

TOPO-EUROPE 2026

Abstract booklet

Hungary, Sopron

6th October 2026. – 9th October 2026



TOPO-EUROPE meeting, 06/10 – 09/10, 2026, Sopron



TOPO-EUROPE Workshop, 2026
Sopron,
Summary of the submitted abstracts

Editor:
Kata Süle

Vision AI Data Factory for Legacy Subsurface Records

Hawkar Ali Abdulhaq^{1,2,4,*}, Andrej Lapanje⁶, David Gerčar⁶, Blaž Bahar⁶, Nina Rman⁶, Njeru Rita Mwendia^{3,4},

János Szanyi^{4,5}

1 Department of Atmospheric and Geospatial Data Sciences, University of Szeged, Egyetem utca 2, 6722 Szeged, Hungary

2 LLMfor Impact B.V., Fluwelen Burgwal 58, 2511 CJ Den Haag, The Netherlands

3 HUN-REN Institute of Earth Physics and Space Science, 9400 Sopron, Csatkai E. u. 6-8., Hungary

4 HUN-REN TKI Rybach Research Centre for Renewable Geo-energy, Hungary

5 University of Szeged, Szeged, Hungary

6 Geological Survey of Slovenia, Ljubljana, Slovenia

** Corresponding author: hawkar.ali.abdulhaq@szte.hu*

Geological surveys and applied geoscience organizations hold extensive borehole and well-log archives that contain interval-level lithology, depth, stratigraphy, geotechnical descriptions, drilling notes, and material classifications needed for hydrogeology, engineering geology, groundwater management, and shallow geothermal assessment, but much of this evidence remains locked in scanned or semi-structured PDF files that are difficult to search, compare, validate, map, or reuse in modern subsurface databases. This study presents a controlled vision-AI workflow that converts such legacy geological records into structured, machine-readable interval data for geothermal-ready database development; its aim is not to calculate geothermal potential directly, but to renovate historical observations so they can support shallow geothermal screening, subsurface characterization, and applied geoscience decision-making. The workflow combines visual inspection of rendered PDF pages, staged large language model extraction, lithology normalization, controlled material-category assignment, rule-based validation, and expert geological quality control. It was applied to Slovenian geological well-log records, where the full operational set included 3,289 source records and produced 27,290 extracted interval records to a maximum depth of 556 m. The documents covered regular tabular logs, very deep wells, logs where depth was encoded graphically rather than in numeric rows, and hand-sketched borehole logs, so the method treats the rendered page as primary evidence because geological meaning is often carried by layout, depth columns, interval boundaries, symbols, and visual structure. Each extracted interval is stored with source identifiers, page reference, depth interval, raw lithology, normalized and simplified lithology, controlled material category, optional stratigraphy and geotechnical fields, confidence information, and a link to the source PDF. Outputs are provided as JSON and CSV tables, and

expert review refined rules for Slovenian lithology terminology, main-noun classification, compound geotechnical symbols, material categories, and character-recognition or encoding errors. By providing structured geological context for reservoir and interval selection, the resulting database can also complement investigations on processes affecting reinjection performance. For publication and reproducibility, an approved public subset was deposited separately with 134 source PDFs, 1,374 interval records, structured JSON and CSV outputs, companion source-to-table figures, and DOI <https://doi.org/10.5281/zenodo.21300936>. The results show that vision AI and large language models, when used in an auditable expert-in-the-loop workflow, can transform legacy geological archives into structured, reviewable, database-ready subsurface data that strengthen shallow geothermal planning, groundwater and environmental assessment, geospatial subsurface mapping, and geological survey data infrastructure.

Keywords: legacy borehole logs; shallow geothermal databases; subsurface data; vision AI; geological data renovation; lithology normalization; structured JSON; expert quality control

Lithosphere structure and evolution: A global perspective

Irina M. ARTEMIEVA

(1) Zhejiang Deep-time Digital Earth International Research Center, China

(2) International Lithosphere Centre, Denmark

The lithosphere concept, despite widely used by various groups of the geoscience community, remains a matter of a strong controversy. The controversy primarily concerns the lithosphere-aesthenosphere transition, the depth to which remains a matter of large controversy. The controversy also includes structural and compositional heterogeneity of the lithospheric mantle in various geodynamic settings, the extent to which the lithosphere can be modified by mantle convection and plate tectonics processes, and if, how and where it may possibly be destroyed. This presentation will provide examples of lithosphere structure from various tectonic settings globally and will compare results from thermal studies, seismic tomography, gravity modelling, and petrological studies of mantle-derived xenoliths.

TopoAsia: A new international geoscience program on 4-D topography evolution in Asia linked to deep Earth and surface processes

(1) Zhejiang Deep-time Digital Earth International Research Center, China

(2) International Lithosphere Centre, Denmark

Asia encompasses some of the most geologically diverse and topographically dynamic regions on Earth, including ancient Archean cratons, impacted by Large Igneous Provinces in Siberia and India, Paleozoic orogenic belts of Central Asia and large basins of West Siberia, China and India, the Meso-Cenozoic Tethyan orogenic belt with the Tibetan, Anatolian and Iranian Plateaus, the active Baikal Rift, active subduction systems with associated back-arc basins in the Indian and Pacific Oceans, and plate boundaries of various types, including the enigmatic diffuse plate boundary that links the Arctic shelf to the Pacific Ocean. This complex landscape reflects a long history of interaction between deep mantle dynamics and plate tectonics, further modified by surface processes like erosion, sedimentation, and climate-driven feedbacks.

TopoAsia, a new international multidisciplinary program in geosciences launched at the Shanghai meeting in October 2025, focuses on 4-D topography evolution in Asia triggered by plate tectonics processes and mantle convection instabilities, and further modulated by surface processes. The geodynamic complexity of the system, the size of the region, and the time-scale of the processes call for a closely integrated set of interdisciplinary studies across tectonic borders and geoscience disciplines.

TopoAsia is proud to build up on the experience of TopoEurope. The program makes its first steps and invites geoscientists from all geoscience disciplines to take part in the TopoAsia research, building on the extensive multi-disciplinary expertise and success of the TopoEurope program.

The effect of depth, temperature and pressure dependency of rock thermal properties on the performance of deep borehole heat exchangers: example from the Pannonian Basin

