 – 11:30, Blue lecture hall)**

#### **8:30 - 10:00 Anthropogenic impact on the development of landscapes**

Chaired by Eileen Eckmeier & Anna Schneider

<b>Wagreich, M.</b>	Anthropocene Geology.
<b>Grimm et al.</b>	Late Holocene sedimentary floodplain architecture & human interaction of the Wiesent River (Northern Franconian Alb, Bavaria, Germany)
<b>Hatzenbühler et al.</b>	Anthropogenic stratigraphic signals downstream a metropolis: Extracting Vienna's signature from Danube River plain archives
<b>Weißl et al.</b>	Die Donau-Auen stromab von Wien als Sedimentarchiv

### **DEUQUA Awards Ceremony (10:30 - 11:30, Blue lecture hall)**

Nachwuchspreis (young researcher award) to **Felix Martin Hofmann**.

Verdienst Medaille (medal of merit) to **Achim Brauer** (followed by a short medal lecture).

### **Pangeo-DEUQUA Closing Ceremony (11:30 – 12:00, Audimax)**

Poster awards and the passing of the baton

## Excursion program

### **Field trip 1, Monday 23<sup>rd</sup> September 2024 (Full day)**

#### ***Engineering Geology - Großglockner Hochalpenstraße***

**Guide: Gert Furtmüller**

The Grossglockner Hochalpenstraße leads over approx. 45 kilometers into the high alpine landscape up to an altitude of almost 2.400 meters and has been an Austrian landmark for around 90 years. The listed road leads through the Hohe Tauern National Park. On this field trip, for which a whole day is planned, a profile is traversed from Salzburg through the Northern Limestone Alps, the graywacke zone and ultimately various units of the Tauern Window. The construction of the Tauern Window and the challenge of maintaining and protecting the road in this high alpine region are also part of the excursion. The protection against gravitational natural hazards in a time of rapidly changing climatic conditions (heat days, permafrost & heavy precipitation) and on the other hand the preservation of the road in this sensitive landscape will be visited and discussed on site using several examples.

Planned stops include e.g. the i) Franz Josefs Höhe with a view of the Grossglockner and Pasterze, ii) Hochtorn and iii) Fuscher Törl.

### **Field trip 2, Monday 23<sup>rd</sup> September 2024 (Full day)**

#### ***Sedimentological and structural evolution of the Salzburg-Reichenhall Gosau basin.***

**Guide: Franz Neubauer**

Based on recent research, including MSc and BSc student's work, we will visit 7-8 key outcrops that illustrate the main stages of the sedimentary facies and structural evolution of the Gosau basin and its boundaries.

### **Field trip 3, Friday 27<sup>th</sup> September 2024 (Full day)**

#### ***The tectono-sedimentary record in the central NCA: from passive margin to the onset of orogeny***

**Guides: Oscar Fernandez, Hugo Ortner, Diethard Sanders**

The central NCA thrust sheets are detached above a Permo-Triassic evaporitic-clastic sequence (Haselgebirge - Werfen) that was deposited during the latest stages of rifting. The preserved Triassic to Lower Jurassic stratigraphic succession above records the progressive deepening of the ensuing Tethyan passive margin with ongoing salt tectonics. The overlying Middle Jurassic to Cretaceous sedimentary rocks record the initial inversion of the passive margin and are locally, strongly controlled by the interaction of pre-existing salt structures. The field trip visits outcrop and panorama (weather-dependent) stops in the Salzach and Lammer valleys (between Hallein and Abtenau).

### **Field trip 4, Monday 23<sup>rd</sup> September 2024 (Full day)**

#### ***Rockfall, glacier recession and permafrost degradation: Long-term monitoring of climate change impacts at the Open-Air-Lab Kitzsteinhorn, Hohe Tauern***

**Guides: Ingo Hartmeyer, Jan-Christoph Otto**

This full-day excursion will visit the Hohe Tauern Range (about 90 minutes from the city of Salzburg) where you will visit the summit region of the Kitzsteinhorn (3202 m a.s.l.). Here, the GEORESEARCH Forschungsgesellschaft has established long-term geoscientific monitoring to investigate the impacts of climate change which are particularly pronounced in high-alpine environments. The monitoring is based on a combination of surface (e.g. laser scanning, UAV surveys, crack meters etc.), subsurface measurements (temperature/inclination measurements in boreholes etc.) and investigates how rock stability is affected by rapid atmospheric warming. The excursion includes three consecutive cable car runs (~ 45 minutes) to the top station (3030 m a.s.l.) and short hikes around the study site to inspect the monitoring sites (if the weather permits). Please bring appropriate protection against the cold (subzero temperatures possible) and the sun (strong UV radiation).

**Field trip 5, Monday 23<sup>rd</sup> September 2024 (Full day)*****Glaciers and mass movements in the Hohe Tauern range: from the LGM until now*****Guides: Jürgen Reitner, Mathias Steinbichler**

The trip will focus on the Rauris Valley and the lower part of the Fusch Valley, where well preserved successions of glacial and gravitational deposits can be studied. During the trip we will show how sedimentary successions of glacial, periglacial and gravitational deposits in combination with dating techniques lead to a model of landscape evolution driven by glaciers and mass movements for this inner alpine part of the Eastern Alps during the Late Pleistocene and the Holocene. At the head of Rauris Valley, we will visit crucial landforms and deposits for understanding the dynamic Late glacial to Holocene history of glacial stands and re-advances.

**Field trip 6, Thursday 26<sup>th</sup> September 2024 (Half Day)*****Sediment dynamics of a major glacier lobe: the Salzach Glacier in the North Alpine Foreland*****Guides: Bernhard Salcher, Reinhard Starnberger**

This field excursion visits some key landforms and sediments of the Salzach foreland glacier lobe that record glacial, glaciofluvial and associated postglacial processes during and after four foreland glaciations. Stops will follow the temporal succession of processes, from ice build-up to the period of maximum ice expansion, to ice wastage at the end of glacial cycles. The excursion will also visit sites reflecting the landscape evolution triggered by warm periods following glacial maxima.

**Field trip 7, Friday 27<sup>th</sup> September 2024 (Full day)*****Brunhes to burials – the Loess region Krems, Lower Austria*****Guides: Tobias Sprafke, Robert Peticzka**

This excursion is dedicated to loess, paleosols, and to Quaternary research history in the region around Krems a.d. Donau. The landscape at the eastern exit of the picturesque Wachau valley, carved by the Danube into crystalline basement rocks, is covered by thick loess and has a more than 100-year-long research history. World-famous are Late Paleolithic findings (e.g., the Venus of Willendorf and Stratzing, Wachtberg infant burials). We will pass Krems-Wachtberg, with a last glacial high-resolution loess record, which we have studied in detail before the closure of the excavation site. We visit still accessible, but almost forgotten tremendous loess outcrops known from literature. The loess-paleosol sequences Paudorf, Göttweig, and Krems have been type localities of the Quaternary until the 1970s. Our recent studies have identified the complex nature of these profiles, with marked discontinuities and polygenetic units. Transport will be by train.

**Field trip 8, 27<sup>th</sup> September 2024 (Half Day)*****The Salzburg City Mountains – A Cultural Geological Excursion*****Guide: Christian Uhler**

During a 3-hour hike over the Nonnberg, Festungsberg, and Mönchsberg, the formation of the Salzburg city mountains is presented, along with their position in the Salzburger Basin. Emphasis is placed on their significance for the historical development of the city of Salzburg, not only as a raw material resource but also as a natural hazard and a space where infrastructural- and medieval to early modern military installations have been incorporated.

*All following abstracts are sorted alphabetically according to the first author named in the program.*

Akhverdiev, Allakhverdi<sup>1</sup>; Zaid, Mohamed<sup>2</sup>; Mahmoud, Adel<sup>3</sup>; Alfassi, Mohamed<sup>4</sup>; Abusaq, Walid<sup>5</sup>

## Methodical seismic inversion techniques for quantitative interpretation in the Libyan Murzug basin

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The Murzug basin, situated in the northern region of the Sahara Desert, it is a significant petroleum province in South Libya. The basin is bordered to the southwest by the Tibesti uplifts, by the Tihemboka High to the southwest, to the north by the Atshan Arch, and to the west by the Akakus mounted area. The Murzur Basin covers an area of over 350,000 square kilometers and accounts for roughly 7.5% of Libya's reserves and 30% of its total hydrocarbon production.

The Murzug Basin is an intracraton and originated from the collision of the Laurasia and Gondwana protocontinents, and the paleo-geographical evolution of Pangea supercontinent throughout the Paleozoic era in North Africa. Orogens and fragmentation of Gondwana and Pangea continents, as well as evolution of the Para-Thetis ocean and the Mediterranean Sea are controlled of the Murzug basin development in Mesozoic to Cainozoic epoch.

The Murzug basin reaches over 11,000 ft in depth and main oil discovery refer to Cambro-Ordovician marine sediments.

The primary objective of the study is to define the properties and prospects of the Murzug Basin using a complex of seismic and petrophysical information. The various seismic inversion methods were employed for the quantitative interpretation and properties prediction.

The interpreted horizons of targeted sequences and resulting fault's system of NNW-SSE and W-E orientation were applied to determine the desirable background model. The diverse array of inverted attributes utilized in seismic inversion, coupled with the distinctive characteristics of the geological formations under investigation, necessitated the implementation of distinct inversion methodologies.

In order to characterize lithotypes and reservoir properties in the Silurian-Ordovician Paleozoic complex, a number of elastic and rock-properties attributes were selected for inversion transformation. The principal set of inverted parameters applied for the subsequent properties of discrimination is included the following parameters: P-wave impedance, S-wave impedance, density, porosity, Poisson's ratio, Lamé constants ( $\mu_{Ro}$  and  $\lambda_{Ro}$ ). As already noted, the particular qualities needed for each technique to seismic inversion rely on the features of the underlying geology.

P-acoustic impedance is a fundamental parameter of inversion results. In order to ascertain the characteristics of this attribute a synthetic 1D modelling was accomplished based on the 5 wells spanning the Late Cambrian (Dembaba formation) to the Hawaz unconformity (Middle Ordovician). Low and Middle Manuniyat sublayers were designated as the base lap in reference to the Hawaz horizon.

The deterministic seismic inversion algorithm was deemed an appropriate means of defining density. The density displays specific behavior in the Murzug basin, particularly in the interval of transition from the Tanezzuft shale (low impedance) to the Mamuniyat sandstones (high impedance value), where the density assumes an opposite character. In this interval, the Mamuniyat sandstones exhibit lower density and high impedance, in contrast to the low impedance values and high density of the Tanezzuft shale at the top. Associated with this phenomenon is the high porosity of the Mamuniyat sands and their very solid matrix properties.

To obtain porosity an additional external elastic cube was generated based on AVO determined attributes. EEI inversion was applied for the porosity cube definition.

Neural network detection was applied to extract S-velocity from petrophysical data. To receive S-Impedance a pre-stack inversion was run. Determined S- and P-Impedance allowed to find Poisson's ratio and Lamé parameters. Poisson's ratio and the Lamé parameters were discovered in order to the obtained inverted S- and P-Impedance.

The cross-plotting analysis of P-Impedance, Poisson's ratio and  $\Lambda/\mu$  attributes enabled the segregation of sand facies within the Mamuniyat formation and to make predictions for further exploration activities. The received correlation of final inverted results with petrophysical data is ranging from 0.78 up to 0.91.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Murzug basin, seismic inversion, quantitative interpretation, Silurian-Ordovician Paleozoic complex, Mamuniyat sands*

Altenberger, Florian<sup>1</sup>; Raith, Johann G.<sup>1</sup>; Weibold, Julia<sup>2</sup>; Auer, Christian<sup>2</sup>; Angerer, Thomas<sup>2</sup>; Krause, Joachim<sup>3</sup>; Berndt, Jasper<sup>4</sup>

## Innovative stream sediment analysis for tungsten exploration: A case study in the Rauris Valley (Salzburg, Austria)

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The European Union has included tungsten (W) in the list of critical raw materials since 2011 and underlined its high importance for technological development in the context of the European green and digital transition by upgrading the metal as an economically strategic raw material in the recently published Critical Raw Materials Act. Although one of the world's largest tungsten deposits is mined at Felbertal in Austria, the European high-tech industry is still dependent on global imports. Therefore, both the development and application of innovative exploration tools play a crucial role in making the quest for critical raw materials in Europe much more effective in terms of time and economics.

The chemical analysis of stream sediments is a globally practiced exploration tool that has been used to locate geochemical anomalies and many deposits of different commodities (e.g., Cu, W, Au etc.) were discovered in this way. Modern analytical methods and new results in the chemical study of certain indicator minerals have significantly increased the contribution of heavy minerals (>4.5 g/cm<sup>3</sup>) in stream sediments to the understanding of regional geology, exploration for raw materials and an early-stage assessment of the regional economic potential. Scheelite (CaWO<sub>4</sub>) is not only the most important tungsten mineral in the Eastern Alps, it is also a heavy mineral that provides important constraints for its provenance and petrogenesis. Intensive research on scheelite since 2019 by Montanuniversität Leoben together with GeoSphere Austria using a combination of cathodoluminescence, electron probe microanalysis and in-situ LA-ICP-MS techniques significantly contributed to our understanding of the systematic trace element incorporation in scheelite and its use for mineral exploration.

Mineralogical-chemical signatures of several tungsten deposits/occurrences in the Eastern Alps (including the world-class Felbertal deposit) form the basis for the application of scheelite as an indicator mineral to determine the potential of regional tungsten anomalies. Scheelite is a common minor mineral in orogenic gold deposits and has also been described in the mineral assemblages of the historically mined Tauerngold veins in the valleys of Rauris and Gastein. A genetic connection has always been suspected, though, this has not been satisfactorily proven yet. Scheelite fingerprinting allows different W-dominated mineralization styles to be distinguished. Importantly, the economically most interesting Felbertal deposit has a very unique fingerprint.

In this case study, we present the spectrum of scheelite signatures from a systematic stream sediment survey in the Rauris Valley and evaluate its economic tungsten potential. Watershed delineation supports the comparison of chemical-mineralogical results of scheelite analyses from Tauerngold samples and from heavy mineral concentrates to find out a genetic link between tungsten and gold mineralization. Interestingly, also an independent W mineralization phase without association to the gold-bearing veins is indicated.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *scheelite, tungsten, critical raw materials, indicator minerals, fingerprinting*

Altenberger, Florian<sup>1</sup>; Krause, Joachim<sup>2</sup>; Auer, Thomas<sup>3</sup>; Auer, Alexander<sup>3</sup>; Berndt, Jasper<sup>4</sup>

## Simplifying LA-ICP-MS data processing and interference correction using the non-commercial G.O.Joe software tool

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Since the coupling of laser ablation systems with inductively coupled plasma-mass spectrometers (LA-ICP-MS) in the 1980s, this technique has become indispensable for rapid, in-situ trace element and isotopic analysis of both natural and synthetic solid samples. Its application extends across various fields, including chemistry, material science, geosciences as well as biological and environmental analysis, bioimaging and forensic investigations. However, analytical advances are still needed to overcome problems in trace element analysis using LA-ICP-MS caused by interferences that cannot be solved instrumentally.

G.O.Joe is a non-commercial software tool designed to calculate trace element concentrations in solid samples obtained by LA-ICP-MS analysis, incorporating several types of optional interference corrections. The software is written in the Dart programming language within the Flutter programming framework and operates web-based without the need of any installation, allowing access from any location with an internet connection. This facilitates immediate data evaluation and the efficient processing of large datasets. The web-based nature of G.O.Joe assures that the user always works with the most recent version of the software.

G.O.Joe features an intuitive user interface that simplifies the data evaluation process. This includes straightforward selections of peak- and background signals, importing instrument settings and reference material compositions to convert the measured raw signals into element concentrations. To ensure a transparent data processing, the results file (.xlsx) includes the calculated element concentrations, associated statistical parameters as well as input data alongside instrument settings. Major advantages of the software are the implemented correction measures for isobaric interferences and abundance sensitivity.

We present G.O.Joe's key features by processing the mineral chemical datasets of two case studies. These include trace element analyses of tungstates (e.g., scheelite) and silicates (e.g., garnet) to demonstrate the a time-efficient, transparent and easy-to-use handling of the software, appealing for both experienced LA-ICP-MS users as well as newcomers to LA-ICP-MS data analysis. More details and the latest version of G.O.Joe will be available at <https://www.gojoe.software>.

**Session:** *Classical Session: Analytical Advances*

**Keywords:** *data reduction software, LA-ICP-MS, correction methods, isobaric interference, abundance sensitivity*

Andreea, Uta<sup>2</sup>; Gawlick, Hans-Jürgen<sup>1</sup>; Muceku, Bardhyl<sup>3</sup>; Onuzi, Kujtim<sup>2</sup>; Prela, Mensi<sup>2</sup>; Milushi, Ibrahim<sup>2</sup>; Bilali, Bujar<sup>3</sup>

## Jurassic to Early Cretaceous history of the obducted Mirdita ophiolites in Albania: new insights based on a Late Jurassic – Early Cretaceous sedimentary succession above the from Mali I Shejtit

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Component analyses of Jurassic mélanges, predominantly the ophiolitic mélanges and various Late Jurassic to Early Cretaceous orogenic sedimentary rocks associated with the obducted Mirdita ophiolites in Albania play a crucial role in the detailed reconstruction of the Late Jurassic to Early Cretaceous geodynamic history of the Albanides. Whereas the Middle-Late Jurassic (Bajocian to Oxfordian) obduction history of the Mirdita ophiolites with the subsequent evolution of the Kimmeridgian-Tithonian is fairly well understood there are still uncertainties and open questions regarding the latest Jurassic to earliest Cretaceous tectonic evolution of the Mirdita zone. In fact several mélange types can be distinguished: 1) intraoceanic ophiolitic mélanges, B) ophiolitic mélanges formed in the frame of ophiolite obduction with scrapped off blocks from the overthrust continental domain and/or mélanges first deposited in trench-like basins and later incorporated into the nappe stack, also containing continental blocks (sedimentary mélanges), and C) ophiolitic mélanges related to subsequent tectonic transport, e.g. formed in the frame of mountain uplift and unroofing. These mélanges show fluvial transported material at the base of their overthrust. These 3 types of mélanges show all transitions between intense sheared rock bodies to units with well preserved primary sedimentary structures. These ones are termed as “flysch”. Another type are sedimentary sequences with similar component spectrum and sedimentary features, but contain younger blocks, i.e. reworked material from carbonate platforms formed on top of the obducted ophiolites in a period of relative tectonic quiescence in the time span between active (west-directed) obduction and further west-directed transport in the frame of mountain uplift and unroofing.

Crucial for the reconstruction of this history is the understanding of the so-called ophiolitic Simoni mélange overlain by the Fierza flysch in central north Albania, which is related to the evolution of various carbonate platform evolutions (Kimmeridgian-Tithonian, Valanginian, Aptian) above the obducted ophiolites. In fact both types are still mixed because there is no detailed analysis of the mélanges. One key area is the Mali I Shejtit, where various ophiolitic mélanges, orogenic sedimentary successions, and shallow-water carbonates are preserved.

Here we describe for the first time a latest Jurassic to Valanginian sedimentary succession deposited above the Mirdita ophiolites with a fining-upward trend throughout the Berriasian-Valanginian. The succession starts with fluvial conglomerates with various subrounded to rounded ophiolite and radiolarite pebbles, and rare angular limestone clasts of the Kimmeridgian-Tithonian platform (Kurbnesh Carbonate Platform). Upsection follow conglomerates with increasing content of carbonate clasts. The age of the predominantly shallow-water limestone clasts is proven by various shallow-water organisms, i.e. calcareous algae and foraminifera. Reefal organisms are common. Calpionellids in the matrix improve an earliest Cretaceous age. Upsection a Middle-Upper Berriasian marl succession with limestone beds follows, in its upper part with intercalated turbidites of a newly evolving shallow-water carbonate platform (Munella Carbonate Platform). These carbonate turbidites in the marly succession with in cases moderately preserved ammonoids contain various age diagnostic calcareous algae and foraminifera pointing to a Valanginian age. In fact these sedimentary rocks deposited in underfilled or in parts newly formed foreland basins.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Mesozoic, Tethys, ophiolite obduction, Albanides, Sedimentology*



Angerer, Thomas; Paulick, Holger

## Geological Surveys as multiplier for domestic exploration incentives - Austria's response to the Critical Raw Material Act

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One of the mitigations of climate change are net-CO<sub>2</sub> free energy supply capacities at a global scale. The substitution of fossil fuel exploitation comes, in the long run, with a net decrease of raw material demand. However, the building of renewable energy infrastructures can only be realised with an unprecedented supply of material from unexploited and unexplored geogene resource. The anticipated demand of raw materials crashes with a narrowing of supply chains, with China being the main factor. The EC Critical Raw Material Act (CRMA) formulates measures to fight raw material criticality: expanding supply chains, recycling and economizing materials, and fostering domestic raw material supply including exploration. Counter acting Europe's slow phasing out of primary resources extraction, the CRMA calls for "National Exploration programs". EU countries interpret these programs diversely; however according to EuroGeoSurvey national geological surveys are about to play key roles. The principal aim of the work of geological surveys in relation to mineral exploration is to provide relevant data at the pre-competitive stage. Only GTK in Finland has the responsibility of commercial exploration programs within the country. How is Austria reacting to the request of "National Exploration programs"? Currently, federally funded research on mineral resources at Austria's geological survey, GeoSphere Austria, is dominantly carried out within the frameworks of two research focus programs, "Vollzug des Lagerstättengesetzes VLG", since 1947, and "Mineralische Rohstoffinitiative, MRI", since the 2010s. The main aim are to conduct studies on mineralization processes and regional mineral potentials. In line with these aims, substantial geological, geochemical and geophysical measurements and sampling have been carried out. Now, Austria plans a new focus program, the "Exploration Initiative", in which GeoSphere Austria plays a strategic role to boost the availability of pre-competitive data on (critical and strategic) raw materials, deep geothermal heat, and carbon capture/storage. The ultimate aim is attracting industry by de-risking exploration investments within Austria. In order to generate these pre-competitive data with research projects, following approaches will be key to integrate: 1) provide system-wide and cross-border homogenized geological maps, 2) densify and reinterpret existing datasets with novel techniques, 3) unravel any systematics of raw material distribution and genesis applying a mineral system approach, and 4) develop and apply techniques in geophysical and geochemical anomaly detection, raw material discrimination and resource (semi-) quantification. Measures also include adopting the "United Nations Framework Classification" (UNFC) to domestic mineral deposits. Data will be made available via free-access reports/publications/data repositories. GeoSphere Austria as a research hub is seeking out to join forces with geological surveys of neighbouring country sharing geological data from prospective larger geological systems (e.g., the southern Bohemian massive and Eastern Alpine Drauzug-Gurktal nappe system). Research consortia with other research institution, such as Universities in Vienna, Leoben and Innsbruck are key for the utilization of fundamental scientific knowledge, e.g. on statistical data mining and ore genesis, and advanced analytical techniques. The alignment of research with industry and the mining authority enables project partners to access to mineral deposits and resource data, drilling, or aerogeophysical services.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *CRM, Geologische Bundesanstalt, Mineral System Analysis*

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## Fingerprinting natural graphite deposits

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Graphite is an essential raw material in a range of applications due to its extraordinary chemical and physical properties. As graphite is also one of the fundamental raw materials in energy storage, its responsible sourcing is of prime importance and it is officially classified as a critical and strategic raw material (CRM and SRM). In the European Union, ambitious goals were set (i.e. Critical Raw Materials Act) with respect to the responsible sourcing of critical raw materials. Among others, not more than 65% of each of these materials should stem from a single third country by 2030. However, currently there is no routine methodology available to distinguish natural graphite deposits from each other.

The EU-funded MaDiTrace (Material & Digital Traceability for CRM Certification) project aims at reinforcing the transparency, reliability and sustainability of critical raw material supply chains. The project is focusing on four critical raw materials: Li (BRGM, France), Co (GTK, Finland), natural graphite (University of Leoben, Austria) and rare earth elements (Ghent University, Belgium). The project's goals include the development of analytical fingerprinting protocols (laboratory and on-site), their incorporation into certification schemes and the integration of the above technological solutions into digital product passports. Analytical fingerprinting aims at the differentiation between different natural deposits and the detection of material characteristics, which can be followed along the value chain from the raw material until the product.

Due to its chemical and thermal stability, the analysis of graphite is particularly challenging. In the framework of the project, we test the applicability of Raman-spectroscopy, Carbon stable isotopes, ICP-MS, LA-ICP-MS and Laser-induced breakdown spectroscopy (LIBS) for distinguishing graphite deposits. In this study, we focus on the results acquired by a LIBS coupled to a laser-ablation system (ImageGEO193) on a series of pressed natural graphite pellets, from the most important graphite producers worldwide. By applying LIBS-mapping with 100 µm spot size and 90 µm x-y overlap on a 1\*1 mm area on each pellet, we can shed light on the spatial distribution of impurities in graphite. Most detected elements (e.g. Ca, Mg, O, Si) show high anomalies in spatially restricted regions implying mineral impurities as possible sources. On the other hand, during the acquisition of the maps, 100 multielemental LIBS spectra are produced per second, which provide an excellent basis for multivariate classification tasks. We introduce several approaches on raw, normalized and quantitative graphite data by various classifiers. Our tests indicate that individual shots on all graphite concentrates can be classified correctly by at least 80% accuracy. This makes LIBS a strong candidate for becoming a standard tool in graphite traceability tasks, in accordance with its successful forensic application on other materials (e.g. [1]), whereas other methods can be used in combination with LIBS to further improve classification accuracy.

[1] M. G. Nespeca, A. L. Vieira, D. S. Júnior, J. A. Neto, E. C. Ferreira. *Food Chemistry*, 2020, 311,125886.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *graphite, LIBS, data analysis, traceability, critical raw materials*

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## Petrographie exotischer Gerölle aus dem Helvetikum im Gschlifegraben (OÖ)

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Der Gschlifegraben am Fuße des Traunsteins bei Gmunden stellt in mehrfacher Hinsicht eine geologische Besonderheit dar. Hier befindet sich im Grenzbereich zwischen Flyschzone und den Nördlichen Kalkalpen ein schmales tektonisches Fenster des Helvetikums. Die helvetischen Gesteine sind v.a. Buntmergel und Sandsteine mit Einschaltungen von fossilführenden Karbonathärtlingen. Unter wassergesättigten Bedingungen neigen besonders die Buntmergel des Ultrahelvetikums zu Großrutschungen und Erdströmen, welche dazu führten, dass im Laufe der letzten Jahrhunderte an dieser Lokalität immer wieder Häuser und Kulturland zu Schaden kamen und aufwendige Sanierungsmaßnahmen notwendig wurden. Innerhalb dieser kompliziert verschuppten, verfalteten und instabilen Gesteinseinheiten finden sich auch einzelne exotische Kristallingerölle, die von einem magmatischen bzw. metamorphen Basement stammen. Es handelt sich dabei v.a. um Granitoide sowie untergeordnet Gneise und Schiefer.

Siebzehn Proben solcher granitoiden Gerölle wurden nun im Rahmen einer Salzburger Masterarbeit im Bereich des Gschlifegrabens aufgesammelt und hinsichtlich ihrer Form, geochemischen Zusammensetzung und Mineralparagenese untersucht. Die Gerölle sind i.A. sehr gut zugerundet, leicht abgeflacht, etwas gelängt und haben eine Größe zwischen 10 und 30 cm. Das Längen-Breiten-Verhältnis der elliptischen Längsschnitte liegt meist zwischen 1.2 und 1.4. Morphologisch ähneln diese Formen rezenten Strandgeröllen. Petrographisch betrachtet sind die Gerölle oft inhomogen, vorherrschend handelt es sich um rötlich bis hellbraun/grau gefärbte mittel- bis grobkörnige Granitoide, die aber manchmal von feinkörnigeren, mafischen Partien durchzogen sind und mitunter auch vergrünt sein können. Häufig ist ein mehrere cm breiter Verwitterungsrand erkennbar. Von den 17 Proben können 15 mit hoher Wahrscheinlichkeit mit dem in der Literatur beschriebenen Buchdenkmalgranit korreliert werden. Granitoide des Buchdenkmal-Typs (nach G. Frasl) sind als exotische Gerölle sowohl im Ultrahelvetikum wie auch in der Flyschzone einigermaßen weit verbreitet. Die zumeist relativ grobkörnigen Granitoide dieses Typs haben granodioritische Zusammensetzung mit deutlich erkennbaren (cm großen) rötlichen Alkalifeldspat-Kristallen. Bei den Proben aus dem Gschlifegraben ist das magmatische Gefüge gut erhalten, auch wenn die Hauptminerale eine leicht grünschieferfazielle Überprägung (Chloritisierung) und z.T. Metasomatose (Albitisierung) erkennen lassen. Der Plagioklas ist saussuritisiert, Quarz zeigt Fluidtrails, der Kalifeldspat ist häufig albitisiert und teilweise am Rand durch Myrmekitbildung verdrängt. Biotit ist partiell chloritisiert und mit kleinen Erzphasen assoziiert. Ein weiteres Merkmal sind karbonatgefüllte Risse und Adern. Akzessorische Minerale sind v.a. Apatit, Titanit, Zirkon, Rutil und Erze.

Zwei weitere der untersuchten granitoiden Proben aus dem Gschlifegraben können auf Grund ihrer mafischeren Ausbildung und Amphibolführung eher dem von G. Frasl definierten Typ Schaitten zugeordnet werden.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Gschlifegraben, Helvetikum, exotische Gerölle, Granitoide*

Asch, Kristine

## IQUAME 2500 - The International Quaternary Map of Europe and Adjacent Areas, scale 1:2,5 Million: Hands-on Harmonisation and Review of the Austrian and German part

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Having started at the 2011 at the INQUA congress in Bern, the project of the International Quaternary Map of Europe and adjacent Areas (IQUAME 2500) now encompasses participants from over 30 countries of Europe and adjacent areas. The endeavour “[...] is creating a pan-European, harmonized, spatial geological (GIS) database, which will provide a summary of the status of European Quaternary geological research. It is a major international initiative coordinated by Germany’s Federal Institute for Geosciences and Natural Resources (BGR), under the auspices of the Commission of the Geological Map of the World (CGMW), Sub-Commission Europe and with support of the International Union for Quaternary Research (INQUA)” (Asch 2020).

Participants from around 40 countries are involved in the project and are contributing their most actual results reduced to small scale to the project according to the mapping guidelines, project standards and requirements. The key features encompass mainly the chronostratigraphical age, lithology, the maximum extent of the last glaciation(s), glaciogenic features, key locations, the actual limits of permafrost and active faults.

This poster will show the Austrian and German part of the IQUAME map and will invite the colleagues participating in the conference to a hands-on review, cross-boundary harmonisation and optimization of the momentary map status, on paper, with a pen.

*Reference*

*Asch, K. (2020): Mapping Europe’s Quaternary: the International Quaternary Map of Europe and Adjacent Areas (IQUAME). Quaternary Perspectives - 28, 4-7*

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Quaternary Map of Europe, IQUAME 2500*

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## The International Quaternary Map of Europe and Adjacent Areas: Based on a plethora of detailed regional mapping results

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Having started in 2011 at the INQUA congress in Bern, the project of the International Quaternary Map of Europe project (IQUAME 2500) now encompasses participants from around 40 countries of Europe and adjacent areas. It is a major international endeavor coordinated by BGR, the Federal Institute for Geosciences and Natural Resources, Germany, supported by the International Union of Quaternary Research (INQUA) and the Commission of the Geological Map of the World (CGMW, Sub-Commission Europe). The IQUAME project is compiling information on numerous aspects of the European Quaternary, which include the geochronological age of Quaternary geological units, lithology, genetic features, direction of ice movement, maximum extent of the Weichselian/Würmian ice sheets, extent of permafrost and Arctic sea ice, active faults and other aspects such as key localities of geological and anthropological interest. The project is based on international cooperation and is encompassing information from more than 40 partner institutions and also presents off-shore map information (in cooperation with the EU EMODnet Geology project) as the geology does not end on the shoreline.

Consequently, the IQUAME is based on hundreds of regional mapping campaigns all over Europe. For example the mapping of Late Glacial moraines in the Eastern Alps in Austria indicating extensive multiple glacier advances after the breakdown of the Last Glacial Maximum ice cap which occur in a high alpine environment with peaks of 3000 m altitude and steep slopes.

Another example comes from the area of the Osterseen (Bavaria, southern Germany) showing landforms, which evolved during the Würmian ice decay. In this area kettle holes, kames, kame terraces as well as eskers occur. Further to the west and northwest a huge drumlin field (= so-called Eberfinger drumlin field) exists, consisting of more than 350 drumlins.

Participation of the numerous international partners and the many different topics requires considerable data harmonization (semantics, structure and geometry). To achieve this aim, common standards and guidelines were set up and used by all participants: structured vocabularies to describe the IQUAME's contents, a common topographic base map, technical procedures to include the map data and guidelines to aid the partners to submit their data to the project. The harmonization is still in progress. This presentation aims to show the path from regional mapping campaigns in the field such as the mentioned examples from Carinthia, Austria and Bavaria, Germany to an overall harmonized.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Quaternary Map of Europe, IQUAME 2500

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## New multiproxy approaches in paleoenvironmental reconstruction – An example from a Late Miocene upwelling cell in the northwestern Indian Ocean

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Accurate paleoenvironmental reconstructions require high-resolution, high-precision analysis of proxy data. In recent decades, it has also become common practice to apply multi-proxy approaches to best characterize all potential controlling factors that may have influenced past changes. Here, we present new high-precision data based on micropaleontological (nannoplankton, planktonic foraminifer assemblages, and diatom abundances) proxies coupled with geochemical proxy data. Geochemical datasets include C and N elemental concentrations and ratios, as well as bulk  $\delta^{13}\text{C}_{\text{org}}$ ,  $\delta^{15}\text{N}_{\text{org}}$ , stable isotope data, coupled with habitat-specific planktonic and benthic foraminifer  $\text{CaCO}_3$   $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  data.

This multi-proxy approach was necessary to fully disentangle the dynamic changes that occurred within a Miocene Monsoon wind-driven upwelling cell in the Western Arabian Sea (WAS) along the Oman Margin. In the WAS upwelling cell, nutrient-rich waters fuel productivity, providing a key example of how the global thermohaline circulation transports nutrients through the intermediate waters of the ocean. Today, these nutrient-rich intermediate waters form within the Antarctic Divergence – located at present around 55° S latitude – before expanding into the middle and lower latitudes where they can upwell, fertilizing upwelling cells throughout the global oceans.

Our data spanning the Middle to Late Miocene at Ocean Drilling Program (ODP) Site 722 details the inception and history of upwelling-derived primary productivity in the Oman Margin. Our data confirms that monsoonal upwelling in the WAS has persisted since the emergence of the Arabian Peninsula after the Miocene Climatic Optimum (MCO) ~ 14.7 Ma. Although fully monsoonal conditions were only detected after the end of the Middle Miocene Climatic Transition (MMCT) at ~ 13 Ma.

Crucially, however, the application of multivariate statistical methodologies based on the multi-proxy bases revealed that upwelling did not simply intensify after the MCO. Changing nutrient fluxes through Antarctic Intermediate and sub-Antarctic Mode Waters (AAIW/SAMW) further influenced paleoenvironmental conditions by ~12 Ma. These changes culminated ~11 Ma, when diatom abundance increased significantly, leading to alternating diatom blooms and high-nutrient-adapted nannoplankton taxa. These changes in primary producers are also well reflected in geochemical proxies with increasing  $\delta^{15}\text{N}_{\text{org}}$  values (> 6 ‰) and high organic carbon accumulation. These proxies provide further independent evidence for high productivity and the onset of denitrification simultaneously.

Foraminifer  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  subsequently compound the evidence for a stepwise evolution of Middle to Late Miocene productivity in the western Arabian Sea. The absence of a clear correlation with existing deep marine climate records suggests that both local wind patterns and intermediate water nutrient changes likely modulated productivity in the western Arabian Sea during the Middle to Late Miocene. Our multi-proxy records, therefore, provide novel insights into how plankton responded to changing nutrient conditions in the monsoon-wind-driven upwelling zone in the WAS during the Miocene after the MMCT.

**Session:** *Classical Session: Analytical Advances*

**Keywords:** *nutrient cycling, paleoclimate, micropaleontology, stable isotope geochemistry*

Bakker, Ronald<sup>1</sup>; Raith, Johann<sup>1</sup>; Hauzinger, Elisabeth<sup>1</sup>; Prochaska, Walter<sup>2</sup>; Stranzl, Christoph<sup>3</sup>

## The origin of sparry magnesite deposits of Brumado (Bahia, Brazil) - evidence from fluid inclusions

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Magnesite deposits in Brumado, Bahia, Brazil, occur in the Serra das Éguas, a mountain range where an Archean greenstone belt is exposed within the Gaviao block in the Sao Francisco Craton in Eastern Brazil. Two different mineralization types of coarse-grained sparry magnesite are distinguished. Type 1 consists of intergrown, coarse-grained red and light-coloured magnesite exposed at Pedra Preta mine and at Pedra de Ferro prospect, while type 2 is composed of more fine-grained, purely white magnesite currently produced at Pomba mine and explored at Pirajá prospect. Finely dispersed hematite is found in the red and light-coloured magnesite of the type 1 mineralization, which is completely absent in white magnesite of the type 2 mineralization.

Analysis of fluid inclusions in ore and gangue minerals are a powerful tool for constraining the nature of fluids as well as the pressure-temperature-chemical (p-T-X) conditions of ore formation. Micro-thermometric, Raman spectroscopic data of fluid inclusions as well as results of crush-leach analyses demonstrates that highly saline H<sub>2</sub>O-CO<sub>2</sub> fluids with a high density were trapped under various conditions in both types of magnesite of the Brumado deposits. The inclusions are exceptionally large (up to 50 µm) and provide a clear estimation of properties with all analytical techniques. The fluid inclusion assemblages are homogeneous and reveal optically only minor variation in volumetric properties. Cryo-Raman spectroscopy reveals that CaCl<sub>2</sub> is the major salt component within inclusions. There is gradual variation from 40 mole% CO<sub>2</sub> and 20 eq.mole% CaCl<sub>2</sub> to 19 mole% CO<sub>2</sub> and 26 eq.mole% CaCl<sub>2</sub> in inclusions in type 1 magnesite (reddish). Inclusions in type 2 magnesite contain up to 71 mole% CO<sub>2</sub> and 10 eq. mole% CaCl<sub>2</sub>. The inferred trapping conditions of these fluids exceed 600 °C and 4 kbar, and a gradual modification towards 400 °C and 1.5 kbar, where the red magnesite (type 1) corresponds to lower T-P conditions. There is no evidence of fluid immiscibility. The sparry magnesite of the Brumado deposits has a metasomatic (metamorphic) origin, similar to the magnesite deposits in the Western Carpathians (Hurai et al., 2011). The Na/K ratios of the inclusions reveal trapping temperatures that exceeds 350 °C according to an improved geothermometer of geothermal waters (Reyna-Avilez et al., 2023).

### References:

Hurai et al. (2011) *Russian Geology and Geophysics*, vol. 52, 1474-1490.

Reyna-Avilez et al. (2023) *Geothermics*, vol. 115, 102822

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core), Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *magnesite, Brumado, fluid inclusions, metasomatism*

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## Inner Dinarides revisited: Opening and closure of a Neotethys branch in Western Serbia

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The Dinarides mountain belt of south-east Europe represents a segment of a complex Mesozoic large-scale fold and thrust belt situated between the Southern Alps in the NW and the Hellenides in the SE. The Dinaride fold and thrust belt contains continental units of Adriatic/Apulian affinity, as well as several Neotethyan ophiolite complexes situated in between. One of these ophiolite complexes is the well-explored 'Inner Dinaric Ophiolite Belt' (IDOB). However, the paleogeography and tectonic position has been a matter of discussion for a century. The IDOB relationship towards the rest of the Neotethyan oceans has been attempted to be explained with one-ocean and multiple-ocean models. The preliminary results of our structural investigations suggest a tectonic solution endorsing the multi-ocean model. The deformational history starts with the Anisian rifting and transtensional-type opening of a Neotethys branch ("Dinaric Tethys") marked by normal faults showing the N-S extension direction. The basin opening is sedimentologically manifested by transgressive clastic deposits. The ongoing deepening of this ocean continued with the development of carbonate ramps and platforms, deep sea pelagic environments, oceanic crust production, and accretionary wedging through the Jurassic. Closure of 'Dinaric Tethys' was initiated at the end of Jurassic/beginning of Cretaceous and is manifested by NW-directed thrust faults (NW-SE directed shortening). The Lower Cretaceous is characterized by a hiatus and a considerably large land area formation due to orogen exhumation. This is supported by evidence of unconformities and the occurrence of manganese and iron nodules, which are a product of the surface degradation of ophiolites. Due to post-orogenic collapse and/or due to the transgressive episode/sea level high-stand in Albian-Cenomanian, a new depositional cycle commenced characterized by shallow water clastics and a subsequent carbonate platform with Rudists limestones. This episode is marked by normal faults showing WNW-ESE-directed extension. The closure of these basins is not yet well understood as it does not show a regressive trend. In the Upper Cretaceous/Paleogene, significant strike-slip movement is recorded. Dextral and sinistral strike slip faults showed NW-SE compression and NE-SW extension. This deformation is linked to restraining bends of the NNW-SSE-striking Zvornik fault system. The following younger deformation, marked by WNW-ESE trending sinistral striking faults, is assumed to be Late Eocene E-W compression noted in previous research. The main stage of compression (microplate collision), occurred in the Late Oligocene and is marked with numerous ENE-WSW trending reverse faults, followed by N-S trending dextral and NE-SW trending sinistral strike-slip faults, as well as the formation of NE-SW oriented folds and joints. Following this, the Dinaric Lake System formed in the (latest Oligocene) early Miocene and is marked with normal faults with NE-SW and N-S-directed extension. The last deformational stage is linked to Pliocene-recent N-S trending contraction, which is marked by the youngest set of joints.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Dinarides, Mesozoic, Neotethys, Multi-Ocean Model, Paleostress Analysis*



## The Eastern Alpine metallogenic province: a resource of critical and strategic elements?

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One of the benchmarks of the Critical Raw Materials Act of the European Union requires a minimum of 10% supply from primary sources within the European Union until 2030. In the Eastern Alps, numerous deposits of base (Cu, Pb, Zn) and precious metals (Au, Ag) have been mined in the past, with production terminating in the 1990s. The contents of trace metals in the ores are largely unknown. In order to close this knowledge gap, a LA-ICP-MS study was conducted covering more than 60 polymetallic sulphidic mineralizations in the Eastern Alps. These comprise polymetallic (Cu-Zn-Pb±Ag) stratiform ores, polymorphic ore bodies and vein deposits in Neoproterozoic to Late Paleozoic, low- to medium-grade metamorphic rocks of the Subpenninic and Austroalpine nappe systems, and “Alpine-type” Zn-Pb-(pyrite) ores in Mesozoic carbonate sequences of the Austroalpine and South Alpine. The results indicate a large compositional variability of sphalerite, chalcopyrite, pyrite and pyrrhotite.

Two chemical types of sphalerite are broadly distinguished: (1) sphalerite in Alpine-type mineralizations is low in Fe (<1 %), Mn, Co, Ga, In, Sn, Sb, but may be significantly enriched in Ge (up to >500 ppm), Ga, As, Tl and Pb; (2) sphalerite in stratiform or vein-type ores hosted by low- to medium grade metamorphic rocks is elevated in Fe, Co, Ni, Cu, Ag, In and Sn.

Chalcopyrite carries Zn, Ag, Sn, Se, Pb and Mn as most important trace elements. Median concentrations of Ag and Sn may reach hundreds to thousands of ppm. Median concentrations of In exceed 40 ppm in several deposits. Concentrations of Co, Ge and Ga only exceptionally exceed the 10 ppm level.

Pyrite carries Co, Ni and As as most abundant trace elements, followed by Mn, Pb, Zn and Cu. The maximum concentrations of In, Ge and Ga reach 20 ppm. The most Co and Ni enriched pyrites occur in the Subpenninic unit in association with Ni-rich pyrrhotite, pentlandite and chalcopyrite. In stratiform ores hosted by Paleozoic low- to medium-grade sedimentary and magmatic host rocks, median values for Co are close to 500 ppm, whereas those from many vein and carbonate-hosted ores are much lower. Pyrite from some ores are Ni enriched with respect to Co.

The preferential incorporation of trace elements in Fe-Cu-Zn sulphide assemblages was investigated using polyphase assemblages comprising 2 up to 4 minerals. The elements Mn, Ga, Se and Cd are preferentially incorporated into sphalerite; Co, Ni into pyrite and pyrrhotite; As into pyrite; Ag and Sn into chalcopyrite. Germanium is present in sphalerite, and/or in chalcopyrite (in Cu-rich ores), rarely in pyrite. Likewise, In may be bound to sphalerite and chalcopyrite. Antimony, Tl, Bi, Mo may be present in all sulphide minerals, albeit usually at low concentrations.

The study provides estimates of critical and strategic metal concentrations in sulphides of the Eastern Alpine metallogenic province. Due to the mostly unknown resource of both, primary (in-situ) and secondary materials (dumps, tailings), geological exploration including drilling is needed to provide resource information for these raw materials.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Eastern Alps, critical and strategic elements, LA-ICP-MS, sulphides, geochemistry*

## Adiabatic winds, put into mathematical formulas

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The development of the air temperature under foehn winds can be put into the following formulas:

On the windward side, under dry adiabatic conditions, there is a fall in air temperature of 1.0°C per 100 m in the air parcel. From the condensation level, there is a change into wet adiabatic conditions, with a fall in air temperature of 0.6 °C per 100 m: we have cloud formation wind with subsequent precipitations. With the arrival of the air masses on top of the mountain crest, the lowest possible temperature is reached:

$$\theta_{h \min} = \theta_{st \ sl} + [(-1.0 \text{ °C}) / 100 \text{ m}] \cdot 400 \text{ m} + [(-0.6 \text{ °C}) / 100 \text{ m}] \cdot (h_{top} - 400 \text{ m}); \textbf{(1)}$$

If the observation locality for the initial temperature takes a height above sea level, the section from it to sea level is subtracted from the height above sea level:

$$\theta_{h \min} = \theta_{st \ ab \ sl} + [(-1.0 \text{ °C}) / 100 \text{ m}] \cdot 400 \text{ m} + [(-0.6 \text{ °C}) / 100 \text{ m}] \cdot (h_{top} - \Delta_{st \ sl} - 400 \text{ m}); \textbf{(2)}$$

$\theta_{h \min}$  = temperature on top of mountain range [°C];

$\theta_{st \ sl}$  = temperature from starting point, on sea level [°C];

400 m = condensation level on windward side, normally, ca. 400 m above observation point, range of condensation level down to sea level and up to more than 400 m possible;

$h_{top}$  = height of air parcel on top of mountain chain [m];

$\theta_{st \ ab \ sl}$  = temperature from starting point, above sea level [m];

$\Delta_{st \ sl}$  = difference in height on sea level from starting point above sea level.

When, from the height, the air parcel, on the opposite side of the mountain range, moves downward, again, from the topmost 500 m, the temperature rises by ca. 0.6 °C per 100 m. Afterward, from the dissipation level of the atmospheric humidity, with a continuous descending motion of the air, from the height downward, there is a rise in temperature of 1.0 °C per 100 m, down to sea level.

$$\theta_{dest \ sl} = \theta_{h \ min} + [(+0.6 \text{ °C}) / 100 \text{ m}] \cdot 500 \text{ m}_{top} + [(+1.0 \text{ °C}) / 100 \text{ m}] \cdot (h_{top} - 500 \text{ m}_{top}); \textbf{(3)}$$

If the destination point takes a height above sea level, the difference from it to sea level, again, is subtracted:

$$\theta_{dest \ ab \ sl} = \theta_{h \ min} + [(+0.6 \text{ °C}) / 100 \text{ m}] \cdot 500 \text{ m}_{top} + [(+1.0 \text{ °C}) / 100 \text{ m}] \cdot (h_{top} - 500 \text{ m}_{top} - \Delta h_{dest}); \textbf{(4)}$$

$\theta_{dest \ sl}$  = air temperature on destination point in wind shade, on sea level [°C];

500 m<sub>top</sub> = uppermost 500 m of mountain range, surpassed by air parcel, in wind shade;

$\theta_{dest \ ab \ sl}$  = air temperature on destination point in wind shade, above sea level [°C];

$\Delta h_{dest}$  = difference in height on sea level from destination point above sea level [m].

Differences in temperature of 20 °C can be reached by adiabatic winds.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** air parcel, condensation, dissipation, formulas, adiabatic conditions.

## Aktueller Stand und Methoden der Bohrungsaufnahme im Quartär Mecklenburg-Vorpommerns

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Die geologische Landesaufnahme von Mecklenburg-Vorpommern (MV) wurde in den letzten Jahrzehnten von wechselnden Schwerpunkten geprägt. Zur Gliederung des Quartärs wurde zwischen den späten 1960er Jahren bis 1989 das Kartenwerk „Lithofazieskarte Quartär 1 : 50 000“ (LKQ 50) im Zentralen Geologischen Institut der DDR erarbeitet. Für die Gliederung von Tillhorizonten wurde mit der TGL 25232 (1971, 1980) ein Standard zur Beprobung, Aufbereitung und Auswertung von Tillproben anhand von Kleingeschiebezählungen 4–10 mm (KGZ) geschaffen, der auch heute noch in MV mit einer modifizierten Auswertungsmethodik genutzt wird. Zwischen 2020 und 2023 wurden dem Geologischen Dienst MV (GD MV) insgesamt 1 037 Bohranzeigen für 2 153 Spülbohrungen zur oberflächennahen Erdwärmegewinnung mit Teufen zwischen 70 und 200 m und 567 Bohranzeigen für 1 003 hydrogeologische Bohrungen mit Teufen bis max. 280 m gemeldet. Dazu kamen 224 Bohranzeigen für 3 540 ingenieurgeologische Flachbohrungen bis max. 40 m Teufe (LBDS MV, 2023). Der GD MV plant die Befahrung und Beprobung neuer Bohrprofile zum generellen Kenntnissgewinn nach den folgenden Kriterien:

- Entfernung zu bisher untersuchten Bohrprofilen > ca. 1 000 m (Umkreis-Puffer),
- Bohrungen mit größeren Teufen als bisher in einem Gebiet erreicht und
- Bohrungen mit besserer Qualität als bisher aus der betreffenden Region bekannt.

