# Stages de recherche Master 2 - 2026/2027

Title: **Deep structure of the Kerguelen archipelago (southern Indian Ocean) from the study of seismic data - Lisisker project**

**Supervisors**: Stéphanie Durand (LGL-TPE, Lyon stephanie.durand@univ-lyon1.fr), Jérôme Bascou (LGL-TPE, Saint-Etienne jerome.bascou@univ-st-etienne.fr), Damien Guillaume (LGL-TPE, Saint-Etienne, damien.guillaume@univ-st-etienne.fr)

**Keywords**: seismic study, Kerguelen, lithospheric structure

**Abstract:**

The Kerguelen Archipelago (Indian Ocean; 49° S, 69° E) results from a particular geodynamic history linked to the long-lived Kerguelen plume. Its formation began about 42 million years ago when the plume was located beneath or near the South East Indian Ridge (SEIR). Today, the archipelago occupies an intraplate position within the Antarctic Plate.

Extensive research, including several geoscience programs supported by the French Polar Institute (IPEV), has highlighted the archipelago's unique geological features and its significance for understanding the origins of the first continents. Kerguelen also serves as an exceptional natural laboratory for studying lithosphere that has undergone extensive partial melting, followed by the percolation of large volumes of plume-derived magma. However, progress in this field has been constrained by a lack of seismological data from the region.

To address this gap, ten temporary seismic stations were deployed since January 2022. In addition, petrophysical characterizations are carried out on xenoliths brought to the surface by the basaltic flows in order to better interpret seismic recordings.

The primary objective of this research internship is to analyze seismic data collected between 2022 and 2025 period of the Lisisker project. Seismic data will be exploited using various techniques of seismological analyses (in particular receiver functions) to map the seismic discontinuities. A complementary petrophysical approach may also be pursued, involving the characterization of seismic properties (Vp, Vs, and anisotropy) through crystallographic orientations EBSD measurements of Kerguelen rocks.
This internship will include collaboration with seismologists from the University of Strasbourg (EOST), who are also involved in the Lisisker project.

**Titre/Title:** Cinétiques haute température des réactions silicate-métal

**Encadrant(s)/ Supervisor(s):** PM Zanetta, B Reynard

**Thématique/mots-clés (Keywords): Nébuleuse solaire, météorites**

**Résumé/Abstract:**

Ce projet propose d'explorer les phénomènes de haute température qui gouvernent la formation des grains de métal-silicate dans le disque protoplanétaire, et in fine la composition après accrétion des astéroïdes primitifs, embryons planétaires, et des planètes telluriques. Les phénomènes de formation et d'équilibration des silicates et des métaux sont relativement bien connus. Ce qui l'est moins concerne les phénomènes hors d'équilibre, contrôlés par la cinétique, comme l'évaporation des alcalins et des métaux à bas point de fusion comme le zinc, ou les phénomènes de transformations de phases à l'état solide et à l'état liquide dans les silicates.

Pour étudier cet aspect cinétique, nous proposons une approche expérimentale à très haute température utilisant une cellule réactionnelle (300-3000 K) mise au point dans notre équipe. Nous soumettrons des assemblages silicate-métal à des températures élevées pour des durées variables afin de contraindre des modèles cinétiques d'évaporation, et de trempe de phases métastables de haute température comme les verres. Le travail combinera caractérisation pétrographique par microscopie électronique et spectroscopie Raman sur chondrites et achondrites et expériences à haute et très haute température de solides et liquides (métal+silicate).

Ces données expérimentales seront utilisées pour contraindre directement l'histoire thermique de grains que nous avons identifiés dans les chondrites carbonées.

**To apply:** bruno.reynard@ens-lyon.fr, pierre.marie.zanetta@univ-st-etienne.fr

Title: **Mineralogy and Petrology of drilled cores in an active volcanic area (La Réunion Island, Plaine des sables) and the link with $CO_2$ soil emissions.**

**Supervisor(s)**: Andrea Di Muro, Isabelle Daniel @LGL-TPE

**Keywords**: volcanic sequences, reactivity at interfaces, XRD, XRF, Raman spectroscopy, microthermogravimetry and MEB analyses

**Prerequisite**: a background in igneous petrology would be appreciated, appetite for analytical methods is an asset

**Abstract**: The Plaine des Sables (PdS) is located west from the active Piton de la Fournaise volcano on La Réunion Island. It is characterized by a low to negative $CO_2$ flux in some specific area, identified by multiple campaigns of gas measurements. This raises the issue of the origin and mechanism of $CO_2$ capture and potentially sequestration (CCS) in a natural environment, which is obviously of high relevance to the strategies and technologies to be developed for CCS. The proposed work is part of a larger project supported by the French ANR. It is called SOSIE, which stands for SOurces and SInks of CO2 soil Emissions in active and quiescent volcanoes**.** In November 2025, two fresh cores were drilled in the main area of interest. Their characterization is now a high priority. They have been measured by X-ray CT-scan while preserving their integrity. They are now ready to be opened to investigate their mineralogy and petrology using a combination of analytical methods to search for a reactive zone that could explain $CO_2$ capture, to search for carbonate minerals or other phases (e.g. imogolite) producing carbon capture. Depending on the results, the investigation could be extended to drilled cores collected nearby in areas of high $CO_2$ flux. The suite of analytical methods will inform us about the chemistry, the structure and the reactivity of the different subsurface volcanic sequences at different resolutions. All metadata are available, including virtual images of the area. The same samples will be analysed to evaluate their microbial community and microbial activity and evaluate the respective biotic and abiotic contribution to the 'negative' $CO_2$ flux in the area and will represent the benchmark for further lab experiments.

Expected outcomes: a detailed and high-resolution mineralogical and petrological description of the drilled cores, which either identify the zones responsible for natural CCS in the system or help to build robust hypotheses to be further tested.
The project can be extended and expanded later on.