Eszter Békési¹, Kristóf Porkoláb¹, László Lenkey^{1,2}

e-mail of corresponding author: bekesi.eszter@epss.hun-ren.hu

1 HUN-REN Institute of Earth Physics and Space Science, Sopron, Hungary

2 Department of Geophysics and Space Science, Eötvös Loránd University, Budapest, Hungary

Deep borehole heat exchangers (DBHEs) are low-risk options for geothermal energy utilization that can be installed in a wide range of geological environments. In DBHEs, the heat carrier fluid is heated through heat conduction from the surrounding rock, thus system performance is primarily controlled by the thermal conductivity of the geological environment. In this study we investigated the effect of depth- temperature- and pressure- (T_p) dependent rock thermal conductivity on the performance of DBHEs, through the case of siliciclastic sedimentary formations in the Pannonian Basin. Bulk thermal conductivity profiles were calculated using porosity-depth trends and thermal conductivity measurements on sandstones and shales, collected from literature data and further corrected for in situ T_p conditions. Additionally, thermal conductivity profiles were estimated from well logs to demonstrate realistic cases with complex lithologies. Results show significant (up to 35 %) differences in DBHE performance estimates between models with constant and depth ($\sim$ porosity)-dependent thermal conductivity profiles and sand/shale lithologies. Depth-dependent models perform better due to increasing thermal conductivity (governed by decreasing porosity) with depth, enhancing heat transfer in the deeper part of the DBHE, highlighting favourable settings in wells penetrating basement rocks with high thermal conductivity. Models with depth-dependent thermal conductivity profiles neglecting T_p dependency overestimate DBHE performance, related to the generally higher input thermal conductivity profiles compared to T_p corrected cases. The T_p dependence of thermal conductivity becomes more relevant with increasing DBHE depth and high thermal conductivities (e.g. sandstones), thus should be considered in performance modelling for DBHE depth $> \sim 2$ km, further depending on local geothermal and geological conditions. This study demonstrates that the adequate performance evaluation of DBHE projects requires carefully selected input thermal conductivity profiles considering in situ T_p conditions, preferably estimated directly from well logs or local thermal conductivity measurements.

Comparative study on CO₂ accumulation, storage and budget in the lithospheric mantle and in the lower crust-what does the Pannonian basin case study indicate?

Márta Berkesi and members of the HUN-REN FI FluidsByDepth Lendület research group

The subcontinental lithospheric mantle and the lower continental crust should be viewed as distinct but geodynamically connected reservoirs for mantle-derived fluids. In the subcontinental mantle, carbon is concentrated mainly in CO₂-rich fluids and volatile-bearing, low-degree melts. During post-rift cooling, asthenospheric material is progressively incorporated into the thickening lithosphere (e.g., Hencz et al., 2026). During lithospherization, carbon remains comparatively incompatible and becomes enriched in the deep lithosphere. The newly accreted lithospheric mantle, therefore, acts simultaneously as a long-lived carbon reservoir and as a continuing source of mobile fluid.

Mantle xenoliths indicate that CO₂-rich fluids are distributed through a substantial vertical interval of the lithospheric mantle column and can be trapped in rock-forming silicates as high-density fluid inclusions. Their noble-gas compositions retain mantle signature, while their association with silicate components shows that these fluids are not chemically inert: they can dissolve, transport and redistribute elements during metasomatism. At basin scale, progressive lithospheric thickening may add large volumes of CO₂-bearing mantle material over millions of years. The mantle reservoir is thus spatially extensive and continuously replenished during thermal relaxation, although only part of its carbon is likely to migrate upward at any given time.

When mantle fluids cross the Moho, the lower crust is not merely a passive transit zone. At granulite-facies conditions, CO₂-rich fluids can be incorporated into growing garnet together with graphite and accessory minerals. Garnet consequently provides a mineral-scale storage mechanism capable of preserving mantle-derived CO₂ for millions of years, even after the regional pressure–temperature field has changed. Compared with the broad, volumetric mantle reservoir, lower-crustal storage is mostly mineral-controlled (Spránitz et al., in prep.). Its importance lies in the possibility of delayed release: decompression and metastable garnet breakdown (e.g., Porkoláb et al., 2026) can liberate inherited mantle carbon long after extension, fluid entrapment and magmatism have ceased.

Our evidence distinguishes several stages rather than a single direct mantle-to-surface pathway. CO₂ may first accumulate in partially molten asthenosphere, become incorporated into newly formed lithospheric mantle, migrate into and be temporarily retained by the lower crust, and only later enter upper-crustal groundwater or escape at the surface. Helium and carbon isotope systematics show that modern groundwater gases can contain a detectable mantle component (Spránitz et al., under review), but their compositions are commonly modified by mixing with

radiogenic helium, sedimentary organic carbon, carbonate-derived carbon and atmospheric gases. Nano channels at the deep lithosphere (Lange et al., 2026), formed by fluid-rock reactions, former volcanic conduits, deep faults and deformation zones may provide the permeability needed to connect these reservoirs.

References:

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Porkoláb et al. (2026) Scientific Reports, <https://doi.org/10.1038/s41598-026-43790-4>

New LAB map in central-eastern Europe based on integrated geophysical modelling

Miroslav Bielik (1,2), Jana Dérerová (2), Michal Grinč (3), Barbora Šimonová (4), Dominika Godová (2), Hermann Zeyen (5), Jozef Hók (6)

(1) Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, P. O. Box 106, 840 05 Bratislava, Slovakia

(2) Department of Engineering Geology, Hydrology and Applied Geophysics, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 842 15 Bratislava 4, Slovakia

(3) INSET s.r.o., Lucemburská 1170/7, 130 00 Praha 3, Czech Republic

(4) Ministry of Environment of the Slovak Republic, Námestie L. Štúra 1. 812 35 Bratislava, Slovakia

(5) Département des Sciences de la Terre Université Paris-Saclay, CNRS, Bat. 504, F-91405 Orsay Cedex, France

(6) Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 842 15 Bratislava 4, Slovakia

We present the analysis and summary of the results obtained by the application of 2-D integrated lithospheric modelling, assuming local isostasy, along 11 profiles, that pass across the Carpathian-Pannonian region and their surrounding units. The results are illustrated on a new map of lithosphere-asthenosphere boundary depth. The Carpathians are characterized by significant changes in the lithospheric thickness both across and along this mountain chain. The internal parts of the Carpathian arc represented by moderately thickened lithosphere (~140 km on average), whereas in their external parts LAB depth reaches up to 240 km. Along the Carpathians, the lithospheric thickness increases from the Western Carpathians (140-200) via the Eastern Carpathians (240 km) up to the Vrancea zone, where the largest LAB depth of 300 km is modelled. No lithosphere thickening was found in the westernmost part of the Western Carpathians. Here, the average thickness of the lithosphere is only ~100 km. The thinnest lithosphere was modelled in the Pannonian Basin (60-100 km). In the Transylvanian Basin it thickens from about 120 to 170 km. The other modelled areas are the East European Craton (100-180 km), the West European Palaeozoic platform (90-160 km), the Trans European Suture Zone (150-240 km), the Apuseni Mts. (100-180 km), the Moesian Platform (160-200 km), the Balkanides (160-180 km) and the Srednogorie and Rhodopes area (140 km on average). The results clearly show that the variations of the LAB depth are modified not only by the age of the tectonic units but also by ongoing geodynamic processes.

