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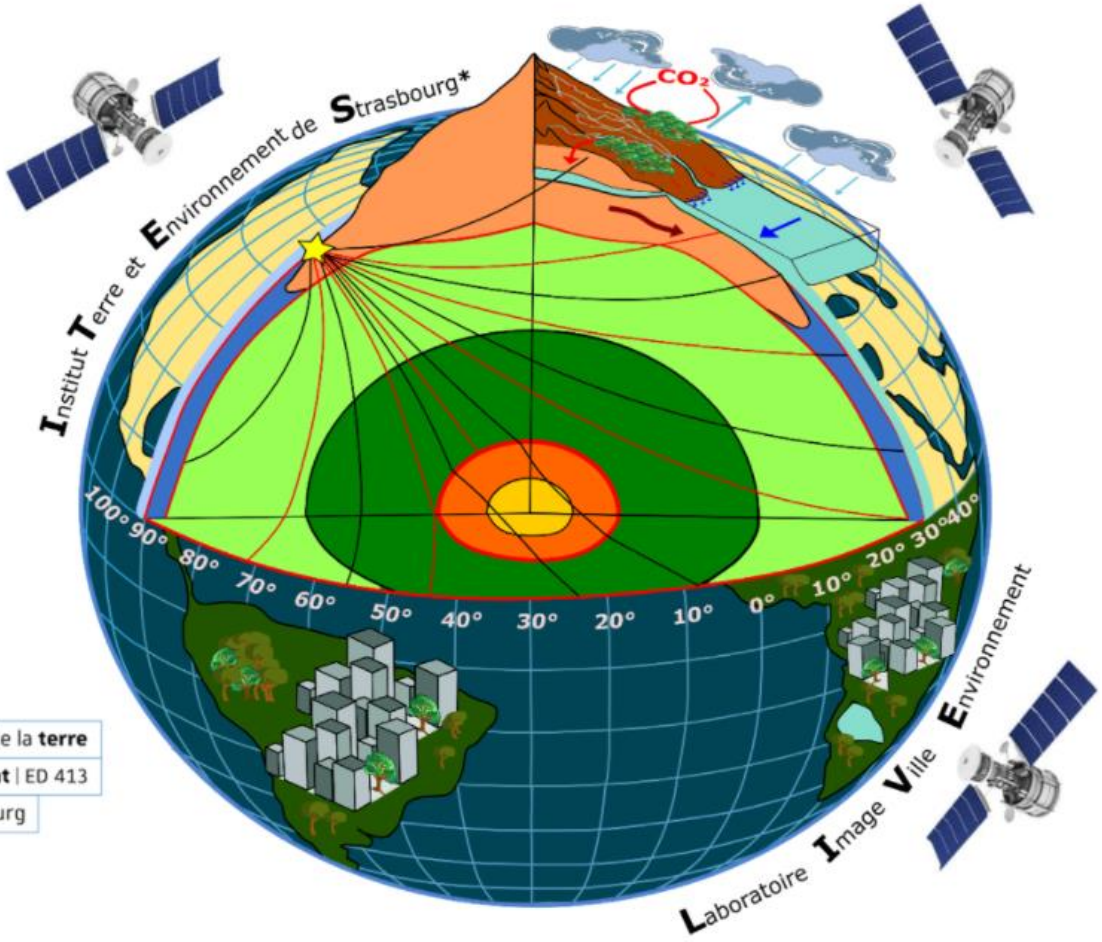
PhD Congress of ED413

L'Ecole Doctorale: Sciences de la Terre et de l'Environnement



École doctorale Sciences de la terre et de l'environnement | ED 413 Université de Strasbourg

Tuesday, March 18th, 2025

CDE, 46 Bd de La Victoire

KEYNOTE SPEAKER

Nicolas Gratiot

DR, IRD/IGE

"Lessons learnt from the coastal erosion of the Mekong delta"

For all the additional information:
(scan the QR code)
http://eost.u-strasbg.fr/stue/
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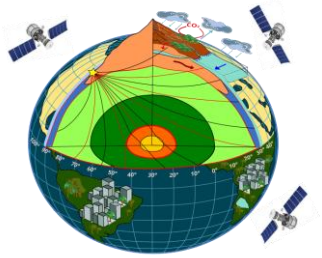
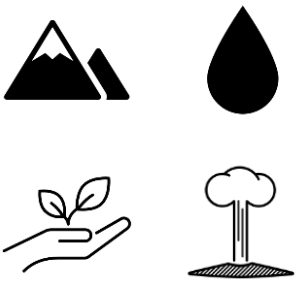
The congress in 5 points



A talk session and a poster session on the 18th of March 2025 with a total of **19 presentations**!

The perfect occasion to meet new people, share sciences and win the best oral and poster prize!



Topics from 5 different fields:

- Hydrology
- Geochemistry
- Geology
- Geophysics
- Geography

A Keynote from **NICOLAS GRATIOT**, will do a presentation "Lessons learnt from the coastal erosion of the Mekong delta"

For any questions do not hesitate to contact us at congresdesdoctorantsed413@gmail.com. You also will find a lot of information on the congress **website.**

Schedule of the day

Appointment at 8:20 a.m. at the room "Amphithéâtre" of the **Collège Doctoral Européen (CDE) (**46 Boulevard de la Victoire, 67000 STRASBOURG)

Keynote

We are very honored to receive **Nicolas GRATIOT**, deputy director of the Institute of Environmental Geosciences (IGE) in Grenoble

10:30 to 11:15	Nicolas GRATIOT
"Lessons learnt from the coastal erosion in the Mekong Delta"	

Oral presentations

The oral presentations are divided in **5 sessions**:

- Seismicity and Reservoir Characterization
- Geophysical Monitoring & Groundwater Studies
- Seismology and Geophysical Data Analysis
- Geochemistry and Environmental Processes
- Tectonics, Rifting, and Sedimentology

For more information, please find the detailed program in the next pages and the abstracts in the website http://eost.u-strasbg.fr/stue/prog.html

Poster Session

At lunch time, poster editors will be present to discuss their research project!
This session will be held from **12:00 p.m to 14:00 p.m** in the Patio space (1st floor) of the Collège Doctoral Européen (CDE) **(**46 Boulevard de la Victoire, 67000 STRASBOURG) . For more informations, please find the abstracts in the website http://eost.u-strasbg.fr/stue/prog.html

Prize for the best poster and the best presentation

After the presentations, we will count the votes for the best poster and the best presentation and give the prizes to the winners

After conference drinks and foods

Please join us at the **CDE** for a convivial moment after the sessions are finished.

Doctoral School Director speech.

Damien LEMARCHAND (from 08:20 to 08:30)

Session I.

from 08:30 to 10:00	Seismology and Geophysical Data Analysis

08:30 - 08:45 | Emile Serra

Tomographic inference of Vp/Vs ratio and its physical interpretation in the mantle beneath Indonesia

08:45 - 09:00 | Ali Mohand-Said

Joint inversion of electromagnetic and direct-current resistivity data

09:00 - 09:15 | Estelle Neyrinck

The slow slip event cycle along the Izmit segment of the North Anatolian Fault

09:15 - 09:30 | Zaur Bayramov

Active deformation in Caucasus & Northern Iran by seismicity and satellite geodesy

09:30 - 09:45 | Bastien Wirtz

Tracking landslide terrain motion with very high resolution optical image time series

09:45 - 10:00 | Rashad Abbasov

The effect of surface tension phenomenon on soil stability

Take a break (coffee, tea, pastries) from 10:00 to 10:30 a.m

Keynote.

from 10:30 to 11:15	**Nicolas GRATIOT**
Lessons learnt from the coastal erosion in the Mekong Delta	

Session II.

from 11:15 to 12:00	Geochemistry and Environmental Processes

11:15 - 11:30 | Florian Labaude

What local contribution to national climate targets? A practical comparison between methods and criteria in Strasbourg

11:30 - 11:45 | Adrien Saphy

Consequences of drought on nutrient biogeochemical cycle in forest soil: Approach by observation, experiment, and modelling

11:45 - 12:00 | Jakob Samuel Popp

Transformation of Sulfamethoxazole and S-Metolachlor under river conditions

Lunch time and poster session

(from 12:00 to 14:00)

Join us for a snack prepared by our caterer and take the opportunity to discuss and meet the PhD students and supervisors

Poster editors will present their work. You can ask questions and vote for the best posters.

Session III.

from 14:00 to 15:30	Geophysical Monitoring & Groundwater Studies

14:00 - 14:15 | **Guillaume Gru**

Global sensitivity analysis of a hydrogeophysical model coupling groundwater infiltration process and surface nuclear magnetic resonance

14:15 - 14:30 | **Yunliang Wang**

Modeling the impact of seasonal water table fluctuations on ambient noise interferometry using acousto-elastic effect

14:30 - 14:45 | **Flavien Mattern**

On the use of ambient seismic noise interferometry for groundwater monitoring in the Upper Rhine Graben, France

14:45 - 15:00 | **Coraline Fuchs**

Mid-infrared spectroscopy in a multi-level karst system (Montmaurin, SW France): an innovative method for assessing sediment provenance

15:00 - 15:15 | **Roxane Mathey**

How to date rifting thanks to vertical movements?

15:15 - 15:30 | **Harmony Suire**

Mantle-melt interaction during mantle exhumation along the Iberia-Newfoundland conjugate margins: the role of mantle inheritance

Take a break (coffee, tea, pastries) from 15:30 to 16:00.

Session IV.

from 16:00 to 17:00	Seismicity and Characterisation

16:00 - 16:15 | **Agata Poganj**

Evidence for permeability heterogeneity in volcanic environments

16:15 - 16:30 | **Arezou Dodangeh**

Injection-induced seismicity and geo-reservoir characterization: insights from the 2019-2020 Strasbourg seismic crisis and Robertsau fault

16:30 - 16:45 | **Rachit Gautam**

Developing high-resolution seismic catalogue using single deep-borehole (2052 m) seismometer during the operational phase 2021 – 2022 at Balmatt geothermal site

Prize for the best poster and the best presentation

(from 16:30 to 17:00 p.m.)

We will count the votes for the best poster and the best presentation and give the prizes to the winners

After conference drinks and foods

(from 16:45 p.m. to 19:00 p.m.)

Please join us at the **CDE** for a convivial moment after the sessions are finished.

