Modern geophysical pathways to mineral discovery: Beyond traditional 3D modelling

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Introduction

Recent advancements in geophysical data collection and processing are enhancing how we identify ore deposits. In particular, 3D Magnetisation Vector Inversion (MVI) and passive electromagnetic techniques for mapping resistivity such as AFMag (Audio Frequency Magnetics), provide new approaches to map sub-surface geophysical properties. These techniques enable explorers to see deeper and with more precision.

By accounting for complex rock properties that had previously been ignored, these methods are reducing "blind spots" in exploration. This paper examines case studies from South America, Indonesia and the United States, and discusses how these techniques are currently being applied to unlock new potential in the Tennant Creek goldfield in the Northern Territory.

The evolution of magnetic modelling

The limitation of early algorithms

Since the early 2000s, industry has relied on 3D magnetic susceptibility modelling to visualize underground anomalies. To ensure these calculations could run on standard desktop computers, various mathematical shortcuts were employed.

One key assumption is that of Induced Magnetisation where all magnetic signatures in the ground are considered to align with the Earth's current magnetic field. While this simplifies the mathematical treatment, it is often physically incorrect. Many rocks instead possess Remanent Magnetism – a 'frozen' magnetic memory from when the rock was formed – that is often oriented differently to the modern-day magnetic field. When traditional 3D Susceptibility Inversion (3D Susc) models encounter remanence, the resulting model is often displaced or distorted, leading to inaccurate drill targeting.

The MVI advantage: Accuracy through complexity

With the advent of cloud computing, we can now move beyond these simplifications using 3D Magnetisation Vector Inversion (MVI). Rather than force the data to align with the Earth's modern magnetic field, MVI allows the actual direction and strength of the magnetism to be revealed through dual approaches:

- **The technical shift:** MVI inverts for both direction and amplitude, producing a set of vectors that represent the true magnetic response of the geology.
- **The exploration value:** This mitigates the remanence problem and creates the ability to map deep fluid pathways and hydrothermal structures with high precision.

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Global case studies in magnetic inversion innovation

Although traditional methods can be successfully applied where host rocks lack significant remanent magnetism, such as at Tujuh Bukit (Indonesia) and Hillside (South Australia), the shift to MVI has elsewhere already proven its worth in Tier-1 discoveries.

For example, at the **Alpala deposit** (Ecuador), traditional magnetic modelling failed to identify the mineralized zone due to remanent magnetism. Only when the data was reprocessed using modern MVI processing did targets emerge; this approach led directly to the discovery of Alpala.

On a more regional scale, recent USGS surveys across Arizona and New Mexico (USA) have yielded an extensive MVI dataset that is enabling the geophysical classification of established deposits such as Chino and Morenci. This approach permits regional benchmarking and the establishment of a framework for the identification of analogous porphyry systems on a global scale.

Seeing deeper: Airborne MT technology

In tandem with magnetic improvements, magnetotelluric (MT) data collection has moved from the ground to the air. Historically, ground-based MT was slow and expensive. Today, new airborne systems can capture data at lower frequencies, extending imaging and interpretation capability 1km beneath the surface. This improvement provides significant geological context at regional scale, including insights around how deep source rocks may connect to potential targets at shallower depths.

Importantly, there are also notable cost efficiencies associated with airborne surveys as they can cover 100 km^2 for a similar cost to a 2 km^2 ground survey a decade ago.

Integrated targeting: Minimizing false positives

The most powerful aspect of modern geophysics is the ability to overlay the results from multiple datasets to increase resolution and insight. That is, both MVI and MT can produce false positives (anomalies that don't host ore) when used in isolation. But when MVI (magnetic structure), MT (conductivity), geology, and geochemistry are stacked, the 'noise' drops away. This integrated approach dramatically reduces the number of barren drill holes required to find the heart of the deposit, as demonstrated by the Onto (Indonesia) and Alpala (Ecuador) discoveries.

Applications to Tennant Creek

At Tennant Creek, NTGS government magnetic data (available at 200 m-line spacing) was used to generate new MVI models over large sections of the field. These models were initially created without considering any known deposit (or other geological information) to assess what an unbiased model could identify.

