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How real is Real Section IP?

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Introduction

This article was inspired by a news item broadcast on the SEGMIN (SEG Minerals Group) news server in mid 2009, alerting subscribers to a publicity release regarding the Zeus IP system. The system had been a topic of discussion earlier in the forum but a lack of information about it had stymied discussion. The publicity was grandly titled *The Future of Oyu Tolgoi Exploration – Zeus* and included several sections of the kind shown in Figure 1. Geophysicists familiar with CSAMT will have seen a lot of this kind of section and know that they are not an accurate representation of the geology. The thrust of the publicity was that the anomalous zone was real and that the company only had to drill deeper to find more ore. This impression was reinforced by summary figures of the kind shown in Figure 2, suggesting every known deposit was just the tip of a very steep sided iceberg of ore.

About the same time, the promoters of this technique spoke at conferences and in talking about the resolution of Zeus, they made comparisons with not only being able to find a Volkswagen Beetle buried 3 km below the surface but to be able to tell its year of manufacture from the shape of its bumper! While this is obviously colourful exuberance, the effect of the apparently deep looking sections and hyperbole was immediate on many geologists and they wanted to have it – *now!* Geophysicists from all over the world started fielding calls from hopeful clients and staff geologists asking why they weren't using this new technology. The consensus of the SEGMIN forum was that the Zeus sections did not represent geology. Surprisingly, consensus amongst geophysicists is rarely comforting to geologists, who needed simple explanation as to why they should not be spending money or trading equity by doing these surveys. This led to a suite of modelling, with the results presented to SEGMIN as a PDF to enable other geophysicists to field queries from enthusiastic Volkswagen hunting geologists. In order to bring this material to a wider audience it has been edited into this article.

What is Zeus?

It is difficult to get any technical information direct from the promoters. However, the following information has been gleaned from SEGMIN submissions, Ivanhoe presentations at conferences and discussions with Ivanhoe staff. Zeus is an expanding gradient array where the potential electrodes are fixed in a rectangular grid, as with conventional gradient array, but the current electrode expands in a series of steps. In the case of the Zeus system, the current electrodes start at 6.6 km and extend out to an impressive 20 km A–B separation. This is achieved with a containerised 100 kVA transmitter with a maximum voltage tap of 10 kV and a maximum output current of 60 A. The current is delivered into the electrodes using a wire that appears to be around 5 cm diameter. It is an impressive system. Near surface information is acquired with conventional gradient arrays. Expanding gradient arrays are not new. Although they were popular amongst some explorers in the 1970s, their popularity waned through lack of success. More recently the method was 're-discovered' by certain Canadian contractors who