CONGRÈS DES DOCTORANTS 2025

PRESENTATION
- of Abstracts -

The effect of surface tension phenomenon on soil stability

Rashad Abbasov[1], Marwan Fahs[1], K.J. Måløy[2], E.G. Flekkøy[2], Renaud Toussaint[1,2]

[1]*Institut Terre et Environnement de Strasbourg, Université de Strasbourg, CNRS, ENGEES, UMR 7063, Strasbourg, France*

[2]*PoreLab, The Njord Centre, Department of Physics, University of Oslo, Oslo, Norway*

Soil stability is a prime important hydro-mechanical problem in natural risk management. Slope instabilities and landslides are commonly associated with intensive rainfall events. Changes in soil saturation cause changes in suction forces in the deformable porous medium. This problem is often investigated using the equilibrium state via the local factor of safety method. Based on the equilibrium state, this method allows for evaluating a local safety factor representing landslide risk. The intense rainfall increases the soil saturation and body load in the domain. The unsaturated flow and the change in soil saturation are often modeled with Richard's equation. This equation is coupled to the mechanical momentum balance equation representing the static equilibrium and the linear elasticity model as constitutive relations.

The existing mathematical and numerical models neglect the effect of the surface tension phenomenon on the effective stress of the unsaturated soils. However, the risk of landslides can be significantly affected by the processes of capillary surface tension. It is important to include these forces in slope stability studies.

Thus, the main aim of this research is to develop a comprehensive framework that incorporates both 2D and 3D surface tension forces into the continuum description of two-phase flow in deformable matrices. By including this force, we provide a more accurate representation of interfacial phenomena. Unlike existing approaches that simplify these effects into a single cohesion term, such as suction stress, this research emphasizes a rigorous mathematical foundation to account for the geometry, composition, and behavior of surfaces. The goal is to bridge the gap between microscopic interactions and macroscopic behavior, offering a robust model for evaluating and predicting forces in multi-phase systems. The validation of the newly developed mathematical model can be done through laboratory experiments.

Keywords: Soil stability, rainfall induced landslides, surface tension, effective stress

VERTICAL AND SPATIAL EVOLUTION OF THE *CONGLOMÉRAT PRINCIPAL* FORMATION, BUNTSANDSTEIN GROUP, NE FRANCE

M. Abdullayev, G. Bozetti, J.-F. Ghienne, M. Schuster, G. Knobelock
Institut Terre et Environnement de Strasbourg (ITES), UMR7063 CNRS - Université de Strasbourg, Strasbourg, France

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The *Conglomérat Principal* Formation, a part of the Lower Triassic Buntsandstein Group in NE France, overlies the *Grès Vosgien* Fm and is overlain by the *Couches Intermédiaires* Fm. Despite having a limited thickness (~ 20 meters), this formation crops out extensively from the Southern Vosges to Germany in a north-easterly direction, and from Lorraine to the margin of the Upper Rhine Graben. This stratigraphic unit of fluvial origin is characterized by pebble-sized conglomerates and pebbly sandstones with subordinate sandstones, and is quite different than bordering sandstone units. Analyzing the distribution of the facies, architectural elements, and facies associations within the unit, and its transitions with underlying and overlying formations is crucial for reconstructing the palaeoenvironments, their succession through time and for identifying controls on heterogeneities in reservoir models at the outcrop to regional scales.

To achieve a high-resolution facies analysis, series of measured sections are conducted during fieldwork in the central Vosges Mountains, from the St Dié (88) to Saverne (67) areas. The data acquired, and additional published data from the north and south of the study area, are integrated to create four maps illustrating lateral variations in lithofacies, grain size, palaeoflow orientations and bed thicknesses, along with a log correlation. They reveal both lateral and vertical variations throughout the system. For instance, in the study area, the unit shows three superimposed, coarsening-then-fining-upward, 5-10 m-thick facies sequences. Cross-stratified facies are abundant, and truncated by each other in the sequences, however low-angle cross-stratified to horizontally stratified facies are less frequent and occur on the higher portions of each sequence.

Preliminary results indicate the necessity for a revised depositional model, involving a network of radially shaped fluvial channels flowing into continental basins, known as a distributive fluvial system (DFS/megafan), instead of the usual proximal braided channels.

Keywords: Fluvial Conglomerates, Buntsandstein, Lower Triassic, Facies Analysis

Coupling between pressure and opening during fluid injection into a fracture

Kamal Ahmadov[a], Jean Schmittbuhl[a], Thibault Candela[b]

[a]ITES UMR 7063, University of Strasbourg, Strasbourg, France [b]TNO, Geological Survey of the Netherlands, Utrecht, The Netherlands

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Our study aims to demonstrate how fracture aperture evolution influences the normal stiffness of fractures during fluid injection—a key factor governing the hydro-mechanical behavior of im- permeable rock formations containing highly permeable fractures. The apparent normal stiffness refers to the effective resistance of a fracture, as a whole, to normal deformation, as observed at a large scale. This differs from the assigned fracture normal stiffness, which is a small-scale property prescribed at the element level in our simulations.

Using the Distinct Element Method (DEM) implemented in 3DEC, we simulate fluid injection into a 100 m planar 2D fracture through a line source under constant overpressure. We find that varying the assigned fracture normal stiffness leads to changes in the aperture gradient. We then analyze how the degree of aperture gradient affects the apparent stiffness. For theoretical valida- tion, we adopt a semi-analytical approach based on two forms of the governing diffusion equation: one assuming a negligible aperture gradient (linear diffusion) and another without this assumption (nonlinear diffusion). Numerical results closely match these semi-analytical solutions.

In both the "soft" and "rigid" fracture regimes—where the initial assigned normal stiffness is low and high, respectively—the apparent stiffness decreases over time as the fluid pressure front advances, i.e., as the length of the fracture affected by fluid pressure increases. Eventually, the apparent stiffness falls below the assigned stiffness. These findings may explain the observed size effect of fractures on stiffness and highlight the role of time- and distance-dependent aperture evolution in controlling fracture stiffness during fluid injection.

Keywords: fluid injection, fracture stiffness, hydro-mechanical coupling, numerical simulations, semi-analytical solutions

USE OF PHYSICS INFORMED NEURAL NETWORK FOR MODELING GROUNDWATER FLOW IN AQUIFERS

Parisa Asghari[1], Marwan Fahs[1], Francois Lehmann[1]
[1] *Institut Terre et Environnement de Strasbourg, Universite de Strasbourg, ITES, Strasbourg, France*

Groundwater modeling is essential for understanding and managing subsurface water resources, especially in heterogeneous aquifers where flow behavior is complex and data availability is often limited. Traditional numerical methods such as the Finite Element Method (FEM) and Finite Difference Method (FDM) provide accurate results but can be computationally expensive for large or highly heterogeneous domains. To overcome these challenges data-driven approaches, including machine learning and deep learning models, have gained attention as alternative solutions. However, conventional neural networks typically require large amounts of labeled data and often struggle to generalize well in data-scarce environments or problems constrained by physical laws.

Physics-Informed Neural Networks (PINNs) integrate governing equations into the loss function, reducing data dependency while ensuring physically consistent solutions. This study evaluates PINNs for groundwater flow modeling in heterogeneous environments with limited data, comparing their performance to conventional neural networks.

A synthetic groundwater flow problem is designed for an unconfined aquifer with spatially varying hydraulic conductivity and Dirichlet and Neumann boundary conditions. Numerical simulations in COMSOL Multiphysics generate reference data for training and validation, enabling direct comparison between PINNs and COMSOL results. To further assess the performance of PINNs under data scarcity, a portion of the available data is intentionally removed and replaced with the governing physical equations. This approach allows for a direct evaluation of the model's ability to generate accurate predictions in the absence of sufficient training data.

Furthermore, this study extends the application of PINNs to a real-world case study with complex boundary conditions and irregular domain geometry. The results are expected to highlight the advantages of PINNs in capturing intricate flow patterns, reducing dependency on large datasets, and ensuring physically consistent solutions. These qualities make PINNs a powerful tool for groundwater modeling in challenging hydrogeological settings.

Keywords: Deep Learning, Groundwater Modeling, Darcy's law, PINN, Heterogeneous Aquifer.

Compaction Localization in Volcanic Rocks

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[3] *Institut Universitaire de France (IUF), Paris, France*

The mechanical response of volcanic rocks to differential stress is shaped by their physical properties, microstructural characteristics, and external factors such as pressure, temperature, and strain rate. In the brittle regime, porous volcanic rocks typically develop localized shear fractures, whereas in the ductile regime, deformation may be either localized or distributed. Experimental research has shown that porous lavas can form compaction bands, while porous granular volcanic rocks, like tuffs, do not. However, the underlying reasons for this difference remain unclear.

Compaction is known to reduce permeability in sedimentary rocks. However, the effects of compaction on permeability in volcanic rocks, as well as the structural characteristics of compaction bands, are still not well understood. Limited experimental studies on porous andesites have demonstrated substantial permeability reductions during ductile deformation, suggesting that compaction bands could play a key role in fluid transport. However, these studies primarily focus on post-deformation permeability measurements of unloaded samples, leaving a gap in our understanding of in-situ permeability evolution.

Additionally, recent findings indicate that pore geometry and alignment within volcanic rocks influence the development and orientation of compaction bands. This suggests that microstructural heterogeneities not only govern compaction localization but also affect permeability changes. To address these knowledge gaps, this study undertakes a systematic experimental investigation to examine: (i) why porous lavas develop compaction bands while granular volcanic rocks do not, (ii) how compaction localization influences permeability evolution, and (iii) the role of microstructural heterogeneities in controlling compaction band formation.

Understanding deformation and permeability in volcanic structures is crucial for fluid transport, eruption dynamics, geothermal energy, and CO_2 sequestration. Permeability controls pore fluid distribution, affecting eruption hazards and subsurface CO_2 storage. Reduced permeability can trap gas, increasing pore pressure and triggering eruptions or leakage risks in CO_2 sequestration. This research aims to improve our understanding on eruption forecasting, hazard mitigation, and CO_2 storage in geothermal systems.

Keywords: Porosity, pore geometry, compaction band, permeability

Active Deformation in Caucasus & Northern Iran by Seismicity and Satellite Geodesy

Z.Bayramov[1,2], R.Viltres[1], C. Doubre[1], A. Maggi[1]

[1]*ITES Université de Strasbourg, CNRS, ITES UMR 7063, F-67084, Strasbourg, France*
[2] *French-Azerbaijani University, Baku, Azerbaijan*

The Caucasus and Northern Iran, part of the Alpine-Himalayan belt, are shaped by the Arabia-Eurasia collision, hosting major thrust belts, foreland basins, and strike-slip faults, including the Greater and Lesser Caucasus, the Talysh-Alborz thrust belts, the Kura-Kartli-Kakheti foreland basin, and the West Caspian and North Tabriz faults. Despite a history of destructive earthquakes, sparse seismic and geodetic data have limited constraints on regional deformation processes. To address this, we analyzed interseismic and transient (co-seismic and slow-slip) deformation using seismicity and satellite geodetic (InSAR) data.

Seismic clustering of a 100-year catalog (1900–2017) classified events into regular, coseismic, swarm, and anthropogenic clusters, confirming the aseismic nature of the West Caspian Fault (WCF). Our AI- based seismic catalog (July 2022–July 2023) from 23 stations captured same seismicity patterns and improved microseismicity detection, helping to correlate and give better timing constraints for transient deformation observed in InSAR data.

