

IPEX: A lower-cost superior reconnaissance RES/IP/MT survey

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SUMMARY

This paper presents a technique derived from the full MIMDAS RES/IP/MT survey called IPEX. It offers a more cost-effective, enhanced reconnaissance IP investigation in areas of post-mineral cover, ensuring that a minimum-sized predefined chargeable body would not be missed.

The MIMDAS system is ideal for its capability to measure very low signals, due to the enhanced telluric correction, especially in caliche-covered areas. A total of four lines were surveyed with IPEX, and substantial anomalies were found, where some in-fill/detailing has been executed.

IPEX takes approximately 1/2 to 2/3 of the normal MIMDAS survey time, making it a lower-cost superior reconnaissance RES/IP/MT survey tool.

Key words: MIMDAS, IPEX, porphyry exploration, caliche, reconnaissance RES/IP, MT.

conceptual prospective areas. More and more of these post-mineral covered areas are coming in the pipeline, as the “easier” gossan-type discoveries are fading away.

A faster and less expensive method, derived from the MIMDAS technology, called IPEX, was designed by Geophysical Resources and Services (GRS) after some collaborative brainstorming work. The MIMDAS system is key for its effectiveness in surveying through caliche, due to its superior standard of telluric noise cancellation. The MIMDAS system, methodology and processing is well known by now, and described in Webb (2003).

The first IPEX survey was carried out at First Quantum Minerals’ (FQM) Project X, located in northern Chile (Atacama Desert). The general location is shown in Figure 1, while the regional geology is shown in Figure 2. One can appreciate the large amount of post-mineral cover from Figure 2 (beige/off-white areas).

INTRODUCTION

Prospects in outcropping areas are much less common in Chile now that these areas have been thoroughly explored. In fact, there are many prospective areas under post-mineral cover, but difficult to assess with the usual geological field observation. There is a new challenge in exploring these covered areas, to turn them over quickly and cost-efficiently.



Figure 1. Project X location in northern Chile.

The geoscience community usually looks to geophysicists when it comes to investigating covered areas, but it is sometimes difficult to justify spending a large budget on

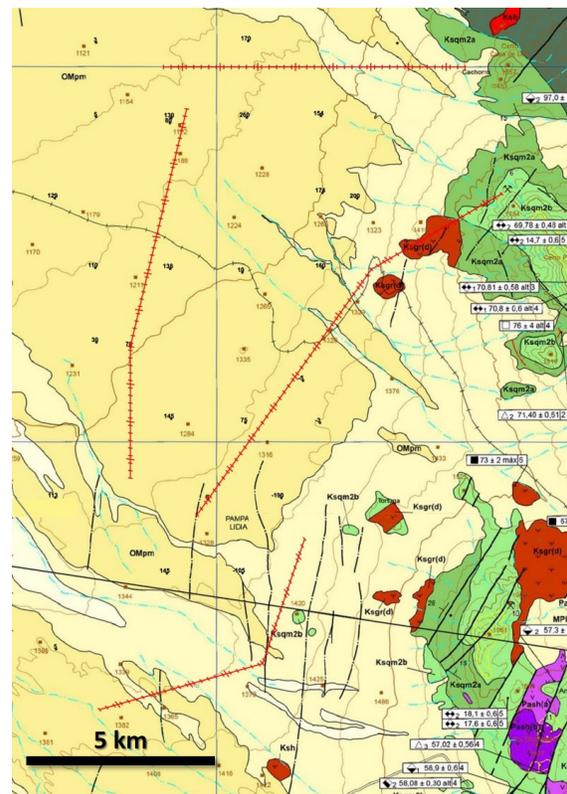


Figure 2. IPEX survey lines in red over geological map of Project X. A large portion of the area is covered by gravels (beige/off-white areas).

The IPEX survey was executed in a total of 29 days, measuring 38 km divided in four original survey lines, after which an additional 6.8 km was surveyed as a follow-up line.

The IPEX method consists in removing most of the transmitter (Tx) sites from the normal MIMDAS array, while maintaining all receiver (Rx) sites collecting the RES/IP and MT data. This has an immediate advantage on the costs, as time for surveying is directly dependent on the number of Tx sites to be prepared.

