ORGMET: The role of organic carbon in the formation of mineral resources of strategic metals

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PROGRAMME DE RECHERCHE SOUS-SOL

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Auteurs
Gleb Pokrovski (PI), Patrice Baby, *GET-CNRS-UT-IRD, Toulouse* / Jean-Paul Callot, Patrice Creux, *LFCR-UPPA, Pau* / Jean-Louis Hazemann, *INEEL, Grenoble*

We are now at the decisive moment of human history where demand for various metals is increasing to unprecedented levels. But recycling alone will be unable to meet the demand. It is a key question of both better managing and renewing currently known mineral resources. The most striking feature of most strategic metal resources is their ubiquitous association with sedimentary rocks rich in organic carbon

CHALLENGES AND QUESTIONS

Sediment-hosted deposits rich in organic carbon (C_{org}) account for **30% Cu** world's supply , **>50% Ga and In**, **>80% Co**, and **>90% Zn, Pb and Ge**. Yet the links between metals and C_{org} remain a major enigma:

- What is the nature of metal-C_{org} associations: chance or symbiosis? What is the role of organic matter in the whole-deposit mineral system: source, transport or trap?
- What are the rates of fluid-organic matter reactions in the Earth's crust and how long does it take for deposits to form?
- Could the presence of organic matter in rocks be evidence of the metal's economic accumulation?
- How the metal extraction from C_{org}-rich rocks and mine wastes can be improved while limiting the ecological impact?

NOVEL INTEGRATED METHODOLOGY

Studying complex fluid-carbon-metal systems requires a synergy of approaches at the interface between geosciences, physics and chemistry, applicable across a very large range of scales – from the molecule to the metallogenic province. In this project, a consortium of 4 partner laboratories under the aegis of 5 different French institutions will develop such a novel methodology.

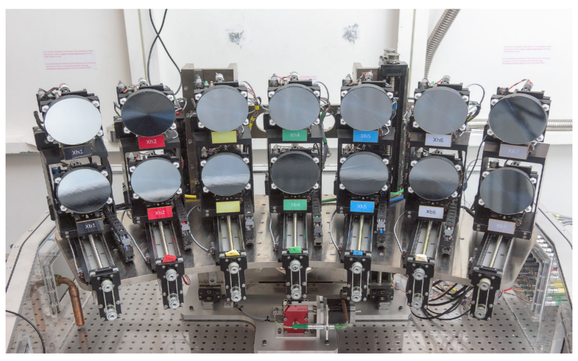
Mecanisms of fluid-carbon-metals reactions:

Explore thermochemical sulfate reduction (TSR) reactions at the molecular scale between hydrothermal fluid, organic matter, sulfur and metals using chemical reactor methods coupled with in-situ spectroscopy and imaging including high-resolution synchrotron techniques

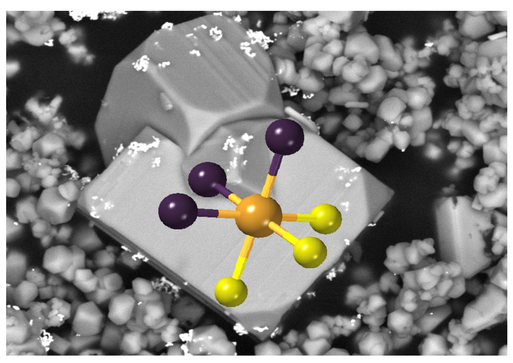
$$SO_4^{2-} + CH_4 + 2H^+ = H_2S + CO_2 + 2H_2O \quad (CH_4 = C_{org})$$

$$ZnCl_2 + H_2S = ZnS_{(sphalerite)} + 2H^+ + 2Cl^-$$

- Intermediate S/C species – CO, HCO, HCS, S_n^{2-}, $[S_3^{\bullet}]^-$, $[S_2^{\bullet}]^-$ – ligands for metals?
- Reaction rates vary from 10^{-3} to 10^7 years ≈ those of deposits?
- Catalytic effects of metals?
- Solubility and uptake of critical metals by major ore minerals?