Species Diversity in Ecological Balance and Geobiological Feedbacks

BILGIN O.C.1

1 Department of Statistics, Faculty Science, Ataturk University, Erzurum, Turkey

Corresponding author: ocbilgin@atauni.edu.tr

The stability and functionality of ecosystems are contingent upon the biodiversity they contain. Species diversity plays a pivotal role in determining the complexity of ecological networks. Moreover, it has been demonstrated that biodiversity is instrumental in ensuring the stability of fundamental Earth system processes, including but not limited to the formation of soil, the cycling of nutrients, the hydrological cycle, the flow of energy, and the balance of atmospheric gases. Geobiological approaches that have emerged in recent years have facilitated a more profound comprehension of the interactions between living organisms and the geosphere. In particular, the role of biotic actors such as microorganisms, plants, and soil invertebrates on earth systems has become a central focus. The present study analyses the effect of species diversity on ecological balance and the resulting geobiological feedback mechanisms. It has been demonstrated that as species diversity increases, the resistance of ecosystems to environmental stress factors increases and post-disturbance recovery processes accelerate. To illustrate this point, it is important to note that plant species diversity has been shown to support organic matter accumulation and water infiltration in the soil through different root structures and mycorrhizal relationships. In contrast, microbial diversity plays a critical role in terms of the continuity of carbon and nitrogen cycles. The loss of species instigates cascading reactions within intricate feedback systems, thereby endangering the equilibrium of Earth's ecosystems. In this context, an interdisciplinary approach to the study of the multi-layered interactions between ecosystem components is of particular importance in terms of protecting biodiversity, especially in the face of pressures such as climate change, land use change, and pollution. This standpoint has the potential to facilitate the emergence of nature-based solutions and the development of sustainable land and resource management policies.

Assessing the role of orographic erosion in subduction dynamics using 2D thermomechanical numerical modelling

Fabiola Caso^{1,2}, Francesco Giuntoli³, Alessandro Petrocchia^{3,4}, Simone Pilia⁵, Pietro Sternai^{1,6}

1 Department of Earth and Environmental Sciences, University of Milano-Bicocca, Milan, Italy

2 now at Institute des Sciences de la Terre ISTerre, Université Grenoble Alpes, Gières, France

3 Dipartimento di Scienze Biologiche, Geologiche ed Ambientali-BiGeA, Università degli Studi di Bologna, Italy

4 Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, IRD, Géoazur, Valbonne, France

5 Earth Sciences Department, Khalifa University, PO Box 127788, Abu Dhabi, United Arab Emirates

6 Istituto Nazionale di Geofisica e Vulcanologia – INGV, Bologna, Italy

**correspondence: fabiola.caso@univ-grenoble-alpes.fr*

Although orographic erosion influences the strain pattern, the exhumation style and topographic evolution of crustal accretionary wedges, its interaction with subduction dynamics remains elusive. We use a fully coupled two-dimensional thermo-mechanical and landscape evolution numerical model to simulate an ocean-continent subduction system undergoing fluvial erosion driven by orographic precipitation. With our models, which account for lithospheric and asthenospheric dynamics, we systematically explore the effects of convergence velocity, continental crust thickness, lithospheric thermal thickness and orographic erosion rates. Consistent with previous studies, high convergence velocity (≥ 3 cm/yr), thin continental crust (≤ 30 km), and thick continental lithosphere (≥ 100 km) promote plate coupling and overriding plate compression, whereas low convergence velocity, thick continental crust and thin lithospheric mantle favour plate decoupling, slab rollback and upper plate extension. In models characterized by a convergence velocity of 1 cm/yr, a 30 km thick continental crust, and a 100 km thick thermal lithosphere, orographic erosion on the pro-wedge promotes plate decoupling, slab rollback, and trench retreat. The same tectonic configuration without orographic erosion or with orographic erosion on the retro-wedge remains in a compressional regime with upper-lower plate coupling. Summarizing, we demonstrate the control of orographic erosion on subduction dynamics, which is maximized when geodynamic settings approach the mechanical threshold between coupled and decoupled tectonic plates. These results emphasize the role of surface processes in governing the evolution of convergent margins.

Multi-scale constraints on magma ascent and volatile evolution during the Minoan eruption (Santorini, Greece): insights from vesicularity, Li–Cl geochemistry and Li diffusion in plagioclases

Maylis DUPONT DE DINECHIN, MTA-HUN-REN CSFK Lendület “Momentum” Pannonian Volcano Research Group, institute for Geological and Geochemical Research & ISTEP Sorbonne Université, dupontdedinechin.m@gmail.com

Hélène BALCONE-BOISSARD, ISTEP Sorbonne Université

Erwan MARTIN, ISTEP Sorbonne Université

Delphine CONTAMINE, LANIE CEA Saclay

The Late Bronze Age (Minoan) eruption of Santorini (Greece; VEI 7) is one of the largest silicic eruptions of the Holocene and provides an exceptional natural laboratory to investigate the mechanisms controlling transitions in eruptive style. The volatile evolution, magma ascent dynamics can explain the transition from a sustained Plinian column to pyroclastic density currents and the different phases.

We develop a multi-scale approach combining physical, geochemical and isotopic observations across the four eruptive phases (from phase 1 to phase 4). At the deposit scale, pyroclast density measurements are used to quantify vesicularity and its evolution throughout the eruption. At the melt scale, Li and Cl concentrations, together with Li isotopic compositions of melt inclusions and residual glasses, are used to track degassing and volatile redistribution. At the crystal scale, high-spatial-resolution Li profiles in plagioclase record chemical re-equilibration associated with magma ascent. Intracrystalline Li diffusion modelling is further employed to quantify diffusion timescales and estimate magma ascent rates immediately preceding eruption.

Our results reveal limited changes in major-element mineral chemistry throughout the eruption, whereas Li and Cl record volatile evolution. Residual glasses are depleted in Li relative to melt inclusions and display heavier $\delta^7\text{Li}$ signatures, while Cl systematics suggest fluid partitioning between melt, vapour and possibly saline brines. Most plagioclase crystals exhibit Li enrichment over their outer tens of micrometres, recording late-stage disequilibrium generated, maybe, by the presence and evolution of brine during decompression. Diffusion modelling indicates that these Li zoning patterns developed over short syn-eruptive timescales, providing quantitative constraints on magma ascent immediately before fragmentation.

By integrating observations from the deposit, melt and crystal scales, this study demonstrates that Li and Cl are complementary tracers of volatile evolution and magma dynamics. This multi-scale framework provides new quantitative constraints on the processes governing in long-lived silicic caldera systems and illustrates the potential of combining petrology, isotope geochemistry and diffusion chronometry to reconstruct the final stages preceding large explosive eruptions.

From Pastoralism to Geobiology: The Contribution of Animal Life to Earth Surface Dynamics

Nurinisa Esenbuga

Pastoralism is a land use that has significant impacts not only on human nutrition and economic production, but also on the physical and biochemical evolution of the Earth's surface. Grazing behaviour, mobility patterns, defecation, and direct interactions of animals with the soil play a decisive role in soil structure, nutrient cycles, vegetation composition, and erosion processes. These interactions can lead to the reorganisation of landforms, the formation of microhabitats, and changes in ecosystem functions over time. While the discipline of geobiology aims to understand the effects of biotic factors on geological processes, pastoral systems provide one of the most concrete examples of this relationship in the field. This study assesses the impact of pastoral systems on earth dynamics and argues that livestock should be considered not only as biological but also as geological agents. Particularly in arid and semi-arid regions, the topographic and biochemical changes observed as a function of grazing intensity and continuity provide important clues for understanding human-interactive geobiological processes. In this context, a holistic approach to assessing the interactions between livestock production and land systems is crucial both for sustainable land management and for understanding nature-culture relationships.

