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Exploring to depth in the shadow of headframes

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ABSTRACT

Brownfield (near-mine) mineral exploration activity is at a record high – driven by the desire to mitigate risk in these uncertain economic times and the old adage that "the best place to explore is in the shadow of a headframe.” Many companies have purchased “old” mines to gain access to mineralization that was “missed” with previous generations of geoscience technologies and to assess new targets. Today, new deep geophysical technologies are assisting in exploration, ore delineation and ground sterilization.

Historically, however, it has been difficult to apply geophysical techniques around mines. Cultural noise, scheduling, electrical noise, remoteness and resistance to new technologies are some of the traditional obstacles (to performing geophysical surveys in brownfield areas) that have been overcome. One of the new technologies that has proven itself is deep electrical imaging -- made available thanks to the distributed acquisition system (DAS) technology. DAS technologies are characterized by a large multi-channel, fixed receiver array and several other factors that together contribute to improved depth of penetration, data quality and detectability.

In this paper, we review the components and capabilities of DAS, focusing on one system in particular, for brownfield work, including near-mine and minesite applications. Three case studies, two from porphyry copper environments in western Canada and a gold project from Bulgaria, are presented. These case studies represent the state-of-the art in geophysics for brownfield work and are a novel application for current DAS technologies.

Key Words: brownfield exploration, distributed acquisition system, induced polarization, resistivity, magnetotellurics.

INTRODUCTION

Making a brownfield discovery is difficult based on a variety of factors. In addition, the financial risk with deep drilling further constrains deep exploration. Technology advances have been hindered because the mining industry is traditionally slow to embrace new technologies. However, the economic downturn may accelerate this as companies seek to mitigate drilling risks.

Recent advances in digital signal processing using faster computers, coupled with the ability to collect very high resolution and deep geophysical data, have led to recognition of physical property contrasts that can now be discriminated from the surface with enhanced accuracy and depth penetration. Drill targeting can be more focused, thereby providing better returns per metre drilled. Consequently, previously under-explored high potential ground may now be more effectively explored.

Economists have often said that a critical failure in exploration is the inefficiency of existing methodologies while exploring highly prospective regions. Today, images to depths of over 1 500 m for key targeting parameters can assist with required deeper exploration within favourable ground. Moreover, technology can now provide a means to revitalize exploration in mature mining camps.

TITAN 24 DEEP PENETRATING GEOPHYSICS (DAS TECHNOLOGY)

Although on its own, geophysics does not produce a picture that is directly related to the geology, the images developed by these technologies provide the most advanced clues to the subsurface that we have. Generally speaking, most types of large ore deposits have disturbed the background geophysical signatures in such a way that characteristic signatures exist. Being able to accurately sample key vectoring parameters, such as resistivity and chargeability, to very great depths should provide a starting point for efficient exploration.

An example of a system that provides deep multi-parameter geophysical data; in this case, magnetotelluric resistivity (MT), direct current (DC). resistivity and induced polarization (DCIP) is the Titan 24 (Figure 1) distributed DCIP and MT survey system. DAS systems use a large multi-channel, fixed receiver array, typically 2.4 km in length, in combination with a wide variety of possible current injection arrays, accurate 24-bit analog/digital (A/D) sampling and digital signal processing to achieve improved depth, data quality and detectability.

Titan 24 was introduced to the industry in 2001 and works from a premise of collecting data through a large array. The large array style of acquisition contributes to deeper DCIP measurements; on the order of 750 m with Magnetotelluric measurements to 1500 m.

The high volume of data, improved signal processing and increased array size provide accurate deep images of the subsurface for key physical property parameters. Deep MT resistivity investigations have had increased usage within the last 20 years for a number of applications. The new approach of measuring very closely spaced MT sites simultaneously in a constant natural field has led to very high quality data, and improved lateral resolution for better accuracy and effectiveness of resulting models used for targeting.

In a test by Newmont, depth of investigation of at least 400 m was achieved easily without sacrificing the spatial resolution that was typically only achievable with small dipole spacing. The cost-benefit and speed of acquiring a higher density of data points were also noted. It has also been recognised that for 3-dimensional (3D) bodies of limited extent, an optimised configuration for deeper ore bodies would be to use array style configurations with multiple electric field measurements, as most of the anomalous response would be from the electric field components. To resolve bodies at depth, station spacing must be sufficiently close. A broadband wide frequency range of MT data is necessary to detect and to delineate the deep geometry of 3D bodies.

