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Magnetic susceptibility models derived from ground magnetic data over the kalahari suture zone

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Introduction

The Kalahari Suture Zone (KSZ) is a large, north-south trending geological structure with a magnetic signature measurable from space, 400km above the surface of the earth. The magnetic response measured at 400km above the ground surface is mainly due to the contrast in magnetic susceptibility between intrusive Proterozoic gabbros aligned along the Kalahari Line (roughly longitude 22°E) and thick successions of non-magnetic sediments to the west. Back on earth, directly below the non-magnetic Kalahari beds, a complex distribution of magnetic gabbroic dykes and sills, distort the magnetic signature of the Proterozoic gabbros at depth. One way to determine the spatial distribution and orientation of the Proterozoic gabbros is through 3 dimensional inversion of the magnetic data to a magnetic susceptibility (magsus) model. With the aid of constraints, eg. borehole logs of geology and susceptibility, the 3D magsus model can be used to facilitate a better understanding of the distribution of the Proterozoic gabbro bodies and associated structure. In this study, the approach described is applied to a small area of the KSZ with the aid of 2 exploratory boreholes.

There are several commercially available software packages for the 3D inversion of magnetic data. Two of the most commonly used products are the UBC-GIF and VP Geophysical Suite software packages used by Mira Geoscience. The current available magnetic susceptibility model for the KSZ, covering a significant portion of Kavango Resources prospecting licenses, was derived by Mira Geoscience using the mentioned software. Mira produced two 3D magnetic susceptibility models – A. relative shallow bodies representing Karoo gabbros, and B. deep bodies representing Proterozoic gabbros. Perspective views of the two models are presented below in Figures 1 and 2.

Another commonly used magsus inversion software is the VOXI module of the Seequent Oasis Montaj package. The latter is a cloud based subscription service to invert several types of geophysical data for licensed Oasis Montaj users. The process is free of charge up to a 50 x 50 grid which in practise translates to a 6.25km^{2}area for the ground magnetic data available to Kavango for the relevant portion of the KSZ under investigation. The area to be inverted can be increased to 25km^2 albeit with less resolution, using the available gridded airborne magnetic data available from the local Geological Survey / Department of Mines. The author ran several inversions covering areas of interest using both the ground and airborne magnetic data sets. The main area of interest was Target Area A with 2 completed exploratory holes, targeting conductors inferred from ground electromagnetic surveys.