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Title: **Investigation of the rheological and seismological properties of Earth's asthenosphere.**

**Supervisors:** Maëlis Arnould (LGL, Lyon, maelis.arnould@univ-lyon1.fr) ) – Stéphanie Durand (LGL, Lyon, stephanie.durand@ens-lyon.fr)

**Prerequisites:** a solid training in seismology, geophysics and geodynamic modeling are necessary.

**Keywords:** Seismic anisotropy, attenuation, asthenosphere, mantle rheology, numerical modeling, mantle convection

The asthenosphere, located at the interface between the lithosphere and the rest of the mantle, plays a key role in Earth's internal geodynamics. However, its nature, dynamics and geometry remain poorly constrained at present, limiting our understanding of the rheology and dynamics of the Earth's mantle, as well as the couplings between the lithosphere and the mantle. Seismological observables can provide information on the rheology of this layer: the low seismic velocities and high seismic attenuation of the asthenosphere would suggest the presence of partial melting, the high seismic anisotropy would show the existence of dislocation creep at the origin of the preferential orientation of olivine crystals, and variations in seismic attenuation could reveal the evolution of grain size in the asthenosphere. Combining these seismological observations on asthenospheric rheology with geodynamic models of mantle convection would allow us to better constrain asthenospheric rheology, and to better understand its dynamics and its role in plate tectonic motions.

The aim of this research internship is to jointly exploit seismological observables (velocities, anisotropy and attenuation) and geodynamic models of mantle convection with plate tectonics to explore the effects of different rheologies (linear or composite, with or without grain size evolution, with or without partial melting in the asthenosphere) on seismological characteristics and the dynamic consequences that such rheologies would produce.
We propose to use the StagYY code (Tackley et al., 2000), which allows to run fully-dynamic 2D numerical models of whole-mantle convection with plate tectonics and a complex rheology (Arnould et al., 2023, Manjón Cabeza-Córdoba et al., *in rev*.) in order to explore the effects of the amount of dislocation creep, of grain-size evolution, and of parameterized partial melt in such models, on the development of seismic anisotropy and attenuation. We will then be able to make quantitative comparisons between the spatial distribution of observed anisotropy and attenuation in the Earth's asthenosphere and the seismic properties predicted from geodynamic models, with the goal to better constrain Earth's asthenosphere rheology, and ultimately its dynamics.

Title: **Compositional heterogeneities within mantle plumes: numerical study / Les hétérogénéités de composition des panaches mantelliques: numerical study**

**Supervisor(s):** Maëlis Arnould, Jean-Philippe Perrillat

**Keywords:** mantle plume, numerical modeling, mantle convection, Reunion hotspot

**Suitable formation level & prerequisites:** Master student with solid bases in geophysics and numerical modeling.

**Context and objectives :**
Most terrestrial hotspots exhibit a wide range of spatio-temporal chemical heterogeneities that are visible in the geochemical signature of emitted lavas at the surface. These heterogeneities can stem from the dynamics of the underlying mantle plumes, their sources and their potential mixing with the surrounding mantle and the crust. However, it is still challenging to explain the large chemical variability observed along hotspot tracks.
The aim of this research internship is to investigate the spatio-temporal distribution of the chemical heterogeneities carried within mantle plumes of various geometries using numerical models of mantle convection self-generating plate-like tectonics at the surface.
A systematic exploration of the effect of mantle rheology, plate and plume dynamics on the chemical variability produced in the emitted lavas at the surface of the models will be conducted, and comparisons with Earth observations will be made.

**Program:**
● Development of numerical models of mantle convection in 3D spherical patch with StagYY, with chemical heterogeneities.
● Automatic tracking of mantle plume and hotspot chemical heterogeneity.
● Qualitative / quantitative comparison with observations of fluctuations of activity of hotspots, and in particular, La Réunion

**Acquired skills:**
numerical modeling, bibliography search, python coding and versioning, interpretation of numerical results, redaction of a scientific report

**Supervision and working environment :**
The internship will be co-supervised by Maëlis Arnould and Jean-Philippe Perrillat at La Doua, Université Lyon 1. It is part of the larger-scale project Plum-BeatR funded by ANR (the funds of the internship will come from this source).

**Length :** 5-6 months

**Period :** January/June 2027

**Contact:** maelis.arnould@univ-lyon1.fr

**Titre/Title: Deciphering the Evolution of Plate Coupling and Deformation Processes Along Exhumed Subduction Interfaces**

**Encadrant(s)/ Supervisor(s):** Samuel Angiboust

**Thématique/mots-clés (Keywords):** metamorphism, paleoseismicity

**Résumé/Abstract:** Exhumed suture zones, such as those exposed in the Western Alps, preserve valuable records of past plate coupling processes through mylonites and paleoseismicity markers. This project aims to investigate deformation regimes and fluid–rock interactions within paleo-accretionary systems using a multidisciplinary approach. Field observations, thin section analysis, and EBSD techniques will be combined to characterize deformation mechanisms and quantify paleo-stresses through paleopiezometric techniques. Coupled with in situ geochronological constraints, these data will allow reconstruction of the stress evolution and deformation history along ancient subduction interfaces. For further information about this project, please contact me directly by email.

**Prerequisite**: a background in tectonics and petrology would be appreciated. Good physical skills and a taste for challenging field conditions is required.

**To apply:** samuel.angiboust”at”ens-lyon.fr

**Title: Reconstructing continental air temperatures during the deglaciation and the onset of the African Humid Period using brGDGTs (Ngaoundaba peatland, Adamawa, Cameroon)**

**Supervision:** Guillemette Ménot (LGL-TPE, ENS de Lyon), in collaboration with Etienne Tertrais (PhD student, LGLTPE, IFPEN) and David Sebag (IFPEN)

**Keywords:** Paleoclimate, organic geochemistry

**Scientific context:** The sedimentary sequence from the Ngaoundaba peatland (Adamawa, Northern Cameroon), cored in 2023 to over 12 m depth, provides a continuous record spanning the last 30,000 years, including the Last Glacial Maximum, the deglaciation, and the onset of the African Humid Period (AHP). This time window remains poorly documented in Central Africa, yet it is critical for testing the ability of climate models to reproduce the non-linear response of the African monsoon and vegetation to orbital forcing. Previous work on this archive (V. Schaaff's PhD thesis, 2021–2023) validated brGDGTs as pH proxies in this type of peat deposit, but their potential as a paleothermometer has not yet been exploited over the pre-Holocene interval.