Advanced digital signal processing of full waveform data means that these systems have applications in brownfield exploration, where cultural interference usually renders traditional approaches ineffective (Figure 2). The ability to filter out much of the random noise in these environments has contributed to the increased usage of MT in conjunction with DCIP in minesite and near-mine applications.

CASE HISTORIES

Three case studies, two from porphyry copper environments in western Canada and a gold project from Bulgaria, are presented These case studies represent the state-of-the art in geophysics for brownfield work and are a novel application for current DAS technologies.

Near mine survey and results, Kemess porphyry area, British Columbia, Canada

A Titan 24 survey was performed over the Kemess North Property, situated in north-central British Columbia. Kemess North is a copper-gold porphyry deposit where hydrothermally-altered, disseminated pyrite-chalcopyrite (py-cp) mineralization is hosted in Triassic age volcanic rocks. These lie close to the surface at the mine, but are down-faulted and progressively buried to the east below younger volcanic rocks, and are cut by post-mineral intrusive bodies. The issue in this environment was that the Kemess North deposit was running out of ore, and it was a prerogative to find new ore nearby, if at all possible.

The Titan 24 survey consisted of three reconnaissance lines. The survey extended eastward from directly over the subcropping portion of the deposit, to the more deeply buried and down-faulted region, known as the Offset Zone, and towards lesser known geology further east, northeast and southwest, where thick sequences of volcanic rocks and talus dominate the rugged, snow-covered mountainous topography.

The surveys were preceded by a 2D synthetic modeling study that tested for the optimal array parameters, and to test the detection limits and sensitivity of the Titan 24 DCIP surveys that were proposed. The results predicted that the Titan 24 surveys would easily penetrate the 300-600 m of younger cover and resolve mineralized porphyry bodies, but might not distinguish between pyrite-halo and cp-py phases at depth. The Titan DCIP and MT surveys corroborated the predicted results, including the discovery of two new zones, the Oro and Althus Zones. .

Mineralized zones were defined below 350 m of cover and suggested to extend below 1 km, This has been confirmed by the drilling of the deepest mineralization in the Kemess camp. Mineralized zones are also indicated to subcrop (i.e., at Oro and Althus) but were previously undetected because of the thick talus cover. Deeper DCIP and MT resistivity low signatures suggest the source is a deeply-rooted, hydrothermal, clay-chlorite alteration system.

Minesite survey and results – Copper Mountain, British Columbia, Canada

The Copper Mountain mine was a past producer and Copper Mountain Mining purchased the shut-down mine. They had restored it to production and were drilling to determine how much ore was left. A Titan 24 survey was carried out directly over the minesite to answer the main question, i.e. determining whether there was sufficient copper mineralization at depth to justify expansion of three smaller pits into one larger one.

In Copper Mountain's press release after the survey, they noted that Titan 24 deep penetrating results suggested large targets at depth. The company has since continued with pit expansion and drilled in the areas of optimal mineralization as suggested by the Titan 24 survey. The following figure shows a 3D image of the chargeability anomalies present at Copper Mountain.

A recent Copper Mountain press release following drilling indicated that more than 40 m of 1.34 % copper and over 10 g/t silver were intersected; a great result that further justified the implementation of a DAS survey and the subsequent pit expansion.

Near mine / minesite survey and results – Chelopech Mine, Bulgaria

In our final example, we have a brief look at the Chelopech Gold Mine, owned by Dundee Precious Metals in Bulgaria. As in the Kemess example, reserves are declining and it is desirous to find a new orebody within the shadow of the headframe. This survey was a combined near mine/minesite survey in which part of the work was performed over the mine (to characterize the local geophysical signature), and the remainder was carried out on either side of the minesite.

The survey was effective in a number of areas, including:

- Characterizing the signature of the main orebody for application nearby.
- New targets with similar signatures discovered.
- Rapid exploration in a very mature setting.
- Effective drill budgeting based on targeting.

These results were achieved in a very challenging environment with significant noise, including culture and more than 50 electric trains a day on the main railway line close to the mine.

SUMMARY

The search for minerals in the future will be dominated by deeper exploration and the need to accurately target "blind" deposits as more and more of the "easy" near surface targets are exhausted, particularly in the near mine or minesite environment. However, the emergence of sophisticated geophysical technologies, such as DAS, is helping to address the requirements for high-resolution, low noise and high quality data in difficult settings, such as mines that are characterized by significant culture and activity.

In a near-mine example, we noted the advantages in a challenging mountainous terrain in which two new porphyry copper orebodies were discovered at depth. In the minesite environment, the Copper Mountain example showed how Titan 24 can be effectively operated in a working minesite while delineating significant new potential for mineralization. The Chelopech Mine example was more of a hybrid, involving both minesite and near-mine aspects, and resulted in the characterization of signatures over the orebody that could then be extrapolated to other targets both at surface and at depth.