The Palæo Data Cube: A FAIR Framework for Deep-Time Earth System Data Inspired by Modern Earth Observations

Florian Franziskakis¹, Christian V  rard², S  bastien Castelltort², Gr  gory Giuliani¹

1 Institute for Environmental Sciences, University of Geneva, Boulevard Carl-Vogt 66, CH-1205 Geneva (florian.franziskakis@unige.ch)

2 Department of Earth Sciences, University of Geneva, Rue des Mara  chers 13, CH-1205 Geneva

Reconstructing Earth’s evolution across geological timescales requires access to spatially explicit deep-time datasets, yet their dissemination remains limited to isolated files with heterogeneous formats. This poster presents the Pal  o Data Cube (PDC), the first open framework applying concepts and technologies from modern Earth Observation (EO) data to deep-time Earth system data. Leveraging the PANALESIS plate tectonic model, the PDC integrates pal  ogeographic reconstructions and derived global products (e.g., crustal thickness, seafloor age, surface dynamics) over 45 time steps covering the last 545 million years (Phanerozoic).

By utilizing open standards such as GeoServer for spatiotemporal access, GeoNetwork for ISO-compliant metadata, and the SpatioTemporal Asset Catalog (STAC) for discovery, the PDC transforms static maps into a harmonized, FAIR-compliant environment. This architecture allows researchers to query, visualize, and analyze deep-time datasets using the same tools commonly used for present-day Digital Earth platforms, significantly enhancing reproducibility and interoperability in pal  oclimatology and geodynamics. Full documentation, access scripts, and tutorials are available at our GitHub repository: <https://palaeo-data-cube.readthedocs.io/en/latest/>.

Beyond its research applications, the Pal  o Data Cube represents a transformative tool for geoscience education by bridging the gap between deep-time reconstructions and modern remote sensing technologies. Because the PDC utilizes the same data standards and access protocols as current EO platforms (e.g., Copernicus), it enables students and educators to apply contemporary time-series analysis techniques to Earth’s deep past.

This approach is already implemented in the SPACE-GEOLOGY open course at the University of Geneva (<https://unige-cgeom.github.io/SPACE-GEOLOGY/>), where learners interactively explore Phanerozoic time-series of mean seafloor age, continental crust thickness, and lithospheric evolution. By treating deep-time data as analysis-ready data cubes, the PDC lowers the technical barrier for students to engage with complex geodynamic concepts, fostering a new generation of scientists capable of seamlessly integrating paleo-reconstructions with modern Earth system analysis. This educational dimension ensures that the "Digital Earth of the past" is not only a research infrastructure but also a foundational resource for training and curriculum development in Earth sciences.

EPOS, a community-driven research infrastructure for open access to interdisciplinary data and services from solid Earth science

Author: Lilli Freda

The European Plate Observing System (EPOS, <https://www.epos-eu.org/>) is a pan-European Research Infrastructure (RI) that enables interdisciplinary collaboration by providing integrated and open access to high-quality data, services, software, and computational resources for solid Earth science. Operated by a European Research Infrastructure Consortium (ERIC), EPOS adopts a federated governance model to ensure the coordination of its heterogeneous distributed resources. The challenge of long-term sustainability is addressed through a synergistic approach encompassing technical, legal, governance, and financial dimensions.

The EPOS Platform, fully compliant with the FAIR principles, serves as a multidisciplinary gateway, enabling seamless access to harmonized data and services provided by nearly 800 data providers across 26 European countries. The Platform is based on a federated architecture, rich metadata, and a service-oriented approach. By addressing challenges related to data interoperability and standardization, EPOS provides a unique point of access to the wealth of resources available in the solid Earth domain. This facilitates excellent science and supports the development of solutions to major societal challenges, including natural and anthropogenic hazard risk assessment and environmental sustainability. Available as an open-source software package, the Platform is envisioned to incorporate data analysis, processing, and advanced visualization tools.

Beyond its European dimension, EPOS embraces a global vision by fostering collaborations with international organizations and sister geoscience research infrastructures that share similar missions and objectives, including partners in the United States, Australia, and New Zealand. Building on these collaborations, EPOS aims to further expand its international network and contribute to the development of a globally federated research infrastructure, strengthening worldwide scientific collaboration and supporting planetary resilience.

International Lithosphere Program: mission and future frontiers

Taras Gerya¹, Qin Wang²

1 ILP President, Department of Earth and Planetary Sciences ETH Zurich, tgerya@ethz.ch

2 ILP Secretary General, School of Earth Sciences and Engineering, Nanjing University, qwang@nju.edu.cn

The International Lithosphere Program (ILP) is a joint scientific program of the International Union of Geodesy and Geophysics (IUGG) and the International Union of Geological Sciences (IUGS) founded in 1980. It serves as a platform for development of cross-disciplinary frontier research and networking initiatives in the fields of Earth sciences (geology, geodynamics, geochemistry, geophysics, geomorphology) and related disciplines spanning over environmental and climate sciences, ecology, biology and life sciences. The Lithosphere is the natural connection between the deep Earth and the Earth's surface and is the key topic for focused cooperation between all these disciplines. Cross-disciplinarity also spans over research approaches as breakthroughs in the study of the lithosphere can only be achieved through integration of imaging and monitoring, reconstruction and process modelling.

ILP stresses that as geologists and geophysicists, we have a better understanding of long-term geological processes and their impacts on environment and human society. Hence the ILP mission focuses on global frontier solid Earth Sciences and global resilient long-term society.

In the future, ILP will continue to advance fundamental lithosphere research and respond to the societal challenges. Through funding dedicated Task Forces and Coordination Committees, ILP will support the following four fields as a priority:

1. Global Earth observatory: Integration of geological-geophysical observations on a global scale for scientific and societal use;
2. Global resources: Origin and long-term availability of various resources linked to Solid Earth evolution processes;
3. Transdisciplinary science: Coupling solid Earth sciences to other disciplines (e.g., environmental science, soil science, public health);
4. Long-term future of Earth-life-human system: Linking solid Earth to life sciences with the unique long-term vision.

In addition, ILP will develop joint initiatives with the mother unions (starting from the Soil Science Initiative), establish collaborations with other global initiatives on both continental and oceanic lithosphere (ICDP, IODP, DDE), multiply resources by new networking (COST) and research (EU, ERC, etc.) initiatives, and encourage leadership and initiatives from young researchers.

Plume-lithosphere interaction and its variable control on Phanerozoic continental rifting and break-up

