MINES GEOPHYSICAL SERVICES

16 VICTORIA STREET,
KALGOORLIE,
WESTERN AUSTRALIA 6430.

Telephone/facsimile 61 8 9021 6970

MT OWEN RESOURCES

MT OWEN: RESULTS OF

INDUCED POLARISATION SURVEY

APRIL 2011

J H COGGON

MAY 2011

MT OWEN:

RESULTS OF INDUCED POLARISATION SURVEY, APRIL 2011

SUMMARY

An induced polarisation (IP) survey carried out in March-April 2011 was designed to find disseminated sulphide mineralisation within the Central Volcanic Complex, beneath Lower Owen Group sediments. The survey was planned on a set of east-west lines, using a 100 m pole-dipole survey arrangement with pole-dipole separations up to 1300 m so as to explore to depths approaching 500 m. Due to very steep terrain and thick vegetation in places the proposed survey of seven 3 km lines was reduced, with three 2 km long traverses and two 1½ km long traverses being completed.

Measured apparent resistivities were typically several thousand ohm m, with only moderate variations with electrode separation. Apparent chargeabilities generally were observed to be somewhat higher for the smaller electrode separations, and no obvious ‘deep’ anomalies were seen. Several readings, however, displayed unusually high (and sometimes large negative) chargeabilities. Some of these ‘odd’ chargeability readings are probably due to a combination of local ground effects, but many are clearly due to interference from steel pipes (carrying cables) on the surface.

Smooth two-dimensional model inversions have been carried out with the aim of recovering reasonable estimates of the ground resistivity and chargeability structure. Inversions have been completed using nearly all of the observed data, and also using reduced datasets that remain after discarding readings considered suspect because of ground conditions or proximity to pipes and cables. The results from the reduced datasets should better reflect the ground structure but suffer because of the missing data points.

Model results indicate that, for the northern part of the survey, resistivities are high near the surface and in the east, with a broad slightly lower resistivity zone lying at depth (>200 m) in the central section. In the northern area chargeability variations are rather irregular with local polarisable zones indicated above 200-300 m depth below surface. Some of these in the western section may be partly caused by nearby pipes and other metallic structures. A broader and more consistent polarisable zone is suggested in the east, but this also does not appear to extend below 300 m. A line surveyed in the south showed lower resistivities near the surface and very low chargeabilities at depth.

CONTENTS

LIST OF PLANS

Separate plans

I396B1	Line 5339600N pseudosection of apparent chargeability
I396C1	Line 5339600N conductivity section from smooth model inversion
I396D1	Line 5339600N chargeability section from smooth model inversion
I396A2	Line 5339600N pseudosection of apparent resistivity
I396B2	Line 5339600N pseudosection of apparent chargeability
I396C2	Line 5339600N conductivity section from smooth model inversion
I396D2	Line 5339600N chargeability section from smooth model inversion
I396C3	Line 5339600N conductivity section from smooth model inversion
I396D3	Line 5339600N chargeability section from smooth model inversion
I393-C	Line 5339300N conductivity section from smooth model inversion
I393-D	Line 5339300N chargeability section from smooth model inversion
I393A1	Line 5339300N pseudosection of apparent resistivity
I393B1	Line 5339300N pseudosection of apparent chargeability
I393C1	Line 5339300N conductivity section from smooth model inversion
I393D1	Line 5339300N chargeability section from smooth model inversion
I390A1	Line 5339000N pseudosection of apparent resistivity
I390B1	Line 5339000N pseudosection of apparent chargeability
I390C1	Line 5339000N conductivity section from smooth model inversion
I390D1	Line 5339000N chargeability section from smooth model inversion
I390C2	Line 5339000N conductivity section from smooth model inversion
I390D2	Line 5339000N chargeability section from smooth model inversion
I381-C	Line 5338100N conductivity section from smooth model inversion
I381-D	Line 5338100N chargeability section from smooth model inversion
IQ-C	Line ‘Q’ conductivity section from smooth model inversion
IQ-D	Line ‘Q’ chargeability section from smooth model inversion
IQ-A1	Line ‘Q’ pseudosection of apparent resistivity
IQ-B1	Line ‘Q’ pseudosection of apparent chargeability
IQ-C1	Line ‘Q’ conductivity section from smooth model inversion
IQ-D1	Line ‘Q’ chargeability section from smooth model inversion
IQ-C2	Line ‘Q’ conductivity section from smooth model inversion
IQ-D2	Line ‘Q’ chargeability section from smooth model inversion
I396-E	Line 5339600N conductivity section from smooth model inversion
I393-E	Line 5339300N conductivity section from smooth model inversion
I390-E	Line 5339000N conductivity section from smooth model inversion
I396-F	Line 5339600N chargeability section from smooth model inversion
I393-F	Line 5339300N chargeability section from smooth model inversion
I390-F	Line 5339000N chargeability section from smooth model inversion

