Forensic geometallurgy of Ni-Co laterites: Sustainable processing of Europe's low-grade ores and tailings into battery-grade metals

Fernando Prado Araujo[1], Philippe Muchez[1], Jens C.Ø. Andersen[2], Nívea Magalhães[2], Richard Crane[2], Hannah Hughes[2]
[1]KU Leuven, Department of Earth and Environmental Sciences, Belgium
[2]University of Exeter, Camborne School of Mines, United Kingdom

Abstract. The global nickel (Ni) and cobalt (Co) demand is expected to increase manyfold in the next decades. Both metals are essential components in rechargeable batteries, which are highly required for the energy transition away from fossil fuels. The current European production/refining landscape is not enough to cover such demand (even if recycling rates improve in the future). Additionally, the state-of-the-art processing routes can be energy intensive and not so environmental-friendly. The Horizon Europe-funded ENICON project offers an alternative HCl-based technology, with a lower eco-footprint, to process Europe's Ni-Co ore deposits and tailings into battery-grade metals. The full metal deportment in all products/by-products and valorised residues is done by combining several characterisation techniques into a mineral-focused geometallurgical protocol. This approach minimizes losses and allows the recovery of multiple valuable metals in the flowsheet, effectively improving the sustainability and viability of the European Ni/Co supply chain.

Introduction

Nickel (Ni) and cobalt (Co) are essential components of rechargeable batteries (Nickel Institute 2023). Hence, many studies forecast a sharp increase in their future demand (Campagnol et al. 2017; IEA 2021; Gregoir and van Acker 2022). However, European sources represent only a minor share of the extraction and refinement of battery-grade Ni and Co in the global market (Mudd and Jowitt 2022), leaving Europe mostly dependent on imports of these metals. Additionally, most of the current production practices are energy intensive and can pose environmental hazards (Bartzas et al. 2021). This poses a serious risk to Europe's plans of transitioning away from fossil fuels. Consequently, ensuring the sustainable supply of these critical raw materials is a key priority for Europe (European Commission 2008).

The Horizon Europe ENICON project (https://enicon-horizon.eu/) responds to this issue by enhancing the potential of Ni/Co resources within Europe – i.e. sulphidic ores and limonitic/saprolitic laterite ores – as well as by developing a more sustainable HCl-based processing route for these materials (Figure 4). The project consists of a multidisciplinary approach to (1) track the metals in the supply chain using forensic geometallurgy, (2) develop a new HCl leaching process to extract Ni and Co from ores and tailings, (3) ultra-refine the metals towards battery grade Ni/Co, and (4) provide solutions for the valorisation of residues. All those steps are further integrated into a Life Cycle-Techno Economic Assessment (LCA-TEA) to optimise the performance and decrease the environmental impact of the mining/refining operations (Figure 3). This contribution introduces the geometallurgical protocol for laterite ores (WP1) within the ENICON context.

Ni(/Co) laterites

Ni/Co-lateritic deposits are regoliths formed through weathering of ultramafic rocks and have low metal grades, commonly lower than 5% for Ni and less than 0.1% for Co (Elias 2002). The mineralisation is mainly hosted in two ore zones, saprolitic laterites and limonitic laterites (also known as oxide zone), with saprolite having a slightly higher grade than limonite (Elias 2002). These laterites are mineralogically and texturally complex materials with Ni and Co residing in several silicate and oxide minerals (Andersen et al. 2009). These features compound into a challenging process to release the metals from the mineral matrix.

Europe's two main laterite-processing companies, ENICON partners Larco and Euronickel, transform mixtures of saprolite and limonite laterite ores into an FeNi (Class-II Ni) product by a pyro-metallurgical route. Besides having a large carbon footprint (Bartzas and Komnitsas 2015) this process is unable to produce battery-grade Ni (Class-I Ni) and fails to recover sufficient Co, which largely ends up in the residues sent to landfills. In order to maximise the extraction efficiency of Ni, Co, and other valuable metals from these complex and heterogeneous deposits, it is crucial to understand the geological and mineralogical characteristics of the ore samples and apply a geometallurgical assessment of the processing flowsheet.

Forensic Geometallurgy

Geometallurgy is a multidisciplinary field that combines geology, mineralogy, and metallurgy to optimize mineral processing and increase the recovery of metals from ore deposits.