Das Modell der quartären Schichten wurde zwischen 2005 und 2023 durch die Aufnahme von weiteren 1 006 Bohrungen, davon 522 Spülbohrungen zur oberflächennahen Erdwärmegewinnung, mit insgesamt 3 141 KGZ ausgebaut bzw. verfeinert. Durch die Geländeaufnahmen des GD MV der letzten Jahrzehnte wurden auch Profile minderwertiger Spülbohrungen für die Kartierung besonders wertvoll, wenn sie eine gesicherte stratigraphische Einstufung von Tillhorizonten mittels KGZ und/oder warmzeitlicher Horizonte mittels Pollenanalyse aufweisen und somit eine verbesserte Schichtengliederung zulassen, was im Folgenden am Beispielprofil einer Spülbohrung bei Wredenhagen erläutert werden soll. Im Jahr 2022 wurde im Ort Wredenhagen eine Spülbohrung zur oberflächennahen Erdwärmegewinnung mit 180 mm Durchmesser abgeteuft. Jeweils für einen Teufenbereich von 3 m wurde ein Haufwerk von ca. 2 kg Gewicht ausgelegt und durch den GD MV vor Ort aufgenommen. Im obersten Till (3–9 m) waren starke Verwitterungsspuren in der Kleingeschiebegruppe „Paläozoische Kalke“ („Brotlaib-Verwitterung“) auffällig. Dieser Till wurde nach KGZ-Analyse (TGL 25232, 1971) dem Jüngeren Saale Glazial zugeordnet. Interessant waren Proben mit leicht organischem Gehalt zwischen 87 und 102 m (-15 bis -30 m NHN). In den Proben zwischen 87-96 m wurden Molluskenbruchstücke extrahiert, die nach Meng (2024) den typischen Paludinen-Schichten aus dem Holstein-IG in Brandenburg entsprechen, aber keine marin-brackischen Arten enthielten. Die pollenanalytische Untersuchung des Profilabschnittes erbrachte ein Holstein-zeitliches Alter der Ablagerungen der Pollenzonen 2, 5a und b (Strahl 2023).

- Durch Geländeaufnahmen des GD MV sind auch Profile aus minderwertigen Spülbohrungen mit gesicherter stratigraphischer Einstufung für die Kartierung des quartären Untergrundes wertvoll.
- Durch die lithostratigraphische Einstufung von Tillhorizonten mittels KGZ, warmzeitlicher Horizonte durch Pollenanalysen oder paläontologische Untersuchungen qualifizierte Profile helfen das Quartär in regionalen und lokalen Dimensionen zu gliedern.
- Durch die regional verbesserte Datengrundlage kann in der hydrogeologischen Modellierung eine verbesserte Zuordnung von Grundwasserleitern bzw. -stauern erfolgen und

- eine qualitativ hochwertige 3D-Modellierung der quartären Schichten und der Quartärbasis ermöglichen.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Quartärkartierung, Bohrungsaufnahme, Lithostratigraphie, Till, Holstein-Interglazial*

Böse, Margot; Hebenstreit, Robert

## The challenge to decipher Late Pleistocene to Holocene geomorphological processes in the Taiwanese mountains

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The vegetational composition and the geomorphological processes change with the altitude in mountains. During the Pleistocene glacial stages, the altitudinal zonation shifted due to a drop of temperature. In addition, changes of the local precipitation regime occurred. The island of Taiwan represents a unique location for the research of long-term climate changes in East Asia, because its high mountains exceed 3500 m. It represents the only high-altitude mountain massifs in a radius of several thousand kilometres and can therefore provide differentiated palaeoclimate data of several altitudinal zones in the north-western Pacific region. As the present-day surface processes are strongly driven by earthquakes, regional tectonic uplift, and typhoons with catastrophic precipitation events, high erosion rates and a distinct backward erosion are destroying Pleistocene landforms and deposits. Nevertheless, in some mountain areas, remnants of “old landscapes” (late Pleistocene) are still preserved.

Evidence has been found that the vegetational and the geomorphological zonation was lowered in Taiwan accordingly by more than 1000 m during cold phases of the last glacial cycle. This is indicated 1.) by a long vegetational climatic record provided by the pollen assemblage from a sediment core in the Toushe Basin in central Taiwan (Liew et al. 2006) and 2.) by the reconstruction of extensive mountain glaciations and the respective depression of the ELA to below 3000 m. OSL and TCN dating from northern Taiwan show that most glacial traces are related to the late-glacial/Holocene transition (Hebenstreit et al. 2011). For the first time, boulders of a glaciation near the LGM were TCN-dated in the Nengao Shan (central Taiwan), recently. The most extensive glaciation is assumed for the MIS 4 from few earlier findings but mainly from palaeoclimatic correlations. It can be shown that the highest parts of the mountains were, like at present, dominated by the westerly circulation of the atmosphere more than by the monsoon. As 3.), the shift of the periglacial zone can be reconstructed from currently above ca. 3400 m, where frost weathering and solifluction dominate above the timberline, but traces of Pleistocene slope activity such as periglacial cover beds composed of weathered rock debris and aeolian dust were found as low as 2500 m.

Fluvial landforms and terraces are preserved in many mountain valleys (Wenske et al. 2012) and basins, like the Puli basin in Central Taiwan (Tseng et al. 2016). The global Pleistocene sea-level lowering affected the geomorphological processes in the mountain foreland by varying sediment transport and fluvial incision. It resulted in the formation of river terraces and tablelands and influenced the coastal development significantly (Liu et al. 2023).

*Hebenstreit et al. 2011: Quaternary Science Reviews 30 (3-4), 298-311.*

*Liew et al. 2006: Quaternary International 147, 16–33.*

*Liu et al. 2023: Quaternary Research, 1–22.*

*Tseng et al. 2016: Quaternary Science Reviews 132, 26-39.*

*Wenske et al. 2012: Quaternary International 263, 26-36.*

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Late Pleistocene altitudinal zonation, glacial landforms, periglacial deposits, fluvial terraces

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## The search for environmental changes in the tropical Lago Enriquillo (Dominican Republic) using multi-isotope (H, C, N, O, S) partitioning

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Tropical Lake Enriquillo in the Dominican Republic is the largest lake in the Caribbean. The hypersaline and endorheic lake is of marine origin and is located within the main development region of tropical cyclones. It showed substantial water level changes in the past and modern times. Within our research project that focuses on a geochemical approach for the identification of hurricane impacts, a multi-isotope (H, C, N, O, S) approach is applied on the lake water column and sedimentary solid phases for a reconstruction of past and on-going changes in hydrology and impacted biogeochemical processes. Measurements include the isotopic characterization of water, and dissolved C and S species, as well as the stable isotope composition (C, N) of organic matter, and S in total sulfur, pyrite, and kerogen. Results are complemented by using sedimentary Hg as a potential anthropogenic contaminant. Water samples along vertical profiles through the lake were taken during dry (March) and rainy (September) season 2022 and compared to lake tributaries. Hydrochemical data are further evaluated using the speciation model PHREEQC.

Substantial changes in the lake water composition were observed between the two campaigns. Together with an evaluation of element stoichiometries, the water isotopes allow for an evaluation of changes in the hydrological balance. C isotopes reflect the role of microbial activity and solution-atmosphere exchange on the modulation of the dissolved carbon system, in contact with biogenic carbonates, like ostracod shells. The contents of N and Hg in surface sediments indicate a sudden increase after the onset of substantial anthropogenic impact on the ecosystem with ecosystem fluctuations impacting the sedimentary record. The C isotope composition of organic matter shifted from marine dominated origin at depth towards substantial terrestrial contributions during the Anthropocene. The S speciation and isotope investigations indicate iron sulfidization and organic matter sulfurization due to microbial activity, as well as evaporative sulfate mineral formation.

**Session:** DEUQUA Session: Anthropogenic impact on the development of landscapes

**Keywords:** Holocene, Tropics, lake, multi-isotopes approach

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## Passive seismic imaging for geothermal reservoirs: the Schwechat depression under Eastern Vienna

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The Vienna Basin is one of the main target areas for deep geothermal exploration in Austria. Knowledge of the subsurface heavily relies on active seismic reflection that is expensive and logistically demanding. Affordable geophysical prospecting methods are needed to reduce subsurface uncertainty. Over recent years, passive seismic tools, e.g., ambient noise tomography, have proven to be cost-effective and environment-friendly. Here we present a passive-seismic study of the central Vienna Basin, which has revealed the shear-wave velocity structure of the neogene as well as the pre-neogene basin. We deployed an array of ~100 seismic nodal instruments during 6 weeks over summer 2023. We measured fundamental-mode Rayleigh and Love-wave group velocity dispersion from seismic ambient noise and employed transdimensional Bayesian tomography to invert for isotropic group velocity maps at periods ranging from 0.8 to 5.5 s. We then extracted Rayleigh and Love group velocity dispersion curves from the group velocity maps at all locations and jointly inverted them for shear-wave velocity as a function of depth using a transdimensional Bayesian framework. We discuss features observed in our 3D shear-wave velocity model as well as interfaces that are relevant to geothermal exploration, such as the Schwechat depression, the Aderklaa Conglomerates, and the sediment-basement interface

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Seismologie, Geothermie, Umgebungsrauschen, Oberflächenwellen, Schwechat-Depression*

## Permotrias-Paläogeographie der westlichen Nördlichen Kalkalpen und deren Zwangspunkte bei Deckenüberschiebungen und Seitenverschiebungen.

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Paläogeographische Rekonstruktionen wurden in den Nördlichen Kalkalpen zum wiederholten Male versucht. Meist waren sie allerdings nicht befriedigend, da man auch bezüglich der strukturellen Entwicklung sehr unterschiedlicher Meinung war. Hier nun ein neuer Versuch aufbauend auf jahrzehntelanger Beschäftigung mit dieser Fragestellung.

Folgende Zwangspunkte sind bei Rekonstruktionen entscheidend:

**(1)** das Vorkommen von Haselgebirge am Haller Salzberg sowie das Salinar bei Bad Reichenhall eines nördlichen oberpermischen Salinarbeckens.

**(2)** Die Transgression der Werfen-Fm. auf Alpenen Buntsandstein.

**(3)** Die spezielle Entwicklung am Nordrand des back-arc-Beckens im Süd-/Ostalpin in der M-Trias. An das nördlich gelegene Reifling-Partnach-Becken schließt im S die mächtige Karbonatplattform der Wetterstein-Fm. an (Lein et al., 2012, J. Alp. Geol., 54). Als Besonderheit folgt östlich von Innsbruck ein weiteres lokales Reifling-Becken (ohne Partnach-Fm.), das die Karwendel-Plattform im S/SE begrenzt. Auffallend ist das Vorkommen von Haselgebirge in eben dieser Zone. Äquivalente finden sich östlich von Salzburg. Reifling-Partnach-Beckenfazies mit direkter Überlagerung der Raibl-Gruppe ist typischerweise in der Lechtaldecke verbreitet, als auch im Liegenden der Inntaldecke und der westlichen Staufen-Höllengebirgsdecke.

**(4)** Das Intraplattform-Becken der Seefeld-Fm. des M. Nor könnte seine Fortsetzung in einer ähnlichen Fazies im Wiestal, SE' Salzburg haben.

**(5)** Oberrhätalkalk und Kössener/Eiberger Becken: die Bank- zu Bankkorrelationen sprechen für ein durchgehendes Eiberger Becken vom NW-Rand der Staufen-Höllengebirgsdecke zu den Vorkommen im Lahnenwiesgraben (NW Garmisch-Partenkirchen) in der Lechtaldecke (Hillebrandt & Krystyn, 2009, N. Jb. Geol. Pal. 253/2). Die NW- und N-Ränder der südlichen Oberrhätalkalkplattform finden sich bei Achenkirch, bzw. an der Waidringer Steinplatte und bei Adnet. Der Geiselsteinoolith der normalerweise auf der nördlichen Oberrhätalkalkplattform folgt, kommt völlig deplaziert auch am Südrand der westlichen NKA, südlich von Imst vor.

**(6)** Oberjurassische transpressive Einengungstektonik samt Plombierung durch die Rofanbreccie im Rofangebirge mit Äquivalenten nördlich vom Wolfgangsee (Missoni & Gawlick, 2010, Int. J. Earth Sc.).

Unter Berücksichtigung obgenannter „Zwangspunkte“ sind das Ausmaß und die Art folgender **Deckenüberschiebungen** und **Seitenverschiebungen** möglich.

Die „Karwendelschuppenzone“ (Heissel, 1978, Geol. Pal. Mitt. Ibk, 8) sowie weitere Schuppenzonen im Liegenden der Inntaldecke und westlichen Staufen-Höllengebirgsdecke entstammen faziell eindeutig dem ursprünglichen Nordrand der Karwendelplattform der Wetterstein-Fm. Dies hat zur Folge, dass die jüngste Neudefinition und Neubenennung der Decken (Ortner & Killian, 2022, Int. J. Earth Sc., 111) in Frage gestellt werden müssen und die Rückkehr zu den alten Bezeichnungen (Inntaldecke, Lechtaldecke) nahegelegt wird.

Die logische Zusammenführung heute deplatzierte paläogeographischer Zwangspunkte erfordert sinistrale Seitenverschiebungen größeren Ausmaßes:

1. Inntallinie: Landeck bis Salzburg. Allein die Rückführung des Haller Salzberges nach Bad Reichenhall beträgt 120 km (Luftlinie).
2. Puitental-Zone – Achensee
3. Nordrand Zugspitzkomplex – Wamberger Sattel

Diese tiefgreifenden Hauptscherungszonen sind einerseits gekennzeichnet durch das Vorkommen von Vulkaniten (Ehrwaldite) subkrustaler Herkunft (Trommsdorff et al., 1990, Geol. Rdsch. 79; Ortner & Killian, 2022), andererseits aber auch durch den räumlich begrenzten erhöhten Wärmefluß (Petschick, 1989, Frankf. Geowiss. Arb. 10). Hier sind spätdiagenetische Dolomitisation (Zebradolomit) und Pb- Zn-Mineralisation verbreitet. Seitenverschiebungen sind der Obertrias und im Jura sind faziell



nachgewiesen, mit der Datierung der Ehrwaldite mit 100 Ma ist die Störungsaktivität nach oben hin begrenzt.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Nördliche Kalkalpen, Perm-Trias Paläogeographie, Zwangspunkte bei Deckenüberschiebungen und Seitenverschiebungen*

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## Sedimentary Architecture of a Pleistocene Tunnel-Valley Fill from 3D Seismic Data in the German North Sea

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The aim of this research project is to analyse the distribution, dimensions, and evolution of Pleistocene tunnel valleys and their infills in northern Germany and adjacent areas. The findings of this analysis will be used to assess potential future tunnel-valley formation with regard to the long-term safety (over the next 1 million years) of a radioactive waste repository. Furthermore, the study aims to analyse sedimentary facies in order to draw conclusions about the infilling process and repeated erosion phases. This analysis will enable us to compare the development to the onshore tunnel valleys.

To achieve this goal, we are relying on a 3D high-resolution seismic dataset. Previously, the mapping of tunnel valleys on land was primarily based on 2D seismic data and boreholes, which have a rather low resolution. Therefore, we have opted to utilise a marine seismic dataset. The 3D seismic dataset, designated as 'GeoBasis3D', was acquired by the BGR in 2021. The survey area covers a region within the German Exclusive Economic Zone (EEZ), the so-called 'Entenschnabel' area. In this region, two intersecting tunnel valleys are present, one of which is situated above the salt dome 'Belinda'.

The following processes are to be examined based on the seismic data: the formation of the tunnel valley base through erosive processes and the influence of crestal faults above the salt dome on the formation and infill of the tunnel valley. The infill of the tunnel valleys will be characterised in terms of seismic facies, thereby enabling the interpretation of various sedimentary processes. The deepest parts of the tunnel valleys are characterised by steep slopes and chaotic internal reflectors, which suggests that this part of the tunnel valley was subglacially filled. The valley widens upwards, with some slump scars and slump deposits identifiable along the slopes of the tunnel valley. The sedimentary succession is characterised by typical cut-and-fill structures and various internal erosional unconformities, which can be traced across the tunnel valley. The tunnel valley displays evidence of multiple phases of sedimentation, including both high- and low-energy depositional processes. This is indicated by the presence of parallel and homogeneous reflectors. The crestal faults above the salt dome 'Belinda' have displaced the tunnel-valley floor and some deeper parts of the sedimentary infill. This leads to the conclusion that the faults must have been active during the Pleistocene. Nevertheless, an increase in the depth of the tunnel valleys along the faults could not be observed.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *tunnel valleys, 3D seismic data, sedimentary facies, German North Sea*

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## Using low-temperature thermochronometers for model selection: an approach for choose the best geometry for the Eastern Alps

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In the Eastern Alps, there is a long-standing discussion about a possible subduction polarity reversal. Deciphering the time-temperature evolution of the orogen and its foreland is key to link deep-seated processes like this to Alpine deformation and surface processes. Thermokinematic models have been used in the past for this purpose. However, thermokinematic models in past studies consider one or at most a handful of model geometries and sequences of deformation. This results in a common problem: solutions are usually non unique - more than one model geometry can explain a certain thermochronological signal. It is necessary to explore a range of possible models, and also of possible model configurations, to accurately address this conundrum.

In this work, we present two 3-D kinematic model hypotheses each for the Subalpine Molasse and for the Eastern Alps' TRANSALP section. One model geometry supports the subduction polarity reversal theory and the other does not. We use available low-temperature thermochronology to quantitatively evaluate how well each model iteration fits the observed data. Using the calculated maximum likelihood estimate (MLE) from each model hypothesis, we use the Bayes factor to determine which geometry is more likely, considering parameter and data uncertainties. For the Subalpine Molasse models, results favor an out-of-sequence triangle zone formation. For the TRANSALP section, the resulting Bayes factor implies very strong evidence against the subduction polarity reversal model, as the alternative model better explains the deep exhumation in the Tauern Window.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *3D Modeling; Uncertainty; Eastern Alps; Thermochronology*

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## Erosion and sediment transport by subglacial water in the Rhine glacier during the LGM

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Subglacial water plays an important role in eroding bedrock and in transporting sediments out of the glacial system. It is responsible for producing erosional features such as tunnel valleys and inner gorges (slot canyon) carved deep into the bedrock. Subglacial water also plays an important role in the formation of overdeepenings. Sediments transported in subglacial streams are deposited in outwash fans in front of the ice margin. They can also form deposits in tunnel valleys and eskers during periods of lower discharge. Here we model the erosion and sediment-transport processes in these subglacial channels using a simple subglacial hydrology model that computes hydraulic gradients from high-resolution ice-flow simulations of the Rhine glacier system in Northern Switzerland. From the hydraulic gradient and a model of surface melt obtained from recent high-resolution climate models over the Alps at the LGM, we estimate the flux of water in these subglacial channels as a function of seasons and during the advance and retreat of the Rhine glacier. The flux of water is then used to calculate local erosion (and deposition) in the subglacial streams. A sediment transport algorithm then estimates the total flux of sediments through these channels flushed out of the glacial system. Model parameters are adjusted using best estimates of observed sediment-size distribution and channel morphology in the Rhine glacier basin. This model has potential applications to understanding the origin and the movement of sediments in subglacial channels and explaining erosional features found today in the Northern Swiss lowlands that cannot be explained using glacial erosion mechanisms such as abrasion and quarrying.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *glaciology, LGM, subglacial, erosion, Rhine*

Conradi, Florian; Siedl, Wolfgang; Stern, Gerald; Knezevic, Nikolas; Novotny, Bernhard

## AQUIFER THERMAL ENERGY STORAGE (ATES) – Review of Principles, Significance and Feasibility of ATES Applications in Neogene Strata from the Vienna Basin.

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The City of Vienna is committed to become climate-neutral by the 2040. Its district heating grid (DHC), with a pipe length of over 1,300 Km connects more than 400,000 households. This large DHC grid size provides the scope for large-scale application of geothermal energy, such as the current field development of the Aderklaa Conglomerate by Wien Energie & OMV. Besides the conventional low-enthalpy geothermal applications, Aquifer Thermal Energy Storage is deemed another important building block in the decarbonization process, as vast amount of thermal energy can be stored & harvested in and from the subsurface, using energy that otherwise would have been lost.

The study outlines the status of the search for ATES suitable strata in the Vienna Basin through interpretation of a proprietary modern 3D seismic survey and a large dataset from oil & gas wells.

Although most hydrocarbon prospective areas are situated in different parts of the Vienna Basin, application of sedimentological and sequence-stratigraphic principles enabled extrapolation of the interpretation into the study area with limited well control. Geological concepts are proposed for three distinct Neogene sequences, each representing a specific depositional system that contains a defined number of architectural elements. With this approach the presence, distribution and geometry of the potential ATES aquifers has been assessed. Additionally, core & wireline log data from offset wells have been used to calculate reservoir properties. By integrating all disciplines and data, Gross Depositional Environment (GDE) maps have been created. These maps reflect the subsurface potential for ATES applications and will steer the upcoming lead & prospect generation.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *ATES, Geology, Neogene, Vienna Basin, Energy Storage*

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## Alpine deformation mechanisms along central and north Iberia Peninsula: a wide-angle seismic cross-section

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Orogen formation in tectonic plates boundaries and deformation transfer to the plate's interior to build intraplate mountain belts are processes that contribute to define topography and delineate continent/ocean transitions. The crustal deformation mechanisms that govern these processes vary deeply according to different tectonic settings and on superimposed tectonic phases. The central and northern Iberian Peninsula comprises from north to south: 1) the partially inverted passive continental North Iberian Margin (NIM), 2) the Cantabrian Mountains (CM) formed in the northern boundary of the Iberian subplate during the Alpine orogeny, and 3) an intraplate mountain range, the Spanish-Portuguese Central System (SPCS), located at ca. 200 km to the south of the CM. Additionally, the CM and SPCS are separated by the Duero Cenozoic basin which represents an elevated *plateau* (~800 m), whereas to the south of the SPCS, the Madrid Cenozoic basin is located at ~400 m altitude. Here, we present a 650-km long crustal-scale cross-section from the NIM to the south of the Madrid Cenozoic basin based on hyperbolic moveout processing of wide-angle seismic reflection/refraction data and on the reinterpretation of previous P-wave velocity models. Our data show an asymmetry of the Moho reflections at both sides of the SPCS and deep subvertical reflectors to the south of the SPCS that we interpret as the image of south-vergent crustal-scale thick-skinned thrusts. This contrasts with the deformation pattern of the CM, where deformation is decoupled between the upper and lower crust and only the Iberian lower crust subducts to the north down at least 40 km depth. This crustal architecture results from the inversion during the Alpine compression of inherited structures and weakness zones: mid-Cretaceous extensional detachments in the NIM and CM; and late- to post-Variscan granitoid intrusion that prompted crustal-scale fault nucleation in the contact with the country rocks in the SPCS. The Conrad discontinuity, separating the upper and lower crust, was assimilated during granitoid intrusion in the late-Variscan extension and played a major role in the different patterns used to accommodate deformation from the Iberian subplate's boundary towards the interior and partly resulting in the different altitude of the SPCS foreland basins.

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**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Spanish-Portuguese Central System, Cantabrian Mountains, North Iberian Margin, intraplate deformation*

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## Characterizing gravimetric and magnetic anomalies in the South of Salamanca (Spain): implications on the tectonic structure and Sn-W mineralizations

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In the Central Iberian Zone, located in the Iberian Massif (the westernmost outcrop of the Variscan orogen in Europe), several aeromagnetic anomalies stand out, and many of them are related to late-Variscan thermal domes. Nevertheless, some of these anomalies are not fully understood due to: 1) the lack of a clear relationship between extensional structures with the thermal domes, 2) the general low magnetic susceptibility of the outcropping rocks, and/or 3) the low resolution of the aeromagnetic map to correlate the anomalies with the local geology. For instance, the Salamanca Magnetic Anomaly (SAMA), in the central-western part of Spain, is a conspicuous reverse polarity magnetic anomaly with a maximum amplitude of 56.1 nT. However, the SAMA does not show any relationship with the magnetic properties of outcropping rocks. Previous studies showed that the outcropping Ordovician slates present randomly reverse polarity Natural Remanent Magnetization which is compatible with that of the SAMA but with very low intensity. To shed some light on the origin and to constrain the source of the SAMA, we have undertaken a large magnetic and gravimetric survey of this anomaly and its continuation to the south. The study area extends to the south of the city of Salamanca covering 1160 km<sup>2</sup> and geologically it comprises the contact between the Neoproterozoic and Paleozoic rocks of the Iberian Massif with the Duero Cenozoic basin along the Alpine Alba-Villoria NE-SW oriented fault. In addition, in the central part of the study area the Salamanca Detachment Zone, is a late-Variscan extensional structure that allowed deep rocks and crustal melt products to reach shallow crustal levels, probably easing Sn-W mineralization in the area. Our high-resolution magnetic and Bouguer anomaly maps depict a straightforward correlation between gravity and magnetic maxima, which are also related to the Alba-Villoria fault. Both gravity and magnetic maxima are aligned in an E-W orientation following the Ordovician slates cropping out west of Salamanca and its prolongation towards the east under the Cenozoic sedimentary rocks. Relatively high values are found towards the SW part of the map, where Neoproterozoic rocks hosting mineralizations are present. Although the magnetic maxima could be the potential field response of dense and magnetic slates common in the area, the ones previously measured do not present high magnetic susceptibility. Accordingly, this new data might indicate that late-Variscan extension triggered the intrusion of dense and magnetic basic rocks in a process that could have contributed to Sn-W mineralization.

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**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *magnetic anomaly, Bouguer anomaly, Salamanca Magnetic Anomaly*

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## Micro-computer-tomographic mineralogical and textural evaluations of Egyptian Blue Spheres

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Egyptian Blue was the first synthetic pigment by humankind. It consists of cuprorivaite, which is a calcium-copper-silicate (CaCuSi<sub>4</sub>O<sub>10</sub>). This study reports the results of a mineralogical and computer tomographic study of Egyptian Blue finds from Aguntum in East Tyrol along with Retznei and Wagna (formerly Flavia Solva) from southern Styria in Austria. The present work aims to extend our understanding of the processes involved in the production of the artificial pigment Egyptian Blue. The samples were investigated with respect to their elemental composition and spatial distribution of the calcium-copper-silicate cuprorivaite CaCuSi<sub>4</sub>O<sub>10</sub> and then compared with data from previous studies. Thin sections of an Egyptian Blue sphere from Aguntum was examined using optical microscopy (OP), micro-X-ray fluorescence analysis ( $\mu$ -XRF) and scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDX). The pigment's initial mixture as well as the manufacturing process seem to be the decisive factor for the quality of the final product. A relationship between the presence of trace iron (Fe), titanium (Ti), and sulfur (S) with the quartz and copper source of the initial mixture is discussed. In addition, micro-computed tomography ( $\mu$ CT) of the Egyptian Blue finds (Aguntum, Retznei, Wagna-Flavia Solva) was performed. Hence revealing several concise differences between the samples. Texture and volumetric results show a distinctive difference in cuprorivaite content and particle size. To better analyse the spatial distribution,  $\mu$ CT-3D images of the individual mineral phases identified within each sample were obtained. The clear differences in the results may not only enable a differentiation of the production process but also show another potential of non destructive  $\mu$ CT for assessment of archaeological and geological findings.

**Session:** *Classical Session: Analytical Advances*

**Keywords:**  $\mu$ CT, Mineral composition, texture analysis, fire coloured pigment



Diersche, Volker

## Blassangerl-Hundstodscharte Fm - a new Lower to Middle Miocene lignite formation from the Steinernes Meer, NCA/Tirol, Germany and Austria

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Geologic fieldwork on tectonics and sediments of the Steinernes Meer Mts. between Lake Diesbach and Blühnbachtörl rose our interest on 2 lignite occurrences, described already 1928 by Nora Hoffmann (“Pechkohle”; “Gosau im Steinernen Meer?”).

Other Alpine and Foreland lignite occurrences are well-known and -researched (Piller 2022), but Hoffmann’s lignite discovery was forgotten for nearly 100 years.

Due to the over-regional importance, we herewith define these lignite occurrences as the Blassangerl-Hundstodscharte Formation, with a revised age of Early- to Middle Miocene.

Type-section “Blassangerl” (1850m NN, 15m long water-ditch 300m southeast of Schönbichlalm, Topographic Map 8343/44 Funtensee) starts above Dachsteinkalk (fault?) with 0.2m carbonate pebbles with lignite streak, followed by 0.5m greyish-brown silty clay with several up to 1.5cm thick, lignite layers, overlain by 0.3m light-grey fine- to middle sand with clayey matrix and lignite flakes. Estimated succession thickness: 4-5m (Hoffmann). The lignite is black, hard, splintery, shiny crush, vitrinite reflexion value of 0.35% VRr (=Weichbraunkohle) (det. Dr. Neumeister). No molluscs, no macroscopic plant-remains.

At reference section “Hundstodscharte”/Austria (2210mNN, ca. 20x60m plain, 30m west of trail. Topographic Map 8443 Königssee; lying on Kleiner Hundstod thrust-block) a more than 0.5m reddish-brown clay contains 1cm thick black lignite, and pieces of 0.5cm greenish-yellow, calcareous sandstone. Footwall boundary at Blassangerl are possibly residual Augenstein Fm and Bohnerz. At Hundstodscharte are no Augensteine at surface, but expected underneath, because Augensteine and Bohnerz occur in nearby ruin-cave “Hundsfott-Wandhöhle” (Kat.nr. 1331/115).

Type section and reference section have as hanging wall boundary the overthrusting Dachsteinkalk of Mts. Hirsch resp. Großer Hundstod., corresponding to the South-directed Hundstod Thrust of Hahn (1913), as part of the K-L-T fault-zone active during the Miocene Lateral Extrusion (Decker et al.1994, Diersche et al.2018). This post-sedimentary overthrusting protected both lignite occurrences from erosion. Pollen research from type-section Blassangerl (det. Prof. Zetter) showed *Pinus*, *Cathaya*, *Cupressaceae* (*Taxodioideae*), *Carya*, *Pterocarya*, *Platanus*, *Quercus* - a pollen spectrum typical for a Lower to Middle Miocene age (statement Prof. Zetter).

This age is in accordance with Steininger et al. (1989) that the inneralpine lignite basin cycle is of Lower to Middle Miocene age.

We interpret the Blassangerl and Hundstodscharte lignite sections, together with lignite traces between, as proof for an originally at least 3km long “Blassangerl-Hundstodscharte Lignite Basin”, partly hidden under the Hundstod Thrust, with NW-SE axis (tectonically corrected).

The newly defined Blassangerl-Hundstodscharte Fm (Lower-to Middle Miocene) contains the highest lignites of the Northern Calcareous Alps of Germany and Austria and fills a gap in the knowledge on Tertiary paleogeography, subsidence and coalification.

### *Acknowledgements*

*We thank Prof. Reinhard Zetter/Boku Wien for pollen and age determination, Dr. Stefan Neumeister/Salzburg for vitrinite reflexion measurements, Bayerische Saalforste /St.Martin and Landratsamt and Nationalpark Berchtesgaden for road and sampling permits.*

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Steinernes Meer, NCA, Middle Miocene*

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## The Ledererkar Formation: a new Late Jurassic Formation with type-locality in the Steinernes Meer (Northern Calcareous Alps)

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Whereas the Late Jurassic sedimentological evolution of the Plassen Carbonate Platform in the Northern Calcareous Alps is fairly well understood, the contemporaneous evolution farther towards the Neotethys Ocean is not: Proximal basinal slope sediments associated with a platform evolution south of the Lärchberg Carbonate Platform, as well as of the proximal Sillenkopf Basin are rarely preserved. Also the evolution of the eroded platform evolving on top of the obducted ophiolites is poorly constrained. Here we describe for the first time an Upper Kimmeridgian-Tithonian carbonate succession from the Steinernes Meer Mountains that received material from an eroded platform south of today's Northern Calcareous Alps. We define this succession as the Ledererkar Formation, being part of the Plassen Group.

These Late Jurassic sedimentary rocks are known since v. Krafft (1897). Their origin and age – Early, Middle, Late Jurassic – were discussed controversially for more than 100 years. The most characteristic sections lie in the Steinernes Meer Mts. (with type section Ledererkar), and one section in the Hagengebirge Mts. (reference section Rotwandalm). At the Ledererkar type-locality the succession was preserved in footwall position in the framework of uplift/unroofing of the southern Northern Calcareous Alps contemporaneously with the uplift of the Lärchberg Platform.

Field analysis during the last 50 years revealed that deposition of the Ledererkar Fm. (Upper Kimmeridgian-Tithonian) starts transgressively above the deeply eroded Triassic-Jurassic sedimentary sequences of Steinernes Meer and Hagengebirge Mts. The Ledererkar Fm. is tectonically overlain by various lithologies of a higher structural unit: Alpine Haselgebirge/Werfen Fm., Wetterstein Fm., Dachstein Fm. The emplacement of these km-sized units ("Juvavic Klippen") around the Jurassic /Cretaceous boundary is supported by a calpionellid finding below the Mt. Graskopf klippe.

The type section Ledererkar has a maximum thickness of 120-140 m and is composed of mostly bituminous, organo-detrital limestones with small chert knobs, rich in up to gravel sized angular carbonate clasts, particularly in the lower 20 m, but also in higher section parts. The Ledererkar section contains 4 detrital mass flows of 15, 5, 7 and 40-50 m thickness, partly with thickness and grain diminution from E to W, and rarely turbidites. The component spectrum comprises Late Triassic light-grey basinal limestones and dolomites, Dachstein reef limestone, yellowish dolomite, ?Dürrnberg Fm., red (Bositra) limestone, radiolarite, Haselgebirge claystone, quartzite, metamorphic and volcanic quartz, wood. Ophiolite debris like in the Sillenkopf Fm. is not detected yet. The lowest 15m mass flow carries large slide-blocks of Adnet/Klaus Fm. Most microfossils occur through the whole section: Saccocoma, spicules, radiolarians, aptychi, shallow-water fossils of Plassen Group as echinoderms, benthic foraminifers, calcareous algae, serpulids, sponges, molluscs, corals, reef builders including incertae sedis, also in re-sedimented platform clasts.

The newly defined Ledererkar Fm fills a gap in knowledge regarding both the evolution of the today eroded southern Northern Calcareous Alps, and the provenance and emplacement of the Alpine Haselgebirge mélange.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *stratigraphy, Jurassic, Northern Calcareous Alps*

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## Old Orogens - Young Topography: Exploring the Effects of Continental Rifting on Erosional Dynamics and Topographic Development

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The evolution of collisional orogens and their drainage systems has been extensively studied. However, there are numerous active intercontinental mountain landscapes that are not located in the immediate vicinity of collisional zones and are therefore influenced by other processes, such as mantle-lithosphere interactions. These interactions include continental rifting, a process whereby rift flanks are uplifted due to graben subsidence in the center and lithospheric unloading, with the Upper Rhine Graben as a prominent example. The Vosges Mountains and the Black Forest delineate the eastern and western boundaries of this graben, respectively, with peak elevations exceeding 1,400 meters.

In a first step, a one-dimensional time-dependent numerical landscape evolution model that incorporates flexural isostasy was used to capture the genesis and evolution of the rift flanks. This model was able to successfully reproduce the high topographic and erosional asymmetry observed across rift flanks. The diverging erosion rates observed on either side of the rift flank can be attributed to variations in the topographical gradient. These, in turn, are directly related to the lithospheric strength, which represents the critical factor in determining the rate of rift flank retreat, and consequently the mobility of the watersheds. Furthermore, an initial topography has been identified as a crucial element influencing the evolution of rift flanks.

However, considering that continental rifting is not solely a one-dimensional problem, the second phase of this study is based on a two-dimensional landscape evolution model, specifically OpenLEM. This approach allows for a model representing a two-dimensional landscape, as opposed to two longitudinal river profiles sharing a common watershed. The model setup includes flexural isostasy, an initial topography, and normal faulting and is used to monitor the evolution of river catchments, local erosion rates, and catchment-wide erosion rates over time.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Numerical Modelling, continental rifting, morphometry*

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## The sedimentological anatomy of a landslide in Embach, Salzburg

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Quaternary deposits are widely distributed across areas of Austria and some of the outcrops are densely inhabited. South of Salzburg, at least 50 m thick gravels and sands are undergoing active mass movement, threatening the adjacent village of Embach. This proposed study, as the core of my Masters thesis, will analyse the sedimentary architecture of these deposits and develop a depositional model.

The deposits, which are overlain by a poorly exposed till of the Last Glacial Maximum (LGM), themselves have excellent exposure over a few hundred metres. They comprise poorly sorted gravels and well bedded sands, organised into sub horizontal beds, some with cross stratification. They appear to be interrupted by sharp discontinuities which are identified by a change in grain sizes and colour.

To date, very little to nothing is done regarding the depositional environment and sedimentological framework in the planned study area.

The Embach succession is thought to record ice build-up by the former Salzach Glacier prior to the Last Glacial Maximum (LGM) (Reitner, 2022). Le Heron et al. (2023) reported similar deposits to the east, where a proglacial lake was interpreted. Thus, given the exposure quality, it is hoped that detailed study will shed light on the build-up of LGM glaciers in the Province of Salzburg. Principal aims are (i) to characterise the sedimentary succession in as much detail as possible and (ii) to establish a depositional model, integrating the outcrop data with borehole data to be provided by GeoSphere Austria and the Province of Salzburg. Determining the stratal geometries and lithological heterogeneities has wider implications for understanding factors influencing future risk of mass movement.

Currently, there are three different hypotheses that may explain the sedimentary architecture at Embach, these are first, a fluvial system, second, a deltaic system and third a hybrid of these two depositional environments with feeder channels (fluvial) and a subaqueous part (foreset). These three different hypotheses will be tested by integrating traditional sedimentological field observations in concept with digital methods. Reconnaissance work reveals large foresets reminiscent of a Gilbert-type delta. If so, careful analysis, including the documentation of stratal geometries, might reveal base level changes charting proglacial lake evolution. Lithological description, sedimentary logging and clast fabric analysis will be performed together with photogrammetry to produce a realistic 3D model of the outcrop, as a foundation for interpretative correlation panels. Although the sands and gravels are expected to yield significant new results owing to the quality of exposure, the overlying till deposits are almost entirely overgrown and exposure is poor to non-existent. To put the deposits into a regional context, the fieldwork will be supplemented by geomorphological mapping of 1 m resolution laser scan data in order to determine the LGM-ice flow directions more precisely. These data reveal excellent evidence for features such as drumlins and large scale glacial lineations.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** quaternary, sedimentology, drones, photogrammetry, salzburg

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## Geomechanical modeling of well sections based on the results of complex geophysical and geological-technological studies during the drilling process

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In recent years, a large number of studies have accumulated on the process of interaction of a rock-cutting tool with rock, in which methods and means have been proposed for determining the physical and mechanical properties and abrasiveness of rocks. Among them are experimental studies, studies based on the analysis of geological and geophysical information, as well as those based on classification methods. As a result, methods have been proposed that make it possible to evaluate the properties of rocks both from cores, cuttings, using the results of geophysical surveys of wells, and data from geological and technological studies during the drilling process. The construction of a geomechanical model involves the use of data from areas of neighboring wells that have characteristics similar to those of the well under study. As is known, to obtain a geomechanical model it is necessary to have a sufficient amount of information.

Geological and technological research during the drilling process, which has become widely used in world practice in recent years, makes it possible to solve a number of problems during the drilling process when information about the section of the well being drilled is missing or is available in limited quantities. The use of the results of geological and technical information in combination with geophysical surveys of wells allows for a deeper study of the section and thereby improves the quality of decisions made.

Solving problems of modeling technological processes is significantly complicated by the presence of uncertainty associated with both the use of random and fuzzy variables. Random variables convey that the quantities under study can take on different values with different probabilities. Fuzzy variables convey approximateness in determining the very values of these quantities. In addition, fuzzy values may be preferable when there is insufficient statistical data and related information necessary for more reliable estimates. Such assessments of the mechanical properties of rocks can be made based on data on their physical properties, assessed using geophysical surveys of wells using probabilistic-statistical methods and fuzzy set theory. The study of the considered dependencies made it possible to develop a reasonable calculation scheme for assessing the characteristics of the geological section. At the same time, it should be noted that in the absence of data from core-sludge studies or marked dependencies that make it possible to assess the indicators of the mechanical properties of rocks, the latter can be assessed using a geological and petrographic description of the rocks. The task in this case is to analyze and summarize information about the properties of rocks in order to create convenience in assessing the drillability of rocks.

The use of complex geological and technological information makes it possible to obtain more reliable information and thereby increase the efficiency of the design decisions carried out during drilling operations. This is very important for making the right decisions and allows you to quickly solve various problems related to the selection of bit types and operating parameters, and the assessment of complicated intervals.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Geomechanics, drilling, fuzzy set theory, rock property, petrographic description*

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## Geoelektrik und Sub-Bottom Profiling an der Grenzmur im Bereich Bad Radkersburg

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Im Zuge dieses Pilotprojektes wurden sechs Geoelektrikprofile in unmittelbarer Nähe der Mur zwischen Halbenrain (Österreich) und Apače (Slowenien) mit einer Dipol-Dipol- Elektrodenkonfiguration und zwei Profile mit einer Wenner-Elektrodenkonfiguration aufgenommen. Vier Profile liegen an der Nordwestseite der Mur (Österreich; orografisch linksseitig) und vier Profile an der Südostseite (Slowenien; orografisch rechtsseitig). Je ein Profil beidseits wurde als Querprofil zur Mur aufgenommen (Profilnummern 3 und 6). Die unterschiedlichen Elektrodenkonfigurationen und auch die verschieden gewählten Elektrodenabstände dienen zum Vergleich des Auflösungsvermögens und der Eindringtiefen bei den gegebenen (hydro-)geologischen Verhältnissen. Damit liegen insgesamt acht Geoelektrikprofile mit einer Gesamtlänge von 4.067 m als geophysikalische Basis für eine hydrogeologische und sedimentologische Interpretation vor. Auf slowenischer Seite konnten Informationen von 14 Bohrungen und auf österreichischer Seite Informationen von 3 Bohrungen in die Geoelektrikprofile erfolgreich eingehängt werden. Die Widerstandskontraste des hochohmigen quartären Aquifers gegenüber dem (miozänen) niederohmigen Stauer korrelieren mit den geologischen Informationen der Bohrungen.

Die Messungen der Sub-Bottom-Profiling Daten (SBP; Sediment-Echolot) umfasste 31 Profile mit unterschiedlichen Frequenzen, mit einer Gesamtlänge von 14.300 m und reichte von Ratzenau (Gemeinde Mureck) Mur-abwärts bis Bad Radkersburg. Während der Akquisition wurden verschiedene Anregungsfrequenzen (4, 5, 6, 8, 10, 12 und 15 kHz) getestet. Im Bereich zwischen Halbenrain und Apače wurde die Anzahl der flussparallelen Profile verdichtet und zusätzlich sechs Mur-Querprofile aufgenommen. In den SBP-Daten konnten einerseits die (miozäne) Staueroberkante, abschnittsweise die quartären Flusssedimente und die Geometrie des Flussbetts erkannt werden. Es konnte nachgewiesen werden, dass abschnittsweise die quartären Flusssedimente im Murbett fehlen und damit die Mur direkt im Kontakt zum Stauer steht bzw. diese bereits erodiert.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Geophysik, Sub-Bottom Profiling, Geoelektrik*

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## Die Forschungsbohrung Klosterrohrbach in der Helme-Niederung (Sachsen-Anhalt) – Interdisziplinäre Untersuchungen an Sedimenten aus dem obersten Mittelpleistozän

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Das Landesamt für Geologie und Bergwesen Sachsen-Anhalt (LAGB) hat in der Helme-Niederung im südöstlichen Harzvorland die Forschungsbohrung Klosterrohrbach (FB-Krb 1/2013) zwecks Untersuchung der vielgliedrigen quartären Schichtenfolge sowie zur Rekonstruktion von langfristigen Senkungsbewegungen infolge der Subrosion von Zechstein-Salzen niederbringen lassen. Nach Angaben aus älteren Bohrungen in der Umgebung des Bohrstandortes war eine mindestens 60 m mächtige Abfolge quartärer Bildungen u. a. mit Eem- und Holsteinzeitlichen Ablagerungen zu erwarten. Auf Feinsandstein und Ton der Bernburg-Formation (Unterer Buntsandstein) im Liegenden folgt ein 64 m mächtiges Quartärprofil. Es besteht überwiegend aus Helme-Schottern, Hochflutablagerungen sowie klastischen Stillwassersedimenten. Untergeordnet treten Fließerden, Schluffmudde und Schwemmlöss auf.

Die quartäre Schichtenfolge wurde interdisziplinär untersucht. Neben der lithologischen Kernaufnahme und den begleitenden sedimentologischen und geochemischen Analysen erfolgten paläobotanische und malakologische Bearbeitungen. Der chronologische Rahmen für die obere Profilhälfte ist durch vier Fading-korrigierte post-IR-IRSL-Daten gegeben. Mit Altern von  $188 \pm 15$  ka bis  $159 \pm 12$  ka ist der Teufenbereich von 33,57 m bis 9,26 m in den oberen Teil des Saale-Komplexes einzuordnen.

Die Sedimente im Teufenbereich von 64,00 m bis 51,60 m werden als Beckenablagerungen, Fließerden und Hochflutablagerungen interpretiert. Sie enthalten drei Steinsohlen. Die scharfe Schichtgrenze von einer mit Feinmaterial vermengten Kiesschicht (Steinsohle) zu Feinsand in 51,60 m Teufe markiert möglicherweise den Hiatus zwischen der Elster-Kaltzeit und dem unteren Teil des Saale-Komplexes (Unter-Saale). Ablagerungen der Holstein-Warmzeit, der Fuhne-Kaltzeit, der Horstwiesen-Warmzeit und der Wormsdorf-Kaltzeit, welche in der nur ca. 3 km entfernten Forschungsbohrung Martinsrieth nachgewiesen wurden, sind nicht überliefert.

Die ältesten pollenanalytisch ausgewerteten Ablagerungen datieren in die Pollenzone 4a-b der Dömnitz-Warmzeit (ca. 47,00 m bis 44,85 m). Die Hochflutablagerungen sind u. a. durch hohe Pollenanteile der Laubgehölze Eiche, Erle, Haselnuss und Linde gekennzeichnet. Die Wasservegetation wird von Teichfaden, Großem Nixkraut, Schwimmendem Laichkraut und Ährigem Tausendblatt geprägt. Sie repräsentiert ein stehendes bis langsam fließendes Gewässer sowie günstige klimatische Bedingungen. Zudem wird die dickschalige Flussmuschel *Corbicula fluminalis* (*C. fluminalis* auct. non O. F. Müller 1774?) mit mehr als 50 Schalenklappen unterschiedlicher Altersstadien nachgewiesen. Sie ist die namensgebende Leitart für die sogenannten *Corbicula*-Schotter, die nach bisherigen Kenntnissen dem unteren Saale-Komplex zuzuordnen sind (Meng & Wansa 2008). Jüngere Ablagerungen der Dömnitz-Warmzeit (Pollenzone 4c-e) mit den charakteristischen Maxima von Hainbuche und Tanne fehlen (Hiatus).

Die nachfolgenden Seetone, Seeschluffe und Seesande werden als Stadal-Interstadial-Abfolgen der Delitzsch-Phase (Ober-Saale) eingestuft. Insgesamt werden drei Bereiche mit interstadialer Vegetation beobachtet. Während des Interstadials A/B (43,00 m bis 34,65 m) sind neben der Kiefer auch Erle, Haselnuss und Fichte in der Gehölzschicht etabliert. Auffällig ist neben hohen Anteilen von Süß- und Sauergräsern das vermehrte Vorkommen von Heidekrautgewächsen in der Krautvegetation. Das Interstadial B/C (31,85 m bis 25,60 m) zeigt eine ausgeprägte Dreiteilung mit Ausbreitung, Maximum und Rückgang des Kiefern-Anteils. Ein analoger Kurvenverlauf ist bei der Grünalge *Pediastrum* zu beobachten. Erhöhte Anteile werden mit einer Erwärmung und/oder einer Verflachung des Sedimentationsraumes in Verbindung gebracht. Auf letzteres könnte auch der Nachweis von Armleuchteralgen-Oogonien hinweisen. Weitere Vertreter der Wasservegetation sind Teichfaden und Schwimmendes Laichkraut. Dieser Kernabschnitt beinhaltet erneut eine reiche Molluskenfauna. Das Arteninventar ähnelt dem der Dömnitz-Warmzeit, *Corbicula fluminalis* tritt hier jedoch nicht auf.

Im Bereich von 20,87 m bis 9,95 m lagern die Helme-Schotter der Haupt-Mittelterrasse. Sie sind durch feinkörnige Sedimente (Hochflutablagerungen), die von 15,10 m bis 14,50 m das Interstadial C/D repräsentieren, unterteilt. Das dritte Interstadial zeigt eine ausgesprochen lichte Bewaldung mit Kiefer, Wacholder, Pappel und Weide. Die Wasservegetation wird von Wasser-Hahnenfuß, Faden-Laichkraut und cf. Gras-Laichkraut geprägt. In diesem

Abschnitt ist erneut eine diverse Molluskenfauna, bestehend aus Süßwasserarten und auch Nacktschnecken (Limacidae/Agriolimacidae), zu beobachten.

Die höher gelegenen, fast 6,00 m mächtigen Helme-Schotter (mit eingeschalteten Hochflutablagerungen) werden als Niederterrasse der Weichsel-Kaltzeit angesehen. Ihre Basis befindet sich nach geröllanalytischer Indikation an der Schichtgrenze in 8,23 m Teufe. Sie bildet vermutlich zugleich die Grenze zwischen dem Saalezeitlichen und dem Weichselzeitlichen Profilabschnitt. Bildungen aus der Eem-Warmzeit sind nicht erhalten.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Quartärgeologie, Stratigraphie, Mittelpleistozän, Saale-Komplex*



Fehleisen, Anna; Hauzenberger, Christoph; Booth, John

## Petrology and geochemistry of the Belhelvie and Arnage-Haddo House gabbro intrusions and their contact aureoles - Aberdeenshire, Scotland

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The Belhelvie and Arnage - Haddo House gabbro intrusions, situated within the Buchan Block of the Scottish Grampian Highlands, are part of a suite intruded at around 470 Ma, coincident with peak regional metamorphism and just predating the regional D3 deformation event. At the time of intrusion the host Dalradian metasediments had reached regional sillimanite migmatite gneiss grade, facilitating extensive partial melting in some places adjacent to the gabbro intrusions. This study uses different petrological, geochemical, and geochronological techniques to investigate the petrogenesis of the contact aureole of the Belhelvie gabbro and the highly anatectic melt contaminated marginal zones of the Arnage – Haddo House gabbro. The Belhelvie gabbro body is a layered intrusion, for which a tholeiitic differentiation trend can be defined. It is composed of varieties of gabbros and norites, together with troctolites and serpentinised peridotites. There is no obvious petrological evidence of contamination by silicious melts generated from the adjacent Dalradian metasediments. In contrast the marginal facies of the Arnage – Haddo House gabbro is heavily contaminated, consisting of a variety of hornblende and biotite bearing quartz norites and cordierite-norites, as well as containing a large number of partly melted garnet – spinel - cordierite xenolith restites derived from the adjacent Dalradian. The metamorphic aureole of the Belhelvie gabbro can be divided into three zones. An outer zone, at least 300 m wide, consisting of garnet – biotite ± cordierite hornfels, and an inner contact zone, some 30 m wide, which was affected by partial melting. This contact zone can be further divided into two subzones. The inner part, immediately adjacent to the gabbro, is characterised by assemblages containing orthopyroxene but no sillimanite, while assemblages in the outer part contain sillimanite and no orthopyroxene. Some silicious poor restite portions of the contact zone contain corundum. Phase modelling has been used to estimate the pressure-temperature conditions across these three zones, which range from 650 to 850°C and 0.33 to 0.41 GPa. Petrographic textures and changes in mineral assemblages have been used to determine the sequence of prograde and retrograde reactions that occurred as the contact aureole overprinted regional metamorphism. In-place U-Pb age dating of zircons from thin sections of a marginal intrusive sample of the Belhelvie gabbro and an aureole hornfels sample show that they both contain identical suites of zircons, indicating there was in fact some contamination of the margin of the gabbro. There are two major groups of concordant zircons, the younger at around 1007 Ma corresponding to a Grenvillian provenance while the older at around 1.6 Ga was probably derived from the core of Laurentia. A clearly defined discordia line has a lower intercept around 470 Ma, indicating lead loss during a significant thermal event, which is interpreted to correspond to the intrusion of the Belhelvie gabbro itself.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Contact metamorphism, Intrusion, contact aureole, age dating*

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## End moraine system of Lake Altaussee

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Lake Altaussee (Salzkammergut, Austria) is considered to be dammed by a so called Gschnitz endmoraine system (Mandl et al. 2012: 46). The terminal position of this endmoraine was determined on the base of former outcrops along the Altaussee Traun close to the west end of the village Altaussee (Van Husen, oral communication). The surface shape of the landscape above the former outcrop points to a streamlined ground moraine landscape from peak glaciation during MIS 2. A prominent lateral moraine was found on the southern lake side close to the Strandcafe. Dating with cosmogenic isotopes of carbonate blocks on top of the Strandcafe moraine was not successful yet. Interestingly, seismic investigations of the lake subsurface found evidence for a wall moraine structure in the western part of the lake and which is buried under a sequence of glacio-lacustrine sediments. This structure could fit together with the southern Strandcafe moraine into one moraine loop. The configuration of meltwater flow from such a low-lying endmoraine system is unclear. Finally, a lateral moraine wall was mapped on the northern lake side at the northeastern end of the village Altaussee. Different (higher) lake levels have been proposed by industry drilling, peat coring, geo-electric profiling and geomorphological mapping, but without age determination. The age of wall moraine systems around and below Lake Altaussee is still under investigation and should shed more light on the genesis of the lake.