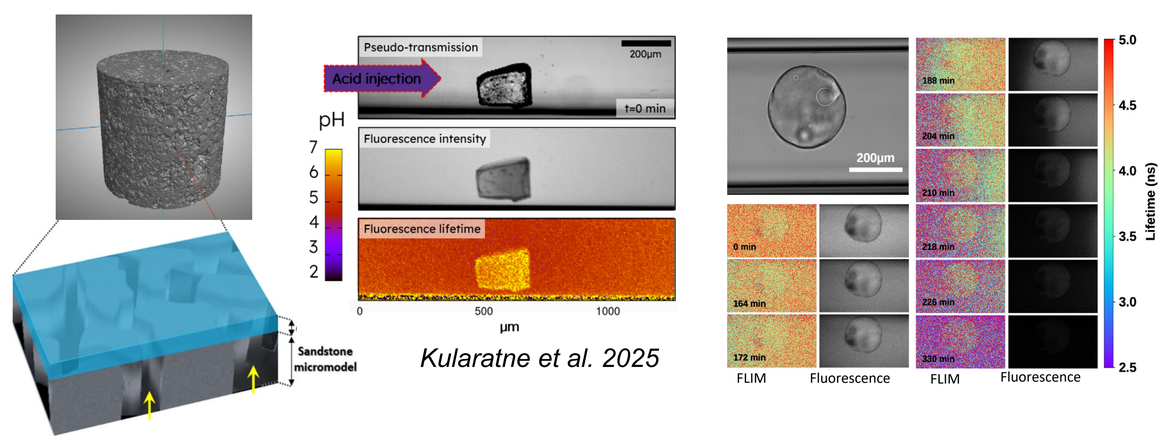
Kulow et al. 2024



Pokrovski et al. 2021

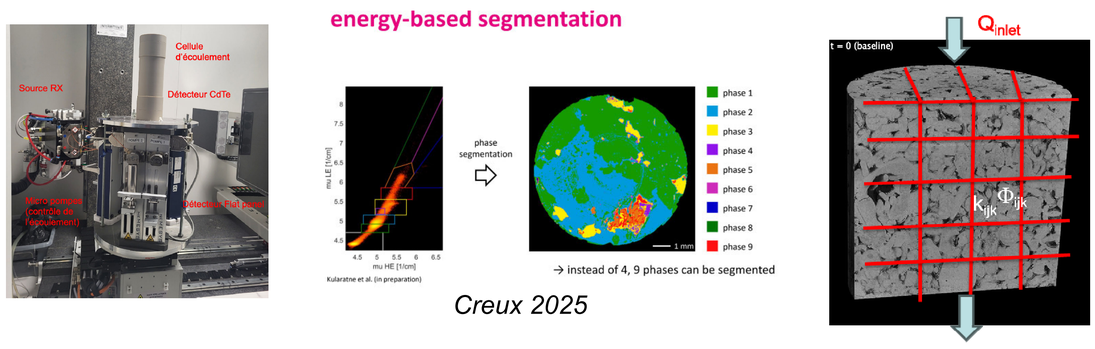
Chemical dynamics of fluid-rock interactions:

Pore-scale fluid flow through carbon-bearing rocks by simultaneous monitoring reaction kinetics, fluid chemistry (pH, Eh), and rock topology (pores, connectivity, texture) in real time and space using innovative imaging techniques – fluorescence, tomography, ptychography, FLIM



Critical metal extraction from C-bearing rocks:

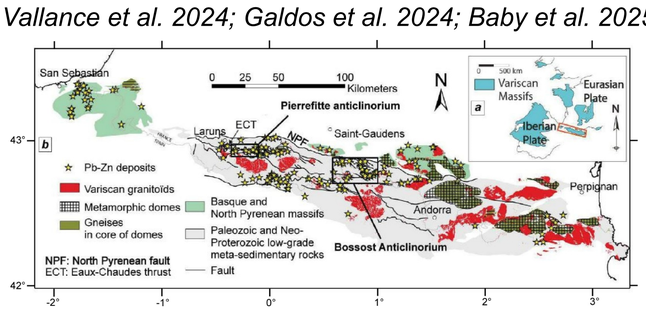
An innovative approach using original flow-through cells to track changes in rock porosity, permeability and mineralogy during the leaching process as monitored by multispectral X-ray tomography. Novel protocols based on electro-oxidation coupled with injection of non-toxic acids (e.g., citric) for in-situ leaching of metals from reduced deep rock formations



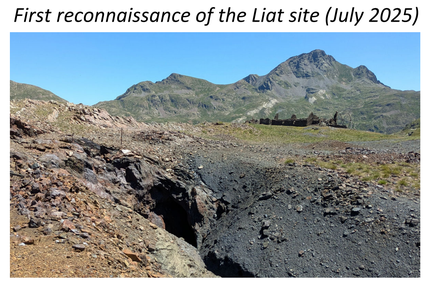
Sediment-hosted deposits: an integrated mineral system approach for strategic metals potential of the Pyrenees:

Vallance et al. 2024; Galdos et al. 2024; Baby et al. 2025

- Inspired by our expertise of the Peruvian Andes
- Compilation of data/targeted field work
- Regional cross-section
- Geochronology
- Sequential restoration
- Multiscale mineral system modeling



First reconnaissance of the Liat site (July 2025)



Bibliographie

- Baby P. et al. (2025) The Northern Central Andes and Andean tectonic evolution revisited: An integrated stratigraphic and structural model of three superimposed orogens. *Earth Science Reviews* 260, 104998. https://doi.org/10.1016/j.earscirev.2024.104998
- Creux P. (2025) The experimental and numerical modeling challenges related to multiphase flows in subsurface resource exploitation. *Energies* 18(4), 826. https://doi.org/10.3390/en18040826
- Galdos R. et al. (2024) Origin and evolution of gold-bearing fluids in a carbon-rich sedimentary basin: A case study of the Algamarca epithermal gold-silver-copper deposit, northern Peru. *Ore Geology Reviews* 166, 105857. https://doi.org/10.1016/j.oregeorev.2023.105857
- Kularatne K. et al. (2025) Pioneering data on detection, identification and quantification of key carbonate minerals using spectral tomography. *Marine and Petroleum Geology* 182, 107536. https://doi.org/10.1016/j.marpetgeo.2025.107536
- Kulow, A. et al. (2024) First X-ray spectral ptychography and resonant ptychograpic computed tomography experiments at the SWING beamline from synchrotron SOLEIL. *Journal of Synchrotron Radiation* 31, 867-876. https://doi.org/10.1107/S1600577524003229
- Pokrovski G.S. et al. (2021) An arsenic-driven pump for invisible gold in hydrothermal systems. *Geochemical Perspectives Letters* 17, 39-44. https://doi.org/10.7185/geochemlet.2112
- Vallance J. et al. (2024) Combined effect of organic carbon and arsenic on the formation of sediment-hosted gold deposits: A case study of the Shahuindo epithermal deposit, Peru. *Economic Geology* 119, 85-112. https://doi.org/10.5382/econgeo.5040

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