## PhD proposal

# Natural $H_2$ in Ultramafic Ophiolitic Systems: Processes and Kinetics of Water-Ophiolite-$H_2$ Interactions in Reservoir Systems – Case Study of Jurassic Ultramafic Ophiolites in Albania

**Scientific context**. Serpentinization naturally generates $H_2$ on Earth. This process is inherent to the hydration of mantle rocks over a wide temperature range, from 50 to 350°C. Natural $H_2$ emissions have been reported on land, particularly in ancient oceanic rocks found in ophiolitic complexes such as those in the Sultanate of Oman, the Philippines, and Turkey. These gas leaks are often associated with hyperalkaline springs (pH 10-12) present in many ultramafic rock outcrops. Hyperalkaline waters have been interpreted as evidence of active serpentinization. In ophiolitic environments, it is generally assumed that this process occurs at temperatures below 150°C, or even 100°C (Abrajano et al., 1988; Etiope et al., 2011). The process responsible for $H_2$ production involves the reduction of water and the simultaneous oxidation of ferrous iron ($Fe^{2+}$) present in ultramafic minerals (olivine and pyroxene) into ferric iron ($Fe^{3+}$), which is notably found in newly formed magnetite. These mineral assemblages are observed in the field, where peridotites are extensively serpentinized, mainly along fracture systems.
This PhD study focuses on the Bulqizë ophiolitic massif, which remains relatively unknown and underexplored in the context of native $H_2$ (Fig. 1). This massif is part of the Tethyan ophiolites within the Alpine orogenic system, which formed along a curvilinear suture zone delimiting a series of continental fragments derived from Gondwana (including Apulia, Pelagonia, and the complex crystalline system of Central Anatolia). These ophiolites represent the remnants of marginal Tethyan basins that evolved between these microcontinents. The Bulqizë ophiolitic massif covers a vast area of 370 km² and includes approximately 400 known occurrences of podiform chromite mineralization (Fig. 1). Our first exploration study conducted at the Bulqizë-Batra chromite mine provides a general framework for the research proposed here. This mine serves as an underground laboratory to study the generation, migration, and trapping of native $H_2$, making it an ideal site for testing and developing exploration methods for this potential primary source of carbon free energy. The first analyses of $H_2$, associated gases, fluxes, and quantities have already been published in an initial study (Truche et al., 2024).

**Research program**
The PhD project is structured around three main research areas:
**Axis 1 focuses on mapping the spatial and temporal distribution of $H_2$ emissions in the Bulqizë mine**. The goal is to characterize the migration pathways of $H_2$ within the massif. In the Bulqizë mine, hydrogen emissions are observed only at deeper levels and appear to be correlated with the presence of a major fault zone. However, it remains unclear which generations of fractures are responsible for gas drainage and whether a sealing zone exists to prevent leakage to the surface. Halite (NaCl) precipitations have been observed along fractures in areas where hydrogen is detected.
To address these questions, we aim to map gas emissions and monitor their evolution over time, leveraging the unique underground laboratory that the Bulqizë mine provides. Measurements will be conducted using a portable gas chromatograph (micro-GC) available at the ISTerre laboratory in Grenoble. This instrument can be deployed within the mine galleries and connected to various boreholes (shot-holes, exploration boreholes, drainage borehole networks, and fractures) to track spatial and temporal variations in gas composition and flow rates. These measurements will allow us to characterize certain reservoir properties and understand why the system does not appear to leak gas to the surface.

