04.01 Prospection and extraction of critical and strategic raw materials in Europe

Targeting deep-seated critical minerals in Poland using symbolic artificial intelligence

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The Suwałki Anorthosite Massif in northeastern Poland contains deep-seated Fe-Ti-V mineralisation associated with anorthosite-related mafic intrusions—resources deemed critical by the European Union. Hidden beneath ~800 metres of sedimentary cover, these deposits require advanced exploration techniques. This study applies knowledge-driven fuzzy inference systems (FIS), a symbolic AI method that integrates expert geological knowledge into computer models, to predict mineral potential using geospatial datasets.

FIS uses fuzzy logic to define key mineralisation indicators, such as magnetic and gravity anomalies and structural features, based on a mineral systems model. This model outlines three critical components for Fe-Ti-V mineralisation: mantle or lower-crust-derived magmas or mushes in post-collisional extensional settings, deep crustal faults as magma conduits, and structurally controlled traps that enable magma differentiation and oxide enrichment. GIS-based predictor maps are generated and combined using logical if-then inferencing rules to produce a continuous prospectivity map.

Due to the depth of mineralisation, limited data availability presents a challenge. Innovative data engineering techniques were used to extract meaningful features from available geophysical datasets, including nationwide magnetic and gravity data and a 3D p-wave seismic velocity model. From these, key features such as deep magma sources, structural conduits, and intrusive bodies were identified. The resulting FIS-based prospectivity map highlights unexplored areas with high potential, supporting future mineral exploration in the Suwałki region by guiding future exploration strategies.