Deep Imaging Technologies Applied to Mine Planning and Exploration Applications for Risk Mitigation at The Mine Site

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1. Abstract

The last 20 has seen vast improvements in geophysical technology thanks in part to advances in computing speed. Several systems have evolved to rapidly collect very deep and accurate information about the subsurface. Collecting deep information at the mine planning stage can provide key insights about the subsurface that can contribute to more effective mine plans. By collecting data and creating comprehensive 3D earth models of the subsurface, where often little information is available, is key to helping reduce associated long term risks to mine operations' systems can rapidly produce images to depths of from surface to 2000 metres by measuring vast amount Resistivity and IP data. This data is often directly related to critical features of the subsurface such as the location of clay layers, faults, shears and water. In addition, large scale images can be used to assist condemnation drilling, map geology and other structural information which may impact the overall plan. Large scale imaging may also provide insights for near mine exploration, these data sets can then be used for life of mine exploration activities, which inevitably occur. In some case the discovery of additional sub deposits at this time, can help avoid disastrous situations such as locating tailings ponds and other infrastructure directly over additional deposits which may exist proximal to the original discovery.

Keywords
Reduce Risk, Brownfield, Mine Site, Condemnation drilling, Exploration, Magnetotelluric, Geophysics.

2. Introduction

In 1994, John Kingman introduced the concept of digital signal processing and this lead to a paradigm shift in instrumentation development. Since that time, things have evolved to a point where, detailed and deep imaging has begun to be routinely used in exploration. A distributed network of sensors collects full waveform data and advanced processing enables the ability to pick up small signals that can represent real structure and targets within the realm of large ambient noise, that typically exists in and around the mine Deep accurate resistivity and chargeability images are provided to roughly 750m.

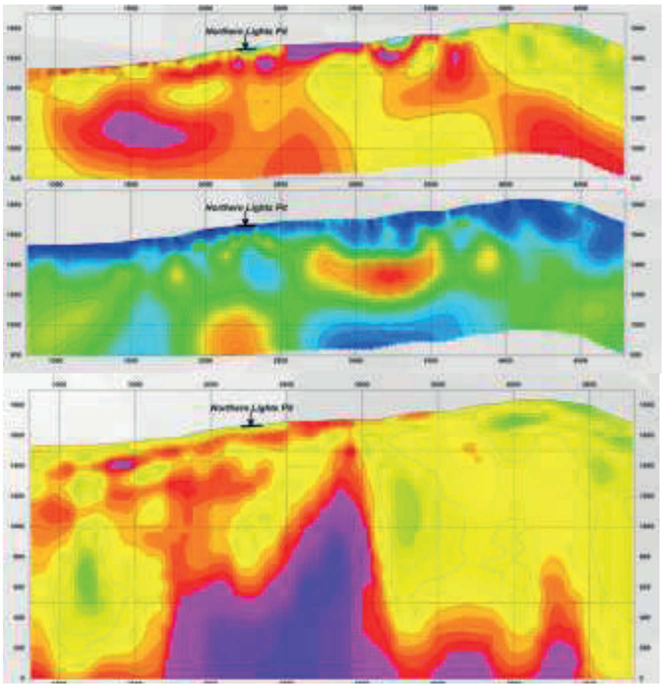

Figure 1 (top) DC resistivity section from 2D TITAN24 distributed array survey. (middle) IP (chargeability) section I. Note how the DC model sees a near surface horizontal layer, senses a second deeper feature and senses something at the bottom of the section. (Bottom) The MT resistivity section corroborates the DC in the near surface but provides additional deeper imaging. Data courtesy Newmont, Nevada USA.

In addition to the deep IP surveys, the applied use of the MT technology, which was routinely used in regional very deep search academic studies (25km deep), for very detailed deep (2000m) surveys was added to deep penetrating IP surveys, thanks to the multi-tasking computers and contributed further to the ability to image more thoroughly and even deeper with greater accuracy. Multi-parameter 2D images are provided for analysis. (Figure 1.) More recently, full 3D surveys have provided even greater imaging capability in geologically complex environments.