**Internship objectives:** The goal is to reconstruct continental air temperature variations over the deglaciation interval (25–8 ka) using brGDGTs extracted from Ngaoundaba sediments, based on MBT'5Me/CBT' indices calibrated for tropical/peatland settings. The candidate will characterize the distribution of brGDGTs along the sequence at high temporal resolution, assess the consistency of these reconstructions with other available proxies (isotopes, palynology, major elements), and discuss the paleoclimatic significance of the observed transitions (end of the Last Glacial Maximum, abrupt deglacial events, onset of the AHP).

**Methodology:** Total lipid extraction by microwave-assisted extraction, purification by chromatography, and analysis and quantification of brGDGTs by LC-MS at LGL-TPE, ENS de Lyon. Calculation of indices (MBT'5Me, CBT', IR6Me) and conversion into temperatures using existing calibrations, with discussion of their applicability in a tropical peatland setting.

**To apply:** guillemette.menot”at”ens-lyon.fr

Title: **Reconstructing seawater temperature evolution during the onset of the Jenkyns event along a proximal-distal transect**

**Supervisors:** Guillaume Suan (LGL-TPE, Villeurbanne – la Doua, guillaume.suan@univ-lyon1.fr), Simon Andrieu (LGL-TPE, Villeurbanne – la Doua, simon.andrieu@univ-lyon1.fr), Pierre Chaumat (LGL-TPE, Villeurbanne – la Doua, pierre.chaumat@univ-lyon1.fr)

**Keywords:** paleoclimate, geochemistry, oxygen isotopes, carbonate shells, Jenkyns event, Jurassic, Morocco

**Context and scientific question:** The Early Jurassic witnessed a series of rapid climate oscillations and carbon cycle perturbations. The most intense of these events occurred ~182.8 Ma ago during the early Toarcian, when subtropical seas warmed by >5 ◦C (Suan et al., 2010; Ruebsam et al., 2020a; Ullmann et al., 2020) in less than few hundred millennia (Kemp et al., 2024). This warming marked the onset of a period of elevated organic burial lasting several hundred thousand years (Boulila and Hinnov, 2017) initially referred to as the Toarcian Oceanic Anoxic Event (T-OAE) (Jenkyns, 1988), although the terminology of "Jenkyns event" is now more widely used. It is thought that this event was triggered by intense volcanic activity in the Karoo-Ferrar Province and associated massive release of greenhouse gases into the atmosphere-ocean system (e.g., Courtillot, 1994; Duncan et al., 1997; Palfy and Smith, 2000; Svensen et al., 2007; Suan et al., 2008). Several reconstructions of sea-water temperatures during the Jenkyns Event were proposed in the subtropical realm (Suan et al., 2010; Ruebsam et al., 2020a; Ullmann et al., 2020), and more recently in the polar record (Fantasia et al., 2026). One of their limitations is that they are mostly focused on relatively condensed and isolated sedimentary sections. This highlights a challenge that remains to be addressed: providing a series of seawater temperature curves with finer temporal resolution, based on sedimentary depth transects ranging from shallow to deeper areas, in order to assess biases related to local environmental conditions.

**Objectives and methods:** This research internship aims at tackling this challenge by taking advantage of the exceptional sedimentary record in the High Atlas Mountains of Morocco, which displays highly dilated outcrops of the early to middle Toarcian (up to several hundred meters compared to few tens of meters in the classic and extensively studied European successions) with outstanding lateral continuity from subaerial to lower offshore setting. This study site offers a great opportunity to tackle the limitations raised above. To do so, the selected master student will work on previously collected samples of well-preserved oysters, *Trichites*, brachiopods and belemnites. The first step of the work will be to carry out a petrographic study of those samples, to estimate their degree of preservation and to select the most suitable shells/rostra for further geochemical analyses. Oxygen isotopes analyses will be conducted on the selected specimens thanks to the IRMS Isoprime available at the LGL-TPE.

**Deformation mechanisms in a major shear zone.**

**Summary:** Following the work of Tapponnier et al. (1990) and Leloup et al. (1993, 1995), the Ailao Shan–Red River (ASRR) shear zone, over 1000 km long, is considered a major strike-slip fault along which Indochina moved 700±200 km during the Oligo-Miocene. A series of studies has refined the geometry, timing, and mechanisms of this deformation (e.g., Leloup et al., 2001; Gilley et al., 2003; Sassier et al., 2009; Boutonnet et al., 2013; 2015), making this zone a tectotype for continental strike-slip deformations. However, questions remain regarding: 1) the northwestward extension of this shear zone into Southeast Tibet; 2) direct dating of lower-temperature deformations (~300°C); 3) the deformation mechanisms, particularly the strain rate and stress levels within the deformation zone.

These questions are critical because the deformation mechanisms of continental crust remain debated, oscillating between models of generalized flow (e.g., Jamieson et al., 2011) and others where deformation is localized in a small number of shear zones.

Research within the laboratory has enabled precise dating of some high-temperature strike-slip deformations (Sassier et al., 2009) and the development of a new method to measure ductile deformation rates based on quartz grain size in mylonites (Quartz-Strain-Rate-Metry, QSR). This method has allowed the measurement of strain rates and the estimation of their variation across the shear zone, as well as the associated deviatoric stress levels (Boutonnet et al., 2013; 2015). However, this study was conducted on only eight samples, and these samples have not been analyzed for crystal lattice-scale deformations, which is now possible using TEM and SEM (TKD system) in Saint-Étienne (Seydoux-Guillaume et al., 2024), EBSD (in collaboration with INSA), and cathodoluminescence (S. Angiboust).

