

Machine Learning-Driven Integration of 3D Geological Modeling and Geodynamics Simulation for Ore Prediction: The Dongguashan Orefield, Eastern China

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The numerical dynamics simulation of mineral systems is a physics-driven approach that has the capability to reveal the coupled multi-process dynamic characteristics controlling mineralization. Machine learning (ML) prediction for mineral prospectivity is a data-driven approach that is advantageous in handling complex spatial variables to quantitatively forecast mineralization potential. In this study, based on the construction of the three-dimensional geological model of the Dongguashan orefield, we integrate the dynamics model with the ML model to quantitatively predict the ore-formation favor spaces at the depth of the Dongguashan orefield in Tongling copper district, Anhui Province, eastern China. The results of the three-dimensional geological modeling show that orebodies are unevenly distributed around the intermediate-acidic intrusion and are closely related to the occurrence of the contact zone between the wall rocks and the intrusion. The three-dimensional distribution of resistivity can provide insights into underground geological structures, rather than capturing a threshold to distinguish ore bodies from wall rocks. The results of dynamics modeling show that dilation zones develop around intrusion and are spatially related to the known orebodies. The spatial correlation of temperature and pore pressure with ore bodies is not as close as that of volumetric strain. By employing the Random Forest algorithm and integrating various geological, geophysical, and dynamics features as evidence variables, eight ML models were constructed to forecast potential ore deposits. The predictive performance on the test dataset indicates that the integration of geological features with dynamics features significantly improves the prediction performance of the ML model. SHAP (SHapley Additive exPlanations) values suggest that volumetric strain contributes most significantly to the prediction. The best-performing three-dimensional ML model, consisting of geological, geophysical, and geodynamic features, predicts that there is abundant potential ore in the northeast and southeast deep regions of the orefield.