3. Deep 2D imaging success Brownfield and Mine sites environment

In 2000, the first commercial surveys were carried out in greenfield environments. It was quickly realized that these surveys could be useful for exploration activities near older mines where new orebodies might extend the life of mine. The use of these deep 2D surveys was particularly useful in near mine environments where noise rejection allowed acquisition of data in areas never possible before (Figure 2).

Figure 2. Deployment of deep imaging receivers in minesite.

Copper Mountain Mine, Canada

In one very significant application a survey was run over several end of life mining pits. Figure 3. The results of the survey were spectacular. Figure 4 The survey highlighted several unique applications of the technology most significantly was the discovery of new ore below the pit which contributed to the extension of mine life. In addition, plans for extensive Acid Base drilling could be adjusted based on the correlation of geology and the images. This contributed to less drilling in an area planned for tailings,

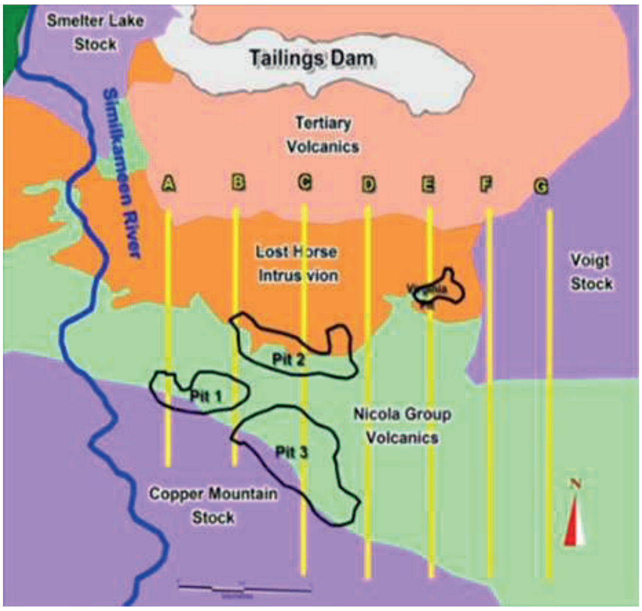

Figure 3. Copper Mountain Open pits and survey layout.

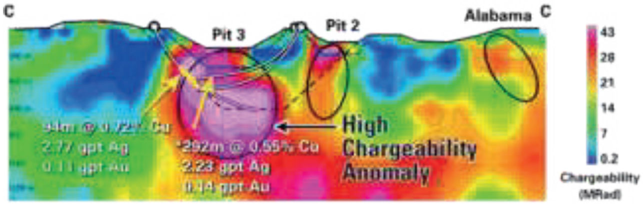

Figure 4 Results from Line C. 2D chargeability section. The section is 750 meters deep and highlights new discoveries directly below existing open pits. Data courtesy Copper Mountain Mining, Canada.

In another near mine application, the images highlighted the importance and the potential cost savings, had the technology been applied at an early stage of mine planning and development.

Kidd Creek Mine, Canada

The multi-parameter system deployed over an area of 5 km by 1 km only 500m from the pit at the top of the mine. (Figure 5.).

The blind test survey was successful at identifying 100 % of the known targets previously drilled within the top 800 metres. A significant region where the survey indicated little further investigation would be warranted (Figure 6) was confirmed by hundreds of barren drill holes that had been previously drilled over 15 years at an estimated cost of over 15 million dollars (Figure 7).