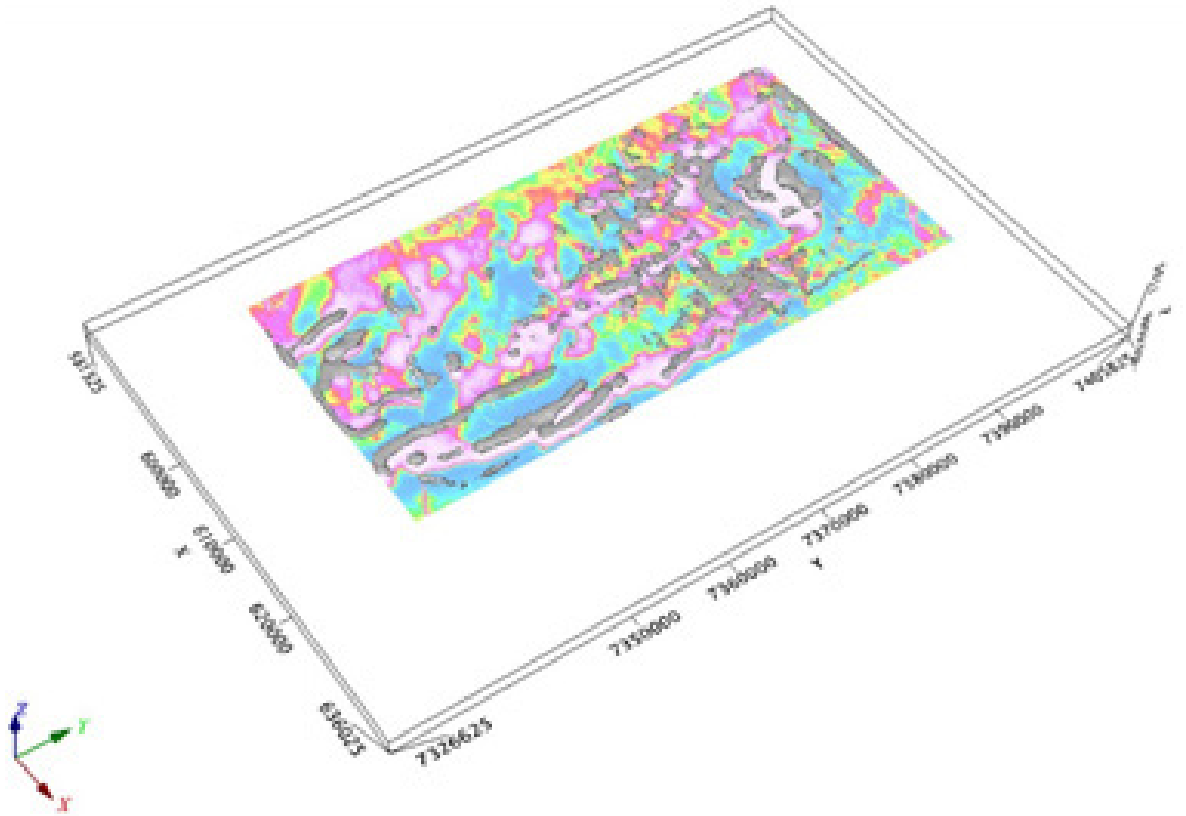

Figure 1. 3D magsus model for shallow (karoo) magnetic sources derived from airborne magnetic data. Correlation between magsus bodies and magnetic anomalies is sub-optimal.