INTRODUCTION

An induced polarisation (IP) survey was designed for the Mt Owen project with the objective of detecting disseminated sulphide mineralisation (hopefully an extensive alteration halo around a base metal deposit) within the Central Volcanic Complex, beneath Lower Owen Group sediments. A pole-dipole survey arrangement was chosen, with 100 m dipoles and pole-dipole separations up to 1300 m, which ideally should provide a depth of exploration of up to about 500 m for large target bodies. As the major structures and expected mineralisation trend in a north-northwesterly direction traverses were laid out east-west to cover the most prospective areas. However, due to steep terrain and thick vegetation not all the traverses were surveyed, and a northeast trending traverse was added to the program.

Zonge Engineering and Research Organization Australia were contracted to carry out the survey. The measurements were made in the time domain (with a 2 s pulse) using a Zonge manufactured transmitter and GDP-32II receiver.

This report presents the results from the IP survey, comments on problems associated with the terrain and grounded metal pipes, and discusses results from inversion modelling.

SURVEY

Plan 1 shows the layout of the traverses. Traverses at 5339600N (Line 1), 5339300N (Line 2) and 5339000N (Line 3), all originally 3 km long, were shortened to 2 km because of a cliff near 386300E and thick bush east of this. The traverses at 5338700N (Line 4) and 5338400N (Line 5) have very steep sections in the central area as well as the cliff further east and were not attempted. The eastern halves of the traverses at 5338100N (Line 6) and 5337800N (Line 7) lie in thick bush, that was cut for access. Line 6 was surveyed east of 385600E, but with very steep sections here and further west the western part was not read. Line 7 was not surveyed as results from Line 6 were not encouraging. However, an additional traverse (Line Q) was laid out obliquely across the eastern parts of Lines 1, 2 and 3 and surveyed.

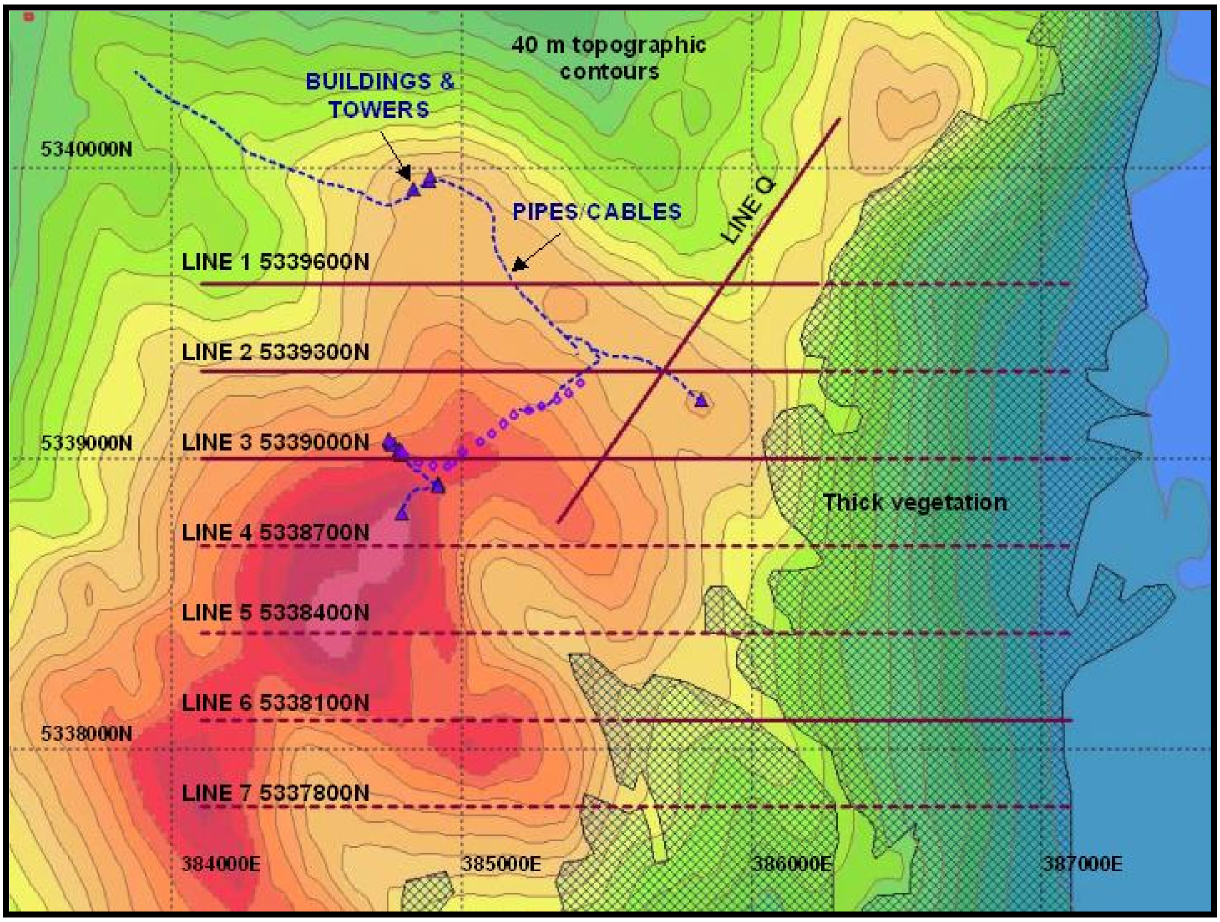
A remote transmit electrode was set up about 1.1 km northwest of the western end of Line 1 for the surveys on Lines 1, 2 and 3. The remote electrode for Lines 6 and Q was set up about 1.6 km southeast of the east end of Line 6. These distances are less than desirable for a 100 m pole-dipole survey but access and safety put some constraints on the transmitter sites.

