A New Paradigm for Geoscientific Insights in the Digital Era: Large Scale Modelling of Orogenic Systems

Jean-Phillipe Paiement[1]
[1]Vrify Technology, Vancouver, Canada

We present a fully automated, data-centric workflow for mineral system exploration that converts heterogeneous geoscientific inputs into high-resolution, probabilistic prospectivity maps within a unified processing framework. Raw datasets—including surface and down-hole geochemistry, airborne and ground geophysics, structural lineament inventories, and 3D wireframe models—are ingested via schema-driven parsers and subjected to robust quality control (outlier detection, spatial–temporal alignment). Domain-aware feature engineering extracts exploration-relevant signals through computer vision decompositions of potential-field grids, tensor-based structural fabric descriptors, automated lineament detection and probabilistic lithological indices derived from geochemical ratios, spectral signatures and lithological labels. Furthermore, generative predictive models reconstruct sparse legacy data (e.g., lake sediment geochemistry, legacy gravity surveys or soil survey data) to augment under-sampled areas. A multi-task deep learning model, trained on >130 000 ground-truth samples across orogenic Au, porphyry Cu–Au–Mo, and LCT pegmatite systems, performs mineral system predictions and pixel-level property reconstruction. We show an example for a large-scale orogenic belt, where model interpretability is achieved via SHAP values enabling understanding of feature importance to predictive modelling results. Application to the Abitibi Greenstone Belt demonstrates accurate recovery of known gold corridors, identification of blind targets beneath cover, and new understanding of multi-scale controls on mineralization. Specifically, an interpolated absolute bouguer anomaly grid, decomposition filter of a reduce to pole magnetic intensity grid, predictive surface geochemical response grids, and simulated strike field grids were strong predictors for known Au systems. These insights demonstrate that AI tools can be used to map complex and subtle multiparameter patterns related to mineralized systems from public domain data for efficient exploration area prioritization. The presented workflow delivers rapid, reproducible, and transparent subsurface insights to guide exploration targeting.