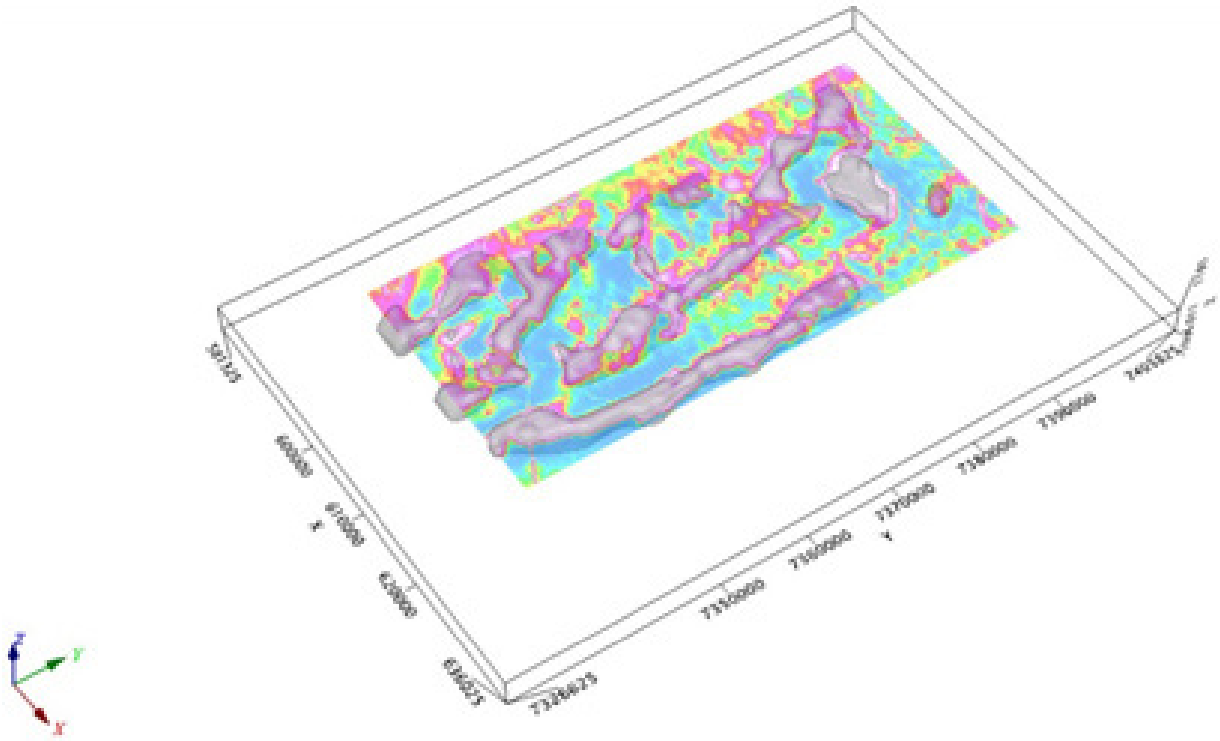

Figure 2. 3D magsus model for deep (Proterozoic) magnetic sources derived from airborne magnetic data. Correlation between magsus bodies and magnetic anomalies is very good.

Ground Magnetic Data

Kavango Resources commissioned a contractor to conduct a ground magnetic survey over a portion of the KSZ as presented in Figure 3 below. The red square indicates the area covered by ground magnetics. The survey was conducted at a line spacing of 200m and reading interval of 12.5m. The small black square denotes the area of 6.25km² which was inverted at 50m resolution and the larger black square, 25km² area was inverted at 100m resolution. The image depicted in Figure 3 is the Total Magnetic Intensity (TMI) Reduced-to-Pole (RTP) merged with the 2nd Vertical Derivative (2VD) of TMI RTP.