Alexander Koptev^{1,2}, Sierd Cloetingh^{2,3}, Qin Wang¹

1 School of Earth Sciences and Engineering, Nanjing University, Nanjing, China

2 HUN-REN Institute of Earth Physics and Space Science, Sopron, Hungary

3 Department of Earth Sciences, Utrecht University, Utrecht, Netherlands

Over recent decades, the causal relationship between mantle plumes and continental break-up has undergone substantial revision. The classical view that plume-induced Large Igneous Provinces (LIPs) drive supercontinent fragmentation has been progressively challenged by both observational and theoretical limitations. To reconcile these contradictions, we adopt a comparative analysis of Phanerozoic rift systems that were initiated above mantle plumes but followed divergent evolutionary paths. We first examine aborted rifts (e.g., West Siberian Rift System) and actively evolving rifts that have not achieved plate separation (e.g., East African Rift System), demonstrating that plume impingement alone is insufficient for lithospheric rupture. We then synthesize the major episodes of Pangea disintegration during the Mesozoic and Cenozoic, focusing on cases where successful break-up was temporally and spatially associated with LIP emplacement. Our synthesis reveals that plume-lithosphere interaction consistently exerts a significant yet non-deterministic influence on continental rupture, manifesting in three distinct geodynamic modes: (1) plume-triggered (e.g., Africa-North America separation), wherein plumes merely accelerate an ongoing rifting process, defining the timing but not the location of break-up; (2) plume-attracted (e.g., Africa-South America), wherein plumes act as rheological beacons that direct laterally propagating rupture toward pre-weakened domains; and (3) plume-produced (e.g., India-Madagascar), wherein plumes exert primary control over both the location and timing of continental separation. These findings challenge the end-member dichotomy between active plume-driven and passive far-field-driven rifting, as neither mantle plumes alone nor far-field extension alone guarantees successful break-up. Future research should refine the temporal resolution of plume-lithosphere interaction through integrated geochronological, geophysical, and numerical modelling, with particular attention to the interplay between plume-induced weakening, lithospheric heterogeneities, and far-field stress. We advocate for a framework that embraces the full spectrum of plume-lithosphere interactions and their diverse expressions in the geological record.

Ascent dynamics of primary mantle plumes: effect of phase changes at the mantle transition zone and generation of secondary plume

Alessio Lavecchia, Magdala Tesauro, Chiara Civiero, Zengsheng Wang, Alexander Koptev, István Kovács, Qin Wang, Marilena Filippucci, Sierd Cloetingh

Mantle plumes are generally viewed as continuous upwellings connecting the core-mantle boundary to the lithosphere, yet seismic observations increasingly indicate more complex flow patterns in proximity of the mantle transition zone (MTZ). We use two-dimensional thermochemical numerical models to investigate how plume excess temperature, eclogite content, and the Clapeyron slope of the 660-km discontinuity influence plume evolution. The simulations reproduce a range of ascent styles, from direct penetration of the MTZ to prolonged ponding beneath its base. Strongly negative Clapeyron slopes favor plume stagnation, whereas moderate eclogite contents enhance secondary plume generation by reducing plume density after phase transitions. In contrast, high eclogite fractions may produce additional stagnation horizons within or above the MTZ, leading to tertiary upwellings driven by thermal and compositional instabilities. These results highlight the MTZ as a dynamic filter controlling plume flow, providing a framework for interpreting complex seismic anomalies beneath hotspot regions.

Insights into the Roches-Genty ignimbrite in Martinique Island: stratigraphy, grain size distribution, geochemistry, and geochronology

Abigail Martens (1), Aurélie Germa (2), Sylvain Charbonnier (2), Xavier Quidelleur (3), Ashley Paschall (2)

(1) MTA–HUN-REN CSFK Lendület

(2) School of Geosciences, University of South Florida, Tampa, FL 33620, USA

(3) Université Paris-Saclay, CNRS, GEOPS, 91405 Orsay, France

The Roches-Genty ignimbrite represents the only documented ignimbrite deposit on Martinique and may present a large-volume explosive eruption that contrasts with the predominantly small-volume volcanism characteristic of the Lesser Antilles. Despite its significance, the deposit has remained largely understudied. We present new stratigraphic, grain-size distribution, geochemical, and geochronological data from the Dizac and Galocha pyroclastic deposits based on a 5 km transect across the southwestern peninsula of Martinique.

Field observations, supported by grain-size distributions and component analyses, reveal a sequence of sub-Plinian to Plinian eruption columns transitioning into pyroclastic density currents, followed by block-and-ash flow, lahar, ash-rich, and fallout deposits. Massive to poorly sorted pumice-rich deposits display variable grain-size distribution modes, reflecting changes in eruptive behaviour during emplacement. New $^{40}\text{Ar}/^{39}\text{Ar}$ dating yields a weighted-mean age of 3.38 ± 0.25 Ma, marking the onset of volcanism in southwestern Martinique. Whole-rock geochemistry indicates that juvenile and lithic clasts are predominantly andesitic, with more evolved dacitic compositions preserved in the earliest eruptive products ($\text{SiO}_2 = 55.5\text{--}70.7$ wt%; total alkalis = 2.7–5.8 wt%), consistent with magma differentiation during prolonged crustal storage.

These results provide the first comprehensive characterization of the Roches-Genty ignimbrite and demonstrate that Martinique experienced a significantly larger explosive eruption than previously recognized. This study expands the inventory of ignimbrites in the Lesser Antilles, refines the early volcanic history of southwestern Martinique, and highlights the importance of re-evaluating complex pyroclastic successions elsewhere in the arc that may also represent previously unrecognized ignimbrite deposits (Martens et al., 2026).

Martens A., Germa A., Charbonnier S., Quidelleur X. & Paschall A. (2026): Bulletin of Volcanology, 88, 29.

Intracontinental rifting driven by post-orogenic radiogenic heating and thermal expansion

Yuriy Maystrenko (1)

(1) *Geological Survey of Norway (NGU), Trondheim, Norway*, yuriy.maystrenko@ngu.no

During ocean closure and collisional orogeny, subduction of sedimentary and upper-crustal rocks enriches the lithospheric mantle with incompatible radioactive elements: uranium (U), thorium (Th), and potassium-40 (K). This enrichment, reflected in potassic and ultrapotassic magmas, creates anomalously high radiogenic source zones that must be accounted for in rifting models. To investigate how this triggers intracontinental rifting, I performed 2D finite-element thermo-mechanical modelling using COMSOL Multiphysics, utilizing two approaches: (1) conductive thermal modelling to simulate stationary and transient lithospheric heat transfer, and (2) coupled thermo-mechanical modelling to evaluate thermal expansion from radiogenic heating. Conductive modelling shows that high U, Th, and K concentrations generate a time-dependent temperature rise. This creates favourable rifting conditions 20–100 million years post-orogeny, depending on isotope abundance and the volume of the enriched mantle domain. Coupled simulations demonstrate that radiogenic heating both weakens the lithosphere and drives thermal expansion sufficient to initiate rifting without external tectonic forces. At an elevated heat production rate of $0.5 \mu\text{W}/\text{m}^3$, 50-100 million years of heating generates thermal stresses that exceed the tectonic stress threshold required for brittle faulting. This study proposes a simple, novel mechanism for intracontinental rift initiation driven by post-orogenic mantle radiogenic heating and thermal expansion. It advances our understanding of localized rift dynamics and global tectonic cycles, highlighting the utility of thermo-mechanical modelling in linking deep geochemical enrichment to lithospheric deformation.