Each survey was carried out using eight 100 m receiver dipoles followed by three 200 m receiver dipoles for each transmit pole position, with variations toward the end of each line.

Plan 1: Mt Owen – layout of IP survey.

Colour shows topography, red – high to blue – low.

Dashed lines show IP traverses as originally proposed, solid lines show traverses actually surveyed.



Coordinates: MGA (GDA94) zone 55.

GENERAL RESULTS

Results from all the traverse lines are presented as pseudosections of apparent resistivity and apparent chargeability in plans numbered as follows: Innn-A and Innn-B, where I indicates induced polarisation section, A is for resistivity and B is for chargeability. nnn indicates the traverse: 396 for 5339600N, 393 for 5339300N, 390 for 5339000N, 381 for 5338100N and Q for Line Q.

The apparent resistivity pseudosection for 5339600N (Plan I396-A) shows high values (several thousand ohm m) with top-left to bottom-right stripes common in pole-dipole pseudosections with the pole on the right. Apparent resistivities in the upper and lower parts of the pseudosection are similar and it appears that there is not much variation of ground resistivity with depth. The apparent chargeability pseudosection for this line (Plan I396-B) displays some very undesirable features. As well as smoothly varying chargeabilities in the range 10-30 mV.s/V there are sharp ‘ridges’ and ‘valleys’, corresponding to specific transmitter and receiver locations, with large positive and negative values. The sharp features make it difficult to discern broader anomalous trends, but it appears that chargeabilities tend to be lower at depth than near the surface.

Apparent resistivities on 5339300N (Plan I393-A) tend to be lower than on 5339600N. The apparent chargeability pseudosection (Plan I393-B) is ‘cleaner’, with fewer extreme positive and negative values, although these still interfere with delineating broad features. There is a suggestion of a broad weak polarisable zone in the central-eastern part of the line.

The apparent resistivity pseudosection for 5339000N (Plan I390-A) generally exhibits values in the range of a few thousand ohm, like those on 5339300N. However, there are some very low and even negative values corresponding to specific transmitters and receivers. The negative values indicate severe current distortion (such as may be caused by localised good conductors). The apparent chargeability pseudosection (Plan I390-B) displays extensive ‘contamination’ by sharp ‘ridges’ and ‘valleys’ and again it is very difficult to see broad weak trends.

The traverse at 5338100N shows lower apparent resistivities (Plan I381-A), particularly in the east where values fall below 1000 ohm m. Apparent chargeabilities (Plan I381-B) are also lower than on the northern lines, typically below 10-15 mV.s/V except for the readings from the easternmost transmitter pole (diagonal down to the left from 387100E).