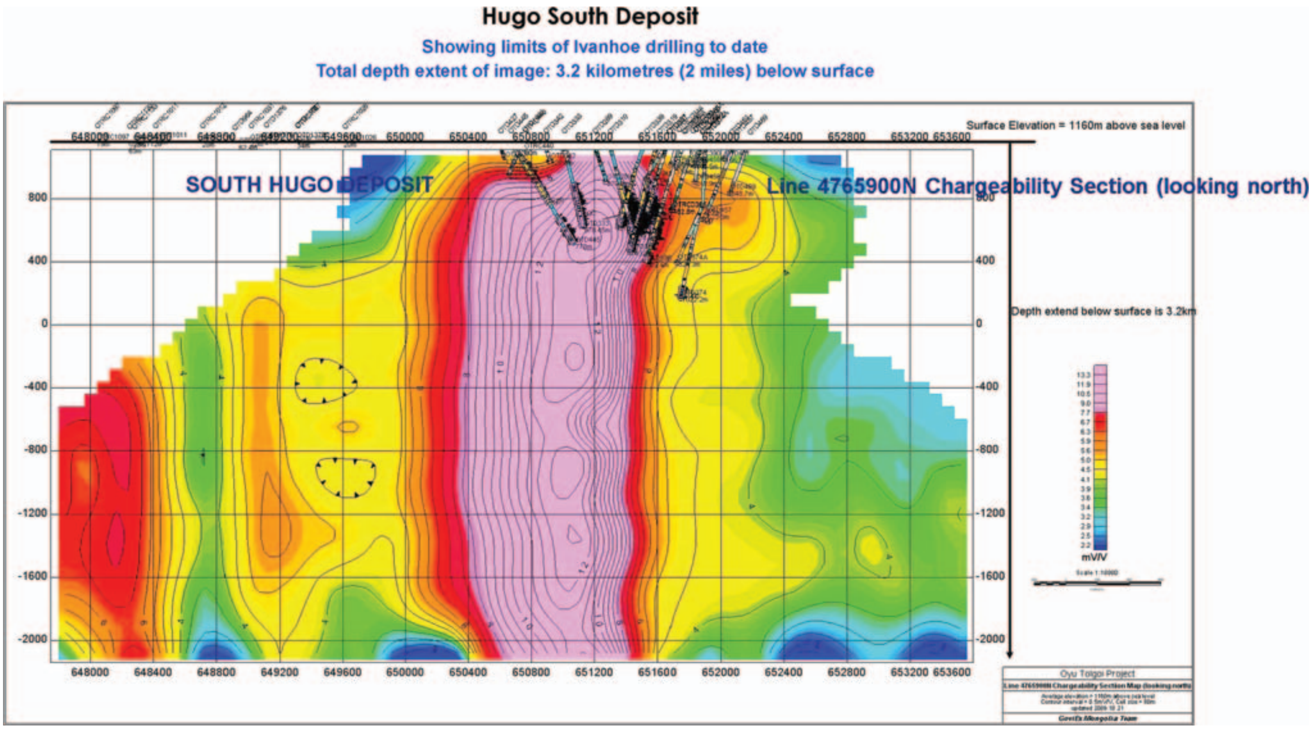

Fig. 1. *Example section from Zeus publicity.*

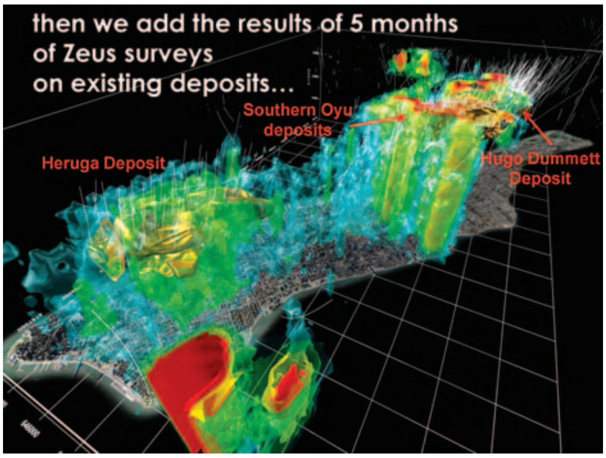

Fig. 2. *Example summary diagram from the Zeus publicity.*

packaged it with a pseudosection plotting method and badged it as Real Section.

What is Real Section?

Real Section is a pseudosection plotting method developed by Perparim Alikay and is described in a paper by Langore et al. (1989). It was originally based on a Schlumberger array but has been generalised more recently to gradient arrays. It assumes the plot depth for the pseudosection is between 0.125 and 0.2 of the current electrode separation A–B. According to the Langore paper, the factor to use in a given area was derived empirically from drill hole control. These values compare well with those given earlier by Edwards (1977) of 0.103 near the edges of the array to 0.192 at the centre. These are the depths at which, for a half space, half the signal comes from above the plot point and half from below. Despite the prevalence of relatively cheap 3D inversion software, the Zeus data is plotted in Real Section form for presentation to geologists rather than as inversions with sensitivity cut offs.

The modelling presented here aims to replicate the presentation format, rather than invert the modelled data. For the shallow targets, at least, inversion is likely to recover a model similar to the upper part of the input data set.

Information collected for the Oyu Tolgoi survey suggests that the gradient array used 100 m potential dipoles (M–N), which were read with a commercial Elrec six channel receiver. From published dipole–dipole inversion sections, the target appears to have a resistance of around 500 Ohm m, with a chargeability of 30 mV/V, in a host of 1000 Ohm m and 10 mV/V. The anomalies on the Real Section plot included in the publicity suggested bodies of about 400 m dimension in plan.

The aims of the modelling were to address four principle questions;

1. What is the effective depth of investigation?
2. How well can it resolve the base of depth limited targets?
3. How sensitive is it to vertical discontinuities in vertical targets?
4. How sensitive is it to changes in dip?

The modelling was undertaken using Geotomo's Res3Dmodx64 (Loke and Barker, 1996). The 64 bit version was required because of the size of the model and the consequent memory requirements. The finite element mesh was regular, with 50 m square cells covering 21 000 m × 2000 m in plan and extending to 6487 m in depth. The mesh had 13 layers, steadily increasing in thickness from 50 m at the surface to 2162 m at the base. A target body 400 m × 400 m in plan was buried at the centre of this mesh and an array of potential electrodes 5000 m × 1800 m with a dipole and line spacing of 100 m was then placed on top of this. Current electrodes were modelled in regular 1200 m steps from 6.6 km out to 21 km separation. All electrodes were contained within the mesh.