Some a priori simulation work was done to verify how many Tx sites could be removed while still allowing the detection of a pre-determined minimum size chargeable system. Vetted chargeability anomalies would be tested with a low-cost reconnaissance drilling campaign to assess the existence of a hydrothermal alteration system.

An additional experiment used offset-line Tx electrodes to help vector to the centre of the anomaly, in the case of a source off the survey line. The results obtained by this offset-Tx are independent of the conclusions reached for this IPEX method.

Three out of four lines did not show any substantial anomaly, however two anomalies were detected on the remaining line. Follow-up was done immediately, either by adding additional Tx locations, or adding a cross-line intersecting the anomaly.

METHOD AND RESULTS

MIMDAS technology was the first geoelectric system to be built and developed in a distributed acquisition framework. This particular design confers a unique flexibility, which translates to a variety of methods that can be surveyed in 2D lines or real 3D arrays. MIMDAS was also the first system capable of quantitatively calculating and removing telluric noise in real time. In-house digital signal processing custom algorithms make MIMDAS a superior technology capable of reading IP responses in the microvolt range (GRS, 2019).

Collaborative brainstorming work between GRS and FQM led to a simulation exercise using existing data from a previously surveyed line in the FQM's Caldera project. The simulation consisted in removing most of the Tx sites from the dataset, leaving only two, evenly distributed along the 6.6 km line. The IP data was then re-inverted using the limited number of Tx's (Figure 3d), while using the complete resistivity section obtained by the MT survey (Figure 3c) as the DC reference for the chargeability (IP) inversion. Thereafter, the same exercise was done using more evenly distributed Tx sites (i.e. 4, 6, 8, etc.), until the desired inverted IP results were considered "acceptable".

The definition of "acceptable" is relative and subjective. In the present case, a +/- 1 km diameter was used as the minimum chargeable size (economically speaking) that should not be missed, which could correspond to the pyrite halo of a hydrothermal alteration system. From the analysis of Figure 3, the inverted IP section using 4 Tx's (Figure 3e) may look adequate, but breaks appear between chargeable features and results look highly dependent on the specific Tx locations when comparing with results obtained from data including all 33 Tx's (Figure 3g). As a precaution, 6 Tx's were selected (Figure 3f) yielding a Tx site every kilometre.

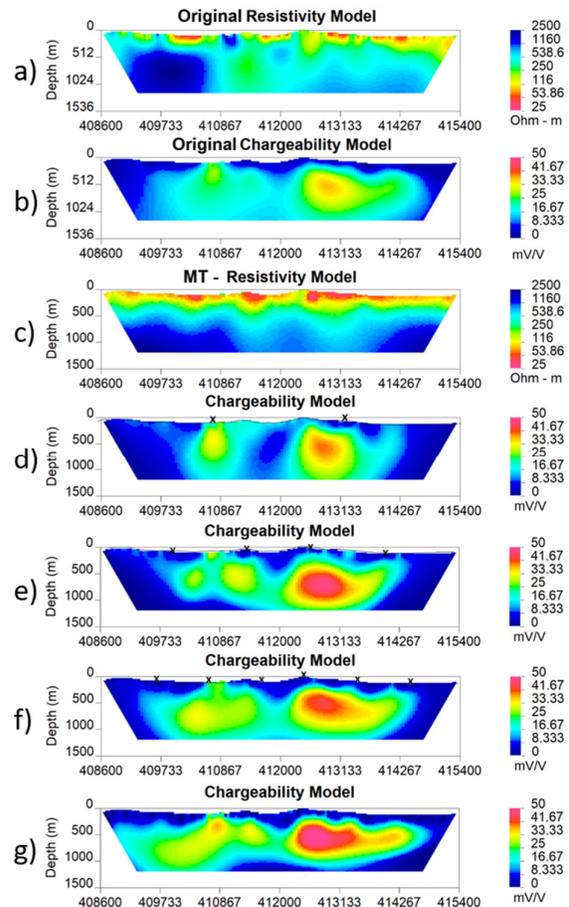


Figure 3. Simulation work done on a previous MIMDAS survey line from Caldera project. Figures 3 "A" and "B" are the original (galvanic) RES and IP models obtained for this line, while "C" shows the inverted RES model for the MT-collected data. "A" and "C" are sufficiently similar for the purpose of a DC reference model when performing the IP inversion. "D", "E" and "F" show the resulting inverted IP models using respectively two, four and six Tx sites, all using the MT resistivity model as the DC reference (Tx locations marked with an "X" at the top of inverted models). "G" shows the resulting inverted IP model using all original 33 Tx sites.