On Line Q the apparent resistivities are several thousand ohm m (Plan IQ-A). The pseudosection shows top-right to bottom-left stripes as the transmitter pole is on the left for this line. The apparent chargeability pseudosection (Plan IQ-B) suggests that chargeability tends to be higher near the surface than at depth. No extreme values or sharp variations are evident.

Overall it appears that there are no obvious broad deep chargeability anomalies in the pseudosections. However, ‘noise’ in the pseudosections for the northern three east-west traverses means that relatively weak deep anomalies may remain undetected.

SOURCES OF INTERFERENCE

There are several possible sources of the sharp local variations and some extreme values observed in apparent chargeability. These include:

the ground conditions close to electrodes,
unduly high electrode contact resistance,
large and varying spontaneous potentials,
electrical noise (natural or man-made signals),
sharp geological changes (leading to sharp changes in conductivity and chargeability),
grounded or partly grounded metallic structures.

Much of the ground covered by the Mt Owen IP survey is exposed rock that leads to difficulty making good stable electrical contacts. Moving water and oxidation are expected to lead to spontaneous potentials. Incipient clay development in fine fractures and local concentrations of minerals such as hematite may cause polarisation. Some of the observed but repeatable ‘odd’ chargeability readings are very likely due to some combination of local ground mechanisms.

Transmission equipment on Mt Owen radiates high frequency signals but these are not thought to cause significant interference at the low frequency (0.125 Hz) used for IP measurements. Lower frequency signals (such as from generators, welding) may have caused problems at some times. It is not known to what extent there may have been this kind of activity in the area.

There is a clear interference from steel pipes (carrying cables) on the surface. The pipes are expected to concentrate current, and could cause severe distortion in this very resistive area. They are also expected to exhibit induced polarisation. The effects are likely to vary depending on the extent to which a pipe is grounded, its angle relative to a traverse line, and the proximity of electrodes. The locations of most of the pipes/cables are shown in Plan 1, but Lines 1, 2 and 3 all cross cables in the vicinity of 384800-900E.

INVERSION MODELLING

Inversion modelling, designed to recover reasonable estimates of the ground resistivity and chargeability structure, has been carried out using software (DCIP2D) developed by the Geophysical Inversion Facility at the University of British Columbia. This represents the earth as a two dimensional structure, in which the physical property distribution is calculated with the criteria of being smoothly varying (a ‘smooth model’) while accounting for the observed IP measurements.

Modelling for each traverse was done first using all, or nearly all, of the observed data. In the next stage data from electrodes near known steel pipes were discarded before modelling. For some traverses there appear to be other suspect data, probably resulting from electrical noise or from the ground and electrode conditions, and inversion was carried out after rejecting these data also. As the locations of the pipes etc. are known, rejection of readings from nearby electrodes is reasonably straightforward. Identification of other suspect readings is more subjective. While the objective is to use only ‘reliable’ data in order to obtain a model of the ground, some regions become very poorly defined due to missing (ie discarded) readings.

MODEL RESULTS

Line 1: 5339600N

Inversion results for Line 1 using all except poorly repeating and extreme data are shown in Plans I396-C (conductivity) and I396-D (chargeability). Apart from local shallow variations in conductivity the broad structure appears to consist of slightly higher conductivity (ie lower resistivity) at depth in the western two thirds of the section. Very irregular chargeabilities are seen within 150 m of the surface while there appears to be a deep chargeability anomaly at the east end of the section. The sections in these plans have been plotted to 450 m below ground surface, but at each end of the line the depth of investigation is less than this and may be estimated as tapering up to the surface at about 45 degrees. The apparent deep anomaly at the east end should be considered unreliable. It is deeper than the effective depth of investigation here and probably results from an attempt to match roughly the irregular high apparent chargeabilities seen in the pseudosection (Plan I396B).

Pseudosections for Line 1 with data from electrodes near pipes and different selections of other ‘suspect’ data discarded are shown in Plans I396A1 and I396B1 and in Plans I396A2 and I396B2. Corresponding inversion models are presented in Plans I396C1 and I396D1 and in Plans I396C2 and I396D2. The conductivity model results are all similar, with minor variations in the shallow features. The chargeability models show more variations, but an anomaly between 100 and 200 m depth near the centre of the section is present in all sections. The deep anomaly at the eastern end is also present. However, a further model based on the data shown in Plans I396A1 and I396B1 but with two more data points discarded does not retain the deep east end anomaly, as shown in Plan I396D3.