Sentinel-1 InSAR analysis (2015–2024) imaged regional interseismic deformation patterns and highlighted: (1) sharp deformation gradients across mountain ranges and basins, (2) localized gradients all along the North Tabriz, West Caspian, and Kura fold-thrust faults, (3) co-seismic signals from events such as the M5.9 Bozgush earthquake (Nov 2019) and the M5.2 Shamakhi earthquake (Eastern Greater Caucasus, Feb 2019), and (4) non-tectonic deformation linked to mud volcanoes, mining activities, and anthropogenic-induced subsidence.

Through InSAR time series analysis, we documented one of the largest known continental aseismic slip events (Feb 4–9, 2023) in the Eastern Kura Basin along the West Caspian Fault (WCF) and six sub- parallel faults, with unrest at 56 mud volcanoes. We interpret the observed aseismic slip as a fluid- mediated transient event dynamically triggered by the surface-waves of a M7.8/7.6 Kahramanmaraş earthquakes (~1,000 km away) which altered pore pressure and normal stress on optimally oriented faults in the region. . Another instance of dynamic triggering in the region was observed following the November 12, 2017, Mw 7.3 Darbandikhan (Zagros) earthquake (~650 km away), which triggered 22 mud volcano eruptions.

Furthermore, using InSAR coherence maps, we identified nine instances (2015–2023) where earthquakes (ranging from 17km to 1,000 km distant) triggered single mud volcano unrest . Further investigations will refine these correlations to establish magnitude-distance scaling relationships for mud volcano activation.

Reconstruction of the Variscan history of the Texenna basement (Lesser Kabylia, Algeria)

Cérine Bouadani[1*], Francis Chopin[1], Pavla Štípská[2], Abderrahmane Bendaoud[3], El-Hocine Fettous[3], Karel Schulmann[1, 2], Jitka Miková[4], Nacer Bouzekria[5]

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[4] *Laboratories of the Czech Geological Survey, Geologická 6, Prague, Czech Republic*
[5] *Ecole Nationale Supérieure de Kouba, Algeria*

The Lesser Kabylia massif, situated within the internal zone of the Alpine Algerian Tell in the Maghrebides, hosts a basement of Precambrian to Paleozoic age (?). Despite the negligible tectono-metamorphic Alpine overprint, the pre-Alpine history of this basement remains poorly constrained.

To address this knowledge gap, we conducted a petrological and geochronological study on the basement in the Texenna area, which comprises two main units: (1) a high-grade metamorphic lower unit and (2) a low-grade metamorphic upper unit containing Cambrian-Ordovician to Silurian-Devonian strata. The high-grade metamorphic unit is dominated by mafic granulites and migmatites with a common assemblage of Cpx-Grt-PI-Qz+Opx±Sp and Grt-Bi-PI-KPI-Qz+Sill±Sp, respectively. Notably, the felsic granulites and migmatites occasionally contain garnet and sillimanite, which enabled us to infer peak P-T conditions of P > 8 kbar and T = 775 °C using pseudosection modeling in the Perple_X software. Zircon U-Pb dating by LA-ICP-MS revealed predominant Permian ages ranging from ca. 266-295 Ma, with notable Carboniferous populations.

Our findings demonstrate the presence of a Variscan basement in this part of the Lesser Kabylia. The observed medium-pressure high-temperature metamorphism may be attributed to the closure of the Paleo-Tethys Ocean or its intracontinental propagator tip near the edge of Gondwana and the southern part of the European Variscan belt, sealed during the Pangea formation

Keywords: U-Pb geochronology,metamorphic modelisation

The Palaeozoic sandstones of Borkou-Ennedi-Tibesti : palaeogeography, palaeoclimates, water resources of the Chadian Sahara

Barnabé Djatibeye[1], Jean - François Ghienne[1], Moussa Abderamane[2]

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[2] Faculty of Exact and Applied Sciences, Department of Geology and Palaeontology, B.P: 1027, N'Djamena, Chad.

Geological outcrops in northern Chad (Borkou-Ennedi-Tibesti regions) reveal one of the finest Lower Paleozoic successions in Africa. It is representative of one of the most proximal segments of the 'North-Gondwanian' platform that extends further northwest into Libya, Niger and Algeria. Despite the scientific, economic and societal interest of the Paleozoic sandstones of Chad, our knowledge of them remains limited and fragmentary, with few academic studies having been carried out since the first geological explorations in the 1950s-1960s. Even the regional distribution of the various geological formations seems in need of revision, as the various maps available to date are not compatible with each other. The aims of my thesis are to : (1) map the main geological units, (2) produce synthetic cross-sections, characterize and understand (3) depositional dynamics and relate them to the geology of adjacent sedimentary basins (Niger, Libya, Sudan) and (4) the regional distribution of deep aquifers.

The Borkou-Ennedi-Tibesti sandstones are essentially fluvial, with channel facies, alluvial bars, fluvio-lacustrine and paleocurrent orientations generally from northwest to southeast, with marine intercalations (bioturbations). Ages are poorly known, with the exception of the late Ordovician and Silurian glaciations (the only level to yield palynomorphs of biostratigraphic value). Here we present some preliminary results concerning ichnofacies (*Arthrophycus Alleghaniensis, Cruziana ancora, Spirophyton, Monocraterion*...), the mapping of geological units and a synthetic section of the Lower Palaeozoic succession (Cambro-Ordovician and Lower Devonian) of the West Ennedi (Fada and surrounding area).

The study of ichnofacies and fossils in Paleozoic sandstones can provide major insights into wet and dry period climate and the impact of ancient climate change on ecosystems in the Chadian Sahara.

Key words : Sandstone, Paleozoic, Chadian Sahara, Fossil tracks.

Injection-Induced Seismicity and Geo-Reservoir Characterization: Insights from the 2019-2020 Strasbourg Seismic Crisis and Robertsau Fault

A. Dodangeh[1], R. Toussaint[1,2], M. Fahs[1], EG. Flekkøy[2,3]

[1] *University of Strasbourg, CNRS, ENGEES, Institut Terre et Environnement de Strasbourg, UMR7063, F-67000 Strasbourg, France*
[2] *PoreLab, Njord Center, Department of Physics, University of Oslo, N-0371 Oslo, Norway*
[3] *PoreLab, Dept. of Chemistry, Norwegian University of Science and Technology, Trondheim, Norway*

Deep geothermal energy is a promising sustainable energy source, but its implementation requires careful management of induced seismicity risks. The Geoven project, located north of Strasbourg, experienced two seismic clusters in 2019-2020: one adjacent to the site and another approximately 5 km to the south. This study investigates the potential link between injection activities and these seismic events by analyzing fault geometry, tectonic stresses, and pressure perturbations induced by fluid injections. Using a friction criterion, we assess the likelihood of triggering seismic activity. Our findings suggest that the fault around the southern cluster was particularly vulnerable, with minimal pressure perturbations sufficient to induce seismicity, while the zone between clusters remained stable despite experiencing higher pressure variations, explaining the spatial gap in seismicity.

To better understand the role of fluid injections, we analyze real pumping data and measured pressure variations in the two wells over an 85-day period. A minimalistic model is developed to characterize reservoir properties, primarily considering porosity and permeability as key parameters. Initial results show that a simple single-component model with homogeneous permeability explains much of the observed pressure response. However, refinements incorporating variations in permeability at greater distances from the wells improve the model's accuracy. Additional factors, such as extra pressure sources linked to fault deformation and slow-slip events following earthquakes, are also considered to capture complex interactions.

This study highlights the critical influence of subsurface pressure dynamics in triggering distant seismicity and underscores the importance of accurate geo-reservoir characterization. By integrating injection data, pressure responses, and fault mechanics, we provide insights into the mechanisms driving induced seismicity, helping to improve risk mitigation strategies in geothermal energy projects.

Keywords: Geo-reservoir, induced sciesmicity, fault mechanics, Pressure perturbation, numerical modeling

FORWARD AND INVERSE MODELING OF SURFACE DISPLACEMENT DURING CO_2 INJECTION IN THE IN SALAH REGION BASED ON A GEOMECHANICAL MODEL

W. Du[1], R. Toussaint[1,2]

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[2] *PoreLab*, The NJORD Centre, Department of Physics, University of Oslo, Oslo, Norway

The In Salah region is a prominent global demonstration site for carbon dioxide (CO_2) geological storage, where approximately 1.2 million tons of CO_2 have been injected annually since 2004 for long-term sequestration. However, the injection of CO_2 leads to changes in the physical and mechanical properties of the reservoir, resulting in surface displacement that may impact the stability and safety of the storage process. This study aims to analyze the evolution of surface displacement during CO_2 injection in the In Salah region based on a geomechanical model and InSAR data. Forward modeling is used to simulate the formation deformation induced by CO_2 injection, while inverse modeling combined with InSAR data (Interferometric Synthetic Aperture Radar) is employed to invert reservoir mechanical parameters, such as permeability, porosity, shear modulus, and Young's modulus. By simulating surface displacement through the geomechanical model, this study enables the estimation of pore pressure variations within the reservoir, allowing for the evaluation of whether CO_2 injection leads to formation deformation or rupture, thus ensuring the safety of the sequestration process. Moreover, anomalous surface displacement may indicate the activation of fractures or faults within the reservoir, thereby increasing the risk of CO_2 leakage. The forward and inverse modeling of CO_2 injection in the In Salah region provides crucial insights into potential leakage pathways, which can help prevent CO_2 leakage into the atmosphere or contamination of underground water reservoirs, thus ensuring the long-term stability and safety of geological CO_2 sequestration.

Keywords: CO_2 , Surface displacement, InSAR , Geomechanical model

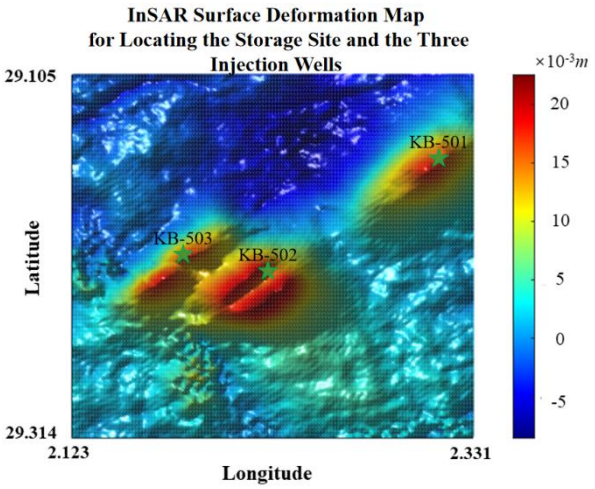

Figure: Surface deformation at the In Salah CO2 sequestration site, Algeria (D. Weihang, 2025) The data is sourced from: *Wright, I., 2011. In Salah CO2 storage JIP lessons learned. In: 10th Annual Conference on Carbon Capture and Sequestration, Pittsburgh, PA, May 2–5, 2011.).*

Transport and transformation of pesticide degradation products through unsaturated zones of agricultural ecosystems: *insight of compound-specific isotope analysis (CSIA)*

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Pesticide transformation products (TPs) are frequently detected in groundwater, yet their transformation and transport remain poorly understood. This study investigates the dynamics of three pesticides and their TPs, focusing on desethylatrazine (DEA), a persistent atrazine (ATZ) TP, in groundwater and soil. A multi-isotope approach was developed to elucidate its transformation pathways in the unsaturated zone of agricultural ecosystems.