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**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *End moraine system, Lake Altaussee, mapping, seismic investigations*

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## Recent sediment dynamics in the landslide-debris flow complex of the Sattelkar, Obersulzbachtal, Hohe Tauern

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High mountain landscapes are dynamic and heterogeneous environments shaped by diverse geomorphological processes, serving as primary sources of sediment and water with significant implications for downstream areas. Climate change can reduce slope stability and thus increase sediment availability. Yet, given the mixed influences of temperature and precipitation, the impact of climate change on mass movements remains unclear. The Sattelkar cirque in the Hohe Tauern mountain range, Austria, has experienced significant landslide activity since 2003. In 2014 a catastrophic debris flow delivered 70,000 m<sup>3</sup> of sediment from the cirque and mobilised a total of 170,000 m<sup>3</sup>, resulting in severe damage to the Obersulzbach Valley.

This study quantifies sediment dynamics based on a multi-temporal surface change analysis. Using high resolution digital elevation models (DEMs) of 2012-2023 surface processes are quantified and interannual dynamics are reconstructed for the cirque area and the adjacent debris cone. Additionally, sediment availability and exhaustion within the active landslide area are reconstructed based on an assessment of sediment volumes in the cirque area.

In 2012-2023, 920,000 m<sup>3</sup> (83,000 m<sup>3</sup>/a) of sediment was discharged from the cirque, of which 540,000 m<sup>3</sup> (39,000 m<sup>3</sup>/a) accumulated at the debris cone. Over the study period, the average sediment discharge from the cirque increased slightly by 1,440 m<sup>3</sup>/a, whereas the debris cone grew by 2,980 m<sup>3</sup>/a. While the sediment dynamics in the area of the cirque show significant spatial and quantitative variations between years, the sediment balance of the debris cone fluctuates only slightly. Yet, in years of high sediment discharge from the cirque, strong height differences in the channels and extensive accumulation areas in the lower debris cone occur. Based on the sediment dynamics of recent years and a remaining sediment volume of 1,000,000-1,800,000 m<sup>3</sup>, depletion is expected between 2033 and 2042.

This study provides estimates of expected sediment dynamics of the Sattelkar landslide-debris flow complex. Together with ongoing monitoring, the investigations enable a hazard assessment based on sediment availability near the cirque threshold.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *sediment dynamics, landslide, debris flow, hazard*

Firla, Gustav; Lüthgens, Christopher; Fiebig, Markus

## The timing of the infilling of glacially overdeepened structures from the northern Alpine foreland in the context of tunnel valleys from the Fennoscandian ice shield.

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Understanding the timing of the sedimentary infill present in glacially overdeepened structures is crucial for reconstructing past glacial dynamics and Pleistocene landscape evolution. Subglacial erosional landforms are known on the southern margin of the Fennoscandian ice shield (tunnel valleys) and in the northern Alpine foreland (overdeepened valleys). The timing of the formation and subsequent infilling of tunnel valleys is attributed to different marine isotope stages (MIS 4-12) largely based on geophysical surveys where cross-cutting tunnel valley generations can be differentiated with absolute minimum and maximum ages provided (Stewart and Lonergan 2011), but a comprehensive numerical chronological framework of the sedimentary infill remains fragmentary. Overdeepened valleys were systematically investigated in the context of the International Continental Scientific Drilling Program – Drilling Overdeepened Alpine Valleys (ICDP-DOVE) project with drill-cores from representative and complementary overdeepened structures (Anselmetti et al. 2022). The investigated overdeepened structures showed a generally similar sedimentary succession. The chronology of the infill is provided by a robust single grain pIRIR SAR protocol luminescence dating approach using potassium rich feldspar as a dosimeter (Buylaert et al. 2009). Using single grains of feldspar from generally poorly bleached sediments, commonly found in glacial environments can circumvent the signal averaging effect of multi grain measurements that would lead to an age overestimation if not addressed (Firla et al. 2024 in press). Results from this and previous investigation concluded that the fine-grained sediments at the base of the analyzed overdeepenings in the northern Alpine foreland were deposited during the penultimate glaciation. The timing of the infill provides a minimum age for the formation of the overdeepened structures but does not provide information about the absolute age of formation. The timing of the infilling of overdeepened Alpine valleys is discussed in the context of the timing of the formation of the Fennoscandian tunnel valleys and potential chronological differences and similarities between overdeepenings and tunnel valleys are highlighted.

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**Session:** Pangeo workshop: Glacial erosion and deposition

**Keywords:** Luminescence dating, single grain, feldspar, glacial basins, European Alps

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## Development of an analytical protocol for solution ICP-MS analysis in (U-Th)/He thermochronometry

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(U-Th)/He thermochronometry is an emerging tool capable to date the cooling of U and Th bearing mineral phases below specific closure temperatures. The two most commonly dated minerals are zircon and apatite, with closure temperatures of  $\sim 180^{\circ}\text{C}$  and  $\sim 70^{\circ}\text{C}$  corresponding, at a typical continental geothermal gradient, to upper crustal depths of approximately 6 km and 2 km, respectively. (U-Th)/He thermochronometrical data can therefore be used to reconstruct the thermal evolution of sedimentary basins, or the exhumation of cratonic plateaus or mountain chains. Furthermore, the timing of past volcanic activity can be constrained due to the  $^4\text{He}$ , formed by alpha decays in U and Th decay series, starting to accumulate in the crystal lattices upon cooling below the above-mentioned closure temperatures.

Major steps of the analytical workflow in (U-Th)/He thermochronometry are dimension measurements to correct for  $^4\text{He}$  lost out of the finitely-sized crystals upon decay, heating individual crystals with an infrared laser to release  $^4\text{He}$  and quantify it with a gas mass spectrometer, dissolving individual crystals, and quantifying U and Th parent nuclides by inductively coupled plasma mass spectrometry (ICP-MS).

At the University of Salzburg, we conduct these ICP-MS analyses with an Agilent 7900 instrument, where we generally achieve sub-ppt detection limits for the most relevant elements. However, we observed mass-dependent sensitivity variations by up to 30% throughout individual, one-day analytical sessions. We therefore present our approach in selecting internal standard elements and isotopes, permitting a precision of typically  $<2\%$  ( $1\sigma$  SD). Furthermore, we discuss our approach to realistically quantify and account for the remaining sensitivity variations using the Agilent MassHunter software.

**Session:** *Classical Session: Analytical Advances*

**Keywords:** *Dating, Cooling, Apatite, Zircon, Thermochronology*

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## A geotechnical view on glacial sediment profiles

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The characterisation and genetic interpretation of glacial (*sensu lato*) sediment profiles is not always straightforward, especially if observations are limited to the narrow window that a drill core offers. Geotechnical data has proven valuable for, among others, the identification of a glacial sediment component, of previous mechanical loading by ice, or of the modification of a deposit by non-glacial processes. Such data can be gathered with often very simple and cost-effective techniques adopted from applied geosciences, but nevertheless appear to have lost some attention by Quaternary geologists in recent years.

We investigate sediment records from overdeepened basins in the Alpine foreland and in the Black Forest, and routinely apply standard geotechnical methods to reconstruct their deglaciation and, where applicable, phases of readvance. These methods include the determination of:

- i) the deposits' shear strength that can be used as an indicator of loading and compaction (i.e. overconsolidation) by an overriding glacier

- ii) consistency limits (i.e. water contents at which the sediment's mechanical behaviour changes), which are a measure of the 'glaciality' of a sample and, in relation to its natural water content, further indicators of a potential overconsolidation

- iii) the settlement in response to an applied load that allows the determination of a preconsolidation pressure (i.e. a pressure that the sample has previously been exposed to)

- iv) water uptake capacities in disturbed and undisturbed state that can provide further information on a sample's internal structure.

We present sedimentological and geotechnical data from several basin infill-profiles, and demonstrate the application and the prospects of, as well as the conclusions that can be drawn from geotechnical testing.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *applied geology, diamicts, geotechnics, glacial sediment, till*

Geringer, Annika<sup>1</sup>; Grasmann, Bernhard<sup>2</sup>; Weber, Leopold<sup>3</sup>; Melcher, Frank<sup>4</sup>; Schuster, Ralf<sup>1</sup>

## Polyphase deformation of the Graz Paleozoic recorded in the Pb-, Zn-, Ba- and Ag-bearing Arzberg deposit

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The Arzberg mine in Styria (Austria) reveals a long history of mining for silver, lead and zinc with a first documentation as early as 1242. Arzberg is one of the biggest occurrences of Pb-, Zn-, Ba- and Ag-bearing SEDEX (sedimentary exhalative) deposits situated in the Schöckel nappe of the Graz Paleozoic (Drauzug-Gurktal nappe system, Austroalpine Unit). The stratiform mineralization is dominated by galena, sphalerite, barite, pyrite and pyrrhotite and accompanied by chalcopyrite, arsenopyrite, fahlore, pyrargyrite, tetradymite, cobaltite, ullmannite, breithauptite, electrum and others. The mineralization is hosted by the upper Silurian to Lower Devonian Schönberg Formation (Arzberg Schichten), which consists of polyphase deformed, greenschist facies metasediments and metavolcanics. This represents an euxinic shelf sequence grading from siliciclastic to carbonatic sedimentation with minor basic tuffogeneous intercalations. It is overlain by the thick carbonate sequence of the Schöckel Formation.

The Arzberg mine is situated a few hundred meters below the SE dipping boundary of the Schönberg and Schöckel Formation. Competence contrasts cause more intense deformation and tectonic slicing along the boundary, whereas the internal deformation within the Schönberg Formation is simpler. In the mine the macroscopically visible deformation is polyphase and three stages can be recognised: (1) The first deformation event occurred during greenschist facies metamorphism and was associated with ductile shearing towards SE. This process led to the development of metamorphic layering, mylonites and phyllonites, as well as the formation of isoclinal folds with fold axes roughly parallel to the shear direction. Within this shearing process, multiple fluid pulses contributed to the creation of syn-shearing veins, which exhibit rotation and stretching to varying degrees confirming the SE-directed kinematics. The subsequent (2) deformation phase resulted in the formation of SE-vergent folds, superimposed upon the pre-existing mylonitic to phyllonitic foliation. The rocks exposed in the area of the Raabstollen may represent the upper limb of a SE-verging antiform, with a hinge area located at both the entrance and the end of the Raabstollen. All of these preceding ductile structures have been overprinted by a (3) phase of ductile/brittle faulting, along with hydrofracturing, and EW-extension accommodated by normal faults with clay gouges.

The ore mineralizations are primarily concentrated within two up to several decimetre-thick layers roughly parallel to the main foliation, which are structurally separated by approximately 30 m. The lower ore horizon is dominated by Fe-Pb-Zn-Cu-sulfides, whereas the upper ore horizon by barite along with magnetite and galena. Two major E-dipping faults displace the ore horizons, where an offset about several tens of meters is presumed. These two major E-dipping faults and numerous smaller faults with centimetre to meter offsets suggest a major component of WE-extension during the deformation phase 3, which is consistent with the lateral extrusion of central parts of the Eastern Alps towards the Pannonian Basin in the E.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *SEDEX, Graz Paleozoic, Structural Geology, Sulfides*

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## Precious and critical metal potential of historic Cu-Au-As mine waste in the Eastern Alps

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For the world to transition from fossil fuels to renewable energies, we need both an amount and a diversity of raw materials the likes the world has never seen. For example, to build the required power grid to move to 'green' electricity we need to mine the same amount of copper in the next 30-40 years as we have in all of human history combined (Cathles and Simon, 2024). The impossibility of finding such a large amount of copper, and other critical metals, in such a short time requires us to identify alternative sources of these critical and strategic metals.

While we will likely not find such large quantities of these metals in new deposits, we note that during much of human history the extraction rates for many metals were less than 50%. This means that in the mine waste of historic districts we might have as much metal in the mine waste as was originally produced. This is particularly true of the historic Cu-Au-As mining districts of the Eastern Alps, which were partially mined from Roman times until the turn of the 19-20th century. Recovery rates for the produced metals such as copper and gold were between 50-66%, and with the rest, largely in the form of sulfide minerals, ending up as mine waste (Paar et al., 2006). This sulfide rich mine waste is both a source of groundwater contamination as well as a source of critical metals that tend to associate with Au and Cu (i.e. As, W, Bi, In, Te; (Gopon et al., 2019).

By combining whole rock geochemistry, geophysics, and advanced micro- to atomic-scale characterization techniques we have produced estimates of the raw material potential of the 4000+ Cu-Au-As mine dumps found throughout the Eastern Alps as well as determined how these metals are found within the waste. We will show examples from historic Cu-Au-As districts from the Hohen Tauern to the Fischbacher Alpen, and discuss what raw materials are present, in what form they are present, and how sulfide minerals are able to play host to such a diversity of important metals. The environmental impact of these sulfide rich mine wastes will also be discussed, as well as ongoing work to remediate these former mine sites by mining the mine waste.

The mining and metallurgical processes necessary to process such a weathered, low grade, and arsenic rich ore presents a significant challenge that needs to be overcome. However, the potential worth of the 70 largest mine dumps in the Eastern Alps (estimated at 1-2 billion euros), the environmental implications of leaving this waste, and the raw materials gap we aim to fill with this resource is such that this is a challenge that we must overcome.

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**Session:** Pangeo workshop: Mineral Raw Materials, and Energy Transition

**Keywords:** Halden, Bergbau, Critical Metals, Eastern Alps, Ostalpen, Gold, Copper, Kupfer, invisible metals



## What happened after the Last Glacial Maximum in the Sölk Valleys (Styria, Austria)?

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The north-south oriented Sölk Valleys are located in the Niedere Tauern mountain range in Styria (Austria). During the Last Glacial Maximum (LGM) they served as catchment area for the Enns glacier, which flowed towards the east. The Sölk Valleys are dominated by cirques (mostly east or west facing), where several latero-frontal moraine ridges are preserved in different altitudes. These can be assigned to two different stadials, the Gschnitz stadial (Heinrich 1 Event; ~17-16 ka) and the Egesen stadial (~13-12 ka) based on their occurrence (altitude, exposure) and their degree of weathering. Commonly, the latero-frontal moraines of the Gschnitz stadial are scarce and where they exist they have smooth crests. Estimated equilibrium line altitudes (ELAs) are in the range of 1850-2000 m a.s.l. Latero-frontal moraines of the Egesen stadial characteristically show a multiphase glacier retreat. Estimated ELAs are in the range of 2100-2200 m a.s.l. ELAs vary greatly due to exposure and debris cover of the ancient glaciers. After the LGM and the late-glacial stadials significant sedimentation occurred in the Sölk Valleys.

In spite of the precision with which latero-frontal moraines and associated diamictos can be used to pinpoint former ice margin locations and reconstruct palaeogeography, open questions remain regarding the precise origin and significance of gravelly deposits. Therefore, this study aims to integrate geomorphological and sedimentological mapping approaches with study of the texture of gravels to provide a sharper palaeogeographic reconstruction than previously possible. Gravels were investigated for clast roundness, clast shape, and grain size charts were produced. For example, whilst some outcrops might be immediately recognized as alluvial fan or fluvial deposits, there are cases where either interpretation would be plausible. Thus, a deeper investigation into sediment composition using a statistical approach, is a useful semi-quantitative approach to improve interpretative confidence. The degree of roundness is categorized by six groups (very angular, angular, subangular, subrounded, rounded and well-rounded) and the shape by four groups (cuboidal, bladed, prolate and discoidal). The roundness data was also subjected to a cluster analysis. Based on this approach, sediments in the Sölk Valleys can be grouped into three categories (glacigenic features were not analysed): fluvial sediment, alluvial sediment and ice margin sediment. In general, fluvial sediments are characterised by an abundance of rounded pebbles and the grain size charts typically show an exponential increase in the coarse fraction. Ice margin sediments are mostly deltaic, as indicated by field evidence (clear bottomset-foreset-topset transitions). They are distinguishable from fluvial sediments by their bimodal grain size charts and the degree of roundness is less pronounced. Alluvial sediments show the most angular clast shape and in terms of grain size, more fine material is abundant in the sediment. In summary, sediment texture analysis proves to be a powerful means of elucidating and differentiating the processes responsible for different sediment packages in the Sölk Valleys, and provides an essential complement to the traditional mapping approach.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keyword:** Sedimentology, Mapping, Clast shape, Lateglacial

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## Late Holocene sedimentary floodplain architecture & human interaction of the Wiesent River (Northern Franconian Alb, Bavaria, Germany)

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Riverine landscapes and their floodplains are subject to constant changes throughout geologic time spans. In the Late Holocene the direct and indirect human activity on the floodplain increases and became the dominant factor in many European catchments, which led to a change from a natural- to a human-dominated floodplain system latest since the Early Middle Ages. This change also caused a transformation in the sedimentary system, causing a general change of the fluvial and therefore the floodplain morphology.

The Wiesent River and its tributaries in the Northern Franconian Alb, northern Bavaria, seems to illustrate this transformation quite well, because direct (e. g. water mills, bridges, river regulations) and indirect (e. g. catchment wide agriculture and soil erosion) transformation processes increase since the Middle Ages. Catchment wide soil erosion due to increased agricultural activities and increased hydrotechnical constructions lead for example to thick overbank deposits and increased sedimentation rates during the Middle Ages as reported for some northern Franconian valley floors (e.g. Fuchs et al. 2011). Sediment dynamics are therefore most likely related to human activity in the catchment, especially direct water management activities along the river course, such as the installation of weirs and water mills, as well as the agricultural use of the floodplain. The identification and quantification of the anthropogenic impact on the sedimentary floodplain architecture and its temporal evolution since the Middle Ages is therefore the main objective of the study.

Here, we present preliminary results of sedimentological, (chrono)stratigraphical and geophysical investigations for several sites along the Wiesent River floodplain. A combination of percussion drilling and trenching with electrical resistivity tomography and electromagnetic induction measurements was used to gain insight into the stratigraphy of the overbank deposits. The chronostratigraphy for reconstructing the sediment dynamics and floodplain evolution is established by OSL dating techniques. Furthermore, the consideration of paleoenvironmental proxies such as phytoliths, biomarkers and ostracods facilitates the attribution of environmental changes in floodplains to anthropogenic and/or natural influences.

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**Session:** DEUQUA Session: Anthropogenic impact on the development of landscapes

**Keywords:** Holocene, floodplain, anthropogenic influence, stratigraphy, OSL dating

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## Cenozoic tectonic evolution of the West Qinling and its effects on the Cenozoic climate evolution, NE Tibetan Plateau

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Understanding the geodynamics of plateau growth necessitates careful consideration of the spatial and temporal constraints associated with mountain building in the Tibetan Plateau. Several competing hypotheses have been proposed to elaborate the mechanisms driving the outward growth of the Tibetan Plateau, including oblique subduction, distributed thickening and shortening, mantle lithosphere removal, and middle-lower crustal flow. These tectonic models yield diverse spatiotemporal patterns of deformation along the plateau margin. Here we considered the West Qinling, northeastern Tibetan Plateau as our studied area, and plan to present new thermochronology data to refine the exhumation patterns of the West Qinling. Combined with existing studies, we aim to (1) link surface deformation in the West Qinling to regional deep structures to constrain mechanisms of the upward and outward growth of the Tibetan Plateau, and (2) connect with the tectonic deformation and paleoclimate conditions in the West Qinling to assess climate effect of the uplift of mountain ranges. This study will provide valuable insights into the mechanisms of surface uplift of orogenic plateaus and their impact on climate change.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *West Qinling, Low-temperature thermochronology, Tibetan Plateau growth, Climate effects*

Haas, Isabella; Kurz, Walter; Hauzenberger, Christoph; Gallhofer, Daniela; Skrzypek, Etienne

## Unravelling the pre-Alpine evolution of Alpine basement units by U-Pb zircon geochronology – a case study of the Austroalpine Schladming nappe system

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Pre-Variscan and Variscan remnants within the Eastern Alps are an important source of information regarding the paleogeographic and tectono-magmatic history prior to the Eo-alpine and Alpine tectonic and metamorphic events. U-Pb zircon dating in combination with Hf-isotope of pre-Alpine metagranitoids of the Schladming nappe system revealed three distinct plutonic suites: (1) the Lignitz, (2) the Untertal and (3) the Eisenhut Plutonic suite. The mostly fine grained, highly evolved metagranitoids of the Lignitz Plutonic suite have an age ranging from  $480.1 \pm 6.4$  to  $501.2 \pm 6.6$  Ma and a weighted  $\epsilon_{\text{Hf}}(t)$  value between  $6.8 \pm 2.7$  and  $11.2 \pm 2.6$ . The Hf-isotopes hint to a partly juvenile source with different degrees of crustal material assimilated during its ascent. The highly evolved granitic Lignitz Plutonic suite can be genetically linked to a crustal contaminated mafic magmatic source with a complex origin at a subduction zone setting. This leads to a likely emplacement of the suite as a batholith within the context of a Ceneric active margin along northern Gondwana. The Hochreichart Plutonic suite of the closely connected Seckau nappe system is regarded as an equivalent of this suite. The metagranitoids to metagranodiorites of the Untertal Plutonic suite are less deformed and show in parts still a magmatic fabric. The U-Pb zircon ages scatter between  $350.4 \pm 4.8$  Ma and  $370.4 \pm 4.9$  Ma while the  $\epsilon_{\text{Hf}}(t)$  values are between 2.6 and 3.9. Ordovician ages and  $\epsilon_{\text{Hf}}(t)$  values of zircon cores indicate an incorporation of older Lignitz Plutonic material. The less complex affinities Untertal Plutonic suite with typical igneous fractionation trends, connect this suite to a subduction related origin. The origin can be attributed to a metabasic granulitic crustal source. The generated granodioritic to granitic melts were then emplaced at the active margin near the southern margin of the Galatian terrane. The Eisenhut Plutonic suite contains highly evolved metagranitoids with ages between  $261.0 \pm 3.5$  Ma and  $263.4 \pm 3.5$  Ma and  $\epsilon_{\text{Hf}}(t)$  values of 2.7 to 5.2. There is no evidence that any material from the older magmatic suites was assimilated or is part of the magmatic source rock. The Eisenhut Plutonic suite is a highly evolved granitic suite with affinities to a dry granulitic residue connected to an extensional tectonic setting. This fits the Permian tectonic conditions during the disintegration of Pangea. The post-orogenic rift-related magmatism due to extension in the Permian probably lead to horst-graben structures.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Schladming Nappe, Lignitz Plutonic Suite, Untertal Plutonic Suite, Eisenhut Plutonic Suit, U-Pb zircon dating*

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## Provenance of the Permo-Mesozoic cover sediments of the Seckau-Schladming nappe system revealed by detrital zircons

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The Permian to Mesozoic cover sequences within the Austroalpine nappe system are an important source of information to reconstruct the paleogeographic evolution of the Eastern Alps. These meta-sedimentary units reflect the tectonic events subsequent to the Variscan orogeny, with the onset of crustal extension and the formation of continental rifts and horst- and graben structures with alternate sediment sources. Detrital U-Pb zircon age spectra of the Rannach and Oberhütte formations, the equivalent sedimentary cover units of the Seckau and Schladming nappe systems, respectively indicate a northern Gondwana margin origin. 550 Ma aged zircons from both nappe systems, which can be associated with an internal source from the Seckau nappe basement, reflect a phase of arc magmatism known from the northern Gondwana area. While the meta-sedimentary Rannach formation of the Seckau nappe system contains Late Miaolingian/Early Furongian detrital zircons (c. 490-500 Ma), related to plutonism within the Cadomian arc and sourced internally by the Seckau nappe basement, the Oberhütte formation of the Schladming nappe complex lacks these zircon ages. Middle Ordovician ages (c. 450-460 Ma) within both nappe systems reflect rifting-related magmatism along the northern Gondwana margin, that resulted in the detachment of continental fragments. For the present-day Seckau and Schladming basement complexes, this evolution resulted in a paleogeographic position at the southern Galatian terrane margin. Early Variscan arc magmatism can be seen within zircons of the Rannach formation, again internally sourced by Upper Devonian/Mississippian (c. 360 Ma) plutonites within the Seckau nappe basement. Detrital zircon ages of early Permian origin for both cover units and a Late Mississippian KDE peak within the Oberhütte formation might be sourced by granitoids within the western Tauern Window.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Schladming Nappe, Seckau Nappe, Rannach Formation, Oberhütte Formation, detrital zircons*

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## Triangle Zones as Mechanical Gages for Fold-Thrust-Belts

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Fault vergence in fold-and-thrust belts and accretionary prisms is characterized by mainly forward verging thrusts and pop-up structures, and only few examples exist where backthrusting dominates. However, backthrusting and triangle zones are known from most if not all fold-thrust belts in the world. The circumstances under which backthrusts instead of forethrusts form are still incompletely understood and a systematic study of parameters that may control backthrusting is still missing. This is unfortunate, because triangle zones form gages that may provide providing tight constraints on fold-thrust belt mechanics.

In this contribution, we present numerical models of fold-thrust belts, focusing on different aspects of their mechanics, and particularly triangle zones. In a wedge-mechanical framework, we test the influence of décollement strength, dip, presence of multiple décollements, and the effect of syn-tectonic sedimentation. While models corroborate the idea that décollement strength and basal dip may control thrust vergence, comparison with natural examples indicates this cannot be the only explanation for the formation of backthrusts. Additionally, syn-tectonic sedimentation, rheological changes across strike, or structural inheritance may play a role. We apply our findings to the Alpine-Carpathian belt, using a compilation of structures along strike the entire fold-thrust belt.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Fold-Thrust-Belts, Mechanics*

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## Uranium-, vanadium- and chromium-bearing reduction spheroids in karst bauxite of the Unterlaussa mining district (Upper Austria)

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Reduction spheroids are millimeter- to centimeter-scale reduction features that are mainly known from siliciclastic red bed sediments. They are characterized by a core containing high amounts of redox-sensitive metals compared to their host rocks and by a Fe(III)-depleted halo. They are generally regarded as biosignatures in the geological record, but the processes leading to their formation remain largely enigmatic and studies on reduction spheroids from settings unrelated to siliciclastic red beds are highly underexplored. Here, we present geochemical and mineralogical results of U-bearing reduction spheroids in karst bauxite of the Unterlaussa mining district (Upper Austria) to better understand the formation of reduction spheroids and the accumulation of U in karst bauxite. For this purpose, we used laser ablation-inductively coupled plasma-mass spectrometry, scanning electron microscopy, micro-X-ray fluorescence and Raman spectroscopy.

The karst bauxite-hosted reduction spheroids of the Unterlaussa mining district are highly enriched in  $\Sigma$ REE (La-Lu) (up to ~2.6 wt.%), U (up to ~47 wt.%), V (up to ~7.6 wt.%), Cr (up to ~4.3 wt.%) and Ti as TiO<sub>2</sub> phases. The U-bearing mineral in the reduction spheroids was identified as carnotite and an unknown Cr-V-Al phase is responsible for the high Cr contents in the reduction spheroid cores. Anatase was found in Ti-rich reduction spheroid cores. The formation of the reduction spheroids started shortly after the burial of the karst bauxite. A clayey sediment was rapidly deposited on top of the karst bauxite and terminated its weathering-controlled formation. The immediate source of U, V and Cr in the reduction spheroids was either the uppermost part of the karst bauxite where U-, V- and Cr-bearing minerals and organic matter were incorporated during a redeposition event, or the clayey hanging wall of the karst bauxite where U and V were present in organic matter. In both cases, decaying organic matter and the consequent acidic conditions caused the mobilization of U, V and Cr. These solutes were reductively immobilized by organic remnants in the karst bauxite resulting in the enrichment of U, V and Cr, and the formation of the reduction spheroid core. The reduction of Fe(III) due to the reducing environment around the developing core led to the formation of the reduction spheroid halo. This mechanism is suggested to be of significance for the formation of U-rich karst bauxite.

Our study reveals that reduction spheroids can form by different mechanisms which makes their occurrence in the geological record unsuitable for a priori conclusions. Finally, the general concepts found for U accumulation in karst bauxite have potential implications for mining operations and environmental protection.

**Session:** Pangeo workshop: Earth Surface Dynamics

**Keywords:** reduction spheroids, U-rich karst bauxite, secondary chromium mineralization, Unterlaussa

Haider, Vicky

## Tethys Research Data Repository – an approach to provide sustainable and readable valuable geoscientific data for further research

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Tethys RDR, the research data repository of GeoSphere Austria available at [www.tethys.at](http://www.tethys.at), serves as a pivotal data publication platform, dedicated to providing open, accessible, and sustainable data. Tethys emphasizes high-quality data publication, with a particular focus on Austrian geology. The RDR publishes and offers an array of freely available resources, including GIS data, various analytic data measurements, monitoring information, and models. Notably, GIS datasets associated with Austria's official geological maps are published on Tethys and are freely accessible for download.

Beyond merely archiving data, Tethys RDR enhances usability through a widely used application programming interface (API) that facilitates technical data harvesting. By adhering to standardized and internationally recognized metadata standards, the platform ensures that metadata can be seamlessly harvested and integrated into other scientific services, such as the scientific search engine BaseSearch ([base-search.net](http://base-search.net)).

This practice not only promotes transparency but also contributes to the sustainability and continuity of the scientific life cycle by linking published data to related research articles and other data publications.

Aligned with the FAIR principles, which stand for Findable, Accessible, Interoperable, and Reusable data, Tethys RDR functions as a disciplinary data publisher and plays a notable role within the broader international research data infrastructure, helping make valuable geoscientific research data more discoverable and reusable. Consequently, all research data published on Tethys RDR are accessible through select scientific search engines like BaseSearch and other scientific services, thereby enhancing their visibility and utility within the scientific community.

Within GeoSphere Austria, Tethys RDR is integrated into a network of related services, including the GeoSphere Maps ([maps.geosphere.at](http://maps.geosphere.at)), Thesaurus ([thesaurus.geolba.ac.at](http://thesaurus.geolba.ac.at)), and Library ([opac.geologie.ac.at](http://opac.geologie.ac.at)), to optimize access to interconnected content. From an international perspective, Tethys has already established its presence within the research data infrastructure, and its ongoing goal is to maximize this integration. By doing so, Tethys aims to make all published data easily findable for researchers and to support ongoing scientific development. A testament to its reliability and sustainability, Tethys RDR recently received certification from CoreTrustSeal, recognizing it as a trustworthy research data repository. This certification underscores Tethys' commitment to maintaining high standards of data preservation and accessibility.

In summary, Tethys RDR stands out as a comprehensive data publication platform that not only provides open access to high-quality geological data but also integrates advanced technical capabilities and international standards. By fostering ease of access, transparency, and sustainable data practices, Tethys RDR significantly contributes to the global geoscientific research community, enhancing the findability and reusability of critical research data. It is therefore not only attractive for scientific foundations, but also for geoscientists to increase the value of their data by publishing it in Tethys.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *OpenData, data publication, GIS data, analysis, regional geology*



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## The Neogene of the Vienna Basin between geodynamics and global climate

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We present a revision of geological and paleontological data of the Vienna Basin (VB) and provide new paleogeographic reconstructions for 5 time slices. Intense research in the area during the last years resulted in a wealth of information from new 3D seismics and the analyses of hundreds of core samples. Absolute ages were published for two tuffs and the lithostratigraphy was largely formalized. These data provide a new stratigraphic framework for the description of the development of the basin. The evolution of the paleoenvironments in the VB strongly reflects the impact by global climatic events such as the Miocene Climatic Optimum, the Middle Miocene Climate Transition and the Tortonian Thermal Maximum. Global 3<sup>rd</sup> order sea level cycles are reflected in the successions of marine depositional environments. Major drops of the relative sea level caused strong erosion along the basin margins, with up to 300 m paleorelief. The strongest phase of erosion, however, was linked to tectonics. Around the Early/Middle Miocene boundary, Lower Miocene strata became tilted during the Styrian Tectonic Phase. Up to 600-m-deep subaerial canyons incised the VB at that time. A second phase of basin-wide erosion occurred during the Late Miocene when more than 200 m of upper Pannonian strata became removed from large parts of the VB after 9 Ma. Throughout the Miocene, sedimentation rates in the VB have been high, ranging roughly around 1 m/kyr.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Miocene, Paratethys Sea, Climate, Paleoenvironments, Stratigraphy*

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## Anthropogenic stratigraphic signals downstream a metropolis: Extracting Vienna's signature from Danube river plain archives

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Among tectonics, lithology, and climate, human impact has become an external forcing control on Earth's environmental and geological processes, leaving its traces in geological archives. Even though this anthropogenic influence can be seen on a global scale, regional studies characterizing the scope and growth of anthropogenic influence centers, such as major cities, are scarce, especially for urban or peri-urban environments.

In this study, we investigate the anthropogenic impact of the metropolis Vienna on its peri-urban environment, and correlate and evaluate the main geological signals for a potential Holocene-Anthropocene transformation in the 1950s during the so-called "Great Acceleration" of Earth System Sciences (Steffen et al., 2015) by applying sedimentological and geochemical methods.

The human influence in urban sedimentary archives of Vienna has already been detected in previous studies by Wagreeich et al. (2022) using artificial isotopes and trace metals as stratigraphic markers on urban coarse artificial ground. Here, the study area is set further downstream of Vienna, in the National Park Donau-Auen, where direct human intervention into the archived Danube river sediments is currently nil and floodplain archives allow to trace and quantify the human stratigraphic fingerprint and test dating techniques using (artificial) radionuclides in an alluvial setting.

Within the proximal floodplain sediments of the Danube, i.e. erosional profiles and sediment cores, sedimentological, geochronological and chemostratigraphic markers are applied to characterize and date the anthropogenic strata in this area. First observations indicate three periods of distinct sedimentation patterns, potentially corresponding to the natural state prior to significant human intervention, the river system's reaction to the first extensive river channelization in the 1870s CE, and its following response to the construction of hydropower stations (1956-1998 CE) and second river regulation (1990s). The lowermost section is characterised by clay- and organic-rich thin layers (few cm to mm) being suddenly replaced by alternating silt and sand packages of 5 to 20 cm beds. The uppermost silt to fine-sand dominated section is massive and shows almost no sediment structures, unlike the other sections, and exhibits a uniform light grey colour distinct from the light beige and dark brown colour of the underlying deposits.

The archive of natural Danube deposits is further analysed for artificial radiogenic isotopes, trace metals, and (micro-)plastics with the aim (i) to disentangle the anthropogenic fingerprint of Vienna from the sediment and characterise the interplay between upstream human interventions and local river dynamics, (ii) to identify and evaluate the geological signal of the Great Acceleration of Earth System Sciences around the 1950s, and (iii) to evaluate markers for a potential Holocene-Anthropocene transformation downstream of Vienna.

### References:

Steffen, W., et al. 2015. *The Anthropocene Review* 2(1), 81–98.

Wagreeich, M., et al. 2022. *The Anthropocene Review* 10, 316–329.

**Session:** DEUQUA Session: Anthropogenic impact on the development of landscapes

**Keywords:** chemostratigraphic markers, anthropogenic fallout, Great Acceleration, Holocene, Vienna

## 3D modeling of topographic stress in alpine landscapes: the competition between relief formation and destruction

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The geometry of alpine landscapes is shaped by multiple stress-dependent factors. Relief formation through valley incision increases topographic stress toward a critical state, where rock failure occurs, which in turn reduces topographic stress due to relief-destroying landslides. Rock strength is a superior control in the delicate balance between the construction and destruction of the rock relief. By computing topographic stresses across entire mountain massifs, we can identify stress maxima in steep landforms prone to landsliding. This allows us to determine the maximum rock strength at the mountain scale, delineate potential surfaces of rock failure, and explain the contrasting geometries of alpine landscapes based on prevailing rock types.

Traditional 2D methods oversimplify complex stress patterns, particularly at converging valleys or around ridges and peaks. Although 3D finite element methods (FEM) provide detailed insights, they are computationally expensive for entire mountain massifs at the required high spatial resolution.

Our study addresses these challenges by combining several state-of-the-art 3D numerical methods into the numerical framework ViktorFCM. We utilize the Marching Volume Polytopes Algorithm for mesh generation, incorporating an octree-like structure and advancing-front meshing techniques to create accurate tetrahedral meshes. The Finite Cell Method (FCM), a fictitious domain approach, serves as an efficient alternative to FEM, transforming the problem of generating a suitable grid for complex geometries into specifying an adequate integration scheme for finite cells, thus saving degrees of freedom and computational resources. This computational efficiency is especially advantageous for equidistant grids such as digital elevation models, which serve as input data.

Benchmarking against other FEM programs showed that our method delivers comparable accuracy with the added benefits of FCM. Verification and validation confirm the algorithm's reliability and robustness.

In our initial study, we computed 3D topographic stress distributions for the three Austrian UNESCO Global Geoparks, characterized by steep valley flanks and high landslide activity. Results indicate high shear stress maxima predominantly in over-deepened glacial valleys, with shear stresses peaking at valley flanks and at or slightly below valley floors. Unexpected stress patterns emerged in areas with complex geometries, such as converging valleys or intersecting ridge lines. Lithological contrasts led to varying stress patterns, with carbonate-dominated units exhibiting the highest shear stress maxima.

Our model provides a new tool for combining local topographic metrics, spatial distribution of observed landslides, and rock types and eventually for assessing landslide potential over large areas (mountain scale). In the field of landscape evolution, before-and-after studies of stress distribution pre- and post-landslides support the hypothesis that landslides reduce topographic stress. Our findings provide new insights into the evolution of alpine landscapes, where, by calculating the topographic stresses, we can shed new light on the cycle of relief-forming (i.e., stress increase) and relief-reducing (i.e., stress decrease) processes towards a topographic equilibrium.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Finite Cell Method, Finite Element Method, Stress Analysis, Landslides, 3 dimensional*

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## Deciphering the 4-D evolution along and across the Insubric Line using a multi-method geo- and thermochronological approach

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The Lepontine dome, the Insubric Line, and the adjacent Southern European Alps are an archetypal example of indentation tectonics. There, indentation of relatively stiff Adriatic lower crust and upper mantle into the weaker continental Eurasian plate led to unroofing of the Penninic Lepontine dome, as well as strike-slip motion along the Insubric Line. Late-stage collision led to a highly asymmetric exhumation pattern with vertical displacement across the fault line in the range of 15 ( $\pm$ 5) km. The brittle faulting and exhumation history has so far received only little attention, and particularly S of the Insubric Line, large-scale interpretations of cooling and exhumation are based on very little quantitative knowledge. Exploring the faulting and exhumation history of the suture between European and Adriatic plates by applying multiple geo- and thermochronometers on both sides of the fault is the main goal of this project.

In this ongoing study (U-Th)/He dating on 44 apatite and 28 zircon samples as well as apatite fission track dating on 25 samples was applied along densely-spaced horizontal as well as vertical transects across and adjacent to the Insubric Line. Apatite (U-Th)/He ages, which monitor cooling below ca. 80 °C, from north of the fault line prominently cluster around 8-12 Ma. Apatite fission track (with a closure temperature of ca. 110 °C) as well as zircon (U-Th)/He ages (with a closure temperature of ca. 210 °C) are only slightly older. These results point to a Late Miocene phase of pronounced cooling and exhumation, significantly younger than previously assumed. Thermochronological results are embedded into paleostress analyses as well as the endeavour to date slickensides.

Additionally, we attempted U-Pb dating on pseudotachylites and mylonites. This methodically challenging approach yielded an age of about 30 Ma for a pseudotachylite sample from the southernmost Lepontine dome in the vicinity of the Insubric Line. The signal was measured for a fine-grained mineral assemblage consisting of chlorite among other minerals. This age corresponds to the phase of major updoming, which we confirmed by mylonite dating, yielding a similar age of 33 Ma. Additional U-Pb apatite data from N of the fault range from 20 to 30 Ma and monitor post-Insubric cooling below ca. 500 °C.

The age pattern will be completed by zircon fission track analyses (with a closure temperature of ca. 240 °C). Upon completion new age and structural data shall lead to a refined model of distinct cooling and exhumation along this prominent segment of the Periadriatic fault line.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Alps, Lepontine dome, Insubric Line, exhumation, faulting*

Heninger, Marianne

## Bringing Order to Chaos: Micromorphological Analysis of Late Palaeozoic Glacial Diamictites

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The Late Palaeozoic Ice Age (LPIA) is Earth's most recent, severe glacial epoch and in Namibia experienced its acme at about 300-298 Ma. The record of the glaciation in southern Africa is exceptional, and many of the deposits consist of poorly-sorted diamictites of the Dwyka Group that were deposited beneath glaciers or at their margins. The study of these deposits has often been neglected, because sedimentologists have tended to regard these deposits as complex, massive, or confusing. New quantitative approaches to oriented samples developed in the course of Quaternary glacial studies is beginning to change this, and thus this study will consist of a detailed evaluation of oriented diamictite samples recovered from northern Namibia (Opuwo) the Aranos Basin (central-southern Namibia) and the Karasburg Basin (Namibia-South Africa border). The aim of this Masters project is to produce a substantial new set of directional data. Previous authors have proposed diverse and often conflicting ice-flow directions from different data sources, and it is hoped that this controversy can be resolved.

Oriented samples were collected during fieldwork in 2019 and 2023 from five different locations. Each was cut in three directions, ie "north-south"-, "east-west"- and "top"-orientations, and thin sections were prepared from these, which were then scanned in high resolution. These scans are being quantitatively analysed using the "microstructural mapping" method proposed by Phillips et al. (2011). Measuring the direction of the longest axis of the grains in each oriented thin section will be achieved using CorelDraw. The data from CorelDraw is then exported to OpenStereo, a program which is used for structural geology analysis, to draw rose diagrams of clast orientation. The rose diagrams from each sample will thus represent three sides of a cube, and this "pseudo cube" will allow the orientation of clasts to be characterised in 3D space. From this, an understanding of the dynamics of sediment deformation, and thereby ice flow orientation, will be determined. At PANGEO, preliminary results will be presented.

The main goal of my thesis is to contribute to a nuanced paleo-reconstruction through a better understanding of glacial dynamics in the LPIA. This will not only improve understanding of ancient glacial environments in Namibia but also further the understanding of contemporary glacial behaviour through exploitation of well-preserved samples. Given the complex issues in unraveling past ice flow in ancient rocks, many datasets have been combined by previous authors to achieve this (striation orientations on bedrock, crossbed orientations etc). By contrast, this will be the first large and significant database of flow directions from the LPIA sedimentary record of Namibia drawn from one single source.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *diamictite, Namibia, LPIA*

Hergarten, Stefan

## A modified Voellmy rheology for modeling rapid mass movements

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Voellmy's rheology was originally developed for snow avalanches in the 1950s. However, it has also been applied to rock avalanches, debris flows, and pyroclastic flows. In its original form, Voellmy's rheology assumes that the effective friction is the sum of Coulomb friction and a velocity-dependent term. While the Coulomb friction term is necessary for letting avalanches stop after a finite time, it causes problems with regard to the long runout of huge rock avalanches. This long runout requires Coulomb friction coefficients much lower than typically assumed for granular media, which finally result in unrealistically smooth morphologies of the deposits. In this presentation, numerical simulations with a recently published modified version of Voellmy's rheology are shown and compared to the conventional version. The modified version assumes two distinct regimes of Coulomb friction and velocity-dependent friction with a transition at a critical velocity derived from the concept of random kinetic energy. The modified rheology explains the long runout of huge rock avalanches without assuming an artificially low Coulomb friction coefficient. Furthermore, it produces hummocky deposit morphologies even with isolated hills similar to toma hills. The question whether the modified rheology is also useful for snow avalanches, debris flows or pyroclastic flows will be subject of future studies.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Landslides, avalanches*

Konrad, Hermann Michael

## Muren, Rutschungen, Felsstürze – der Landesgeologe im Katastropheneinsatz

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Nahezu jedes Jahr werden Teile der Steiermark von Starkregenniederschlägen heimgesucht, die unterschiedliche Landschaftsteile treffen, ob es die nördlichen festgesteinsdominierten Gegenden oder die Lockergesteinsareale im Südosten oder Südwesten dieses Bundeslandes sind. Die geogenen Phänomene sind jeweils bezogen auf den Untergrund stark unterschiedlich ausgeprägt. Dominieren tiefgründige Rutschungen die südlichen Landesteile, werden die nördlichen Landesteile von Muren und Felsstürzen bedroht.

Nachdem 2023 die südlichen Bezirke des Bundeslandes Steiermark zwischen 3. und 6. August 2023 von einem Adriatief erfasst wurden, die zwischen 150 und 220mm Niederschlag in drei Tagen brachten, folgten in der Nacht von 8. auf den 9. Juni 2024 neuerlich Starkregenereignisse, die den Raum nördlich von Graz und die nordöstliche Steiermark erreichten und katastrophale Auswirkungen nach sich zogen. Die Regenmengen von bis zu 125 Liter in einer Stunde führten zu Überflutungen und Erosionserscheinungen, die in ihrer Anzahl in den letzten 50 Jahren nicht vorgekommen waren.

Großflächige Hangablösungen waren die Folge, bei denen die Humusdecken in einer Mächtigkeit von bis zu 50 cm auf dem darunterliegenden Felsuntergrund abgeglitten waren. In mächtigeren Lockergesteinsarealen kam es zu tiefgreifenden Hangbewegungen, die jedoch in der Minderheit blieben. Daneben führte das Abtragen von Feinanteilen zur Ablösung von Felskörpern. Die Folge war die Ausrufung der Katastrophen in den Bezirken Graz-Umgebung und Hartberg-Fürstenfeld.

Ähnlich verhielt es sich schon im August 2023, wo neben großflächigen Überschwemmungen tiefgreifende Rutschungen die Lockergesteinsregionen der Steiermark im Südosten und Südwesten trafen. Die hohe Anzahl an geogenen Schadensstellen nach Durchzug der Schlechtwetterfront mit Gefährdungen von Wohnobjekten und Infrastruktureinrichtungen veranlassten die zuständigen Behörden, die Katastrophe auf Basis der Landesgesetze für Katastrophenschutz für drei Bezirke Deutschlandsberg, Leibnitz und Südoststeiermark) auszurufen.

Nun stellt sich die Frage, welche Aufgaben der Landesgeologe im Regime des Katastrophenschutzes innehat und wie er sein Fachwissen zum Schutz von Mensch und Umwelt einbringen kann und soll?

Seit 2005 werden Katastrophen nach den Grundregeln des Steiermärkischen Katastrophenschutzgesetzes abgewickelt. Dem Zufolge ist der Landesgeologe als Amtssachverständiger für die leitende Behörde, die Bezirkshauptmannschaft, für die Beurteilungen der Lage im Hinblick auf die Gefährdung von Mensch und Umwelt durch geogene Ereignisse verantwortlich. Und nicht nur das, er ist auch aufgefordert, Maßnahmen zum Schutz von Menschen, wertvollen Sachwerten und Infrastruktur vorzuschlagen und zu begleiten.

Die sofort einzuleitenden Maßnahmen zur Gefahrenabwehr sind mannigfaltig und reichen von der Evakuierung von Wohnobjekten oder der Erhaltung der Bausubstanz durch Einziehen von Stützelementen bis zum Abtrag von Bauwerksteilen, um ein Übergreifen auf andere Objektseile zu verhindern.

Bei Rutschungen selbst werden sehr oft die zutretenden Oberflächenwässer vom Eintritt in die offenen Anrisse oder bereits abgegangenen Hangteile durch Überplanen der Schadstelle oder Herstellung von Ableitgräben gehindert. Tiefgründige Rutschungen erfordern gelegentlich den Einsatz von Grabgerät, um durch den Einbau von Stützrippen oder Drainagen zur Entwässerung des Hanges die Reibung der Masse zu reduzieren.

Eine Verlangsamung der Bewegungen wird daraus erwartet. Um dies auch feststellen zu können, werden behelfsmäßige Messeinrichtungen zur Beobachtung der Massen eingerichtet.

Bei Wegen und Straßen reichen die Maßnahmen vom bloßen Niveaueausgleich, um die Fahrbahn für Einsatzkräfte wieder befahrbar zu machen bis zum Austausch des Unterbaus und der Errichtung von Drainagen, um die zutretenden Wässer schadlos abführen können.

Im Zuge von Felsstürzen werden neben Straßensperren die Felsräumung der betroffenen Felsareale veranlasst und überwacht.

Alle diese Maßnahmen zur Abwehr von Gefahren für die Bevölkerung werden vom Landesgeologen vorgeschlagen und der Behörde koordiniert und umgesetzt.

Glück Auf!

Mag. H. M. KONRAD - Landesgeologe Land Steiermark

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Geogene Gefahren-angewandte Geologie-der Geologe in der Verwaltung-Katastropheneinsatz-*



Hilberg, Sylke

## Geologie begreifen – digitale Lernspiele und analoge Modelle für den Geologie - Unterricht

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Die Themen Klimakrise und Energiewende stehen in direktem Kontext zu geologischen bzw. erdwissenschaftlichen Prozessen. So bieten Klimaveränderungen in der Erdgeschichte eine wichtige Basis zum Verständnis und für Prognosen über aktuell ablaufende Entwicklungen. Zur Bewältigung der Energiewende ist vielfältiges geologisches Knowhow gefragt. Trotz dieser großen und vielfältigen Bedeutung geologischer Aspekte, sind sie im Bildungsangebot stark unterrepräsentiert. Eine große Herausforderung des Geologie-Unterrichts ist es, die zeitlich und räumlich schwer greifbaren geologischen Prozesse anschaulich zu machen. Die Geologie, die erklärt werden soll, spielt sich tief unter der Erde ab oder läuft so langsam ab bzw. ist vor so langer Zeit abgelaufen, dass es unsere Vorstellungskraft übersteigt. Die schnellen geologischen Prozesse wie Steinschlag, Erdbeben oder Vulkanausbrüche sind meist mit großen Schäden verbunden und damit negativ konnotiert. Um Schülerinnen und Schüler trotzdem für geologische Themen zu interessieren oder besser noch zu begeistern, braucht es Unterrichtsmethoden, die die Prozesse begreifbar machen. Eine Möglichkeit dafür ist der Einsatz von Modellen in analoger oder digitaler Form.