ENICON's forensic geometallurgy protocol (Figure 5) is a proactive approach that collects mineralogical, textural, and geochemical data of European Ni-Co deposits. It provides information

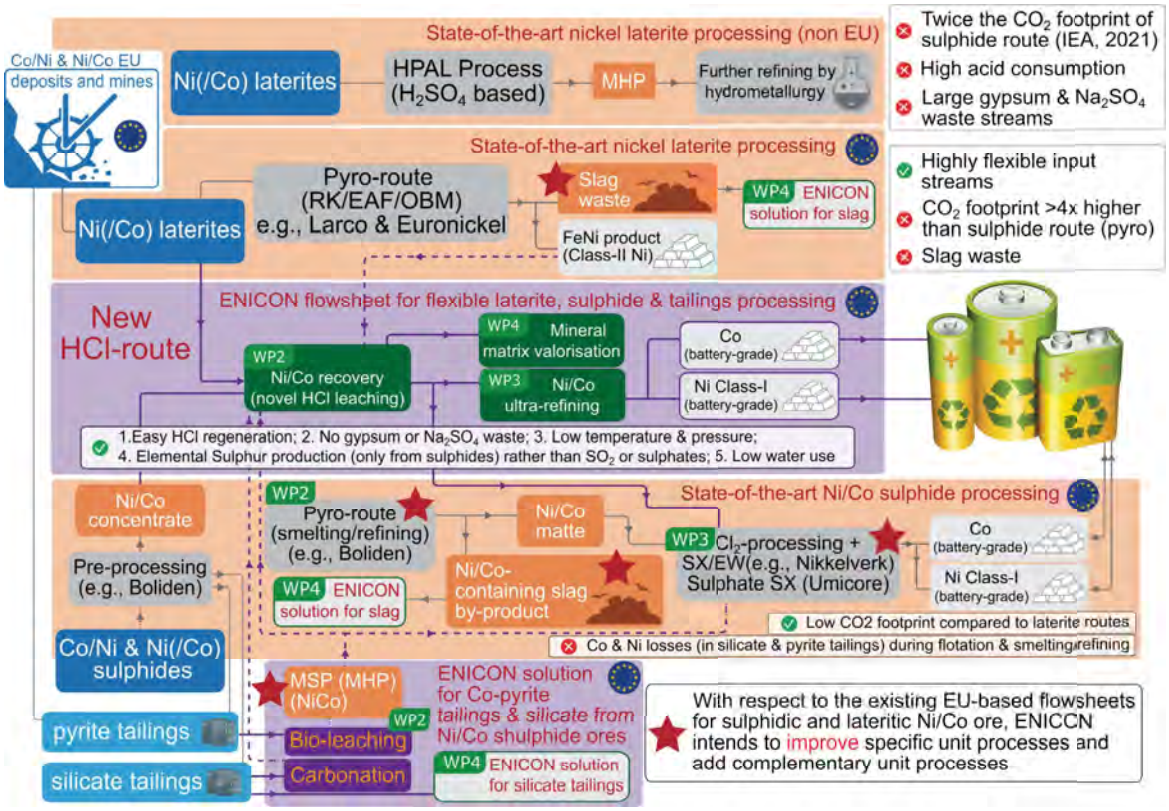

Figure 4. ENICON goes beyond the state-of-the-art for Ni/Co mining, recovery, and refining (orange boxes and grey arrows - source: IEA 2021). The new HCl route (upper purple box and purple arrows) is able to convert both laterite-based and sulphide-based materials into battery-grade Ni and Co, overcoming some of the issues associated with the state-of-the-art routes (green checks and red marks in white boxes near each specific flowsheet). A high-resolution version can be viewed at https://enicon-horizon.eu/.

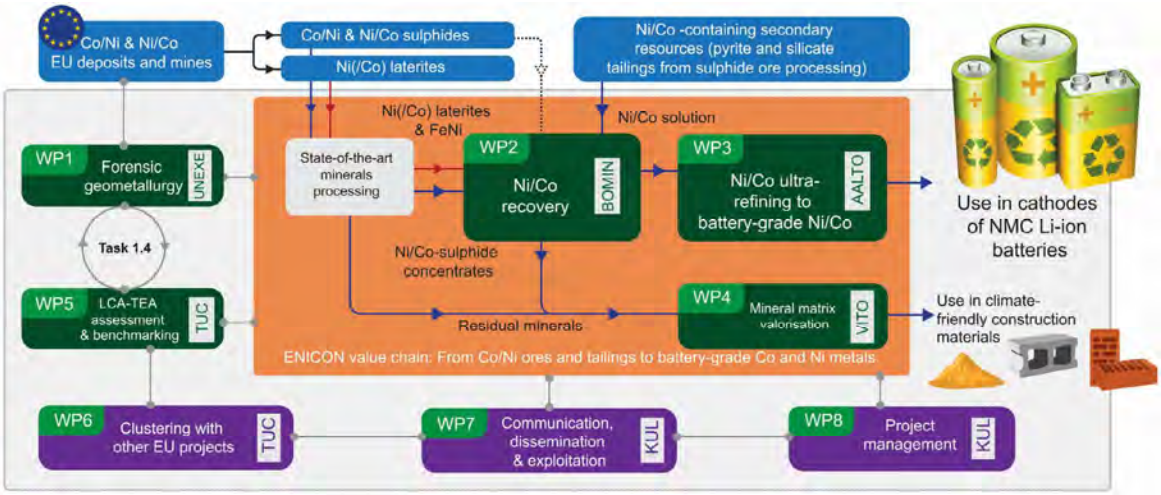

Figure 3. Division of the work package (WP green boxes) structure within the ENICON project. The link between raw material (EU Ni/Co deposits and tailings) to final product (battery-grade metals and climate-friendly construction materials) is monitored by the forensic geometallurgy protocol