Field investigations are conducted in two contrasting sites: a river-connected aquifer in Lampertheim and an agricultural wellfield in Sélestat. Groundwater and soil samples are analyzed for TP concentrations, hydrochemistry, dissolved organic matter (DOM) quantity and quality, and microbial community dynamics. At Sélestat, wells showed strong contrasts, with DEA ranging from 0.01 to >0.1 µg/L, S-metolachlor (SMET) from 0.1 to 0.9 µg/L, nitrates from 10 to 90 mg/L, microbial activity from undetectable to highly active, and generally low DOM. Soil samples showed extractable/non-extractable SMET, ATZ, and TPs, with higher surface concentrations and abundant SMET-ESA at all depths, indicating rapid transformation. Laboratory experiments examine DEA transformation under controlled conditions to determine isotopic fractionation factors associated with specific DEA transformation pathways. DEA hydrolysis tests reveal a DT_{50} of 2.8 days at pH 2 and 1.8 days at pH 12, confirming abiotic transformation under extreme pH conditions, while DEA biodegradation was not significant under oxic groundwater conditions.

To refine the interpretation of DEA transformation in the unsaturated zone, a multi-element Compound-Specific Isotope Analysis (CSIA) approach is being developed, targeting carbon, nitrogen, and chlorine isotopes. Isotopic fractionation factors obtained from controlled experiments will be applied to field conditions, allowing pathway identification based on the three-dimensional isotope plot. This approach enables to differentiate closely related transformation processes such as hydrolysis, dealkylation, and microbial degradation. By integrating field monitoring, laboratory experiments, and isotopic techniques, this PhD study advances understanding of pesticide TP persistence and informs groundwater protection strategies.

Keywords: Unsaturated Zone, Compound-Specific Isotope Analysis, Desethylatrazine, Transformation pathways.

Mid-infrared spectroscopy in a multi-level karst system (Montmaurin, SW France): an innovative method for assessing sediment provenance

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Determining the origin of sediments is crucial for understanding the movement and deposition of particles. This is particularly important in archaeological research, where it helps reveal the sedimentary environment of excavated materials, offering valuable insights for age determination. Mid-infrared spectroscopy, widely used in both ancient and modern river systems, provides an efficient, affordable, and accurate way to trace the sources of sediments. In this study, we apply this technique for the first time to a multi-level cave system situated along the Save and Seygouade rivers (Montmaurin, Haute-Garonne, France). We identified and analysed seven potential sediment sources for the sediments trapped in the karstic network, using 311 reference samples collected from seventeen locations. Discriminant analyses were performed to examine the relationship between the samples and reference groups. Additionally, artificially mixed sediments were tested to explore their spectral signatures. This approach refines the interpretation of geochemical signatures when multiple sediment sources contribute to the complex fillings of caves. Our results indicate that the trapped sediments in the caves share geochemical similarities with both modern and ancient alluvial deposits. These findings point to various deposition processes, such as slackwater flood deposits and vertical withdrawal, resulting in many caves containing sediments from multiple sources.

Developing High-Resolution Seismic Catalogue Using Single Deep-Borehole (2052 m) Seismometer During the Operational Phase 2021 – 2022 at Balmatt Geothermal Site

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The Balmatt geothermal doublet located in northern Belgium targets the fractured Lower Carboniferous Limestone reservoir in the Campine Basin at the depth of around 3000 – 4000 m. The development of the project began in 2015 and operation started in 2018. The geothermal operation had to be suspended after the occurrence of a stronger ML 2.2 event in June 2019 (1st operational phase). Production then resumed in April 2021 after the expansion of the seismic monitoring network. Geothermal activities were suspended again after the occurrence of another strong ML 2.1 event in November 2022 (2nd operational phase).

The current seismic catalogue for operational phase 2021 - 2022, compiled using the existing seismic network, contains around 250 locatable events. Although this data set provides valuable information on the broader seismic activity within the reservoir, its resolution is insufficient to capture subtle changes in seismic behaviour and the reservoir's response to fluid injection. Given the complexity of induced seismicity in deep geothermal systems, a more detailed catalogue is essential. A higher-resolution seismic catalogue enables a more precise assessment of seismic activity. This level of detail is crucial for understanding and mitigating seismic risks associated with geothermal operations.

In this study we took advantage of a deep borehole seismometer installed at the depth of approximately 2052 meters to create a detailed seismic catalogue. Here, we present our seismic catalogue generation workflow, which includes event detection and phase picking on the continuous seismic data from the deep seismometer, event localisation and magnitude estimation, followed by the first results from a preliminary analysis of the newly generated catalogue.

Keywords: Induced Seismicity, Deep Geothermal Energy, Seismic Catalogue

Global sensitivity analysis of a hydrogeophysical model coupling groundwater infiltration process and Surface Nuclear Magnetic Resonance

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Water resources in mountainous areas are of major importance for local ecosystems as well as for human activities. Therefore, it is crucial to monitor the availability of these resources and to be able to predict their evolution accurately in the context of climate change. Hydrologic modeling is a useful tool to achieve this goal. To do so, the models need to be properly parameterized. Geophysical sounding techniques are very useful tools to provide information for the model calibration process.

This work focuses on the Surface Nuclear Magnetic Resonance (SNMR) sounding technique. This geophysical method is based on nuclear magnetic resonance and has the advantages of being non-destructive and directly sensitive to the groundwater content. A time-lapse SNMR survey was conducted in the Strengbach headwater catchment in the Vosges Mountains (France) during the winter 2021 with the aim of following an infiltration event.

Before using this data set for hydrologic model calibration, we used Global Sensitivity Analysis (GSA) tools in order to determine which hydrologic parameters were most influential on the geophysical sounding outputs. This first step is useful for estimating parameters' identifiability. In order to quantify the sensitivity of the SNMR signals to variations in the hydrological parameters, we used a tool called variance-based sensitivity analysis. The principle of variance-based sensitivity analysis is to consider a model's input parameters as random variables following given distributions. Then, a computational framework allows for the quantification of the impact of each model input parameter variance on the model output variance through sensitivity indices called Sobol indices.

Keywords: Vadose zone, Hydrogeophysics, Surface Nuclear Magnetic Resonance, Global Sensitivity Analysis, Polynomial Chaos Expansion

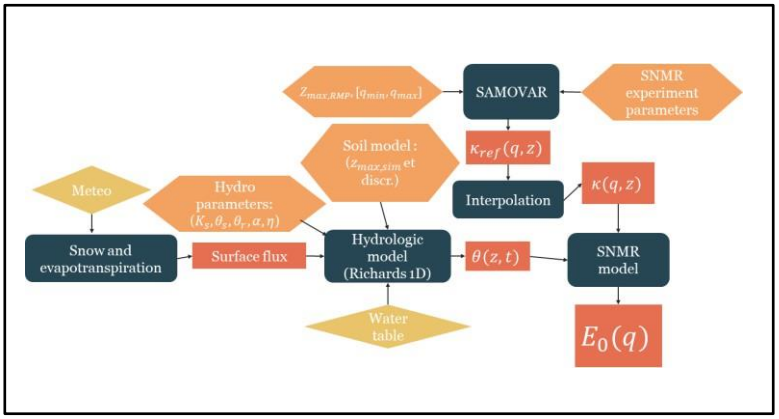

Figure: Flowchart of the hydrogeophysical model (G. Gru, 2025)

Acknowledgements : this project was supported by ED413 (PhD scholarship), the institute of Mathematics for Planet Earth (iMPT), the prime 80 program from MITI (CNRS) and ANR CASH (LS290980)

Krw-S Curve Estimation: Integrating Local Water Content and Direct Pressure Sensing in Unsaturated Porous Media Column Experiments

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Laboratory experiments were conducted to determine water relative permeability (K_{rw}) as a function of water saturation (S) in porous media. Accurate characterization of these properties is essential for understanding multiphase flow, with applications in hydrogeology, petroleum engineering, and contaminant transport. Traditional methods often rely on bulk measurements or assume a unitary hydraulic gradient, which can be difficult to achieve in practice, necessitating alternative methodologies that facilitate permeability estimation under controlled conditions. The approach integrates water content and direct pressure measurements to obtain K_{rw}-S relationships. A PICO TDR probe is used to measure localized water content, minimizing errors associated with bulk averaging. Simultaneously, two pressure sensors positioned along the column provide direct measurements of pressure differences (Δp), eliminating the need to impose a unit gradient assumption. A constant water flux is imposed at the top of the column to generate the pressure gradient, and Darcy's equation is then applied to compute the absolute water permeability (K_w). The water relative permeability (K_{rw}) is obtained by normalizing Kw at different saturation levels with respect to its value at full saturation ($K_{w,max}$). Experimental results indicate that the proposed technique ensures the accuracy and reproducibility of permeability assessments. The experimental setup allows for the determination of water relative permeability during both drainage and imbibition processes, enabling the assessment of potential hysteresis effects. The precision and reliability of the experimental data support its implementation as a valuable tool for both laboratory research and applied field studies.

Keywords: water relative permeability, water saturation, Darcy equation

Impact du changement climatique sur la mobilité des radionucléides : rôle de la matière organique dans la mobilité actuelle et future du radium.

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L'exposition aux rayonnements internes et externes issus des matériaux naturellement radioactifs (NORM) représente environ 50 % de la dose annuelle absorbée par l'Homme. Parmi ces éléments, le radium, un alcalino-terreux aux propriétés similaires à celles du calcium, est particulièrement mobile dans l'environnement, notamment dans la biosphère. En raison de cette mobilité, il constitue la deuxième source de radioactivité dans l'alimentation humaine, ce qui en fait un radionucléide essentiel à considérer en radioprotection. Des études montrent que le radium interagit fortement avec des ligands minéraux dans l'environnement (minéraux argileux, oxydes), par adsorption. Il se lie également à des ligands organiques (acides organiques de faible poids moléculaire, matière organique humifiée), en particulier via des groupements phénoliques et carboxyliques. Toutefois, la disponibilité de ligands organiques dans les sols dépend de processus biologiques complexes, influencés par le climat (humidité, température, etc.). Certaines recherches ont montré que des variations climatiques peuvent modifier la composition et de la quantité de cette fraction organique dans les sols. Ce qui pourrait amplifier, ou altérer l'adsorption du radium, affectant ainsi son assimilation par les plantes et sa mobilité.