AdriaArray – a passive seismic experiment to explore geodynamic drivers of plate deformation and geohazards in the Central Mediterranean

T. Meier, P. Kolínský and AdriaArray Seismology Group

The densely populated area around the Adriatic Sea is prone to geohazards including earthquakes, tsunamis, landslides, floods and volcanic activity as the Adriatic Plate is consumed in a tectonically active belt spanning from Sicily, over the Apennines to the Alps, Dinarides, and Hellenides, generating earthquakes up to magnitude 7. To identify drivers of associated plate deformation and continental subduction, the plate boundaries, slabs, properties of active faults and of the stress field have to be studied. AdriaArray, a dense plate-scale regional seismic network deployed in the central Mediterranean, provides data for imaging of the crust and upper mantle structure and for the analysis of seismic activity. The network consisted of 1092 permanent and 436 temporary broad-band stations from 23 mobile pools. A homogeneous coverage by broad-band stations in an area from the Massif Central in the west to the Carpathians in the east, from the Alps in the north to Sicily and the Kefalonia Fault Zone in the south, was achieved. The backbone network (2022 – 2026) was complemented by locally densified and LargeN networks, e.g. in the western Carpathians (Poland, Slovakia, Hungary), along the Dubrovnik fault (Croatia), in the Vrancea region (Romania), in Albania and the Hellenides (Greece). Data recorded by temporary stations was transmitted in real-time to 9 nodes of the European Integrated Data Archive (EIDA). Regular availability and quality checks ensure high data usability. AdriaArray, the largest passive seismic experiment in Europe so far, was based on cooperation between local network operators, mobile pool providers, field teams, ORFEUS (Observatories and Research Facilities for European Seismology) and EPOS (European Plate Observing System), encompassing 64 institutions from 30 countries. They form the AdriaArray Seismology Group, founded in 2022. Collaborative Research Groups were established to coordinate the data analysis. We present maps of the AdriaArray Seismic Network, discuss the station properties and coverage, data quality checks as well as main research topics and planned activities.

CORRELATING GEOCHEMICAL ANOMALIES WITH SEISMICITY PARAMETERS FOR VRANCEA SEISMOGENIC AREA USING MULTIPARAMETRIC GEOPHYSICAL PLATFORMS DEVELOPED IN NIEP

Iren-Adelina MOLDOVAN¹, Bogdan-Dumitru ENESCU^{1,2}, Andrei MIHAI¹, Anica Otilia PLACINTA¹, Victorin-Emilian TOADER¹, Cristian GHITA¹, Mihai ANGHEL¹, Liviu MANEA¹, Lucian PALANGEANU¹,

¹ *National Institute for Earth Physics, Calugareni 12, Magurele, Ilfov, Romania*

² *Department of Geophysics, Kyoto University, Japan*

The National Institute for Earth Physics (INCDFP) has developed several web-based platforms aimed at integrating, visualizing, and analyzing seismic and multiparametric geophysical data, among which PHENOMENAL (<https://ph.infp.ro/>), AFROS (<https://afros.infp.ro/AFROS.php>), and the newly developed PHAZER stand out.

The PHENOMENAL platform provides access to integrated geophysical datasets, with a focus on geomagnetic observations and related environmental parameters acquired within experimental monitoring networks. It enables the exploration of time series and supports the investigation of temporal variations and potential correlations with seismic activity.

The AFROS platform is designed for advanced analysis of seismicity and associated geophysical and geochemical parameters. It incorporates near real-time monitoring and visualization of physical-chemical parameters, including geomagnetic field variations, radon concentrations, and CO₂ emissions recorded in the Vrancea seismogenic area, featuring a dedicated module for the statistical detection of geochemical anomalies. For spatial-temporal seismicity analysis, the platform utilizes regional seismicity rate models based on Relative Intensity (RI) and Pattern Informatics (PI) algorithms to map and assess localized changes in seismic activity.

The newly developed PHAZER platform represents a step forward in multidisciplinary data integration, combining seismic, geomagnetic, and geochemical observations within a unified framework, facilitating complex data interpretation and supporting advanced research methodologies.

This presentation focuses on an integrated case study within the Vrancea intermediate-depth seismic zone, utilizing these platforms to correlate geochemical anomalies with seismic parameter variations. By crossing localized geochemical outgassing anomalies (such as radon and CO₂ fluctuations detected and processed via AFROS statistical tools) with high-resolution

seismicity rate changes and b-value variations analyzed through PHAZER, we explore the geodynamic feedback mechanisms preceding intermediate-depth seismic events.

This paper was carried out within Nucleu Program SOL4RISC, supported by MCI, project no PN23360201, Phenomenal Project PN-III-P2-2.1-PED-2019-1693, 480PED/2020 and AFROS Project PN-III-P4-ID-PCE-2020-1361, 119 PCE/2021, supported by UEFISCDI, and EPOS-RO project, co-funded by the European Union under Contract No. G 2026-56292/390115 (PCIDIF/146/PCIDIF_P1/OP1/RSO1.1/PCIDIF_A3, Code SMIS2021+ 313109).

Seismotectonic Insights into the Intra-Carpathian and Adjacent Regions of Western Romania: Rupture Properties and Source Scaling from Earthquake Sequences

Placinta A.O. (1), Borleanu F. (2), Oros E. (1), Petrescu L. (1,3), Radulian M. (1), (4), (5), Moldovan I.A (1) Anghel M. (6)

(1) National Institute for Earth Physics, Department of Seismology and Lithosphere Structure, Măgurele, Romania.

(2) National Institute for Earth Physics, National Data Center Department, Măgurele, Romania.

(3) Faculty of Physics, University of Bucharest, Măgurele, Romania

(4) Romanian Academy, Bucharest, Romania.

(5) Academy of Romanian Scientists, 54 Splaiul Independentei- 050094, Bucharest, Romania.

(6) National Institute for Earth Physics, National Seismic Network Department, Măgurele, Romania.

Intraplate deformation can localize along inherited lithospheric structures long after major tectonic events, generating unexpected seismic sequences in low-strain regions. This study investigates the source properties, rupture dynamics, and scaling relationships of recent crustal earthquake sequences located across western Romania and the intra-Carpathian area, focusing on the Orșova, Hațeg, Caransebeș-Mehadia, and Maramureș seismic zones.

In order to estimate the source parameters, we applied the empirical Green's function and spectral ratio deconvolution techniques for pairs of co-located earthquakes. These techniques proved to be suited for a good constraint of the source parameters: seismic moment, corner frequency, source duration, stress drop and allowed a robust determination of the specific scaling relationships. The obtained results provide critical insights into the rupture processes of small-to-moderate intra-continental earthquakes and highlight that even low-strain intraplate regions with sparse seismicity can generate abrupt, high-stress-drop earthquakes when deformation localizes along long-lived lithospheric structures, posing a relevant challenge for regional seismic hazard assessment.

ACKNOWLEDGEMENTS: We thank the NUCLEU Program SOL4RISC supported by the Ministry of Education and Research, projects PN23360201, PN23360101 and EPOS-RO project, co-funded by the European Union under Contract No. G 2026-56292/390115 (PCIDIF/146/PCIDIF_P1/OP1/RSO1.1/PCIDIF_A3) for supporting our research.

Keywords: earthquake sequence, source parameters, seismic source scaling, western Romania, intra-Carpathian area, source directivity.

