Imperial College London

Natural Environment Research Council

2023_43_ESE_Richards: Integrating Geochemistry and Geophysics to Make Critical Metal Treasure Maps

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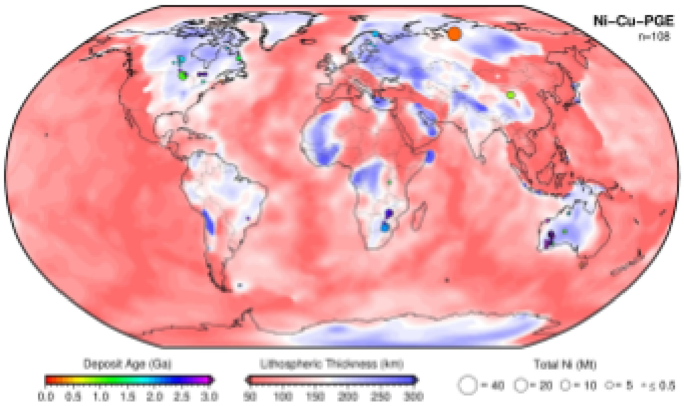
With climate change accelerating and its damaging impacts already biting, rapidly transitioning to a zero-carbon global energy system has become a pressing priority. Many technologies that will allow us to achieve this transition are now proven; however, they require large quantities of 'critical' metals (e.g., copper, nickel, lead, cobalt, and molybdenum). For example, the World Bank projects that over 3 billion tonnes of these metals will be required to deploy the amount of wind, solar, and geothermal power, as well as energy storage, that is needed to keep global mean temperatures below 2°C. While some of this surging demand can be supplied via recycling, we are forecast to use more of this raw material in the next 25 years than has been mined in human history to date, necessitating the discovery of many new deposits. The project outlined here aims to tackle this challenge by integrating emerging geophysical and geochemical data sets with state-of-the-art numerical models to generate 'treasure maps' of critical metal endowment and to gain new insight into geodynamic controls on different types of mineralisation.



Distribution of known magmatic sulphide deposits. *Circles = deposit loci coloured by age (Ga = billion years ago) and scaled by metal content (Mt = megatonnes); red/blue = low/high lithospheric thickness (Hoggard et al., 2020, Nat. Geosci.).*

Despite over a century of research, the geological mechanisms responsible for many styles of ore formation remain enigmatic (e.g., magmatic sulphide deposits), hampering efforts to find new resources. In particular, while mantle dynamics are inferred to play a key role, our understanding of how these deep processes connect to near-surface mineralisation is limited. Fortunately, several recent advances now allow us to make substantial progress. First, improvements in seismic and magnetotelluric imaging, combined with new data from mineral physics experiments, have greatly enhanced our knowledge of mantle temperature, viscosity, and conductivity structure. Secondly, when integrated with these geophysical constraints, growing compilations of mantle xenoliths (mantle rock fragments brought to the surface during volcanic eruptions) and surface geochemistry allow compositional variations to be traced across the lithosphere. Thirdly, spatio-temporal mantle temperature variations—a key control on mineralisation—can now be reconstructed with sophisticated models of mantle convection and melting. Finally, innovative machine learning techniques allow relationships between these potential mineralisation diagnostics to be assessed within a probabilistic framework, so that prospectivity prediction uncertainty can be quantified.

This project seeks to capitalise on these breakthroughs with objectives including: i) creation of accurate thermochemical models of continental lithosphere; ii) development of probabilistic machine learning-based predictors of critical metal concentrations; iii) establishment of mechanistic understanding for how mantle dynamics influence ore genesis. It will suit a geoscientist, applied mathematician or physicist with computational experience and an interest in conducting multidisciplinary research at the interface between economic geology, geochemistry, and geophysics.