Cette thèse vise à étudier la mobilité du radium dans les sols, en se focalisant sur son interaction avec les ligands organiques dans les sols forestiers. Pour cela, les concentrations en radium dans les sols et les solutions du sol (suivi sur une année, à deux profondeurs) du bassin du Strengbach (Observatoire Hydrogéochimique de l'Environnement, OHGE, Vosges) seront mesurées par des techniques de spectrométrie (Spectromètre de masse à thermo-ionisation, spectrométrie gamma). La matière organique du sol et des solutions sera caractérisée par diverses techniques analytiques (Pyrolyse-GC-MS, RMN ^{13}C, chromatographie ionique). Ces analyses permettront de mieux comprendre le lien entre le radium et certaines caractéristiques de la matière organique (solide ou dissoute), mais aussi d'alimenter une seconde partie de la thèse qui vise à simuler la dynamique du radium dans ces sols. Pour cela, un modèle de bilan hydrique (BILJOU), alimenté grâce au suivi des paramètres hydrologiques et climatiques assuré par l'OHGE, et un modèle de végétation dynamique (LPJ) seront utilisés en cascade avec un modèle géochimique (WITCH). Les analyses des solutions de sol réalisées en amont seront comparées aux résultats fournis par la cascade de modèle. Des tests de sensibilité seront ensuite réalisés pour étudier la dynamique future du radium, en fonction de différentes projections climatiques.

Holocene Geoarchaeology of the Groundwater Fed Rivers of the Grand Ried between Sélestat and Erstein (Alsace, France)

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The "Ried durable" project, which includes this thesis, focuses on the groundwater-fed rivers flowing through the Grand Ried, an area of the Alsace plain between the Ill to the west and the Rhine to the east, and between Colmar-Sélestat to the south and Erstein-Strasbourg to the north. Most of these streams are almost exclusively fed by groundwater, to which they are connected by limnocrene springs. This provides them exceptional hydromorphological and ecological characteristics that are vulnerable and threatened, particularly due to climate change and agricultural withdrawals, which are both lowering the water table.

The project is structured around three temporal and spatial scales, with the hypothesize that interlocking them will provide deeper insights into the futur of these hydrosystems. We assume that this approch will enable us, in collaboration with stakeholders, to propose new management solutions for these exceptional environments. First, as presented in this poster, we've focused the landscape dynamics of the Grand Ried during the Holocene period. Next, we plan to examine historical timescales, through archives in order to better understand their anthropization. Finally we plan to investigate the contemporary hydromorphological and ecological functioning of these rivers.

While a substantial Lidar dataset has been available for nearly 15 years in the Alsace plain, the IGN's LidarHD program, completed in 2024 in our area, has significantly enhanced our knowledge of the very high-resolution relief of the Ello-Rhenan plain. The "Relative Relief Model (REM)" processing of this data minimizes the effect of longitudinal slope and improves the depiction of landscape macroforms. On this basis, a new geomorphological map has been produced to provide a more accurate spatial context for the evolution of the landscape on the plain.

This geomorphological map served as the fondation for a new model of hydromorphological landscape dynamics in this area. Our study on a large corpus of data gathered from the scientific literature, wich we supplemented with new, original data. This additional information allowed us to characterize and date all the geomorphological units of the Grand Ried Central d'Alsace. We now understand that, over time, the Rhine not only moved eastwards, but above all northwards, gradually creating space for the Ill up to the present-day confluence.

Keywords: Grand Ried, Rhine River, Holocene, Datation, Palaeochannels, Lidar.

INFLUENCE OF THERMAL EFFECTS AND MATERIAL DISORDER ON FRACTURE PROPAGATION

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Understanding the fracture behavior of solid materials is a critical issue for both engineered and natural materials, especially in the context of Earth's crust, where rock formations are inherently fragile. Fracture initiation and damage localization within an interface are complex phenomena that have been a subject of scientific inquiry for centuries. Fracture mechanics are strongly influenced by the material's toughness distribution, which can be heterogeneous in nature, as well as by thermal fluctuations. These fluctuations can facilitate fracture propagation by helping cracks overcome material heterogeneities.

The combined thermal and pinning effect at the crack tip can play a crucial role in the transition between slow and fast fracture propagation. This transition is commonly associated with a first-order phase transition, where the material's response shifts significantly, often leading to catastrophic failure. Such thermal phenomena are particularly relevant when considering materials under extreme stress conditions, where localized heating can significantly affect fracture dynamics.

In the framework of my doctoral research, we focus on the dynamics of fracture propagation in disordered materials, with particular attention to the interplay between material heterogeneities and thermal effects. The study centers on crack propagation in mode I (tensile opening mode), investigating how these factors influence crack speed, energy dissipation, and the overall rupture kinetics. Our work primarily involves extending an existing numerical model to incorporate these two interrelated effects and assess their impact on fracture behavior in heterogeneous media.

By integrating these aspects into a comprehensive model, we aim to improve predictions of material failure and enhance our understanding of fracture propagation under realistic conditions, particularly for engineering applications where both material composition and thermal conditions can vary widely.

SPATIAL AND TEMPORAL EVOLUTION OF THE MIDDLE BUNTSANDSTEIN GROUP, LOWER TRIASSIC, UPPER RHINE GRABEN (NE FRANCE AND SW GERMANY)

Gabriela Meyer Knobelock[1] (presenter), Guilherme Bozetti[1], Jean-François Ghienne[1], Mathieu Schuster[1], Lucas Bofill[2], Claiton Scherer[3] and Ezequiel Souza[4]

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During the Early Triassic, the NE of France and SW Germany composed the Central European Basin System (CEBS), which was made out of a series of intracontinental sedimentary basins sharing a common depocenter. At the SW margin of the CEBS, the fluvial-aeolian successions of the Middle Buntsandstein (Vosges Sandstone Fm) are recorded in the Vosges and Palatinate regions. These deposits have been interpreted as part of a large braided fluvial system with main palaeocurrent towards NE. In this study, sedimentological survey was performed from 50 outcrops and core (EPS-1 well - Upper Rhine Graben). More than 450 metres of outcrops of the Middle Buntsandstein, organised into eight composite logs, and c. 500 metres of core were recorded. Three facies associations were defined: fluvial-channel-fill, sheet flood, and wind- and water-laid. The correlation of composite logs and core shows retrogradational and progradational trends in the Middle Buntsandstein. These are marked by the transition between fluvial dominant, to fluvial and sheet flood deposits, and to an increase of aeolian deposits in the distal part. This was also observed in the trends of Mean Set Thickness (MST) of fluvial aggradational dune elements (AE) with statistical significance and it is proportional to mean channel depth. A decreasing MST trend is related to a retrogradational pattern, and an increasing MST trend is related to the deepening of proximal and medial fluvial channels during the progradation of the fluvial system. In logs where AEs were fully preserved, the channel flow depth was calculated. In addition, the palaeocurrent data from fluvial deposits shows a radial pattern towards SW in the southern region, and towards NE-N in the northern region. Considering the aforementioned indicators, we propose in this study a new palaeoenvironmental model of a distributive fluvial system for the Middle Buntsandstein in the Vosges Mountain and Palatinate region.

Key words: Distributive fluvial system, Central European Basin System, Early Triassic

What local contribution to national climate targets? A practical comparison between methods and criteria in Strasbourg.

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Over years, many strategies have been developed following the Paris Agreement, with the aim of limiting the rise in global average temperature well below 2 °C above pre-industrial levels and pursue all efforts to limit it at 1.5°C. These strategies, drawn up as directives at European level, are transposed to national, regional and municipal levels (whether mandatory or not, depending on the country). In this context, one may ask to what extent the coordination between administrative levels is managed regarding climate targets. In France, a recent analysis of regional and municipal contributions to the national climate objectives points out some important inconsistencies. Indeed, the sum of the local targets doesn't fit with the national carbon neutrality objectives, and methodological issues persist. The current paper presents a new framework to analyze the local contribution to a national climate objective using different and specific downscaling criteria.

The methodology proposed in this work first analyses existing downscaling methods regarding energy-climate targets at municipal level and their respective downscaling criteria. In order to avoid or to question the mismatches between energy-climate targets as highlighted in the introduction, some authors propose methods for downscaling national objectives to municipal scale and developing principles when designing the local targets. For example, the joint collaboration {ADEME[1], negaWATT Institute, Solagro}recently proposes a tool to decline the national climate strategies to municipal scale. Considering the existing methods, our work compares different approaches to raise their differences, propose new method and examine in more details the choice of downscaling criteria and their meaning. This would provide further recommendations for the use of downscaling criteria methods. All the methodologies are applied in the specific case of the Eurometropolis of Strasbourg as a municipality and Metropolitan France as a country. The climate targets are based on the last national climate mitigation plan, the SNBC[2] n°2.

The first results show that the application of the reviewed methods and criteria to the Strasbourg case leads to a wide range of climate targets (even for similar criteria) (Figure 1). However, the analysis of the criteria and their meaning offers a possible means to consider climate justice and/or local context (Figure 2). The new method also makes it possible to assess and specify municipalities' contribution to national carbon neutrality (Figure 2). This last point questions the ability for local stakeholders to transform activities that are beyond their competences and scope of actions, but are included in their energy-climate diagnosis. Finally, general recommendations for the use of downscaling approaches and their criteria are given.