With the advent of these technologies and their routine application, the potential to discover mineralization located within/near an operating or defunct mine is now within reach.

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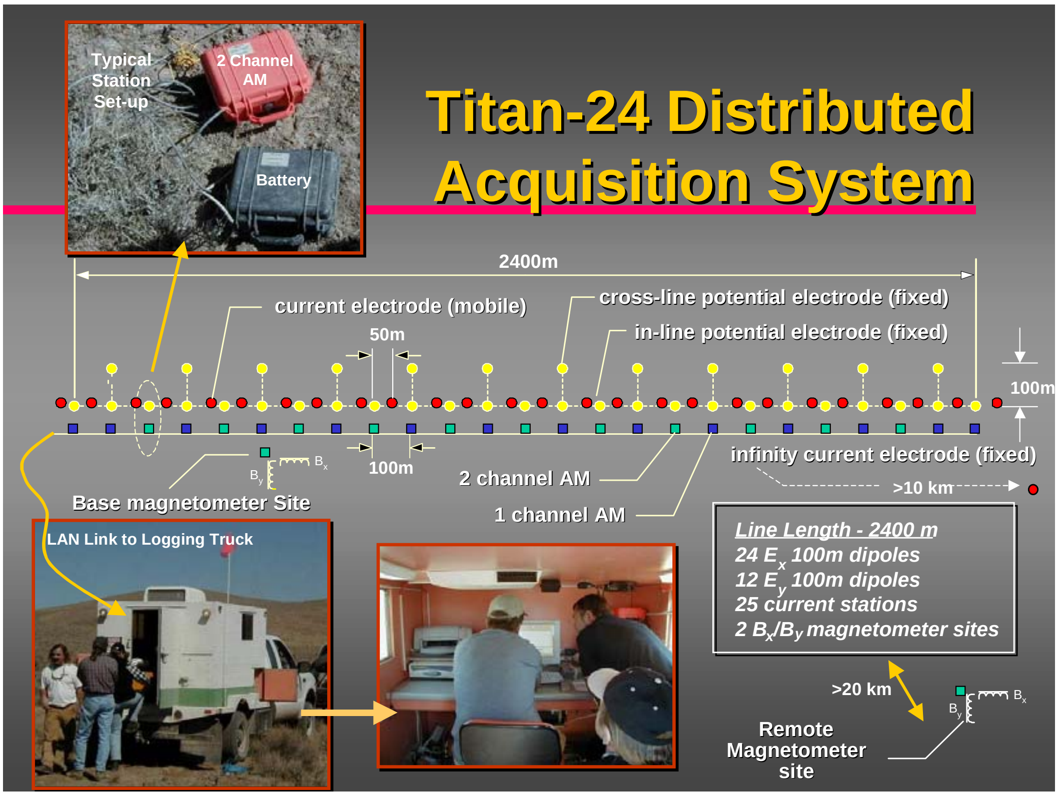

Figure 1: DAS elements and typical survey layout for multi-parameter DC resistivity, IP and MT measurements.

Figure 2: DAS survey collecting DCIP and MT data in active open pit mine. Receiver nodes shown with 50 m spacing in this application mapping side walls in kimberlite. Photo taken in Venetia Diamond Mine, South Africa.

