Geophysical Responses from Orogenic Gold Mineral Systems

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Different authors have defined the various components of a mineral system in slightly different ways although many describe hydrothermal and orthomagmatic systems as comprising a source of fluids, metals and other elements and a pathway along which fluids transport the metals to a location where they are precipitated via some kind of trapping mechanism (*source-pathway-trap*). The concept of a mineral system leads to reconsideration of the way geophysical methods are deployed in mineral exploration, including in exploration for orogenic gold. A mineral system represents a much larger target than an individual mineral deposit and rather than the conventional practice of seeking geophysical responses from the immediate mineralised environment (mineralisation, alteration, host rocks) the whole mineral system can be thought of as constituting a target. Early phases of exploration can concentrate on responses from source zone and pathway. As the exploration space is reduced to say, camp-scale, the reservoir zones become an attractive target. Finally, once the most prospective parts of the system are identified the immediate mineralised environment may be targeted.

Interpreting geophysical responses potentially caused by components of orogenic gold mineral systems is hindered by the incomplete understanding of these systems. In particular, the source of the gold remains contentious with the mantle, metamorphism in the deep crust and even sediments in the upper crust proposed as source zones.

Sources zones

Where metal-bearing fluids are sourced in the lower crust or mantle it is possible that the processes that create the fluids, or the preferential removal of certain components of the rocks, cause changes to the physical properties of the rocks. For example, depleted mantle may be different from primitive mantle, as may be mantle that has been re-fertilised via metasomatism.

Pathway

Pathways are potentially detectable if the associated alteration comprises a wide zone (which is unlikely), otherwise these comprise very difficult targets given they are expected to be at significant depths. Given that it is expected to be shallower, the fluid flow pathway post-deposition of metals, is a more attractive target.

Reservoirs

The most attractive target which emerges from the mineral systems concept, as proposed by McCuaig and Hronsky (2014) is the postulated reservoir that contains high pressure fluid which is subsequently rapidly emptied causing concentrated fluid flow and metal deposition. With dimensions measured in kilometres, and occurring at depths of a few kilometres, these are potentially attractive geophysical targets. Moreover, reservoirs represent exploration targets at a camp/district scale and hence fill the gap between prospect scale geophysical targets (mineralisation, alteration haloes) and regional/terrane scale targets (major linears, suture zones).

Geophysical Responses from Mineral System Components in Western Australia

Magnetotelluric (MT) surveys have proved to be very useful in Western Australia for mapping mineral system components in the Archean Yilgarn Craton. The method has been successfully used to map favourable lithospheric architecture, specifically suture zones between major crustal blocks and deep penetrating faults.

Also important deposits have been shown to be associated with zone of anomalous electrical properties in the deep crust and upper mantle. For example, data from north of Kalgoorlie, passing through two major gold mines, show there is a zone of resistive upper mantle spatially associated with known gold deposits, but also a deeper zone of conductive mantle. The resistive zone may be indicative of a melting event that sourced the gold. The reason for the conductive zone is unknown.

The Gruyere orogenic gold deposit is located in the Yamarna Terrane in the eastern Yilgarn Craton. Dentith et al., (2018) present horizontal and vertical slices through an MT-derived resistivity volume in the vicinity of the Gruyere deposit, and other known gold mineralisation further west. Mineralisation is associated with a pipe-like zone of lower resistivity. This is interpreted as being due to alteration caused by mineralising fluids, e.g. the geophysics has mapped the fluid flow paths of the mineral system. At lower crustal depths there is an elongate zone of lower resistivity materials, which is linked to the pipe-like zones. This zone is tentatively interpreted as a palaeo-reservoir zone. A conductive zone in the upper crust in the Kalgoorlie survey may have a similar cause.

Discussion

There is emerging evidence that orogenic gold mineral systems can be mapped in the deep crust and mantle using MT methods. Evidence is primarily based on spatial associations and geometries of low-resistivity zones relative to known geological structure and deposits. On-going research will seek to better understand the causes of the changes in resistivity.

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References

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