If the substitution of MT for galvanic resistivity worked perfectly, there should be no difference in the chargeability distributions between Figures 3B and 3G. The reality is that galvanic and inductive methods will produce similar yet different resistivity models, so the chargeability anomalies do differ in amplitude and geometry. However, the correspondence is adequate and can be considered equivalent given the objective of this method.

For the field trial of this method at Project X, three out of four lines did not show any substantial anomaly, however two anomalies were detected on the same remaining line. The first anomaly detected is shown on Figure 4, where the upper part shows the inverted RES section from MT-collected data, while the lower part shows the inverted IP section for the first portion of that last survey line.

The detection of this anomaly triggered an immediate cross-line follow-up survey to verify if the anomaly could be shallower

and/or extend on either side of the original survey line. Results from this follow-up survey line confirmed that the anomaly seen on the original line is in fact the edge of a larger, shallower, and more chargeable anomaly (Figure 5).

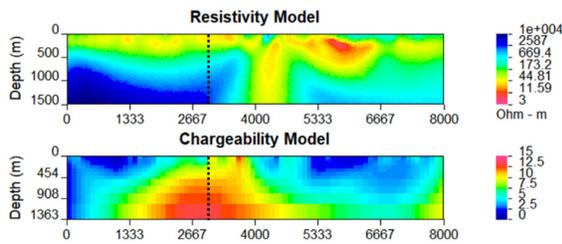


Figure 4. Resistivity inversion from the MT-collected data (top) and corresponding chargeability inversion (bottom) for the first anomaly. The dotted line marks the location of the cross-line follow-up survey.

From the inverted IP model for the original line (Figure 4), the >12mV/V zone is roughly 1000m in size at a depth of 800m, whereas the chargeable area recovered from the follow-up cross line extends for a few kilometres and the main chargeable target (i.e. >20 mV/V) measures approximately 1000 m, and also comes closer to surface (Figure 5).

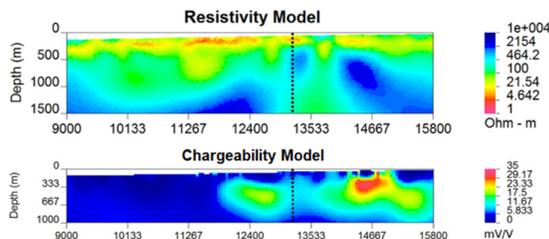


Figure 5. Resistivity inversion from the MT-collected data (top) and corresponding chargeability inversion (bottom) for the follow-up cross-line. The dotted line marks the location of the original survey line. Note the change in the colour scale w.r.t. Figure 4.

During the survey execution, if measurements are showing some chargeability, it is possible to use a constant half-space RES model as the DC reference to perform an inversion in the case that urgent follow-up is required, for a quick estimate of source location and intensity. However, it is much better to use a proper RES model (from galvanic RES or MT) as it will lead to a more accurate chargeability model for source location and intensity.

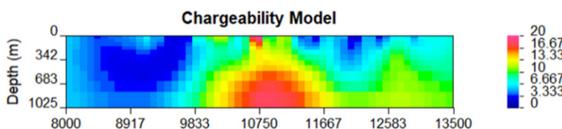


Figure 6. Chargeability inversion for second anomaly.

Figure 6 shows the inverted IP model for the second anomaly detected on the fourth survey line. On this particular part of the line, when higher chargeability values were seen in the measurements, immediate follow-up was achieved by increasing Tx density along the line. More Tx were also added at the end of the survey line as the anomaly wasn't "closed-off", showing the possibility of quickly adapting while the crew is measuring a given survey line.

The time required for RES/IP surveys are directly related to the number of Tx sites that are setup in the survey lines, even more so when there is caliche to break through. Caliche is classified as a sedimentary rock, hardened by natural cement of calcium carbonate, which could become extremely hard to break through, and usually sits at the top of the post-mineral cover. It possesses both very low and very high resistivities, due to the interlayering of salt horizons trapped into layers of hardened cement. Its total thickness ranges from tens of centimetres to few meters.