Potential of repeating earthquakes in the Vrancea seismic nest (Romania) and possible underlying mechanisms

Authors: Mircea Radulian^{1,2,3}, Felix Borleanu¹, Kevin Maeda⁴, Anca Plăcintă¹, Laura Petrescu¹, Mihaela Popa², Raluca Dinescu¹

1. National Institute for Earth Physics, Romania

2. Romanian Academy, Bucharest, Romania

3. Academy of Romanian Scientists, Bucharest, Romania

4. Air Force Technical Applications Center, Patrick Air Force Base, Florida, U.S.A.

Clustering properties of earthquakes provide key information on underlying processes that generates specific seismicity patterns. We investigate clustering properties of seismicity recorded at intermediate depth in the Vrancea seismic nest. Small and moderate earthquakes (M_w 3 – 5) occurred after 2000 were considered. Cross-correlation approach is applied to identify repeating earthquakes on three segments on depth, able to generate maximum events of different size, ~ 7.5 (60 – 100 km), ~ 5.5 (100 – 120 km), and ~ 7.9 (> 120 km). We investigate the source characteristics by using spectral ratios of both seismic coda, and direct S-waves and empirical Green's function deconvolution. For larger events (M_w above 4), the moment tensor is obtained by full-waveform inversion. Clustering and scaling properties are interpreted to see to what extent specific asperities distribution and aseismic creeping processes are possible in the Vrancea subcrustal domain, if they depend on depth and how they can control the seismicity release.

Keywords: intermediate depth seismicity, Vrancea nest, repeating earthquakes

Magnetotelluric and Gravity Anomaly Data Analysis in the Bakony-Balaton Highland Volcanic Field

Tibor Rubóczki (1,2), Jaroslava Pánishová (3), Thomas Peter Lange (1,2), Jan Vozár (3), Márta Berkesi (1,2)

(1) HUN-REN Institute of Earth Physics and Space Science, Sopron, Hungary

(2) MTA FI Lendület (Momentum) FluidsByDepth Research Group, Sopron, Hungary

(3) Earth Science Institute, Slovak Academy of Sciences, Bratislava, Slovakia

The Bakony-Balaton Highland Volcanic Field (BBHVF) is one of the most geodynamically complex regions within the Pannonian Basin. Legacy telluric and magnetotelluric (MT) surveys have suggested the presence of prominent high-conductivity anomalies at crustal depths beneath this Neogene volcanic field. Several hypotheses have been proposed to explain these features, ranging from graphite-bearing lithologies to deep-seated fluid circulation. In this study, we analyze new long-period MT datasets using 3D inversion schemes, combined with 3D Bouguer gravity anomaly forward modelling. Additionally, dimensionality and directional analysis of the MT response functions provide direct constraints on the regional geoelectric structure. By integrating these geophysical datasets, we aim to constrain the subsurface geometry and determine the most plausible geological and petrophysical origin of the observed anomalies.

Tracing natural hydrogen and geofluid migration in metamorphic terrains at the eastern margin of the Alps: a fluid inclusion perspective

Tamás Spránitz^{1,2,3}, Viktória Gere^{1,3*}, Gábor Tari⁴, Bence Gucsik⁵, Thomas Pieter Lange^{1,2}, Csaba Szabó^{1,2,3}, Alexander Pengg⁶, David Misch⁶, Ronald Bakker⁶, Erich Draganits⁷, Eszter Békési^{1,2}, Kristóf Porkoláb^{1,2}, Tamás Sági⁸, Jenő Ivancsics¹ & Márta Berkesi^{1,2}

1 MTA-HUN-REN FI FluidsByDepth Lendület Research Group, HUN-REN Institute of Earth Physics and Space Science, Sopron

2 HUN-REN Institute of Earth Physics and Space Science, Sopron, Hungary

3 Lithosphere Fluid Research Lab, Department of Petrology and Geochemistry, ELTE, Budapest

4 OMV Energy, Vienna, Austria

5 Roth Gyula Doctoral School of Forestry and Wildlife Management Sciences, University of Sopron

6 Montanuniversität Leoben, Leoben, Austria

7 University of Vienna, Vienna, Austria

8 Department of Petrology and Geochemistry, ELTE, Budapest

** spranitz.tamas@epss.hun-ren.hu*

Natural hydrogen exploration requires an improved understanding of the geological processes controlling hydrogen generation, migration, and trapping. We present the concept and first results of an integrated cross-border research approach targeting metamorphic terrains made up by Austroalpine–Penninic units at the eastern margin of the Alps, with particular emphasis on the Sopron Metamorphic Complex. These areas record multistage deformation, fluid–rock interaction, and localized enrichment of U–Th–REE-bearing minerals, providing favorable conditions for serpentinisation and also radiolysis-driven hydrogen generation and fluid migration. Preliminary Raman analyses have already confirmed the presence of molecular hydrogen in late-stage secondary fluid inclusions. Our approach combines systematic geological sampling coupled with handheld gamma spectrometry together with fluid inclusion petrography, microthermometry and Raman spectroscopy. By integrating newly acquired data with geochemical, structural and hydrogeological datasets, we aim to reconstruct the temporal and spatial evolution of fluid migration pathways. The results will provide new constraints on hydrogen-generative processes, associated with permeable fault- and shear-zones, and the potential distribution of natural hydrogen systems in metamorphic terrains.

Numerical investigation of the effectiveness of managed surface water infiltration through surface canals in semi-arid areas

Márk Szijártó 1,2,3,4*, Adél Petneházy 1,2,3,4, Szilvia Simon 2, Judit Mádl-Szőnyi 2

1 Department of Geophysics and Space Science, Institute of Geography and Earth Sciences, ELTE Eötvös Loránd University, Pázmány Péter sétány 1/C, H-1117, Budapest, Hungary

2 Department of Geology, József & Erzsébet Tóth Endowed Hydrogeology Chair, Institute of Geography and Earth Sciences, ELTE Eötvös Loránd University, Pázmány Péter sétány 1/C, H-1117, Budapest, Hungary

3 Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budaörsi út 45, H-1112, Budapest, Hungary

4 CSFK, MTA Centre of Excellence, Konkoly Thege Miklós út 15-17, H-1121 Budapest, Hungary

* Corresponding author: mark.szijarto@ttk.elte.hu

Keywords: natural water retention measures (NWMR); groundwater flow simulation; saturated vs. unsaturated zone; drought damages

In the upper part of the subsurface area (~0.5–1 km depth), the groundwater flow systems are controlled by the topography, to be more precise, the shape of the (ground)water table. However, the combination of natural and artificial processes can significantly alter the groundwater table and simplify its hierarchy, leading to changes in groundwater flow patterns and thereby causing irreversible, long-term damage to agriculture, ecosystems and drinking water management. Two-dimensional numerical modelling was carried out to investigate local-scale hydraulic changes in the near-surface groundwater flow system caused by water infiltration through surface canals. The time-dependent simulations were performed in synthetic models, where (i) the depth of the water table, (ii) the water level in canals, (iii) the hydraulic conductivity of the near-surface porous media, and (iv) the shape of the water table were varied between the values characteristic for the Danube-Tisza Sand Ridge Region, which has become a semi-arid (semi-desert) area in Hungary.

We found the position of the groundwater table to be a crucial parameter: (i) if the groundwater table is above the water level in the canal, the canal discharges the groundwater and dries the soil; (ii) if the groundwater is below the water level in the canal, the surface water can infiltrate in the unsaturated zone. However, this process is strongly influenced by the thickness of the unsaturated zone. Continuous water supply in the canal is essential for effective infiltration, while the hydraulic conductivity of the porous medium determines the intensity of the infiltration. As a result of the comprehensive parameter test, we found a “critical distance” beyond which the (extra) water infiltration no longer raises the water table. Of course, this “critical distance” varies across space and time, depending on model parameters; hydraulic equilibrium was established in all simulations. For example, after 10 years, the additional

hydraulic effect extends up to a maximum of 160 m from an individual canal in the case of a real case study (Bátya, Hungary).