The following presentations all follow a common format. They are for a Real Section display along line 1000, over the centre of the body. A depth conversion factor of 0.2 × A–B was used in all cases. All have the same ingredients:

- a colour image of the chargeability, using a non-linear lookup table with each image individually stretched from its minimum to maximum to show fine detail;
- overlain with contours of chargeability, using a 0.5 mV/V contour interval, which is an appropriate interval for the accuracy and resolution of currently available commercial IP receivers and shows what would be recordable as distinct from what is theoretically possible;
- the plot points are shown as crosses and the true location of the body is shown in blue.

All data have been included in the presentation and no attempt has been made to remove readings with primary voltages below the resolution of current receiver systems. No noise has been added i.e. these are best case plots. The upper section of the display is blank because the minimum A–B spacing modelled was 6.6 km, resulting in a minimum pseudo depth of 1320 m. Presumably, published pseudo sections around Oyu Tolgoi use older conventional gradient array data to fill this gap.

Depth of investigation

Figures 3 through to 6 show the results obtained by varying the depth to the top of a vertical prism, which extends to the base of the mesh. It is clear that the target could not be seen at a depth of 2000 m and in the presence of real geological noise it is unlikely it could be seen at 1000 m depth. Although increasing the contrasts between the target and host would improve the depth of investigation, the improvement will not be significant for realistic contrasts.

Ability to resolve the base of depth limited bodies

Figure 7 shows the Real Section plot for a 200 m thick body with a depth to top of 400 m. This is not dissimilar to the previous figure and has a lot in common with the figures in the Zeus publicity. The Real Section presentation does not resolve the base of the target at all.

Sensitivity to vertical discontinuity

Based on the results from the previous test, it should come as no surprise that the presentation is not sensitive to breaks in the body. Figure 8 shows the results for a model with a 600 m break between the upper and lower sections. This is extended to 1400 m in Figure 9, with no significant change in the output results. The presentation does a poor job of imaging breaks in a vertical target.

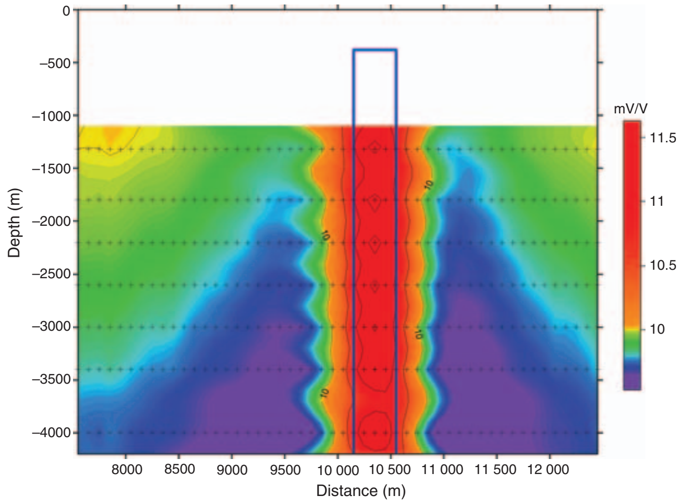

Fig. 3. *Real Section chargeability plot for a vertical prism starting at a depth of 400 m.*

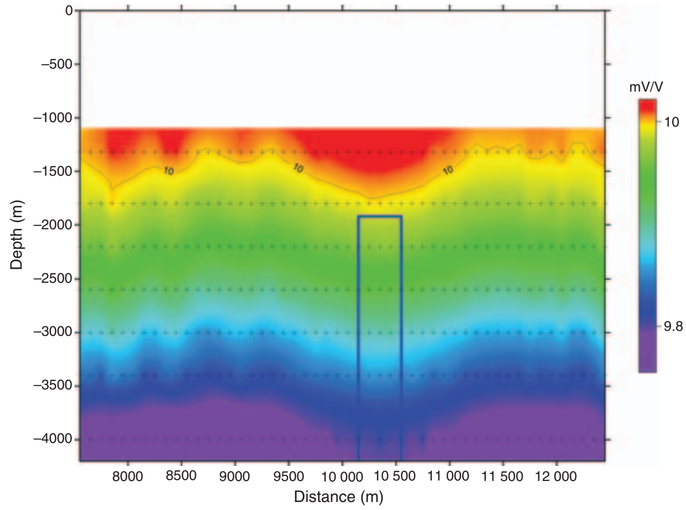

Fig. 6. *Real Section chargeability plot for a vertical prism starting at 2000 m depth.*