Even with broad 200 m-spaced data, the MVI models accurately identified the location, dip, and plunge of known historical mining at Warrego **(Figure 1)**. Similar results were obtained for the White Devil and Juno deposits.

On a more regional scale in the Tennant Creek field, new airborne MT data is revealing conductive ‘pipe-like’ features that resemble the ironstones typical of the district but which remain hidden at depth.

Signatures from new MVI and airborne MT data have also identified a different target type based on signature typing from multiple porphyry copper targets around the globe. Although this target type is higher risk, due to its unproven geological characterisation, it represents an interesting and exciting potential target type for the Tennant Creek district.

Conclusion

The integration of MVI’s enhanced accuracy with the deep penetration capabilities of airborne MT is revolutionizing exploration strategies for targeting beneath cover. This approach facilitates more effective capital allocation by increasing success rates in drilling programs. The deployment of these advanced techniques aims to establish a new methodology: Drill Less and Discover More.

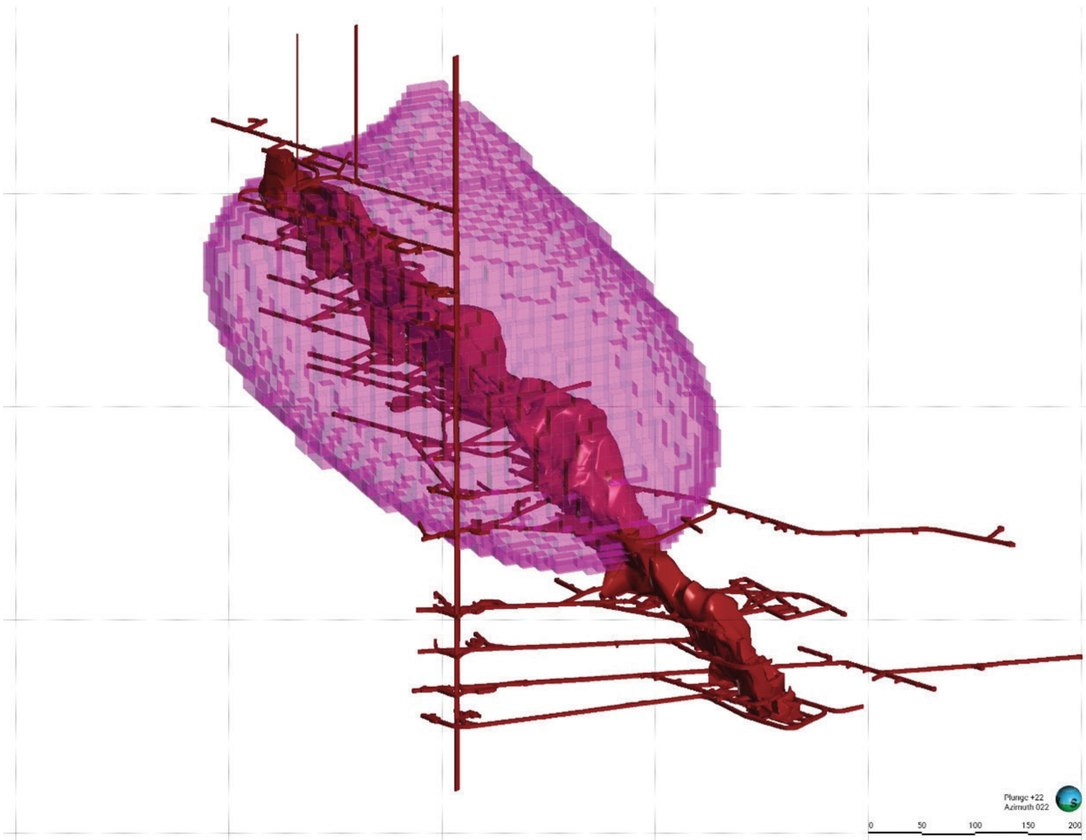

Figure 1. Oblique view of the Warrego deposit highlighting the MVI model filtered to high magnetic intensity (purple) relative to the historical underground workings (red).