Line 2: 5339300N

Model results for Line 2 with some data from electrodes near steel pipes discarded are illustrated in Plans I393-C and I393-D. As well as shallow variations a deep shallowly dipping more conductive zone is indicated in the central area. This is similar to that seen on

Line 1, but appears to be deeper. There are numerous local shallow chargeability anomalies, and possible deep anomalies near the centre and in the eastern half near385600E.

Some additional ‘suspect’ data points were identified and rejected, with the remaining points as shown in the pseudosections of Plans I393A1 and I393B1. Inversion models for this dataset are drawn in Plans I393C1 and I393D1. The deep conductivity structure is little changed, while the deeper chargeability anomalies remain but are weaker and more diffuse.

Line 3: 5339000N

Inversion was only carried out for this line after discarding data clearly strongly influenced by steel pipes etc. The remaining data are shown in the pseudosections of Plans I390A1 and I390B1. Inversion results are given in Plans I390C1 and I390D1. A wide deep relatively conductive zone is suggested in the central area, and this is roughly consistent with the results from the lines to the north but appears more conductive. The chargeability anomalies are comparatively weak, and while there is a shallow zone of irregular features (as on other lines) there is also a weak deep anomaly in the central area. With a few additional data removed another model was obtained, as shown in Plans I390C2 and I390D2. The chargeability features are stronger in this result. However, before taking too much notice of the deep chargeable zone near 385100E it is important to see that there is a large gap in the data in this area, and visually the pseudosection (Plan I390B1) does not support the presence of this zone. The weaker mid-depth chargeable zone at 385700-800E in Plan I390D2 is supported by data in the pseudosection.

Line 6: 5338100N

This line is not near and does not cross any steel pipe and only one dataset appears suspect – that for the transmitter at 386700E. Inversion results with these data discarded are shown in Plans I381-C and I381-D. The models indicate relatively conductive material in the upper hundred metres or so in the eastern two thirds of the line. As expected from the pseudosection (Plan I381-B) the chargeabilities are low and show no anomalies at depth.

Line ‘Q’

All data were used for the inversion model shown in Plans IQ-C and IQ-D. The broad tendency for conductivity to increase at depth is consistent with the results from Lines 1, 2 and 3. The chargeability patterns show irregular shallow variations, also similar to those seen on the northern east-west lines. A weak deep anomaly at the northeastern (righthand) end is probably below the effective depth of investigation.

Line ‘Q’ crosses a pipe near 1630 and data from electrodes near this were discarded for the next inversion. Observed pseudosections with the data used for modelling are given in Plans IQ-A1 and IQ-B1 and the model sections are shown in Plans IQ-C1 and IQ-D1. The differences between the inversion models are mainly for shallow features near 1600-1700.

Further inversions were carried out on the same dataset using different parameters for the modelling. One of the variables is the model reference chargeability that the inversion process tries weakly to match. In all the models shown so far, this was set at zero – on the basis of the rocks being non-polarisable in the main. However, the most common values of measured apparent chargeability lie in the vicinity of 10-15 mV.s/V, so a value of 13 mV.s/V appears a suitable reference. Inversion for Line Q with the data shown in Plan IQ-B1 and this reference value gave the model shown in Plan IQ-D2. Apart from some changes near the centre (where there is a data gap because of the pipe) the main difference is that the deep eastern anomaly is virtually non-existent in Plan IQ-D2. Both models match the data equally well and the differences indicate where the models are not defined properly.

All northern east-west lines

Additional inversion models for the three northern east-west lines were run using the reference background chargeability of 13 mV.s/V as for Line 'Q'. Plans I396-E, I393-E and I390-E show conductivity and Plans I396-F, I393-F and I390-F show chargeability. The line sections are plotted together to facilitate comparison from line to line.

For conductivity I396-E is the same as I396C3, I393-E is the same as I393C1 and I390-E is the same as I390C2.

For chargeability I396-F used the same data as I396D3, I393-F used the same data as I393D1 and I390-F used the same data as I390D2, but all the -F models were obtained after changing the model reference from 0 to 13 mV.s/V.

CONCLUSION

The IP survey at Mt Owen covered roughly half of the original planned area, with proposed traverses in the southern section abandoned due to the dangerous terrain.

