Bayesian Lithological Inversion

Juerg Hauser,[1*] David Annetts,[1] and James Gunning[2]

[1] CSIRO, Mineral Resources Flagship, Kensington, Western Australia, Australia
[2] CSIRO, Energy Flagship, Clayton, Victoria, Australia

*E-mail, juerg.hauser@csiro.au

In greenfield exploration, geophysical data is commonly used to produce an image of the distribution of a geophysical parameter in the subsurface that represents a model with a response that is a good fit to the data. These images are then qualitatively interpreted to extract features of interest such as an orebody or an unconformity. In the Bayesian approach introduced in this presentation, we attempt to directly invert for geologically meaningful parameters and their uncertainties, while accounting for the expected spatial coherency and additional prior information, such as boreholes.

Bayesian approaches have the advantage that there is a clear separation of prior information and data. This allows us to determine to what degree the distribution of final models is a product of our prior beliefs or the data we have attempted to fit during the inversion. Furthermore, the Bayesian posterior has the property that the natural resolution of geophysical techniques is reflected in a tendency for parsimonious model selection, i.e., the posterior probability tends to favor models only as complex as necessary to fit the data.

Nonetheless, the set of parsimonious models is likely to include models that do reflect necessary geological characteristics. For instance, the expected spatial characteristics of an orebody or the regolith, or both, is valuable prior information that can improve inference. The ability to account for prior information is critical to guiding such inversions towards basins of attraction that are desirable from both geophysical data and geological perspectives.

Using airborne electromagnetic data (AEM), we illustrate the questions that can be answered by employing a Bayesian perspective. Field data examples will include the Kintyre uranium deposit in Western Australian and its surrounding paleotopography, and the Harmony Ni-S deposit, also in Western Australia. Maps of the probability of encountering a given lithological unit contribute to a better understanding of the subsurface, and can be seen as complementary to the commonly obtained smooth images of resistivity distribution in the subsurface. Often, information about the robustness of a feature in the model can be just as important as being able to image the feature. Recovered model uncertainties increase with increasing depth and increasing cover thickness, as expected from the physics of electromagnetic induction.

Information about the robustness of models recovered from data could potentially be used to optimize an exploration strategy on a tenement scale. For example, we may estimate the value of information (VOI) for different AEM systems and different noise levels of surveys, given reasonable assumptions about the relationship between orebody geoelectrical parameters and economical value. It is then possible to estimate the probability of a deposit exceeding a certain value, given the information provided by an AEM survey.