Mineralogical and geochemical controls on metal leaching efficiency in laterite ores using eco-friendly solvents.

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Project Highlights:

- Geometallurgy of critical metals in nickel laterites
- Green solvents
- Mineralogy and crystallography

Overview:

Nickel laterites are a major global source of nickel (Ni) and contain recoverable cobalt (Co) and scandium (Sc), albeit at lower concentrations. These critical metals are in high demand for the green energy transition for electric battery storage (Ni, Co) and high-performance alloys and SOFCs - solid oxide fuel cells (Sc). Ni-laterite ores are mineralogically complex, comprising magnesium silicates (e.g., serpentine, olivine), iron (oxyhydr)oxides (e.g., goethite), and secondary phases such as garnierite (a mixture of Ni-bearing serpentine, talc, smectite, chlorite) and asbolane-lithiophorite (poorly crystalline manganese (oxyhydr)oxide); all capable of hosting critical metals either within their crystal structures or adsorbed onto their surfaces.

Conventional processing methods like high-pressure acid leaching or HPAL (e.g., the Taganito HPAL, Philippines) and pyrometallurgy are effective at the recovery of Ni and Co but are cost and environmentally intensive, involving high energy input and the use of concentrated sulfuric acid and producing millions of tonnes of waste. Emerging alternatives—such as organic acids (e.g., citric, oxalic) and deep eutectic solvents (DES)—offer selective metal recovery with lower environmental impact due to their biodegradability and low toxicity (Jenkin et al., 2016, Matsumoto et al., 2021, Faria, 2024, Ijardar et al., 2022). While the concept of using these green solvents is not new, the mechanisms governing metal release from specific crystallographic sites under different leaching conditions remain poorly understood.

Building on our recent findings, we hypothesise that *the efficiency of a solvent–nickel laterite reaction is strongly governed by the geochemical interplay between the crystal chemistry and structure of the host mineral, and the specific chemical role of the solvent in the leaching reaction*. For example, our preliminary data showed that an organic acid selectively dissolved asbolane but not goethite, whereas a DES containing an organic acid leached both minerals with similar efficiency.

To optimise solvent selection and leaching performance, further multiscale and multitechnique studies are needed to unravel the fundamental properties of minerals and geochemical mechanisms controlling Ni, Co, and Sc release from various host phases, including poorly crystalline materials. This research will also investigate the dominant leaching pathways—such as ligand-mediated complexation, proton-promoted dissolution, or reductive leaching. Collectively, this PhD project will support further development of low environmental impact extraction methodologies for critical metals from complex yet strategically important Ni lateritic ores. The project is particularly timely given the rapid expansion of the nickel laterite industry in Indonesia, the Philippines, and the urgent need for sustainable processing technologies for critical metals.