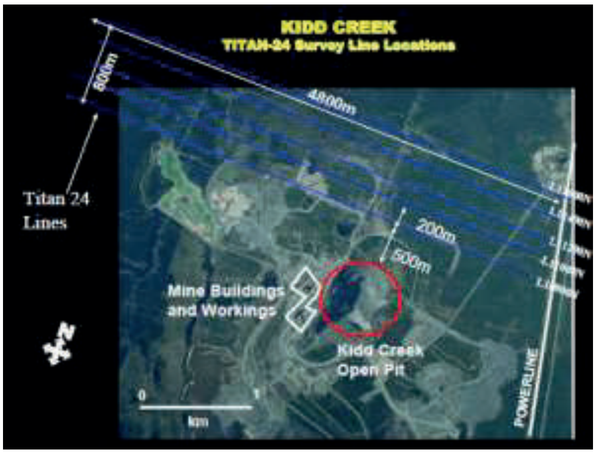

Figure 5. Survey lines near mine and power lines

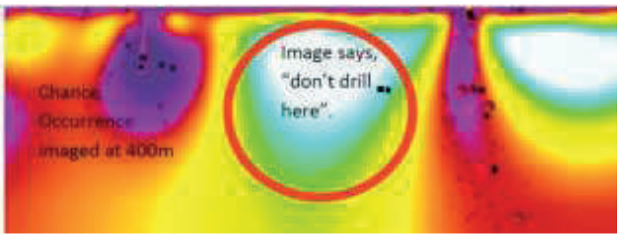

Figure 6 Resistivity section, shown to > 700m depth. Blue/ white regions represent resistive rock, warm colors represent increased conductivity

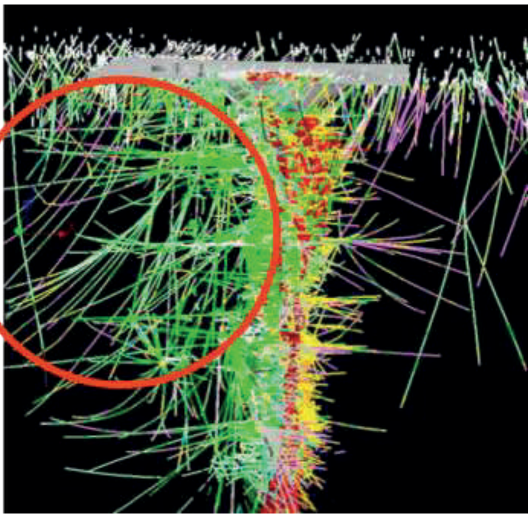

Figure 7. 3D model showing ore body and 15 years of underground exploratory drilling.

4. 3D systems

Following the lead of the oil industry, 3D technology was developed to address limitations in 2D data acquisition techniques. With the advances in 3D data inversion techniques in the early 2000's for single point data collection techniques such as Mag, Gravity and MT, the natural progression was to develop methodologies for collecting full 3D DCIP data.

The further advancement of computing technology allowed the deployment of more sophisticated computers (receivers) that would allow omni directional energizing of the ground as well as omnidirectional measurements of the responses for DCIP surveys. There are several unique features of these systems including a large footprint of 2 x 2 km and more to optimize DC and IP depth of investigation in the 600 m to 900 m depth range; and a large numbers of in-line and cross-line receiver dipoles that maximizes coupling with any target. (Figure 8)

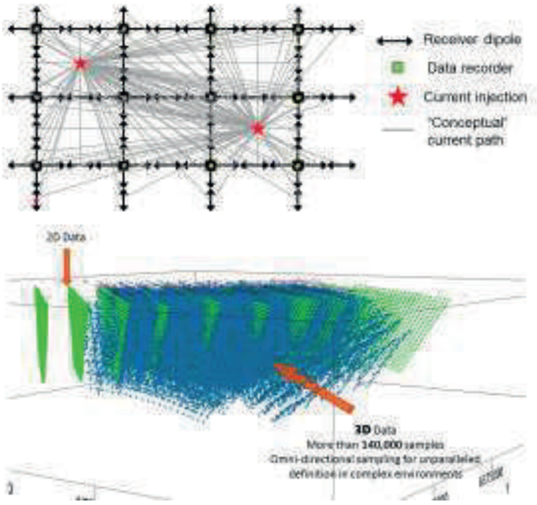

Figure 8 An example of a 3D deployment of receivers with conceptual current paths for just 2 injection points. (bottom) A survey would involve typically over 250 injection points are made on a grid. 3D data plot points are shown in blue and compared to data plot points from a 2D survey shown in green.