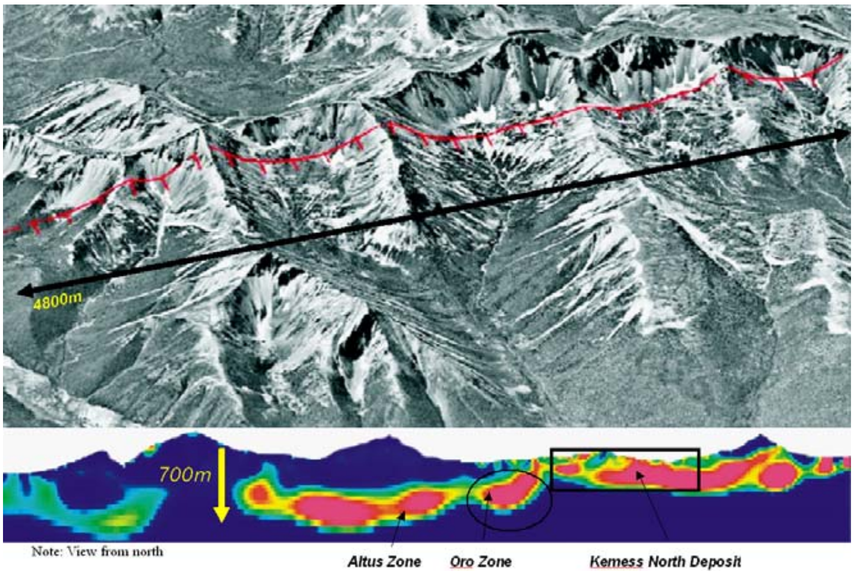

Figure 3: Kemess North survey results showing initial survey path over mountains (top) and inverted IP section showing two new mineralized zones at depths of up to 700 m. Drilling over the new zones intersected the highest copper and gold grades in the camp to date.

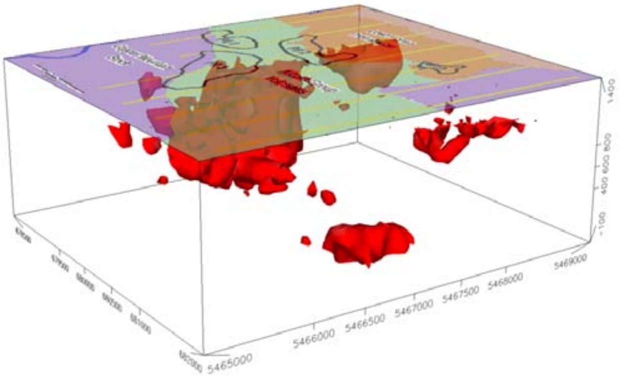

Figure 4: 3D image showing 40 millirad IP chargeability surfaces, i.e. areas with abundant disseminated sulphide. Titan 24 results show a significant portion of the deposit is still available for mining at depth; the subsequent development of a super pit is now in progress.

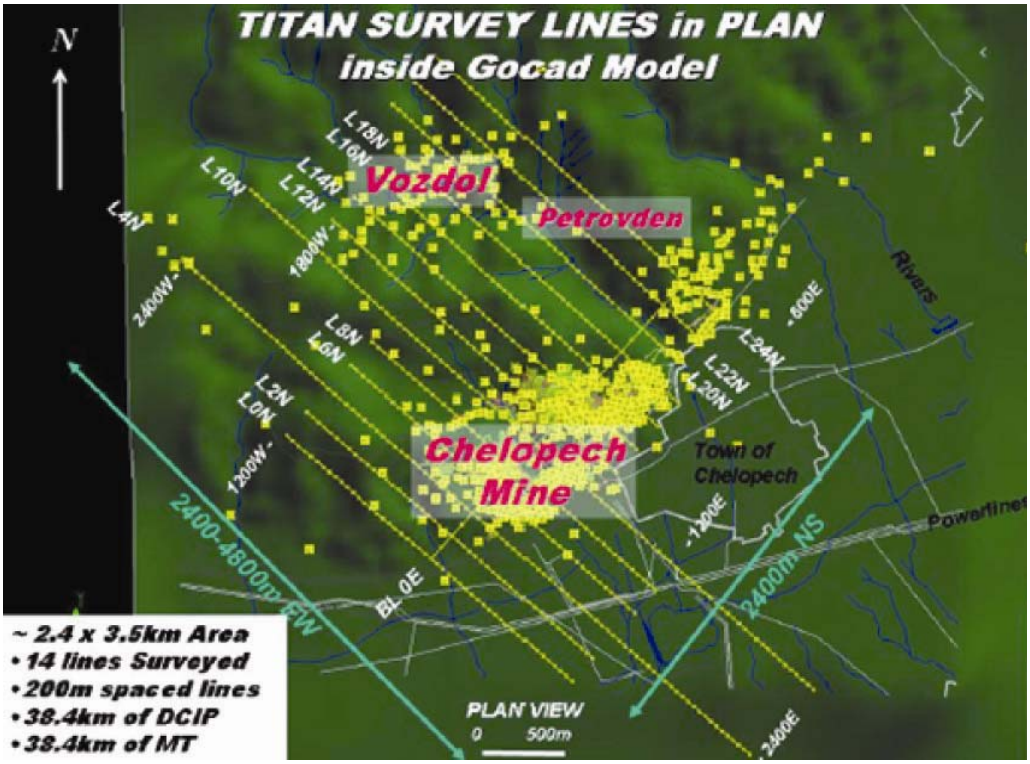

Figure 5: Plan view of the Chelopech Mine with DAS survey lines. The main orebody was characterized and applied on adjacent lines to discover new, potentially economic, targets both at surface and at depth.