In conclusion, since this technique has limitations in both space and time, site-specific, integrated solutions were proposed for surface water and groundwater retention.

This project was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences. The research was supported by the National Multidisciplinary Laboratory for Climate Change, RRF-2.3.1–21-2022–00014 project.

CONTINENTAL PLATEAUX UPLIFT BY ECLOGITIZATION, UNDERPLATING AND CRUSTAL MELTING

H. Thybo^{1,2}, Z. Zhou³, G. Wang⁴ and I. Artemieva^{1,2}

1Zhejiang Deep-time Digital Earth International Research Center, Hangzhou, China

2International Lithosphere Centre, Zealand, Denmark

3China Earthquake Administration, Beijing, China

4Yangtze University, Wuhan, China

Corresponding email: h.thybo@gmail.com

The processes leading to uplift of the world's highest continental plateaux in Tibet, the Andes and East Anatolia are enigmatic. A number of tectonomagmatic processes are proposed, and it is generally believed that the crustal structure is key to explaining their high topography. Main processes affecting the crustal structure include the metamorphic formation of eclogitic rocks from lower crustal material, underplating and partial melting of the crust.

We show that the whole continental crust has low seismic velocity (<6.7 km/s) in the central Lhasa terrane of Tibet, which indicates that this thickest crust on Earth is felsic down to the Moho at 80 km depth¹. The new crust formed during subduction included a mafic layer at the base of the crust and felsic material added to the upper crust. Solidification and cooling at high pressure at the base of the overthickened crust, led to continuous metamorphic transformation of the mafic layer into dense eclogite facies rocks, with subsequent episodic delamination whenever the eclogitic body would obtain sufficient mass. This delamination process left behind a purely felsic crust with a thickness of up-to 80 km which, by isostasy, may explain around half the present topography of the Lhasa block.

Recent studies show that high-grade eclogitic rocks may survive at the base of cratonic crust for billions of years², and that also low-grade eclogitic mafic rocks may explain the high topography of the NW Scandinavian mountain range³. Our findings suggest that the amount of sub-Moho eclogite can be generally underestimated globally!

Based on our new receiver function interpretation of the East Anatolian Plateau and the transition into the Arabian Shield, integrated with results from seismic tomography, MT and geochemical studies, we demonstrate the presence of an up-to 20 km thick underplated layer and a 10 km thick intra-crustal partially molten layer. The low density of these layers explains isostatically the high topography in eastern Anatolia⁴. The thicker crust in Tibet and the Andes show similar characteristics and, by a comparative study, we show that the high topography of

all three plateaux can be explained by isostatic uplift due the low density of these layers containing pockets of partially molten rocks.

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Integrating hydraulic data processing and conductive temperature modelling for heat transport analysis: a case study from the Zala Basin (Hungary)

The increasing demand for sustainable energy sources highlights the importance of reliable and efficient geothermal exploration. We aim to develop workflows to understand heat transport processes and constrain the geothermal potential in low-moderately explored areas. Our study area, located in the Zala Basin (SW-Pannonian Basin, Hungary), represents a prospective geothermal setting. However, heat transport mechanisms remain poorly understood, especially in the Mesozoic carbonates that are buried below 2-5 km of Neogene-Quaternary sediments. Here we focus on the integration of hydraulic data processing and conductive heat transport simulations as part of a broader geothermal exploration framework.

Horizons of geological formations were compiled into a unified database and integrated into a single three-dimensional geological model, which provides the framework for the heat transport simulations. Available a priori information on the relevant physical properties was incorporated into the modelling process. A substantial dataset of measured temperature values was used to evaluate the simulated temperature distribution and constrain the model through inversion.

In parallel, hydraulic data were processed to characterize the hydrogeological conditions of the study area. The resulting information provides an independent perspective on subsurface fluid-related processes and complements the interpretation of the conductive thermal model. The joint analysis of these datasets aims to improve the understanding of spatial temperature distribution of the study area and the factors controlling it.

The presented workflow contributes to a more comprehensive characterization of the study area and demonstrates the potential of integrating thermal and hydraulic information to support more reliable and cost-effective geothermal exploration in general.

Does the strength of the ductile crust control the structural evolution of strike-slip faults?

A brittle-ductile analogue modelling research

Strike-slip faults are multi-scale structures of frequent occurrence that affect large areas and the lithosphere and may cause seismic hazards, an example being the San Andreas fault in California, USA. While much is known about the structures of the different types of strike-slip faults and part of their evolution, little is known about the early development and the effect of different variables on the evolution and the finite structure. This research aims to provide insight into the early development of these fault systems and to find the influence that strain rate exerts on systems containing ductile layers. This is important because strain rate influences the strength of the ductile layer. This experiment used brittle-ductile analogue modelling with a variable strain rate. The amount of displacement required for characteristic structures to form, as well as the cross sections, maximum topography, and width of deformation in the system, were analysed. The different types of strain and the incremental strain type evolution were also studied. These were all compared to a fully brittle model. It was found that the lower the strain rate, the more deformation was needed for the same structures to form, leading up to more than 3x the displacement needed for the lowest strain rate. The base decoupled model needed relatively less displacement than expected. The amount of shears did not directly relate to strain rate, though the base decoupled and brittle model showed much less Riedel shears. The angles that the Riedel shears made to the basement fault, which are directly related to the orientation of the principal strain axis, were highest for the brittle model and decreased with increasing strain rate for the ductile models. The sections also showed that the lower the strain rate, the further away from the velocity discontinuity the fault systems could originate in brittle-ductile models. For both the maximum height and the maximum width, a negative relation was found where the higher the strain rate, the smaller the height and the width with an exception being the highest strain rate model. The evolution of incremental strain corresponded to the timing of the structural evolution and it showed evidence that much of the found relations could be explained by a difference in the distribution of strain caused by the silicone putty. In order for faulting to happen, the peak strength needs to be acquired. This leads to variations in the timing of structures and the height of the system, depending on the strain rate. A low strain rate results in lower strength, which means more displacement is needed for faulting to occur.

The Panalesis Atlas

Christian V  rard & Florian Franziskakis

The Panalesis model consists of global maps created every 10 million years or so from the Neoproterozoic to the present. These maps rely on a maximum of data from multiple sources (pal  omagnetism, fossils, lithofacies, geochemistry, etc.) and comply with the rules of plate tectonics, following our Dual Control Approach methodology.

Once the global plate tectonics model is defined, it is possible to derive many other types of maps. The first type of derivative maps are pal  ogeographic maps, which represent not only the determination of the position of continents over the globe, but also the definition of topography (orography and bathymetry), and the interaction with the sea-level to define the position of the coast-line. We supplement them however by maps of the age of the sea-floor, maps of accretion/subduction rates, maps of volume of subducted material, maps of hydrothermal alteration at mid-oceanic ridges, maps of crustal and lithospheric thicknesses. In addition, in association with climate models, we derive hydrological maps (drainage system, rivers) as well as erosion/sedimentation fluxes.

All these maps are compiled in an atlas: the Panalesis Atlas.