Upscaling of micro- and meso-scale structures to the deposit-scale: implications for 3D models of complex, structurally controlled mineralisation

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Upscaling of brittle and ductile structures in the Neoarchean to Paleoproterozoic banded iron formations (BIF) of the Hamersley Province (Australia) showed that deformation is controlled by contrasting rheological behaviors of different multi-layered rock types. We hypothesize that these structural associations established a framework for later enrichments and replacements that lead to the formation of high-grade iron ore.

Many aspects of BIF formation, the structural evolution of the region and the enrichment processes that lead to high-grade iron ore deposits are still under debate. Models range from electrochemical, supergene metamorphic (Morris, 1980), synorogenic (Powell et al., 1999), combined supergene/ hypogene enrichment (Taylor et al., 2001; Dalstra, 2006) and chert-free BIF models (Lascelles, 2006).

The established structural geological principle of extrapolating small-scale structures to larger scales and vice-versa is the key approach used in this study. Our goal is to evaluate whether insights provided from micro- and meso-scale structures observed in thin sections 1 - 6 can be upscaled to the geometry and spatial-temporal relationships at the larger deposit scale 7 - 8. Our approach is to visualize complexly deformed samples of BIF using explicit (Move, Midland Valley Ltd.) and implicit (Leapfrog, AranzGeo Ltd.) modelling techniques to characterize the 3D geometry of the Mt. Tom Price iron ore deposit (operated by RioTinto Ltd.), supported by microstructural observations and X-ray microscopy (XRM, X-radia XPM-520). The results are compared with structural observations in 3D mine-scale models 9 to test for significant similarities with possible economic relevance.

Microscopic (optical and XRM) and meso-scale studies indicate significant removal of quartz 2 - 3, which leads to a reduction of layer thicknesses and hence a compacted sequence of iron oxides alongside reprecipitation as fibrous strain fringes 1 in extensional domains or subparallel to the bedding 4. A cleavage also developed in the flattening plane and is indicated by a second generation of iron oxides precipitated by iron-rich fluids 5. Structural investigations have shown that early extensional structures (boudins, pinch-and-swell structures) are probably overprinted by two shortening events (thrusts, buckling, mullions) 4. Meso- and deposit-scale 3D models have shown that most structures are non-cylindrical and deformation is not necessarily transferred across/ along layers 5 - 6.

Our preliminary analysis shows that differences in the rheological properties of chert and iron oxide layers (BIF) as well as their interaction with shale, carbonates and volcanics has lead to complex deformation patterns at all scales. Our study demonstrates that deformation style varies strongly between different lithologies and that folding, faulting, dissolution and reprecipitation developed simultaneously. Contrasting fluid flow properties between lithologies and thickness variations (e.g. BIF and shales) may also have played a major role in the development of the aforementioned structures.

Our approach of multi-scaling illustrates that 3D analysis of structures and subsequent extrapolation to other scales is an effective way to significantly improve understanding of spatial/temporal relationships between structures and structural controls on mineralization in ore deposits.

References


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