We propose to:

- Conduct a nano-scale study of the existing samples to better parameterize the QSR method;
- Extend QSR measurements across the entire shear zone using already collected samples;
- Directly date the mylonites (Ar/Ar and Rb/Sr on thin sections) and refine the petrographic evolution to clarify the deformation timeline, which is currently indirectly constrained (dating of deformed veins; thermochronology).

**Supervisors / Workflow:** The internship is supervised by Philippe Hervé LELOUP (CNRS Senior Researcher), who coordinates the study. Depending on the intern's skills and interests, the focus can be tailored to one of the three aspects mentioned above. Co-supervision will be provided by: A.-M. Seydoux-Guillaume (CNRS Senior Researcher) for micro-scale analyses; S. Angiboust (Professor, ENS) for EBSD and cathodoluminescence; Clémentine Fellah (ENS Research Engineer) for imaging techniques and G. Mahéo (Lecturer) for petrography. Dating analyses will be carried out in Montpellier (Ar/Ar) and/or Clermont-Ferrand (Rb/Sr).

Internal laboratory funding has been secured to cover the analysis costs.

This internship can serve as a Master 2 research internship or a gap-year internship (6 months or longer).

**Prerequisites:** The internship requires strong proficiency in thin-section deformation analysis and a theoretical understanding of imaging and dating methods.

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**The Carboniferous basin of Bessèges-Grande Combe (Alès Basin): mineralized Faults, 3D Modeling, and geodynamic implications**

**Subject:** The Carboniferous Basin of Bessèges-Grande Combe is located on the southeastern edge of the Massif Central, near the Cévennes Fault (Figure 1). It has been proposed that this basin formed during E-W extension above a normal fault at the end of the Variscan orogeny, and was later cut by left-lateral N-S strike-slip faults (Allemand et al., 1977).

Since 2006, M1 students from the Laboratoire de Géologie de Lyon have participated in a 3D cartography teaching Unit organized in collaboration with the BRGM. This unit combines field mapping and 3D digital modeling, with the goal of creating a 3D geological model of part of the basin. During this work, a large amount of field data has been collected (structural measurements and outcrop observations). 1) No syn-sedimentary normal faults related to the Carboniferous deposits have been identified. 2) The Carboniferous is affected by N-S thrust faults with westward vergence, which are unconformably covered by Triassic sediments. This Permian compressive tectonics phase (known as the Saalian phase) is poorly documented in France and is generally absent from geodynamic reconstructions. 3) The basin is divided in two by a basement culmination (Le Rouvergue), whose post-Mesozoic exhumation timing and cause remains unknown. 4) Subvertical faults with a N120° orientation, sometimes associated with massive baryte mineralization, cuts through both the Carboniferous basin and the Mesozoic cover. 5) The eastern part of the area is affected by normal faults related to the formation of the Eocene-Oligocene Alès graben.

Key questions about the tectonic history of the region thus remain unanswered: 1) What mechanism caused the subsidence of the Carboniferous basin? 2) What are the characteristics of the Saalian compression phase? 3) How are the Pyrenean and Alpine compression phases expressed in this area?

These questions extend beyond the basin itself and have broader implications for the geodynamics of the Massif Central, which is currently at the heart of discussions on mineral resources.
To address these questions, the internship proposes: 1) The creation of a database compiling field data and bibliographic references. 2)The development of a 3D geological model of the area. 3) The proposal of a new geodynamic evolutionary model for the Bessèges-Grande Combe Carboniferous Basin.
**Organization:** the internship is jointly supervised by Séverine CARITG-MONNOT – Regional Geologist, BRGM Montpellier and Philippe Hervé LELOUP – CNRS Research Director, Laboratoire de Géologie de Lyon
Since 3D geological modeling is an iterative process, the internship will include periods in Lyon (structural analysis, database compilation), Montpellier (3D modeling) and in the field.
This internship can be completed as a 6-month M2 research internship or a gap-year internship.
**Prerequisites :** strong proficiency in field geology ; experience of 3D geological modeling

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# Paleoaltimétrie des Andes au Miocène

Le système Cordillère des Andes/Bassin Argentin constitue un laboratoire naturel exceptionnel pour comprendre les interactions entre la tectonique, l'érosion et le climat.
Depuis le début de la convergence atlantique au Crétacé supérieur, le Miocène est la période où s'est produite la plus grande reconfiguration tectonique régionale (Ramos et Folguera, 2008) et le transfert sédimentaire le plus intense des zones sources vers les environnements de dépôt distaux (Rohais et al., 2021). Le système de drainage du Río Negro de plus de 700 km de long, témoigne de cette évolution dynamique grâce à un vaste enregistrement synorogénique qui s'étend des Andes jusqu'à la région distale, sur le plateau continental argentin et dans le bassin argentin (COPLA, 2017 ; Fig. 1).