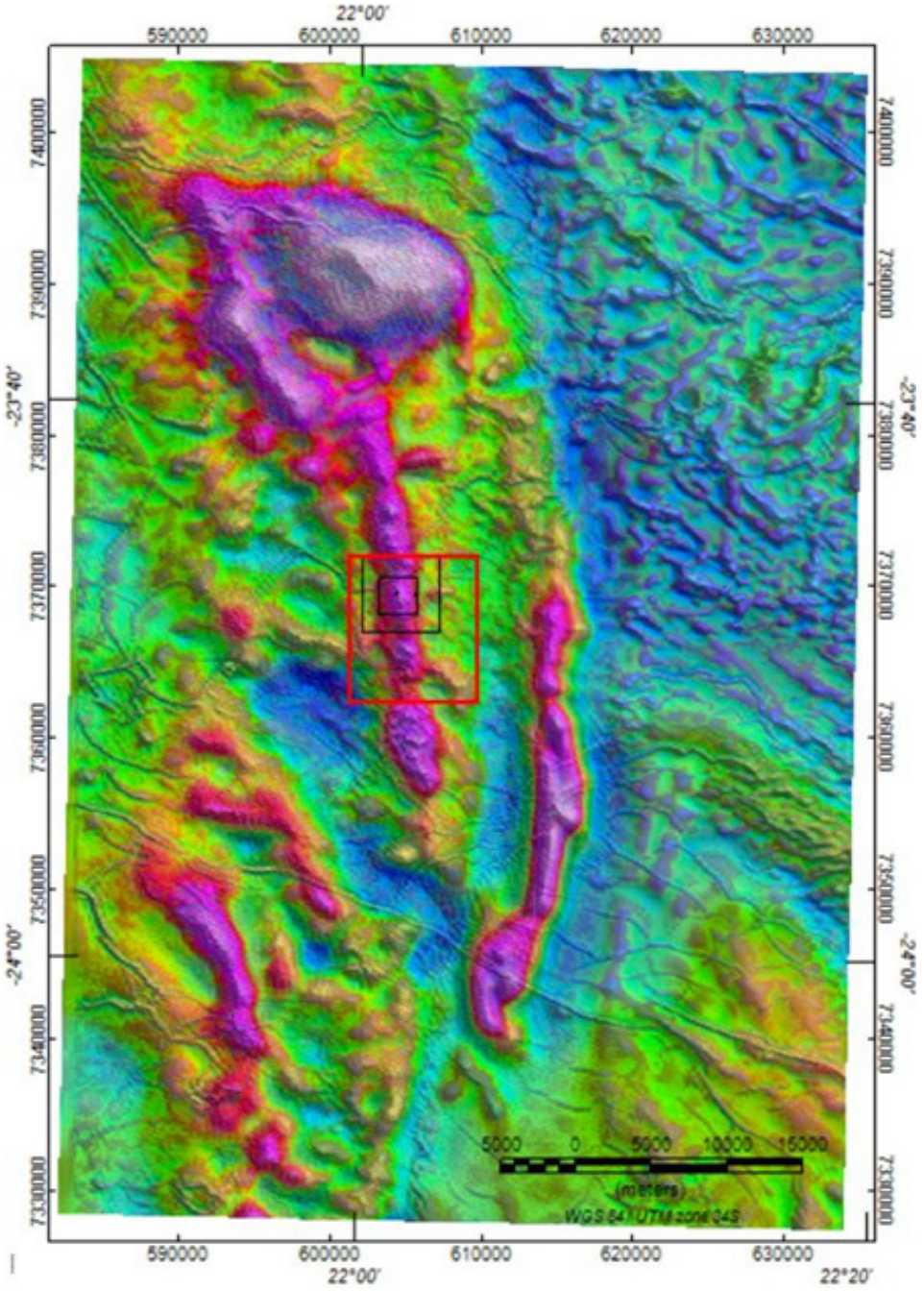

Figure 3. Regional airborne magnetic data over a portion of the KSZ.

It is clear from the figure above that the area of interest is underlain by a complex configuration of shallow, narrow, curvi-linear and weakly magnetic bodies over moderate magnetic anomalies at intermediate depths which in turn is super-imposed on large amplitude anomalies caused by highly magnetic Proterozoic gabbros at depth. The narrow curvi-linear anomalies are caused by gabbroic dykes and the edges of sills directly below the Kalahari beds – it is a trivial exercise to filter out these anomalies. The anomalies caused by sills at depth, above the Proterozoic gabbro intrusions, are more difficult to recognise and require a priori information ie. borehole information (depth to top, thickness, measured magsus etc.).

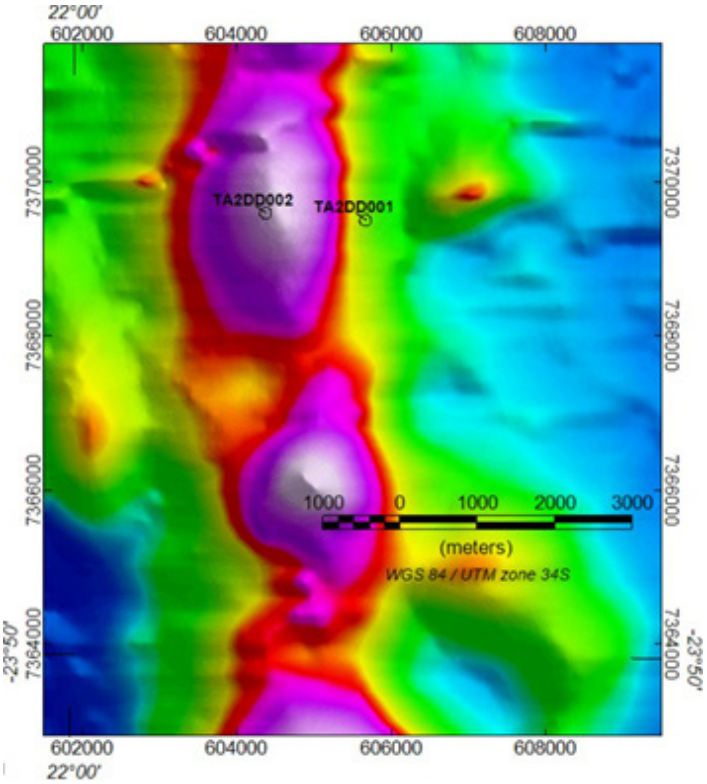

Figure 4. Filtered ground magnetic used for 3D inversion.

