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Sustainable exploration for orthomagmatic ore deposits, progress of the HEU SEMACRET project

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The SEMACRET project aims to develop socially and environmentally responsible exploration methods for green transition (Critical) Raw Materials (PGE, Co, V, Ti, Ni, Cu, Cr) hosted by ultramafic-mafic orthomagmatic mineral systems. The primary focus is on refining ore deposit models following the mineral systems approach, optimising regional-scale exploration targeting, and developing efficient local scale exploration methods. There are 4 reference sites serving as case studies for testing these methodologies, including Lapland in Finland, the Beja area in Portugal, the Ransko area in the Czech Republic, and the Suwalki and Sleza areas in Poland.

The project has refined multiple geochemical proxies to identify the key source (mantle) component and degree of melting for generating metal rich magmas, in both rift and orogenic belts settings. Using computational modelling, magma transportation on a whole-crustal scale and within the upper crust have been modelled. High temperature experimental studies and thermodynamic modelling have been applied to constrain the metal precipitation mechanisms. All these provide fundamental clues for guiding mineral exploration in both regional and local-scale exploration.

Regional exploration targeting for orthomagmatic mineral deposits involves the compilation of mineral system models for Ni-Cu-rich conduit-type and PGE-Cr-V-rich layered mafic intrusion systems, supplemented by the insights gained from geological modelling. We applied new deep penetration geodata as predictor proxy in the modelling. These predictor maps are then integrated using a knowledge-driven approach for prospectivity modelling. The implication for future upscaling is to build up a GIS based deep penetration geophysical database across Europe from dispersed sources, as part of the European Geological Data Infrastructure, to facilitate the utilization of these data for guiding mineral exploration. In addition, an innovative outliner detection method has been developed which can be applied for identifying occurrence of mineral deposits.

Local-scale exploration focuses on creating an integrated solution that combines innovative methods to identify high potential areas at the deposit scale to be applied in brownfield exploration. The project developed innovative geophysical inversion methods. These include 3D inversion for electromagnetic (EM) data of sulfide ores taking into account induced polarization (IP), and joint inversion of EM and ground IP data in QGIS plug-in, advanced modelling algorithms

of full tensor magnetic gradiometry (FTMG) data and 3-component passive seismic modelling. Novel environmentally friendly surficial geochemistry tools based on upper soil horizons and plant geochemistry are also being explored. In addition, machine learning-based resource modelling and 3D prospectivity modelling are under development. Many of these technologies have potential for future upscaling. Different technologies can be integrated and combined with litho-geochemical modelling, for an optimized solution for the best practice on different mineralization styles.

Sustainable mineral exploration needs to promote social awareness on the significance of raw materials. In SEMACRET, social community events, interview and machine learning based social media analyses have been carried out to understand the attitudes towards exploration and mining from different stakeholders. Mineral source data on key raw materials hosted in orthomagmatic mineral systems have been collected across Europe, and conversion to UNFC code is on going.