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Uncovering hidden resources: Geospatial techniques in mineral prospectivity modelling and their application to Beja's layered gabbros

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Mineral prospectivity modelling is a geospatial technique used to predict the likelihood of discovering economically viable mineral deposits in unexplored areas. This method integrates various geoscientific data, such as geological, geophysical, geochemical, and remote sensing data, using simple mathematical, statistical or artificial intelligence algorithms to identify regions with high mineral potential. By expert knowledge or by analysing spatial patterns and correlations between known mineral occurrences and various geological features, prospectivity modelling aids in reducing exploration risks and costs. It typically involves developing a mineral systems model for the mineral system of interest, feature selection and extraction through data processing, and applying predictive models. Newer methods involve unsupervised data-driven methods to eliminate bias from lack of knowledge. The output is a prospectivity map highlighting areas with varying probabilities of mineralisation. This approach is increasingly vital for sustainable mineral exploration, enabling more efficient targeting of resources while minimising environmental impact. Besides providing a brief overview of prospectivity modelling, this talk presents a case study from southern Portugal.
The layered gabbros of Beja are valuable sources of critical raw materials (CRMs) such as Titanium (Ti) and vanadium (V), which are considered critical by the European Union due to their high demand for modern industries and supply risk.
This study describes computer-based exploration targeting of evolved gabbros enriched in oxide ores using two approaches: (1) a first-pass data-driven unsupervised analysis and (2) a knowledge-driven analysis utilising Fuzzy Inference Systems (FIS), a knowledge-based artificial intelligence technique.
The first pass data-driven analysis employed self-organising maps, a machine learning-based clustering algorithm that generated clusters of features from geophysical data such as magnetic, gravity and topography. Clusters representing differentiated gabbros were isolated based on a geological review of the clusters. This led to identifying new targets in the northwestern part of the study area, where new outcrops were found during a subsequent field visit. The analysis also

helped generate more robust datasets for the knowledge-driven study.

The FIS model relies on a generalised mineral systems model to identify targeting criteria and the FIS's structure. The mineral system model includes (1) Primitive, mantle-derived, metal-rich magmas emplaced in a syn-post collisional setting, serving as metal sources; (2) trans-lithospheric faults and suture zones acting as magma pathways; and (3) dilatational zones of high, fracture-related permeability and localised structures that physically trap the mineralising fluids, allowing fractional crystallisation to generate evolved, oxide rich gabbros.

Spatial proxies representing critical processes of the mineral system were mapped from various geoscientific datasets in the form of GIS predictor maps. This study also included singularity maps detecting geochemical anomalies based on the methods described by Gonçalves et al. (2024). All predictor maps were incorporated into the FIS model to generate the prospectivity map highlighting promising areas for further exploration.

The two approaches utilising different inputs form a complimentary workflow, enhancing exploration targeting.