A Multi-Scale Integrated Geological Modeling Approach of the Northern Norrbotten Ore Province, with a Focus on Iron Oxide-Apatite Mineral Systems

Ervin Veress[1], Tobias E. Bauer[1], Oskar Rydman[1], Joel BH. Andersson[1], Maxim Smirnov[1], Thorkild M. Rasmussen[1], Irvine R. Annesley[2]
[1]Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, Luleå, Sweden, [2]GéoRessources, Université de Lorraine, CNRS, CREGU, Vandœuvre lès Nancy, France

Critical raw materials, particularly metals, are at the center of the energy transition as the shift towards a renewable energy infrastructure accelerates. The subsurface has long been utilized for energy production and resource extraction, and geoscientists play a key role in providing the geological knowledge required to locate, assess, and manage the mineral resources essential for future energy systems. Explorers need to locate more deposits, in particular giant orebodies, to minimize the environmental footprint of mining and ensure sustainable practices. However, most giant ore deposits with surface expressions have already been discovered, and prospectors must work in new frontiers to explore and understand deeply buried mineral systems. Collaborations across and beyond traditional geoscience disciplines are becoming increasingly important as discoveries require multidisciplinary and integrated exploration tools. These tools should integrate the mineral system paradigm with existing geological and geophysical models and interrogate and characterize the spatial and temporal relationships of its components.

The Northern Norrbotten Ore Province (NNOP) is located in the northernmost part of Sweden and is regarded as a major metallogenic province hosting more than 40 iron oxide-apatite (IOA) deposits, including the giant Kiirunavaara deposit. More than a century of mining, exploration, and geological surveying in the NNOP has led to an outstanding repository of geoscientific data, encompassing geological mapping, deep drill core archives, high-resolution geophysical datasets, and detailed three-dimensional geological models at the local scale. Our study leverages this solid conceptual framework and geoscientific knowledge, proposing an integrated geological modeling workflow to characterize the spatial and temporal characteristics of the IOA mineral system components from the NNOP. The integrated workflow facilitates the interpretation of ore deposit expressions and their components within the broader mineralizing system context, and improves the predictive capability of exploration programs to delineate geologically favourable zones for mineralization at a regional scale.