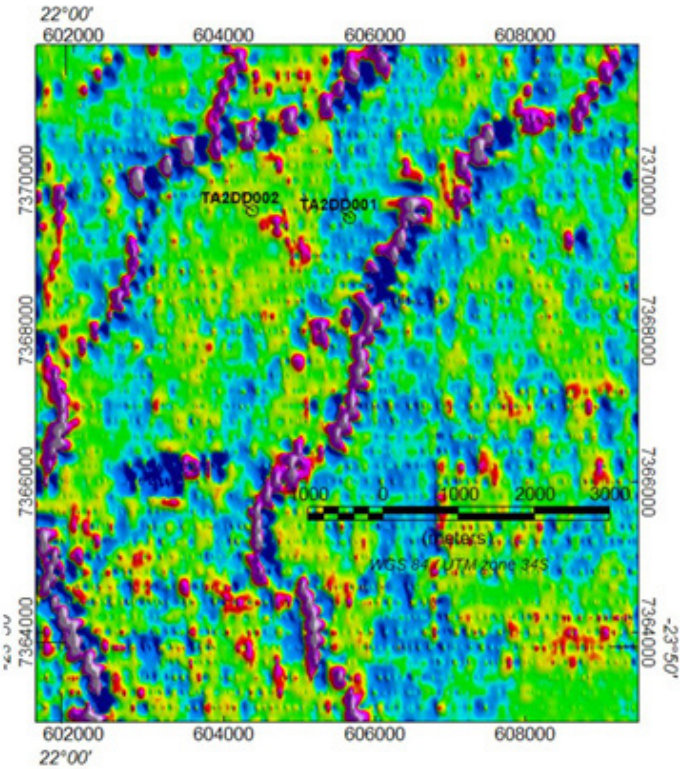

Figure 5. Anomalies removed from original measured ground magnetic data using non-linear filtering.

3D Inversion

The ground magnetic data set presented in Figure 4 was used to invert to a 3D magnetic susceptibility distribution., utilising the VOXI routine of Seequent's Oasis Montaj software. The area inverted include the 2 exploratory boreholes TA2DD001 and TADD002. The resolution used was 50m square model cells horizontally and variable cell size, vertically – model cell size increases with depth as illustrated in Figure 6 below.

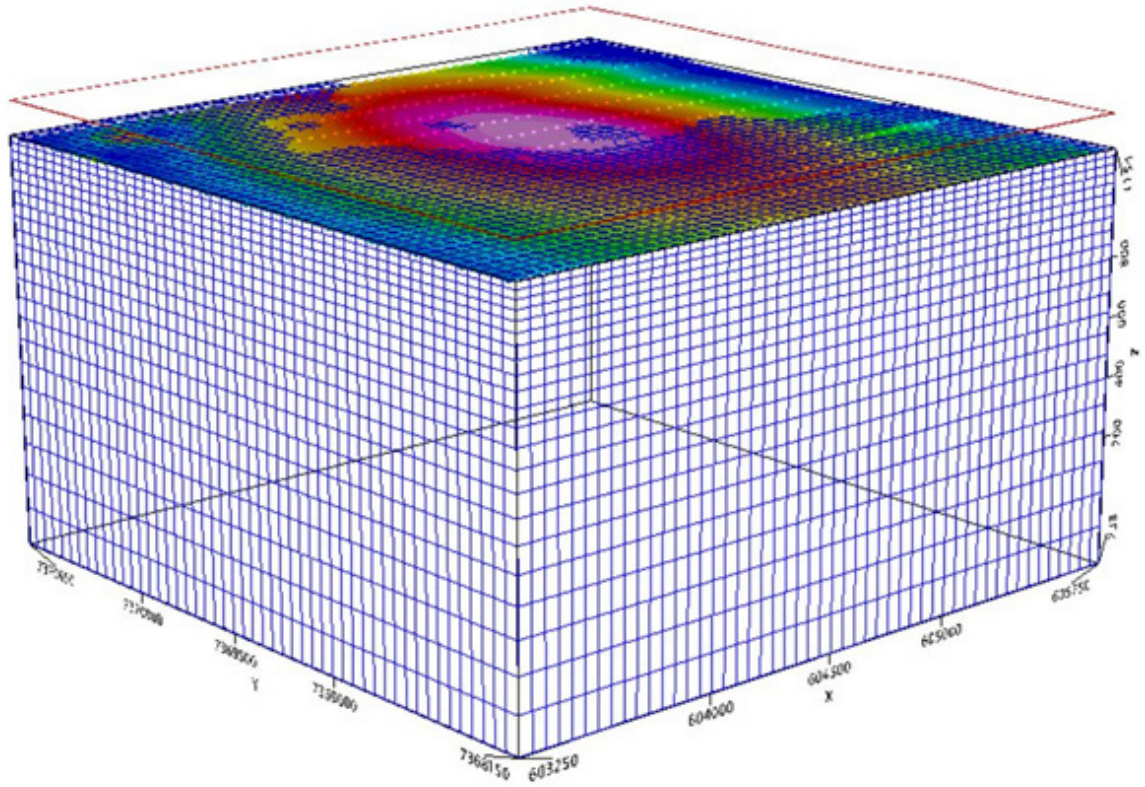

Figure 6. 3D mesh used for inversion of ground magnetic data – 50m resolution.