Im Workshop werden zwei digitale Lernspiele und mehrere analoge Modellansätze vorgestellt. Den Workshop-Charakter der Veranstaltung wollen wir nutzen, um den Teilnehmenden die Gelegenheit zu geben, die Spiele und Modelle direkt selbst auszuprobieren. Die Workshop -Teilnehmenden können sich an den Lernspielen „Zwischen Regenwolke und Wasserhahn“ zum Thema Grund- und Trinkwasser sowie „Nach dem Kohlebergbau“ zum Thema Bergbau versuchen. Beide Spiele wurden speziell für den Unterricht entwickelt.

Ein Grundwassermodell sowie weitere kleinere und mit einfachen Mitteln selbst zu entwickelnde analoge Modelle werden vorgestellt und können von den Teilnehmenden im Workshop ausprobiert werden.

Im Anschluss an die Testphase sollen die Vor- und Nachteile der Unterrichtsmethoden diskutiert und Verbesserungsvorschläge oder überhaupt neue Modellideen entwickelt werden, die sich einfach in den Unterricht integrieren lassen.

**Session:** Lehrendenworkshop

**Keywords:** Modelle, digitale Lernspiele, Hydrogeologie, Bergbau

Hilberg, Sylke; Hauser, Dominik

## Grubenwässer der Altbergbaue im Geopark Erz der Alpen

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Zentrales Thema des UNESCO Geoparks Erz der Alpen im Salzburger Bezirk Pongau in Österreich ist der prähistorische und historische Erzabbau. In den Schaubergwerken Mühlbach, St. Veit und Hüttau werden Besucher über den über Jahrhunderte in der Region betriebenen Kupferbergbau informiert. Eine umfassende Studie zu Bergbau- und Hüttenstandorten im Bundesland Salzburg aus dem Jahre 1998 umfasste auch die Standorte im Geopark Erz der Alpen und beschreibt montangeologische Grundlagen der Lagerstätten, beleuchtet den Erzbergbau in der Region aus montanhistorischer Sicht und stellt Bergbau- und Hüttenstandorte aus Sicht des Umweltschutzes dar. Eine Erfassung und Bewertung von Grubenwässern erfolgte in diesem Rahmen nicht. Dies lässt darauf schließen, dass die aktuell aus den Altbergbauen austretenden Grubenwässer keine erhebliche Umweltgefährdung darstellen, anderenfalls wären sie vermutlich bereits im Laufe der vergangenen Jahrzehnte detektiert worden. Dennoch ist der Einfluss von Stollen und Halden auf die Beschaffenheit der Grubenwässer in den Altbergbaugebieten des Geoparks Erz der Alpen für das Gesamtverständnis der Bergwerke relevant und wurde durch das präsentierte Projekt untersucht. Ziel der präsentierten Studie war es zudem, einen Beitrag zu der generellen Frage leisten zu können, ob sich Grubenwässer im Sulfid-Erzbergbau auch nach Jahrzehnten noch signifikant von unbeeinflussten Grundwässern unterscheiden und ob bzw. in welchem Ausmaß „Natural Attenuation“ im Grubenwasser stattfindet, wenn eine Grubenwasserbehandlung im Nachbergbau völlig ausbleibt.

Im Zuge von Gelände- und Stollenbegehungen wurden repräsentative Stellen zur wiederholten Beprobung von Gruben- und Grundwässern festgelegt. Die Auswahl der Probenahmestellen wurde so gestaltet, dass sowohl Wässer, die eindeutig innerhalb des Stollensystems zirkuliert sind als auch solche, die außerhalb des Einflussbereichs bekannter Bergbaubereiche aber in vergleichbarem geologisch-hydrogeologischen Setting zirkulieren und damit als Referenzquellen dienen können. Es wurden Quellen und Fließgewässer erfasst. Neben der hydrochemischen Analyse auf Haupt- und Spurenparameter wurden ausgewählte Proben hinsichtlich ihrer Sulfatisotopie untersucht. Das Verhältnis von  $\delta^{18}\text{O}$  und  $\delta^{34}\text{S}$  im Sulfat kann Auskunft darüber geben, ob die gemessenen Sulfatgehalte das Ergebnis von Sulfidoxidation oder der Lösung von mesozoischen Sedimenten sind bzw. ob bei der Interpretation der gemessenen Sulfatkonzentrationen der Prozess der bakteriologischen Sulfatreduktion zu berücksichtigen ist.

Die Ergebnisse zeigen, dass sich Grubenwässer vor allem in der Sulfatkonzentration deutlich von Grundwässern unterscheiden. Auf Basis der Sulfatisotopie ist deren Genese durch Sulfidoxidation klar nachweisbar.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Altbergbau, Grubenwasser, Sulfatisotopie*

## Geometrical kinematical forward modelling of stages in easternmost Alps development

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Regional balanced cross sections very often represent a visual depiction of the governing processes that led to the finite state. However, for some regional cross sections the deformation processes are poorly understood or constrained. What is the relationship of different tectonic units and how and when were they deformed and brought into contact? Answering such questions often requires an understanding of lithosphere-scale processes and paleogeography at the same time.

Generating crustal scale geometric forward models can be a valuable step to better constrain regional cross sections. In such sections certain geodynamic and mechanical behaviours can be implemented in a simplistic manner (e.g. isostatic movements by flattening the section to an assumed or known sea level). The value of such sections is the consistency over longer periods without showing sudden steps from one evolutionary stage to another. Such sections help in the understanding of geometrical relationships (i.e. contacts between different tectonic units, missing basement etc.). In addition, while constructing such forward sections new questions or solutions evolve that have not been obvious before. The models visualize arrangements over time and help define more specific problems in the regional development that subsequently can be checked by more sophisticated modelling (physical or numerical).

In this session we like to present some attempts of generating forward models illustrating possible kinematics of the alpine collision in the easternmost Alps (Vienna Basin area). Models are generated iteratively to better match the known constraints. We start our models from a (partly schematic) lithosphere/crustal cross section from Middle/Late Jurassic time. This section features from south to north: 1) an extended margin of Adria (towards Tethys) with the deposition of the Northern Calcareous Alps under the influence of halokinesis, 2) a carbonate platform without halokinesis to the north, 3) an extended Adria margin towards the Penninic ocean, 4) an opening Peninnic ocean and 5) an extended European margin.

We start deforming the cross section from South to North with an oceanic upper plate overriding the extended Tethys margin. Some ideas developed via this process are:

- Allochthonous salt generation at frontal accretion of NCA in front of the obducting oceanic upper plate.
- Switching from frontal accretion to overthrusting of Adria (Lower Austro-Alpine units) related to Jurassic extension towards the north
- We are currently speculating that some uplift/erosion and subsidence signals that the orogen could represent varying crust/lithosphere thickness of the lower plate
- Significant duplexing, back and out-of-sequence thrusting in latest shortening increments (post Gosau).

Although some of the model steps are already relatively complex, they are a rough simplification of the real development. We did not include strike-slip deformation and subduction initiation and we certainly miss deformation events and other constraints. We hope for a discussion enabling to refine the models and our understanding of the regional development. Ideally the discussion will trigger follow-up research which includes looking further into dynamic aspects of some of the proposed events.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Geometrical forward modelling, Eastern Alps, kinematic development, Vienna Basin area*

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## EAGLe = Erstellung der Allgemeinen Geologischen Legende für Österreich im Maßstab 1:50.000

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Im Januar 2024 startete an der Geologischen Landesaufnahme der Geosphere Austria (mit Unterstützung aus dem Bereich der Angewandten Geologie) das Projekt EAGLe (= Erstellung der **Allgemeinen Geologischen Legende** / Establishing the **Austrian General geological Legend**) mit dem Ziel, bis 2026 eine erste Version eines österreichweiten Gesamtdatensatzes mit einheitlicher Generallegende im Maßstab 1:50.000 basierend auf dem Status quo der publizierten Daten zu erstellen.

Das erste große Ziel des Projektes ist die Erstellung einer Generallegende für diesen Gesamtdatensatz, die eine hierarchisch strukturierte Liste von Legendenbegriffen darstellt. In der ersten Phase liegt der Fokus auf der Vereinheitlichung der lithostratigraphischen Legendeneinträge. Diese Arbeit erfolgt in Regionalteams und soll in einer ersten Version bis Ende 2025 vorliegen. Gerade in den kristallinen Gebieten (Tauernfenster und östlich und westlich davon, sowie in der Böhmisches Masse) stehen die Regionalteams dabei auch vor der Herausforderung, schlüssige Konzepte für die lithostratigraphische Gliederung ihrer Gebiete zu erstellen. Stellenweise sind jedoch Legendeneinträge, gerade von älteren Karten, nicht aussagekräftig oder stark veraltet, stellen aber die einzige Information zur jeweiligen geologischen Einheit dar. Diese können dann ohne Geländebegehungen nur sehr generellen Begriffen zugeordnet werden. Eine detaillierte Aufarbeitung aller Legendenbegriffe ist somit in diesem ersten Schritt nicht möglich, daher werden die Originallegendeneinträge auch im Gesamtdatensatz zur Nachvollziehbarkeit mitgeführt.

Die Datengrundlage bilden die Legendeneinträge der publizierten geologischen Karten im Spezialkartenmaßstab 1:50.000 zusammen mit GeoFAST-Karten, die auf Kompilierung von ausgewähltem Archivmaterial ohne zusätzliche Geländebegehung basieren, und Gebietskarten, teilweise im Maßstab 1:25.000. Die entsprechenden Vektordatensätze sind jedoch in ihrer geologischen Information und der jeweiligen Datenstruktur sehr heterogen. Stellenweise sind gar keine Vektordaten (vor allem von älteren Karten) verfügbar. Daher ist das zweite große Ziel die Zusammenführung dieser Datensätze zu einem Datensatz mit einheitlicher Datensatzstruktur sowie die Digitalisierung der älteren analogen Karten (um die digitalen Lücken zu schließen). Allerdings werden in dieser ersten Version keinerlei Geometrieadjustments (z.B. Überarbeitung der „Blattrandstörungen“) vorgenommen.

Diese erste Version des Gesamtdatensatz mit der soweit als möglich implementierten ersten Version der Generallegende soll zum Abschluss des Projektes als Datensatz auf Tethys publiziert und über das Webservice der Geosphere Austria ([gis.geosphere.at](http://gis.geosphere.at)) öffentlich einsehbar sein. Ein zusätzlicher Layer soll Informationen über die Qualität der zu Grunde liegenden publizierten Quellen zur Verfügung stellen.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Österreich, Harmonisierung, Generallegende, Gesamtdatensatz*

Hinterwirth, Simon<sup>1</sup>; Ortner, Hugo<sup>1</sup>; Schreilechner, Marcellus<sup>2</sup>; Binder, Heinz<sup>2</sup>; Lüschen, Ewald<sup>2</sup>; Jud, Markus<sup>2</sup>

## Re-interpretation of the TRANSALP seismic section in the light of a new tectonic subdivision of the western Northern Calcareous Alps

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Since the early Late Cretaceous, during Eoalpine orogeny, the Permo-Mesozoic sedimentary succession of the Northern Calcareous Alps (NCA) and its basement were involved in nappe stacking and folding. The nappe stack was refolded and faulted in the Late Cretaceous-Eocene collision of Adria and the European distal margin, continued by post-collisional processes, which lead to an eastward extrusion of crustal blocks in Oligocene-Miocene. The subdivision of nappes in the western part of the Northern Calcareous Alps is under discussion since it was proposed over 100 years ago. Recent findings have shown, that some of the established nappe thrusts are actually younger thrusts, cutting older nappe boundaries in an out-of-sequence fashion, and therefore leading to a new subdivision of nappe sheets in the western NCA, and a reduction in number of thrust sheets. In this study we present an interpretation of a re-processed part from the TRANSALP seismic section, between the Austria-Germany border and the Zillertal, which offers new insights into the deep structure of the NCA around the lower Inn valley. We show that Paleogene out-of-sequence thrusting plays an important role in understanding the relation between different tectonic units, overprinting pre-existing nappe boundaries, and being falsely interpreted as the latter. We propose to accept the internal subdivision of a continuous unit (Tirolic Staufer-Höllengebirgs- and Bajuvaric Lechtal thrust sheets) by an out-of-sequence structure. This means to abandon the concept of a tectonic subdivision entirely based on Cretaceous (in-sequence) nappe stacking. Oligocene-Miocene thrusting along the Subtauern ramp and eastward extrusion along steep strike-slip structures - like the Inntal shear zone - are complicating the tectonic history of the region, displacing older in- and out-of-sequence structures, and finally exhuming the basement units underneath the NCA, south of the Inn valley.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *TRANSALP, Northern Calcareous Alps, Tectonics, Seismic interpretation*

Höfer-Öllinger, Claudio Giorgio<sup>1,2</sup>

## 25 Jahre Quartär- und Hydrogeologie des Nordöstlichen Flachgaus

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Die Erforschung von Quartär- und Hydrogeologie des Nordöstlichen Flachgaus ist eng mit angewandten Fragestellungen wie Baugeologie und Trinkwasserversorgung verknüpft.

Seit der Bearbeitung 1999-2000, die damals ebenfalls auf der Pangeo (2002 in Salzburg) präsentiert wurden, haben sich geologische und hydrogeologische Informationen vervielfacht, sodass die damaligen Konzepte bestätigt und/oder ergänzt, teilweise korrigiert werden können.

Zahlreiche Studien, die in diesen 2,5 Jahrzehnten umgesetzt wurden, gipfeln schlussendlich in die größte wasserwirtschaftliche Studie des Landes Salzburg, Wasserversorgung Salzburger Seenland und Nachbargemeinden.

Anhand von 68 Dauermesseinrichtungen für Grundwasser, mehr als 1000 Isotopenuntersuchungen und etwa 400 Erkundungsbohrungen, die damals noch nicht vorlagen, können heute nicht nur Aussagen zu Ausdehnung und Ergiebigkeit von Erkundungsbohrungen durchgeführt werden, sondern auch interessante Rückschlüsse auf die Quartärgeologie gezogen werden. Ergänzt wurden die Daten mit umfassender chemischer Analytik und Färbeversuchen an einigen der zahlreichen Sickerstellen.

Eine Besonderheit ist ein Beitrag der GSA über Klimaänderungssignale, die von GGA in einem 130-jährigen Grundwassermodell auf Tagesbasis umgesetzt wurden.

Die Zusammenschau von einem aktualisierten Quartärgeologischen und einem Hydrogeologischen Modell mit Klimamodellen und numerischen Grundwassermodellen erlaubt dem strategischen Planungsorgan, der Allgemeinen Wasserwirtschaft in der Salzburger Landesregierung, weitere Entscheidungen hinsichtlich der übergeordneten Raumplanung.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Hydrogeologie, Quartärgeologie, Klimaänderung, Grundwassermodell, Flachgau*

## Geoenergie – Ziele, Potentiale und Forschung in Österreich

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Mit dem Sammelbegriff Geoenergie wird meist die Nutzung des Untergrundes in den verschiedensten Facetten zusammengefasst. Der Bogen wird von der Nutzung geothermischer Energie über geologische Speicher bis hin zur Aufsuchung und Gewinnung von Kohlenstoff- und Mineralressourcen und möglicher anderer Energiequellen wie zum Beispiel natürlichem Wasserstoff gespannt. Es geht in diesem Fachgebiet um die Eigenschaften und Prozesse in natürlichen und technischen Systemen damit eine optimale und sichere Nutzung des Untergrundes gewährleistet werden kann. Die vielen Nutzungsmöglichkeiten befinden sich auf den unterschiedlichsten technischen Entwicklungsstufen und stehen in Konkurrenz zueinander und bedürfen unterschiedlicher Qualitätskriterien/Anforderungen an den Untergrund, sodass eine generelle Kenntnis um die Gesteinseigenschaften und Strukturen unerlässlich ist.

Die Geoenergie soll das österreichische Ziel der Erreichung der Klimaneutralität bis 2040 unterstützen. Die Potentiale liegen in der tiefen und seichten Geothermie (2022: 0,2% Anteil und 4,7% Anteil an den erneuerbaren Energien; Energiebericht 2023, BMK), wo neben Erdwärme mittels Wärmepumpen unter anderem Thermalwässer zur Energie- und Wärmeabgewinnung genutzt werden können. Dafür sind die geologischen Voraussetzungen in vielen Teilen Österreichs (z.B. in den Sedimentbecken) gegeben. In der Vision für 2030 für die tiefe Geothermie in Österreich soll die Nutzung von mindestens 25 % der bekannten geothermalen Ressourcen in der Fernwärmeerzeugung, die Versorgung von 500 000 Wohneinheiten und die Einsparung von 600 000 Tonnen CO<sub>2</sub> durch die Substitution des Einsatzes fossiler Brennstoffe betragen (Verein für Geothermie; GTÖ).

Der Anteil von fossilen Energieträgern sinkt indessen. Die inländische Kohlenwasserstoffproduktion sinkt seit den 1970ern und deckt nur mehr zu 7% bzw. 8,5 % den heimischen Öl- und Gasbedarf mit sicheren Reserven, die noch für 10 Jahre Produktion auf heutigem Niveau reichen.

Da Österreich auf eine lange Kohlenwasserstoffproduktion zurückblicken kann, sind viele der Lagerstätten soweit ausproduziert, dass andere Gase eingespeichert werden können. Viele dieser alten Felder werden schon seit Jahren als Erdgasspeicher benutzt (Gesamtkapazität in Österreich sind ca. 8 Mrd m<sup>3</sup>). Derzeit wird in der Molassezone in einem Pilotprojekt die Speicherung von Wasserstoff in einem geologischen Speicher getestet. Für CO<sub>2</sub> Speicherung bieten sich nicht nur alte Felder, sondern auch (salinare) Aquiferlagen an, in die CO<sub>2</sub> eingebracht werden kann. Technologisch ist diese Form der geologischen Speicherung weit fortgeschritten, rechtlich sind noch nicht alle Weichen für größere Mengen gestellt.

Einige der genannten Themen sollen Energiegewinnung ohne den Ausstoß von CO<sub>2</sub> bewirken, andere werden überschüssiges CO<sub>2</sub> binden und viele (kritische) Minerale sind die Basis für Erzeugnisse anderer erneuerbarer Energietechnologien, wie Solar oder sie sind als Rohstoffe für (Batterie-) Speichermedien von erhöhtem Interesse.

Es bedarf der Zusammenarbeit verschiedener Fachgebiete, beispielsweise vom geologischen Wissen und technischer bis hin zur chemischen Expertise. Einen weiteren Faktor in der Entwicklung spielt die Datenverfügbarkeit (z.B. Grad der Digitalisierung von Bohrdaten und der Zugang zu diesen). In diesem Zusammenhang sind auch Klärung vieler Rechtsfragen und Regelungen für neue Technologien nötig, um durch klare Genehmigungsprozesse für planbare Projekte zu sorgen und somit die Entwicklung voranzutreiben.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Geothermie, Geologische Speicher, Lagerstätte, Wasserstoff, Kohlendioxid*

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## Extent and dynamics of the last glaciation in Kellwassertal, Harz Mountains, central Europe

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During marine oxygen isotope stage (MIS)-2 (29-14 ka), north-western and northern Europe hosted large ice sheets, while a network of valley glaciers and piedmont lobe glaciers covered the Alps and their forelands, respectively. Beryllium-10 cosmic-ray exposure (CRE) ages of glacially transported boulders confirm that ice caps and glaciers temporarily covered the currently ice-free mid-elevation mountainous regions of central Europe, including the Jura, the Vosges, the Black Forest, the Bavarian/Bohemian Forest, and the Giant Mountains. It has been suggested that the Harz Mountains in northern Germany (maximum elevation: 1141 metres above sea-level) were also temporarily glaciated during this period. However, due to the lack of age datasets, the validation of this assumption is still pending. As a pilot study for an upcoming research project on the last glaciation of this mountain range, glacial landforms in Kellwassertal were mapped. The identification of ice-marginal moraines involved both the interpretation of derivatives of a high-resolution digital elevation model (x–y resolution: 1 m) and an extensive field survey. Geomorphological mapping confirmed the glacial cirque in the uppermost reach of the valley. The mapped ice-marginal moraines point towards the temporary presence of a small cirque glacier in this valley. Ice surface reconstructions were undertaken for each ice-marginal position to calculate equilibrium line altitudes (ELAs). Due to the influence of topoclimatic factors, i.e., shading, snow blow, and avalanching, the reconstructed ELAs likely underestimate the climatic ELA. Future work will have to exposure date the quartz-bearing boulders on the mapped landforms to employ the calculated ELAs for precipitation reconstruction. For a comprehensive glacier chronology for the Harz Mountains, moraines at other key sites in the Harz Mountains, including the Kalte Bode valley and the Oder valley, will be revisited.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *Moraine, glaciation, Harz, equilibrium line altitude, glacial geomorphology*



Hofmayer, Felix<sup>1</sup>; Kettler, Christoph<sup>2</sup>; Studeny, Martin<sup>3</sup>

## A new vertebrate fossil in Upper Austria – Preparation, 3D Modelling and Regional Geology

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In Upper Austria a nearly complete skull of a marine vertebrate was discovered in the Vöckla-Formation, enclosed in a solid carbonate concretion. It is a Odontocete skull, most likely belonging to the family of the Eurhinodelphinidae. The deposits belong to the so called Molasse, a set of different stratigraphic units deposited in the North Alpine Foreland Basin from the Oligocene to Miocene. The Vöckla-Formation is deposited in a shallow marine environment with strong tidal influence and an ongoing transgressive sequence. Despite of diverse ichnofossils, these deposits are usually depleted in any other remains. Therefore, are vertebrate fossil of this time interval in the North Alpine Foreland Basin virtually unknown. This makes the present individual invaluable for the study of evolutionary dynamics of Odontocetes in Europe and thus for large scale palaeobiogeographic considerations.

The skull, which was enclosed in about 100 kg of concretion, was donated to the Upper Austria Landes-Kultur GmbH and was prepared by Martin Studeny, using a pressurized air graver. The skull is nearly complete and three-dimensional preserved. Nevertheless, teeth, lower jaw and large parts of the parietal bone are missing due to taphonomical processes. Accompanying finds are gastropods, bivalves, plant material and a nautiloid. For in depth morphological investigation we created a digital high-resolution 3D-Model of the specimen. To achieve that we used a photogrammetry approach, where the specimen is placed on a turntable and numerous photos from various angles are taken. These are subsequently processed with Agisoft Metashape to create a representation of the cranium with submillimetre precision to capture finest details of the visible anatomy.

In this presentation we would like to show the results of the preparation and the 3D-modelling and share this exceptional fossil with the scientific community. The aim is to gain detailed taxonomic insight and to classify evolutionary traits. Moreover, this finding should give motivation to gather more stratigraphic insight into the Vöckla-Formation.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Vöckla-Formation, Odontocete, North Alpine Foreland Basin, Ottnangian, Miocene*

Hofmayer, Felix<sup>1</sup>; Coric, Stjepan<sup>2</sup>; Gebhardt, Holger<sup>2</sup>; Hadler Boggiani, Beatriz<sup>3</sup>; Soman, Rohit<sup>4</sup>; Andrade, Juan David<sup>4</sup>; Reichenbacher, Bettina<sup>1</sup>

## Revision of the „Robulus-Schlier“ in Austria – A stratigraphic enigma in the North Alpine Foreland Basin

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The recent mapping campaign of the Geological Survey of Austria (Geosphere Austria) in Upper Austria caused the revision of the so called „Robulus-Schlier“. It is a stratigraphic unit of the miocene North Alpine Foreland Basin in Austria and is exposed extensively in the vicinity of Linz. It is one of the most common units on the surface in Upper and Lower Austria. Nevertheless, it is very poorly investigated and its precise stratigraphic age and lateral range is still uncertain.

Therefore, we studied the „Robulus-Schlier“ in detail using micropalaeontology, nanoplankton, magnetostratigraphy, lithofacies and chemostratigraphy. Under investigation is an artificial outcrop in Upper Austria, exposing 30 meters of the marine fine-grained sediment. Additionally a composite profile in Lower Austria was used for comparison.

We recognized strong stratigraphic and lithofacies differences between the „Robulus-Schlier“ of Upper and Lower Austria. Therefore, we suggest the definition of a new stratigraphic term for the „Robulus-Schlier“ in Upper Austria and suggest further research for the eponymous deposits in Lower Austria. For interpretation of present deviations, we also considered varying tectonic regimes along the alpine thrust front, which was still active during the deposition. Finally, a large scale palaeogeographic concept was constructed for the depositional time of the „Robulus-Schlier“ in Austria, possibly contributing to the understanding of North Alpine Foreland sediments and Alpine tectonics.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Molasse, Miocene, Ottnangian, Stratigraphy*

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## Not sexy, but still dateable: Unravelling the P-T-t-d evolution of low-grade Permian metasediments using xenotime geochronology (Austroalpine Unit, Eastern Alps)

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The Austroalpine Unit is a nappe stack formed by the accretion of Adria-derived material during the Late Jurassic to mid-Late Cretaceous. Its geological history is primarily recorded in upper crustal, non-metamorphic rocks and lower crustal, metamorphic rocks ranging from upper greenschist to eclogite facies. However, data from the ubiquitous mid-crustal, low-grade metamorphic units are either absent or difficult to interpret, complicating the connection between shallow and deep orogenic levels. We present new pressure-temperature-time-deformation data for the Permian Präbichl Formation, sampled in the Tirolic-Noric Nappe System (TNNS) below the overlying Juvavic Nappe System (JNS) at two localities. The formation consists of lower greenschist facies clastic sediments, corresponding to the Permian cover of the pre-Variscan basement.

The metamorphic assemblage contains chloritoid + muscovite ± pyrophyllite + hematite + rutile + quartz. Phase equilibrium calculations and Raman spectroscopy on carbonaceous material indicate peak P-T conditions of ~350°C and 0.4-0.5 GPa. In both samples, xenotime crystals (10 to 30 µm) exhibit systematic chemical zoning with heterogeneous cores and MREE-rich rim. We targeted each chemical domain by in-situ LA-ICP-MS U-Pb dating. The concordant U-Pb dates from the cores range between 632 Ma and 250 Ma, likely reflecting inherited grains. Younger dates were obtained from the xenotime rims. In the eastern sample (Noric Nappe), a concordant cluster yields a weighted mean age of  $133.6 \pm 2.8$  Ma (MSWD: 1.7, n: 14). Host-inclusion relationships between chloritoid and xenotime suggest simultaneous growth of the xenotime rim and chloritoid porphyroblasts, linking the U-Pb age to the formation of the main metamorphic assemblage. An additional set of discordant analyses provides an anchored discordia age of  $91.5 \pm 3.6$  Ma (MSWD: 1.2, n: 7). In the western sample (Staufen-Höllengebirge Nappe), a set of concordant and discordant analyses yield an anchored age of  $90.1 \pm 1.4$  Ma (MSWD: 1.8, n: 16). Xenotime and chloritoid are not in direct contact but their relationship is constrained by microstructures. This sample is characterized by pervasive crenulation cleavage that postdates chloritoid growth. The distribution and morphology of xenotime suggest that post-peak dissolution-precipitation related to crenulation cleavage formation facilitated xenotime rim growth.

These results have two significant implications. Firstly, the  $133.6 \pm 2.8$  Ma date coincides with the age of the latest syn-orogenic sediments overthrust by the Juvavic Dachstein Nappe. It is therefore, interpreted as the age of peak metamorphism following the cessation of JNS thrusting over the TNNS. The peak pressure of 0.4-0.5 GPa at this time corresponds to an overburden of ~17 km. This may imply the existence of a missing unit, given the present-day thickness of the JNS is 5-10 km. Secondly, the 90-92 Ma dates correspond to the onset of post-orogenic sedimentation in the Gosau basins overlying both the TNNS and JNS and the exhumation of the Austroalpine eclogites, indicating a major shift in orogenic dynamics at that time.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *xenotime geochronology, low-grade metamorphism, Austroalpine Unit*

Hubmann, Bernhard; Krenn, Kurt

## Die Grazer Perspektive auf das Lehramtsstudium Biologie und Umweltkunde: wie sieht die Ausbildung aus und wie „ticken“ die Studierenden?

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Das derzeitige Curriculum für das BIUK-Studium im „Verbund Südost“ enthält im Bachelor 95 ECTS-Punkte (ECTS = European Credit Transfer and Accumulation System entspricht 25 Echtstunden an tatsächlichem Arbeitsaufwand für Studierende pro Punkt). 67 Punkte entfallen auf Lehrveranstaltungen im Fach, 23 auf Fachdidaktik und 5 auf Pädagogisch-Praktische Studien. Die Erdwissenschaften sind mit 5 ECTS im Fach (also mit 7,5%) vertreten, mit einem zusätzlichen ECTS in der Fachdidaktik. Im Master entfallen 20 ECTS auf Fach- und Fachdidaktik-Lehrveranstaltungen, davon werden 3 ECTS von den Erdwissenschaften abgedeckt; eine weitere Beteiligung findet sich in gemeinsamen bzw. wählbaren Lehrveranstaltungen.

Somit ist derzeit eine gewisse erdwissenschaftliche Präsenz im BIUK-Curriculum gegeben.

Im Studienjahr 2023/24 wurden Lehramts-Studierende des Faches Biologie und Umweltkunde (BIUK) der Grazer Universität während ihres ersten Studiensemesters hinsichtlich ihres Studiums befragt. Die „Kernfragen“ waren dabei welche Motivation ihrer Studienwahl zu Grunde lag, welche Themen die Studierenden besonders interessieren und welche Themen in welchem quantitativen Umfang während ihrer Schulzeit behandelt wurden. Das Lehramtsstudium besteht i.a. aus zwei kombinationspflichtigen Unterrichtsfächern. Nachdem an der Universität Graz bereits mit dem Studienjahr 2022/23 die Aufnahmebeschränkung (Limitation auf 80 Studierende im Fach BIUK) gefallen war, wurde erhoben, ob das BIUK-Studium tatsächlich „die erste Wahl“ der Studierenden war. Gaben auf diese Frage im Vorjahr fast die Hälfte der Befragten an, dass sie das BIUK-Studium als „Erstfach“ gewählt haben, so sank der Wert im heurigen Jahr auf 39%.

Betreffend der bevorzugt im schulischen Kontext behandelten Themen gaben die Probanden an, dass sie ihren Schulunterricht zu 25% mit Humanbiologie, zu 21% mit Genetik, zu 12% mit Zoologie, ebenfalls zu 12% mit Botanik, zu 10% mit Ökologie, zu 11% mit Molekularbiologie, zu 6% mit Verhaltensbiologie und zu 3% mit Erdwissenschaften verbinden.

Geologische Themen stellen also keine signifikante Größe dar. Diese Tatsache verwundert wenig, wenn man in Betracht zieht, dass die befragte Klientel angab, dass erdwissenschaftliche Themen während des gymnasialen Unterrichts nur im bescheidenen Ausmaß behandelt wurden: 51% gaben an, dass lediglich 0-2% des Unterrichts auf entsprechende Inhalte entfielen. Zudem meinten 35% dass die Inhalte „wenig interessant“, 18% sogar „uninteressant“ vermittelt wurden.

Immerhin waren im vergangenen Studienjahr Studierende des ausgehenden Bachelor-Abschnittes – gemäß ihrer Ausbildung knapp davor in der Sekundarstufe I „offiziell“ zu unterrichten – zu 40% der Meinung, dass Erdwissenschaften für das Verständnis global-vernetzter biologischer Sachverhalte „wichtig“ sind.

Ein nicht unwesentlicher Aspekt betrifft die Umstände, wie man zum BIUK-Studium gefunden hat. Dabei gaben die Studierenden an, dass zu 8% der Einfluss durch Verwandte, zu 10% durch Medien bestimmend war. 20% führten ihre Studienwahl auf die eigene Naturverbundenheit zurück. Den Löwenanteil für die Wahl des zukünftigen Unterrichtsfaches macht der (gute) schulische Unterricht – mit immerhin 62%! – aus. Zieht man diese Tatsache in Betracht, dann kommt der Lehrer:innenausbildung und Lehrer:innenfortbildung gewichtige Bedeutung zu. Gelingt es nämlich, angehende oder bereits beruflich aktive Lehrer:innen für die Erdwissenschaften zu begeistern, ist anzunehmen, dass geologische Themen entsprechend motiviert im Schulunterricht „ankommen“.

**Session:** Lehrendenworkshop

**Keyword:** Lehramtsstudium Graz BIUK, Studierendenbefragung

Iglseder, Christoph<sup>1</sup>; Huet, Benjamin<sup>1</sup>; Schneider, David A.<sup>2</sup>

## Initial exhumation of the Upper Austroalpine Unit along the Walchen Shear Zone (Styria, Austria)

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The timing of the Cretaceous Eoalpine Event in the Upper Austroalpine Unit (Eastern Alps) is well established. The phase of collision and nappe stacking with (W)NW-directed kinematics lasted from c. 135 Ma to c. 95 Ma and the phase of exhumation of metamorphic units through extrusion between thrusts with (W)SW-directed kinematics and large-scale normal faults with (E)SE-directed kinematics lasted from c. 95 Ma to c. 65 Ma. Large-scale normal faults are mostly documented in the hangingwall parts of the Upper Austroalpine Unit, while deformation in the footwall parts is rarely described.

We here present new data constraining the Walchen Shear Zone, which is a major shear zone formed during Eoalpine extrusion. The shear zone is located at the northern border of Eoalpine amphibolite facies rocks between the Wölz- and Ennstal complexes (Koralpe-Wölz Nappe System, Niedere Tauern). Evidence of Permian metamorphism is described in both complexes. The timing of Eoalpine peak metamorphism is however different. Allanite growth in the Ennstal Complex is dated around 105 Ma while prograde REE-rich epidote growth in the Wölz Complex is documented at 96-98 Ma (Stumpf et al., 2024). Note that the age in the Ennstal Complex is older than typical Sm-Nd garnet ages in the Koralpe-Wölz Nappe System (c. 95–94 Ma, Thöni et al. 2008).

The deformation along the Walchen Shear Zone affects rocks of the underlying Wölz Complex as well as the overlying Ennstal Complex. The shear zone could be traced on the surface for around 800 m perpendicular to strike (ca. 450 m in the Wölz and 350 m in the Ennstal complex). In general, the mylonitic schistosity dips moderately steep to the N(NW). The mylonitic stretching lineation is mostly subhorizontal or dips shallowly to the W(NW) or E(SE). The degree of deformation increases in the Wölz Complex towards the hangingwall, whereas the deformation is strongest in the footwall of the Ennstal Complex. The mylonitic deformation in light-colored mica-rich quartzite of the Ennstal Complex can be studied very well, especially in the area of the Walchen deposit. Quartz and calcite show evidence of dynamic recrystallization while garnet, feldspar and ankerite form porphyroclasts indicating that the shear zone was active under greenschist-facies conditions between 300 and 450 °C. C-type and C'-type structures in phyllosilicate-rich rocks, indicate a dominant top-to-W(NW) shear sense. For Ar-Ar dating, six samples of deformed quartz veins with coarse grained white mica as well as two fractions of white mica in a mylonitic impure quartzite were collected in both complexes along the shear zone. They show total fusion dates between 91-94 Ma, which are interpreted as formation or deformation ages. The kinematic and age data indicate that the Walchen Shear Zone is most likely related to the extrusion within the Koralpe-Wölz Nappe System.

Stumpf, S., Skrzypek, E. & Stüwe, K. (2024): *Contributions to Mineralogy and Petrology*, 179, 63 (2024). <https://doi.org/10.1007/s00410-024-02130-3>

Thöni, M., Miller, C., Blichert-Toft, J., Whitehouse, M.J., Konzett, J. & Zanetti, A. (2008): *Journal of Metamorphic Geology*, 26, 561–581. <https://doi.org/10.1111/j.1525-1314.2008.00778.x>

**Session:** Pangeo workshop: Regional Geology

**Keywords:** Upper Austroalpine Unit, Ennstal Complex, Eoalpine extrusion, Ar-Ar dating, Shear zone

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## Landesgeologie Wien im U-Bahn-Bau: Geologie in Prognose und Ausführung

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Im Gegensatz zu allen anderen Bundesländern, die großflächig und tlw. gebirgig sind, hat Wien eine kleine Fläche, die jedoch umso stärker verbaut und daher für Geologen nicht direkt zugänglich ist. Umso willkommener sind daher große Infrastruktur-Bauvorhaben wie U-Bahnen: dafür werden zahlreiche und tiefe Bohrungen erstellt und umfangreiche Untersuchungen durchgeführt.

Im Fall der U2-Verlängerung vom Schottentor bis zum Matzleinsdorfer Platz wurden seit 2015 ca. 640 Bohrungen hergestellt. Auf deren Grundlage und unter Hinzuziehung von weiteren Aufschlüssen aus dem Bohrdatenarchiv Baugrunderkennung entstand ein dreidimensionales geologisches Modell des Untergrundes. Dazu wurden die einzelnen ausgewiesenen Gesteinsschichten der Profile zu lithostratigrafischen Einheiten zusammengefasst und Schichtkontakte definiert. Diese wurden mit geologischen Karten, dem Geländemodell und vorhandenen stratigrafischen Daten in Zusammenhang gebracht und unter Einsatz des Programms „Leapfrog“ (Firma Seequent) als 3D-Volumenkörpern modelliert.

Im Zuge der Vorarbeiten zum eigentlichen Tunnelbau musste für gewisse Trassenabschnitte ein Wasserhaltungskonzept entwickelt werden, um die notwendige Absenkung des Grundwasserspiegels zu erreichen. Mit den dafür erstellten Brunnen und Pegel wurde das Modell verfeinert. Zusätzlich wurde ein geotechnisches Modell aufgesetzt, dass die Gebirgsarten gem. ÖGG-Richtlinie („RL für die geotechnische Planung von Untertagebauwerken mit zyklischem Vortrieb“) beinhaltet. Daraus konnte eine detaillierte Prognose für den Tunnelvortrieb in NÖT erstellt werden.

Als Praxisbeispiel soll der Tunnelbau im Detail in demjenigen Bereich vorgestellt werden, in dem der Vortrieb aus dem Pleistozän ins Neogen übergeht. Dies ist insofern interessant, als im Zuge der Voruntersuchungen dort eine Störung bzw. deren Ausläufer diagnostiziert wurde. Weiters sind in diesem Bereich stärkere Wasseraustritte festgestellt worden.

Im gegenständlichen Beitrag soll die aus der Modellierung und den geologischen/geotechnischen Untersuchungen erstellte Prognose den im Tunnelvortrieb vorgefundenen geologischen Verhältnissen gegenübergestellt werden.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keyword:** *Landesgeologie Wien, U-Bahn-Bau, 3D-Modellierung*

Jud, Markus; Hainisch, Alexander; Eichkitz, Christoph; Schreilechner, Marcellus G.; Binder, Heinz

## Seismische Exploration für tiefe Geothermie in Braunau– Akquisition und Processing einer kabellosen 2D-Vibro-Seismik mit STRYDE Nodes.

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Die Geothermie-Wärmegesellschaft Braunau-Simbach mbH (GBS) plant im Zusammenhang mit dem Ausbau der Fernwärme durch Erweiterung von Anschlüssen im Bereich "Braunau-Ost" und der damit verbundenen Steigerung des Fernwärmebedarfs die Errichtung einer zweiten geothermischen Dublette mit einem bevorzugten Standort in Braunau am Inn. Der Standort für die Bohrungen sowie das Aufschließungsziel der Dublette soll rein auf österreichischem Staatsgebiet, im Osten von Braunau, im Bereich der regional entwickelten sogenannten "Mattig-Störung", liegen.

Basierend auf bereits vorhandenen, neu bearbeiteten Daten von der RAG wurden drei neue Seismikprofile im März 2024 im Raum Braunau und St. Peter am Hart aufgenommen und anschließend ausgewertet.

Ziel dieser seismischen Untersuchung war es, den strukturellen Aufbau des Geothermie-Reservoirs (Malmkarbonat) abbilden zu können. Basierend auf den daraus abgeleiteten Erkenntnissen, sowie weiterer geologischer Informationen, sollen detailliertere Aussagen bezüglich der räumlichen Ausdehnung des Geothermie-Reservoirs möglich sein. Um Hinweise auf eine mögliche geologische Störung unter dem Inn zu bekommen, wurden nördlich des Inns, in Deutschland, zusätzliche aktive Aufnehmer („Nodes“) platziert und somit das N-S Profil für die Datenaufnahme komplettiert. Die Vermutung, dass sich nördlich des eigentlichen Untersuchungsgebietes in Braunau und St. Peter am Hart ein Inn-paralleles (W-E verlaufendes) Störungssystem befindet, konnte nach der Datenbearbeitung bestätigt werden.

Die für die seismische Akquisition notwendige Energieanregung fand über zwei Vibratoren Thomas 65 (je 32 t) der Firma Smart Seismic Solution (S3) in einer Flotte ausschließlich auf österreichischem Staatsgebiet statt.

Als Empfänger wurden kabellose „Nodes“ der Firma STRYDE verwendet.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Geothermie, Geophysik, Exploration, Vibro-Seismik, Braunau*

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## Modelling tunnel valley erosion in northern Germany during the first ice-sheet advance (Elsterian, MIS 12) – a conceptual model and preliminary results

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This study, supported by the Bundesgesellschaft für Endlagerung (BGE), presents a computationally efficient model for simulating the formation of tunnel valleys, erosional features carved by subglacial meltwater that offer insights into past meltwater drainage and possible erosion under the future ice sheets. Understanding tunnel valley formation is crucial for predicting future glacial erosion, particularly in areas considered for radioactive waste disposal repositories.

We focus on a region previously glaciated by the Scandinavian Ice Sheet in northern Germany, leveraging geological data and taking the maximum Elsterian ice extent (MIS 12) as the primary erosional event. The ice-sheet thickness and solid Earth deformation are estimated using ICESHEET 2.0 (Gowan et al. 2016) and gFlex (Wickert 2016), assuming a steady-state ice-sheet configuration. The model incorporates both basal meltwater and surface meltwater input via simulated moulins, routed through the subglacial system using the FastScape landscape evolution model (Benoit & Lange 2023). Erosion and deposition within these channels are calculated based on the Walder & Fowler (1994) model, considering factors like channel shear stress, geometry, and sediment properties.

Preliminary results demonstrate the model's suitability and efficiency for addressing the research tasks. We have tested the model on a 425x625 km grid at a 100x100 m grid resolution (4251x6246) for simulating tunnel valley erosion using generic parameters. The model runs in under 60 seconds per iteration, typically requiring less than 20 iterations to converge, making it versatile and relatively fast considering the grid size.

Future development will focus on incorporating a diffusion equation to enable simulating transitions between sheet flow and channelized flow and allowing for spatially variable hydraulic conductivity and potential coupling with groundwater flow models. A regional-scale geological subsurface model of Lower Saxony will be used in the modelling framework to predict erosion patterns there. The outcome of this model will be compared to smaller-scale high-resolution models to inform about the importance of resolving uppermost strata to high resolution with regards to subglacial hydrology and erosion patterns, rates, and depth limits. This will facilitate investigation into the influence of diverse lithologies and hydraulic parameters on tunnel valley erosion, enhancing the model's predictive capabilities for assessing future glacial erosional impact on the study area.

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*Wickert, A. D. (2016). Open-source modular solutions for flexural isostasy: gFlex v1.0. Geoscientific Model Development, 9(3), 997–1017. <https://doi.org/10.5194/gmd-9-997-2016>*

**Session:** Pangeo workshop: Glacial erosion and deposition

**Keywords:** Tunnel valleys, glacial erosion, numerical modelling, subglacial processes



Kahre, Michel; Otto, Jan-Christoph

## Sediment core analysis of glacial lakes Löbbensee and Salzbodensee, Hohe Tauern, Austria

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Glacial lakes represent important sedimentary archives that provide information on recent and postglacial dynamics in terms of climate, glacial development, geology, depositional processes, and mass movement dynamics in the catchment. This study investigates the sediment of two glacial lakes, Salzbodensee and Löbbensee, in the Hohe Tauern National Park, Austria. The work aims to characterise the lake sediments, to relate sediment composition to catchment characteristics, and to calculate sedimentation rates. A broad analysis of sedimentological parameters, including grain size, water content, organic content, magnetic susceptibility, bulk density, P-wave velocity, as well as geochemistry (X-ray fluorescence) was conducted on five sediment cores. Based on the radiometric dating (Pb-210 and Cs-137), sedimentation rates for Lake Löbbensee were calculated. The analysis reveals that fine sand predominates in both lakes. Due to the size and shallowness of Lake Salzbodensee the fluvial sediment entering the lake is distributed equally, whereas Lake Löbbensee shows proximal-distal fining. Deeper locations generally exhibit a higher water content, whereas in shallow water greater deviations exist. Organic contents of both lake sediments are low compared to similar studies. Measured XRF elements and magnetic susceptibility relate to gneiss in the catchment. Higher values of Si and Ca in the cores correlate with sandy samples. In turn, all main component elements Fe, K, Ti, Ca and Si are more frequent in silty samples. The sediment of Lake Löbbensee is up to  $145 \pm 24.4$  years old with an average sedimentation rate of 3.54 mm/a. This research provides the first sedimentary analyses of Lake Salzbodensee and Lake Löbbensee.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *glacial lake, lacustrine sedimentation, XRF, radiometric dating, sedimentation rate*

## Pre-Alpine Metamorphism in Alpine low-grade metamorphic units in the Eastern Alps

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Pre-Alpine basement units, originating from the northern Gondwana margin, have been incorporated into the Austroalpine Nappe System and were overprinted during Alpine nappe stacking. Some of these units were only slightly affected by Alpine metamorphism, offering valuable insights into their pre-Alpine history. The Kaintaleck Metamorphic Complex, part of the Eastern Greywacke Zone, along with the Silvretta-Seckau Nappe System, underwent only greenschist facies metamorphism during Eo-Alpine times and thus still preserve Variscan or even pre-Variscan information within their mineralogical assemblages. To enhance our understanding of the pre-Alpine metamorphic evolution of the Eastern Alps, different basement units are being investigated by geochronological, geochemical and geothermobarometric techniques to reconstruct their pre-Alpine tectonic and metamorphic evolution.

The Kaintaleck Metamorphic Complex consists of a mafic suite, including amphibolite, garnet-amphibolite, greenschist, and serpentinite, and a felsic suite, primarily composed of gneiss and mica-schist, some of which are garnet-bearing. Geochemical analyses of the metabasites indicate a tholeiitic basalt source with MORB affinity. U-Pb zircon dating of a garnet-bearing amphibolite suggests an Early Devonian age ( $414 \pm 5.6$  Ma) of protolith formation. Chemical U-Th-Pb dating of monazites reveals Late Devonian to Early Carboniferous ages ( $362 \pm 6$  Ma,  $358 \pm 15$  Ma,  $351 \pm 4$  Ma,  $349 \pm 3$  Ma), which represent peak metamorphic conditions during the Variscan orogeny. The Kaintaleck Metamorphic Complex underwent a two-stage metamorphic history, characterized by a HT/LP metamorphic event of  $\sim 600$ - $700^\circ\text{C}$  and  $\sim 0.5$ - $0.7$  GPa, followed by a LT/HP metamorphic event of  $\sim 550^\circ\text{C}$  and  $\sim 1.7$ - $2.2$  GPa, inferred from Zr-in-rutile thermometry and thermodynamic modeling. This development is related to the opening and closure of the short-lived Balkan-Carpathian Ocean and also suggests a correlation with other Devonian-aged ophiolitic relics in the North-Gemeric Klatov and Rakovec Complexes in the Western Carpathians (Neubauer et al., 2022; Putiš et al., 2009).

The Seckau Complex, part of the Silvretta-Seckau Nappe System, is characterized by various metagranitoids, such as the Late Cambrian to Early Ordovician Hochreichart Plutonic Suite and the Late Devonian to Early Carboniferous Hintertal Plutonic Suite. These large intrusions are hosted by the Glaneck Metamorphic Suite, which is predominantly composed of garnet-bearing paragneiss and mica-schist, but also includes amphibolite and tschermakite-bearing gneiss, which might be of magmatic origin. U-Pb zircon dating of the paragneisses indicates a detrital origin, with age clusters in the Neoproterozoic, Paleoproterozoic, and Ediacaran, ranging from 2.7 Ga to 559 Ma (Mandl et al., 2018). A migmatized paragneiss yielded an age of 505 Ma, suggesting that migmatization was likely triggered by the intrusion of the Hochreichart Plutonic Suite. Thus, the timing of pre-Alpine metamorphism can be constrained between 559 Ma and 505 Ma. Most samples exhibit two-phase garnet growth with a strong increase in grossular towards the rim, indicating an additional metamorphic event, possibly during the Variscan orogeny. Preliminary results from conventional geothermobarometry and thermodynamic modeling for paragneisses and metapelites suggest metamorphic conditions of  $\sim 550^\circ\text{C}$  and  $\sim 0.4$ - $0.5$  GPa for incipient garnet growth and  $\sim 570$ - $620^\circ\text{C}$  and  $\sim 1.1$ - $1.2$  GPa for garnet-rim compositions. Garnet-bearing amphibolites show quite homogeneous garnet-compositions with only a subtle increase in spessartine towards the core, revealing peak metamorphic conditions of  $\sim 680$ - $720^\circ\text{C}$  and  $\sim 1.1$ - $1.2$  GPa. Whole-rock geochemical data of amphibolites suggest a tholeiitic differentiation trend deriving from basaltic to andesitic protoliths. Trace element compositions indicate MORB and Within-Plate-Lava affinities.

**Session:** Pangeo workshop: Regional Geology

**Keywords:** Pre-Alpine, Kaintaleck Metamorphic Complex, Seckau Complex, Variscan

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## Alpice - ongoing compilation of geochronological & geo(morpho)logical constraints on Alpine paleoglacier evolution

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Enhanced by machine learning techniques, a new generation of glacier evolution models (e.g. the Instructed Glacier Model) facilitates high-order 3D glacier simulations to be run at high resolutions (few hundred of metres), over several tens of millennia, and mountain range scales – at a fraction of the computational cost of conventional ice flow models. Such advances enable to conduct ensemble-type experiments, where a large number of perturbed simulations are produced. Facing a multitude of simulations, a robust framework of empirical data against which to quantitatively score transient glacier model output is indispensable. Despite abundant publications on the topic of paleoglacier reconstruction, the integration of field evidence for model validation in the Alps has thus far largely been restricted to the Last Glacial Maximum (LGM) ice extent and trimline observations. Inspired by work from the (former) British, Fennoscandian, Patagonian, and Greenland ice sheets, we aim on establishing a comprehensive and standardized dataset on paleoglacier fluctuations in the Alps. The so called Alpice database combines published geo(morpho)logical and geochronological markers that restrain the build-up, culmination, and disintegration of the Alpine LGM glaciers as well as subsequent Alpine Lateglacial and Holocene glacier advances. For now, surface exposure and radiocarbon dates are considered. Reliability assessments and paleoglaciological context classifications are undertaken concurrently. Where applicable, the chronological constraints are linked to related geo(morpho)logical features (e.g. moraines) using GIS software. Alpice shall act as empirical basis for future quantitative model-data comparison and is designed as an open-access resource. It hopes to prove useful for both modelling and empirical communities and beyond the scope of model validation.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *European Alps, Quaternary glaciation, model-data comparison*

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## Drive by vestiges of the past: A non-salient Vertebrate track site from the Upper Triassic near Lake Achensee/Tyrol

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Ichnofossils from tetrapod vertebrates are remarkably sparse in Austria. Contrary to the French- Italian- and Swiss Alps, where vertebrate track sites of similar age are well-documented, the only known Austrian footprints from the Middle and Upper Triassic are recorded of the Drau Range, Carinthia. Here we present a new track assemblage from the early Upper Triassic Northalpine Raibl Beds near Lake Achensee in Tyrol, Austria. Tracks are directly located near the federal highway B181 and are imprinted on the top of steeply inclined decimetre thick dolostone banks and occur over multiple horizons within an interval of 10 m within the Northalpine Raibl Beds. They occur solitary or as assemblages at three individual stratigraphic levels.