The highly resistive ground meant that good signal strengths were achieved, but the rocky ground conditions resulted in unreliable chargeability readings in some places. A more major problem was interference from grounded steel pipes and cables. These caused both distortion of current and induced polarisation effects. The influence of pipes etc. was usually evident in readings from electrodes close to a pipe. By discarding data from electrodes suspect because of ground conditions or proximity to pipes and cables it was hoped that inversions would lead to 'uncontaminated' ground models. However, as significant amounts of data had to be rejected for some lines, some model results were not very well defined and did not provide reliable information down to the depths desired. These limitations need to be considered when interpreting the model sections.

Model structures

The conductivity sections for lines 5339600N, 5339300N and 5339000N (Plans I396-E, I393-E and I393-E) all show three features: shallow irregular variations above about 100 m depth, a relatively resistive region in the eastern quarter of the traverse, and a deep (generally >200 m) zone of increased conductivity covering the central third to half of the traverse extent. The shallow anomalies probably come from variations in conductivity related to fracturing, joints and oxidation as well as local geometric effects from the irregular terrain – not defined by the terrain model or the IP model. The broad deep zone appears to approach the surface in the west and is more conductive and shallower on the southernmost line. The western ends of the lines vary: 5339600N appears resistive, 5339300N is more conductive near the surface and 5339000N is more conductive at depth.

Chargeability sections for these lines (Plans I396-F, I393-F and I393-F) display irregular patterns above 200 m. These shallow variations in chargeability may reflect partly the effects of pipes etc. adjacent to the traverses and partly polarisation due to local hematite occurrence and perhaps incipient clay alteration. Deeper variations in chargeability are much more subdued. On line 5339600N the rocks in the eastern third of the traverse appear to be about twice as polarisable those in the west, below about 200 m. On line 5339300N the eastern five eighths below 200 m is relatively polarisable, while line 5339000N generally appears less polarisable at depth apart from a 400 m wide zone west of centre. This anomaly on 5339000N is the only discrete zone extending below 200 m on this set of sections, but whether or not it reflects a real feature in the ground is uncertain. It may be due to pipes and other infrastructure adjacent to the traverse. The broad eastern deep more polarisable zones on 5339300N and 5339600N look more like background variations than signs of localised mineralisation

Results from the oblique line ‘Q’ (Plans IQ-C2 and IQ-D2) that runs across the eastern parts of the three northern east-west lines are consistent with models for these lines in showing noisy shallow variations in conductivity and chargeability. As on these lines there is also increased conductivity below about 200 m, particularly in the southwest and northeast sections. Broad weak deep variations in chargeability are also evident.

The survey on line 5338100N was the most satisfactory in terms of obtaining good data free of the effects of pipes and cables. The conductivity model section shown in Plan I381-C shows a clear change in character from shallow resistive ground in the western third of the traverse to shallow conductive ground in the eastern two thirds. This conductivity is probably caused by weathering (facilitated by plant roots). The chargeabilities at depth are low compared with most of the models for the northern traverse lines, with no anomalies of interest.