Once the magsus model was derived, a suitable iso-surface value was derived based on the magsus values measured on the core of TA2DD001. A modelled magsus value of 5.5 X 10^{-3} SI units was found to produce a surface that predicted the intersection depth of the Proterozoic gabbro exactly, as is clearly illustrated in Figures 7 and 8.

The existing exploratory borehole are drawn with measured on core magsus values indicated by the maroon disks. It is obvious that the Proterozoic gabbro is an order of magnitude more magnetic than the Karoo gabbros (indicated by the small discs higher up in both the boreholes. Figure 8 suggests that TA2DD002 was drilled close to the western contact of the proterozoic gabbro body, while TA2DD001 would have missed the same body completely.

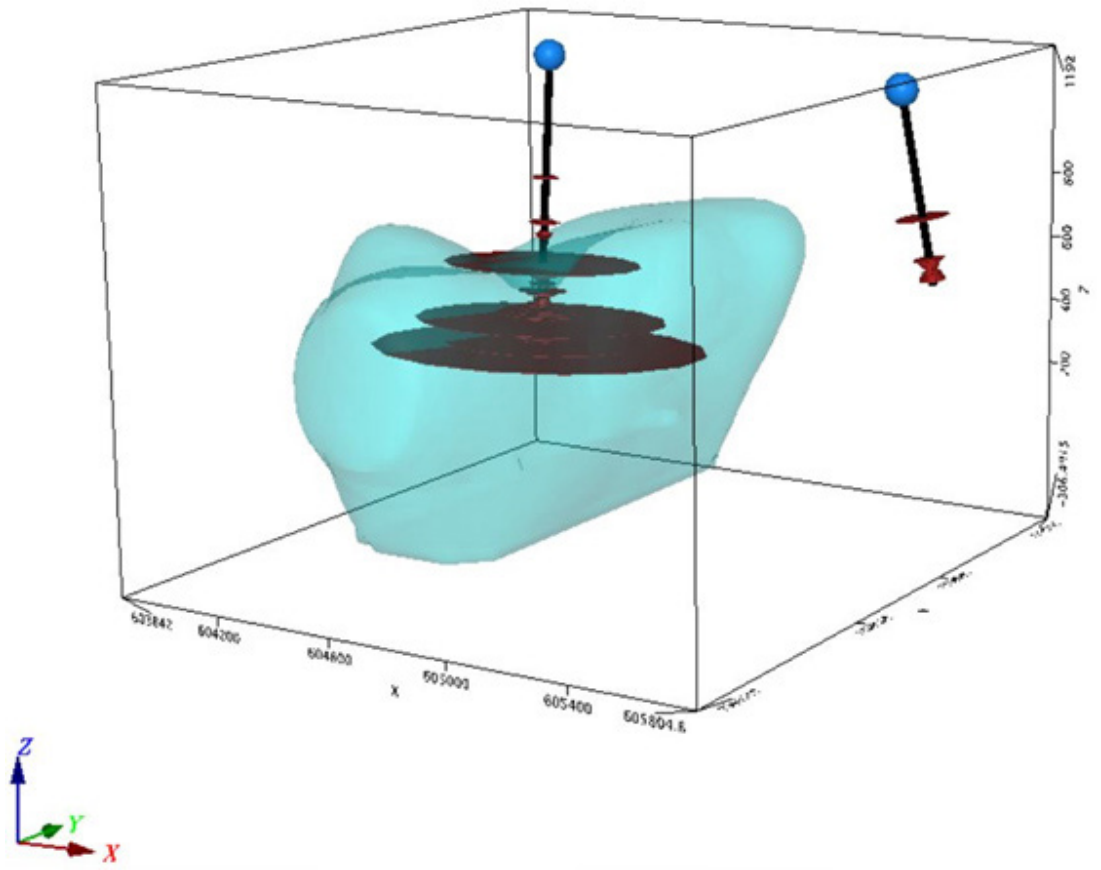

Figure 7. Perspective view from the SE of magsus iso-surface 5.5x10^{-3}SI units.