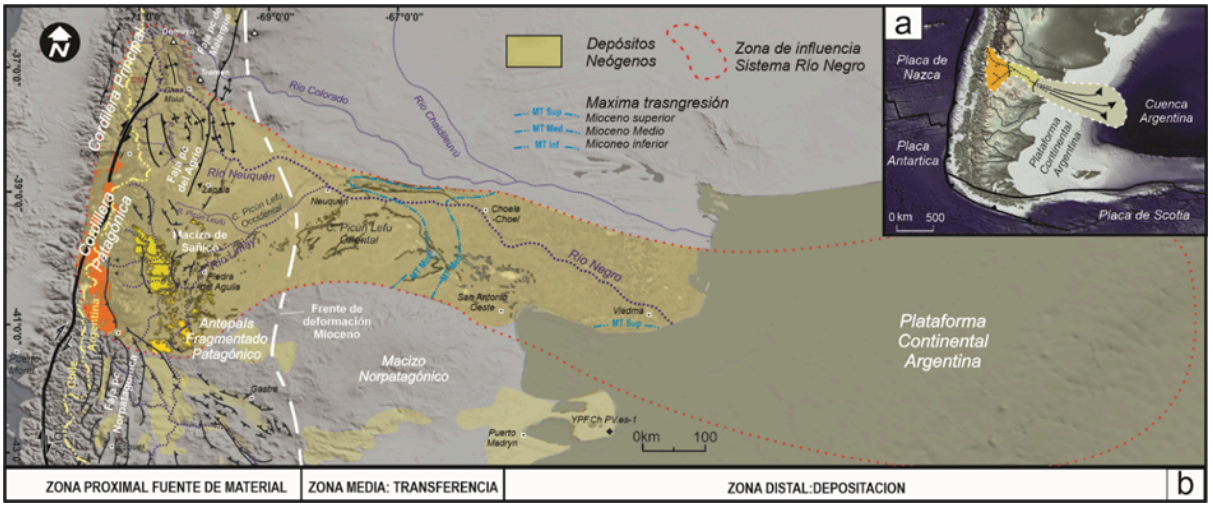


*Figure 1 : (A) Vue d'ensemble du système de transport sédimentaire miocène du Río Negro, des Andes de Patagonie septentrionale au bassin argentin. (B) Vue rapprochée du système de transport sédimentaire synorogénique miocène du Río Negro.*

L'étude des dépôts sédimentaires du plateau continental Argentin a mis en évidence une Surface de Discontinuité Miocène (SDM) tout le long du système de transfert, séparant deux cycles de sédimentation distincts. Un cycle de sédimentation daté du Miocène inférieur, dominé par des matériaux volcanoclastiques puis, un cycle de sédimentation daté du Miocène supérieur dominé par des matériaux épiclastiques.

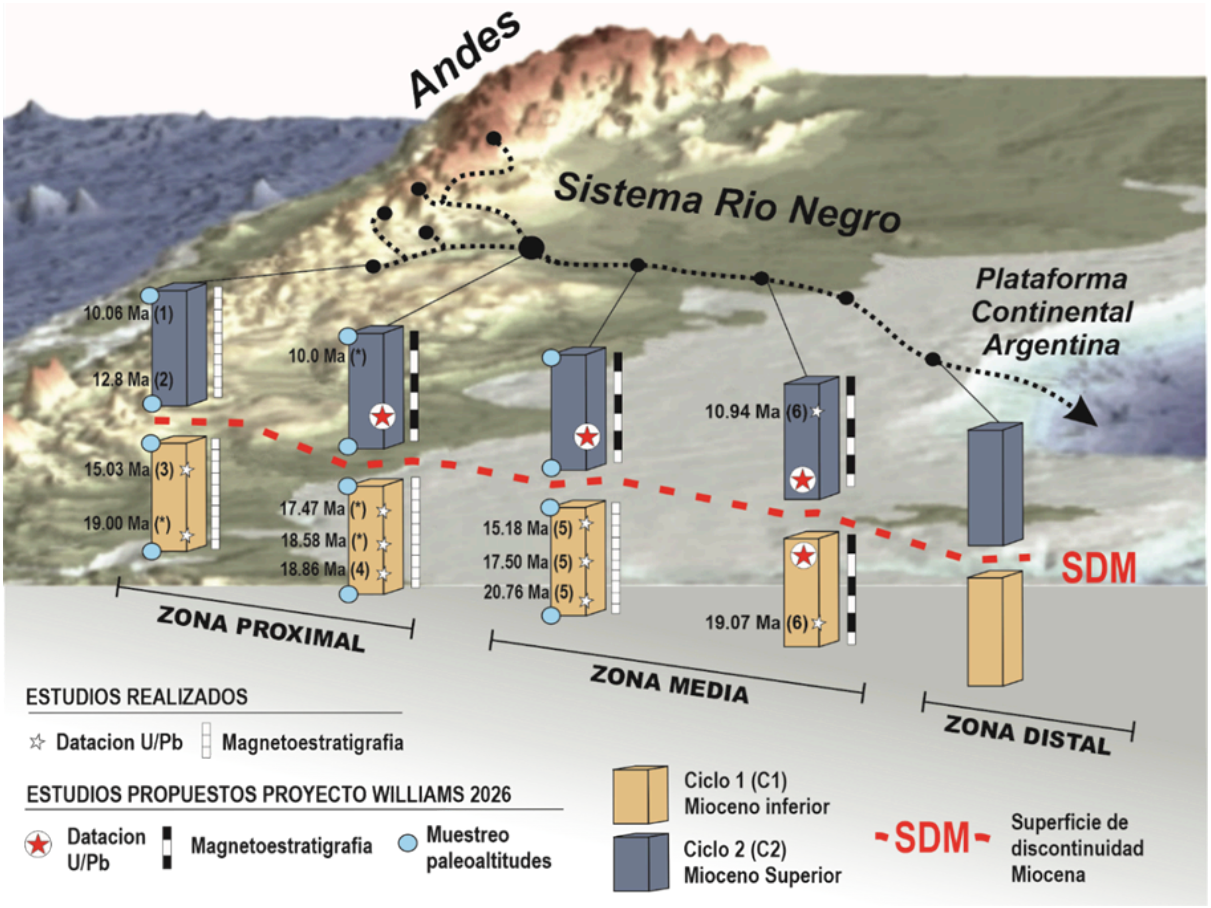


*Figure 2 : sédimentation du système miocène du Rio Negro. A) Sédimentation du Miocène inférieur et du cycle de sédimentation du Miocène supérieur, dans les zones proximale, séparés par une surface de discontinuité miocène (SDM).*

