The Deposit Model Paradox

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Tectonic processes are responsible for the formation of nearly all mineral deposits on Earth in one way or another. This statement is generally accepted by geologists, and it is implicitly assumed that structural geological controls at the deposit-scale are necessary for the emplacement of ore deposits.

If it is accepted that processes that deform the crust can also be responsible for the emplacement of mineral deposits, then it follows that the geometries of mineral deposits reflect structural permeability resulting from deformation. Consequently, the geometries of deposits provide important clues to the origin of mineral deposits; therefore, structural studies of deposit geometries should greatly assist with the efficient exploitation of mineral deposits.

Given the importance of deformation in the emplacement of mineral deposits, it is perplexing to find a lack of detailed 3D geometrical descriptions and accompanying structural interpretations of deposits from drill-hole data in the economic geological research literature.

Many research papers that discuss the origin of specific deposit types are used as references for finding more of the same deposits elsewhere. However, in general, these works generally do not provide details of the deposit geometries, with accompanying 3D models directly generated from drill-hole and mapped data. If you check SEG's One Hundredth Anniversary Volume (Hedenquist et al., 2005), you will find only one article that displays a 3D model of a mineral deposit (Oyu Tolgoi porphyry deposit, described by Yakubchuk et al., 2005, figure 13) in the entire 1136 page volume. Google image searches of key phrases such as "ore deposit models" and "ore deposit classification" also show a similar lack of 3D geometrical documentation linked to key mineral deposit types. The most common method of describing a mineral deposit is by its geochemical data, but geochemical elemental distributions are seldom discussed in terms of 3D geometries and what they might mean.

Detailed descriptions of 3D models of actual deposits are rare in the public domain. In the absence of such models, authors use cartoons, schematic diagrams, and cross-sections of deposits. It is these simplistic diagrams that establish the geometric image of "type ore deposit" models in most geologists' minds. However, many schematic diagrams are assumed "pre-deformational" geometries of mineral deposits, and most are illustrated in two-dimensions; therefore, the 3D shape of type deposits cannot be deciphered easily.

The lack of 3D geometries of mineral deposits in the academic literature is, perhaps, expected, as university researchers often may not have access to exploration and mining datasets, such as drill-hole data, geochemical data, and detailed mapping. This poses the question—what about the published work by resource geologists working in the resource industry? How often do resource reports describe at least the enveloping shape of a deposit and provide a structural explanation to these shapes?

Methods of analysing mineral deposits from drill-hole data have increased in efficiency by more than three orders of magnitude over the last three decades. A resource modelling task that took two months to generate in the early 1980s can now be done in hours. The technologies to document the 3D geometries of mineral deposits have been evolving rapidly since the 1980s, from paper, pencil, and light table drawings, to rapid implicit modelling methods introduced over the last decade (Lajaunie et al.,1997; Cowan et al., 2002, 2003, 2004, 2011; Chilès et al., 2004; Calcagno et al., 2008). However, even with the availability of modern methods of rapid modelling, the resource geologist's task (to estimate the resource) has not changed, and is not focused on understanding the genesis of mineral deposits. The consequence of this unwavering and short-sighted focus is that there has been little information available to exploration geologists to enable them to understand the resource models from the perspective of deposit origin. In terms of deposit genesis, the industry as a whole still appears to rely on the generalised cross-sections and cartoons of key mineral deposit types provided by academia.

This disconnect between well-established ore deposit models from the actual 3D geometry of ore deposit geology was the rationale for the development of a fast, three-dimensional, and structurally focused method of implicit geological modelling (Cowan et al., 2002). Used in conjunction with structural concepts, implicit modelling methods contrast with the conventional largely non-geological

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modelling methods entrenched in the industry in several ways, including speed (structural modelling is much faster than modelling without a structural framework), ease of modelling, and, from a structural perspective, these methods are very logical (e.g. interpolation of planar data as tangents to a potential field; incorporation of triaxial strain in the modelling workflow; modelling with respect to the structural geometric axes and ignoring conventional plan and vertical section views).

Incorporating structural geological concepts into the 3D modelling process of deposits is key to better understanding the origins of mineral deposits. The resource industry cannot realise the benefits of understanding mineral deposits if software is used blindly to generate 3D shapes, no matter how fast these shapes can be generated. When geometries of deposits are modelled with a structural geological framework, rather than with modelling focused on resource estimation, unexpected patterns start to emerge. Several case studies will be discussed that highlight these results.

Acknowledgements

I thank Colin Arthur for insightful discussions of the history of mining software. Brett Davis and Toby Davis are thanked for useful discussions and feedback.

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