Practical uses for forward model studies with respect to deep terrain investigations – a case study of use and discovery at Kemess in Northern BC

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Summary

Exploration near the Kemess mine in Northern BC, Canada presented several challenges including finding additional deposits at depth and rugged terrain (Figure 1), with the potential reward being an expansion of the existing mine and improved economics. Drill testing in 2006 had returned encouraging results, but drilling was unsuccessful in outlining the prospective mineralization. To assist the exploration, a TITAN distributed DCIP & MT survey was proposed.

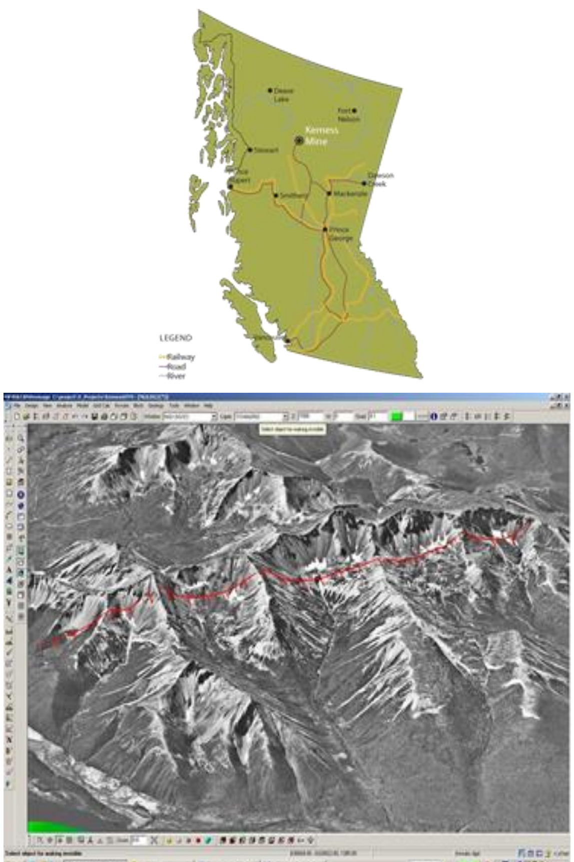


Figure 1 Kemess mine location and proposed deep DCIP & MT line highlighting difficult terrain.

The distributed DCIP & MT technology proposed was first introduced by MIM mining in Australia in 1999 and subsequently evolved and commercially introduced to the industry as TITAN in 2000. The ability to see significantly deeper with DCIP technology meant the industry could now test deeper terrains with multiparameter investigations. However, the industry did not immediately accept the technology. Many companies demanded previous success with the technology or proven ability to "work" in various environments.

The question at Kemess was, would this new technology provide answers about the geology at depth? Would the cost be worth it? In order to reduce the risk, forward modelling of the survey response to the host rock environment and potential deposits in the deep terrain was recommended, and carried out. A TITAN survey was designed and simulated prior to an actual survey. A geological model was developed with several zones of potential mineralization to test the system's DCIP sensitivity to detect mineralization at a variety of depths ranging from 300 to 600m below the surface.

This paper describes the application of the forward model studies at Kemess and the subsequent distributed technology survey, results and ultimate new discovery at depths greater than 600 metres.

Introduction

Distributed array based technology was introduced as a means to provide deeper DCIP information than was technically possible at the time. DCIP traditionally relied on a receiver which could measure a specific number of dipole measurements on one side of the receiver. After measurements were made, the receiver and dipoles would be moved, thus providing some data redundancy and verification. The depth of the survey was limited to the maximum length of array that was deployed at a time. (Figure 2, Top). Typically, dipoles would be measured across 25-50 metres and the receivers were capable of 6 to 12 channels, so the array length would be limited to 125 m – 300 m. A simple rule of thumb for IP was that the survey depth of penetration would be limited to roughly 1/3 the length of the array. In order to get deeper, the dipole size might be increased, however to do this meant the use of very long wires which ultimately could contribute to loss of signal or coupling within the wires, ultimately leading to incorrect and spurious readings.