Le but de ce travail sera de reconstituer les paléoaltitudes miocènes des Andes avant et après la SDM, et d'évaluer leur relation avec la tectonique locale ou régionale ainsi que l'évolution climatique. Pour cela, nous allons utiliser la paléoaltimétrie par isotopes stables. Les mesures des isotopes en $\delta^{18}O$ et $\delta D$ des minéraux formés dans la roche en présence d'eau météorique et d'inclusions fluides aqueuses contenues dans ces minéraux hydrothermaux servent de base aux méthodes de reconstruction des paléoaltitudes (Rowley et al., 2001 ; Mulch et Chamberlain, 2007 ; Melis et al., 2023 ; Gardien et al., 2026). Pour initier cette étude nous disposons de 34 échantillons de quartz et de calcites récoltés lors d'une campagne de terrain en Mars 2026 par nos collègues Argentins qui collaborent à cette étude. Les échantillons géoréférencés (lat/long/alt) couvrent les périodes du Miocène inférieur (17 Ma) Moyen et Supérieur (10Ma) et du Pliocène.

Encadrement :
LGL-TPE (Lyon) ; Véronique Gardien et Gweltaz Mahéo
CENPAT-CONICET (Université La Plata, Argentina) : Andrés Bilmes et Léandro D'Elia

**Computing strain rates from diverse geodetic data set using the B-Strain transdimensional inversion tool** (see online description)

**Encadrant(s)/ Supervisor(s):** The internship will take place at the Laboratoire de Géologie de Lyon (LGL-TPE) or the Institut de Ciències del Mar (Barcelona), under the supervision of Thomas Bodin (ICM), Marianne Métois (LGLTPE, Lyon) and Cécile Lasserre (LGLTPE, Lyon). The student will collaborate with Aimine Méridi, a thesis student on Balkan tectonics.
**Thématique/mots-clés (Keywords):** Strain, tectonics, bayesian inversion, transdimensional, GNSS, InSAR, seismic hazard
**Pré-requis / Suitable formation level & prerequisite :** The trainee should have a solid background in geosciences or computer science. He or she should be familiar with python and Fortran (see code https://forge.univ-lyon1.fr/marianne.metois/bayesianstrainrate), as well as with the Bayesian transdimensional inversion method for theoretical aspects. The trainee will be required to work on cluster environments under UniX.
**Résumé/Abstract:** GNSS observations can be used to measure the velocity of the earth's surface at a given geographical point. If these measurements are made on a network of stations, they can be spatially interpolated and a continuous velocity field reconstructed. This velocity field can then be differentiated to reconstruct a map of the rate of deformation in a given region. These deformation maps contain a wealth of information (expansion/compression rates, shear, etc.) and are useful for understanding the tectonic processes at play in the region processes at play in the region, identify the most active structures and estimate the seismic hazard. However, the spatial distribution of GNSS stations is often irregular, leaving some areas undersampled, and standard techniques for calculating strain rates suffer from artifacts due to the uncertainties associated with interpolating velocities on a regular grid. At the LGL-TPE, we have developed an adaptive interpolation and differentiation method based on a transdimensional Bayesian approach, notably developed by Thomas Bodin for imaging the inner Earth. The B-Strain method has been successfully used in California [Pagani et al. 2021], in the Balkans [Métois et al., 2025], using GPS data sets assumed to be uniform. Nevertheless, it is not uncommon to want to combine different datasets from different GNSS calculations, or from other geodetic techniques, in the same deformation rate calculation. For example, InSAR time series can now be used to extract interseismic velocities over vast regions with high spatial resolution (a few tens of meters for Sentinel 1A data). The B-Strain tool needs to be adapted to integrate different datasets in the same inversion.
The internship project aims to implement in the B-Strain tool the possibility of inverting several datasets simultaneously. This involves increasing the number of hyperparameters, as well as considering strategies for decimating InSAR data. The new version of B-Strain will be applied in mainland France and the Balkan area.
**Practical information:** Internship gratification provided by a CNES or INSU PNTS AAP project.
**To apply :** Please send a CV, a covering letter and possibly the names of referees we could
**contact :** tbodin@icm.csic.es , cecile.lasserre@univ-lyon1.fr,marianne.metois@univ-lyon1.fr
**References**: Pagani, C., Bodin, T., Métois, M., & Lasserre, C. (2021). Bayesian estimation of surface strain rates from global navigation satellite system measurements: Application to the southwestern United States. Journal of Geophysical Research: Solid Earth, 126(6), e2021JB021905.

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https://doi.org/10.1111/j.1365-246x.2012.05414.x
https://forge.univ-lyon1.fr/marianne.metois/bayesianstrainrate
https://bstrain.readthedocs.io/en/latest/
https://bstrainplotter.univ-lyon1.fr

**Les microbialites holocènes comme archives des températures du lac Sevan**

**Encadrants :** Colombié, C. (claude.colombie@univ-lyon1.fr), Le Houedec, S. (Lyon 1), Joannin S. (Montpellier)

**Contexte :** La région du lac Sevan (Arménie) abrite un patrimoine archéologique exceptionnel, témoignant d'importantes réorganisations des peuplements Kuro-Araxe durant l'âge du Bronze ancien (5450-4450 BP). Ces changements pourraient être liés aux modifications des ressources disponibles et des conditions environnementales, elles-mêmes associées aux fluctuations du niveau du lac d'origine tectonique ou climatique. Pour vérifier cette hypothèse, les microbialites du lac Sevan, des dépôts carbonatées organo-sédimentaires capables d'enregistrer les conditions physico-chimiques du milieu au cours de leur croissance, constituent des archives particulièrement favorables. Les datations radiocarbone acquises récemment indiquent qu'elles couvrent près de 10 000 ans d'histoire. Des travaux récents fondés sur les isotopes stables de l'oxygène ($\delta^{18}O$) et du carbone ($\delta^{13}C$) ont également montré que certaines microbialites ont conservé leur signature géochimique primaire. Elles constituent ainsi d'excellentes archives paléoclimatiques permettant de reconstruire l'évolution des températures et des conditions hydrologiques du lac au cours de l'Holocène.