Two distinct types of tracks on the biggest bedding surface could be identified as manus and pes tracks as they show differences in size and occur as pairs (manus on average 15 cm and pes on 30 cm in length) indicating lateral sequence walking. The morphology of the autopodium is weakly preserved, as the tracks are only perceivable as elliptical shaped concave epireliefs, some still partially filled with the surrounding substrate material. However, the morphological features suggests digitigrade locomotion of at least one undetermined ichnotaxon.

The occurrence of vertebrate tracks in the Northalpine Raibl Beds, which show current ripples, subaquatic dunes and other indicators of shallow water milieu, allow for new insights into the paleoenvironment and enhance its biostratigraphic significance.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Paleoichnology, Paleoenvironment Reconstruction, Vertebrate tracks, Photogrammetry*

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## Unravelling the maximum extent of Middle Pleistocene Glaciation in the Ybbstal Alps, Austria

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Unlike deposits from the LGM in Austria (Würm Pleniglacial; MIS 2) the sedimentary record from the Middle Pleistocene glaciations like Riß Glaciation (MIS 6) and older are usually fragmentary, concealed and significantly overprinted by post-depositional processes (e.g. erosion, weathering) and by the Late Pleistocene landscape evolution. This specifically applies to deposits associated with terminal positions of the ice tongues.

Contrary to parts in Western Austria, where extent, terminal positions and size compared to the LGM extent from the Mindel- (MIS 12) and Riß glaciations are well constrained, our study area shows gaps in this regard.

The Ybbstal Alps however, with peaks of 1800 m and valleys of around 500 m in elevation, shows an unique sedimentological archive which is preserved in a way that allows the reconstruction of glacier dynamics at the terminal positions of the Enns and Ybbs glaciers. Our reconstructions are based on sedimentological data and mapping results of several gravel pits and additional sediments from valley flanks. Deposits generally show at least four major facies assemblages, starting with fluvial to distal glaciofluvial deposits (1) from the phase before the Riß climax. Followed by glacial diamictons (2) which are overlain by rhythmites (3) that are associated with a glaciolacustrine environment. Finally, the successions generally end with several metres of deltaic conglomerates (4) indicating a rapid and quick aggradation due to high sediment influx associated with glacial retreat. The record from the pre-Riß includes glaciogenic and deltaic sediments that point to a much larger glaciation. Our preliminary results indicate a much larger glaciation during the Middle Pleistocene in the Eastern Alps than previously thought.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *Mapping, Quaternary Glaciation, Glacial Sedimentology*

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## Pleistocene river terrace development in the Baza Basin, Spain: Processes and chronology.

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River terraces are common features of landscapes worldwide, formed by the complex interplay of erosion and sedimentation processes. Despite their ubiquity, many questions remain unanswered about the mechanisms and their boundary conditions that influence their formation and evolution. The Guadix/Baza Basin in Andalusia, located within the Granada UNESCO Geopark, is an ideal natural laboratory for studying terrace evolution. Over time, this basin has undergone significant geological changes, from being a closed depression filled with sediments from the surrounding mountains to the establishment of a new river system during the Middle to Late Pleistocene after river capturing. This change from an endorheic to an exorheic fluvial system resulted in the formation of several generations of river terraces, often accompanied by calcareous sinter formations, in deeply incised valleys.

This DFG-funded research project aims to investigate the processes underlying the evolution of the newly established fluvial system after river capturing, with a particular focus on the dynamics of fluvial erosion. To establish a terrace chronostratigraphy, luminescence dating techniques for the terrace sediments are applied in combination with U/Th dating for terrace-associated calcareous sinter formations. The chronostratigraphy will elucidate the dynamics of landscape evolution following the pivotal event of river capture. Expected outcomes include estimates of erosion rates and an understanding of the typical incision patterns of local rivers.

This poster provides an overview of the project objectives, outlines the methodology employed, and presents and discusses the first chronostratigraphy of the eastern Baza sub-basin based on luminescence and U/Th datings.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Fluvial landscape evolution, terrace sediments, luminescence, U/Th, Andalusia

Költringer, Chiara; Linner, Manfred; Rötzel, Reinhard

## The Sankt Leonhard nappe: HP-UHT metamorphic rocks within the Gföhl Nappe System, where and how to draw the nappe boundary

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The Sankt Leonhard Nappe in Lower Austria, Austria, represents high-pressure (HP), ultrahigh-temperature (UHT) lithologies within the Gföhl Nappe System in the Moldanubian Superunit. It mainly consists of ultramylonitic felsic garnet+kyanite-bearing granulites, occasionally associated with mafic garnet+clinopyroxene-bearing granulites. Ultramafic rocks, i.e. serpentized peridotite, occur only subordinately. These lithologies and their contact to the underlying nappe within the Gföhl Nappe System are particularly well exposed in the Bründlleiten south of the Kamp River close to the village Wanzenau. So far, however, research attention was mostly given to the felsic granulites, while adjacent lithologies are less studied in respect to their HP-UHT metamorphism. As a result, the boundary of the Sankt Leonhard Nappe remains ambiguous. Here, we attempt to define the Sankt Leonhard Nappe and its lithological content through comprehensive geological mapping and the study of thin sections.

The granulite body and its associated ultramafic rocks are surrounded by garnet-clinopyroxene amphibolites. Two types are distinguished; amphibolites in the immediate vicinity of the granulite body are mylonitic, dense, and bronze-coloured due to brown hornblende. This indicates higher-grade metamorphic conditions than the adjacent well-foliated, green amphibolites of the underlying nappe within the Gföhl Nappe System. In contact with syntectonic intrusions of quartz-syenite, the latter amphibolite type also shows an initially migmatic character. This so-called Wolfshof intrusion does not affect the Sankt Leonhard Nappe. It occurs at its base within the underlying nappe of the Gföhl Nappe System. In general, an increasing deformation gradient can be observed towards the nappe boundary in direction of the hanging wall. While these observations signal a change in metamorphic conditions within a short distance, an E-W orientated lineation predominates the whole area around the nappe boundary suggesting a wider-reaching structural influence of the emplacement of the Sankt Leonhard Nappe.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Moldanubian Superunit, Sankt Leonhard Nappe, HP-UHT metamorphism*

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## Lithium resources in geothermal brines of the Upper Rhine Graben and possible extraction technologies

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Lithium is one of the most important raw materials for the mobility transition and energy storage, as it is irreplaceable for battery technology at least for the next decade. Europe is dependent on imports of lithium-ion batteries and has only very few lithium deposits in production that supply this raw material for domestic battery production. In addition to conventional lithium ore deposit types in granitic rocks, unconventional resources in geothermal basin brines have received exploration interest globally.

The Upper Rhine Graben in southwestern Germany and northeastern France hosts numerous warm springs. Geothermal waters in porous rock at depths of 2000-5000 metres have been used in geothermal power plants since the early 2000s. Although lithium contents of 150-600 mg/l are lower than in the salt lakes of South America, high flow rates and energy or balneological co-utilisation make the resource economically interesting. Four geothermal power plants in the Upper Rhine Graben alone could produce more than 1000 tonnes of lithium per year, which would correspond to a global share (2021) of 1% and would put Germany in 5th-6th place among global lithium producers.

However, technologically lithium extraction from the brine in a running geothermal power plant or bath is challenging. The following requirements for process stability have to be met in a fully industrial implementation: (1) temperatures of up to 150°C and pressures between 20 and 40 bars; (2) flow-rates of 20-100 L/s; (3) complex solute concentration of 100-200 g/L; pH of 4-5; (4) locally gas saturation of the liquid; and (5) lithium concentrations between 70 and 250 mg/L. Sorption on solid crystalline material is one of the most promising extraction technologies, as it is very selective for lithium, relatively robust, simple and fast, and already widely used in water treatment. Geologists have the necessary understanding of crystallography and fluid mineral interaction under the conditions given above and thus, play an important role in technology development. Currently, different Al-, Ti-, Mn-based minerals are tested. We developed Mn-based sorbents and tested zeolite and lithium-iron phosphate successfully in a pilot plant. The industry and research on the extraction technology, but also targeted exploration is ongoing and still in the pilot- or small demonstrator stage. The Upper Rhine Graben was amongst the first sites globally, but strong funding opportunities brings Canadian companies at the forefront of the technology.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*  
**Keywords:** *brine, lithium, geothermal, extraction, sorption*



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## How 'refrigeration weakening' drives catastrophic subduction initiation

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New subduction zones have initiated repeatedly throughout Earth's history, meaning that some process inherent to the evolution of oceanic lithosphere regularly overcomes net resistance to subduction. However, thermal histories of metamorphic rocks formed during subduction initiation pose a rheological paradox: the highest temperatures, at which rocks are theoretically the weakest, coincide with a protracted phase of mechanical resistance to subduction. Moreover, rapid cooling and depression of slab-parallel isotherms (i.e., 'refrigeration'), during which rocks would be expected to stiffen, occurs at the onset of self-sustaining subduction when the lower plate collapses into the mantle. Here, we present microstructures from metamorphic rocks formed along ancient hot, warm, and cold plate interfaces and demonstrate that refrigeration drives changes in metamorphic phase stability, distributions of strain-accommodating minerals, and deformation mechanisms that dramatically weaken the developing plate boundary. Paleopiezometry and flow laws bracket rock strength, and quantify a ~2–3 order of magnitude viscosity reduction along the interface from ~10<sup>20</sup> to 10<sup>17</sup> Pa-s at a ~500°C/GPa threshold, facilitating feedbacks that accelerate subduction rates, sustain refrigeration, and maintain plate boundary weakness. The 'refrigeration weakening' hypothesis explains observed changes in upper plate stress state, inferred slab velocity, and timing of proto-forearc volcanism.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Subduction, Microstructure, Rock Strength*

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## FT-IR microplastics identification in natural sediments of Austria and the Republic of Korea – introduction and first results

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Plastics became a very abundant novel material since the late 19th century, with a significant increase in production and diversity starting from the 1950s CE onwards. Today, plastics, and especially microplastics (MP), are found almost everywhere around us, including remote places like the deep sea, isolated lakes, glaciers, and even within the human body. MP has also been proposed as a secondary marker for the stratigraphic Anthropocene and was detected in numerous geological sections suggested for the Global Stratopoint and Section (GSSP) by the ISC Anthropocene Working Group. Nevertheless, a standardized definition of the size and shape classification of polymer particles is still missing, although several established size classification schemes do exist, commonly defining the size class boundaries of MP in geosciences between 1 µm to 5 mm. MP, either manufactured as small polymer particles (primary MP) or fragmented by degradation of larger plastic litter pieces (secondary MP), are nowadays noticed as an environmental pollutant and studied by a broad range of disciplines worldwide.

In contrast to the initial attempts of MP identification in natural sediments, where particles were determined and counted by visual criteria using a stereo-microscope, the identification of polymer types has become essential. This is often accomplished by destructive thermoanalytical methods, such as pyrolysis gas chromatography-mass spectrometry or thermal desorption gas chromatography-mass spectrometry. To avoid the loss of sample material, non-destructive vibrational spectroscopic identification techniques, like Fourier transform infrared spectroscopy (FT-IR) or Raman spectroscopy can be used. An additional advantage of FT-IR is that it is a comparatively inexpensive and fast technique to gather information of the chemical composition, allowing also further sample analysis by different methods.

For this study, core samples of coastal sediments collected offshore Ganghwado island (Yellow Sea, Republic of Korea) and riverbed sediments of the Fugitz River, a tributary of the Thaya River in Lower Austria (Austria), were prepared for MP identification by FT-IR (Bruker Lumos II, nitrogen-cooled MCT detector). No established workflow existed for this technique at the labs of the Department of Geology, University of Vienna so far. Existing methods described in literature lack standardization regarding sampling, removing natural organic matter, sample density separation and measuring mode (transmission, ATR, type of detector). Additionally, in a lot of studies, sediments are artificially spiked with new polymers that have not been altered by natural processes. Therefore, in our study, the main focus shifted towards implementing a best practice approach suitable for natural sediment samples yielding altered MP particles and fibers. These particles might have encountered sorting, (re)deposition, burial, compaction, cementation, leaching, degradation, UV and/or biofilm exposure, depending on the environment and depositional history of the sediment. Another challenge is given by the fact that most polymers contain producer-specific additives, based on the intended use, which can be substituted in the recipe quickly and without any declaration. This might cause problems for the interpretation of FT-IR spectra, particularly for older samples, because limited information exists regarding the alteration and degradation effects of the additives in combination with changes of the main polymer component.

**Session:** DEUQUA Session: Anthropogenic impact on the development of landscapes

**Keywords:** microplastics, FT-IR, Anthropocene, Fugitz river, Yellow Sea

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## Continuative foraminiferal research using the Enhanced Benthic Foraminifera Oxygen Index

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In 2022, Kranner et al. refined and enhanced the widely used tool of the Benthic Foraminifera Oxygen Index (BFOI) of Kaiho (1994) leading to the EBFOI. Additionally, a transfer function was introduced to directly calculate dissolved oxygen (DO) values for the first time ( $DO_{[m/l]} = 5.28475e^{0.00616x} - 3.78475$ ). The authors adjusted the original formulas by combining calcareous and agglutinate foraminifer taxa, occupying the full range of infaunal and epifaunal habitats. Therefore, the EBFOI more fully considers both bottom water and pore water oxygenation, providing a clearer picture of oxygen levels prevailing within the total habitat space occupied by foraminifera. Through these adjustments, this new approach significantly improves the accuracy of quantitative reconstruction of marine (paleo-)oxygen and, thereby, also (paleo-)eutrophication. All formulas are calibrated with modern samples, demonstrating an accuracy increase of up to ~38% near OMZs compared to the original BFOI. Subsequently, we further tested the validity of the EBFOI as an oxygenation proxy by applying it to several hundred samples recovered from the east-coast of the US. These results further support its application on three Cenozoic fossil datasets, which were previously published. Thus, our new formulas provide a major improvement in reconstructing paleo-oxygen levels and enhancing the reliability of benthic foraminifera as an oxygen proxy. Henceforth, the formulas have been and are still being applied to the datasets of different geological timeframes and have been now also widely adopted in the benthic foraminifer community at large.

To further showcase the validity of the EBFOI we applied it to foraminiferal assemblages recovered during the Paleocene Eocene Thermal Maximum (PETM ~56 Ma). The PETM is one of the most prominent and closest analogues of modern climate change, providing tantalizing glimpses into potential analogues for near-future responses of bottom water oxygenation and productivity changes during major changes in pCO<sub>2</sub> concentration. Further studies are under way, targeting Plio-/Pleistocene (5 ma – 11ka) sapropelic samples from the Mediterranean Ocean Drilling Program (ODP) Leg 160. Finally, we aim to test and validate the EBFOI by integrating geochemical analyses. This validation is crucial and will not just provide more credibility for the proxy but also allow reliable results for problematic samples.

In the near future this research will be continued and intensified by being applied on samples of the Bavarian Molasse Basin. Since preservation and reworking of foraminiferal shells is a frequent issue in these sediments, geochemical analyses often show conflicting results. This will then highlight the usefulness of assemblage-based analyses over pure geochemical analyses which can be easily hampered by reworking.

**Session:** Pangeo workshop: Regional Geology

**Keywords:** Micropaleontology, Foraminifera, Oxygenation, Proxy, EBFOI

Kulich, Jakob; Ott, Holger

## CO<sub>2</sub> Storage options in Austria & current developments

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Austria is committed to becoming climate net-neutral by 2040, no later than 2050. Reducing the countries hard-to-abate CO<sub>2</sub> emissions will require the substantial application of CCS to reach this challenging goal. Due to legal regulation and missing public acceptance across Europe, storage sites for CCUS hubs are typically being developed offshore. This is especially challenging for landlocked countries like Austria where domestic storage is currently not developed and export of CO<sub>2</sub> can only take off once transport infrastructure is completed. The talk will shortly discuss the development of legal regulations concerning CCS in Austria and touch upon possible export routes to offshore storage sites. Afterwards new results on storage potential in hydrocarbon fields are presented and compared to already existing studies. Storage of pure hydrogen in porous media is an emerging technology that is hoped to be used for balancing fluctuations in renewable energy and decarbonizing heavy industry. At the same time geothermal energy production is seen as a key technology in providing green base-load energy for decarbonization of the heating sector in cities with district heating networks. The competitive usage of the Austrian subsurface as well the possible contribution of CCS to Austria's climate goals are finally being discussed. We believe that in the future, while all three technologies can significantly contribute to energy transition as well as the countries climate goals, CCS should not be neglected as only development of domestic CO<sub>2</sub> storage can bridge crucial time periods for hard-to-abate emitters.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *CO<sub>2</sub> storage potential in Austria, Competitive usage of the subsurface*

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## Cyclic patterns within Quaternary vega formation on the eastern Canary Islands

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On the eastern Canary Islands, several valleys exist that were dammed later on by volcanic activity. Since that damming, these valleys (locally called "vegas") have acted as sediment traps. The deposited materials include volcanic material, redeposited (soil-)sediments from the surrounding slopes, and dust originating from the northern African continent. Hence, these vega sequences store information about local and overregional palaeo-environmental conditions.

To elicit the stored information and to use vega sediments as terrestrial dust archives, a deep understanding of the archive formation is required. With this study, we aim to contribute to the understanding of vega formation using grain size analyses, geochemical (XRF) and mineralogical analyses (XRD), as well as luminescence dating.

The vega sediments are characterised by an alternation of pale-coloured, calcified layers (PCL) and reddish, clay-enriched layers (RCL). This alternation shows a recurring pattern within the profile. We interpret one PCL and one RCL above (in combination as one vega sequence) as follows:

We assume a massive deposition of silt-dominated dust at the beginning of the formation of such a sequence. That massive dust event is indicated by silt, quartz, and Zr maxima in the bottom of a PCL. Increasingly humid conditions lead to de- and recalcification, resulting in increased CaCO<sub>3</sub> contents up to 45%, and to soil formation on the slopes in the catchment area. Due to the onset of aridisation, clay-rich material (>80%) formed on the slopes is eroded, which, in combination with a simultaneous increase in dust accumulation, completes the formation of an RCL. The aridisation culminates in another massive aggradation of silt-dominated dust at the beginning of the next PCL formation. The recurring pattern indicates a climate-controlled sediment cyclicality, which is possibly linked to African Humid Periods.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Drylands, Vega sediments, Stratigraphy, Saharan dust, Canary Islands

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## Structural control on tunnel-valley incision: Fact or fiction?

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Tunnel valleys are impressive glacial erosional landforms that may attain depths of more than 500 m, for example in the North German Basin. Characteristic features of tunnel valleys include undulating basal profiles, abrupt terminations and steep flanks, all indicative of subglacial formation by pressurised meltwater discharge. Tunnel-valley fills represent important archives of past glaciations and may provide economically important reservoirs for groundwater or hydrocarbons. Furthermore, tunnel-valley incision beneath potential future ice sheets is regarded as a major challenge for the long-term safety of radioactive waste repositories, as the incision may reach depths under consideration for such repositories. Therefore, an understanding of the controlling factors of tunnel-valley formation is an important contribution to long-term safety assessments. The distribution and orientations of buried Pleistocene tunnel valleys in northern Germany are compared to regional structural features such as the basin geometry, faults and salt structures. The deepest tunnel valleys occur along the basin axis, where thick erodible deposits occur. The relationship between tunnel valley, fault and salt-structure orientations is ambiguous. We observe that the correlation between the orientation of tunnel valleys and the regional fault trend is strong, if the inferred main palaeo-ice-advance direction is parallel to the fault trends. Overall, a correlation between the trends of tunnel valleys and neotectonically active faults is regarded. It is postulated that neotectonic faulting may have increased erosion susceptibility and thus created preferential areas of subglacial incision. No clear correlation between the orientations of tunnel valleys and elongated salt structures can be identified in this dataset. In summary, the presence and orientation of faults and salt structures do not provide reliable indicators for future tunnel-valley incision with regard to long-term safety assessments.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *tunnel valley, fault, salt structure, North German Basin, Pleistocene*

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## Hierarchische Liste der Gesteinsbegriffe der GeoSphere Austria – Standard für geologische Aufnahmen, Lithologie und Generallegende

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An der GeoSphere Austria werden geologische Standards für interne und externe Nutzung entwickelt und als Berichte im pdf-Format (<https://www.geologie.ac.at/services/standards>) und online im Thesaurus (<https://thesaurus.geolba.ac.at/>) veröffentlicht. Neben der hier präsentierten Liste für Gesteine stehen dort die definierten Begriffe für Quartär und Massenbewegungen sowie für Strukturen zur Verfügung. Die Entwicklung der Standards und deren Publikation wurde durch die Entwicklung eines Workflows und spezieller Computerwerkzeuge unterstützt. Diese erlauben eine automatisierte Bearbeitung und Übertragung von Definitionen in eine Datenbank und den entsprechenden Bericht.

Mit dem verbreiteten Bedarf an Gesteinsbegriffen entwickelten sich an der ehemaligen Geologischen Bundesanstalt unterschiedliche Listen für spezifische Applikationen. Dabei waren nicht nur die jeweils inkludierten Gesteinsbegriffe an sich in Schreibweise und Definition variabel, die Listen waren je nach Applikation in Umfang und Aufbau verschieden. Der neue Standard an Gesteinsbegriffen erfüllt mehrere Bedingungen. Die Liste selbst ist monohierarchisch gegliedert und basiert auf zweisprachigen (Deutsch, Englisch) Definitionen und Referenzen. Die Gliederung und die Begriffsdefinitionen folgen dabei den Empfehlungen der International Union of Geological Sciences (IUGS) (Le Maitre et al., 2005; Fettes & Desmons, 2007) und sind auf das INSPIRE-Datenmodell abbildbar.

Den Vorgaben der IUGS zufolge wird in der obersten Hierarchiestufe nach der Genese in Magmatisches (133 Begriffe), Sedimentäres (158 Begriffe) und Polygenetisches (143 Begriffe) Material gegliedert. Diese Gruppen werden angepasst an die Vielfalt der Gesteine untergliedert, also vornehmlich entsprechend der Verfestigung und anderer gesteinsbildender Prozesse sowie orientiert an mineralogischer und chemischer Zusammensetzung, Korngröße und weiterer dazu anwendbarer Merkmale. Bei den Definitionen der Gesteinsbegriffe waren sichtbare Gesteinsmerkmale prioritär, um die praktische Anwendung im Gelände, speziell bei der geologischen Kartierung, zu erleichtern. Bei der Auswahl der Begriffe war einerseits die bisherige Verwendung in Legenden von geologischen Karten und Datensätzen und andererseits der Bedarf an Gesteinsbegriffen für die Darstellung der Geologie Österreichs maßgeblich.

Ein definierter Gesteinsbegriff bildet das Kernelement jeder lithologischen Beschreibung. Präfixe können die Gesteinsbegriffe hinsichtlich einer Mineral- oder Fossilführung sowie der Zusammensetzung weiter spezifizieren (z.B. Granat-Glimmerschiefer). Durch vielfältige Attribute, wie beispielsweise zu Korngröße, Farbindex oder Deformationsgrad oder -art, wird der Gesteinsbegriff schließlich zum Begriff der Lithologie erweitert (Granat-Glimmerschiefer, feinkörnig, biotitführend). In diesem Sinne ist Lithologie die Beschreibung von Gesteinen auf Basis ihrer charakteristischen Merkmale, vorrangig ihrer Zusammensetzung und Textur. Entsprechend der internen Vorgaben der GeoSphere Austria muss daher jeder Legendeneintrag einer geologischen Karte oder in Datenmodellen zumindest einen definierten Gesteinsbegriff beinhalten.

Zur unmittelbaren Anwendung kommt die hier präsentierte Gesteinsliste in dem seit Jänner 2024 laufenden Projekt „EAGLe“ (Erstellung der Allgemeinen Geologischen Legende) der GeoSphere Austria, wo aus verschiedenen Datenquellen im Maßstab 1:50.000 beziehungsweise 1:25.000 mit unterschiedlicher Datenstruktur und blattspezifischen Legenden (GK50-Datensatz, Geofast-Datensatz, Gebietskarten, analoge Karten) die erste Version eines österreichweiten Gesamtdatensatzes mit einheitlicher Datenstruktur und vereinheitlichter Lithostratigraphie entstehen soll. Für dieses Projekt

sind einheitliche Auswahllisten, am besten basierend auf Standards, beispielsweise für Strukturen und Gesteine (wie hier präsentiert), ein wichtiger Aspekt.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Gesteinsbegriffe, Standard, Geologische Landesaufnahme*



## Low-temperature thermochronology and vitrinite reflectance data reveal long-wavelength exhumation of the Molasse basin

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The processes driving the late-stage evolution of the Alps and in particular the influence of mantle-driven processes remain uncertain. Since the Molasse basin shows uplift and exhumation since the Miocene, it can help to constrain exhumation processes, which may at least partly be associated with mantle processes. However, until now, thermochronological data to constrain exhumation is mostly available from the western part of the basin (e.g. Mock et al. 2020; Hagke et al. 2015; Hagke et al. 2012). Here, >900 m of stratigraphic succession has been removed. The driver of this exhumation is still debated: Tectonic shortening, increased erosion due to river capture or climate-change and the resulting isostatic rebound, or mantle related processes. Additional data covering larger parts of the basin that have not been affected by tectonic shortening of the external Jura Mountains could help to better understand the processes causing this exhumation.

To better quantify the wavelength and timing of exhumation, a new apatite (U-Th)/He data set from surface outcrops of the German Molasse was generated in this study and complemented with a compilation of already existing vitrinite reflectance data spanning the entire basin. The new apatite (U-Th)/He ages in the unfolded part of the basin (Foreland Molasse) are mostly older than their respective stratigraphic age. This means, they were not buried below the Apatite partial retention zone (=PRZ =40-75°C) and therefore show that exhumation is smaller than ~1.5 km. In the folded and thrust part of the basin (Subalpine Molasse), apatite (U-Th)/He ages are partially reset showing that they witnessed exhumation below the PRZ with a strong peak at approximately 20 Ma. This timing coincides with the proposed formation of a slab window in the Eastern Alps. Vitrinite reflectance data reveal a trend of exhumation increasing gradually from east to west across the entire basin. Therefore, exhumation in the west cannot be solely related to Jura thrusting. Although the Subalpine Molasse shows evidence of localized exhumation driven by thrusting, on the large scale, a longwave exhumation pattern with a spatial scale of over 700 km and exhumation exceeding 1000 m is suggested by earlier work (Frings et al. 2022; Cederbom et al. 2011; Mazurek et al. 2006). With the new data set, the magnitude, timing and spatial distribution are constrained in more detail. The derived exhumation pattern of the Molasse basin (high in the West and low in the East) coincides with the extent of the down-going European slab beneath the Alps, as mapped in recent tomographic images (Handy et al. 2021; Paffrath et al. 2021; Kästle et al. 2020). These maps interpret that the European slab is still-attached to the European lithosphere in the Western and Central Alps, semi-attached in the eastern Central Alps and detached in the Eastern Alps. However, a causal relationship is not evident since we would assume higher exhumation in areas where a lithospheric slab is detached. Hence, in this poster the new data set is presented and an outlook with open questions and future work is given.

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**Session:** Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)

**Keywords:** Molasse, exhumation, Thermochron, mantle processes

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## 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. This dust transport is not just a recent process but has been going on for hundreds of thousands of years with changing intensities. The availability of dust depends mainly on the vegetation cover in the source areas and is therefore a function of changing climate. 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. The reddish silty layers are what we call paleo surfaces and they are heavily influenced by dust imprint from the northern African continent. The aim of our research project is hence to conduct detailed analyses on those layers to reconstruct the 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?

Besides extensive fieldwork we plan to realise a variety of laboratory analyses, for example luminescence dating, (grain size specific) XRF- and XRD-analysis, micromorphology and isotopic analysis. With this, we hope to contribute to the understanding of the large-scale development in the Western Mediterranean region and on the Canary Islands during the last glacial.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Drylands, Aeolianites, Stratigraphy, Saharan dust

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## A composite geochemical record based on X-ray fluorescence scanning and radiocarbon dating for the Upper Palaeolithic site Kammern-Grubgraben (Austria)

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The Kammern-Grubgraben site is among the few early Epigravettian sites in Central Europe. It is located in a vineyard in Lower Austria, 12 km north-east of the town of Krems. The main archaeological horizons, AH 1 and AH 2, of Kammern-Grubgraben occur in loess-palaeosol sequences and have been dated to 22.6-22.3 ka cal BP (AH 1) and 23.3-22.4 ka cal BP (AH 2), respectively, with several radiocarbon dates from bone collagen. Previous luminescence dating provided additional but rather imprecise data for sediment above and below the archaeological horizons.

As part of an interdisciplinary German-Austrian research project, we tested the possibility of matching archaeological profiles and adjacent drill cores using semi-quantitative element data obtained by X-ray fluorescence (XRF) core scanning. In addition, different materials were tested for radiocarbon dating depending on their availability. However, only charcoal and gastropods provided reliable results, whereas rhizoconcretions and humic acids were unsuitable for dating. The overall aim of this part of the project was to produce a well-dated composite profile, where the archaeological horizons are embedded in a wider palaeoclimatic context.

Eight loess profiles (total length: 13 m) were sampled with steel U-profiles. Since the loess sequences in the excavation area are truncated by sediment removal for terracing due to viticulture, two percussion cores (6.5 and 7.5 m long) were drilled approximately 30 m northwest of the archaeological excavation site, in a higher terrace where sediment was accumulated onto the former surface. The element counts from XRF scanning of all records were standardized using the centred log-ratio transformation to reconcile the geochemical records. Prior to this, only those elements with reproducible results were selected, i.e. Si, K, Ca, Ti and Fe. Wiggle matching of geochemical records was supported by archaeological tie points and seven additional radiocarbon dates from gastropods and charcoal. The Ca content is considered as the most significant indicator of palaeoclimatic changes, with the lowest (highest) values during interstadial (stadial) conditions due to more (less) weathering and leaching. Overall, our study documents that XRF scanning data are useful for aligning loess-palaeosol records in an archaeological context.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** loess-paleosol sequences, Palaeolithic, Last Glacial Maximum, archaeological horizons, geochemistry

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## Quantifying surface elevations in deep time through stable isotope paleoaltimetry

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Reconstructing the elevation of mountain ranges in the geological past is crucial for understanding the drivers of mountain building, as well as interactions of topography with the hydrosphere and biosphere. Mountain building results in regional climatic changes, including cooling and changes in wind speed and direction. Simultaneously, mountain building affects regional biodiversity through climate change and landscape differentiation.

Stable isotope paleoaltimetry allows for the quantification of surface elevations in deep time. The method is based on the systematic inverse relationship between the stable isotopic composition ( $\delta D$ ,  $\delta^{18}O$ ) of meteoric waters and elevation. The method highly benefits from contrasting the isotopic composition of minerals that incorporated meteoric waters from low- and high-elevation sites. Such minerals may include e.g. lake or authigenic soil carbonates that formed in foreland and intra-montane basins or hydrous minerals from detachment and fault zones. However, incorporation of soil/lake water into pedogenic/lake carbonates and hence setting its  $\delta^{18}O$  values depends both on temperature and water oxygen isotope composition. We therefore couple results of  $\delta^{18}O$  measurements with clumped isotope paleothermometry ( $\Delta_{47}$ ) to determine both carbonate formation temperatures and the  $\delta^{18}O$  values of soil and lake water. This approach refines the estimation of past elevations reconstructed from bulk isotope measurements exclusively.

Here, we show examples of paleoelevation reconstructions of the European Alps and the Anatolian plateau (Turkey) since the Miocene. Results from the Alps support the theory that surface uplift in the Central Alps predates that of the surface uplift in the (far) Eastern Alps. In Anatolia, surface uplift of the plateau occurred rapidly during the latest Miocene – possibly in response to removal of lithospheric mantle - and affected regional large mammal overturn on the plateau, as well as its margins.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *stable isotope paleoaltimetry, clumped isotope paleothermometry, proxy data, Miocene-Holocene, Alps, Anatolia, regional biodiversity*

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## Heterogener und tiefer als zuvor bekannt – aktueller Stand der Neumodellierung der Quartärbasis in Niedersachsen (Norddeutschland)

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Die Geologie Niedersachsens ist sehr stark geprägt durch Ablagerungen des Quartärs. Die Basis der quartären Ablagerungen wurde während der Kaltzeiten durch hochenergetische Prozesse beeinflusst. Insbesondere während der Elster-Kaltzeit wurden Rinnen in den präquartären Untergrund erodiert, die bis in Tiefen von 400 m u. NHN reichen (Kuster & Meyer, 1979).

Die Erarbeitung eines neuen 3D-Modells der Quartärbasisfläche ist aus mehrfacher Hinsicht von hohem Interesse. Die quartären Lockersedimente sind für die Rohstoffgewinnung und die Wasserwirtschaft von großer Bedeutung. Darüber hinaus kann die Tiefenlage der Quartärbasis einen Anhaltspunkt für die Prognose der Erosionstiefe möglicher zukünftiger Vereisungen darstellen, z.B. im Rahmen der Suche nach einem Endlager für radioaktive Abfälle.

Für die Modellierung werden alle im LBEG verfügbaren Daten genutzt, wie der Isolinienplan der Quartärbasis im Maßstab 1:500.000 (Kuster & Meyer, 1995), Bohrungen der Bohrdatenbank Niedersachsen inklusive Bohrlochmessungen und Datierungen, geologische Profilschnitte und kleinräumige 3D-Lockergesteinsmodelle. Insbesondere die Einbeziehung der am LBEG vorliegenden 2D- und 3D-Seismik, die vorwiegend aus der privatwirtschaftlichen Erkundung auf Kohlenwasserstoffe stammt, liefert wertvolle Informationen für die Quartärbasis, die in früheren Arbeiten noch nicht so stark beachtet worden sind.

Die geologische Modellierung der Quartärbasis erfolgt mit Aspen SKUA™ (AspenTech). Alle Eingangsdaten müssen zunächst zeit- und arbeitsintensiv aufbereitet und geologisch bewertet werden, bevor sie für die Modellierung verwendet werden können. Die Kartierung von Rinnengeometrien in der 2D- und 3D-Seismik, die sich als Erosionsformen in den präquartären Untergrund einschneiden, erfolgt im Zusammenspiel mit allen weiteren vorhandenen Daten. Der weit überwiegende Anteil der reflexionsseismischen Daten liegt in der Zeit-Domäne vor. Die Zeit-Tiefen-Konvertierung der darauf basierenden Interpretationen wird mit einem einfachen konstanten Geschwindigkeitsansatz durchgeführt.

Die bisherigen Ergebnisse der Neubearbeitung (ca. 4000 km<sup>2</sup>) zeigen deutliche Unterschiede zur bestehenden Quartärbasis von Kuster & Meyer (1995). Der Großteil der bereits bei Kuster & Meyer (1995) postulierten Rinnen konnte verifiziert werden. Die Komplexität der Rinnen hat im Detail aber stark zugenommen. Abweichungen in der Tiefe von bis zu 250 m wurden nachgewiesen. Die Geometrie der Rinnen (z. B. räumlicher Verlauf, interne Erosionsstrukturen, Rinnenflanken) konnte in vielen Fällen deutlich besser aufgelöst werden. Allerdings haben sich auch wesentliche Änderungen zur bestehenden Datengrundlage ergeben. So konnten einige Rinnenverläufe nicht bestätigt werden und neue Rinnen wurden kartiert. Die Änderungen beziehen sich dabei nicht nur auf die Rinnen, auch die Morphologie der Hochflächen konnte verfeinert und aktualisiert werden.

Insgesamt gewinnt die neu modellierte Quartärbasisfläche durch die Einarbeitung einer sehr umfangreichen Datenbasis an Detailgrad, Belastbarkeit und Aktualität.

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*Kuster, H.; Meyer, K.-D. (1995): Karte der Lage der Quartärbasis in Niedersachsen und Bremen, 1:500.000; Hannover.*

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *regionale Geologie Norddeutschland, Quartärbasis, seismische Datenauswertung, 3D-Modellierung*

Melcher, Frank

## The Critical Raw Materials Act: what does it mean for domestic production?

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One of the most important objectives of the Critical Raw Materials Act (CRMA) is to reduce the EU's dependence on third countries for supplies of critical and strategic raw materials. A quota of 10% relative to the demand is required for mine production in EU member states in 2030. To determine the future demand for raw materials, the Joint Research Centre (JRC) has developed demand scenarios for 5 strategic sectors and 15 technologies. The sectors are: renewable energy, E-mobility, energy-intensive industry, ICT (information, communication and digital technologies), aerospace and defence. Although the 15 strategic technologies will likely grow more than others, their current share of the production is surprisingly low for most raw materials. The ratio between the demand of a given raw material for strategic technologies in 2020 was calculated relative to the 2020 production. Sixteen raw materials have shares greater than 5%, led by tellurium and terbium with up to 88%. For a number of important materials, the share needed by strategic technologies was quite low in 2020: copper 3.6%, steel 1.2%, aluminium 0.6%, phosphorous 0.4%, concrete 0.15%, iron 0.13%. However, for cobalt, lithium, nickel and graphite, a very high future demand is predicted. An increasing demand can partly be compensated by savings in other sectors with less demand. The development of these "other sectors" (e.g. chemical industries, construction, infrastructure, steel production) in the future has not been taken into account in the JRC report. JRC calculated the demand for raw materials used in the 15 strategic technologies using a low- and a high-demand scenario. In the low-demand scenario, highest growth rates are expected for phosphorus, zirconium, fluorspar, graphite, lithium, nickel, cobalt, ruthenium, and platinum. In the high-demand scenario, extreme growth rates are postulated for germanium, phosphorus, fluorspar, graphite, lithium, platinum, zirconium, and yttrium. The demand for lithium in strategic technologies in 2050 will be 14 to 19 times higher than the global production in 2020, that of graphite 7 to 9 times, and of cobalt 4 to 5 times.

According to the World Mining Data, production of critical and strategic raw materials in EU member states in 2022 reached the following shares of the world production: <1% for cobalt, manganese, tantalum, bauxite, lithium, tin, PGE, graphite, phosphates; 1-5% for nickel, chromium, tungsten, copper, indium, lead, zinc, and fluorspar. There was no EU production of magnesium, borates, niobium, titanium, vanadium, gallium, germanium, rare earth elements, and zircon. However, demand is estimated in the range of 15-25% of the world for most commodities. Assuming demand of 20% for each raw material, current production would only suffice for Cu to fulfil the 10% benchmark.

Therefore, EU member states need to provide strategies to increase domestic production of mineral raw materials. Resources exist for most of the critical and strategic materials; however, the decline in exploration activities within the past 40 years has meant that economically recoverable reserves for many raw materials are not known. This, together with the widespread lack of social acceptance and political support, will make it difficult to reach the 10% target of the CRMA.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Critical Raw Materials*

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## Ein GIS basiertes Dokumentations- und Kommunikationstool für Gemeinden im Katastrophenfall

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In der ersten Augustwoche 2023 zog ein Tiefdruckgebiet von Norditalien nach Osteuropa (Tief Zacharias) und führte im Bereich der Alpensüd- und Alpennordseite in kurzer Zeit zu großen Regenmengen. Hunderte von gravitativen Massenbewegungen wurden in einigen Gemeinden in Kärnten (Österreich) im Zuge dieses viertägigen Starkniederschlagsereignisses ausgelöst. Diesem extremen Niederschlagsereignis war eine mehrwöchige Regenperiode vorausgegangen, die zu einer starken Durchnässung des Bodens führte. Die monatlichen Durchschnittsniederschläge waren um 50 bis 200 % höher als in den 60 Jahren zuvor. Neben Überschwemmungen und Muren dominierten Rutschungen und Hangmuren, die zum Teil erhebliche Schäden verursachten.

Die Zunahme extremer Wetterereignisse infolge des Klimawandels stellt Gemeinden vor wachsende Herausforderungen. Häufigere und intensive Hochwasser sowie gravitative Massenbewegungen führen zu erheblichen Schäden an Infrastrukturen und Umwelt. Anhand der Erfahrungen aus der Unwetterkatastrophe August 2023 in Kärnten (Österreich) wurden Erkenntnisse in Zusammenarbeit mit den betroffenen Gemeinden zusammengefasst. Diese Erfahrungen flossen in die Entwicklung einer benutzerfreundlichen Web- Applikation für die Meldung von Naturereignisse/Prozesse und Schäden ein.

Die Web.- Applikation ermöglicht den Gemeinden eine Erfassung betroffene Gebiete und Schäden und eine rasche Meldung an die Behörden. Durch die Integration von GIS-Technologien können Schadensorte auf Karten visualisiert und in Echtzeit aktualisiert werden. Im Unterschied zu traditionellen GIS-Systemen (z.B. ArcGIS, QGIS) ist die Web- App nicht nur GIS Spezialisten vorbehalten und erlaubt die Mehrfachnutzung von Daten mittels unterschiedlicher Geräten (Computer, Tablet oder Handy). Durch die standardisierte Erfassung und die zentrale Verwaltung der Informationen wird die Kommunikation erheblich vereinfacht.

Die Web- App erleichtert somit auch die Zusammenarbeit zwischen verschiedenen Behörden und bietet eine zentrale Plattform für die Koordination von Hilfsmaßnahmen im Katastrophenfall, was letztlich zur Minimierung von Schäden und zur besseren Unterstützung der betroffenen Bevölkerung beiträgt. Die GIS-Daten und Metadaten der jeweiligen Katastrophe können zeitextensiv jederzeit den Landesregierungen und den Bundeseinrichtung zur Verfügung gestellt werden.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Klimawandel, Extremwetterereignisse, Naturkatastrophe, GIS Web.-App, Ereignisdokumentation*



## Holocene mollusc faunas in a northern German lowland river system of the Baltic Sea region (Peene River, Mecklenburg-Western Pomerania)

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Despite the numerous Holocene deposits of northern Germany, e.g., lake sediments or calcareous fen formations, hardly any coherent sequences are known that also reflect the development of the molluscs in relation to the diverse climate and landscape history. One exception is the Holocene sequence of Meschendorf (Mecklenburg), for example, with an almost complete profile series from the Preboreal to the Subatlantic, whose species-rich terrestrial faunas reflect the Holocene landscape development very detailed (Hensel et al., 2022).

With the new study on depositional sequences in the lower Peene River area, the Holocene faunal development in a river system can now be examined in more detail for the first time.

The Peene River in NE Germany (Mecklenburg-Western Pomerania) is a typical coastal river with no connection to a larger river system. After about 180 km, the Peene flows into the Baltic Sea near Anklam via the so-called Peenestrom. The Peene valley itself forms one of the largest contiguous lowland peatlands in Central Europe.

In 2007, several liner boreholes were drilled at the crossing of the Peene valley near Stolpe village for the engineering geological exploration of the OPAL natural gas pipeline construction. The borehole (Ig Stp 8/007) was drilled directly in the present-day Peene River course. In addition to limnic-fluviatile Eemian sequence (MIS-5a) at a depth of 23-25 m and Weichselian glacial deposits (MIS-2) (Meng et al., 2009), a 10 m thick Holocene sequence was recorded. The Holocene sediments are predominantly fine-grained, often organic muds, and contain only some sand and gravel layers in the lower part. The current overlying water column of the Peene at the drilling point is about 2 m. The section ranges from the Preboreal/Boreal transition to the Atlantic, Subboreal and older Subatlantic. The younger Subatlantic is obviously disturbed. The dating based on pollen stratigraphic investigations (Strahl, 2009) and additional <sup>14</sup>C dating of molluscs (unpubl.).

A total of over 50 freshwater mollusc species (Bivalvia, Gastropoda) were found in the Holocene sediments of the Peene River system. Terrestrial elements were almost completely absent.

The surprising result is that the limnic-fluviatile faunas in the Peene area were relatively stable during the whole Holocene and were apparently hardly influenced by climatic and landscape developments, which clearly contradicts the development of terrestrial mollusc faunas, e.g., from Meschendorf (see Hensel et al., 2022). The Eemian faunas of the Peene are also already comparable to the modern faunas of the Holocene, but differ significantly from the still conservative fluvial faunas of Holsteinian (Meng et al., 2009).

Despite the short distance from Stolpe to the Baltic Sea coast and the low elevation, today only slightly above 0 m above sea level, no marine/brackish influences could be detected for the Holocene development of the Peene by molluscs.

The Holocene faunas are also relevant to nature conservation, as they also allow a clear reference and comparison to the recent faunas of the Peene. The focus is on the following questions: Which mollusc species have recently become rare due to anthropogenic influences or what are neozoa and which species have only recently immigrated (Zettler, 1998) or are there species that have been misinterpreted in this context?

*Hensel, R., Janke, W., Meng, S. & Lorenz, S. (2022): Stratigraphie und Genese eines karbonatreichen Beckenprofils am Kliff von Meschendorf (Ostsee, Nordwestmecklenburg). – Brandenburger Geowissenschaftliche Beiträge, 28 (1/2): 97-124.*

Meng, S., Börner, A., Strahl, J. & Thieke, H.-U. (2009): Bio- and lithostratigraphical investigations of Eemian fluviolimnic sediments and tills from the lower Peene-valley (NE-Germany). – *Polish Geological Institute Special Paper*, 25: 37-48.

Strahl, J. (2009): Bericht zur pollenanalytischen Bearbeitung der Bohrungen Ig StpWo 6/007, 8/007 und 9/007, Peenetalquerung OPAL-Trasse, Land Mecklenburg-Vorpommern. - Bericht LBGR, 21 pp., Kleinmachnow (unpubl. report).

Zettler, L.M. (1998): Die Wassermollusken im Einzugsgebiet der Peene (Nordostdeutschland). – *Malakologische Abhandlungen*, Band 19, Nr. 13: 127-138.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Quaternary palaeontology, molluscs, Holocene, river, NE Germany

Moser, Bernd

## „Es sind die G'schichten, Herr Professor...“ – Erfahrungen und Erkenntnisse aus 22 Jahren Edelsteinkunde-Unterricht im Fachbereich „Schmuck Metall Design“ an der HTL Ortweinschule Graz.

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Normalerweise wird Edelsteinkunde an den wenigen Fach-HTLs in Österreich von Juwelier\*innen bzw. Goldschmied\*innen unterrichtet. Da ist ein naturwissenschaftlich ausgebildeter Fachmineraloge mit künstlerischer Schlagseite ein eher seltenes Unikum.

Aber die dadurch mögliche Kombination von scheinbar konträren Wissens-/Interessens-Gebieten eröffnet für die Schüler\*innen auch völlig neue bzw. ungewohnte Denk-Ansätze bei der Auswahl von (Stein)Materialien bzw. bei der Gestaltung von Schmuckstücken.

Der „Luxus“ in diesem speziellen Fall liegt einerseits in der relativ geringen Zahl von Schüler\*innen – nämlich vier bis elf Personen pro Jahrgang – und andererseits in der üppig zur Verfügung stehenden Zeit von 2,5 Schuljahren, in denen man sich eingehend mit einem speziellen Wissensgebiet innerhalb der Mineralogie – nämlich der Gemmologie – befassen kann. Die Tatsache, dass es sich bei der HTL Ortweinschule um eine BHS mit sehr spezifischen Fachabteilungen handelt, geht aber einher mit der allgemeinen Problematik, bei Schüler\*innen welche Interessen auch immer zu wecken. Dabei konnte die Erfahrung gewonnen werden, dass die Vernetzung von mineralogischen „hard facts“ mit kunstgeschichtlichen, aber auch technisch-industriellen Informationen und oft launigen Background-Stories, mit dem tatsächlichen Be-Greifen von Materialien in roher und verarbeiteter Form, Museumsbesuchen und – wenn möglich – Sammelexkursionen im Gelände die zündende Mischung sein kann. Die Realität der geringen Schüler\*innenzahl erleichtert die Verwirklichung einer solchen Vernetzung natürlich.

Ein anderer Aspekt ist offenbar noch die Begeisterung, mit der man mit dem Lehrstoff an die Auszubildenden herantritt. Eine Rückmeldung zu diesem Thema seitens der Schüler\*innen an die Lehrperson ist wahrscheinlich eher selten. Deswegen erstaunen vorerst diesbezügliche Äußerungen, geben aber wichtige Aufschlüsse zur Wichtigkeit solcher Faktoren bei der Vermittlungsarbeit. Als Geowissenschaftler hat man natürlich den Vorteil, aus einem breiten Wissens- und Erfahrungspool schöpfen zu können, aber die Reaktionen aus dem Klassenzimmer weisen darauf hin, dass „Stoffsicherheit“ ein latent wichtiger Faktor ist, wenn es um die mitschwingende Begeisterung bei der Vermittlungsarbeit geht.

Hier liegt in der Situation, die sich bei der Vermittlung von geowissenschaftlichen Inhalten im „normalen“ Biologieunterricht an einer AHS oder MS ergibt, sicherlich eine größere Diskrepanz. Nämlich in der Gegenüberstellung von Zeit-/Energieaufwand einer Lehrkraft zur Verinnerlichung geowissenschaftlicher Inhalte und dem höchst geringen Stundenausmaß für das Thema Geowissenschaften im Unterricht.

Eine Diskussion über neue Möglichkeiten und Ansätze bei der Vernetzung von geowissenschaftlichen und „anderen“ Inhalten im AHS-Unterricht sowie über unterschiedliche Faktoren zur Interessens-Weckung sollte zumindest einmal (erneut?) geführt werden – unabhängig von derzeit festgeschriebenen inhaltlichen und zeitlichen Vorgaben im Regel-Lehrplan.

**Session:** Lehrendenworkshop

**Keywords:** Edelsteinkunde, Schmuck

Mrdak, Milica<sup>1</sup>; Wegerer, Eva<sup>2</sup>; Gawlick, Hans-Jürgen<sup>2</sup>

## Enigmatic traces of volcanism in the Rhaetian of a far-travelled Late Triassic Hallstatt nappe in northern Montenegro

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In northern Montenegro on the road east of Gradac in direction to Šula a more than 120 m thick overturned Late Triassic succession of bedded Early Norian to Rhaetian siliceous hemipelagic limestones is exposed above Early Norian fore-reef Dachstein limestones. This section is part of a far-travelled nappe stack deriving from the stacked and overridden Hallstatt shelf by obducting Neo-Tethys ophiolites. The Hallstatt nappes in northern Montenegro were bulldozed in Middle-Late Jurassic times by the ophiolites to the west and rest today as outliers on top of the East Bosnian-Durmitor megaunit (Outer Dinarides).

