COMMON EARTH MODELING

Introduction and Summary

Common Earth Modeling is a method that employs 3D and 4D (time) computer modeling techniques to integrate all available geological information into a single, 3D environment that can be viewed and queried on a computer.

Creating a Common Earth Model requires developing a clearly defined litho-structural model based on quality geology, structural interpretation and forward and inverse modelling of available potential field data, such as gravity and magnetic data. With these components, a coherent model for the formation of the 3D geology can be put together in a geological time context, which serves to clarify processes and their interactions involved in the production of a significant deposit. It is increasingly common to use software such as goCad (www.gocad.com) to complete this type of model.

To create a Common Earth Model that can be effectively queried, it is desirable to define and build into the model all criteria likely to affect the formation of a significant deposit. This includes exploration criteria known to be important as well as those that may have some significance. With established criteria, data sets that can be used to define them must be assembled and built into the model. Only when this definition process is complete will the model be useful for directly assessing the location, in 3D space, of high quality targets. Without such definition, the model's utility is limited to use as a visualisation tool.

On completion, a properly constructed Common Earth Model can be used to conduct a series of database type queries. They can be made using a range of technology, from conventional desktop computers to sophisticated Data-Caves, in which one can literally walk through the model to define volumes within the model that conform to the query criteria. The volumes can then potentially be used as specific targets that can be drilled directly. Of course, the model's ability to define such targets is limited by the amount and quality of the data. Because it is possible to interpret the same data in a number of different ways, it is recommended that such flexibility be factored into the model design during development.

Getting the Right Data

Creating a viable 3D Common Earth Model (CEM) requires a significant data set; certain data sets in particular are critical. Data usually falls into three main categories:

- Hard data. This includes geological mapping and drill hole assay data, etc., that put hard constraints on the model. The data cannot and should not be allowed to vary within the model. Hard data, as far as practically possible, should be available in 3D space.
- Potential Field data, such as aeromagnetic and magnetic data, is dealt with differently than hard data because it has two uses. First, it is used, much like hard data, to constrain the model, largely in aiding initial interpretations. Second, assuming that the data is of high enough quality/resolution, it is used to test the models ultimately validity. This is done at several stages during and after the creation of the model.
- Intangible data, such as tectono-stratigraphic concepts and exploration models, are needed in order to build a viable model. A clear understanding of what one is trying to represent in the model is necessary because it ultimately defines the way in which the model is used and tested.

Hard Data

- Lithology: Geological maps, both as outcrop and solid geology interpretations, are required. The latter must reflect the overall tectono-stratigraphic understanding, which will later be built into the third dimension. Appropriate level of detail is necessary.
- Structure. Large scale form surface and structural elements (anticline/synclines, faults, etc) maps will be of significant use early on in creating the model. These will show the broad regional trends of foliation, bedding and significant folds with axial traces, etc. As much detailed information should go into building these layers as possible.
- Other Hard Data. These can include assays, alteration mineralogy, PIMA, multi-element data, SG, and Magsus. It is likely that a key set of alteration minerals and/or elements, etc., are accepted as being associated with significant mineralisation. These data sets need to be set up to allow them to be queried and visualised in a 3D environment

Potential Field Data

As previously noted, this type of data serves two purposes: aiding in the development of initial interpretations and validating the model at various levels along the way. Key datasets in this category are detailed magnetics (generally available) and detailed gravity (less commonly available). As gravity is less available, it is important to identify the level of resolution necessary to resolve specific features within the model.

At an early stage, gravity and magnetic data can be used to constrain interpretation in 2D. Using a combination of both high resolution magnetic and gravity data will allow cross validation. Areas that have poor magnetic contrast may have good gravity contrast. Developing inversion models supports the creation of the overall architecture of the model. In conjunction, these will help to significantly constrain the 3D architecture. Once a set of cross-sections are completed, based on the defined tectono-stratigraphic model, the gravity, and to a lesser extent magnetics, which become useful at more detailed levels, can be used to validate them.

Once the model is completed, a block model of the geology can be created and a forward modeled to verify against observed gravity and magnetic data. Ultimately, this is the final validation process for the model, and will likely require a number of iterations and variations within the model itself, before a satisfactory result is achieved.

Other potential field data can be populated into the model in 3D space, including IP. Information such as EM may be useful in determining depth of cover sequences, and can be utilised to remove the influence of thick cover sequences from the gravity data sets, effectively increasing the resolution.

Intangible Data

In many ways, the intangible data is the most important early information required in creating a CEM. For example, it is relatively straightforward to build a geometric model that conforms to hard data. However, this may not serve to provide desired answers to defined questions because it does not represent the key ideas that one intends to test. For example, if it is believed that dilational or anti-dilational jogs in major shear zones are important for focusing fluid flow for the development of a deposit, some effort must be put into identifying these features prior to the commencement of the model, not only in 2D, but also in 3D space. This may be a demanding exercise, and may rely on extensive geophysical modelling and the use of such tools as “Worms” (based on edge detection algorithms) or inversion modelling.

Probably, the most important piece of intangible data required is the development of a reasonably constrained tectono-stratigraphic model for the geological development of the area to be modelled. Given that much of the deep interpretation is to be based largely on this model, with small amounts of hard data, such as seismic, to add some hard constraints, this has significant bearing on the way in which the deeper architecture is put together. Ultimately, when relating the model back to potential field data, any model can be made to conform. If no clear tectono-stratigraphic model is defined, the project will result in the creation of a mish-mash of different styles over the area, which is likely to result in a less than desirable outcome.

Included in the development of the tectono-stratigraphic model should be a concept or testable hypothesis of what causes mineralisation to occur – and when. In most cases, exploration groups are aware, either formally or informally, of a set of key criteria that are used to aid in the targeting process. If these are formalised, with an understanding of why they are important, i.e. how they affect the processes involved in the formation of a deposit, prior to the creation of the model, it becomes much easier to build a model that is sympathetic to the testing of and/or use of these concepts to define targets.

Conclusion

It is clear that substantial groundwork is required prior to the creation of the actual model. If the groundwork is incomplete, or shortcuts are taken, it will significantly diminish the value of the final result, in particular the functionality of the model. However, if completed with a high degree of geology and mineralisation process related information built into the model, allowing for effective queries, the 3D Common Earth Model can be a very powerful tool for defining and testing exploration targets.