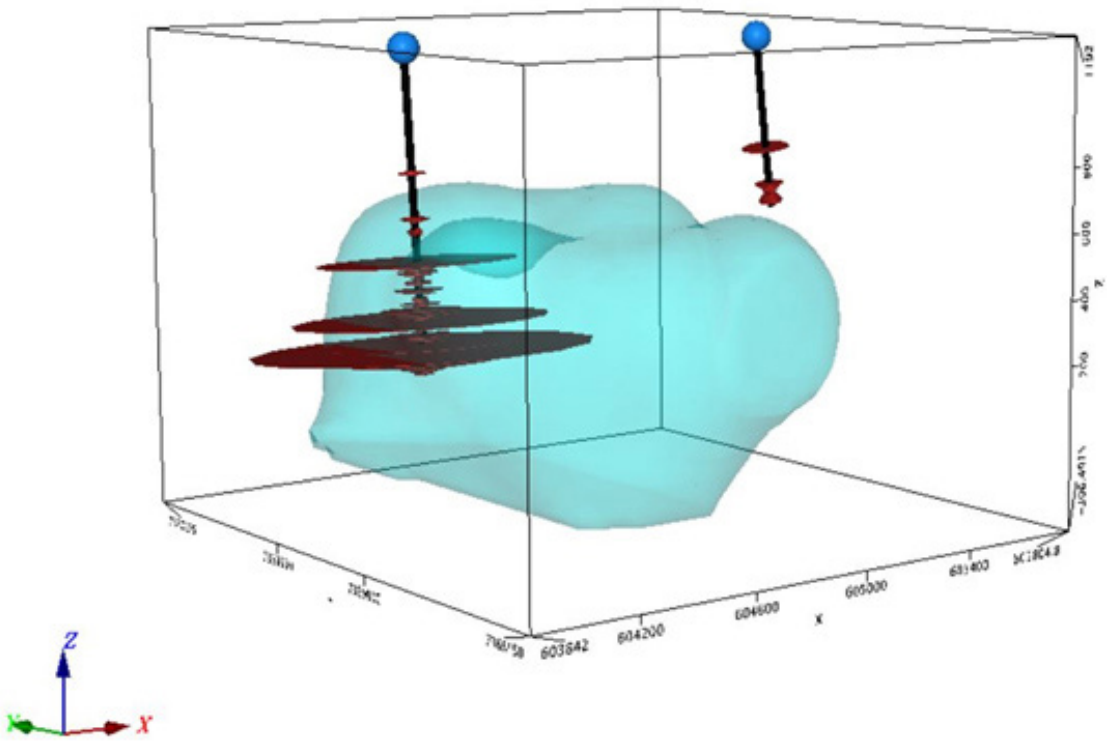

Figure 8. Perspective view from the SW of magsus iso-surface 5.5x10^{-3}SI units.