With the advancement of computing technology, it became possible to deploy multiple receivers along a networked line, with each receiver being responsible for measuring a dipole and digitizing the data, which was then transmitted through the network to a computer in a doghouse. In doing so, the issues of signal strength and current coupling were avoided, and most importantly the length of the array could be extended to great lengths with the addition of many receivers

(Figure 2 bottom) which resulted in significantly greater depths of investigation.

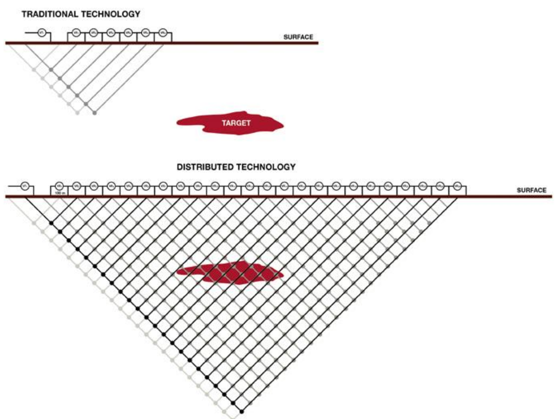


Figure 2. Top: Traditional DCIP data collection using 1 receiver to measure dipoles. Bottom: Distributed array DCIP data collection.

As a bonus, with the addition of some cross wires and magnetic coils, an array of many MT sites could be constructed effectively at the same time. In practice the DCIP survey would be collected in the daytime and MT could be collected at night.

MT measures the natural electric and magnetic (EM) fields at the surface of the earth. Sources of these EM fields are initiated by solar winds and lightning strikes. Systems typically measure in a very broad frequency range (10,000 Hz down to <.0001 Hz). By simultaneously measuring the magnetic and electric fields across a wide range of frequencies, we were now able to provide resistivity of the subsurface to great depths, nominally from a few tens of metres to a few hundred kilometres.

In order to convince the Kemess exploration team that the technology was a valid approach, a forward model study was proposed.

Case Study – Forward Model studies at Kemess

In order to carry out forward model studies, an approximation of the geological scenario needs to be created with the application of physical rock property parameters that are characteristic of the local geology. At Kemess, a geological model was constructed based on current drilling knowledge, coupled with regional mapping and some hypothetical conjecture (Figure 3).

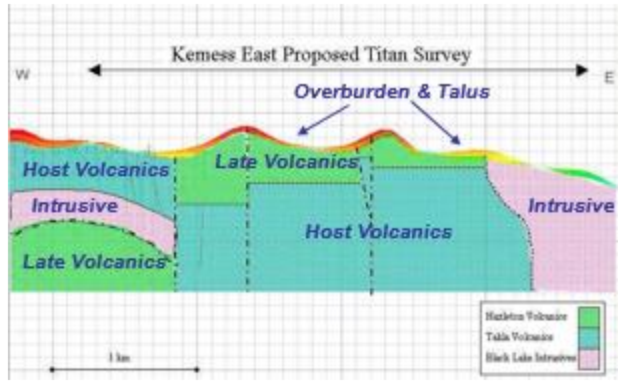


Figure 4 Simplified geological model of the Kemess area.

Physical rock properties are the numerical characterizations of rocks based on common properties. These include parameters such as density, magnetics, chargeability and resistivity. To populate the model, measurements can be made of the rocks and geology of the given property or area of interest. Measurements can be made on core, hand samples, and outcrops, and the tools to make these measurements vary, but many are handheld devices. Detailed measurements can also be made down the hole utilizing borehole probes. For the purpose of the study at Kemess and the application of the TITAN distributed technology modeling, the focus of the physical rock measurements was on chargeability and resistivity, and in this case estimates of the parameters were made from a preexisting historical DCIP survey that had covered the various rock types in the area. A chart of the resistivity responses of various rock types is provided in Figure 4.

Unit	***Resistivity****	***Chargeability****
1. Hazelton volcanics (host)	*1 000 ohm-m*	*7 milliradians*
2. Takla volcanics (late)	*300 ohm-m*	*10 milliradians*
3. Black Lake Intrusive (late)	*5000 ohm-m*	*1 milliradian*
4. Overburden	*200 ohm-m*	*0.5 milliradians*

Figure 5 Typical physical rock properties of the Kemess host geology.