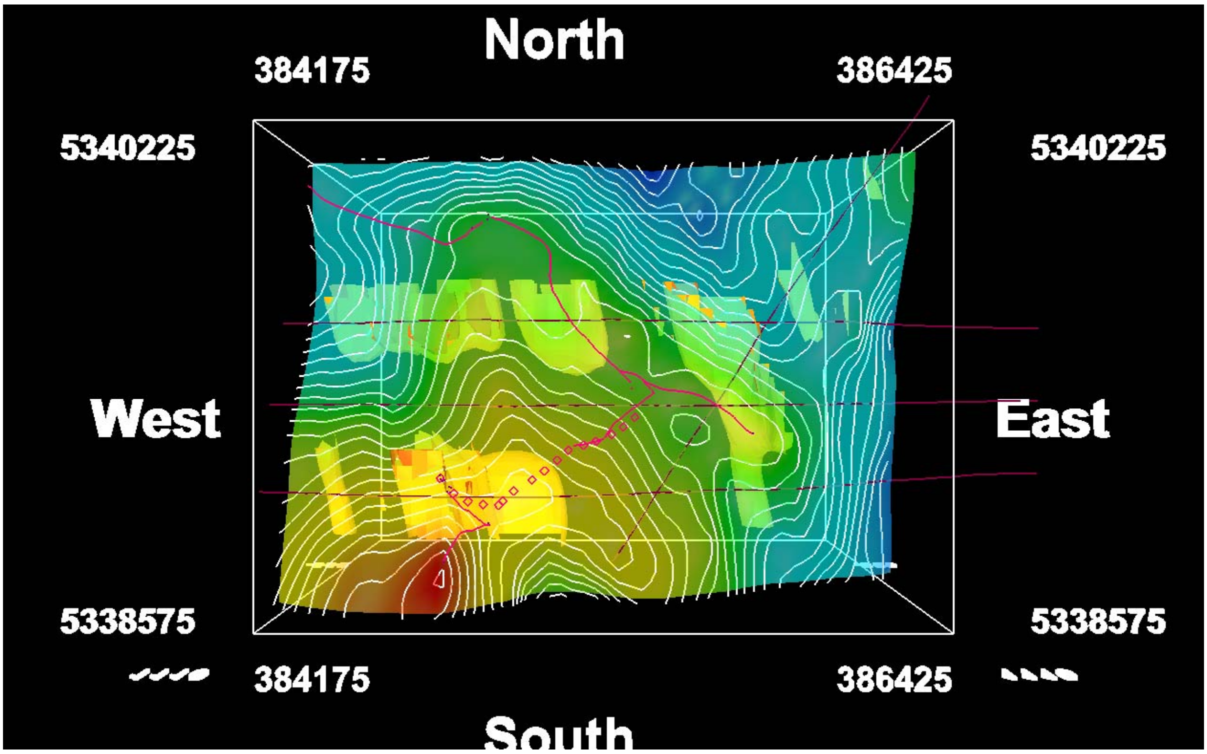
Three-dimensional relations

The model chargeability results for the northern group of traverses (Lines 1-3 and Q) have been combined to form a three-dimensional model. The 3D values are weighted averages of the 2D model values. Averages were calculated from data within an ellipsoid with semi-axes of 120 m at azimuth 75^0, 320 m at azimuth 345^0 and 60 m vertical, using a bell shaped (cosine squared) weighting function.

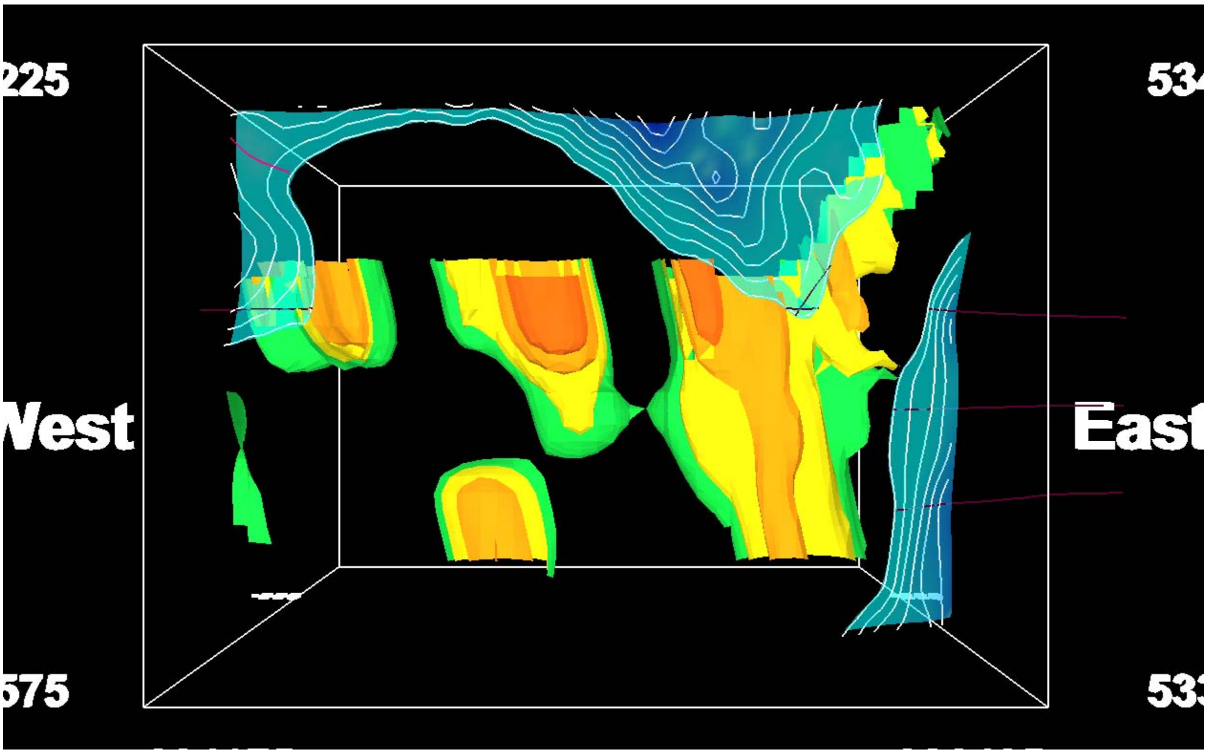
The chargeability patterns are portrayed by isosurfaces in several perspective views shown on the following pages. Included with the model are the surface topography (the transparent coloured surface with white contour lines at 25 m interval) and IP traverse lines (east-west at 5339600N, 5339300N and 5339000N, and NE trending line Q, all in dark purple). The locations of steel pipes are shown by red lines and small diamonds.