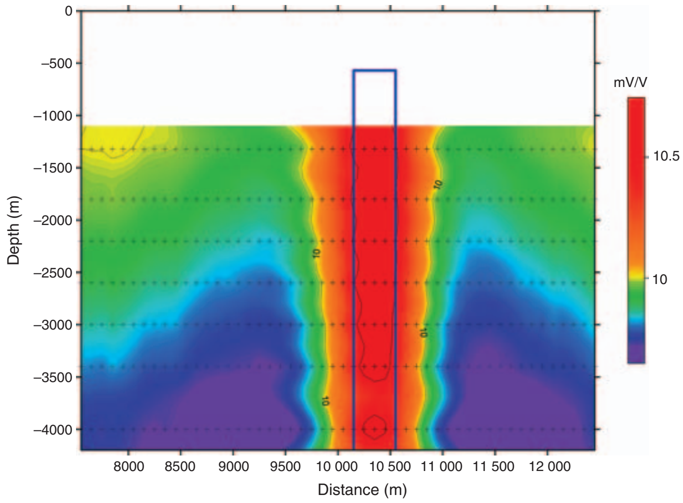

Fig. 4. *Real Section chargeability plot for a vertical prism starting at 600 m depth.*

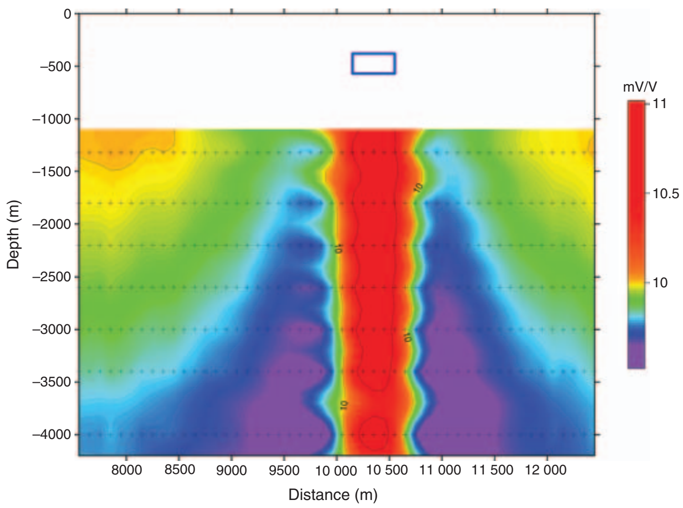

Fig. 7. *Real Section chargeability plot for a 200 m thick body at 400 m depth.*

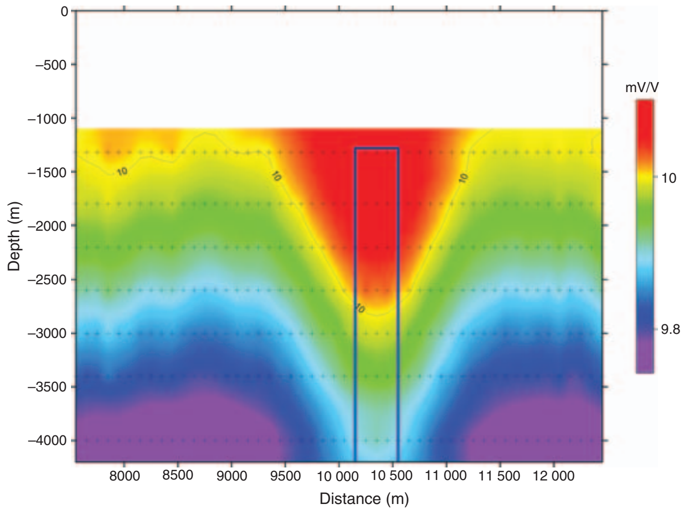

Fig. 5. *Real Section chargeability plot for a vertical prism starting at 1300 m depth.*

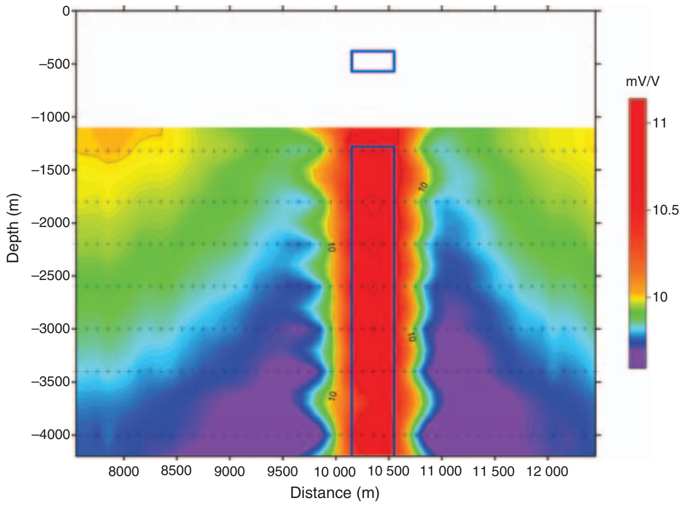

Fig. 8. *Real Section chargeability plot for a body with a 600 m break from 600 m depth.*

