XAS Studies Of Metal Transport In Hydrothermal Fluids : Autoclaves And Photons.

Denis Testemale[1,2], Eric Lahera[2,3], Alain Prat[1,2†], Isabelle Kieffer[2,3], Olivier Proux[2,3], William Del Net[2,3], Gleb Pokrovski[4], Joël Brugger[5], François Guyot[6], Marion Louvel[7], Jean-Louis Hazemann[1,2]

1- Institut Néel, CNRS, Grenoble. 2-FAME-PIX and FAME-UHD beamlines, ESRF, Grenoble. 3-OSUG, Grenoble. 4- GET, Toulouse. 5-Monash University, Melbourne, Australia. 6-MNHN, Paris. 7-ISTO, Orléans.

ABSTRACT

Hydrothermal fluids, though minor in the Earth's lithosphere (~1%), play a pivotal role in forming economic metal deposits by extracting, transporting, and precipitating metals. Central to this process is the solubility and speciation of metals and volatiles in the fluid phase **[1]**. In situ synchrotron X-ray Absorption Spectroscopy is the method of choice to probe metal species, offering direct insights into their molecular structure and concentration. When combined with *ex situ* hydrothermal methods (e.g., batch and flow-through systems) and thermodynamic modeling, XAS has revolutionized our understanding of metal transport by geological fluids.

A key challenge lies in performing *in situ* XAS measurements under extreme conditions. This requires high-pressure, high-temperature experimental cells capable of withstanding the chemical reactivity of hydrothermal fluids while allowing X-ray access. Among the available technologies, autoclaves stand out for their versatility and robustness **[2]**. In this contribution, we present XAS methods developed using high-pressure, high-temperature autoclaves at the FAME and FAME-UHD french CRG beamlines at ESRF. These methods enable *in situ* acquisition of X-ray transmission and fluorescence spectra for hydrothermal fluids and silicate melts, providing both solubility and speciation data for metal complexes. Our autoclaves operate across a broad range of conditions, from liquid- to vapor-like hydrothermal fluids (metal concentrations: <1–10,000 ppm) to magmatic fluid-melt systems at 1000°C **[3]**. Scientific examples highlight the advantages of our spectroscopic "micro-batch" reactors, while integration with the FAME-UHD crystal analyzer spectrometer further enhances their capabilities.

During the last 25 years the FAME and FAME-UHD beamlines have pioneered the development of specialized XAS methods based on autoclaves, enabling unprecedented *in situ* studies of metal speciation and transport in hydrothermal systems **[4]**. These advancements allow for the calibration of solubility constants and quantitative predictions of metal transport, bridging the gap between laboratory experiments and natural processes.

REFERENCES

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