Deliverable 8

Improved geologically intelligent geophysical inversions, supported by a rock property database

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Extracting geologically realistic physical property models from gravity and magnetic inversions requires high quality geophysical data, an understanding of the geological environment, and a solid understanding of the physical properties of the rocks in the area. Recent advances in 3D geological modelling capabilities, such as those available in the GeoModeller software package (Intrepid Geophysics; McInerney et al., 2007), facilitate the rapid creation of 3D subsurface models that look geologically feasible. The process of integrating a variety of datasets and building such geometry-based models is a powerful way to enhance our understanding of subsurface geology. However many of these models are unsuitable for use in constraining potential field inversions because they may be based on limited physical property data, don't apply the available property data directly to the model, or ambitiously apply constraints in areas of the model where no reliable geological information is available. As physical property information becomes more accessible through increased measurement and the availability of public databases, such as Canada's rock property database (http://www.mirageoscience.com/rpds; Parsons and McGaughey, 2007), it is important to ensure that the data is included effectively into constraining geophysical inversions to enhance the value of the inversion results.

To develop an understanding of the relative contribution of different types of constraints to an inversion result, Williams (in press), as part of this project, developed a simple synthetic density model of Yilgarn-like geology for which he calculated a gravity response. The gravity data was then inverted using the UBC–GIF GRAV3D inversion package (Li and Oldenburg, 1998) in a series of geologically-constrained inversions with progressively more detailed geological data to simulate the contribution of knowledge at different stages of an exploration program. The results showed that the most effective constraints are those based on 1) surface maps, 2) reliable 3D models defined in small areas of abundant geological information, and 3) deep drill holes. All require reliable physical property information to guide the inversion towards a geological realistic result. Importantly the results showed that a full 3D physical property model for the entire inversion volume was not required to recover predictive results.

Since geological observations will generally be limited to surface exposures and relatively shallow drill holes in all but the most advanced projects, the reliability of a 3D subsurface model built for the entire inversion volume will be questionable. Yet any full 3D model that is built will primarily be based on those near surface geological observations. This suggests a simpler method for developing constraints for geophysical inversions. Ideally, this method would automatically build a physical property model from the raw geological observations in only those regions where sufficient information is available to warrant constraints. This new method of generating constraining models for UBC–GIF inversions moves away from hypothesis testing and towards tight integration of geological data with the geophysics. A demonstration version of this model building code is being developed by N. Williams as part of his ongoing Ph.D. research and the preliminary method is documented in Williams (2007). The approach limits the amount of interpretation required for building the model, and ensures that all available geological datasets are used, including (in order of priority and reliability):

1. Physical property measurements on surface samples
2. Physical property measurements on drill core or down drill holes
3. Geology logs from drilling
4. Outcrop geology maps
5. Basement geology map interpretations
6. 3D geological models (if available)

In this approach, available physical property measurements (items 1 and 2) are applied directly to a constraining model. They are also used to develop a physical property database for all geological units for which property measurements are available. The database is used to automatically apply physical property estimates to geological observations present in maps, drilling logs, and 3D geological models (items 3-6). An option exists to extrapolate the observed physical properties outwards a short distance from the observed locations but most cells which contain no observations retain default property values that are not-enforced as constraints in UBC–GIF inversions. Initial results suggest that geological structure and geometry can be resolved based on these sparse physical property and geological observations without specifying the geometry directly.

Any geophysical inversion result, whether geologically-constrained or not, must be interpreted in terms of geology. In early targeting stages it may be sufficient to loosely correlate regions of density or susceptibility highs with rocks known to have higher physical property values. More advanced exploration may require more quantitative interpretations to extract geological information from the inversions' physical property models. Williams and Dipple (2007) describe a method for calculating the possible range of mineral abundances present in a sample, either a rock or an inversion model cell, based on the density and susceptibility of the sample, the expected mineralogy, and known petrological relationships between each of the minerals present.

Certain minerals are known to influence the physical properties of rocks more than others – densities and magnetic susceptibilities are strongly controlled by magnetite and other oxides, sulphides, and low density alteration phases such as sericite and serpentine. Ore

deposit models will provide some additional knowledge regarding the associations between those minerals: Fe-oxide Cu-Au deposits like Olympic Dam usually contain more oxides than sulphides; heavily serpentinised ultramafic rocks are likely to contain more magnetite than less-altered equivalents; volcanic-hosted massive sulphide deposits will typically have more pyrite than other sulphides. The method proposed by Williams and Dipple (2007) allows this information to be supplied as mathematical constraints on a linear programming optimisation problem that calculates the range of abundances for each of the components. Used to calculate the percentages of hematite, magnetite, and sulphides present in regional-scale gravity and magnetic inversion models of Olympic Dam, the technique clearly identified the largest known mineral occurrences in the region, including Olympic Dam, but also identified several smaller target regions where the available geological knowledge may be insufficient to explain the observed geophysical responses. The technique provides a quantitative way to evaluate targets based on their likely mineralogy rather than some more tenuous proxy.

References

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