about the metal pathways in all processing stages, aiming to track what happens to Ni, Co, potential by-products (e.g., platinum-group elements, Sc), penalty elements (e.g., As, Bi, Te, and Sb), active and passive gangue, and environmentally-deleterious products throughout the flowsheet from ore to battery-grade metal. This approach identifies the mineralogical and textural reasons for processing underperformance and mitigates losses in the Ni/Co mining, processing, and refining flowsheets and for the valorisation of waste materials. Additionally, the data will tell us how metals and minerals behave in the new HCl route compared to traditional stages of processing.

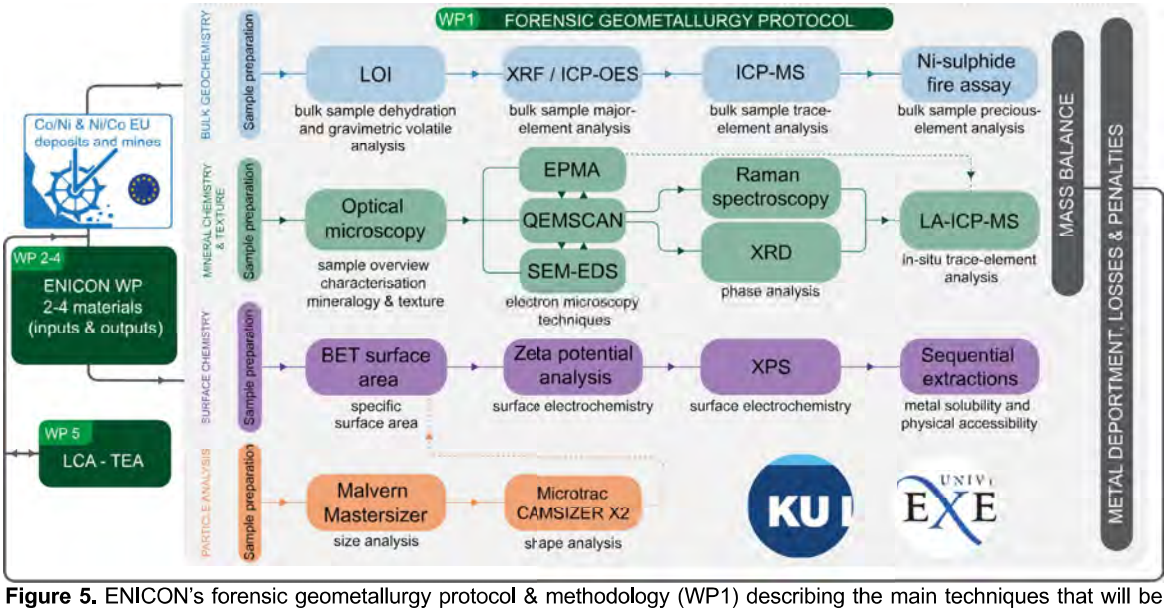

Figure 5. ENICON's forensic geometallurgy protocol & methodology (WP1) describing the main techniques that will be used in the project.

This advanced characterisation of materials involves a holistic investigation of their physical, chemical, and mineralogical parameters and characteristics. An array of techniques such as bulk geochemistry (loss on ignition, X-ray fluorescence, inductively coupled plasma (ICP)-optical emission spectroscopy, ICP-mass spectroscopy, and NiS fire assay), bulk and in situ mineralogy (optical microscopy, X-ray diffraction, scanning electron microscopy, electron microprobe, Raman spectroscopy, and laser ablation ICP-MS), and other analytical tools for particle size and shape distribution analyses are combined. This allows the definition of the metal deportment and losses from ore to battery-grade metal, and in all products/by-products, valorised waste, and residues.

Conclusions

The geometallurgy of nickel laterite deposits is a critical aspect to ensure effective mining and processing of these materials. By optimizing mineral processing and maximizing metal recovery, geometallurgical studies can play a vital role in improving the efficiency and sustainability of Ni and Co production from these ore deposits in Europe. The ENICON project targets to develop a competitive technology to treat the existing, newly exploited, and future low-grade Ni/Co European deposits to produce Class-I (battery-grade) Ni and Co with a lower eco-footprint. This will increase the effectiveness and sustainability of the Co/Ni supply chain in Europe, anticipating the increase in production required to meet Europe's electrification plan. The multi-metal mining approach and the residue valorisation strategies are needed to make the Co/Ni supply chain a near-zero-waste system in the future.

Acknowledgements

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