1 French Environmental and Energy Agency

2 « Stratégie Nationale Bas Carbone » - Low-Carbon National Strategy

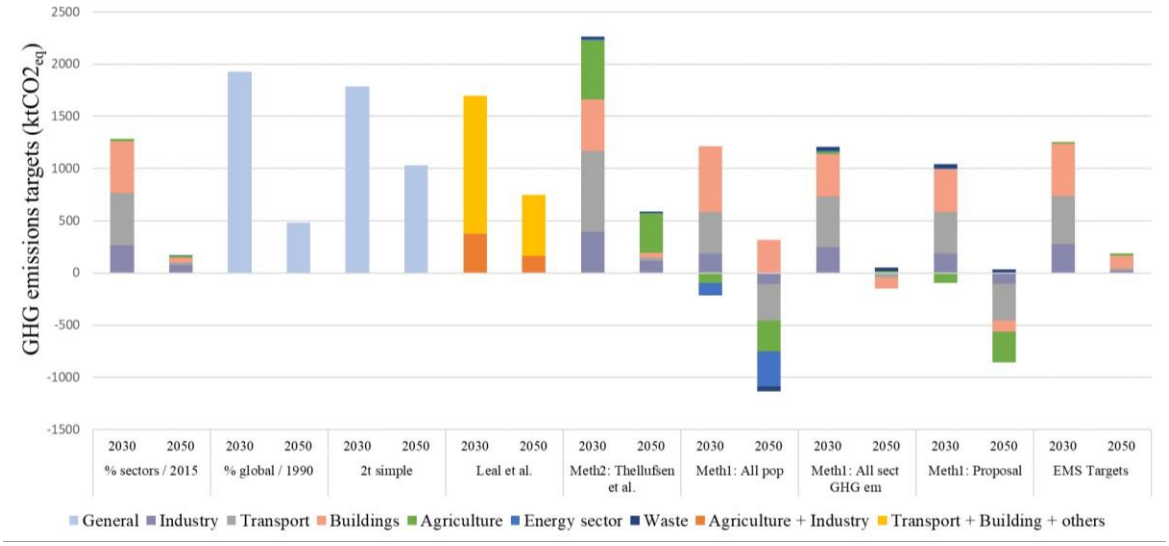

Figure 1: Greenhouse emission targets based on different methodologies (F. Labaude, 2025)

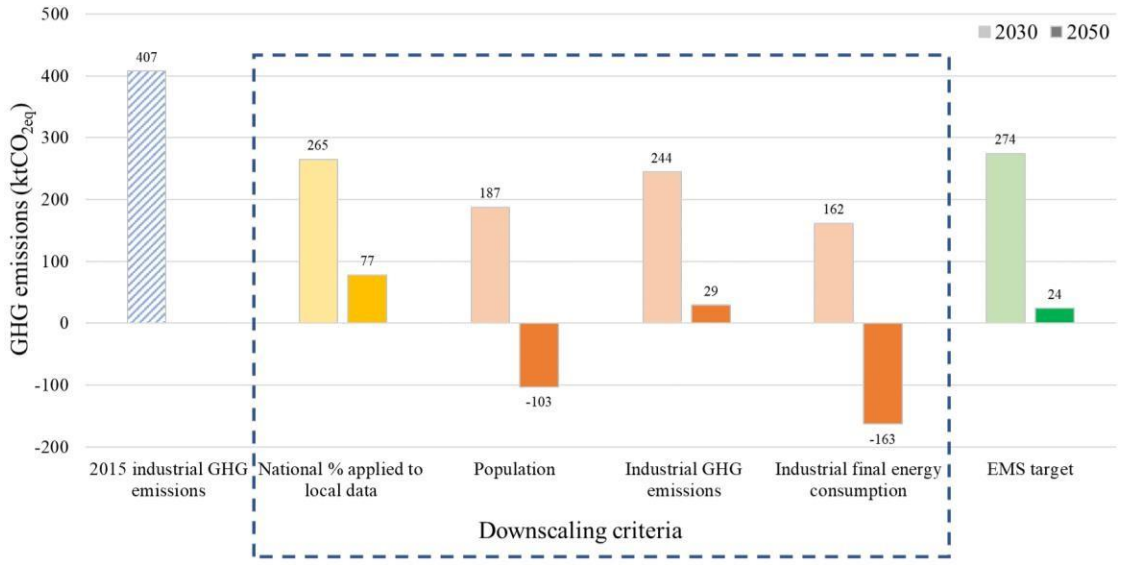

Figure 2: Industrial GHG emission targets based on different downscaling criteria (F. Labaude, 2025)

CHARACTERIZATION OF AQUATIC REFUGES TO SUPPORT THE RESILIENCE OF FRESHWATER ECOSYSTEMS IN A CONTEXT OF GLOBAL CHANGE

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Freshwater ecosystems are particularly vulnerable to the effects of global change and anthropogenic pressures, such as extreme hydraulic and thermal variations, pollution and fragmentation of species ranges. In this context, aquatic refuges play a crucial role in ecosystem resilience, providing viable conditions for species during periods of environmental stress. Despite their importance, the identification and characterisation of refuge areas in rivers remains limited, first by the lack of consensus on their definition, and then by the absence of diagnostic tools. To address these knowledge gaps, a systematic literature review was conducted, utilising the PECO strategy as a recognised framework. This preliminary stage enabled the following: (i) the assessment of the importance of aquatic refuges in ensuring the resilience of lotic ecosystems in the face of environmental disturbance, and (ii) the identification of the structural, physical, spatial and biological parameters that define the refuge areas. Utilising this conceptual framework, the parameters were then assessed in a real-life context within the Wieslauter catchment as part of the Interreg RiverDiv project. This assessment is based on a multidisciplinary approach combining macro-invertebrate sampling, detailed mapping of the river mosaic and the use of drones, including visible and thermal imagery. This integrative approach opens up concrete prospects for identifying aquatic refuge areas in order to improve their management, particularly in a context where their maintenance is subject to increasing anthropic pressures without consideration of their importance.

Keywords : Aquatic refuges, biodiversity, freshwater ecosystems, global change, resilience

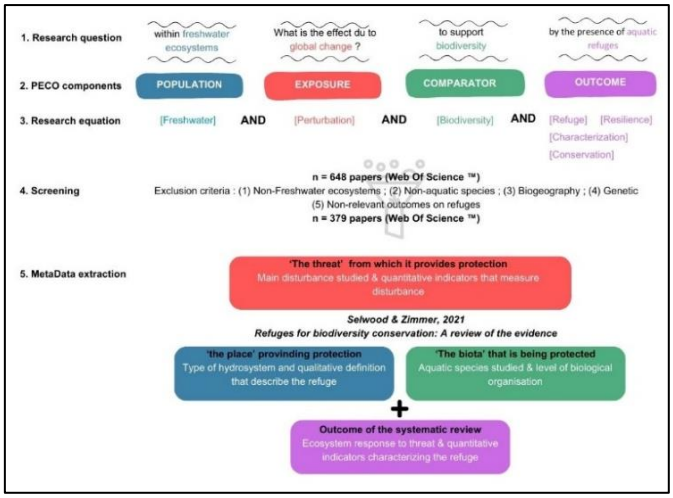

Figure: The first systematic review : how to define refuges to support biodiversity in freshwater ecosystems utilising the PECO framework ?
(M. Lucchini, 2025)

Mechanical and physical properties of oolitic limestones from the Upper Rhine Graben

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The Grande Oolithe (GO) is a Middle Jurassic oolitic limestone, present at various depths within the Upper Rhine Graben (Alsace, France). It is considered a prospective target for geothermal energy extraction. A comprehensive evaluation of its geothermal potential hinges on understanding its mechanical behavior and fluid flow. Porous carbonates often exhibit diversity and the microstructural complexity, with their mechanical behavior and fluid flow being strongly influenced by degree of cementation and proportion of macro and micropores, typically arranged in a dual porosity structure. To address these challenges, we initiated a systematic study on GO samples taken from outcrops and boreholes throughout the Upper Rhine Graben.

The aim is to characterize the pore space in GO and investigate its impact on mechanical strength and the initiation of failure modes, such as compaction bands, which affect permeability. This will involve deformation experiments on both dry and water-saturated samples to assess water-induced weakening.

Previous studies on dual-porosity limestones showed that effective stress coefficients for permeability and porosity change can exceed one, implying that changes in pore pressure can disproportionately control the evolution of permeability and porosity, significantly affecting fluid transport. Thus, the second objective is to quantify effective pressure coefficients for permeability, porosity change, brittle strength and onset of shear-enhanced compaction, while also assessing the temperature effect on these coefficients.

Carbonates can also exhibit time-dependent deformation, with lower creep strain rates leading to a larger damage accumulation before failure, suggesting that another deformation mechanism, different from crack growth, could be active at low strain rates during creep. Consequently, our study will aim to characterize the creep behavior in GO, and in particular compactant creep. The resulting dataset will provide essential parameters for large-scale numerical models which can predict in situ strain rates and pore pressure evolution in reservoirs, thereby advancing low-energy geothermal applications.

Keywords: Geothermal energy, limestone, fluid flow, mechanical behavior

Modeling seawater intrusion in coastal aquifers using physics-informed neural networks: Insight from the Henry problem

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Modeling seawater intrusion in coastal aquifers is crucial for sustainable water management, particularly as coastal populations grow. Accurate predictions can aid in better decision-making and resource allocation. With the rise of artificial intelligence (AI) in scientific research, machine learning (ML) has shown great potential in addressing this challenge. ML models can provide reliable predictions by learning from data without requiring explicit knowledge of physical processes. However, their dependence on large datasets, which are often costly and difficult to obtain, limits their applicability in fields like seawater intrusion. Additionally, conventional ML models function as "black boxes," lacking interpretability and struggling with generalization to unseen scenarios.

To overcome these limitations, physics-informed neural networks (PINNs) have emerged as a promising alternative. Unlike traditional ML models, PINNs integrate governing physical equations, such as differential equations, into the learning process. By embedding these constraints, PINNs ensure that predictions remain consistent with fundamental physical laws, making them particularly useful in data-scarce environments.

This study applies PINNs to model seawater intrusion in coastal aquifers using the Henry equation as a governing physical constraint. Results indicate that standard PINNs effectively capture key aspects of saltwater intrusion, demonstrating their potential in hydrogeological modeling. While this method is effective for modeling seawater intrusion using PINNs, it faces challenges when dealing with complex problems, especially in transitioning from a wider to a narrow mixing zone. A key finding of this research is that transfer learning, applying knowledge from simpler cases to more complex ones, can help improve results.

Keywords: Seawater intrusion, Physics informed neural networks (PINNs), Henry equation, Transfer learning

HOW TO DATE RIFTING THANKS TO VERTICAL MOVEMENTS?

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In plate tectonic, a process of lithospheric extension, the rifting, leads to the separation of tectonic plates. A rift involves into two passive rifted margins which can be magma rich or magma-poor. Syn-rift sequences, breakup unconformities and magnetic anomalies have been widely used to date rifting. However, it is generally accepted that rift systems are diachronous, both along dip and strike, and that the rifting processes are complex and difficult to date, in particular at magma-poor rifted margins. Therefore, new approaches need to be developed to date rifting. In our study we use the stratigraphic record of vertical movements to date a specific rift event and its propagation. We focus on two origins of uplift during rifting. First, the necking process, which corresponds to onset of localized deformation and significant differential crustal thinning. It may result in a characteristic, fast and short-lived uplift limited to the future distal margin, followed by its fast subsidence (Chenin et al., 2018). Second, dynamic topography, which refers to a large wavelength and fast uplift (Jones et al., 2012), due to convection/heterogeneities within the asthenospheric mantle, not necessarily linked to rifting. In this work, we use the example of the widely studied Late Jurassic to Early Cretaceous southern North-Atlantic magma-poor rift system, forming the present-day West Iberian margin, its conjugate the Newfoundland margin, and the Bay of Biscay rifted margin. Thanks to the specific and characteristic fingerprints of each of the two types of vertical movements, they can be used to date rifting in an absolute and relative way. While vertical movements associated with necking allow us to directly date the onset of crustal thinning and rift localisation, dynamic topography does not date a particular rift moment, but allows us to define an isochronous event that can be used for along strike time correlations and thus, for relative dating within propagating rift systems.