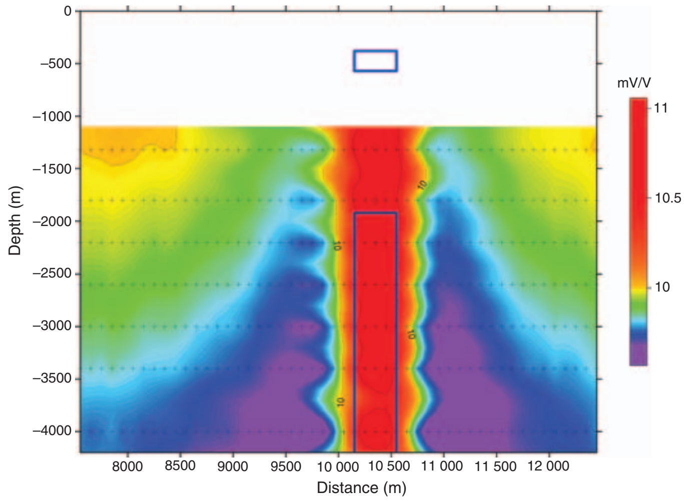

Fig. 9. *Real Section chargeability plot for a body with a 1400 m break starting at 600 m depth.*

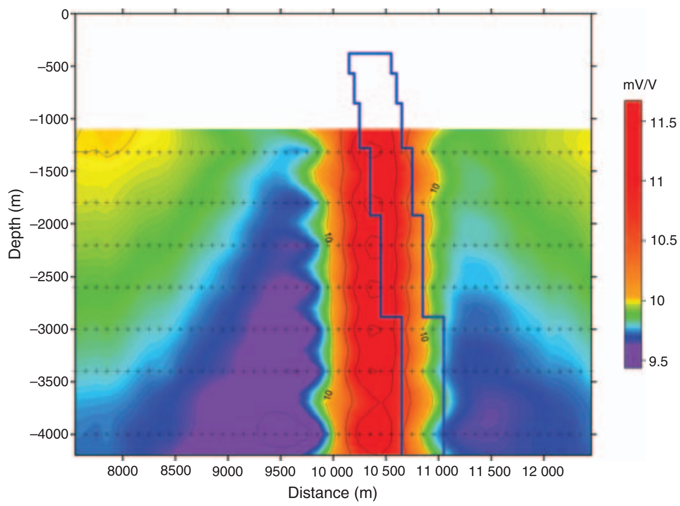

Fig. 10. *Real Section chargeability plot for a body dipping at 80° to the right.*

Sensitivity to dip

Gradient array is known to be insensitive to dip and Figure 10 shows this clearly. The body dips at 80° to the right (discretised to the mesh) while the modelled response looks like all the previous figures. Although the image shows asymmetry which reverses as the dip reverses, the amplitude of those variations are below the level of resolution of commercial receivers.

Many more models and variations could be shown. However, despite significant changes to the model geometry, the forward modelled response changes little and the majority of the response comes from the shallowest part of the body. This should come as no great surprise as the gradient array has maximum sensitivity at the surface and quickly decays with depth. At large A–B spacing the depth of investigation is controlled more by the M–N spacing than increases to the A–B spacing. Increasing the M–N spacing would improve penetration at the expense of horizontal resolution. There doesn't seem to be any evidence that this was being done in the case of the Oyu Tolgoi data.

Conclusion

In conclusion, the claims made by the promoters of Zeus are not supported by modelling and any geologist wanting to use this system to look for Volkswagens at 3 km should prepare themselves for disappointment and barren drill holes.

Readers wishing to undertake further studies on these data, including inversion, are welcome to contact the author for copies of the input models and output data from Res3DModx64. The original SEGMIN presentation and the Zeus publicity are also available on request, as it appears that the latter is not as easy to find on the web as it once was. Contact the author at kim@exploregeo.com.au

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Loke, M.H., and Barker, R.D., 1996, Rapid least-squares inversion of apparent resistivity pseudosections using a quasi-Newton method: *Geophysical Prospecting* **44**, 131–152. doi:10.1111/j.1365-2478.1996.tb00142.x