The section starts with a roughly 20 m-thick reef to fore-reef limestone succession with deep-water matrix in the upper part (Lacian 2 in age according to conodonts). Near the base the reef limestone is thick bedded to massive, higher up in the section variously bedded. We consider these fore-reef limestones as part of the Dachstein Reef Limestone, interestingly with a deepening upward sequence from the middle Lower Norian onwards. Around the Lacian 2-3 boundary the depositional characteristics changes relatively abrupt. The upsection following 30 m-thick dm-bedded grey-reddish limestones contain chert nodules and layers. Conodont dating shows that the age of this part of the section is Lacian 3 to Alaunian 3 in the upper part. The higher Alaunian 3 to Sevatian is characterized by a thick series of slump deposits with carbonate turbidite intercalations. In these slumps, mainly grey siliceous thin-bedded limestones of the higher Alaunian, appear polymictic breccias (debris flows) and turbiditic microbreccias with older (Lacian and Alaunian) hemipelagic components. The overlying dm-bedded grey-reddish siliceous limestones with red chert nodules are of Rhaetian age dated with the appearance of *Misikella posthernsteini*. In these reddish-grey limestones also slump deposits are common. The diagenetic overprint of the whole sequence is low as proven by low Conodont Colour Alteration Index (CAI) values of CAI >1.0.

In the lowermost part of the Rhaetian grey siliceous limestones above the slump horizon occur yellowish siliceous marls with a high amount of clay minerals of the mica group but also with a remarkable amount of mixed-layer clay minerals which point to deposition of most probably far-transported (wind-blown) volcanic ashes. Such volcanic ashes are so far also not proven in the ALCAPA region, where marly sediments (Zlambach marls and equivalents) replace in the Rhaetian the formation of open-marine limestones on the Hallstatt shelf. In contrast, in the Dinarides such marls are not known and deposition of siliceous limestones continues. Only deposits indicating intense tectonic motions like Mass Transport Deposits or slumpings are age equivalent in both palaeogeographic different domains. Beside the direct biostratigraphic age dating, event deposits, the deposition of volcanic ashes around the Norian/Rhaetian boundary can be an indicative lithostratigraphic marker. Intense volcanic activity is known from northern Peru or the Canadian Cordillera, where the Norian/Rhaetian boundary was dated precisely by zircons.

**Session:** Pangeo workshop: Regional Geology

**Keywords:** volcanic ashes, Rhaetian, lithostratigraphic marker

Nachtmann, Wolfgang

## Fossil Energy Sources in Light of the Energy Transition

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*“In the West, many people are of the impression that a radical shift from oil and gas (‘red meat’) to a rapid and complete phase-out of hydrocarbons (‘vegan’) is the way to go, often without differentiating between oil and natural gas at all. As we are now waking up to the realization that it is not so easy and that natural gas is the transition energy source – ‘the chicken’ – that could help bridge the gap in hydrocarbon energy supply and the demand for net zero emissions”*

(Edward Wiarda, president of EAGE). In light of this here some critical words to my topic:

Over 2 billion people worldwide, half of them in Africa, are typically cooking over open fires and basic stoves. Using charcoal, wood, agricultural waste, and animal dung as fuel, they inhale harmful toxic fumes and smoke with dire consequences for health. It is the second leading cause of premature death in Africa. Women and children account for most of the lives lost, the vast majority of them in sub-Saharan Africa. Opportunities for education, employment and independence are limited because women instead spend hours each day foraging for rudimentary fuels.

Question: shouldn't we support these underprivileged people in improving their energy-technologic standards timely by appropriate means?

Coal, petroleum, natural gas – often seen as today's 'best hated enemies' of climate and human lives – are natural products, generated from ancient biomass.

Living in an industrialized world with steady economic growth they have become basic raw materials for almost all kinds of progress mankind has made during the last two centuries. Today's technical, medical, pharmaceutical, communications or mobility and even food and cosmetic products were impossible without these fossils. We could not enjoy the comfort of living and health standards we do now and billions of people worldwide are still striving for.

2022, our growing community and economy consumed about 100 million barrels of oil per day and demand has still not reached the often discussed peak. Beyond this oil volume some 8.8 billion tons of coal and 4 trillion m<sup>3</sup> of natural gas satisfied the world market.

To reach the agreed COP15 climate targets the IEA estimates annual investment needs of USD 1.3 trillion in renewable energy sources. Between 2012 and 2022 several trillions of invested dollars in renewables reduced the fossils' share from 81 to 79 percent of the worldwide growing energy consumption.

Extremely ambitious energy transition targets require an almost total replacement of fossil energy sources by renewable ones by 2050. Is this doable? We don't know.

The public discussion often neglects the widely differing energy content of 'bad fossils' versus 'good renewables' in favor of the fossils. Running steel mills or concrete plants with energy from wind mills or PV plants is rather unrealistic, ample 'green nitrogen' a vision.

What should be a realistic target? 'Out of the fossils' may be valid for the long term. For the coming decades, global availability at competitive prices for coal, oil and gas with their high energy contents and expanding renewable energy sources need to complement each other where possible – either source has its justification and business segment. The call to minimize their ecologic footprint needs to be heard and obeyed by all!

First indications for degrowth by de-industrialization are already visible in our immediate neighborhood, merely caused by high gas prices and abnormally high subsidies for 'green power' combined with partly chic industry aversion. Climate anxious politicians and public opinion leaders should rather 'follow the science', means physics based natural laws, instead of often ideology-driven activism and emotions. Eventually, beyond energy generation, the multiple roles of fossils as valuable industrial raw materials are fundamental foundations of our wealth.

**Session:** Pangeo workshop: Mineral Raw Materials, and Energy Transition

**Keywords:** coal, oil, gas, energy transition

Neubauer, Franz<sup>1</sup>; Salcher, Bernhard<sup>1</sup>; von Hagke, Christoph<sup>1</sup>; Dunkl, István<sup>2</sup>

## Controls of the collisional architecture in an evaporite-bearing fold-thrust wedge: the central Northern Calcareous Alps

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Fold-thrust wedges are common in external sectors of orogens and include strongly imbricated thin-skinned cover strata, ramp-anticlines, and show generally a forward dip of the wedge surface and an orogen-ward base of the orogenic wedge. The shape and internal structure are controlled, e.g., by the presence of rheologically weak layers (evaporites, clay) at the basal decollement and its coupling and the flexure of the underlying lower-plate crust. To study individual contributions to these effects, we investigated the N–S Osterhorn–Werfen Imbricate zone (WIZ) section across the central Northern Calcareous Alps (NCA), which exposes a flat-lying thrust-fold wedge. The principal goals of this contribution are threefold: (1) Based on industrial reflection seismic lines calibrated by few deep wells and field work, we examine the structure of the Osterhorn–WIZ section. (2) We examine the role of uppermost Permian to Lower Triassic evaporite mélangé (Haselgebirge Fm.). (3) Finally, we propose several key stages for the tectonic evolution of the central NCA.

A dense net of reflection seismic lines (OMV AG) was investigated within a project between 2016 and 2019. From north to south, the lines allow to deduce four major sectors in the Osterhorn–WIZ section: (i) The Osterhorn Mts. are composed of the flat-lying Tirolic Osterhorn unit, which is affected by gentle km-scaled folds implying NE–SW shortening and small-scale NNW-trending normal faults due to ENE–WSW extension. In well Vordersee 1, the underlying Bajuvaric Nappe (BN) includes Paleogene and Jurassic lithologies indicating thrusting during late Paleogene. The BN is underlain by the Rhenodanubian Flysch zone, which reaches the latitude of the antiformal Strobl window in the eastern Osterhorn Mts., the reflective Subalpine Molasse, and, over wide portions, by the autochthonous Mesozoic cover on the European plutonometamorphic basement. (ii) The southern margin of the Osterhorn unit is well expressed by losing internal consistency of seismic reflections, and a faulted pattern appears with short N-dipping reflectors. Both reverse and normal faults indicate ca. top-N indentation. (iii) A W–E seismic section (Lammer valley), calibrated by well Golling Thermal 1, includes typical Tirolic strata in upper portions and is very reflective down to ca. 10 km. Small internally transparent evaporite-like lenses are rare. Consequently, uppermost reflectors could be interpreted as Rossfeld and Dachstein Fms. as the southern extension of the Tirolic Osterhorn unit. This finding implies that the Schwarzer Berg unit of the Lammer Mass can be interpreted as a tectonic nappe with Haselgebirge at its structural base. (iv) The Abtenau–St. Martin N–S section shows the transition between the N-dipping, S-vergent thrusts of the WIZ underneath the Tennengebirge to the Haselgebirge in the north. Rocks of the Tennengebirge unit never reach a subsurface level in this section. The WIZ includes small transparent lenses interpreted as evaporites here combined with surface exposures of Triassic pelagic limestones of the classical Lower Juvavic nappe. At the southern end, the N-dipping pre-Permian Graywacke zone basement is underlain by two triangular structures interpreted as indenting Lower Austroalpine and Penninic basement-cover triangle structures. These indentors and the WIZ imply late Paleogene décollement, internal shortening and surface uplift of NCA also supported by Neogene apatite (U-Th)/He ages.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Orogeny, Passive continental margin, Extension, Thrusting, Tectonic Inversion, Evaporite Tectonics*

**Neubauer, Franz**

Facies analysis in a poorly exposed siliciclastic area: the Upper Cretaceous basal Gosau Conglomerate at Gaisberg, Austria

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Facies analysis in a poorly exposed sedimentary successions hampers on outcrops, and exposed lithologies are strongly biased towards erosion-resistant lithologies, weak lithologies are often simply not mapped. Here, an example is shown, where a combination of surface exposures, digital terrain models (DTM) backed up by a well-documented abandoned coal gallery allows facies analysis of an Upper Cretaceous, virtually pure conglomerate-dominated succession. This section shows terrestrial to deltaic-lacustrine facies, among which marls dominate ca. one third of the surface area. High-resolution DTMs also allow the recognition of a high frequency, climate-controlled cyclicity of the clastic succession, and the geometry of beds allows facies interpretation. The Upper Cretaceous section was deposited above an angular unconformity after the Early Alpine orogeny. Based on the new DTM-derived data, several informal lithostratigraphic units can be distinguished from base to top: (1) In the south, the basal coarse-grained reddish conglomerate lithofacies with reddish coated clasts represents the infilling of a valley. (2) On its northern lateral extension, the basal grayish conglomerate lithofacies is exposed with lens-shaped conglomerate ridges indicating ca. east-to-west sedimentary transport. This lithofacies represents a lateral equivalent to or is younger than the basal coarse red conglomerate lithofacies in the south. (3) In the south, the basal coarse red conglomerate lithofacies is followed by the reddish conglomerate-sandstone lithofacies with its alternation of conglomerate with reddish silt- and sandstones, and yellowish siltstones indicating a flat valley floor. (4) In the eastern part, above the basal grayish conglomerate lithofacies, a regular four layer-conglomerate ridge unit is exposed with a remarkable long lateral continuity interpreted to represent a lake shore facies. (5) Above, grayish siltstone and marl are following, defined here as the grayish marl lithofacies, for which the formal term Felberbach Marl Fm. is here introduced. It covers a wide area and is obviously more than 100 m thick and potentially contains, near the base, reddish marls, too, which grade laterally into the reddish conglomerate-sandstone lithofacies (3). (6) The grayish conglomerate unit overlying the grayish marl unit is here formally defined as Aigen Conglomerate Fm. and include also separate, decametric thick marl members.

DTM-based lithofacies units (1) to (4) corresponds to the classical Kreuzgraben Fm., and (5) and (6) likely correlate with the Streiteck Fm. as defined by Wagreich & Faupl (1994, *Palaeogeography, Palaeoclimatology, Palaeoecology* 110, 235–254).

Four groups of clasts can be identified in these six lithofacies units, all are typical for the Northern Calcareous Alps. (1) Various types of cherts, (2) a large variety of Upper Triassic and Jurassic limestones and rare dolomites, (3) rare greenish to grayish Lower Cretaceous sandstones, and (4) a small group of intraformational clasts, interpreted as clasts of likely Late Cretaceous age. Together, they constrain erosion down to Upper Triassic levels, and strong enrichment of erosion-resistant cherts. Interesting is also the low amount of dolomite clasts due to chemical weathering. No exotic clasts were found. This implies short valleys and no connection to the Austroalpine basement exposed in Central Alps.

In summary, the application of high-resolution DTMs is an easy tool for mapping of clastic succession in the case that few outcrops support the lithological and facies interpretations.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Gosau basin, facies analysis, remote sensing, Northern Calcareous Alps, Digital Terrain Model*

Neubauer, Franz

## Tectonic models for the Austroalpine structure in Eastern Alps: nomenclature matters

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Current structural models of the Austroalpine nappe complex (ANC) need significant revision, and a new one will be proposed. The ANC is a mostly continental basement-cover nappe complex, which is separated from the Southalpine unit by the Periadriatic fault. Both are part of the Adriatic microplate representing a similar Triassic-Jurassic passive margin. In a high structural level within the Northern Calcareous Alps (NCA), the ANC also includes remnants of the Ladinian-Jurassic (oceanic) suture-like Meliata basin representing the slope-basin facies to the Middle-Upper Triassic shallow water successions. Many models were proposed for the ANC based on a few principles including (1) the presence of Permian-Triassic cover between pre-Alpine basement units, (2) the assignment to distinct Middle-Upper Triassic paleogeographic domains explaining the transition of shallow water to pelagic sediments, (3) the degree of Cretaceous metamorphism associated with top-NW and subordinate top-N ductile shear, particularly the presence of early Late Cretaceous-aged eclogites (UHP/HP unit) in Central Alps testifying intracontinental subduction, and (4) the need of putting all structural and lithostratigraphic units into a GIS for getting an internally consistent map. Among others, major challenges to present models include: (1) the non-correlation of the uppermost nappes (Noric-Tirolic, Graz Paleozoic, Gurktal nappes & Drauzug) by eliminating the former Middle Austroalpine unit, (2) the disputed relationships between the basal incomplete NCA cover nappes with metamorphosed basement-cover nappes with decapitated sections in Central Alps, (3) the different application of lithostratigraphic vs. structural nomenclature, (4) the correlation of units underneath and above the UHP/HP unit, (5) the potential role of postulated Jurassic-Cretaceous transform faults, which, e.g., brought the Drauzug into its current position, (6) the role of mostly Mid-Late Triassic to Cenozoic evaporite tectonics, and (7) the role of Late Cretaceous-Paleogene Gosau basins (syn-orogenic compressional vs. extensional/collapse). A great advance was the clarification of degree and timing of the Cretaceous metamorphism ranging from very low-grade/greenschist in uppermost units to eclogite facies in middle levels to greenschist facies in lowermost units. The timing of metamorphism ranges from ca. 120 Ma to 78 Ma with a clear trend of downward decreasing ages in distinct structural units testifying overall footwall propagation and in-sequence thrusting. The age range of metamorphism also implies that Lower Cretaceous Rossfeld turbidites in NCA are synchronous with ductile deformation in uppermost ANC units. Late Cretaceous Gosau basins, all deposited in uppermost structural units, postdate metamorphism and are synchronous with synmetamorphic nappe stacking of deepest structural units (Lower Austroalpine) and exhumation of the HP/UHP wedge in the middle part. In Central Alps, Gosau basins were deposited in a (trans-)extensional setting following Early Cretaceous nappe stacking, folding and an erosional phase down up to the Middle Triassic Wetterstein Fm. The Lower Gosau Group deposition was associated with a huge (>340 km) E-directed detachment system reactivating the former earliest Late Cretaceous thrust planes at the base of the uppermost structural units. In contrast, northwestern NCA Gosau-type basins are syncompressional and correlate with Lower Austroalpine thrusting. Consequently, there is no need to assume that Penninic subduction started earlier than Santonian.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Eo-Alpine orogeny, thick-skinned tectonics, footwall propagation thrusting, evaporite tectonics, collapse basin, metamorphism*



Nievoll, Gabriel

## "Die unsichtbaren Schätze im Klassenzimmer: Kritische Rohstoffe für eine nachhaltige und digitale Welt"

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"Die unsichtbaren Schätze im Klassenzimmer: Kritische Rohstoffe für eine nachhaltige und digitale Welt"

Hinter jeder Batterie, hinter jedem Smartphone, hinter jedem Datenserver steckt eine unbesungene Geschichte der Geologie. Diese unsichtbaren Schätze sind kritische Rohstoffe wie Seltene Erden, Lithium und Kobalt. Sie sind die Grundpfeiler der Technologien, die unseren Alltag bestimmen, und die Triebkräfte für den Übergang zu einer nachhaltigen Wirtschaft darstellen.

Doch was wissen wir über diese Rohstoffe? Woher kommen sie?

Diese Thematik gewinnt zunehmend an Bedeutung, da wir uns inmitten eines grundlegenden Wandels hin zu einer nachhaltigen und digitalen Zukunft befinden. Die Europäische Kommission arbeitet intensiv daran, die Versorgungssicherheit Europas mit kritischen Rohstoffen zu gewährleisten und dabei ökologische sowie soziale Standards zu wahren.

Die unsichtbaren Schätze im Klassenzimmer sollen sichtbar gemacht werden. Schülern zu vermitteln, wie eng unser moderner Lebensstil mit der Geologie unseres Planeten verknüpft ist, bildet eine Grundlage. Eine Grundlage, für das Verständnis unserer Gesellschaft für die uns umgebende Welt und unsere Ressourcen, für einen verantwortungsvollen Umgang mit unserem Planeten und um die Herausforderungen der Zukunft erfolgreich zu meistern.

**Session:** *Lehrendenworkshop*

**Keywords:** *Geologie, Schule, Rohstoffe, Zukunft, Europa*

Novak, Andrej

## From seasons to centuries: activity of sedimentary processes on alpine alluvial fans (Planica Valley, NW Slovenia)

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Alluvial fans are sedimentary environments where sedimentary processes ranging from dilute water flows to dense mass flows occur. These processes are controlled by factors such as bedrock geology, morphometry of alluvial fan and its catchment, hydrology, local and regional climatic conditions, vegetation, and anthropogenic activity. Usually, but not exclusively, they are triggered by intense rainfall events. The study site of the Planica valley (NW Slovenia) is covered by several active Holocene alluvial fans, while the steep slopes are composed predominantly of Upper Triassic carbonates, with some scattered outcrops of claystone, mudstone, and marl layers. A detailed analysis of sedimentary processes documented in outcrops and on the surface of fans was performed. Analysis of sediment structure and texture was used to identify the predominant building process of the fans. Dendrogeomorphological dating of deposits enabled to produce spatio-temporal chronology of events covering the whole 20<sup>th</sup> century, while a few centuries old deposits were dated using <sup>14</sup>C dating of paleosoil. Dendrogeomorphologically dated events were linked to triggering precipitation records from a nearby meteorological station to determine the exact triggering meteorological event. Seasonal depositional activity was monitored using Unmanned Aerial Vehicle (UAV).

Based on sedimentary analysis the deposits were categorised as debris floods, fluvial deposits, sieve-lobe deposits, hyperconcentrated flows and debris flows. Majority of the fans are built by debris floods, fluvial deposits, and sieve-lobe deposits, which are typical for locations where bedrock is composed of carbonates, which do not weather into fine-grained particles (silt and clay). Debris-flood deposits are characterised by crudely stratified closed-framework sandy-gavels containing cobbles and boulders. Fluvial deposits are characterised by up to 20 centimetres thick layers of either imbricated open-framework gravels or closed-framework sandy-gravels, containing less than 1% of mud fraction. Several sieve-lobe deposits are present on the surface of fans. Sporadic and rare debris and hyperconcentrated flows occur where bedrock weathers into fine grains. Debris flows consist of massive matrix- to clast-supported muddy-sandy-gravel packages containing up to 16% of mud fraction. Hyperconcentrated flows consist of a few centimetres thick layers of sandy mud.

The oldest <sup>14</sup>C dated debris-flow event occurred in the 17<sup>th</sup> century AD. A hyperconcentrated event occurred in the 7<sup>th</sup> century AD. More than 60 debris-flood events spanning from 1897 to 2011 were dendrogeomorphologically dated with an annual precision. Precipitation records enabled to pinpoint the exact date and amount of triggering rainfall. Further on we establish the magnitude of debris flooding by comparing the number of trees affected by sedimentary processes to the return period of individual triggering meteorological events. More than 5 years of UAV monitoring depicted seasonal activity of sedimentary processes on fans which were linked to triggering precipitation events. Monitoring concluded that at least one event with over 1000 m<sup>3</sup> of sediment transport occurs annually, which is triggered by rainfalls exceeding 50 mm of precipitation in 24 hours.

The results of the multimethod research offer a reconstruction of complex alluvial fan sedimentation and erosion activities on different temporal scales, which are strongly related to the bedrock geology and triggering precipitation events.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** alluvial fans, sedimentary processes, debris floods, dendrogeomorphology, UAV

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## Holocene Coastal Dynamics in the Eastern Gulf of Thailand

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In the light of global warming and rising sea level, it is important to understand coastal sedimentary systems with their variety of processes acting on different timescales, spatial dimensions, and with different effects. The Gulf of Thailand is located on the continental shelf of the South China Sea and is an economically important and densely populated area. The present proposal represents a continuation of previous work in the eastern Gulf of Thailand that was done in close collaboration with colleagues from Bangkok. The aim of the project is to contribute to the reconstruction of the coastal evolution in the region. This is done by identifying evidence of past sea-level change, coastline movements and deciphering the role of sediment accumulation in the area between the Chantaburi and Welu estuaries. A combination of geomorphological mapping, geophysical surveying and drilling of sediment cores at selected locations is used for this purpose. The latter will be used to reconstruct sedimentary facies and optically stimulated luminescence signal of quartz, and potentially radiocarbon, will be used to place sediment deposition into a chronological frame.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Gulf of Thailand, Coastal Evolution, Sea-level Change, Coastline Movements, OSL-Dating*

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## Central European LGM temperatures revealed using an innovative luminescence approach

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Understanding and quantifying variations in past climate is paramount to our awareness of the scale and impact of current and future climate change. Especially surface air temperature reconstructions for major changes in our climate system like the Pleistocene-Holocene transition including the rapid warming and environmental adaptations following the Last Glacial Maximum (LGM) enable a better understanding of accelerated warming trends. Generally, climatic records are plenty, especially for the more recent Holocene. However, the further back in time the period of interest, the more sparsely temperature proxies are available. Especially the lack of terrestrial proxy records for past temperature leads to increased uncertainty in reconstructions of the continental temperature for times like the LGM and the following transition period.

Applying the recently developed thermoluminescence (TL) paleothermometry approach (Biswas et al., 2020), we here present first results of LGM surface air temperature reconstructions at central European study sites. The method exploits the physical principles best known from trapped charge dating, where valence electrons are released from their natural sites through ionizing radiation and then stored in lattice defect sites (traps) of quartz and feldspar crystals before being thermally released to produce luminescence.

In feldspar, trapped electrons with comparatively short lifetimes in the 200-250 °C TL glow curve range can be thermally released from their trapping sites at ambient temperatures between ~0-30 °C, making the trapped charge population of these metastable traps susceptible to surface air temperature fluctuations. The currently measured trapped charge population at known ambient temperature can thus be used to infer paleotemperatures in the form of temperature histories through inverse modelling.

Assuming past temperature variations followed fluctuations recovered from other time resolved temperature records such as the Greenland ice sheet  $\delta^{18}\text{O}$ -, speleothem-, or pollen records, these relative time-temperature series can be manipulated to fit the measured luminescence data using Bayesian modelling, depending on the study site. The best-fitting variations of the manipulated record are then extracted and combined into a “most-likely” temperature history. For the presented results,  $\delta^{18}\text{O}$  records from the Greenland ice sheet form the base of the temperature reconstruction.

We are confident that the presented central European data, together with further samples taken from study sites along a latitudinal profile from Norway to the Equator, as well as two altitudinal transects within the Rwenzori mountains (Uganda) and Mont Blanc Massif (France) will improve our understanding of Euro-African LGM continental surface air temperature and climate sensitivity.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Paleothermometry, Thermoluminescence, Last Glacial Maximum, Modelling

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## Signals of two earthquakes at Lake Altaussee (Salzkammergut, Austria)

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Assessing strong earthquake recurrence in a low seismicity region such as the Salzkammergut (North-Eastern European Alps) is difficult, due to the relatively short time span covered by instrumental and historical data. Lacustrine sedimentary records enable to investigate the various geohazards typically occurring in an inner-Alpine setting. Lake Altaussee is studied in the frame of the Walter-Munk-Project "Lake Altaussee". It is mainly fed by subaqueous karst springs and has no major subaerial river inlet and therefore it contains rather slowly-accumulating (~0.6 mm/yr) organic-rich sediments. Analysis of multibeam bathymetry, subbottom profiles and sediment cores shows two striking sedimentary event deposits which are hypothesized to be induced by earthquake shaking. (1) Around 1767-2127 yr cal BP (modelled 95% probability range) a change from organic-rich sediments to numerous intercalated clastic carbonate layers is observed at the subaqueous karst spring site. At this transition, an in-situ soft sediment deformation structure (SSDS) can be distinguished by computer tomography analysis. The identified SSDS present at ~50m water depth and unrelated to mass movement processes is a indicator for seismic shaking. Moreover, seismic shaking might have influenced the hydrogeological system, increasing upward water velocity of the karst spring or increasing the sediment load, leading to the build up of inclined sediments forming a crater rim. (2) The second event deposit occurred between 957-1196 yr cal BP (modelled 95% probability range). Subbottom profiling data and sediment cores show a megaturbidite (> 0.5-2m thick), which can be traced across the basin lake floor and a bit thinner onto large blocks which are present in the eastern part of the Lake. The blocks are up to 70 m large. The estimated impact volume of the large blocks is ~400,000 m<sup>3</sup> causing widespread deformation of basin-plain deposits, as well as developing into mass flow and turbidity currents. Specifically, the basin long core with hole A and B (~10 m apart) show a strikingly different sequence with fold structures and inclined laminations below the mass flow deposits. Moreover, radiocarbon ages in this sequence are out of order and show ages between ~8000 and ~11000 yr cal BP. The megaturbidite can be divided into a lower 'graded unit' with stacked medium and fine sand beds with varying thicknesses within the sediment cores. The upper 'homogenous unit' of the megaturbidite contains silty deposits and are interpreted to have formed under influence of seiche bottom currents, followed by suspension fallout. Numerical modeling results of a wave generated by a mass movement impacting the lake show flooding at the western shoreline with a flow depth and flow speed of 4-8 m and 6 m/s respectively. The distribution pattern of the large blocks and the internal structure of the megaturbidite likely indicate multiple large gravitational mass movements that occurred quasi-simultaneous. The Megaturbidite shows multiple sand layers ('pulses') which could be formed by turbidite amalgamation but this needs further investigation. This study provides an important step for improving the seismic hazard assessment of the North-Eastern Alps and as well as characterizing cascading effects of the two formerly-unknown earthquakes.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Lacustrine Sediments, Earthquake, Rock fall, Lake Altaussee, subaqueous spring*

## Thrusts and unconformities in tectonic maps: The Trattberg thrust and the Trattberg fault system

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We present a case study on the Jurassic-Cretaceous tectonic evolution in the Trattberg area (Salzburg, Austria), that shows the value of age-classified faults and unconformities in tectonic maps. Tectonic mapping in combination with 3D-modelling makes it possible to understand the evolution and geometric relationships of structures in this area.

The Trattberg thrust (TT) has been known for a long time (Plöchinger, 1953). The TT is located close to the southern margin of the Osterhorn unit ("Osterhorntirolikum"). The thrust has a length of 13 km, and a maximum offset of about 1,5 km measured parallel to the thrust faults. The central part of the fault features three fault splays. The TT superimposes Rhaetian shallow water limestones on Upper Jurassic deep water limestones. S-C-fabrics and occasional slickensides indicate reverse dip-slip motion. A coarse-grained syntectonic breccia was deposited at fault tips and on uplifted hanging wall units, the "Oberalmer Basiskonglomerat". These syntectonic deposits overlie a locally angular Upper Jurassic unconformity.

Upper Jurassic deep water limestones in the footwall of the TT form a footwall syncline containing growth strata. The growth wedge allows us to date activity of the TT to the Tithonian to Berriasian, however cross section geometry and differences in Jurassic facies indicate an onset of shortening and uplift during the Oxfordian.

In map view the TT merges with steep E-W faults, that display transpressive to transtensive sinistral strike-slip. In cross section, the southern block is downthrown across these faults, and normal offset is in the same range as reverse offset across the TT. In most sections, reverse faults dip shallower than normal faults. Only at Trattberg, the reverse fault was reactivated. In their footwall, the steep faults exhume the Dachstein Limestone of the Trattberg. Limestones of the Schrambach-Fm. unconformably overlie Dachstein and Upper Rhaetian limestones, in several places with a coarse basal breccia. The unconformity at the base has a Late Jurassic age in the hanging wall, but an Early Cretaceous age in the footwall of the steep faults.

Fault geometry and cross-cutting relationships on brittle faults suggest that the faults on the southern margin of the Osterhorn unit belong to one fault system, the Trattberg fault system. Strain partitioning caused separation of dip-slip thrusting/normal faulting across the northern, shallow dipping faults, and strike-slip movements across the steeper faults. E-W faults of Jurassic-Early Cretaceous age were suggested by previous authors and are part of an intracontinental transform fault system related to opening of the Penninic oceans (Sieberer & Ortner, 2022). Probably, the Trattberg fault system localized where the Triassic sedimentary cover was thin (relative to the Osterhorn unit) due to its position on the flank of a Triassic-age salt ridge (Fernandez et al., 2024). Salt inflation during Late Jurassic shortening and posterior collapse might help explain the succession of kinematic events and recycling of structures.

*Fernandez, O., et al. (2024): Int. J. Earth. Sci., 113: 245-283. <https://doi.org/10.1007/s00531-023-02377-4>*

*Plöchinger, B. (1953): Jb. Geol. Bundesanst., 96: 257-273.*

*Sieberer, A.-K. & Ortner, H. (2022): Austrian Journal of Earth Sciences, 115: 124-145. <https://doi.org/10.17738/ajes.2022.0006>*

**Session:** Pangeo workshop: Regional Geology

**Keywords:** transpression, growth strata, Jurassic shortening

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## New perspectives on volume and emplacement dynamics of the Köfels rockslide deposits by combined geophysical–geological studies

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The Köfels rockslide (Eastern Alps, Austria) represents one of the largest prehistoric rockslides in the Alps and has been extensively investigated for its surface geology, geomorphology, event age, and detachment- and deposit volumes. However, the interaction of the rockslide mass with the pre-existing topography and valley-fill substrate, as well as the emplacement mechanisms, remain unclear.

This study presents new geophysical data and documentation of temporary outcrops in the upstream valleys of the rockslide to elucidate the dynamics of the rockslide emplacement. New reflection seismic data image the subsurface of the Längenfeld basin, revealing rockslide deposits several kilometers south (upstream) of the main rockslide area. This indicates that after halting at the opposite valley side near Niederthai, the rockslide mass collapsed and divided into two branches. The downstream branch traveled at least 1.9 km, as evidenced by a surface outcrop, while the upstream branch extended 2.3 km upstream. The rockslide dammed the Ötz river, causing subsequent burial of the rockslide deposits under an up to 238 m thick, generally coarsening-upward deltaic backwater sedimentary sequence. Seismic data reveal no postglacial sediments between the rockslide and bedrock beneath the central rockslide, indicating extensive scraping of the pre-rockslide valley infill. The upstream branch's basal shear surface displays a south-verging ramp-flat geometry with at least three ramps accompanied by low-angle thrusts. Thrusting and buckling of the rockslide topography resulted in the formation of toma-hills, with normal fault sets forming depressions between the hills. These observations indicate that the internal collapse dynamics of the rockslide mass are governed by a combination of thrusting (buckling) and normal faulting, with the rockslide mass thinning progressively with distance.

Electric resistivity tomography and ground-penetration radar investigations of the Niederthai plain (~450 m above the present-day valley floor) reveal no sign of lake sedimentation typically expected from a rockslide-dammed backwater lake. Instead, observations in a temporary construction pit show that the uppermost succession of the plain is composed of an overall graded but largely homogeneous silt-sized sedimentary deposit with abundant dykes and large flame structures filled with coarser-grained sands and rounded pebbles of upper Ötz valley provenance. Geophysical data reveal superposition and lateral thrusting geometries of subsurface intervals with high resistivity overlying/overthrusting moderate resistivity packages in the deeper subsurface. These findings indicate significant mobilization, bulldozing, and fluidization of the pre-event fluvial sediment in the Ötz valley floor.

Three-dimensional mapping of all available data estimates the minimum rockslide depositional volume at 5.8 km<sup>3</sup>, at least 1.5 times larger than the estimated detachment volume (3.1-4.0 km<sup>3</sup>). This discrepancy cannot solely be explained by the tendency of the rockslide mass to gain volume during progressive destabilization but highlights the significant erosion and incorporation of pre-rockslide water-saturated sediments into the moving mass, which in turn likely further influenced the rockslide's mass propagation and depositional behavior. Thus, our findings enhance the understanding of the Köfels rockslide's emplacement mechanisms and highlight the interaction between the rockslide and the pre-existing valley infill.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Köfels, rockslide, sediment dynamics, volume estimation, geophysics*

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## Reconstructing past glacier extents in the Chilean Altiplano (18.5°-19° S) - Regional patterns and paleoclimatic implications

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In today's climate, glaciers are very rare in the western Altiplano, even on peaks above 6000 m. However, glacial landforms, especially moraines, are frequently observed, testifying to very different climatic conditions that favoured glacial advances in the past. Although other areas of the Altiplano have been widely considered in palaeoclimate reconstructions, the western Altiplano has often been overlooked. Here we present a detailed map of glacial landforms and a reconstruction of paleoglacier extents in the western Altiplano of Chile between 18.5° and 19°S. We reconstructed regional equilibrium line altitudes (ELA) for several moraine stages representing extensive past glacier advances in the region. During a prominent and ubiquitous 'Principal Moraine (PM)' stage, glaciers advanced from most peaks and all orientations to elevations down to 4000 m asl. Reconstructed PM ELAs along 90 valleys range from 4400 to 5000 m asl. The ELA distribution shows a strong aspect dependence at the western boundary of the Altiplano, with ELAs 300 m lower on west-facing glaciers than on east-facing glaciers. The coincidence of such a steep gradient with a prominent NW-SE ridge explains the topographic control on precipitation, and thus on glacier advance along the western boundary of the Altiplano. To the east, the ELAs of the peaks overlooking the Altiplano are comparable to those of the east-facing glaciers at the western Altiplano boundary but show little or no aspect dependence. Since increased moisture advection from the Amazon basin alone cannot explain this pattern, we suggest that westerly moisture associated with increased frequency of cold fronts and cut-off events has played an important role in glacier dynamics at this latitude. However, further research is needed to assess the relative role of both precipitation regimes on glacier dynamics in the westernmost Altiplano.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Paleoglacier, Western Altiplano, Chile, Equilibrium line Altitude, Paleoclimate



Pauly, Niklas; Grimm, Bastian; Fuchs, Markus

## OSL dating of Holocene fluvial sediments of the Wiesent River in the Northern Franconian Alb (Bavaria, Germany)

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As part of the DFG SPP 2361 "On the way to the Fluvial Anthroposphere" we investigate the interaction between human activity and the floodplain environment of the Wiesent River, Northern Franconian Alb / Bavaria. The landscape of the catchment has been influenced by human activities at least since the Middle Ages through direct (e.g., water mills) and indirect (e.g., soil erosion) transformation processes, which is documented by alluvial sediments within the floodplain. These sediments can be used as natural archives for the reconstruction of the interaction between humans and the environment.

Establishing a chronostratigraphy of the alluvial sediments is essential for reconstructing the floodplain evolution and can provide important information about the transition from a natural to a human dominated fluvial environment. The chronostratigraphy is established by optical luminescence dating (OSL), which is a suitable dating method for fluvial sediments, as it directly determines the age of the sediments. However, OSL dating of fluvial sediments can be challenging due to insufficient bleaching of the sediments, but the general suitability of fluvial sediments from the Wiesent River catchment for OSL dating was demonstrated by Fuchs et al. (2010) in earlier studies.

In this study, we were OSL sampling an alluvial 3 m floodplain section at 5 cm intervals. The coarse-grain quartz fraction was measured following the SAR protocol by Murray and Wintle (2000). Here we present the first high-resolution results of the OSL samples from the Muggendorf site.

**Session:** DEUQUA Session: Anthropogenic impact on the development of landscapes

**Keywords:** chronostratigraphy, optical stimulated luminescence, alluvial sediments, floodplain evolution, human activity

Pengg, Alexander<sup>1</sup>; Misch, David<sup>1</sup>; von Hagke, Christoph<sup>2</sup>; Gier, Susanne<sup>3</sup>; Drews, Michael<sup>4</sup>; Gawlick, Hans-Jürgen<sup>1</sup>; Zamolyi, Andras<sup>5</sup>

## Petrophysical and sedimentological characterization of fault rocks from the Vienna Basin: Implications for induced seismicity and fault reactivation

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The use of geothermal energy bears a great potential to reduce greenhouse gas emissions and consequently to reach the set climate goals. To further establish geothermal energy production and other geoenergy-related applications (e.g., geological storage of carbon dioxide) in our society and increase public acceptance, however, a more profound understanding of induced seismicity associated with such operations is essential. Thereby the reactivation behaviour of (sub-seismic) faults plays a crucial role. This contribution aims for a detailed petrophysical and sedimentological characterization of faulted mudstones, a common seal lithology in sedimentary basins. Core samples from mudstone fault zones in the Vienna Basin (near Bockfließ) have been investigated. The sample set consists of 10 mudstones of Badenian age, all originating from a depth of approximately 1650 m. Observations from thin sections and handsamples suggest an early syn-sedimentary and a later deformation phase. The mineral assemblages (authigenic glauconite, early diagenetic framboidal and later diagenetic euhedral pyrite) document the evolution of increasingly anoxic conditions in the sediment column. Biogenic quartz (e.g., siliceous sponge spicules) provided silica for both the diagenetic formation of clay minerals and of microcrystalline quartz cement. Cation exchange capacity measurements as well as clay mineralogy determined by X-ray diffraction indicate that a higher degree of deformation leads to a better crystal order (illitization) of illite/smectite mixed layer minerals which is related to fluid and heat flow. In general, the microscale observations point to low grade deformation under relatively low p/T conditions. Porosity measurements (broad ion beam – scanning electron microscopy, mercury intrusion capillary pressure, helium pycnometry) reveal systematically lower porosity values for the fault rocks compared to the un-faulted mudstone “host rocks” from a similar depth range. Despite the lower porosity of the fault rocks they show larger capillary displacement radii in relation to the median pore diameter. This suggests that the fluid displacement pressure into these fault zones can eventually be lower compared to the surrounding un-faulted mudstones, which may increase the risk of fault reactivation by higher pore pressure or other fluid injection-related alteration (e.g., mineral dissolution).

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Vienna Basin, sub-seismic faults, induced seismicity, mudstones, diagenesis*

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## Response of till to subglacial shear stress simulated in ring-shear experiments derived from X-ray computed microtomography

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Limited accessibility to the subglacial environment leaves processes operating therein poorly constrained. Understanding these processes is imperative for deciphering the dynamic behaviour of past ice sheets, in particular related to glacial erosion and sediment advection at the ice-bed interface. Their legacy is typically studied through investigating deposits left behind the ice sheets, but conclusions often remain equivocal due to the scarcity of well constrained reference studies and modern analogues (e.g. Menzies et al., 2016).

Here we report preliminary results of a project sponsored by the Bundesgesellschaft für Endlagerung (BGE) in which we used a ring-shear apparatus to simulate the response of a subglacial traction till from northern Germany to stresses imposed on it by an overriding glacier. Bearing in mind all the simplifications and limitations inherent to *in-vitro* laboratory settings, these experiments intend to mimic as closely as possible the conditions beneath ice sheets. A homogenized natural water-saturated till was continuously sheared at an effective normal pressure of 85 kPa and shearing velocity of 2 mm/min (i.e., parameters considered representative for ice sheets) to a total displacement of 800 mm. In the course of shearing, five undisturbed oriented 8x6x4-cm-large samples were taken at the displacements of 0, 100, 200, 400 and 800 mm. Subsequently, these samples were scanned using X-ray computed tomography ( $\mu$ CT) with a spatial resolution of 60  $\mu$ m to constrain the structural evolution of the till as a function of the shearing distance. In focus was the progressive development of till fabrics and pore spaces resulting from intergranular advection of sediment mobilized by subglacial shearing. In each sample, between 1612 and 2195 clasts with mean lengths of ca. 1 mm were manually selected and automatically measured. The long axes of clasts revealed eigenvector values' increase during the shearing, showing that the clasts tend to become progressively aligned parallel with the shear direction as the strain accumulates. This indicates a plastic mode of deformation. There is also a distinct relationship between the elongation of clasts (a/b axis ratio) and their orientation; the orientation of clasts with a/b ratios above 2.0 differs by ca. 5° from clasts with a/b ratios above 1.5. During the shearing, the volume of pores steadily decreased, suggesting progressive compaction, pore-water expulsion, and lack of dilatant behaviour of the sheared till (possibly due to its fine-grained composition).

Our data show progressive evolution of till microfabrics broadly consistent with a similar study based on a two-dimensional micromorphological analysis of Phillips & Piotrowski (2023). The observed reduction of porosity entails a decrease of hydraulic conductivity of the sediment and thus its ability to conduct meltwater, with possible consequences for the mechanical characteristics of the ice-bed interface.

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**Session:** Pangeo workshop: Glacial erosion and deposition

**Keywords:** Subglacial deformation, ring-shear experiments, till, microtomography

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## Water at the ice-bed interface and below: processes, sediments and landforms

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Subglacial water is a critical element of the glacial system modulating the nature of interactions between ice sheets and their beds. Its impact can be deciphered using the sedimentary and geomorphological record of past glaciations coupled with numerical simulations. Water pressurized by the overlying ice reduces the strength of coupling between the glacier and the lithosphere below, which accelerates the flow of ice and reduces its stability. Modulated by the ice surface slope, the water will be driven to the ice margin either through distributed or channelized drainage systems at the ice-bed interface, or it will recharge the subglacial aquifers and drain to the ice margin as groundwater flow. Heavily pressurized porewater reduces the strength of the underlying sediment, which may lead to sediment advection in a mobile traction carpet and generate subglacial diamictos found in such landforms as drumlins, mega-scale glacial lineations and flutings. Here we present examples from the geological record indicative of specific meltwater-related processes including deeply incised tunnel valleys, glacial curvilineations, infilled meltwater channels, subglacial sheet-flow deposits, mega-scale glacial lineations, and subglacial traction tills. Taking into consideration also numerical experiments on groundwater flow under past ice sheets, we highlight possible genetic relationships between these elements and suggest the mechanisms driving them. Growing evidence points to ubiquity of pressurized meltwater under large continental ice sheets of the Pleistocene and its importance for the palaeoglaciological conditions.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *Glacial erosion, meltwater channels, tunnel valleys, glacial landforms, sediment deformation, subglacial groundwater*

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## Chemical erosion and dissolved load of a calcareous torrential catchment in the northern Alps

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Studies on fluvial erosion often focus on the solid load, while the solute load receives less attention. However, chemical weathering and denudation contribute significantly to the mass redistribution and landscape evolution, especially in carbonate regions. In this study we present a chemical denudation rate for the 50 km<sup>2</sup> sized Taugl catchment in the Northern Calcareous Alps. The catchment is predominantly covered by the bedded carbonates of the Oberalm-Formation.

To determine the chemical denudation rates for the Taugl catchment, we installed a probe at the riverbank to record water level, conductivity and temperature. Additionally, we performed discharge measurements using a current meter, which were used in combination with the measured water level to create a rating curve. Water samples were collected at different runoff conditions and analysed by ion chromatography. The hydrogen carbonate samples were titrated using an automatic titrator. These analyses enabled the determination of the correlation between the ion concentration and the electric conductivity and its integration over time.

During the study period (2021/08/20 – 2023/11/23), the total discharge was  $1.16 \times 10^8$  m<sup>3</sup>. The measured water levels varied between 0.48 m and 3.23 m and the conductivity ranged from 82 µS/cm to 245 µS/cm. The analysis of the water composition shows a dominance of Ca<sup>2+</sup> (89.7 %) followed by Mg<sup>2+</sup> (4.3 %) among the cations and HCO<sub>3</sub><sup>-</sup> (95.0 %) among anions. The cation concentrations were then converted into their rock equivalents and interpolated over the gauging period.

An estimated sum of  $9.8 \times 10^3$  t of carbonate rock is transported out of the catchment during the study period, representing a total volume of 3600 m<sup>3</sup>. This results in a chemical denudation rate of 71 µm (0,071 mm) for the 27-month period. Considering that the annual precipitation sums of 2021 (1490 mm), 2022 (1500 mm) and 2023 (1609 mm) are below the long-term annual mean (1700 mm) and that the wet spring in 2021 was not measured, an annual denudation rate of at least 32 µm/a (0.03 mm /a or 30 m / Ma) is proposed. This aligns with the results of prior studies in similar regions and is of the same order of magnitude as the catchment-wide erosion rates determined by the concentration of cosmogenic nuclides in crystalline low mountain ranges such as the Bohemian Massif. Our findings emphasize the relevance of chemical erosion in carbonate-dominated catchments.

**Session:** Pangeo workshop: Earth Surface Dynamics

**Keywords:** chemical weathering, chemical denudation, erosion rates, carbonate, Northern Calcareous Alps

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## The Subpenninic units in the southwestern Tauern Window

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The stratigraphic and tectonic relationships within the Subpenninic succession in the Tauern Window are still under discussion. In recent years the data base, especially in the Brenner - Pfitsch area, has increased considerably due to detailed mapping, exploration drilling and the ongoing construction of the Brenner base tunnel project. Based on these data we present a tectonic model for the Brenner – Pfitsch area.

Due to the Permo-Carboniferous Horst and Graben structures present on the southern European continental margin the stratigraphic succession is very variable, with Palaeozoic sediments forming the base of the succession in the troughs. Finally, in the early Jurassic, shallow-water limestones of the Hochstegen Formation are also deposited directly on top of the exposed basement of the Horsts. During Cenozoic Alpine orogeny, the former Horst and Graben structures were inverted to form the well-known duplex of the Venediger nappe system. During shortening, the autochthonous sediments were intensively deformed and stacked. The Hochstegen Formation, for example, shows large-scale isoclinal folding and internal thrusting in the Brenner area, resulting in a tectonically tripled thickness. On the other hand, this rather stiff marble formation is almost absent in most of the Pfitsch valley. Here, more incompetent Lower Jurassic and Permo-Triassic sediments dominate, which were squeezed into the hinge areas of the isoclinal folds no present as verticalized succession due to the Miocene updoming of the Tauern Window.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Tauern Window, Subpenninic, Collision, nappe stack*

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## Overdeepening-fill profiles in southwestern Germany

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Overdeepenings are closed basins incised into the bedrock by subglacial erosion, and following ice retreat, they become infilled with water and sediments. The sedimentary fillings, some of which are composed of multiple cycles representing separate glaciations, are archives of enormous scientific value. Investigation of overdeepenings and their infills is the key to understanding the processes and drivers of subglacial erosion, the timing and sequence of past glaciations, and thus their cumulated impact on landscape and topography.

We present the stratigraphic successions of three high-quality drill cores from Upper Swabia in the North of the Lake Constance area (southwestern Germany), which are part of the project “Drilling Overdeepened Alpine Valleys” (DOVE; Anselmetti et al. 2022) supported by the International Continental Scientific Drilling Program (ICDP).

These drill cores recovered the complete Quaternary succession at each site, including the infill of two, potentially three separate overdeepenings (Lichtenegg Basin, Gaisbeuren Basin?, Tannwald Basins. These were selected because they should represent, according to previous studies (Ellwanger et al., 2011), large parts of the Early, and early Middle Pleistocene (i.e. pre-Holsteinian), and are therefore excellent candidates for the investigation of a time interval that is currently only poorly understood in the northern Alpine foreland.

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*Ellwanger, D., Wielandt-Schuster, U., Franz, M., & Simon, T. (2011). The Quaternary of the southwest German Alpine Foreland (Bodensee-Oberschwaben, Baden-Württemberg, southwest Germany). E&G Quaternary Science Journal, 60(2/3), 22.*

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *Quaternary, Overdeepening, Stratigraphy*

## Fremddatenmanagement an der GeoSphere Austria

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Daten von Aufschluss- und Datenerhebungsarbeiten, die von Dritten durchgeführt werden, wie Bohrungen oder geophysikalische Vermessungen, stellen aufgrund ihrer hohen Entstehungskosten einen wertvollen, unwiederbringlichen Datenschatz dar, welcher für die Aufgabenerfüllung der GeoSphere Austria im Bereich der basisgeologischen und angewandte geologischen Landesaufnahme essentiell ist, und zu erheben und für zukünftige Generationen zu bewahren ist. Ziel ist, eine nachhaltige Verwahrung und Verwendung dieser Daten im Zuge der Arbeiten der GeoSphere Austria sicherzustellen.

Nach dem Vorbild des Geologiedatengesetzes in Deutschland, das 2020 in Kraft trat, wurde im GeoSphere Austria-Gesetz die Anzeigepflicht bei Aufschluss- und Datenerhebungsarbeiten (§ 11 GSAG), sowie die Datenbereitstellungspflicht (§ 12 GSAG) verankert. Diese ist seit 1. Jänner 2023 gültig. Seither müssen der GeoSphere Austria geplante Aufschluss- und Datenerhebungsarbeiten angezeigt werden, insbesondere – aber nicht nur – wenn diese im staatlichen bzw. öffentlichen Auftrag durchgeführt werden.

Geologische Bohrungen und Grabungen sind spätestens 14 Tage vor Beginn der Aufschluss- und Datenerhebungsarbeiten anzuzeigen, wenn dafür Bohrtiefen von über 50 Metern oder Grabtiefen von über 25 Metern vorgesehen sind, ansonsten spätestens 3 Tage vor Beginn dieser Arbeiten.

In weiterer Folge steht den Organen der GeoSphere Austria der Zutritt zu allen Bohrungen und sonstigen Aufschlüssen jederzeit offen, außerdem sind diesen auf Verlangen die für die Erfüllung ihrer Aufgaben erforderlichen Fach-, Nachweis- oder Bewertungsdaten samt Forschungsmaterial zu übermitteln.

Derzeit wird im Bereich Geophysik und Angewandte Geologie an einem Einmeldeportal für diese Informationen gearbeitet, welches eine Meldung von Aufschluss- und Datenerhebungsarbeiten über die Homepage der GeoSphere Austria ermöglichen soll. Dabei wird neben dem Gebiet, in welchem die Arbeiten geplant sind, auch der voraussichtliche Umfang der Arbeiten und das Verfahren abgefragt werden.

Nach Eingehen einer Meldung wird diese inhaltlich durch Mitarbeiter geprüft, und gegebenenfalls um die Übermittlung der Daten nach der gesetzlichen Frist nach Abschluss der Aufschlussarbeiten per Email ersucht.