Reducing the Tx density without compromising the survey objective has proven to be effective for this project. This actual survey was executed in approximately 2/3 of the time that it would have taken with a 200m Tx density (i.e. normal MIMDAS), when comparing execution time with the previous Caldera project. However, the comparison is not entirely fair as there was no caliche at Caldera. After additional analysis and conversation with operators, it is estimated that an additional 7 to 8 days would have been saved on this project 'X' if conditions were the same as Caldera, yielding a 50% reduction in survey time.

Additional Offset Tx

An additional experiment was conducted during the execution of the IPEX survey. All original survey lines had offset electrodes located approximately 1 to 3 km away from the line. Sometimes electrodes were placed in open shallow reverse-circulation (RC) holes; in other places additional Tx sites were prepared at surface. Figure 7 shows an example of a typical offset Tx setup. Note that the time for this additional experiment is not accounted for in the survey statistics in the last section.

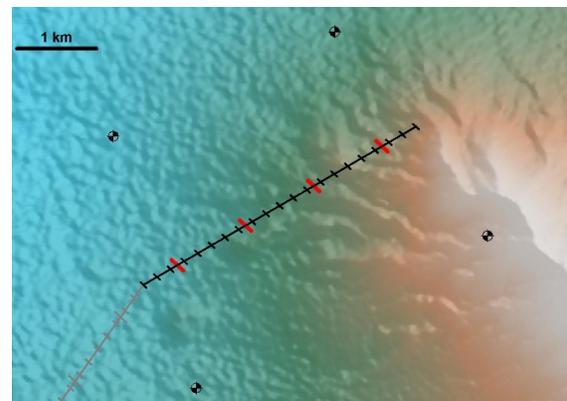


Figure 7. Plan map showing an example of a survey line with 4 offset Tx electrodes shown with crosshair symbols. In-line Tx sites are marked with longer red ticks.

Using offset Tx sites increases the 3D sensitivity, in the case of performing a 3D RES/IP inversion, but it can also be used in a simpler way for vectoring. However, in our case, many RC holes were blocked and Tx electrodes weren't in a "pool" of salted water/mud as the blockage was leaking through the gravels. This resulted in low transmitted current, yielding in very noisy and small measured potentials.

Forward modelling using a 1 km³ 40 mV/V chargeable body buried 300 m under an offset Tx was conducted to try to understand some of the chargeabilities measured on the survey line when current was transmitted on a given offset Tx site.

Generally, the calculated measurements physically closer to the Tx location are in the 10 to 15 mV/V range.

With these results of the forward modelling in mind, a second look was taken at the results of the offset Tx measurement for the same anomaly shown in Figure 4 (first anomaly). When current was transmitted in an offset Tx site located to the southeast of the original survey line, the measured chargeability values on the line were also higher, in the 12 to 20 mV/V range. However, when current was transmitted for other offset Tx sites, chargeabilities were much lower. These observations, along with the results of the cross line follow-up survey (final anomaly to the southeast of the original survey line), indicate the potential benefits of offset Tx's for quick vectoring in case of an off-the-line anomaly.

CONCLUSIONS

IPEX is a new array geometry derived from the proven MIMDAS technology. A reduced number of IP transmitter stations are used in conjunction with full resistivity coverage via MT to produce an equivalent chargeability result. Reducing the number of Tx stations along a survey line should be planned with great care, because it could lead to not detecting a chargeable body. This needs to be defined by the minimum

chargeable body size, which may vary for different exploration/mining companies.

Removing most Tx sites, and leaving one every km allowed us to detect some chargeable bodies of less than one km across. The final geometry and intensity may be slightly different compared to the results of a full MIMDAS survey, but the objective of detection was met successfully and the survey was done much more quickly. This is a promising technique for rapid, efficient and cost-effective RES/IP/MT surveys on prospects under post-mineral cover.

More interpretation work is needed for a better understanding of the additional offset Tx, whether it can be incorporated in a 3D RES/IP inversion, or simply be used for vectoring.

REFERENCES

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