Mapping subsurface alteration from gravity and magnetic inversion models

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Inversion of geophysical data can readily provide models of the distribution of physical properties in the subsurface, but rigorous geological interpretation of those property models is challenging. For mineral exploration, qualitative interpretations may be based on associations expected for mineralisation or alteration, such as the existence of "coincident magnetic and density anomalies". However, there is merit in assessing prospectivity more rigorously.

For most basement rocks the magnetic susceptibility and density of a sample are linearly related to the susceptibility and density of the constituent minerals. Measured or predicted susceptibilities and densities can therefore be used to identify and quantify the presence of minerals, especially sulphides, that have extreme physical properties. With selection of appropriate minerals and their physical properties, we can extract mineralogy estimates from drill core property measurements or 3D inversion property models where the minerals of interest have significantly different physical properties from the host rocks. When applied to district- or regional-scale inversion models it can be used to prioritise exploration targets.

Property measurements from the Perseverance komatiite-hosted nickel-sulphide deposit in Western Australia were used to test the mineral estimates against independent assessments of the mineralisation in the samples. The abundance of six major components (monoclinic and hexagonal pyrrhotite, pentlandite, pyrite, magnetite, and barren host rock) was calculated for each sample based on the measured sample densities and susceptibilities. The problem is underdetermined, with three data constraints and six unknowns, so estimates were obtained using linear programming. Two different objective functions sought solutions that minimised and maximised the proportions of nickel-bearing pentlandite in each sample, thus providing an estimate of the possible range of abundances. Constraints based on petrographic relationships were included to constrain the solutions; these can take the form of expected ranges of mineral abundance (e.g. < 5 % pyrite), or relationships between minerals (e.g. pyrrhotite is more abundant that pentlandite). The solutions also allow for measurement uncertainty.

The results provide realistic estimates of the possible range of pentlandite in each group; a high proportion of samples with known anomalous sulphide content were identified from their physical properties alone. Application of this procedure, with a different set of end-members, to gravity and magnetic inversion models from the Olympic Fe-oxide Cu-Au province in South Australia demonstrates how it can be used to map, in 3D, areas of potentially anomalous sulphide accumulation to aid exploration and target selection.