Angeforderte und eingegangenen Daten sind – soweit nicht anders vereinbart, und sofern es sich nicht um staatliche Daten handelt – für 10 Jahre vertraulich zu behandeln.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Fremddaten, Einmeldeportal, GeoSphere Austria-Gesetz, Geologie, Geophysik*



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## A 7500 year long, 30-yr-resolution $\delta^2\text{H}$ record from Moossee, Switzerland, indicates strong influence of solar activity on paleohydrology

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While we have a good understanding of the vegetation and temperature changes in Europe during the Holocene, multiple studies indicate strong spatio-temporal variability of hydroclimate. Flood records and lake level reconstructions provide valuable information, yet not all ecologically relevant aspects, like evapo(transpi)ration, are covered. Moreover, it is not always trivial to disentangle various influences of temperature and precipitation, but also human activity, which increased a lot with the beginning of the Neolithic period ~7000 years ago. Over the last few years, several biomarker methods have become available, allowing to reconstruct hydrology and human impact independently. Moossee is a key site to apply such paleoenvironmental methods, because the presence of humans is well-documented by lake pile-dwellings since the Neolithic. Moreover, the sediments are partly varved providing a very robust and precise chronology, and high-resolution pollen and charcoal data are available.

We present new results from Moossee based on compound-specific  $\delta^2\text{H}$  analyses on *n*-alkanes covering the past 7500 years at an outstanding temporal resolution of ~30 years. By comparing the  $\delta^2\text{H}$  signal of aquatic (*n*-C<sub>23</sub>, *n*-C<sub>25</sub>) and terrestrial *n*-alkanes (*n*-C<sub>29</sub>, *n*-C<sub>31</sub>), we are able to explore the paleohydrology of Moossee, i.e. lake evaporation history. Our results indicate high evaporative enrichment during the Mid Holocene (~7500 – 5500 years BP), followed by less enrichment until ~2500 years BP. On centennial to decadal timescales our isotope record shows similarities with total solar irradiance, suggesting that solar activity had a strong influence on lake water evaporation. Our results show also linkages to past lake level, glacier and climatic oscillations.

During the upcoming months, we will further contextualize and evaluate our leaf wax  $\delta^2\text{H}$  record with the palynological and archeological evidence of Neolithic settlement activity around Moossee. Moreover, we work on a high-resolution polycyclic aromatic hydrocarbon dataset to further explore Holocene fire dynamics in addition to the existing charcoal record from Moossee.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** lipid biomarkers, compound-specific deuterium, paleohydrology, Holocene

## Miocene and Quaternary sediments in the Wachau region, revisited

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Compared to the geological map sheet 37 Mautern (scale 1:50.000; Matura et al., 1983), current mapping of the Wachau (scale 1:10.000) confirms the distribution of the Variscan metamorphic bedrock, but shows differences in the Oligocene-Miocene and Quaternary deposits. The latter are discussed in this contribution.

Middle Miocene (Badenian) sediments in the Wachau valley were deposited in an elongated marine embayment, following the present-day Danube valley upstream to Spitz. The geological map of Matura et al. (1983) shows chaotically layered deposits north of Wösendorf within strongly weathered paragneiss, which are referred to a pre-Miocene mass movement. The age of the blocky deposits around Weißenkirchen, consisting mainly of Gföhl orthogneiss, is not specified, although a relationship to the pre-Miocene deposits is implied. Further, the map shows about a dozen localities of marine clay, marl, sand and rounded gravel, mostly dated as Early Badenian due to their microfossil content. These sediments are known from valley slopes at altitudes up to 330 m, but also from lower than 150 m from boreholes 55 m below the Danube level.

In the course of the current mapping a supposedly pre-Miocene, cemented gravitative deposit northwest of Wösendorf was sampled for micro- and nannofossil analyses, as well as the clayey matrix beneath Gföhl orthogneiss blocks. Additional smaller mass movement deposits, represented by unconsolidated diamict sediment, were found. The largest are located west of Hundsheim, interbedded with marine sands and clays. Therefore, at least some of these deposits are interpreted as olistostroms, deposited in a tens of meters deep marine basin. They may have been mobilised due to the transgressions of the Central Paratethys sea into the pre-existing valley. First nannofossil data from the cemented breccia and the matrix beneath the Gföhl orthogneiss blocks indicate an Early to Middle Miocene age. New outcrops of greyish-green marl and pale yellow sand of presumably marine origin have been mapped e.g. near Dürnstein and Mauternbach. Boulders, gravel and sand pockets, found north of Spitz at an altitude of about 350 m probably represent a coastal sedimentary environment. Further micro- and nannofossil analyses are in progress, and several samples have already been dated to the Early to Middle Miocene, and one to the Early Badenian.

Quaternary to Holocene sediments in the map of Matura et al. (1983) include loess, fluvial deposits of the River Danube and minor remnants of rockfall deposits, talus or debris fans. During the recent mapping, additional slope talus and solifluction deposits were added to the map. The distribution of aeolian loess must be reduced in favour of fluvial sediments on the valley floor. Fluvial gravels occur in several levels up to 330 m a.s.l. or 130 m above the recent Danube River. While the gravels of the lower fluvial levels are rich in limestone pebbles originating from the Northern Calcareous Alps, those more than 50 m above the recent level are mostly composed of quartz-rich lithologies with only a few pebbles of flysch sandstone and radiolarite. Interpretation of the age and provenance of the individual levels is ongoing.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Wachau, sediments, fluvial, Badenian, transgressions*

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## Diabases are petrologists best friends: quantitative P-T constraints on the Eoalpine metamorphic gradient in the Ötztal nappe using diabase dikes

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The Ötztal nappe (austroalpine domain, Eastern alps) is a polymetamorphic unit that consists of metapelites with various intercalations of orthogneisses, amphibolites and rare metacarbonates. These rocks have been cut by numerous diabase dikes of basaltic to andesitic composition. Field- and textural investigations revealed a post-Variscan emplacement, since these dikes only show Eoalpine metamorphism and deformation. The aim of this study is to extend the P-T constraints for the Eoalpine metamorphic gradient in the Ötztal nappe further to the NW by using diabase dikes. Therefore multi-equilibrium geothermobarometry paired with classical geothermobarometry was performed on 19 diabase samples from the Ötztal nappe, the Texel Unit and the Silvretta nappe. The diabase dikes contain the mineral assemblage plagioclase + amphibole + biotite + quartz + epidote + muscovite + titanite ± garnet. The anorthite content ( $X_{An}$ ) in plagioclase and the edenite component in Ca-amphibole shows increasing P-T conditions from the NW to the SE of the Ötztal nappe. The thermobarometric calculations with multi-equilibrium geothermobarometry (THERMOCALC v.3.21) yield P-T conditions of 250-300°C and 2-4 kbar for the northwestern Ötztal nappe, reaching 550-600°C and 8-10 kbar in the southeastern Ötztal nappe, near to the Schneeberg unit. The diabase sample from the Texel unit yields P-T conditions of  $540 \pm 41^\circ\text{C}$  and  $8.9 \pm 1.6$  kbar. Thermobarometric calculations with THERMOCALC v.3.33 and v.3.45 yield similar results, but tend to overestimate the P-T conditions, especially for the lower greenschist-facies. Our thermobarometric results are representing the first quantitative P-T estimates for the Eoalpine metamorphic gradient in the Ötztal nappe above the chloritoid isograd.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *diabase dikes, Ötztal nappe, Eoalpine orogeny, geothermobarometry, metamorphic petrology*

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## Investigating the Influence of Uplift on the Central European Drainage Pattern using a Landscape Evolution Model

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The evolution of river systems in Central Europe has been extensively studied. Nevertheless, the mechanisms that led to river reversals and the formation of a cuesta landscape remain poorly understood. There has been considerable speculation as to the reasons behind the radical change in the flow direction of the rivers Main and Neckar. The lowering of the Upper Rhine Graben (URG) and the subsequent lowering of the associated base level have often been proposed as explanation for a complete river reversal. However, this is a questionable assumption, as it does not account for other contributing factors such as lithospheric folding. To gain a deeper understanding of the controlling mechanisms of river system evolution in Central Europe, we employed terrain analysis and numerical landscape evolution modelling using TopoToolbox and the recently developed landscape evolution model TTLEM 3D.

The evolution of the Central European drainage pattern commenced at the transition from the Cretaceous to the Paleocene, marked by a dome-shaped exhumation event in Europe. This event gave rise to the development of a radial river network. Some rivers, such as the Wörnitz and the Brenz, retain the flow direction established at that time. In contrast, although the direction of the Neckar's course remains unchanged, the river now flows in the opposite direction to that of the past. The subsequent formation of the URG in the Eocene was associated with a significant lowering of the rift valley, as well as an uplift of the rift shoulders and a tilting of southern Germany to the east-southeast. The rivers were not initially connected to the URG or reversed in their flow. When the stress field in Europe changed to a northwest-southeast oriented compression regime in the Miocene, the lithosphere was folded from the Alpine front to the North Sea in connection with the second phase of the formation of the Alps. River reconstructions indicate a reversal of the Neckar and Main rivers in this time period, which aligns with the observed uplift and subsidence pattern of the lithospheric folds. Our simulations demonstrate that the river reversal was only possible through the complex interplay between various tectonic mechanisms, which in turn led to the development of the landscape as we know it today.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Landscape Evolution, Drainage Pattern, Central Europe, Uplift*

Reitner, Jürgen M.<sup>1</sup>; Menzies, John<sup>2</sup>

## Subglacial deformation, till formation and deformable bed conditions: The Late Pleistocene sequence of Einödgraben (Aurach, Kitzbühel Alps, Austria)

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Knowledge of subglacial conditions is of great relevance in understanding glacier dynamics. A combination of micro- and macrosedimentological analysis of diamictons and deformation structures can form the basis for the reconstruction of past subglacial conditions. We present the results of such a study on subglacial tills, within an Alpine environment, at Einödgraben in the Kitzbühel Alps (Tyrol/Austria; Reitner & Menzies, 2024). The Late Pleistocene succession there (MIS 5d-MIS 2) shows great diversity in facies from wood-bearing alluvial to glaciolacustrine to subglacial deposits. Two glaciogenic diamictons (tills) within the sequence were analysed at the microscale and are correlated to the Last Glacial Maximum (LGM; Würmian Pleniglacial) and the early Lateglacial phase of ice decay. The first deformation phase of pre-LGM deposits occurred most likely in a subglacial setting close to the advancing glacier margin and resulted in diapir-like glaciotectonic macrostructures, which are unique for an inneralpine area. Subglacial erosion over these structures occurred and later pre-LGM emplaced deposits underwent deformation and partial homogenisation immediately beneath the glacier base leading to diamictons, indicative of subglacial deformable bed conditions. The tills of the LGM and the Würmian Lateglacial show a range of microfacies and deformation structures evidence of close and rapid changes in till rheology and stress field dynamic in the subglacial environment. Our study demonstrates the need for a reinvestigation of deposits occurring in the proximity of past active ice interfaces. The paleoglaciological evidence assembled from the detailed and spatially close research on the microsedimentology of till at Einödgraben reflects our increasing comprehension and understanding of till microsedimentology in Alpine environments. An awareness is also shown of the need for much further research on the glacial depositional mechanics in mountainous terrains that are different from those in the immense lowland plains of the extensive paleo-ice sheets of North America and Northern Europe.

*Reference:*

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**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *Sedimentology, subglacial, stratigraphy, LGM, Lateglacial*

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## Glacier evolution in the Valsugana (south-eastern European Alps) during the Last Glacial Maximum and the Late Glacial

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The evolution of Late Pleistocene glaciers in the south-eastern part of the Alps is still incompletely understood. This is partly related to the difficulties of establishing chronological control in this region that is dominated by carbonate bedrock. Here, we present new data concerning the Last Glacial Maximum (LGM) extent and the deglaciation history of glaciers in the Valsugana (Trentino, Italy). We report first surface exposure ages for an LGM glacier in the south-eastern Alps and discuss morphological evidence for readvances during the Late Glacial period.

During the LGM, the Valsugana was covered by an extensive glacier network that was fed by transfluence of ice from the Adige Valley and by major tributaries from the Calamento and Cavè valleys. The glacier reached a maximum ice thickness of ca. 1000 m and extended down to the area of Cison del Grappa, where it came to a halt before reaching the foreland plain. In marginal positions, smaller, independent glaciers developed. The reconstruction of these marginal glaciers indicates that the regional Equilibrium Line Altitude (ELA) during the LGM was situated at around 1500 m a.s.l. To constrain the timing of the LGM in the region, three erratic boulders from Monte Lefre, a nunatak within the glacier network, were sampled for <sup>10</sup>Be surface exposure dating. The ages demonstrate that the Valsugana Glacier remained at an elevated lateral position until the very end of the LGM (ca. 19 ka), after which glaciers retreated and the glacier network dissected into smaller tributaries. Morphological evidence in the upper valleys suggests at least three stages of glacier readvance and/or stabilisation during the Late Glacial. A reconstruction of these glaciers and their ELAs allowed to establish a relative deglaciation chronology that will represent a framework for future exposure dating efforts.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Equilibrium Line Altitude, Glacier reconstructions, Last Glacial Maximum, Late Glacial, Surface exposure dating

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## Young European GeoExplorer

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Verbesserung der englischen Sprache durch Einbezug von Naturwissenschaften, Geodiversität und Kulturerbe. Das Erasmus+ Projekt **GeoExplorer** zielt darauf ab, die Qualität des Lehrens und Lernens in der Sekundarstufe durch einen innovativen Lernansatz, der naturwissenschaftlichen und sprachlichen Bildung sowie durch die Methode des sprach-integrierten Lernens auszubauen. Neben Schulpartnern sind weitere UNESCO Global Geoparke Teil dieser Projektkooperation. Eine wichtige Zielsetzung ist die Entwicklung neuer Lehrmethoden und Lehrinstrumente für Lehrer der Sekundarstufe sowie Sprachlehrer. Hierbei soll es zum Einsatz praktischer Workshops, kostenlose „Toolboxen“ und Schulungen für Lehrer, Schüler sowie Naturvermittler kommen.

**Session:** Lehrendenworkshop

**Keywords:** Geopark, GeoExplorer, Naturvermittlung, Naturpark, Geodorf

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## Old orogen - young topography: lithology governs landscape evolution in the uplifting Bohemian Massif

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Although the topography of the Variscan orogen was largely leveled in the Permian, outcrops of Variscan rocks occur in the form of several low mountain ranges that form tectonic windows framed by Neogene sediments. The Bohemian Massif is one of these low mountain ranges and consists of high-grade metamorphic rocks and magmatic intrusions that dip southward below the weakly consolidated Neogene sediments of the Molasse Basin.

The timing and rates of Neogene uplift of the region are largely unconstrained, but the occurrence of marine sediments several hundred meters above sea level is a clear indication of significant surface uplift during the last few million years. Morphologically, the Bohemian Massif is characterized by rolling hills and extensive plains above 500 m, contrasting with deeply incised canyons with steep and morphologically active valley flanks. The central ridge of the Bohemian Massif forms a continental divide with the Vltava River and the Danube River draining the northern and southern parts of the mountain range. To constrain the pattern of landscape change and its rates, we calculated topographic metrics and determined catchment-wide erosion rates from the concentration of cosmogenic <sup>10</sup>Be in river sands.

Morphometric analysis reveals a landscape out of equilibrium. Longitudinal profiles of the river show an abundance of knickpoints at elevations of about 500 m, separating steep channel segments at lower elevations from less steep channel segments at higher elevations. Hypsometric maxima near knickpoint elevations, along with high and low values in geophysical relief downstream and upstream of major knickpoints, indicate a bimodal landscape. The continental divide has a pronounced asymmetry expressed by across-divide gradients in channel steepness. The higher average channel steepness in the southern Danube catchment predicts the northward migration of the Danube-Vltava divide. Erosion rates of 20 to 50 m per million years in the 20 catchments studied are very low compared to the Alps and seem to contradict the steep topography close to the receiving streams. The lowest erosion rates occur in catchments with a large proportion of low relief areas at medium altitudes. The highest erosion rates occur in the elongated catchments of the Danube tributaries, although these catchments also have a large proportion of low gradient topography.

Based on our results, we suggest that the Bohemian Massif was affected by low but long-lasting uplift without significant gradients between the Bohemian Massif and the nearby Molasse Basin. In our model, the presence of contrasting bedrock properties between the Neogene sediments of the Molasse Basin and the crystalline basement represents the overriding control on the topographic evolution of the entire region. As river incision progresses, there is a transition from highly erodible sediments to the much less erodible crystalline rocks below, which abruptly reduces the ability of a river to incise. As a result, relief forms and channel gradients increase until the erosion rate can balance the uplift rate. We propose that the Bohemian Massif is currently in such a transient state, expressed by landscape bimodality, where the two contrasting landscape types are separated by upstream migrating knickpoints.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Bohemian Massif, erosion rate, landscape evolution, contrasting lithology, young uplift*



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## Die Forschungsbohrungen Concordia-See und Königsau (ehemaliger Ascherslebener See, Sachsen-Anhalt): Neue Multiproxy-Analysen zur detaillierten Gliederung der Weichsel-Kaltzeit

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1967 beschrieb Dietrich Mania aus den damaligen Braunkohlen-Tagebauen Königsau und Nachterstedt (nordöstliches Harzvorland, ehemaliger Ascherslebener See) erstmals bis zu 25 m mächtige vielgliedrige Abfolgen oberpleistozäner und holozäner Ablagerungen. Die Schichten dokumentierten 13 klimatisch gesteuerte Ablagerungszyklen vom Eem bis in das Holozän und damit das vollständigste Profil der Weichsel-Kaltzeit des norddeutschen Periglazialraums. Überdies konnten in Königsau mehrere mittelpaläolithische Fundhorizonte untersucht werden (u.a. Mania & Toepfer 1973). Aufgrund der großen überregionalen Bedeutung der Sedimentfolgen und Fundhorizonte initiierte das Landesamt für Geologie und Bergwesen Sachsen-Anhalt (LAGB) unter Mitarbeit weiterer Institutionen eine umfängliche Neubearbeitung der jungquartären Schichtenfolge. Das Methodenspektrum umfasst neben der sedimentgeologischen-geochemischen Analyse auch mikro- und makropaläontologische Untersuchungen (Pollen und Sporen, botanische Makroreste, Ostrakoden, Mollusken), die Bestimmung gesteinsmagnetischer Parameter sowie IRSL-Datierungen.

Südlich der Ortschaft Schadeleben wurde die Forschungsbohrung Concordia-See (CON 1/2020) niedergebracht. Die zwei ca. 14,5 m langen Parallelkerne zeigen eine vielschichtige Abfolge von grob- und feinklastischen Sedimenten mit geringen Humusgehalten während der Weichsel-Kaltzeit. IRSL-Daten dokumentieren den Zeitraum von MIS 6 bis MIS 3/2, mit hohen Sedimentationsraten während MIS 4. Ablagerungen der Eem-Warmzeit (MIS 5e) sind nicht erfasst (vgl. Endtmann et al. 2022). Aufgrund starker Beeinflussung durch umgelagertes Tertiär-Material und geringer Pollenkonzentration erweist sich die palynostratigraphische Interpretation der limnisch-fluviatilen und periglazialen Sedimente als schwierig. Nach weiteren Auswertungen von Manias Profilbeschreibungen und älteren Bohrungen der Braunkohlen-Erkundung sowie eigenen geoelektrischen Untersuchungen im unverritzten Gebiet wurde zusätzlich die Forschungsbohrung Königsau (KOE 1/2023), ebenfalls mit zwei Parallelkernen, am Südwest-Stoß des ehemaligen Tagebaus Königsau abgeteuft. Die 21,9 m langen Kerne beinhalten nach ersten palynostratigraphischen Untersuchungen bei 20,9 m Teufe eine auch von Mania (1967) beschriebene Kalkmudde, welche gesichert in das beginnende Eem datiert. Die überlagernden Schluffe und Sande weisen höhere Mächtigkeiten auf als im Kern CON 1/2020. Sie versprechen eine deutlich bessere zeitliche Auflösung des noch zu untersuchenden Profils.

Die Gesamtheit der vorliegenden bzw. noch zu erhebenden Daten wird das Verständnis der klimatisch induzierten geomorphologischen Prozesse während der Weichsel-Kaltzeit deutlich verbessern und die relativchronologische Parallelisierung mit bekannten Weichsel-zeitlichen Sedimentfolgen Mitteleuropas ermöglichen.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Quartärgeologie, Stratigraphie, Oberpleistozän, Weichsel*

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## From peat facies to oil quality: Investigations in the Barito Basin (Indonesia)

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The Barito Basin in southern Borneo (Kalimantan; Indonesia) is a small oil-producing hydrocarbon province, but hosts major Eocene and Miocene coal deposits. Two oil families are present in the Barito Basin. High wax paraffinic oil (“Tanjung oil family”) is produced mainly from Eocene reservoirs, while a paraffinic-naphthenic-aromatic mixed oil with moderately high wax content (“Warukin oil family”) occurs dominantly in Miocene reservoirs. Detailed petrographic and organic geochemical investigations (maceral analysis, Rock-Eval pyrolysis, MSSV pyrolysis, biomarkers, pyrolysis-GC) have been applied to relate the Tanjung and Warukin oil families to Eocene and Miocene coal deposits, respectively. A clear relation between peat facies (e.g., presence or absence of specific resin-producing plants in Eocene rheotrophic and Miocene ombrotrophic mires) and oil composition has been recognized. Apart from the local aspect, this study therefore contributes significantly to the understanding of petroleum systems with coal-derived oil deposits.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Kohle, Erdöl, Torffazies, Borneo*

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## CO<sub>2</sub> Storage Potential of Low-rank and Medium-rank coal deposits from Austria and Kazakhstan

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To assess the CO<sub>2</sub> storage capacity of coals with different ranks, coal samples were collected from an abandoned coal mine in Austria (Fohnsdorf) and a highly productive coal seam in Kazakhstan (D6 seam in the Lenina mine; Karaganda Basin). A variety of techniques, including Rock-Eval pyrolysis, organic petrography, and measurements of ash yield and sulfur content measurements, were applied to compare the coal composition and characteristics. Additionally, low-pressure N<sub>2</sub> and CO<sub>2</sub> adsorption measurements were employed to investigate the pore structure characteristics and gas storage capacity of the coals. The thermal maturity assessment indicated that Austrian coals are subbituminous coals with a mean vitrinite reflectance (%Ro) value of 0.46% and a mean temperature of maximum hydrocarbon generation (T<sub>max</sub>) of 414 °C. In contrast, Kazakh coals are medium-volatile bituminous coals with mean %Ro and T<sub>max</sub> values of 1.21% and 466 °C, respectively. The mean total organic carbon (TOC) content in Austrian coals was 66.2%, while in Kazakh coals, it was 80.4% reflecting the differences in maturity. Sulfur and ash measurements showed mean values of 1.3% and 5.48% for Austrian coals and 0.4% and 11% for Kazakh coals, respectively. According to the N<sub>2</sub> adsorption measurements at 77 K, subbituminous coals showed a lower BET-specific surface area (BET-SSA) (avg. 1.91 m<sup>2</sup>/g) and BJH pore volume (avg. 0.007 cm<sup>3</sup>/g) than medium-volatile bituminous Kazakh coals (avg. BET-SSA = 2.98 m<sup>2</sup>/g; BJH pore volume = 0.01 cm<sup>3</sup>/g). The lower BET-SSA and pore volume of subbituminous coals resulted in a lower N<sub>2</sub> adsorption capacity of subbituminous coals (4.68 cm<sup>3</sup>/g @STP vs. 6.65 cm<sup>3</sup>/g @STP). However, the CO<sub>2</sub> volume adsorbed at 273 K by subbituminous coals was higher (18.26 cm<sup>3</sup>/g) than that of medium-volatile bituminous coals (11.46 cm<sup>3</sup>/g). This could show that the BET and BJH methods applied in the N<sub>2</sub> adsorption data may not sufficiently estimate CO<sub>2</sub> adsorption capacity trends in the investigated sample set. Additionally, the existence of a hysteresis loop between CO<sub>2</sub> adsorption and desorption isotherms in all subbituminous and medium-volatile bituminous coals indicates the occurrence of weak chemisorption during CO<sub>2</sub> adsorption. This process enhances CO<sub>2</sub> uptake and storage safety, as the bonds that are established via the weak chemisorption process are stronger than those formed by pure physisorption. Overall, this study revealed that low-rank coals (Austrian subbituminous coals) had a higher CO<sub>2</sub> storage capacity than medium-rank coals (medium-volatile bituminous Kazakh coals). This could be due to the filling of pores by generated hydrocarbons in the medium-rank coals, leading to a lower CO<sub>2</sub> adsorption capacity.

**Session:** Pangeo workshop: Mineral Raw Materials, and Energy Transition

**Keywords:** Coal, pore structure, CCS, chemisorption, Austria, Kazakhstan

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## EPMA and LA-ICP-MS monazite dating in the Western Gneiss Belt, Northern Thailand: An Over 200-Ma Spread of Dates

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The Western Gneiss Belt in northern Thailand preserves multiple tectono-thermal events reaching medium-grade metamorphic conditions. We use the accessory mineral monazite to constrain the timing of these events. We document the texture and chemical composition of monazite, and use electron probe microanalyzer (EPMA), and laser ablation inductively coupled plasma-mass spectrometry equipped with a quadrupole (LA-ICP-MS) or with a time of flight analyzer (LA-ICP-TOF-MS) to obtain precise age data from garnet-bearing paragneiss and orthogneiss samples from the Inthanon metamorphic core complex. Orthogneiss localities are intruded by foliated biotite-garnet leuco-mylonitic granite emplaced at 40 Ma.

Garnet-bearing paragneiss samples preserve two episodes of garnet growth (grt-core and grt-rim), with some samples showing partial resorption. The composition of the grt-core is linked to at least two metamorphic events. Both EPMA and LA-ICP-MS dating indicate two age populations at 200 and 80 Ma, with LA-ICP-MS results being about 2030 Ma older than EPMA results. Monazite inclusions in garnet cores yield  $^{238}\text{U}/^{206}\text{Pb}$  dates around 200 Ma, while monazite at garnet rim shows a homogeneous composition with dates around 80 Ma. Monazite in the matrix shows sector zoning with both age populations and the youngest dates are typically found in Y-rich monazite overgrowths.

Monazite in the orthogneiss exhibits patchy zoning, indicative of multiple resorptions and reprecipitation events. EPMA dating yields dates of approximately 185 Ma and 60 Ma, with a trend toward younger ages. In contrast, LA-ICP-MS dates show an older range of 230–210 Ma, with a younger cluster around 75 Ma, and a lead loss trend down to 20 Ma. Trace element mapping using LA-ICP-TOF-MS confirms the patchy distribution of dates, without any core-to-rim trend. U-rich zones that cut through the grain yield approximately 40 Ma.

Our results show that monazite is a valuable geochronological tool for constraining the evolution of polymetamorphic terranes. It not only records the peak of metamorphism but also captures retrograde processes and metamorphic overprints in the Western Gneiss Belt of Northern Thailand. The main age peaks identified are 230–200 Ma, ascribed to medium P-T regional metamorphism and magmatism related to the closure of the Paleo-Tethys Ocean. The ~80 Ma peak is associated with monazite overgrowths and likely reflects metamorphic overprint and associated granitic activity during the collision of Sibumasu and the West Burma block. The third event, dated between 40–20 Ma, is related to large-scale shearing and local thermal events associated with the Paleogene India-Eurasia collision.

**Session:** *Classical Session: Analytical Advances*

**Keywords:** *monazite dating; Western Gneiss Belt, Northern Thailand*

Santitharangkun, Srett; Hauzenberger, Christoph A.; Skrzypek, Etienne; Gallhofer, Daniela

## Petrology and Geochronology of Igneous and Metamorphic Rocks from the Inthanon Zone: Implications for the Tectonic Evolution of Northwestern Thailand

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The Inthanon zone of northwestern Thailand comprises numerous plutonic rocks within a metamorphic basement which displays a multi-stage magmatic and metamorphic history starting in the Early Mesozoic. The latest activity occurred during the Cenozoic extensional phase which led to the development of various rift basins (e.g., Chiang Mai basin) but also exhumed the Inthanon zone by low-angle detachment faults. We provide P–T estimates and geochronological data (monazite and zircon) from metamorphic rocks, along petrographic, geochemical and zircon U–Pb age data of granitoids to reconstruct their tectonic history.

The sampled granitoids are biotite granite, syenite/monzonite, and hornblende granite. The biotite granite is a peraluminous S-type granite belonging to the high-K calc-alkaline to shoshonitic series. In contrast, syenite/monzonite and hornblende granite are metaluminous with shoshonitic affinity. The biotite granite and syenite/monzonite have comparable REE patterns: elevated LREEs, a negative Eu anomaly, and a flat HREE profile. The hornblende granite is enriched in LREEs compared to HREEs and lacks a negative Eu anomaly. Zircon U–Pb geochronology dates the biotite granite at 217–210 Ma, the syenite/monzonite at 70–65 Ma, and the hornblende granite at around 21 Ma.

Metamorphic rocks consist of orthogneiss and paragneiss, some garnet-bearing. The orthogneiss shows a mylonitic texture with large K-feldspar augen and contains intercalated of foliated garnet leuco-granites with a zircon U–Pb age of ~40 Ma. Ti-in-biotite geothermometry indicates temperatures of 650–700 °C. Notably, two distinct populations of zircon ages are identified: one around 200 Ma with a high Th/U ratio (>0.1), interpreted to represent the protolith age, and one around 80 Ma with a low Th/U ratio (<0.1). The garnet-bearing paragneiss shows two garnet growth episodes. The garnet core reflects medium-grade metamorphism (0.7–0.8 GPa; 530–570 °C) and yields a monazite age of ~230 Ma, while the rim, formed under upper amphibolite facies (0.4–0.5 GPa; 640–670 °C) at about 80 Ma. Monazite in the matrix shows complex zoning, suggesting recrystallization and re-precipitation during multiple stages of metamorphism, with a primary age population around 230 Ma and sporadic clusters indicating lead loss at about 80 Ma.

Our data indicate that northwestern Thailand underwent several tectonic events. The first event in the Late Triassic is associated with widespread plutonism and an initial medium P–T regional metamorphic phase related to the Sukhothai-Sibumasu collision. This was followed by a widespread upper amphibolite facies overprint and granitic emplacement in the Late Cretaceous, linked to the collision between the Sibumasu and West Burma blocks. Additionally, our data reveal a late Eocene–Oligocene metamorphic event including the intrusion of small magmatic body resulting in upper amphibolite facies to lower granulite facies metamorphism associated with large-scale shearing, as evidenced by the Mae Ping and Three Pagodas shear zones.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Thailand; Western Gneiss Belt; U–Pb dating*

## When and why did floodplain sediments in Mongolia start to accumulate?

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The aim of this project was to use floodplain sediments in Mongolia for reconstructing the Holocene landscape development. More specifically, we aimed at finding out, when the sedimentation of the thick floodplain deposits started, and which factors triggered the onset of floodplain sedimentation. Possible factors included mainly enhanced runoff and increased availability of sediment in the catchments - which led to the follow-up question, whether climatic or anthropogenic causes - or both - were the main drivers of those changes.

To tackle these questions, we described profiles in stratified floodplain sediments, analysed them for particle size distribution and organic carbon content, and subjected suitable sediment samples to luminescence dating, and organic material to radiocarbon dating.

The sediment bodies were usually 50-200 cm thick in total, but sometimes reached more than 4 metres thickness. The profiles exhibited sequences of layers of alluvial and aeolian fine material, alternating with humic layers and palaeosols. The thickness of the layers ranged from centimetres to decimetres.

We interpret the alternation of alluvial and aeolian layers as follows: The alluvial sediments primarily accumulated during episodic flood events. After their deposition, the bare sediment surface often acted as a dust source, which led to deflation and aeolian redeposition of sediment, before reestablishment of a vegetation cover stabilised the surface.

The accumulation of the floodplain sediments must have been triggered by a regime with increased surface runoff leading to enhanced flooding dynamics, and by accelerated soil erosion in the catchments. A decline in vegetation cover may provide an explanation for both processes: It would cause increased surface runoff because of reduced interception and transpiration. Enhanced surface runoff and reduced protection of the soil surface by vegetation would in turn result in accelerated erosion.

Most of the layers showed ages of less than 2 ka, and the ages of the lowermost layers of the sediment sequences ranged between 4.5 ka and 2 ka. Apparently, sediment deposition happened very rarely in the period between the end of the Late Glacial to the Late Holocene, and the main upbuilding of the sediment sequences started around 2000 years ago.

This change might have been caused by a climate change towards more heavy precipitation and longer periods of drought leading to vegetation decline. In addition, anthropogenic logging of forests and the use of fire, as well as intensification of pasture most likely led to enhanced surface runoff and accelerated soil erosion.

Archaeological evidence of animal husbandry in Mongolia goes back to the Early Bronze Age. It started about 5000 years ago with the appearance of the Afanasievo, Okunev and Andronovo cultures. However, substantial human impact on the landscape only began 2000 years ago, with the Xiongnu culture, Turkmen, Uyghurs, Kyrgyz and Mongols, prevailing one after the other. This probably marks a turning point of enhanced socio-economic development and rapid increase in population, accompanied by an increase in livestock and grazing pressure. Further research is needed to determine the extent to which climate change also played a role in this transformation.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Holocene landscape development, soil erosion, vegetation decline, climate change, grazing pressure

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## Geochronology, Geochemistry and Petrology of Metabasites and Metadacites from the Nan Suture Zone, Northern Thailand

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Greenschists, blueschists and rare garnet bearing gneisses and amphibolites were tectonically emplaced within the mafic – ultramafic belt of the Nan suture zone of northern Thailand. Greenschist mineral assemblages are Amp (actinolite, barroisite) + Chl + Ep + Ab + Qz + Wm ± Ttn ± Hem. The blueschists are typically composed of Amp (glaucofane – riebeckite, barroisite – winchite) + Ep + Wm + Chl + Ab + Qz ± Ttn. The garnet bearing samples fall into three groups: (1) Grt – Wm; (2) Amp (hornblende) – Grt – Wm; (3) Amp (glaucofane – riebeckite, barroisite, winchite) – Grt – Wm. The rest of their assemblages being + Ab + Chl + Qz ± Stp ± Ep ± Rt ± Aln ± Zrn ± Ap)

Whole-rock geochemical data shows that the blueschist and greenschist protoliths were basalts, with a few outliers of trachybasalt, picrobasalt and basaltic-andesite. Plots follow a general tholeiitic trend, with TiO<sub>2</sub> and Fe<sub>2</sub>O<sub>3</sub> increasing as MgO decreases. Samples outside of this trend represent either Cpx + Ol or Plg dominated cumulates. The chondrite normalized REE patterns are generally characteristic of MORB. However, some could be enriched MORB or within plate / ocean island basalts, as compared to normal MORB they are enriched in light and depleted in heavy REE.

The majority of the garnet bearing rocks plot within the dacite field. As a whole the sample group follows a general calc-alkaline trend, with a decrease in TiO<sub>2</sub> and Fe<sub>2</sub>O<sub>3</sub> as MgO decreases and SiO<sub>2</sub> increases. They are mainly peraluminous (Shand, 1943) and magnesian (Frost et al., 2001 XFe – SiO<sub>2</sub> diagram).

Zircons have only been found in garnet bearing samples, while allanite occurs in garnet amphibolites and metabasites. Their U-Pb isotopic compositions were analyzed with LA-(MC)ICP-MS, four in-place and two from separated zircons, which are generally euhedral to subhedral and 30 to 100 μm in length. The determined magmatic emplacement ages of these six samples are: 329.9 ± 1.2, 326.3 ± 1.4, 326.0 ± 0.9, 325.5 ± 0.8, 320.0 ± 1.3 and 316.1 ± 0.5 Ma. One garnet amphibolite sample contains an additional group of zircons, with an age of 359.4 ± 2.5 Ma. The allanite grains appear to be magmatic. They are euhedral to subhedral, from 100 to 400 μm in length, some with metamict cores and patchy zonation. They yielded ages similar to those determined from zircons: 338.7 ± 5.5, 333.4 ± 2.1, 330.5 ± 4.9 and 323 ± 29 Ma.

By integrating the geochemical and petrological information with precise radiometric ages, we are beginning to determine the igneous protoliths and metamorphic history of the blueschists, greenschists and garnet bearing rocks that were produced with the subduction zone that destroyed the oceanic Nan basin of northern Thailand. Thus, providing constraints on tectonic models of the amalgamation of Indochina.

**Session:** *Pangeo workshop: Regional Geology*

**Keywords:** *Blueschist, Nan-Uttaradit suture, Allanite dating*

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## The paleolake deposits of Bad Aussee (Austria): New insights into pre-LGM inner-alpine landscape dynamics of the Eastern Alps

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Due to glacial erosion during the Last Glacial Maximum (LGM), sedimentary archives of earlier glaciations in inner-alpine regions are scarce. The Bad Aussee basin (Salzkammergut, Austria), situated in the central Northern Calcareous Alps (NCA), hosts an exceptionally thick sequence of Quaternary sediments mostly predating the LGM. A thickness of at least 880 m was confirmed by an industry drilling and has been interpreted as the result of subglacial dissolution of a salt body. Below thick subglacial till attributed to the Traun Glacier LGM, (glacio-)lacustrine and deltaic sediments are preserved. Recently, the drilled sediments have been studied in detail as part of the DOVE (Drilling Overdeepened Alpine Valleys) project, supported by the International Continental Scientific Drilling Program (ICDP). New luminescence dating results suggest that the entire drilled sequence was deposited since the penultimate glacial cycle, indicating high sedimentation rates. In large parts, the mineralogical and petrographic composition of the Bad Aussee paleolake deposits reflects a source area dominated by crystalline basement rocks, closely resembling the sediments of the modern Enns River further south. In contrast, today's Traun River catchment lies entirely within the NCA. Thus, the drillcore records a major drainage network reorganization from an initial configuration where the Upper Enns Valley drained northwards to a configuration where the Enns Valley was cut from the Aussee area and the Traun catchment became dominant. Lacustrine and deltaic sediments with a similar composition are exposed in several outcrops in the Bad Aussee basin and the adjacent Koppen Valley. Their distribution and stratigraphic position suggest that a glacial advance from the Dachstein plateau further down-valley caused the formation of an ice-dammed lake extending into the Bad Aussee Basin. Furthermore, we will present first results from a multi-method geophysical study (reflexion seismics, electrical resistivity tomography, gravity modelling), which elucidate the spatial extent and stratigraphic architecture of the basin fill and the geometry of the basin.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *glacial overdeepening, glaciolacustrine deposits, geophysical survey, Eastern Alps, provenance study*



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## Anthropogene Kleinreliefformen als Relikte früherer Landnutzung – Großflächige Kartierung aus digitalen Geländemodellen

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Die direkten Auswirkungen menschlicher Landnutzung auf Böden und Sedimente betreffen häufig nur wenige Dezimeter Tiefe unter der Erdoberfläche, erstrecken sich horizontal aber sehr weiträumig. Indirekte anthropogene Einflüsse auf geomorphologische und hydrologische Prozesse als ein Merkmal des Anthropozäns ergeben sich als kumulative Auswirkungen solcher wenig intensiven, aber großflächigen Eingriffe. Viele Landnutzungsformen hinterlassen charakteristische anthropogene Reliefveränderungen und Kleinreliefformen, die in hochauflösenden digitalen Geländemodellen (DEMs) abgebildet sind. Die Auswertung von DEMs ermöglicht es damit, anthropogene Kleinreliefformen über große Areale zu erkennen und so (prä-)historische Landnutzung zu lokalisieren und hinsichtlich ihrer flächenhaften Verbreitung und Verteilungsmuster zu beschreiben. Während sich die technischen Möglichkeiten zur DEM-Auswertung v.a. durch KI-gestützte Methoden rapide weiterentwickeln, bleiben vielfach Unsicherheiten hinsichtlich der zeitlichen Klassifizierung und Repräsentativität der erfassten Formen.

Wir präsentieren Ergebnisse aus mehreren Fallstudien, in denen anthropogene Kleinreliefformen aus DEMs großflächig kartiert und ergänzt durch bodenkundliche und sedimentologische Untersuchung morphogenetisch interpretiert wurden. Diese Studien konzentrieren sich auf Relikte der Holzkohleproduktion, des Bergbaus und der landwirtschaftlichen Nutzung in Untersuchungsgebieten in Brandenburg, Nordbayern, Schlesien, Nordwestirland und dem Nordosten der USA.

Unsere Ergebnisse zeigen durchwegs eine große Verbreitung anthropogener Kleinreliefformen in rezenten Waldgebieten und damit einen erheblichen Einfluss früherer Landnutzung auf aktuelle Bodenlandschaften. Während Relikte der historischen Holzkohleproduktion nur vereinzelt mit Bodenerosion in Verbindung stehen, zeigt sich für Kleinreliefformen aus Bergbau und Ackerbau häufiger ein Zusammenhang mit anthropogen beeinflusster Morphodynamik. Die Fallstudien zeigen auch Effekte der Überprägung und eine Tendenz zur Abbildung überwiegend jüngerer Landnutzungsrelikte in DEMs und unterstreichen damit, dass für ein Verständnis von Mensch-Umwelt-Interaktionen die DEM-gestützte Rekonstruktion der vergangenen Landnutzung mit Auswertung weiterer Geoarchive kombiniert werden muss.

**Session:** DEUQUA Session: Anthropogenic impact on the development of landscapes

**Keywords:** Landnutzung, anthropogene Reliefformen, Bodenerosion, DEM, GIS

Schultz, Kaja; Bufe, Aaron

## Weathering fluxes under moderate erosion rates – the case of the Black Forest, Germany

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Chemical weathering modulates Earth's carbon cycle on geologic time scales. Weathering rates depend on the climatic conditions (especially temperature and precipitation) and the availability of minerals, which are, in turn, influenced by uplift and erosion rates. The impact of weathering on the carbon cycle depends on the type of mineral that is being weathered. Whereas weathering of silicate rocks produces alkalinity and draws down carbon dioxide (CO<sub>2</sub>), the oxidation of sulfide consumes alkalinity and acts as a CO<sub>2</sub> source. A recent analysis suggests that the weathering of silicate, carbonate and sulfide minerals have varying sensitivity to erosion rates. These differences imply that the CO<sub>2</sub>-drawdown-flux from silicate weathering is highest in landscapes of moderate relief and erosion rates. However, weathering-rate data from such landscapes remains rare and important uncertainties in the behaviour of the "CO<sub>2</sub>-drawdown maximum" remain.

Here, we investigate the link between erosion and weathering in the Black Forest (Schwarzwald) in Germany. The southwestern Black Forest exposes relatively homogeneous granites and gneisses with catchments draining across a relief of between 100 m and 1000 m. We use solute chemistry and runoff data to derive weathering fluxes of silicate, carbonate, and sulfide, and we estimate erosion rates from existing cosmogenic nuclide data and topographic metrics. Our data will quantify fluxes of CO<sub>2</sub>-drawdown under moderate erosion rates, which is key to understand the evolution of the Earth's carbon cycle on anthropogenic and geologic timescales.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *CO<sub>2</sub>-drawdown, geologic carbon cycle, erosion rates, weathering fluxes, Black Forest*

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## Quantitative CT scan analysis: an innovative tool for interpreting ice-contact sediments from overdeepened basins of the northern Alpine foreland

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Overdeepened basins are shaped and filled by the interplay of erosion and deposition during one or more glacial-interglacial cycles. Understanding and correlating the sedimentary infill of overdeepened systems is a key to understanding glacial dynamics in terms of the timing, extent, and character of Quaternary glaciations. Therefore, numerous overdeepened structures in the northern Alpine foreland have been explored by research drilling in recent years, resulting in a large collection of sediment cores of excellent quality, providing a unique opportunity to gain insight into these structures. Exploration of these basins shows that a depositional sequence in the sedimentary record of a glacial overdeepening typically begins with the subglacial deposition of coarse-grained units (diamicts and gravels), reflecting complex ice-bed-interactions during the transition from erosion to deposition. The identification and interpretation of these potential ice-contact sediments is crucial for understanding the glacial sedimentary sequences.

In this study, we use X-ray computed tomography (CT) scanning to identify and quantify sedimentological features and systematically characterise a wide range of potential ice-contact sediments from different levels within the sedimentary record of several overdeepened basins in the northern Alpine foreland. CT scanning provides a powerful tool for the detailed analysis of sedimentary drill cores, particularly in these glacial sediments, where such examinations have never been carried out on a large scale. This study aims to establish a CT analysis workflow and a database of characteristics of ice-contact sediments. This will contribute to the controversial discussion of the relevant processes that form ice-contact sediments and improve our ability to identify ice-contact sediments and their genesis in overdeepened basins.

**Session:** *Pangeo workshop: Glacial erosion and deposition*

**Keywords:** *drill-cores, CT-scanning, diamicts, glacial overdeepening*

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## Unraveling the micromechanical response to mudstone compaction: A combined approach of nanoindentation mapping and machine learning data analysis

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Mudstones and similar fine-grained lithologies serve as key elements in various geoenergy applications, e.g., as source rocks for conventional oil and gas deposits, as unconventional reservoirs, or as top seals in geological storage complexes. Understanding compaction processes in these rocks therefore is crucial for energy transition initiatives. This study investigates the compaction processes in mudstone samples from varying depths (723.5 to 3213.5 m) in the Vienna Basin, focusing on micromechanical properties and porosity changes in the clay-rich, fine-grained fraction (“clay matrix”). A novel approach combining nanoindentation mapping with machine learning data analysis was developed to capture compaction-depth trends, efficiently extracting representative mechanical values semi-automatically. Results indicate a significant arithmetic mean increase in mechanical strength of the clay matrix with depth, with an increase of the reduced elastic modulus ( $E_r$ ) and hardness ( $H$ ) from  $6.8 \pm 3.4$  to  $22.6 \pm 7.5$  GPa and from  $0.2 \pm 0.2$  to  $0.9 \pm 0.2$  GPa, respectively. Additionally, a strong correlation between depth and porosity (3.3–26.4%  $\Phi_{\text{MICP}}$ , Pearson correlation coefficient  $r = -0.94$ ) and consequently micromechanical properties of the clay matrix ( $r = 0.94$ ) was observed. Broad ion beam-scanning electron microscopy (BIB-SEM) analysis showed that porosity reduction mainly resulted from mechanical compaction rather than mineral diagenesis. The correlation coefficient matrix between multiscale porosity and nanoindentation measurements confirmed that porosity loss was closely linked to enhanced mechanical properties of the clay matrix. Empirical equations were derived to describe mechanical properties as functions of depth and porosity. This study offers a promising approach to study compaction processes across various burial depths at microscale, yielding information that may later be used to understand geomechanical behavior at macroscale. The obtained porosity data and mechanical values contribute to the understanding of burial history, porosity evolution, and associated mechanical changes, representing a potential avenue for assessing mechanical seal parameters in future geological storage applications.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Nanoindentation, Compaction, Mudstone, Vienna Basin, Geoenergy*

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## Control of lateral strength variations on deformation of the Adriatic plate: insights from lithospheric-scale analogue models

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In convergent settings, indenters are strong lithospheric blocks that deform relatively weaker lithosphere. Within the frame of the Cenozoic Alpine orogeny, the Adriatic continental (upper) plate, represents such an indenter. Recent 3D gravity and thermal modelling studies (Spooner et al., 2019), supported by strength calculations (Willingshofer and Cloetingh, 2003), suggest that the Adriatic crust is more mafic, denser and thus stronger when compared to the European crust. Also, thermal modelling studies show that the geothermal gradient within Adria is relatively low, consistent with “cold” and thus strong lithospheric conditions. Yet overall stronger, lateral strength variations linked to Permian intrusives and extrusives and a pre-existing platform-basin geometry related to Jurassic extension, seem to have existed within the Adriatic crust at the onset of Alpine shortening.

We present new lithospheric-scale analogue experiments to address the effect of laterally varying crustal strength conditions on the deformation of the eastern Southern Alps (ESA) lithosphere, which is key for establishing causal relations between crustal and lithospheric deformation and surface uplift patterns associated with Miocene S(E)-vergent basin inversion.

Different to previous lithospheric-scale analogue modelling studies on Alpine-style continent-continent collision settings which focused on shortening of weak orogenic wedges at plate boundaries, our study centres on internal deformation of the indenter. Our models incorporate intra-crustal heterogeneities that are aligned with the direction of convergence and mimic above named heterogeneities. Furthermore, we assume a relative “weak” lower crust, a pre-condition for the formation of a lower crustal wedge.

The modelling results show that variations in lithospheric strength control the localisation of strain and the wavelength of deformation. Additionally, lateral variability of ductile lower crustal thickness predicts stronger uplift in areas of thicker lower crust. A similar relationship has been documented for the northwestern ESA, where Miocene thickening of the lower crust is expected to correlate with higher uplift in the Tauern window (Jozi Najafabadi et al., 2022).

*Jozi Najafabadi, A., Haberland, C., Le Breton, E., Handy, M. R., Verwater, V. F., Heit, B., and Weber, M.: Constraints on Crustal Structure in the Vicinity of the Adriatic Indenter (European Alps) From Vp and Vp/Vs Local Earthquake Tomography, Journal of Geophysical Research: Solid Earth, 127, 2022.*

*Spooner, C., Scheck-Wenderoth, M., Götze, H.-J., Ebbing, J., and Hetényi, G.: Density distribution across the Alpine lithosphere constrained by 3-D gravity modelling and relation to seismicity and deformation, Solid Earth, 10, 2073-2088, 2019.*

*Willingshofer, E. and Cloetingh, S.: Present-day lithospheric strength of the Eastern Alps and its relationship to neotectonics, Tectonics, 22, 2003.*

**Session:** Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)

**Keywords:** lithospheric-scale analogue modelling, crustal inheritance, indenter-internal deformation, eastern Southern Alps

## Comprehensive characterization of rock salt from the Haselgebirge Formation: Insights for cavern storage of hydrogen

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Underground hydrogen storage (UHS) is currently broadly discussed as an efficient way to store renewable energy in the subsurface. Besides long-term, high-volume storage in depleted gas fields and low-volume and short-term storage in surface facilities, UHS in salt caverns could fill the intermediate gap. In Austria caverns from salt mining exist in the Haselgebirge Formation, an evaporitic succession that has been tectonically deformed, resulting in a complex deposit structure. This study aims at a comprehensive characterization of the variable rock salt types with respect to geomechanical behaviour and hydrogen permeability under confinement. These data can be used in future cavern assessment for UHS.

Five different lithologies from a depth range of 477 – 755 m have been tested (red salt with mudstone clasts – RS 477 m, two types of grey salt with anhydrite – GS1, GS2 from 649 m and 755 m depth, anhydrite with dolomite – AD 555 m, dolomite with vein-type salt – DVS 540 m). Porosity, permeability, bulk mineralogy via X-ray diffraction (XRD), as well as ultrasonic velocities ( $v_p$ ,  $v_s$ ) have been measured for baseline characterization, and computed tomography (CT) and scanning electron microscopy (SEM) imaging were used to visualize sample textures. Plugs from each sample (2.54 cm diameter, 1:2 aspect ratio, 70% relative humidity) were then tested in an autonomous triaxial cell with a multiple failure state procedure, setting pressure stages at 1 MPa, in-situ pressure (11, 12.5, 15, 17.5 MPa), and 25 MPa. To test for permeability, additional single stage tests have been conducted with low confinement (1 MPa), and high confinement (25 MPa) pressure with 0.5 and 3 MPa nitrogen ( $N_2$ ) pore pressure at the downstream side respectively. The upstream pressure and corresponding ultrasonic velocities were monitored during the testing procedure.