Note that the physical properties of rocks are determined by a combination of the chemical and physical attributes of the rock, which obviously can vary considerably with very few rocks being of one consistency geochemically. Therefore the physical properties are generally defined across a range for any given rock type. Figure 5 shows a general chart for resistivities of various rocks.

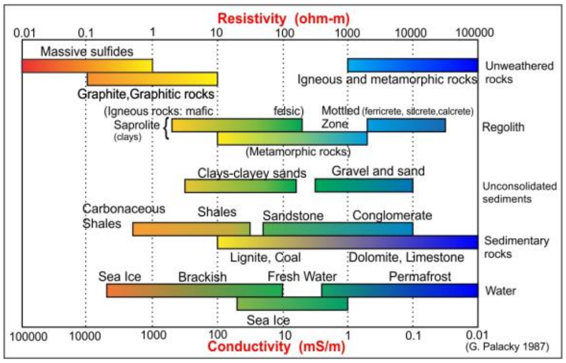


Figure 6 Resistivity physical properties for various general rock types. Adapted from George Palacky.

At this point the model can be described by numbers. A forward model study involves calculating data responses of the hypothetical application of a given survey over the defined model, and then inverting the simulated data. The inverted data is then evaluated by comparing it with the initial model; the closer they are the better. In this way surveys can be tested for geometry of the layout, depth of penetration and resolution (Figure 7).

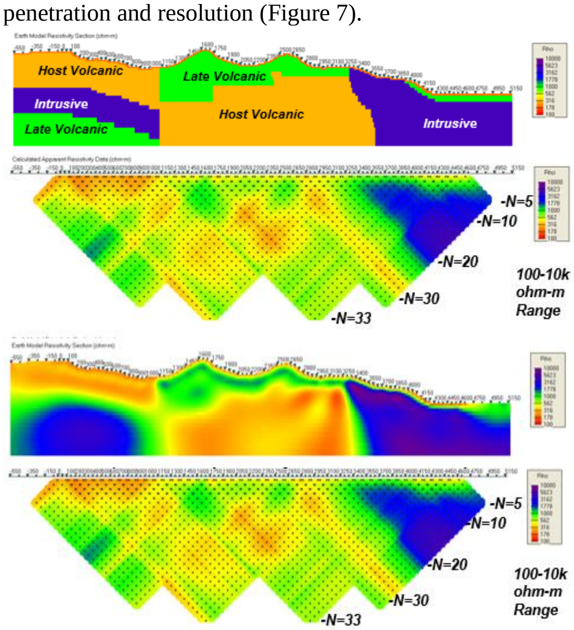
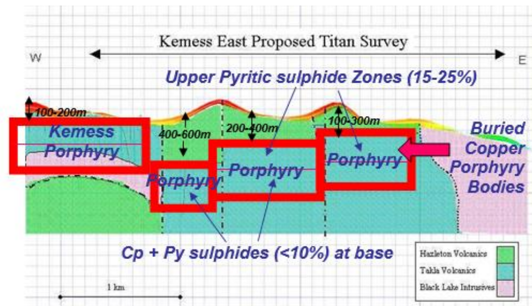


Figure 8 Top: Geologic model represented by resistivities. 2nd from top: Calculated 2D DC resistivity forward model from geologic model (TITAN pole-dipole array with A=100/ N= .5 to 32.5 and TITAN deployed as 2 overlapping spreads.) 3rd from top: Inversion model. Bottom: Calculated response from inversion model.

As a second step, the potential target material and size can be added to the generic geological model. i.e. a hypothetical but realistic deposit can be inserted into the model and subsequently we can calculate the theoretical chargeability and resistivity responses. Figure 7 shows the geological model with some potential ore zones and the physical properties for the various rock types used to populate the model. The red box represents zones of disseminated sulfide with up to 15-20% pyrite in the upper half of each block and 2-3% chalcopyrite and 5% pyrite in the lower portions of each block. The green lithology above the red boxes in the eastern portion are post mineral volcanics with spotty disseminated sulfide up to 2%, though less than 1% overall (Figure 8).