Keywords: Magma-poor rifted margin, necking, dynamic topography, uplifts, time constraints, rifting

On the use of ambient seismic noise interferometry for groundwater monitoring in the Upper Rhine Graben, France

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Ambient seismic noise interferometry is a powerful tool to monitor changes in seismic velocities within the upper crust induced by various forcings. Several studies have shown that the dynamics of aquifers can generate significant seismic velocity variations, concealing more subtle variations linked to other phenomena. Here, we present a temporal and spatial analysis of subsurface seismic velocity variations over a portion of the Upper Rhine Graben in north- eastern France, hosting one of the largest water table in Europe. We analyze 4 years of continuous seismic records between 2019 and 2023 from 144 permanent and temporary seismological stations, together with data from 777 piezometers across the area. Ambient seismic noise cross-correlations were calculated using horizontal and vertical components records, and we performed velocity variations in different frequency bands (ranging from 0.1 to 4 Hz) and lapse times. Overall, our results indicate a strong seasonality of seismic velocity changes above 1 Hz mainly in the ballistic surface waves time window and the beginning of the coda of correlations. This signature persists at lower frequencies, around 0.5 Hz, for longer times in the coda of correlations only. We spatially localised seismic velocity changes using coda waves sensitivity kernels and found patterns consistent with piezometric observations.

Keywords: Ambient seismic noise interferometry, Monitoring, Groundwater

Joint inversion of electromagnetic and direct-current resistivity data

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The Athabasca Basin is a world-class uranium mining province with several high-grade and high-tonnage deposits. The development of mineralization is driven by hydrothermal fluid flow, at the unconformity between basin sediments and basement's metamorphic and magmatic rocks. This flow is channelized by graphite-bearing crustal faults. Fluid flow also led to the alteration of basin and basement rocks modifying their petrophysical properties, including resistivity. Thus, the association of extensive alteration, graphitic faults at the unconformity constitutes targeted tracks to find uranium mineralization. However, these objects are usually buried at several hundred meters depth and drilling represents the main expense in exploration budgets. Improvements in drillhole targeting are thus a priority to gain in efficiency of mineral exploration projects.

Graphitic faults and alteration haloes both show contrasts of resistivity with their host-rocks. Electromagnetic (EM) and Direct-Current (DC) methods, being sensitive to electrical properties of the subsurface, are, in the Athabasca, the go-to methods to identify these objects. EM and DC methods are active survey methods, but the properties of the source used to illuminate the subsurface being different, the responses obtained do not highlight the same objects. Inductive EM methods are primarily used to localize highly conductive graphitic faults. DC methods are expected to give an insight into mild resistivity contrasts associated with alteration. However, the lack of sensitivity of EM methods to shallow mild resistivity contrasts leads to uncertainty on the location and geometry of recovered conductive plates, while DC methods are not able to constrain the signature of highly conductive graphitic faults leading to uncertainty on contrasts observable close to the unconformity.

A crosstalk from EM and DC data through joint inversion is expected to increase the resolution of geo-electric structures of the subsurface by benefiting from the specific sensitivity of both methods. Constraint on shallow resistivity contrasts should allow precise geometries of conductive plates, while precise location of the plates should allow mild resistivity contrasts close to the graphitic faults to be distinguished.

Keywords: Inversion, Resistivity, Electromagnetic, Electrical, Mining

The slow slip event cycle along the Izmit segment of the North Anatolian Fault

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Since the 1999 Mw7.6 Izmit earthquake, several geodetic observations suggest that the Izmit segment of the North Anatolian Fault (NAF) in Türkiye is aseismically creeping [Çakir et al., 2012; Hussain et al., 2016], with the occurrence of episodic slip events in September 2015 and December 2016 [Özarpacı et al., 2020; Aslan et al., 2019]. By using Interferometry Synthetic Aperture Radar (InSAR) time series from Sentinel-1 A and B acquisitions, automatically processed in the framework of the FLATSIM project [Thollard et al., 2021], based on the NSBAS processing chain [Doin et al., 2011], we analyzed the dynamics of the aseismic creep along the Izmit segment from 2016 to 2021. We extracted the tectonic signal by applying specific post-processing including a decomposition of the line of sight signals of the ascending and descending tracks into vertical and East-West velocity fields as well as independent component analysis within the Izmit basin. We analyzed separately a temporal linear trend corresponding to continuous creep and transient slow slip events (SSEs). Modeling the slip distribution using a 2D fault interface in a layered elastic half space, we estimate a locking depth of about 11 km with continuous creep restrained between 2 and 5 km-depth. We estimated the geodetic moment of the two new SSEs in March 2018 and in November 2019, corresponding to magnitudes of 4.4 and 4.3, respectively. These SSEs occurred within the upper section of the fault (1-3 km-depth), coinciding with the sediment thickness in the Izmit basin and suggesting the critical role of frictional properties variations on the occurrence of these events. The presence of a cycle of SSEs along the Izmit and Ismetpasa segments of the NAF [Rousset et al., 2016; Jolivet et al., 2023] questions the underlying physical mechanisms and key parameters defining their amplitudes, recurrence intervals and propagation speeds.

Keywords: Shallow aseismic creep, slow slip events, seismic cycle, strike-slip fault, SAR interferometry, North Anatolian Fault

Evidence for permeability heterogeneity in volcanic environments

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The permeability network of volcanic systems influences the behavioural modes of volcanoes. For instance, low-permeability rocks can act as vent seals, causing pressure accumulation and potentially triggering explosive eruptions. Whereas, high-permeability rocks, often associated with fractured domes, are more prone to outgassing leading to effusive behaviour. Hydrothermal alteration can significantly impact permeability, potentially sparking instability and mass movements. To examine potential hazards numerical volcanic stability models are used, which require input parameters. However, numerical models often disregard the necessity to incorporate heterogeneity in their simulation, exclusively, the ranges of permeability and alteration that exist in different parts of the volcanic environment.
Our contribution studied the relationship between alteration grades and permeability in nearly 600 volcanic rock samples. Our field permeability measurements, were calibrated to laboratory permeability, demonstrating a broad range of values, shwoing heterogeneity in both alteration and permeability between and within different sampling locations. Alteration grades (AGI 1 to AGI 5) showed a range of permeability values from 10^{-18} to 10^{-11} m², with alteration positively correlating with permeability. We, however, observed a very heterogeneous sample suite with large variability in permeability, porosity, and uniaxial compressive strength. Interestingly, the most altered samples (AGI 5) exhibited both low and high permeability.
Our findings highlight the importance of understanding the spatial distribution of both permeability and alteration. We conclude that volcanic models should incorporate permeability heterogeneity to improve predictions of volcanic behaviour. By including permeability heterogeneity into volcanic models, we aim to improve accuracy and reliability of prediction regarding volcanic hazards, thus enhancing our understanding of volcanic systems and hazards they might pose.

Keywords: Permeability, Hydrothermal alteration, Tiny Perm

Transformation of Sulfamethoxazole and S-Metolachlor under river conditions

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Micropollutants are frequently detected simultaneously in surface waters, posing ecotoxicological risks and compromising water quality. Their dissipation involves both transformative and non-transformative processes, affected by environmental factors such as matrix composition, dissolved organic matter quality and quantity, and co-occurring pollutants. This study investigates the dissipation of *S*-Metolachlor and especially sulfamethoxazole, representing pesticides and pharmaceuticals, the two dominant micropollutant classes in European rivers.

Conventional field observations based solely on quantitative analyses prove insufficient to distinguish simultaneous transformation and non-transformation processes. Since transformation products may be toxic and often remain unidentified, elucidating transformation pathways is crucial. Compound-Specific Isotope Analysis (CSIA) was applied, to improve the assessment of micropollutant transformation and thus, dissipation in rivers.

Microcosm experiments under varying environmental conditions — different matrices, initial micropollutant compositions, oxic and anoxic conditions and the addition of dissolved organic matter — demonstrated rapid biological degradation of sulfamethoxazole (DT50 = 0.57 ± 0.08 d) in sediment from the agriculturally impacted Souffel River (Bas-Rhin, France) adjacent to wastewater treatment plants. The potential primary transformation product, Sulfanilamide, results from ε-cleavage, a pathway not previously linked to biotransformation. Under simulated sunlight, a similar degradation rate (DT50 = 0.49 ± 0.03 d) was observed with 3-amino-5-methylisoxazole, a compound previously associated with direct photodegradation, as the main transformation product. The addition of organic matter standards delayed degradation (up to DT50 = 1.71 ± 0.13 d), depending on absorbance properties, without altering transformation products. This confirmed direct phototransformation and sediment-associated biotransformation as dominant pathways, leading to the formation of potentially persistent transformation products.

Preliminary CSIA results support this conclusion and will aid in distinguishing transformation pathways, with a combination of nitrogen and carbon isotope analysis. A recently developed derivatization method CSIA of sulfamethoxazole offers potential for differentiating the processes contributing to sulfamethoxazole dissipation in surface waters, such as the Souffel River.

Keywords: Sulfamethoxazole, transformation, S-Metolachlor, dissolved organic matter, CSIA

MODELLING THE IMPACT OF FILM FLOW AND ADJUSTABLE SURFACE TENSION EFFECTS IN RESERVOIR FLOW MANAGEMENT

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Understanding fluid flow in porous media is essential for applications ranging from hydrocarbon recovery to groundwater management. The displacement of multiphase fluids has been widely studied for the past few decades. The drainage process in porous media primarily happens through bulk of pores and pore throats which is referred to as primary drainage. As primary drainage passes, wetting fluid in a form of trapped clusters surrounded by a non-wetting fluid can be found in a porous network. Capillary bridges and fluid films affect the mobilization of these trapped clusters. This study numerically investigates how film flow through capillary bridges and corner flow networks mobilizes trapped wetting fluid clusters, significantly reducing residual saturation. Additionally, the transport of dissolved species that modify wetting properties and surface tension will be modeled, exploring their impact on flow efficiency.

To study the influence of liquid films and capillary bridges on contaminant spreading, a porous matrix was modeled similar to previously conducted experiments in which cylindrical obstacles were placed in a plane using Random Sequential Adsorption (RSA) method. To analyze the system's geometry, Delaunay Triangulation of the cylinder positions was applied, and the related Voronoi lattice represented the network of pores connected by pore throats, enabling a quantitative assessment of capillary interactions. The relationship between volume and pressure of fluid in a pore is studied using Young-Laplace equation which is also implemented in modeling the pressure perturbations in a porous network. The pressure field evolves based on flux exchanges between neighboring pores, governed by a Poiseuille-type flow approximation through constrictions between cylinders. By bridging experimental observations with numerical modeling, this research provides new insights into the impact of film flow on multiphase fluid distribution and contaminant transport in porous media.

