The role of geophysics in the "mineral systems" approach to mineral exploration

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ABSTRACT

In the earliest days, geophysics was used to *directly detect* mineral deposits, with, for example, gravity and magnetic methods being used to identify anomalous responses associated with ore deposits that were denser and more magnetized than the surrounding host rocks. Geophysics was later used for *indirect detection*, where geophysical signatures, generally displayed on a map where interpreted to indicate geological features. Then aspects of these geological maps were used to identify locations that might be prospective for mineral deposits, for example the nose of a fold, proximity to a shear zone, or a cross-cutting structure.

More recently, a “mineral system” approach has been adopted in mineral exploration. Conceptually, this approach requires energy, ligands, a source of metals, and a fluid that flows though the source and dissolves the metals. A fluid pathway is required to carry the fluid away to a sink location with pressure, temperature chemical and physical conditions appropriate to precipitate metals. The physical conditions can include porous regions for the trap.

Geophysical methods are now starting to be used to identify some of the key locations of the mineral system. One of the earliest example is in the discovery of the Olympic Dam iron-ore copper gold deposit, near Roxby Downs in South Australia. Explorationists were looking for a copper deposit and this requires a source of copper. They felt that the most likely source of copper was a mafic or ultramafic body in the basement and these are expected to be both dense and magnetic. Hence they looked for gravity and magnetic anomalies that were coincident and expected that there might be shallower location where the metals had been transported upwards and deposited. Some creative reinterpretation of gravity contours found a gravity anomaly close to a magnetic anomaly and subsequent drilling near this deposit discovered the Olympic Dam deposit at 300 m depth. This discovery was largely serendipitous, as the gravity anomaly is believed to be associated with the magnetite in the ore body and the magnetic body is interpreted to be more than 2 km deep and may or may not be the source of metal, or heat. More recent geophysical work at Olympic dam has shown that there are conductive and seismic features that suggest that the fluids may have travelled along pathways from sources that are potentially much deeper in the crust.

Work on the Metal Earth project, in the Archean Abitibi subprovince of the Superior craton of Canada, has also identified similar sub-vertical pathways associated with orogenic gold deposits, and these are also seen in similar parts of the world, such as the Yilgarn craton of Western Australia. These pathways generally appear as seismically transparent as there are few coherent reflectors evident. In many cases these vertical features have been also been identified as conductive and these are often cheaper and easier to identify in magnetotelluric data.

The explanation for the higher conductivity is unclear as the deposits and the minerals systems are almost 3 billion years old, so any fluids and sources of heat would have been removed or cooled by now. One possibility is that the conductive material is comprised of clay or graphite. The sub-vertical conductive features emanate from extensive sub-horizontal conductors in the midcrust (15 to 20 km depth) that could have a similar explanation. Graphite is believed by some to be the most likely possibility as this has been observed in gneissic rocks uplifted in the Kapuskasing structural zone and interpreted to be mid-crustal. The magnetotellurics suggests that the mid-crust could be the source of the metals, the seismic data suggests that the zone of transparency continues to at least 40 km depth, close to the base of the crust.

The geophysics can also be used to identify locations that could be the traps. One example is from the Malartic gold deposit. Geological work shows that the gold occurs in areas that are more structurally complex. Resistivity maps derived from airborne electromagnetic data shown that these zones of structural complexity as being more conductive.

The fluid pathways carrying metals from below, but can continue above, without the metals, and can alter the rock and these altered zones are identifiable in geophysical data. Examples where alteration is evident include locations where magnetite in magnetic formations has been destroyed, perhaps near a cross structure, or the alteration zones that surround porphyry copper deposits. These alteration zones surrounding a porphyry can be mapped with resistivity and induced polarization methods. When modern distributed arrays are used to acquire this type of data during the day, the same wire layouts can be used to collect magnetotelluric data that can map potential mineralization pathways deeper below the deposit.

In the future, the challenge is for geophysics to be used for understanding all phases of the mineral system.

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