For every current injection, all receivers are active. This results in a true omnidirectional coverage for each current injection and gives multiple intersecting current paths over the entire survey with a very large number of data points acquired. The result is greater volumes of data and better coupling with complicated 3D geology and structure which enhances resolution and target detection at both shallow and deep depths. The omnidirectional coverage provides a better 3D inversion result because there is no acquisition directional bias and each cell in the inversion volume is sensitive to multiple omnidirectional current paths.

The increase in data volume coupled with the omnidirectional sampling provides the basis for highly data constrained 3D models. In Figure 9 we see significantly more detail extracted from the full "3D" survey.

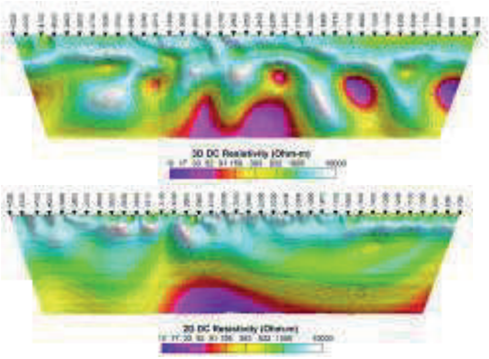

Figure 9 Deep resistivity sections. Depth of the section is roughly 800 meters. (Top) 2D section sliced from a 3D inversion model of 3D data. (Bottom) 2D resistivity section from 2D inversion of single line of receivers. (2D data)

5. Deep imaging at the Yauricocha Mine, Peru

The Yauricocha Mine is in the Alis district, Yauyos province, department of Lima approximately 12 km west of the Continental Divide and 60 km south of the Pachacayo railway station. Until very recently mineralization at the Yauricocha Mine has been represented by variably oxidized portions of a multiple-phase polymetallic system with at least two stages of mineralization, demonstrated by sulfide veins cutting brecciated polymetallic sulfide mineralized bodies.

A deep minesite survey was designed with 23 lines, spaced 200m of length 2.4 km. Sierra Metals confirmed the discovery of a new style of mineralization based on testing of the deep geophysical anomalies, in the quartz monzonite intrusive. Discovery drilling of a new style of mineralization (porphyry) at over 1,300 m was based on deep electrical earth imaging provided by MT data. (Figure 10).

Conclusions

With the great advances in computing power, coupled by the ability to measure small signals in a background of noise, technology is available to address significant mine planning and life of mine issues. Deployment of these technologies at an early stage immediately after discovery at pre- or feasibility stage, can help provide risk mitigation and enhance future exploration initiatives at the mine. Improved condemnation planning, enhanced targeting and ultimately more efficient use of drilling budgets while working around the mine can be achieved. Examples clearly demonstrate effective investigations for mine planning, exploration discovery and extended life of mine in several cases.

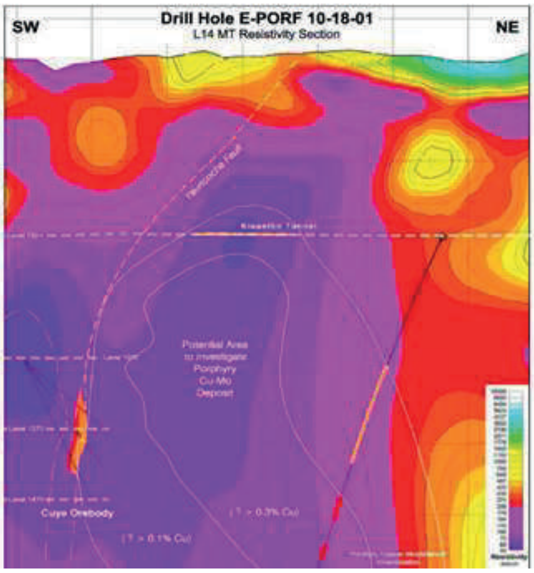

Figure 10. Deep MT resistivity with intersection at 1394 m.

Thanks

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