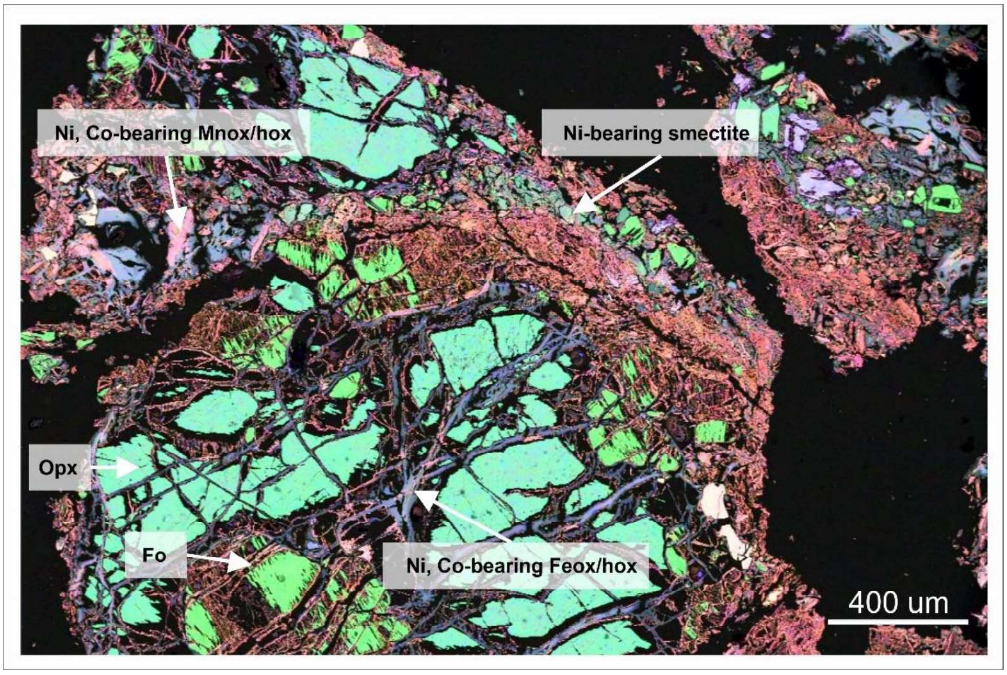

Figure 1 Phase map showing a fragment of saprolite with multiple mineral hosts of nickel and cobalt (based on SEM EDS X-ray mapping). Mnox/ohx – Mn (oxyhydr)oxides; Feox/ohx – Fe (oxyhydr)oxides, Opx – orthopyroxene, Fo - forsterite

Methodology

The student will mainly work with laterite samples from the Sta. Cruz Ni deposit (Zambales, Philippines). Mineral separates (e.g., nontronite, asbolane, serpentine, goethite) will be synthesised or sourced for phase-specific leaching experiments.

1. **Material Characterisation**

- SEM-EDS: Elemental mapping and point analysis pre- and post-leaching.
- XRD: Bulk and micro-XRD for phase and crystallographic identification.
- XAS: Oxidation state and coordination analysis of Ni, Co, Sc (subject to synchrotron beamtime).
- Bulk Chemistry: ICP-MS of solids and residues.
- Leachate Analysis: ICP, IC, pH, and alkalinity measurements.

2. **Mineral Synthesis & Leaching**

- Synthesis of pure and metal-substituted Fe/Mn (oxyhydr)oxides and silicates.
- Adsorption experiments to dope mineral hosts with critical metals.

- Batch leaching under controlled pH, temperature, and solvent concentration using both bulk and individual mineral phases.

3. Geochemical Modelling

- Thermodynamic modelling: Predict solubility, speciation, and extraction efficiency.
- Reaction path modelling: Understand leaching mechanisms and metal complexation.

Possible Timeline

Year 1:

- Literature review
- Training in electron microscopy techniques
- Training in laboratory experiments, setting up batch reactors, collection and preservation of samples
- Introduction to geochemical modelling
- Bulk analysis and microanalysis of starting materials
- Preparation of proposal to synchrotron facility
- TARGET-specific activities

Year 2:

- Main experimental batch leaching experiments
- Microanalysis of remaining pre and all post-test materials
- Synchrotron XAS work
- Conference attendance – for example, geometallurgy IOM3, GORDON CONFERENCE ON GEOCHEMISTRY OF MINERAL DEPOSITS 2028, Goldschmidt, Conference of Metallurgy and Materials
- TARGET-specific activities
- Paper writing

Year 3 – 3.5:

- Data processing and interpretation
- Development of conceptual models
- Conference attendance – for example, geometallurgy IOM3, GORDON CONFERENCE ON GEOCHEMISTRY OF MINERAL DEPOSITS 2028, Conference of Metallurgy and Materials
- Thesis and papers writing
- TARGET-specific activities

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;

- additional online events and in-person workshops attached to relevant conferences.
- The PhD programme will equip the student with a broad and interdisciplinary skill set, encompassing geology, critical minerals, experimental mineralogy, geochemical modelling, and materials characterisation across scales—from nano-scale to field-scale. Through this research, the student will develop a strong understanding of the environmental impacts associated with mineral processing, alongside innovative approaches for the sustainable recovery of critical minerals essential to the green energy transition. Collectively, the proposed PhD will prepare the student for a successful career in the mining and mineral processing industries, with opportunities to work on both primary raw materials and secondary resources, e.g. waste streams.

Partners and collaboration (including CASE):

This PhD project is a joint initiative between the BGS, UoLE, and UoLD (supporting role for synchrotron studies). The supervisory team brings a strong track record of successful collaboration. The close proximity of BGS and UoLE enables regular in-person and online meetings, as well as easy access to laboratories and supervisory support.

At BGS, the student will receive hands-on training in analytical/experimental instrumentation and gain exposure to a wide range of geoscience topics, including critical minerals, sustainable mining, and geohazards. At UoLE, the focus will be on environmentally benign solvents and metal extraction. UoLD and synchrotron facility will support investigations into the functional properties of materials and the chemical environment during leaching.

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply.

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References and further reading

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DEScycle | clean tech for critical metals recovery