RS has the lowest porosity and permeability (0.14-0.38%, 0-0.0027 mD) while GS1 & GS2 (0.15-2.53%, 0-0.24 mD) exhibit the highest. Intermediate porosity and permeability values (0.04-0.84%, 0-0.20 mD) are observed for samples dominated by anhydrite and dolomite (AD, DVS). Young's moduli range from 5 to 10 GPa in RS, are slightly higher (8-12 GPa) in GS1 & GS2 and reach 23-40 GPa in AD & DVS. Gas permeability is generally higher at lower initial confinement (1 MPa). The permeability of softer salt types (RS, GS1 & GS2) increases during loading, indicating the progressing formation of microfractures before the maximum load is reached. Stiffer salt types containing more dolomite (AD, DVS) fail with a rupture and an immediate gas breakthrough at the maximum load. In contrast, no gas breakthrough could be observed at high confinement pressure conditions for all tested formations, supporting the more ductile behaviour at high confinement. In general, the investigated salts can be considered effective seals for gas storage. While a locally elevated gas permeability related to microfractures could occur at cavern walls under high storage gas pressure, the increased confinement within the intact salt formation would likely impede gas leakage.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *UHS, salt caverns, permeability, gas breakthrough, triaxial tests*

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## Environments during the Late Middle Pleistocene in the Heidelberg Basin, Upper Rhine Graben (Germany)

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A drill core, 136 m long, from the southern Heidelberg Basin was investigated by two dating methods as well as by pollen and mollusc analyses to reconstruct the environmental conditions. The chronological framework is based on post-infrared infrared-stimulated luminescence dating supported by additional amino acid geochronology. The sediment sequence comprises fluvial, colluvial, and palustrine deposits representing more or less continuously at least the last ~500 ka. The lower part of the drill core is composed of fluvial gravel and colluvial diamicts of a lateral alluvial fan into the Upper Rhine Graben. The central part of the succession comprises a large-scale fining upward cycle belonging to the Ludwigshafen Formation. The fining upward cycle terminates with palustrine fines with rich mollusc and pollen assemblages.

The pollen record encompassing these palustrine fines shows a succession from open vegetation conditions in the lower part of the profile to a dense forest vegetation indicating interglacial conditions in the upper part. During the uppermost local pollen zone 7, *Alnus* (20-50 %) is accompanied by *Abies* (15-25 %) and a low presence of thermophilous trees, such as *Quercus*, *Ulmus*, *Carpinus*, and *Fagus*. Noteworthy is also the occurrence of *Buxus*. Furthermore, there is a high presence of *Azolla filiculoides* (121 % of the reference sum). These frequent findings of *Azolla* are indicative of warm and sub-oceanic conditions.

Unfortunately, the palustrine succession in Eppelheim ends with a sharp erosive boundary, so that the interglacial succession is incomplete. From a palynostratigraphical point of view, the investigated archive is very similar to the (presumed Cromerian) Mannheim Interglacial (Knipping 2008) as defined close by, whereas a correlation with the Holsteinian Interglacial appears unlikely. A tentative correlation with Mannheim Interglacial is supported by the amino acid geochronology. In contrast, the pIRIR ages are younger and correspond to MIS 11. However, these dating results are roughly in agreement with previous luminescence studies on correlative deposits in other drill cores (Lauer et al. 2011, Li et al. 2018).

Knipping, M. (2008): Early and Middle Pleistocene pollen assemblages of deep core drillings in the northern Upper Rhine Graben, Germany. – *Netherlands Journal of Geosciences* 87, 51–65.

Lauer, T., Frechen, M., Hoselmann, C., Tsukamoto, S., 2010. Fluvial aggradation phases in the Upper Rhine Graben – New insights by quartz OSL dating. – *Proceedings of the Geologists' Association* 121, 154–161.

Li, Y., Tsukamoto, S., Frechen, M., Gabriel, G., 2018. Timing of fluvial sedimentation in the Upper Rhine Graben since the Middle Pleistocene: constraints from quartz and feldspar luminescence dating. – *Boreas* 47, 256–270.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Amino Acid Geochronology, Luminescence Dating, Molluscs, Pollen

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## Surface uplift of the Eastern Alps - much faster than we thought?

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Surface uplift of the Eastern Alps is generally considered to have occurred more or less continuously over the last 30 Ma. Since this time the fine interplay of many kilometres of rock uplift and erosion has resulted in net surface uplift of some 2-3 kilometres. However, reference frames that allow to discern between rock uplift and surface uplift are often hard to identify. One way of measuring surface uplift rates is through the study of areas where erosion did not occur. That is, identification and dating of relicts of ancient base levels. In the eastern Alps elevated low relief landscapes (ELRLs) are a common feature at a series of discrete levels up to 3000 m surface elevation and have been identified as relicts of base levels.

In this contribution we present a map of these ELRL landforms for much of the Eastern Alps and present <sup>10</sup>Be, <sup>21</sup>Ne, <sup>26</sup>Al cosmogenic nucleide data of fluvial sediments sampled in some 50 caves across the Eastern Alps that are interpreted to have formed at the same time as the ELRL paleosurfaces. We collected samples that were interpreted to have been deposited during cave formation at the vadose-phreatic transition. As such, they form markers for base level and the age of their burial into the cave may be interpreted as the time the cave was at base level. Interpretation of our data indicates that the uplift rate of the Eastern Alps may be in the order of 200 m – 500 m per Million years for much of the Pliocene. As such, much of the observed surface uplift of the Eastern Alps may have occurred since the late Miocene and surface uplift is thus much faster than previously thought.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *surface uplift, cave dating, cosmogenic nucleides*



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## Alpine soils from the Rieding valley: geochemical, mineralogical and granulometric analysis

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Soils of the alpine zone are of particular interest in the context of soil formation after progressive glacier retreat and climate change. In this study, three alpine soil types from the Rieding Valley were analysed in the laboratory with regard to geochemistry (X-ray fluorescence analysis), mineralogy (using X-ray diffraction and the Rietveld method), determination of the organic content (wet and dry ashing) and granulometry with laser diffraction (particle sizer). The soils originate from different horizons (A, B and C horizons) and have different parent rocks (carbonate, silicate). The samples are of the type Rendzina (Cv horizon), Pseudogley (A horizon) and Brown Earth (Bt horizon).

Rendzina, as a shallow soil on carbonate rock, predominantly contains the oxides MgO and CaO. As the sample originates from the Cv horizon, it directly contains the weathered parent material (dolomite). In terms of trace elements, Sn and Sr in particular are enriched. The organic content is 5.7 wt% (dry ashing) and 3.0 wt% (wet ashing).

Pseudogley consists mainly of quartz, feldspar and phyllosilicates (with corresponding SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> contents). Increased iron and manganese contents compared to the Rendzina are clearly recognisable. Higher enrichment is also found in: Ba, Cr, Ni, Rb, Sr, Sn, V and Zr. The sample comes from the A horizon - the mineral topsoil, which is enriched in humus and therefore has a higher organic content (dry ashing: 15.1 wt%; wet ashing 12.0 wt%).

The colour of the brown earth is caused by the oxidative weathering of Fe<sup>2+</sup> from phyllosilicates (biotite) to Fe<sup>3+</sup> and iron (hydro)oxides, e.g. frequently goethite - this correlates with the main element contents of the sample. Of the three soils, brown earth has the highest iron content. Among the trace elements, Ba, Cr, Ni, Rb, Sr, Sn, V and Zr are clearly represented. The organic matter content was determined by dry ashing to be 5.0 wt% (wet ashing 2.0 wt%).

All three soils have grain sizes with a maximum between 10 and 20 µm. For the grain size analyses we used the laser diffraction method which has become a recognised method for particle size analysis of soils. However, there are a number of requirements for the pre-treatment of the sample, e.g. the removal of organic matter or carbonate components. The type of pre-treatment is a form of intervention in the distribution of the grains in the sediment. This study evaluates different methods of preparing optimal sample aliquots for a representative distribution of the grains. The fine fraction <63 µm was selected as the starting material for the grain size analysis. The following pre-treatment methods were compared: 1) untreated raw material including organic content, 2) prepared sediment without organic matter - humus destruction by dry ashing, 3) prepared sediment without organic matter - humus destruction by wet ashing. The grain sum curves produced using raw material correspond well with those of the ashed samples, but only as long as the organic content does not exceed about 5.0 wt%. Light mortaring does not falsify the result.

Furthermore, the type of sample feed into the dispersion unit was analysed (dry versus pipetting). The preparation of an aqueous suspension and subsequent pipetting proved to be less suitable than dry sample feeding.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *alpine soil types, geochemistry, mineralogy, granulometry, sample pre-treatment*

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## The relevance of periglacial cover beds and interbedded loess-like slope deposits

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Multilayered periglacial sediment sequences with intercalated slope wash deposits are well known for the loess regions. For the Central European subdued mountains, however, they are hardly a subject of research. In the transition areas between loess basins and higher regions, loess-like slope wash sediments occur rather regularly in and along concave slope structures, such as channels or Pleistocene valley bottoms. Locally, deep cuts expose the Quaternary sequences as well as older geological layers. For landscape research, it is highly relevant that loess-like sediments of Pleistocene valley floors enable reliable OSL dating if they are sufficiently bleached. Thus, these reworked loess deposits can complete the chronostratigraphic interpretation of cover-bed sequences and give a more complex impression of landscape evolution in upland regions, as they represent indispensable paleoenvironmental archives with almost untapped scientific potential.

In Central Europe, the occurrence of Upper Weichselian reworked loess shows that modification of primary loess by slope wash was a rather common phenomenon on subdued mountain slopes as well as on river terraces in/near loess landscapes in the Late Pleistocene. Studies in Austria in the Vienna Forest in the Alpine Foreland, as well as in the Neusiedlersee area show the relevance of such sediments in transitional areas between loess regions and subdued mountains. Recent research in the mountain and loess regions of Poland and Germany is focused on periglacial loess as well as on loess-like slope deposits interfingering with periglacial layers.

The presentation focuses on loess-like slope deposits associated with periglacial cover beds in subdued mountain ranges located in close vicinity to loess regions in order to i) refine the chronostratigraphy of periglacial cover beds, to ii) establish the mentioned archives as valuable records of Pleistocene landscape genesis, and to iii) expand the knowledge on different periglacial sediments and processes.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** loess-like slope deposits, periglacial cover beds, landscape genesis, periglacial processes

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## Exceptional gravitational mass movements within the Austrian UNESCO Geoparks

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As part of the ÖAI project Movemont, gravitational mass movements (GMM) are recorded in the UNESCO Global Geoparks (UGGps) Karawanken, Erz der Alpen & Steirische Eisenwurzten. The aim of these field surveys is:

a characterization of the GMMs as a basis for an assessment of their social relevance (opportunities and risks), to verify the modeling tool to be developed in the project for a GIS-based simulation of the dynamics of GMM,

and to study biodiversity in mass movements of different dynamics.

Using high-resolution laser scanning analysis, previously unknown unusual GMMs were identified and mapped in detail in the field.

An emphasis was placed on slow-flowing mass flows, complex deep rock slides and slope deformations as well as the dynamics within long runout landslide deposits.

What was striking was that the older the maps of the geological survey where, the worse the recording and assessment of GMM was - until the 1990s it was mainly mapped the basement and the Quaternary. At best, scarps and erosion edges are presented without reference to the type and dynamics of the GMM and often relocated material is depicted as bedrock.

In summary, the following exceptional GMMs can be assigned to the UGGps:

In the calcareous alpine area of the UGGps Karawanken, complex deep rock slides and slow-flowing mass flows are occurring.

In the greywacke zone of the UGGps, an area of exceptionally large landslide deposits in combination with an accumulation of translational and rotational slip was observed – probably an indication of a previously unknown earthquake event.

In the limestone alpine area of the UGGps Steirische Eisenwurzten, beside the large long runout landslide Wildalpen mainly complex deep rock slides and slope deformations are occurring.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Massenbewegungen UNESCO MOVEMONT*

Unger, Clara-Louisa

## Erdwissenschaften und Schulbücher

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Die Erde unterliegt seit ihrer Entstehung zahlreichen dynamischen Prozessen, die das Leben auf der Erde beeinflussen. Somit sind die Erdwissenschaften wesentlich für ein Grundverständnis biologischer Phänomene und bilden einen integrativen Bestandteil im Biologieunterricht. Seit Herbst 2023 treten die neuen Lehrpläne in den Mittelschulen und AHS-Unterstufen in Kraft, in denen erdwissenschaftliche Anwendungsbereiche unterrepräsentiert sind. Immerhin soll mithilfe fünf zentraler fachlicher Konzepte der Fokus auf den Vergleich biologischer Phänomene aus allen Anwendungsbereichen gerichtet werden. Das bedeutet, dass wiederkehrende Prinzipien der Biologie (z.B. Evolution und Verwandtschaft) übergreifend in allen Themengebieten aufgegriffen werden sollen. Abstrakte Prinzipien und Konzepte verständlich und altersadäquat vermitteln zu können, ist eine große Herausforderung in der didaktischen Aufbereitung der Lerninhalte. Die Einbeziehung der Erdgeschichte kann dabei unterstützen, Konzepte und Zusammenhänge zwischen den verschiedenen Anwendungsbereichen verständlich zu vermitteln. Bereits in der Unterstufe wäre der Aufbau solch eines Grundwissens von Vorteil, um aktuelle Ereignisse und Prozesse (z.B. die Folgen des Klimawandels) und allgemeine Konzepte (z.B. Evolution) besser verstehen zu können. Durch die Einführung der neuen Lehrpläne wurden und werden auch die Bildungsmedien nach dem neuen Lehrplan überarbeitet, darunter auch die Schulbücher. Ein Wunsch nach mehr Einbezug der Erdwissenschaften in Biologie-Schulbücher ist einer von vielen Ansprüchen an zukünftige Biologie-Schulbücher. Um Änderungen erreichen zu können, sollte vorerst der Entwicklungsprozess eines Schulbuchs verstanden werden. Von der Hand der Schulbuchautoren und Schulbuchautorinnen bis zur Verwendung im Unterricht durchläuft ein Schulbuch mehrere Verfahren, darunter ein Approbationsverfahren des Bundesministeriums für Bildung, bei dem das Schulbuch meist mehrmals nach Gutachten überarbeitet werden muss. Da die Verordnung des neuen Lehrplans sehr spät erfolgte und die Entwicklung eines Schulbuchs mindestens zwei Jahre lang dauert, standen und stehen die Schulbuchverlage unter Zeitdruck, um die Schulbücher lehrplankonform und fristgerecht drucken zu können. Im Rahmen des Lehrerworkshops sollen die vielfältigen Anforderungen an Schulbücher dargestellt und darüber diskutiert werden, wie die Erdwissenschaften in alle Anwendungsbereiche integriert werden können. Zusätzlich soll unter Berücksichtigung des politischen Einflusses auf Schulbücher erörtert werden, wer die relevanten Ansprechpartner für die Forderung nach mehr Erdwissenschaften in Biologie-Schulbüchern sind und welche realistischen Ansätze es gibt, um Änderungen zu bewirken.

**Session:** *Lehrendenworkshop*

**Keywords:** *Erdwissenschaften, Biologieunterricht, neuer Lehrplan, Schulbücher, Schulbuchverlag*

## Rutschung Hochreute in Hörbranz/Vorarlberg

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Die Gemeinde Hörbranz liegt 3 km östlich des Bodensees in Österreich/Vorarlberg. Hier ereignete sich in der Parzelle Hochreute in der Nacht vom 28. auf 29. April 2023 nach einem von Regen geprägten Frühjahr ein Felssturz mit anschließender Großrutschung.

Der Festgesteinsuntergrund wird von den Pfänderschichten der Oberen Süßwassermolasse aufgebaut. Diese zeichnen sich durch eine Wechsellagerung aus Mergel, Sandstein und Konglomeraten aus und fallen mit 6° flach Richtung Nordwesten ein. Die Mergel und Sandsteine enthalten hohe Anteile quellfähiger Tonminerale. Aufgrund dieser neigen die Mergel zu einer rasch rückschreitenden Verwitterung. Verbreitet sind im Pfänderhang überhängende Konglomerat-Bänke festzustellen, unter denen die Mergel rückgewittert sind. In diesen Überhängen kommt es laufend zum Abbruch von größeren Felspartien. Die Konglomerate sind im oberflächennahen Bereich verkarstet und können bei Niederschlägen Wasser mit hoher Geschwindigkeit über große Distanzen transportieren. Am Kontakt zwischen Konglomeraten und Mergeln kommt es zu einer Aufweichung der Mergel, was dazu führt, dass sich die Konglomerate verschieben, was zu einer weiteren Aufweitung der Klüfte führt.

Aufgrund der tektonischen Prozesse sind die Schichten durch Kluftsysteme parallel zur Einfallrichtung und senkrecht zur Einfallrichtung durchzogen. Ein drittes Trennflächengefüge wird von den Schichtflächen gebildet. Durch eiszeitliche Frostsprengung und Wassereinträgen aus den Kluftsystemen der Konglomerate und Sandsteine sind die Klüfte tiefgründig aufgeweitet und weisen teilweise eine starke Verwitterung auf. Überlagert wird das Festgestein von Verwitterungslehmen bzw. der alten Rutschmassen.

Eine Auswertung der Laserscandaten aus dem Jahr 2017 hat ergeben, dass die Struktur, an der sich der Felssturz ereignet hat, bereits zu erkennen ist. Dies lässt den Schluss zu, dass es bereits vor einigen 100 Jahren schon einmal an gleicher Stelle ein ähnliches Ereignis gegeben haben muss. Auch ist im Fußbereich der Felswand die Abgrenzung der ebenfalls vorhandenen Rutschung in Form einer Geländeerhöhung deutlich zu erkennen.

Durch die Auflast des Felssturzes wurde diese Masse mobilisiert und es haben sich insgesamt 360.000 m<sup>3</sup> Material in Bewegung gesetzt. Beim Ereignis wurden bis heute 5 Häuser zerstört.

Nachdem die Hauptbewegungsrichtung zunächst Richtung Norden erfolgte, hat inzwischen eine Verlagerung der Bewegungsrichtung nach Westen und Osten stattgefunden.

Vom Landesamt für Vermessung und Geoinformation, Feldkirch wurde umgehend ein Vermessungsprogramm gestartet. Der schnellste Punkt hat sich bis heute um 62 m talwärts verschoben. Auch wurde ein automatisiertes GPS-Monitoring mit 6 Messpunkten installiert.

Unmittelbar nach dem Ereignis wurde zum Schutz vor abgehenden Schlammmassen Richtung Wohnsiedlung ein Schutzdamm unterhalb der Felswand errichtet und eine Tiefendrainage eingebaut. Aufgrund der starken Bewegungen hat sich dieser Damm zwischenzeitlich bereits ebenfalls stark verschoben.

Erkundungsbohrungen ergaben, dass der Fels in einer Tiefe von 6-15 m beginnt. Die Inklinometermessung hat gezeigt, dass die Bewegung im Übergangsbereich zwischen Locker- und Festgestein erfolgt.

Aufgrund der anhaltenden Bewegungen der reliktschen Rutschmasse wurde entschieden, eine Kopffentlastung dieser durchzuführen. Dabei wurde das auf die alte Rutschmasse gelangte Material ausgebaggert, was sich aufgrund der extremen Wassersättigung und damit Dünflüssigkeit als extrem schwierig herausstellte. Dies führte jedoch zu einer starken Beruhigung der Bewegung. Des Weiteren wurden am nordöstlich verlaufenden Eplisgehrbach Sperren eingebaut und die Ufereinänge stabilisiert, um eine Aktivierung des derzeit noch ruhigen Gegenhangs zu verhindern.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *Rutschung, Felssturz, Molasse, Reaktivierung*

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## Slab length and slab tearing control asymmetric exhumation of the Calabrian Arc

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Slab dynamics play a fundamental role in shaping the landscape through subduction, tearing, and rollback. The Calabrian Arc, situated along the convergent margin of the Eurasian and African plates, offers a natural laboratory to investigate the interplay between rollback, slab geometry, and tearing. Building upon prior studies that have primarily focused on large-scale geophysical or tectonic data, our study incorporates insights from locally derived low-temperature thermochronology to provide a more comprehensive understanding of the long-term evolution of the Calabrian Arc. Our integrated analysis reveals a cessation of exhumation earlier in the north relative to the south, suggesting that the more extended Ionian slab segment in the north reached the 660-mantle transition zone first (~14 Ma). This event initiated a cessation of exhumation and a faster retreat in the northern region, while the shorter Ionian slab segment in the south continued to subduct for a longer period, maintaining exhumation in that domain (~9 Ma). A slab tear in the Catanzaro trough delimits the boundary between the longer and the shorter slab segments and provides further evidence to this model. This study provides an explanation for the asymmetrical exhumation of the Calabrian Arc, emphasizing the role of heterogeneous slab length and tearing dynamics in the shaping of tectonic patterns within subduction zones.

**Session:** *Pangeo workshop: Earth's Spheres (Crust, Mantle & Core)*

**Keywords:** *Thermochronology, exhumation, rollback, geodynamics, Calabrian Arc*

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## Lake Bosumtwi – A million year record of hydro-climate oscillations in West Africa

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Situated within a 1.07 million-year-old meteorite crater, Lake Bosumtwi in Ghana stands as a pivotal location for comprehending fluctuations in the hydro-climatic situation in sub-Sahara West Africa. The region is highly sensitive to climate oscillations due to the movements of the tropical rain belt driven by atmospheric circulation leading to pronounced dry or wet conditions on seasonal to orbital scales. Consequently, Lake Bosumtwi is perfectly suited for studying movements of the ITCZ and possible effects of inter-hemispheric climate differences close to the tropical W-Atlantic. Recently, we have published a correlative age-depth model for this site that is underpinned by available published datings (<sup>14</sup>C, OSL, U/Th) and cyclostratigraphy. Our correlative age-depth model bases on a sedimentary mechanism assuming increased in wash of soil material enriched in radiogenic K (<sup>40</sup>K) from the (~ 100 m) steep crater rims into the Lake during moist interglacial periods and reduced input of soil material during stadials and possibly K-depleted input of dust. This variability in K is very similarly reflected in our natural gamma ray data (NGR, likely dominated by <sup>40</sup>K and its daughters in our case) that we determined in high resolution for the entire core and that we used for correlation to the Iberian Margin sea surface temperature stack. To best constrain our correlative age-depth model, we integrated our recently obtained palaeomagnetic data. The integration and comparison of the datasets indicates independent support for our model at the Brunhes-Matuyama boundary.

Rock magnetic parameters tend to also show glacial-interglacial variability. In addition, we extracted mean annual precipitation (MAP) reconstruction climate model data (PastClim package in R) that base on orbital parameters, CO<sub>2</sub> concentration and ice volume variation as main forcing functions. Our NGR data and the MAP model output are strikingly similar, especially in terms of amplitude. We interpret the Lake Bosumtwi record as driven by a combination of insolation and glacial-interglacial climate variability latest since the Mid-Brunhes transition.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Lake Bosumtwi; ICDP; African Climate Change; ITCZ-dynamics

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## Trend analysis of Alpine spring discharge in Austria: Interplay between climate and catchment characteristics

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Alpine springs play a critical role in water supply systems across mountainous regions and can also serve as key indicators of environmental change and related part of the water cycle. In this study, we analyzed a 24-year historic dataset of spring discharge (1997 to 2020) from 29 monitoring stations operated by the Austrian Hydrographic Service. Our evaluation focused on trends in the volume and timing of both mean and extreme flows throughout the Austrian Alps, where mean catchment elevations reach as high as 2500 meters above sea level.

After clustering the springs into distinct groups based on the Pardé coefficient and autocorrelation analysis, the Mann-Kendall test and Theil-Sen slope estimator were used to assess trends. Findings indicated that springs under nival regimes, primarily driven by snowmelt, have experienced significant increases in winter discharges. The analysis also revealed variations in summer discharge trends, identifying two primary groups: springs at higher elevations in the western Austrian Alps showing positive discharge trends, and springs in the eastern Northern Alps where summer discharges have declined. Furthermore, we observed shifts in the timing of peak and minimum flows, suggesting changes in timing of the hydrological cycles. A general increase or decrease in spring discharge over this period is however not deduced from the data. By integrating these hydrological observations with regional precipitation trends, the study deepened the understanding of the interplay between meteorological and hydro(geo)logical dynamics, providing new insights into how climatic variables affect the sensitive Alpine runoff. These results highlight the complexity and regional variability of mountain water systems' responses to climate change, underscoring the necessity for adaptive water resource management strategies in these regions.

This study makes a significant contribution to ongoing efforts aimed at modeling and predicting the impacts of climate change on Alpine hydrology. It highlights the critical need for continued monitoring and advanced analytical methodologies to understand the complex relationships between climatic factors and hydrological responses in high-altitude environments.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Quellschüttung, Trendanalyse, Klimawandel, Hydrometeorologische Indizes*



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## Anthropocene Geology

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The Anthropocene Working Group (AWG) of the Subcommission on Quaternary Stratigraphy (SQS) of the International Commission on Stratigraphy (ICS) was founded in 2009 to investigate the potential of the Anthropocene as a chronostratigraphic unit of the Geological Time Scale. After more than 14 years of work, many key publications and hot discussions both within and outside the AWG, and several rounds of voting, the AWG concluded by great majority that the Anthropocene concept has stratigraphic reality and that a formal GSSP definition is pragmatic and suitable at the mid-twentieth century. This coincides with the Great Acceleration of Earth System Sciences that resulted in a dominance of human influence on the Earth System. The resulting GSSP proposal is located in Crawford Lake (Canada) sediment core with the base of the Anthropocene marked by an upturn in plutonium coincident with autumn 1952. However, during the years of AWG investigations, criticisms from outside and a minority group within the AWG opposed to the AWG majority consensus and published results of the AWG (see Zalasiewicz et al., 2024) and have undermined the significance, importance and usefulness of the Anthropocene as a (chrono)stratigraphic unit. Finally, the SQS rejected the proposal of an Anthropocene epoch/series and a Crawfordian age/stage, supported by the ICS and an IUGS official statement (IUGS, 2024), not without noting that the Anthropocene "remains an invaluable descriptor in human-environment interactions" and "will continue to be widely used not only by Earth and environmental scientists" (IUGS extended statement, March 20, 2024, <https://www.iugs.org/>). Beyond its debated geological implications, the term has evolved into a symbol emblematic of global change, and the current climate and ecological crises. An argument of prominent critics is that the AWG is politically and not scientifically motivated when dealing with the Anthropocene. However, a political dimension is implicitly imposed on both, the Anthropocene supporters but also at the Anthropocene sceptics. Rejection of the Anthropocene proposal by the geological community was partly interpreted outside of the geosciences as a rejection of the scale of the current global crises. Research into the Anthropocene has resulted in awareness and engagement of the discipline in a crisis for which geology has some liability. Hence, one may interpret geological research in the Anthropocene sedimentology and stratigraphy as a timely societal and interdisciplinary mission for the geosciences.

Zalasiewicz, J. et al., in press. *The Anthropocene within the Geological Time Scale: a response to fundamental questions*. *Episodes* 2024; 47(1), 65-83. <https://doi.org/10.18814/epiugs/2023/023025>

**Session:** DEUQUA Session: Anthropogenic impact on the development of landscapes

**Keywords:** Anthropocene, stratigraphy, environment, epoch, bomb spike

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## Integrated geological map of the East Eifel Volcanic Field (EEVF)

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The Quaternary East Eifel Volcanic Field (EEVF) is an area that is subject to a wide variety of land use and economic interests. Many of these, such as the search for drinking water, CO<sub>2</sub>-extraction and mineral mining, rely on the availability of precise geological information about both the shallow subsurface and the deeper underground. In addition, several upcoming research projects in the area of the EEVF focus on scientific and applied geological questions for which detailed knowledge of the regional geology is an important prerequisite. To meet these requirements, we prepare a new and integrated geological map of the EEVF including a total of 9 geological cross-sections of the subsurface. We not only focus on geology and tectonics but also on issues such as seismicity and volcanic gas geochemistry to yield insights on potentially active magmatic processes in the EEVF.

**Session:** *Classical Session: Topics in regional Quaternary science and applied Geology (in German)*

**Keywords:** *geological map, volcanism, seismicity, gas geochemistry, Eifel*

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## Die Donau-Auen stromab von Wien als Sedimentarchiv

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Menschliche Eingriffe in das System großer Flüsse haben Auswirkungen auf die Strömungsdynamik und damit auch auf den Sedimenttransport. Die anthropogenen Veränderungen an bedeutenden Wasserwegen gehen oft Jahrhunderte zurück und prägen heute die Morphologie von Flusslandschaften von der Quelle bis zur Mündung. Im Projekt "From Romans to the Anthropocene, from Carnuntum to Vienna: An Urban Anthropocene Field Lab" (WWTF ESR20-027), untersuchen wir siedlungstopographische Entwicklungen und geomorphologische Transformationen in den Donau-Auen zwischen Wien und Bratislava. Die Entwicklung eines alten Siedlungsraumes im Übergangsbereich vom zentralen zum östlichen Europa wird so unter Berücksichtigung historischer und sedimentologischer Aspekte betrachtet.

In Wien begann die konsequente Flussbegradigung mit entsprechenden Uferbefestigungen und Hochwasserschutzdämmen nach langen Planungsarbeiten im Jahre 1870. Mit den Regulierungsmaßnahmen war neben der Errichtung eines wirksamen Hochwasserschutzes auch die Gewinnung neuer Siedlungsgebiete verbunden. Die Wiener Donauregulierung (1870-1875) war deshalb neben der Schleifung der Stadtbefestigung (1858-1874) eine Voraussetzung der Entwicklung Wiens zur modernen Metropole.

Nach der vollständigen Flussregulierung entlang des gesamten österreichischen Donauabschnittes startete 1956 die Errichtung von Flusskraftwerken, die 1998 mit dem Kraftwerk Wien-Freudenau ihren (vorläufigen?) Endpunkt fand.

Flussregulierung und Kraftwerksbau wurden viele Jahrzehnte lang unter dem Gesichtspunkt ingenieurtechnischer Meiserleistungen und technologischen Fortschritts gesehen. In jüngerer Zeit wird aber vielerorts die Korrektur solcher wasserbaulichen Eingriffe diskutiert. Die Störung des kontinuierlichen Sedimenttransports von den Gebirgen bis zum Schwarzen Meer führt zu einer Reihe unbeabsichtigter Effekte. Problematisch sind die rasche Eintiefung des Flussbetts als Folge des Sedimentdefizites ebenso wie die wachsenden Feinsedimentablagerungen im Staubereich der Kraftwerke.

In den Uferwällen stromab von Wien haben sich Donausedimente als Resultat natürlich-ausbalancierter wie auch anthropogen-gestörter Flussdynamik über einen Zeitraum von ca. zwei Jahrhunderten abgelagert. Die sedimentologische Analyse ufernaher Profile in den Donauauen ermöglicht daher Aussagen über schwankende Wasserspiegellagen, den Verlauf extremer Hochwasserereignisse, Änderungen im Korngrößenverhältnis des Hochwassersediments infolge technischer Eingriffe und epochen-spezifische Verschmutzung (Holzkohle, Koks, Kunststoffe etc.). Die Datierung einzelner Hochwasserereignisse erfolgt anhand von Artefakten und durch die Analyse radioaktiver Isotopen.

**Session:** DEUQUA Session: Anthropogenic impact on the development of landscapes

**Keywords:** Flussregulierung, Geomorphologie, Sedimentbalance, Siedlungstopographie, Uferrückbau

## Geochemical characterization of the Göstling formation in the Scheiblingbachgraben: Implications for climate change and hydrocarbon potential

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The lower Carnian Göstling and Reingraben formations form the basal part of the Upper Triassic succession in the Northern Calcareous Alps. Due to the presence of a *Konservat-Lagerstätte* in the Reingraben formation, a significant hydrocarbon source rock potential seemed possible. However, recent geochemical investigations have shown that the Reingraben formation only has a limited oil potential. In contrast, very little is known about the amount and type of organic matter in the underlying Göstling formation.

Therefore, the main aim of the present study is to characterize the organic matter in the Göstling formation, which is about 5 m thick and excellently exposed in the Scheiblingbachgraben near Großreifling (Styria). The Göstling formation consists of about 50 siliceous limestone beds, gradually evolving into thinly laminated dark mudstones. The siliceous limestones as well as the thin intercalated layers were sampled in detail for geochemical analysis. Additional samples were taken from the limestone of the underlying Reifling Formation and the mudstones of the overlying Reingraben formation to enable geochemical differentiation between the formations. From a total of 50 samples, TIC (total inorganic carbon), TS (total sulphur) and TOC (total organic carbon) contents were determined and Rock Eval pyrolysis was conducted to determine the hydrocarbon potential of all samples.

The laminated dark marls and claystones in the Göstling formation have locally very high TOC contents (max. 11 wt.%). Low  $T_{max}$  values of about 430°C suggest low thermal maturity and are consistent with low amounts of (free) S1 hydrocarbons (average 0.10 mg<sub>HC</sub>/g<sub>TOC</sub>). The slope of the linear regression of the amount of S2 hydrocarbons against TOC yields an average hydrogen index of 400 mg<sub>HC</sub>/g<sub>TOC</sub>. This indicates the presence of oil-prone Type II Kerogen. The lithologic change from the Reifling Formation to the Göstling formation is characterized by a strong increase in TOC. The middle part of the Göstling formation shows low TOC content, even in laminated dark layers, whereas the uppermost part shows the highest TOC content. The TOC content decreases again within the Reingraben formation.

The strata observed in the outcrop was deposited during the climate change of the late Triassic Carnian Pluvial Episode (CPE). In the course of the CPE carbonate platforms drowned and carbonate productivity decreased drastically, due to increased siliclastic input in the marine domain caused by increased precipitation. The laminated sediments of the Göstling and Reingraben formations overlying the limestone of the Reifling Formation reflect this change. Therefore, a detailed biomarker study of the organic rich layers will also form part of this work.

**Session:** *Pangeo workshop: Mineral Raw Materials, and Energy Transition*

**Keywords:** *Organic geochemistry, Carnian Pluvial Episode, Climate change, Göstling formation, Biomarkers*

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## Multiple Datierung eines Holozänen Bergsturzes am Stöttlbach in der Mieminger Kette (Nördliche Kalkalpen, Tirol).

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Der Bergsturz am Stöttlbach in der Mieminger Kette (Nördliche Kalkalpen) stellt ein bedeutendes geomorphologisches Ereignis in den österreichischen Alpen dar, bei dem es zu einem massiven Abbruch eines Felshangs kam. Die Ablagerung der Felslawine, die eine Fläche von 3,6 km<sup>2</sup> bedeckt und eine Kubatur von rund 21,5 Mio m<sup>3</sup> aufweist, kann eine relativ lange wissenschaftliche Forschungsgeschichte aufweisen. Sehr lange wurden die sehr eindrücklichen Ablagerungen sogar als eine Typlokalität des Gschnitzstadial geführt. Der Bergsturz befindet sich in räumlicher und zeitlicher Nähe zu anderen Massenbewegungen des Fernpass-Bergsturzclusters.

Diese Studie zielt darauf ab, das Ereignis genau zu datieren und den zeitlichen Kontext zu verstehen, indem eine Kombination fortschrittlicher Datierungsmethoden eingesetzt wird. Durch die Integration von Radiokohlenstoffdatierung, kosmogener Nuklidatierung und Dendrochronologie wird ein umfassender chronologischer Rahmen für den Bergsturz geschaffen.

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Die Integration dieser Datierungsmethoden ergibt eine valide Abschätzung der chronologischen Abfolge des Bergsturzes und der landschaftsformenden Prozesse nach dem Ereignis. Unsere Ergebnisse deuten darauf hin, dass sich das Ereignis vor etwa 4000 Jahren ereignete, mit anschließenden Stabilisierungsprozessen und anderen lokalen geomorphologischen Implikationen. Der multimethodische Ansatz verbessert nicht nur die Genauigkeit unserer Datierung sondern gibt auch Einblicke in die Landschaftsentwicklung nach dem Ereignis. Darüber hinaus können dadurch im Abgleich mit anderen Forschungsdaten die klimatischen und tektonischen Rahmenbedingungen diskutiert werden, die Zeitpunkt und Dynamik des Bergsturzes beeinflusst haben könnten. Diese Forschungsarbeit unterstreicht, wie wichtig es ist, mehrere Datierungstechniken einzusetzen, um einen robusten chronologischen Rahmen für komplexe geologische Ereignisse zu schaffen.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Fossile Baumstämme, Bergsturz, Holozän, Multiple Datierung, Landschaftsgeschichte*

Winkler, Gerfried<sup>1</sup>; Seelig, Simon<sup>1</sup>; Seelig, Magdalena<sup>1</sup>; Vremec, Matevz<sup>1</sup>; Wagner, Thomas<sup>1</sup>; Haslinger, Klaus<sup>2</sup>; Avian, Michael<sup>2</sup>

## Das Abflussverhalten von Blockgletschern und übergeordneter alpiner Einzugsgebiete – ein Blick in die Zukunft

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Die Alpen sind in besonders hohem Maße von den Auswirkungen des Klimawandels betroffen. Insbesondere das Abflussverhalten der Gebirgsbäche und -flüsse verändert sich infolge zunehmender Extremwetterereignisse wie Starkniederschläge oder Dürreperioden, veränderter Schneedeckendynamik, des Abschmelzens der Gletscher und des Auftauens alpiner Permafrosts. Regional nehmen Schuttakkumulationen wie Blockgletscher eine zentrale hydro(geo)logische Rolle ein, deren Porenraum Niederschlagswasser als Grundwasser speichert und mit zeitlicher Verzögerung wieder abgibt. Die vorliegende Studie liefert Erkenntnisse zum Abflussverhalten von Blockgletschern und deren Einfluss auf übergeordnete Einzugsgebiete bis zu einer Fläche von 200 km<sup>2</sup>. Ausgewählt wurden fünf Regionen mit unterschiedlichen meteorologischen Gegebenheiten entlang des österreichischen Alpenhauptkamms. Das Abflussverhalten von insgesamt 15 alpinen Einzugsgebieten (3 pro Region) wurde mittels Niederschlags-Abfluss-Modellierung simuliert. Die Ergebnisse der Modellierung wurden mit kontinuierlichen Abflussaufzeichnungen und Satellitendaten abgeglichen und durch Auswertung stabiler Isotope (2H, 18O) verifiziert. Prognosen zum zukünftigen Abflussverhalten wurden anhand von 3 Klimaszenarien (RCP 2.6, RCP 4.5, RCP 8.5) mit insgesamt 40 Modellläufen bis ins Jahr 2099 erstellt und die wasserwirtschaftlichen Implikationen diskutiert. Die Ergebnisse zeigen zukünftig höhere Wasserführung während der Wintermonate, Verlagerung der Spitzenabflüsse ins Frühjahr und geringere Abflüsse während der Sommermonate. Schnee erwies sich als die einflussreichste und zukünftig variabelste Grundwasserneubildungskomponente. Die Veränderungen der Abflussdynamik sind regional im österreichischen Alpenraum unterschiedlich und hängen von den lokalen klimatischen und hydrogeologischen Gegebenheiten ab. Auf Basis der Ergebnisse lassen sich die Wasserressourcen und ihre zukünftigen Änderungen durch den Klimawandel auf regionaler Ebene abschätzen.

**Session:** *Pangeo workshop: Earth Surface Dynamics*

**Keywords:** *Abflussverhalten, alpine Einzugsgebiete, Blockgletscher, Klimawandel*

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## Entangled external and internal controls on periglacial alluvial fan evolution: the Late Pleistocene Senne and Heller fans in the Münsterland Embayment and Elbe Valley (Germany)

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The morphology and depositional architecture of periglacial alluvial fans represent the interplay of external controls (tectonics and climate) with internal processes such as channel migration and lobe switching. However, the nature of this interaction is poorly understood. Here we present sedimentological data from two different Late Pleistocene alluvial-fan systems. The studied fans developed under similar tectonic and climate conditions, however, differ in size and drainage area, allowing to estimate the role of climate, tectonic and autogenic controls on flow processes and facies architecture. Both fans represent rather small tributary-junction fan systems that developed over a short time period. Such systems rapidly respond to climate change and the relatively low complexity of fans is well comparable to experimental fans.

Luminescence dating was used to determine the timing of fan onset and aggradation rates. Fan onset occurred in response to climate change at the end of MIS 3 when temperatures decreased and periglacial climate conditions were established in northern central Europe. A related increase in sediment supply and strongly variable precipitation patterns probably promoted fan formation. The sand-rich, steep sheetflood-dominated Heller fan (5°-17°) is related to a larger, low-gradient fan catchment. The steeper, dip-slope catchment of the Senne fan enhanced stream gradients and promoted the transport of coarser-grained sediments. This fan has a lower gradient slope (2-6°) and is dominated by channelized flows, alternating with periods of unconfined sheetfloods.

The major period of fan aggradation was approximately between 33-18 ka. Sediment mobilization probably occurred through sporadic high-energy floods during snowmelt, rapidly filling the available accommodation space. The highest aggradation rates are recorded from the early stage of fan building, during which more than 35 m thick sediments accumulated within a few thousand years. Meter-scale coarsening-upward successions, characterized by sandy sheetflood deposits at the base, overlain by multilateral or smaller single-storey gravelly channel fills are related to high-frequency climatic fluctuations or seasonal fluctuations in water and sediment supply. These coarsening-upward successions are commonly bounded by a paleo-active layer, from which ice-wedge casts penetrate downwards. The recurrent pattern of multistorey, multilateral and single-storey channel bodies with a lateral offset to vertical stacking pattern most probably was controlled by autogenic switch in avulsion-dominated systems.

The change in deposition from alluvial-dominated processes to aeolian sedimentation with minor alluvial influences records alternations of dry and ephemeral wetter phases that are related to rapid climatic variations. The main phase of aeolian sand-sheet deposition probably correlates with Heinrich event H1 between approximately 18-16 ka and reflects sedimentation in response to aridification and high mean wind speeds.

*Winsemann, J., Hartmann, T., Lang, J., Fälber, R., Lauer, T. (2022): Depositional architecture and aggradation rates of sand-rich, supercritical alluvial fans: control by autogenic processes or high-frequency climatic oscillations? *Sedimentary Geology* 440, 106238. <https://doi.org/10.1016/j.sedgeo.2022.106238>.*

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** alluvial fan, periglacial, Late Pleistocene

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## Tectonics and landscape evolution in the Gurktal Alps: New data, models and open questions

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The Gurktal Alps are a key region to understand the tectonic and geomorphological evolution of the Eastern Alps but their exhumation, erosion and (de)glaciation history remain poorly constrained. Here we present (a) new low-temperature thermochronological data and thermokinematic models that provide new insights into the tectonic evolution of the Eastern Alps (Wölfler et al., 2023), (b) the first catchment-wide <sup>10</sup>Be-derived erosion rates from the Nock Mountains (Hampel et al., submitted) and (c) the first <sup>10</sup>Be surface exposure ages from glacially polished quartz veins (Wölfler et al., 2022).

With respect to the exhumation history, our thermochronological data and thermokinematic models revealed that Austroalpine units located at a high structural level and farther away from the Adriatic indenter cooled through the zircon fission track (ZFT) closure temperature in the Late Cretaceous and have resided at depths of ≤6-7 km since then. Thermokinematic modelling constrained that these units experienced enhanced exhumation between ~99 and ~83 Ma due to syn- to late-orogenic Late Cretaceous extension. After a phase of slow exhumation, the exhumation rate increased to ~0.16 km/Ma at ~34 Ma due to the onset of the Europe-Adria collision. In contrast, ZFT ages from units at a lower structural level and near the indenter indicate cooling during the Eocene. These units were rapidly exhumed from ~44 to ~39 Ma during an Eocene phase of shortening prior to the Europe-Adria collision. After slow exhumation between ~39 and ~18 Ma, the exhumation rate increased to ~0.27 km/Ma in the wake of Miocene escape tectonics in the Eastern Alps.

A comparison between exhumation rates derived from thermochronology and catchment-wide <sup>10</sup>Be erosion rates reveals that long-term and short-term erosion rates are remarkably similar. In the central Nock Mountains, the average <sup>10</sup>Be erosion rate (~170 mm/ka) is almost identical to the average exhumation rate since the Oligocene (~160 mm/ka). The southern Nock Mountains show a higher <sup>10</sup>Be rate (~200 mm/ka) and a higher long-term exhumation rate (~270 mm/ka). The agreement between short-term and long-term erosion rates suggests that average erosion rates in the Nock Mountains did not change significantly during the late Cenozoic.

Our <sup>10</sup>Be exposure ages from glacially polished quartz veins provide the first quantitative age constraints on the deglaciation history in the Gurktal Alps, where mapped and modelled LGM and Late-Glacial ice extents show large discrepancies. According to our data, deglaciation of the Gurktal Alps occurred between 16 and 14 ka, which questions the mapped LGM extent (van Husen, 2011) but agrees with predictions from ice-sheet models (Seguinot et al., 2018). This finding suggests that ice-sheet models may have overestimated the LGM ice extent in the easternmost Alps. Our results highlight the need for more age data from the eastern Alps and for a reappraisal of the LGM ice extent and the deglaciation history. Our own future work will include additional sampling in the former region of the Drau valley glacier and in the Lavanttal Alps.

**Session:** Pangeo workshop: Regional Geology

**Keywords:** Low-temperature thermochronology, catchment-wide <sup>10</sup>Be erosion rates, <sup>10</sup>Be exposure ages



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## Middle to late Holocene climatic changes in the Dominican Republic, Caribbean Region, deduced from ostracode and coral stable oxygen and carbon isotope values

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The tropical hydrologic cycle plays a critical role in low-latitude climate dynamics as it provides one of the most significant moisture sources globally and has proven to influence high-latitude climate conditions, too. Our ability to predict future environmental changes benefits, therefore, from the understanding of timing and causes of precipitation variations in tropical areas during the past. Records of tropical hydroclimate variability are, however, insufficient in number, distribution, and temporal length and therefore limit the understanding of past precipitation changes in many tropical regions such as the Caribbean region. Also, proxy records reveal whether a coherent, interhemispheric pattern of millennial-scale precipitation variability that is linked to orbital forcing during the e.g., Holocene, or they reflect a more complex signal that is largely attributable to local-regional influences superimposing the large scale oceanic-atmospheric trend.

Our study area, the hyperhaline lake Lago Enriquillo, lies in a semi-arid region and is characterized by strong seasonal contrasts in precipitation, intense evaporation, and severe tropical cyclone impacts resulting in rapid lake level fluctuations and salinity changes. The lake is therefore anticipated to represent an ideal archive of hydroclimate variability recorded by stable oxygen and carbon isotopes ( $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$ ). The present study aims on the understanding of controls on the  $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$  composition of ostracode carbonate precipitated in Lago Enriquillo.

Modern ostracodes were collected by surface sediment sampling along different water depths in March and September 2022. Also, lake water was collected for measurements stable isotopes ( $\delta^{18}\text{O}$ ,  $\delta^2\text{H}$ ,  $\delta^{13}\text{C}_{\text{DIC}}$ ) and major anions and cations. Stable oxygen and carbon isotopic signatures of ostracode valves were analysed of different ostracode species (*Cyprideis similis*, *C. edentata*, *Perissocytheridea cribrosa*, *Thalassocypria cf. sarbui*) which have been proven to show seasonal differences in their temporal-spatial distribution.

The results show that the variability of  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values of modern ostracodes is large between the species, which can be explained by differences in spatial variability of the lake isotopic composition, difference in microhabitats, and/or life cycles of the species, but is low between the seasons similar to the lake water. If these data are compared with  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  records from fossil skeletal carbonates (ostracodes, corals) of single species and colonies, respectively, a long-term trend of decreasing  $\delta^{13}\text{C}$  and increasing  $\delta^{18}\text{O}$  values is shown. The  $\delta^{18}\text{O}$  record is similar to  $\delta^{18}\text{O}$  variations of the Haitian Lake Miragoane, which is interpreted to reflect a change from wetter climatic conditions during the early to middle Holocene followed by long-term drying trend in the late Holocene. This variation is explained by orbitally induced (Milankovitch) variations in seasonal insolation which modified the intensity of the annual (hydrological) cycle. Importantly, the trend in  $\delta^{18}\text{O}$  (and  $\delta^{13}\text{C}$ ) of Lake Enriquillo is independent to the considered organism group and whether fully marine conditions or lacustrine conditions prevailed during calcification. This probably results from a long residence time of the lake water of the closed basin lake Lago Enriquillo.

**Session:** DEUQUA Session: Terrestrial records of paleoenvironments and – climates

**Keywords:** Holocene, Tropics, lake, stable oxygen isotopes, biogenic carbonates

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## Preliminary geochemical results from a gravity core from Stechlinsee in northeastern Germany

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Northeastern Germany is one of the driest regions in Germany. Due to global warming, droughts are projected to further increase while groundwater levels already decreased significantly. As the area is characterized by many postglacial lakes, paleoclimate studies using lake sediments can help to provide a long-term perspective on climate changes and to potentially anticipate future impacts on the lake ecosystems. This study aims to evaluate the potential of Stechlinsee as an archive for paleoclimate and paleoenvironmental reconstructions using sedimentological, geochemical, and particularly lipid biomarker proxies. We present preliminary results from a 95 cm long gravity core. While numeric age control for the sediments is not yet available, we estimate the core to cover roughly the last 500 years. The bottom part of the core shows an increase in P probably related to settlements and land use. A distinct Pb peak at ~50 cm depth might be associated with the establishment of a glass production facility in 1737 CE. Thereafter, an increase in clay, Al, Mg and K can be explained with the construction of an artificial channel from 1745 to 1751 CE that was needed for wood transportation. First results of the *n*-alkane analyses show that concentrations are high, preservation generally good (OEP >5), and high Paq indicates that both aquatic and terrestrial compounds are available. Compound specific  $\delta^2\text{H}$  analyses are in progress to establish a proxy for hydroclimate, as well as polycyclic aromatic hydrocarbons (PAH) to explore human activities in the area.

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## Reconstructing past climate from Loess-Palaeosol Sequences: Challenges of calibration functions

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Loess-Palaeosol-Sequences (LPS) are widespread geoarchives connecting climate subsystems across continents. They can record paleo-environmental changes and terrestrial system responses to external forcing. Yet, our knowledge of terrestrial palaeo-climates remains incomplete, challenging the reconstruction of terrestrial environments.

To overcome this, multiple climofunctions have been suggested for qualitative and quantitative reconstruction of precipitation, temperature and aridity from LPS, and all have their theoretical concepts, special applications and come with specific limitations and challenges. Here we provide an overview of frequently applied climofunctions. In a second step, we test several rock magnetic methods for their applicability in paleosols and provide a dataset from Europe. Our results show that especially rock magnetic properties prove useful even considering small climate gradients (10s of mm/a in precipitation, less than 1°C temperature), but their general applicability seems not possible.

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