**Objectifs du stage :** L'objectif est d'améliorer la reconstruction paléoclimatique du lac Sevan à partir d'un enregistrement isotopique à haute résolution. Les principales étapes seront :
- de renforcer le cadre chronologique grâce à l'intégration de nouvelles datations radiocarbone et à leur comparaison avec des datations U/Th afin de mieux contraindre l'effet réservoir ;
- d'acquérir des analyses isotopiques ($\delta^{18}O$ et $\delta^{13}C$) à haute résolution sur plusieurs microbialites sélectionnées pour identifier les variations climatiques de l'Holocène aux échelles séculaires à millénaires ;
- d'acquérir les mesures XRF à très haute résolution comme proxy indépendant des isotopes pour l'évolution hydrologique du lac Sevan.

Le ou la stagiaire prendra en main la préparation des échantillons et les analyses isotopiques et XRF, puis il-elle portera le traitement et l'interprétation des données. Les résultats seront confrontés aux archives climatiques régionales ainsi qu'aux données archéologiques afin d'évaluer l'influence des changements environnementaux sur les dynamiques des populations de l'âge du Bronze.

**Profil recherché:** Étudiant(e) en Master 2 en géosciences, géologie, géochimie, paléoclimatologie ou discipline voisine, avec un intérêt pour les approches analytiques, la géochimie isotopique et l'étude des archives paléo-environnementales. Des connaissances en traitement de données (R, Python ou équivalent) seront appréciées.

**Environnement du stage :** Le stage se déroulera au Laboratoire de Géologie de Lyon – Terre, Planètes, Environnement (LGL-TPE, Université Lyon 1), dans le cadre du projet ANR Homeland de Bérengère Perello, archéologue à la Maison de l'Orient et de la Méditerranée, Université Lumière Lyon 2.

# Continental diaspores from the Berriasian of Angeac-Charente (Charente, France): diversity, taphonomy and palaeoenvironmental reconstruction

**Supervisors:** Bernard Gomez*, Léa De Brito, Véronique Daviero-Gomez*
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## Scientific background

Diaspores are the dispersal units produced by plants (spores, megaspores, seeds and other propagules) that ensure reproduction, dispersal and the long-term persistence of species. In palaeobotany, their study provides essential information on past plant diversity, reproductive and dispersal strategies, and the evolution of terrestrial vegetation.

Beyond their taxonomic and systematic significance, fossil diaspore assemblages offer considerable potential for taphonomic and palaeoecological investigations. Their production, transport, hydrodynamic sorting and accumulation within sedimentary deposits provide valuable insights into depositional processes, continental environments, and the interactions between vegetation, hydrology and sedimentary dynamics.

The Berriasian locality of Angeac-Charente (Charente, France), renowned for its exceptionally rich assemblage of vertebrate and plant fossils, has been excavated continuously since 2010. The numerous sediment samples collected during these field campaigns constitute a unique resource for investigating Early Cretaceous continental diaspores from ecosystems that predate the emergence of angiosperms.

## Project aims

The main aim of this project is to characterise the fossil diaspore assemblages from Angeac-Charente and to assess their significance for palaeoenvironmental reconstruction.

The project will include:

- sorting and cataloguing diaspores recovered from washed sediment residues;
- identifying the principal morphotypes of megaspores and seeds;
- documenting their diversity, abundance and state of preservation;
- providing a preliminary taxonomic characterisation of the assemblages;
- interpreting the taphonomic processes responsible for their accumulation;
- evaluating the palaeoecological and palaeoenvironmental significance of the assemblages through comparison with the sedimentological and palaeontological data available for the site.

## Methods

The project will involve a predominantly morphological and taphonomic approach, including:

- sorting washed sediment residues under a stereomicroscope;
- photographing and describing specimens morphologically;
- observations using transmitted-light and fluorescence microscopy;
- characterisation of surface microstructures using scanning electron microscopy (SEM);
- construction of an illustrated database and quantitative analysis of the assemblages.

Depending on the progress of the project, comparisons may also be made with fossil diaspore assemblages described from other Upper Jurassic and Lower Cretaceous localities.

## Candidate profile

Applicants should be enrolled in the second year of a Master's degree (M2) in geology, palaeontology, Earth sciences or evolutionary biology, with an interest in palaeobotany, micropalaeontology or palaeoecology. Previous experience in microscopy or systematic palaeontology would be advantageous but is not essential.

## Skills acquired

During the project, the student will gain experience in:

- preparation and sorting of fossil plant microremains;
- morphological identification of fossil diaspores;
- the use of light, fluorescence and scanning electron microscopy;
- taphonomic and palaeoecological analyses;
- processing, illustration and interpretation of palaeontological datasets.

# Deciphering diagenesis in microbial carbonates: a multi-method approach using high-resolution imaging and geochemistry

***Supervisors*** *: Margherita Martini, Claude Colombié and Arnauld Vinçon-Laugier*

***Keywords :*** *Microbial carbonates - Diagenesis - Dual-Energy Computed Tomography (DECT) - Raman spectroscopy - Stable isotopes - Geochemistry - Lake Sevan*

## Context

Microbial carbonates are valuable archives of past environmental and climatic changes because they record the physico-chemical conditions prevailing during their formation[1]. Their stable carbon and oxygen isotope compositions ($\delta^{13}C$ and $\delta^{18}O$) are widely used to reconstruct past hydrological and climatic variations[2]. However, the interpretation of these geochemical records remains challenging because post-depositional diagenetic processes, such as dissolution and recrystallization, may alter both carbonate fabrics and their original isotopic signatures[3]. Distinguishing primary environmental signals from secondary diagenetic overprints is therefore essential to improve the reliability of carbonate-based palaeoenvironmental reconstructions[4]. This internship aims to develop a methodological workflow combining high-resolution Dual-Energy Computed Tomography (DECT), Raman spectroscopy and stable isotope geochemistry to characterize diagenetic alteration in microbial carbonates. Holocene microbialites from Lake Sevan (Armenia) is going to serve as a natural case study to develop and evaluate this approach[5].