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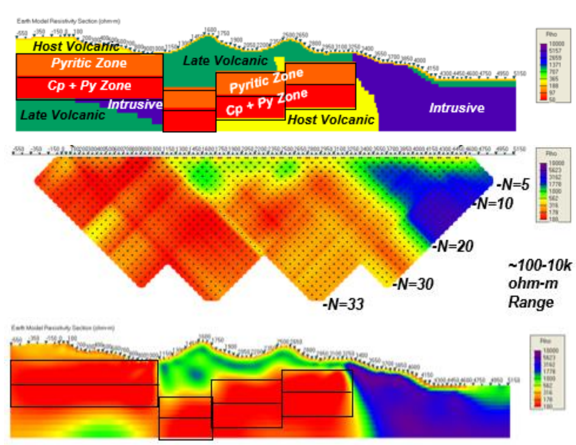
4. Overburden	200 ohm-m	0.5 milliradians
5. Pyrite Cap	100 ohm-m	50 milliradians
6. Cu-Py Ore	50 ohm-m	30 milliradians

Figure 7 Top: Geological model with copper porphyry bodies inserted in hypothetical locations. Bottom: Physical rock properties used in the exercise.



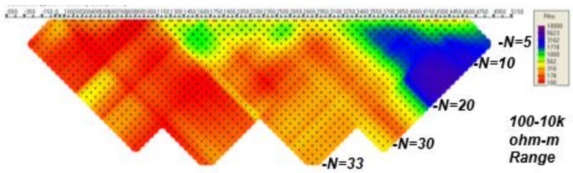


Figure 8 Top: Resistivity model including the orebodies. 2nd from top: Forward model response of the resistivity model using TITAN pole-dipole array with A=100/ N= .5 to 32.5 and TITAN deployed as 2 overlapping spreads. 3rd from top: Inversion model. Bottom: Calculated response from inversion model.

The process was repeated for the chargeability parameter and the results of the modeling process for the "fertile" chargeability model are shown in Figure 9.

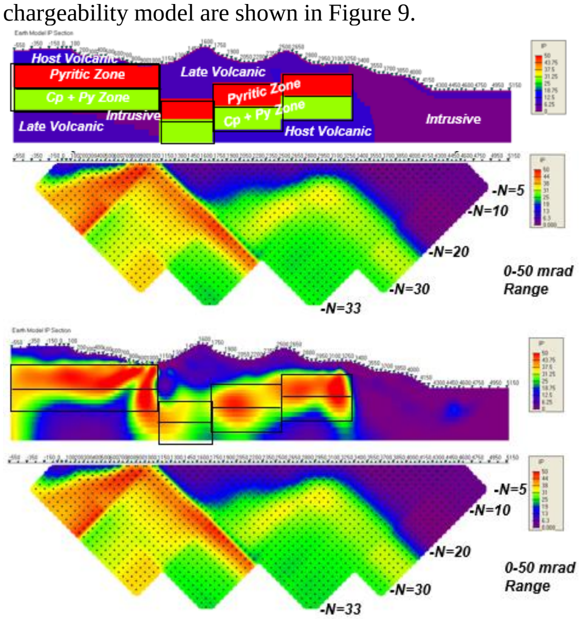


Figure 9 Top: Chargeability model including the orebodies. 2nd from top: Forward model of the chargeability model using TITAN pole - dipole array with A=100/ N= .5 to 32.5 and TITAN deployed as 2 overlapping spreads. 3rd from top: Inversion model. Bottom: Calculated response from inversion model.

The results from the forward model and resultant inversion indicated several key items for the exploration team;

- TITAN DCIP & MT surveys should be able to penetrate and resolve porphyry bodies below 300-600m of Takla volcanic cover.
- TITAN results should be able to image top and possibly bottom of porphyry mineralization, but may not be able to discriminate between pyrite-only and Cp+Py phase in ore zones at depth.
- Chargeability parameter may provide better detectability and resolution due to stronger contrasts, versus resistivity. DC resistivity image will nevertheless assist in mapping alteration and structure.
- The modelling study helped provide design criteria for the actual field survey. The proposed 2D TITAN survey would require 2 separate 2.4 km receiver spreads, with 200m overlap, and 0.6-1 km current extensions – total length 4.2km with a=100m, n=0.5-33.5 separations.
- TITAN MT will provide additional support and improved resolution. 2D TITAN DCIP survey imaging will possibly improve using 3D inversion tools (better image along NS strike), provided 3 or more lines are surveyed (300-400m line spacing).