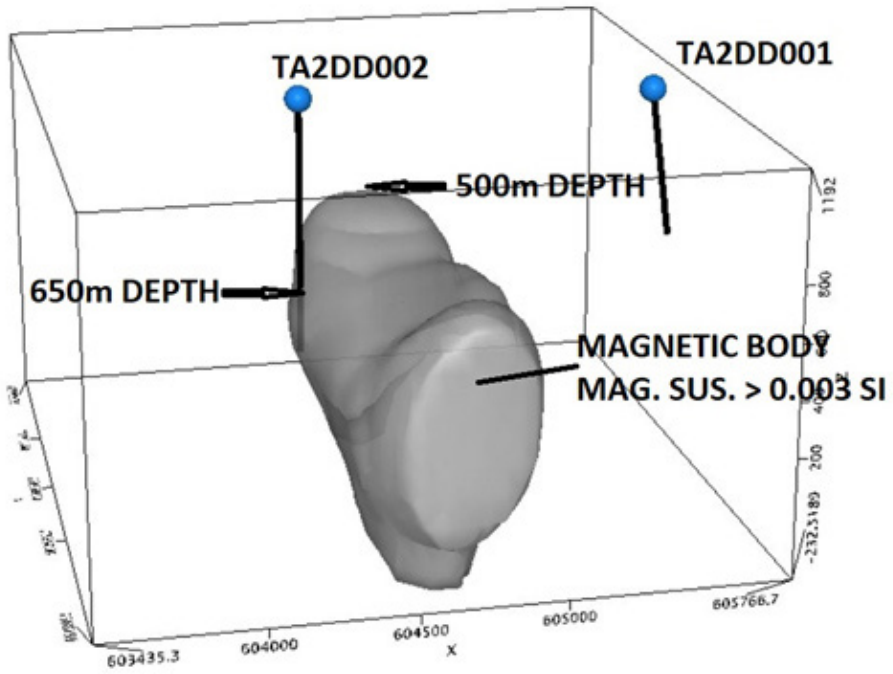

Figure 9. Magsus model derived from regional airborne data.

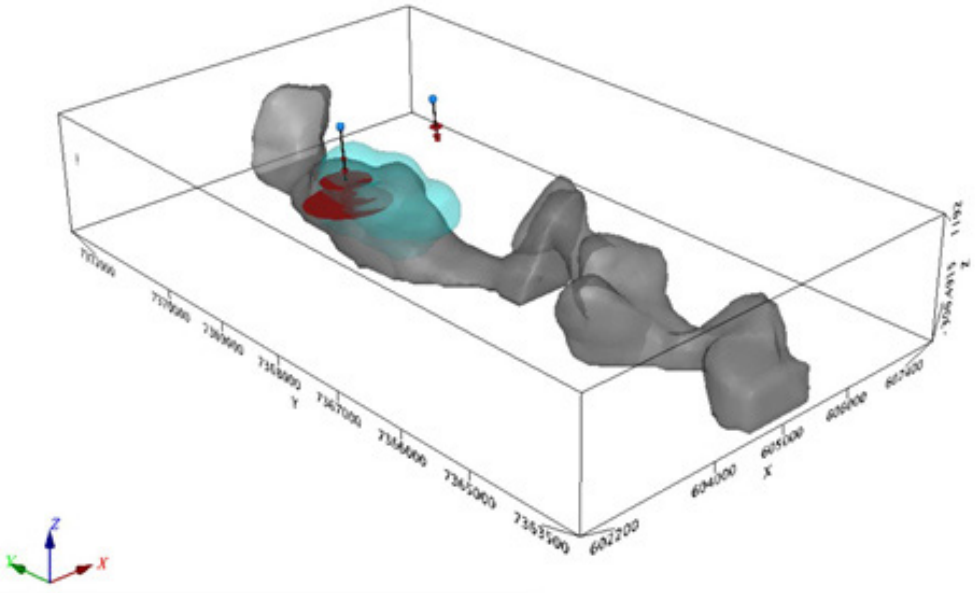

Figure 10. Comparison of 50m and 100m cell size 3D magsus models.

Figure 10 was compiled merging two 25km² inversion blocks using 100m square model cell sizes. The original 50m square cell size model (light blue) is super-imposed. The regional model displays a significant amount of structure / variation in depth along strike and it is obvious that the Proterozoic gabbros could probably be intersected at shallower depths than was the case in TA2DD002.

Conclusions

3D / 2D inversion or any quantitative modelling of available magnetic data, ground or airborne, can provide very useful information to focus mineral exploration over the KSZ. Not much have been done in this regard to date. Comprehensive modelling of the available magnetic data, specifically to map the spatial distribution and orientation of the Proterozoic gabbros, is highly recommended. Proper modelling of the Karoo gabbros within a depth range of 400m will require higher resolution magnetic data. It is recommended that Seequent's Oasis Montaj VOXI paid subscription Magnetic Vector Inversion (MVI) product be utilised for comprehensive modelling of the magnetic anomalies associated with the KSZ.

Respectfully submitted
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