Keywords: Porous Network, Fluid Flow, Drainage, Capillary Bridges

Constraining Earth's Mantle Rheology Through Love Numbers and Tidal Response of Maxwell, Burgers, Andrade, and Sundberg-Cooper Models

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The Earth's visco-elastic deformation due to tidal forces is commonly represented by Maxwell and less frequently, Burgers rheologies in the mantle. Tidal Love numbers have been actively used for decades as a way to describe tidal effects and study the interior structure of planets and satellites in the Solar System.

In this work, we present a comparative analysis of four major rheological models— Maxwell, Burgers, Andrade, and Sundberg-Cooper— to assess their effectiveness in modeling the Earth's rheological behavior. While Andrade and Sundberg-Cooper models are rarely applied to Earth, they have demonstrated effectiveness in modeling the visco-elastic tidal response of planetary bodies and satellites. We have developed theoretical responses for each of these models from seismic frequencies to very long periods. We first compare the advanced Andrade (1910) and Sundberg-Cooper (2010) models with the classical Maxwell and Burgers models. We then focus on tidal responses by comparing predicted gravimetric factors for these models with those observed from long-term gravimetric data collected by superconducting gravimeters within the IGETS (International Geodynamics and Earth Tide Service) network and by SLR (Satellite Laser Ranging).

Keywords: , Rheology, Tidal forces, Earth deformation, love numbers

Consequences of drought on nutrient biogeochemical cycle in forest soil : Approach by observation, experiment and modelling

Saphy, Adrien

The frequency and intensity of droughts will increase with climate change, particularly in mid-mountain areas that were unaffected just a few years ago. The consequences of drought on nutrient cycles in soils are still poorly understood, and are particularly worrying in nutrient-poor soils. This study focuses on the chemistry of soil solutions, which are of interest because they are the nutritive solution for trees.

The study site is the Strengbach watershed, which hosts the Observatoire HydroGéochimique de l'Environnement (OHGE). This is a mid-mountain forest watershed, where we are studying plots of spruce planted on acid brown soils with podzolic tendencies, particularly poor in alkaline Ca and Mg nutrients. The drought of summer 2022 was the longest ever recorded at the observatory, and very specific signals were noted in the chemistry of soil solutions: peaks in concentrations of K+, Mg2+, Ca2+, Al3+, NO3-, NH4+, DOC.

To better understand the complex signal observed in the field, soil column experiments were carried out under controlled laboratory conditions. The columns were simpler because they contained no vegetation, enabling us to better understand geochemical processes and to deconvolute the vegetation signal in the field. A water deficit was applied to these columns. Soil columns 30cm high are compared with soil solutions 30cm deep.

In order to better understand and quantify the various biogeochemical processes, a numerical modeling approach is proposed, with a coupling of three models HYDRUS-LPJ-WITCH.

This triple approach provides a better understanding of biogeochemical processes in forest soils and how they are affected by drought.

Tomographic inference of Vp/Vs ratio and its physical interpretation in the mantle beneath Indonesia

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The ratio of compressional-wave to shear-wave velocity (Vp/Vs) is a key physical parameter linked to the Poisson coefficient. It provides insights into how materials respond to stress and, indirectly, about the Earth's thermo-chemical structure. We develop a methodology for computing this ratio (or an approaching one: R=dlnVp/dlnVs) in a robust way, including uncertainty estimates. Our approach is based on the SOLA-Backus-Gilbert inversion, which provides not only estimates of P-wave (dlnVp) and S-wave (dlnVs) velocity anomalies but also their associated uncertainties and local resolution. If the local resolution of both models is similar, ratio maps (R and 1/R) can be constructed without restricting the dataset to pairs of P- and S-wave arrivals, as is commonly done. This allows for the inclusion of a much larger dataset in the inversion, improving resolution. Additionally, by incorporating model uncertainties, we estimate the uncertainty in the ratio using the Hinkley formula. The computed ratios differ from the true Vp/Vs anomaly, dln(Vp/Vs). However, by analyzing dlnVp, dlnVs, and R (or 1/R), we can infer how Vp/Vs varies. Depending on the sign of the velocities and the value of the ratio, six distinct cases emerge, each leading to different geophysical interpretations. Thanks to the uncertainty estimates from the SOLA method, we can assess the probability of each case, simplifying the analysis, and enabling deeper geophysical interpretations. We tested this approach in the upper mantle beneath Indonesia, down to 800 km depth. The inferred dln(Vp/Vs) map shows strong coherency with known subducted slabs and partial melts beneath volcanic arcs, validating the methodology. Additionally, we identified evidence of grain size reduction at the top of the Mantle Transition Zone (MTZ) in the cold Java-Sumatra subduction zone. A depth-dependent variation in dln(Vp/Vs) was also observed beneath the Sumatra slab in the Subslab Hot Mantle Upwelling (SHMU) region, potentially caused by adiabatic decompression of deep mantle material or silica enrichment in the rising mantle.

Keywords: SOLA, Uncertainties, Velocity ratio inference, Interpretation, Grain Size reduction

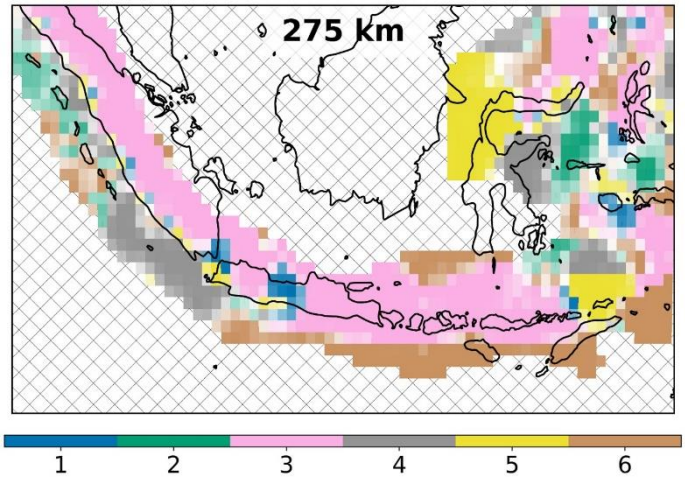

Figure: Map of the six possible interpretations at 275 km depth. (Serra et al. 2025, in preparation)

Mantle-melt interaction during mantle exhumation along the Iberia-Newfoundland conjugate margins: the role of mantle inheritance.

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This research focuses on the Iberia-Newfoundland margins to elucidate the role of mantle inheritance in its geodynamic history. The study of dredged and drilled magmatic and mantle rocks from the Western Iberia and conjugate Newfoundland margins together with those from the fossil Alpine Tethys and the present-day Australia-Antarctica margins (Ballay et al., 2025), led to the development of models for the mantle-melt evolution of magma-poor rifted margins. However, it remains unclear to what extend the nature, origin, and history of the subcontinental mantle lithosphere (SCLM) controls the magmatic budget and mantle-melt reactions during mantle exhumation.

In this study, we use a set of dredged and drilled samples from the Northwestern (Galicia Bank and the Iberia Abyssal Plain) and Southwestern Iberia margin (Tore-Madeira Rise) but also from its conjugate margin, the Newfoundland margin. Petrological and geochemical data including in-situ major and trace element concentrations of minerals from peridotites are presented and discussed with the aim to characterize mantle-melt interactions and identify the source(s) of melts. Also, partial melting modeling will be used to characterize the magmatic processes occurring during exhumation and breakup at the conjugate Iberia-Newfoundland rifted margins. These data will bring new constraints on the SCLM inheritance at the scale of the southern North Atlantic and will provide key-information on how mantle inheritance controls subsequent mantle-melt interactions, the nature of percolating melts at the early stages of oceanization and the PT-paths of mantle exhumation occurring at magma-poor rifted margins.

Keywords: peridotites, mantle inheritance, melt-rock interactions, partial-melting modelling

Modeling the Impact of Seasonal Water Table Fluctuations on Ambient Noise Interferometry Using Acousto-Elastic Effect

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Ambient noise interferometry has become a common technique for monitoring slight changes in seismic velocity in a variety of contexts. However, the physical origin of the resolved small velocity fluctuations is not well established for long-term seasonal effects. Here we propose a physical forward model of scattered waves in a deformable medium that includes acousto-elastic effect, which refers to non-linear elasticity with third-order elastic constants. The model shows that small pressure perturbations of a few kPa due to seasonal variations in the water table can induce seismic velocity changes compatible with those measured at the surface by ambient noise interferometry. The results are consistent with field observations near the deep geothermal site of Rittershoffen (France). They illustrate the capability in modeling the diffuse wavefield from scattering synthetic waves to reproduce ambient noise signals for monitoring environmental and/or deep reservoir signals.

Keywords: ambient noise interferometry, acousto-elestic effect, Specfem/Code_Aster, water table elevation, seasonal velocity changes, reservoir monitoring

TRACKING LANDSLIDE TERRAIN MOTION WITH VERY HIGH RESOLUTION OPTICAL IMAGE TIME SERIES.

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Times series of VHR optical imagery, with their high spatial resolution (<0.5 to 2 m) and stereoscopic capabilities are offering huge potential for monitoring surface deformation using Optical Image Correlation techniques. Very-High spatial resolution allows to enhance both the sensitivity and the accuracy of the measurements leading to the detection of small changes in deformation rates for Pléiades imagery. However, the exploitation of time series remains challenging because of errors associated with the image acquisition geometry, which are potentially high in mountain regions with complex and string topography.

We propose an automated and generic processing chain, based on the GDM-OPT workflow initially tailored for Sentinel-2 image time series in order to process time series of Pléiades Panchromatic monoscopic and stereoscopic data products.

The approach consists first in the generation of intermediary DSMs by classical stereo- photogrammetric processes. Second, in order to compensate for the planimetric and vertical errors, we correct the generated DSMs through an alignment to a reference topography. We then compute the ground coordinates of tie points of the image system taking into account the newly aligned topography. Considering these points as GCPs and by performing a new bundle adjustment forced to fit to them, the alignment step is integrated in the stereo- photogrammetric process. Then, a new DSM and an ortho-image mosaïc consistent with the reference topography are calculated. Finally, the ortho-image mosaïcs are correlated using a specific pairing network. At the end of this step, all the displacement maps obtained (North- South, East-West) are inverted into a displacement time series. The processing workflow is tested on the two landslides of La Valette and Aiguilles/Pas de l'Ours, allowing to retrieve the mean velocity and the ground displacement time series for each pixel. We validate the proposed workflow by comparing the results of the processing chain and in-situ dataset. We show that the proposed methodology allows the monitoring of large landslides displacement, with velocity larger than 0.07 m/year.

Keywords: VHRO satellite imagery, OIC, Landslide monitoring, Stereo-photogrammetry