Case Study – Application of deep penetrating TITAN DCIP & MT survey at Kemess

At Kemess, following these studies an actual survey was commissioned.by Northgate exploration.

Figure 10 TITAN receiver deployment at Kemess.

The TITAN survey outlined several previously unknown exploration targets which are shown in Figure 11.

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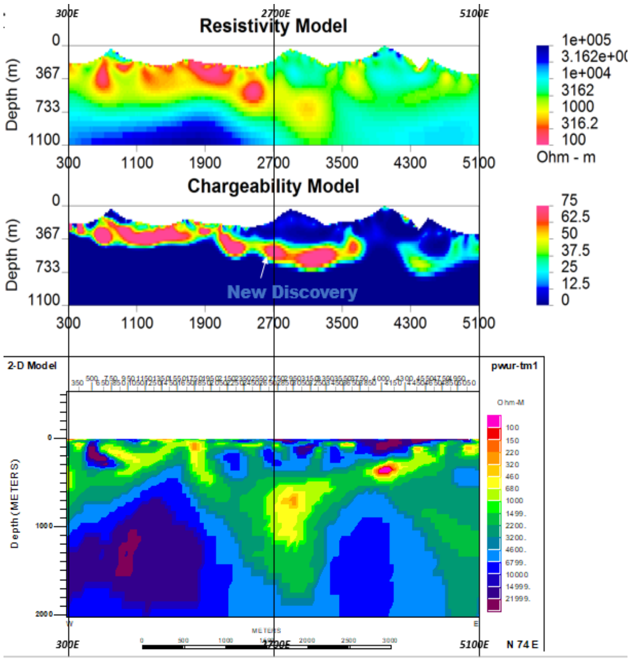

Figure 11 Top: Resistivity inversion model of collected data from TITAN survey. Middle: Chargeability inversion model. Bottom: MT resistivity inversion model.

Plans were made to drill several holes to test these targets east of the Kemess North during late 2006. Subsequently, it was announced that a third large system was discovered at Kemess. At the time TITAN was credited as an excellent predictive tool. From a press release at the time: "The Ora Zone discovery - Holes KH-07-02 and KH-07-04 were drilled to test the deep chargeability anomaly that was defined in Figure 11. Hole KH-07-04 intersected the longest mineralized interval ever drilled on the Kemess property with 441.3 m of 0.38 g/t gold and 0.391% copper. This hole also represented the deepest mineralization (850 m deep) so far discovered in the Kemess camp, highlighting impressive grade and thickness." The MT was important because it mapped the ORA zone to depth where Cu mineralization was found at a depth of 700m. The MT also hi-lighted the root of the system showing the potential deep structure associated with mineral emplacement typical of porphyries. The results and this new discovery suggested that the Kemess North mineralizing system was far more extensive than previously understood.

The best drill result was from below the Kemess Offset Zone shown in figure 12. KH-15-06A which intersected 817.5m grading 0.273g/t Au, 0.216% Cu, 1.43 g/t Ag and 0.006% Mo from 459.0m depth. This interval included 81.5m grading 0.437 g/t Au, 0.292% Cu, 1.44 g/t Ag and 0.010% Mo.

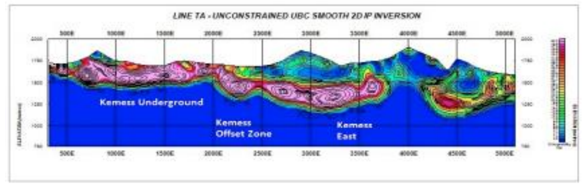

Figure 12 TITAN IP Inversion model with deposit locations for Kemess, Kemess offset zone and the Kemess East deposit.

Conclusions

Deep imaging surveys have practical applications for mapping structure, alteration, and mineralization. Incorporating forward model studies into exploration processes has practical uses for survey design and implementation purposes. In addition, the measurement of physical rock parameters both before surveying and after drilling can provide great insights and assist with interpretation processes. The use of constrained inversions, where following drilling, the actual physical properties in the drill hole are applied back to the inversion process of the collected data, can also in some cases provide an iterative means to improve drill targeting.

Acknowledgements

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