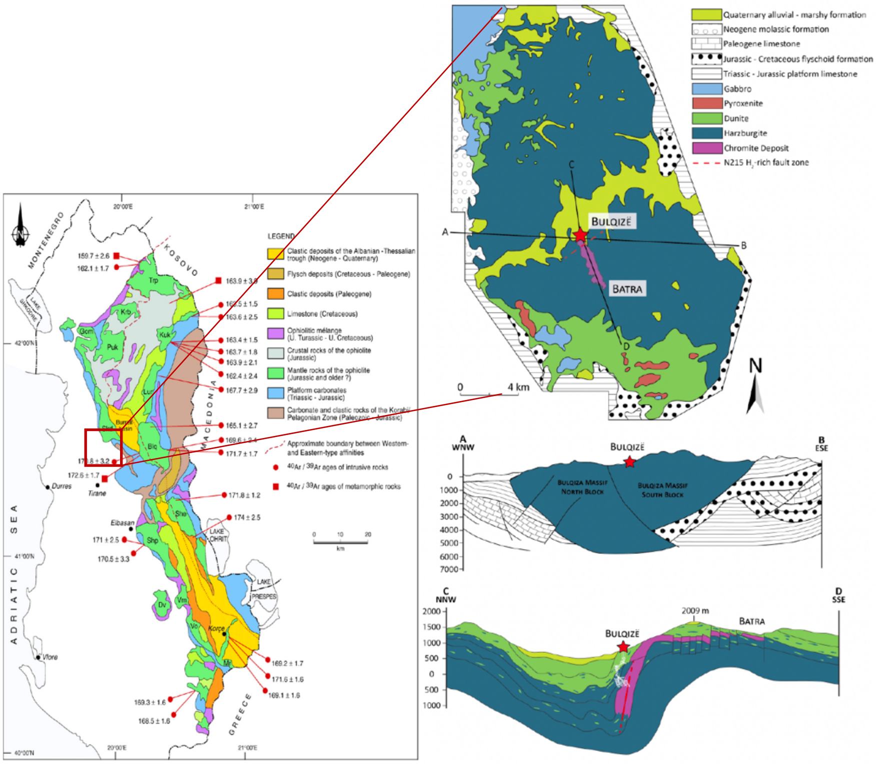


**Figure 1**: A) Geological map of the Albanian ophiolites and surrounding units (modified from Dilek et al., 2005); B) Simplified geological map of the Bulqizë ultramafic massif, showing the surface projection of the ore deposit and the deep fault zone rich in $H_2$. Bottom: Geological cross-sections along transects A-B and C-D. (Truche et al., 2024).

**Axis 2 axis aims to understand: the physicochemical processes of hydrogen production in relation to iron-rich levels within the ultramafic ophiolitic massif.**

To achieve this, rock samples will be collected from different facies of the ultramafic rocks in the Bulqizë mine and massif, with varying degrees of serpentinization. Additionally, minerals filling the fractures will be sampled to better understand the kinematics and dynamics of fluid circulation within the fracture network.

Several types of analyses are planned:

• ICP analyses to determine the total concentrations of key elements such as Fe, Cr, Ni, Co, and PGE.

• Mössbauer spectroscopy on iron-rich rocks to determine Fe speciation. $Fe^{2+}$-rich rocks are considered to have a high potential for $H_2$ generation due to redox reactions, whereas $Fe^{3+}$-rich rocks are not expected to generate $H_2$. This method will allow us to determine the redox state of each mineral in the rock sample.

• The identification of $Fe^{2+}$-, Cr-, Ni-, and Co-bearing minerals will be carried out using optical microscopy and scanning electron microscopy (SEM) on thin sections. Mineral and elemental mapping, using SEM images combined with WDS probe analyses, will help identify iron-bearing minerals. This identification will allow us to evaluate the $H_2$ production potential of the rock based on the reactivity of each mineral during water-rock interactions.

• XCT analyses will be performed on core samples to extrapolate small-scale observations and quantifications to a larger scale, thereby estimating the true $H_2$ source potential normalized to volume.

Analyzing paragenesis will help sequence the different alteration processes of ophiolites over time through serpentinization and date these diagenetic transformations in relation to $H_2$ generation. This will provide valuable insights into the mechanisms of $H_2$ formation. The analytical results will contribute to evaluating the relative importance of source terms (serpentinization and alteration of ferrous minerals) and sink terms (Fischer-Tropsch-type reactions, microbial consumption), which are still subjects of debate.

**Axis 3 aims to quantify petrophysical properties related to mineralogical transformations during $H_2$ generation**. The objectives include:
i) Characterizing the petrophysical properties of both source and reservoir rocks.
ii) Understanding the mineralogical transformations of the source rock and their impact on transport properties (reactive surface area, porosity, permeability) during serpentinization and $H_2$ generation.
iii) Identifying the trapping mechanisms of hydrogen produced during serpentinization.

The analytical methods will involve various parameters, including: porosity, permeability, relative permeability, specific surface area, pore distribution, capillary pressure, wettability, electrical behavior of reservoir rocks (via Archie's exponents: a, n, m), nuclear magnetic resonance (NMR), mechanical properties, acoustic properties, and tomography imaging.
This petrophysical database will be integrated with the paragenesis and microporosity characterization results obtained in Research Axis 2, providing a comprehensive understanding of how serpentinization influences reservoir properties.

**Candidate Profile**
The ideal candidate will have a background in geosciences, with a strong foundation in physics and geochemistry of gases and waters applied to reservoir systems. Knowledge of gas-water-rock interactions, petrophysics, and hydrogeology will be essential. Experience with analytical methods would be an advantage for the progress of the PhD.
This position also requires strong communication skills, openness to interdisciplinary teamwork, and the ability to conduct part of the research in Albania. The candidate will collaborate with various project partners.

The PhD will be co-supervised and conducted between two research laboratories:
• UMR EPOC (University of Bordeaux), hosted at ENSEGID-Bordeaux INP
• ISTERRE (University of Grenoble)
It will involve close collaboration with Pr. Bardhyl Muceku (Univ. Polytechnic Tirana)

**Contacts** :

- Adrian CEREPI : adrian.cerepi@bordeaux-inp.fr
- Corinne LOISY : corinne.loisy@bordeaux-inp.fr
- Laurent TRUCHE: laurent.truche@univ-grenoble-alpes.fr


- Application opening date: 01/02/2025
- Application deadline: 10/04/2025
- PhD start date: October 2025

All applications must include the following documents: a) A CV, b) A cover letter, and c) The names and contact details of three references who can recommend the candidate.