## Objectives

The internship aims to develop a methodological workflow to identify and characterize diagenetic alteration in microbial carbonates. The student is going to:

- characterize the internal structure of microbial carbonates;
- identify diagenetic features and mineralogical transformations;
- evaluate the impact of diagenesis on stable isotope signatures.

## Methods and analytical techniques

The student is going to participate in sample preparation, data acquisition and data interpretation, combining:

- Dual-Energy Computed Tomography (DECT) for high-resolution 3D imaging of carbonate structures;
- Raman spectroscopy for mineralogical characterization;
- Stable isotope analyses ($\delta^{13}C$ and $\delta^{18}O$) on targeted samples selected from the imaging results.

## Candidate profile

- Master's student in Earth Sciences, Geology, Geochemistry or a related discipline.
- Motivation to develop laboratory and analytical skills.
- Scientific curiosity, autonomy and a careful approach to data acquisition and interpretation.

**To apply: *margherita.martini@univ-lyon1.fr***

***Bibliography :*** *[1] https://doi.org/10.1016/j.earscirev.2008.10.005 ; [2] https://ui.adsabs.harvard.edu/link_gateway/1993GMS....78..123C/doi:10.1029/GM078p0123 ; [3] https://doi.org/10.1111/sed.12933 ; [4] https://hal.science/hal-03587936v1 ; [5] https://doi.org/10.1016/j.jglr.2025.102647.*

**Title: Structure and Dynamics of hydrothermal chimneys**

**Supervisors**: **Isabelle Daniel**, Rémi Coltat (ISTO Orléans), Margherita Martini, Muriel Andréani, Jean-Philippe Perrillat

**Keywords**: water-rock reactions; hydrothermalism at mid-oceanic ridges; X-ray tomography; image processing

**Background**: a background in petrology would be appreciated, basic knowledge in fluid dynamics and appetite for analytical methods would be an asset

**Abstract**: In 1977 the first hydrothermal black smoker was discovered on the Galapagos rift. As of today, close to 750 hydrothermal fields have been found or inferred along 65,000 km of mid-ocean ridges (MORs). In nearly 50 years since the first discovery of oceanic hydrothermal venting, much has been learned about the generation of vent fluids and associated deposits. Hydrothermal vents and associated deposits form at seafloor depths ranging from a few meters below sea level to ~5000 m. There are strong similarities among seafloor vent fields in terms of the processes of heat and mass transfer that result in venting of hydrothermal fluids to the oceans, formation of mineral deposits, and creation of chemical and thermal environments conducive to biological activity in the deep sea. Hydrothermal chimneys display spectacular and diverse morphology. Detailed morphological study of the chimneys reveals that their structure and compositions depend on a number of factors, which are so far poorly understood. When focussing on sulfide chimneys resulting from the cooling of hot, reduced, and acidic fluids (black smokers) interacting with cold seawater, their structure isn't simply cylindrical with a nice cooling mineral sequence as described in the literature (i.e., low-T mineral assemblages in the outer part grading to high-T mineral assemblages in the inner part of the chim,ney). Preliminary X-ray Computed Tomography scans of sections of sulfide chimneys show a complex structure and fluid paths. They show multiple, superimposed fluid channels, some of them displaying upward intricate conduits, others exhibiting complex 'circular' fluid circuits not yet described in the literature.
As of today, such tomographic measurements on natural chimneys are the first of their kind. We have collected chimneys during 3 oceanographic expeditions in 2022, 2023 and 2025. They have already been CT-scanned at different resolutions and are awaiting processing and interpretation.

**Methods**: Segmentation and 3D reconstruction with the software Dragonfly; Scanning electron microscopy coupled to EDX; X-ray fluorescence.

**Expected outcomes**: Comparison of the relation/interplay between mineralogy, fluid flow and detailed structure of selected hydrothermal chimneys formed in a mafic-hosted, high-temperature system and in a high-temperature ultramafic-hosted system associated with serpentinization of the subseafloor.

**To apply**: please send a cv to 'isabelle.daniel'@univ-lyon1.fr

Title: **Dynamo experiments with anisotropic conductivity**

M2 project supervision: **Thierry Alboussière**

Many large natural objects produce their own magnetic field, most likely through the dynamo effect. This is notoriously difficult to reproduce in the lab. We have recently investigated the possibility of using anisotropic conductivity which turned out to be an efficient way to produce a dynamo effect. We have built a first setup, called Fury, a kinematic dynamo with solid parts. Now, during this M2 project, we plan to assemble and test a second setup, Fury-Fluid, which will combine anisotropic solid parts (copper) and a fluid region (galinstan). It will be possible to increase the size of the fluid region step-by-step to go from a kinematic to a dynamical dynamo where the highly turbulent flow will produce some feedback on the dynamo regime. This opens the way to study phenomena observed in geomagnetic data, such as magnetic variations, excursions and perhaps change of large-scale magnetic pattern or reversals.

Data acquisition will be an important aspect of the project. While it is relatively easy to measure the magnetic field outside the experiment, we will also attempt to get magnetic measurements within, or as close as possible of the fluid region. This should give us information on the influence of the dynamo magnetic field on the flow characteristics (mean flow, velocity fluctuations). We can also test other types of measurements, potential probes or ultrasound Doppler velocimetry.

This study is part of the ANR project EDAEN, with another group (led by Caroline Nore, LISN laboratory Paris-Saclay University) investigating numerically the same configuration. Franck Plunian (ISTerre lab, Grenoble) and Nicolas Plihon (Physics lab, ENS de Lyon) are the other members of the project.

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