The 3D compilation illustrates more clearly the geometry of the modelled chargeable zones. These appear to be relatively shallow and localised in the western part of the survey area, but there is a more extensive and consistent zone in the east. The polarisable rocks are likely to be within Lower Mt Owen Group sediments. There is no clear suggestion of localised chargeable bodies below about 300 m depth or 500 m elevation.

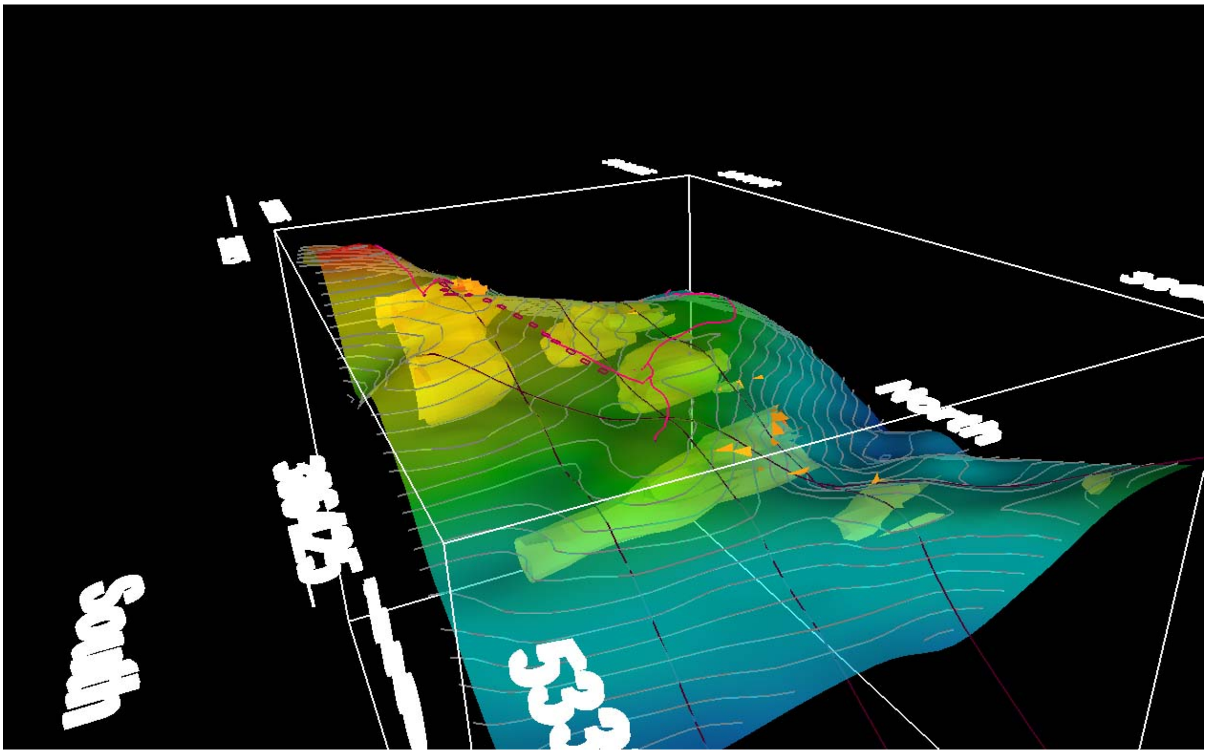
Plan 2a: 3D model view vertically down, showing topographic surface, and chargeability isosurfaces at 20 mV.s/V and higher below the topographic surface.



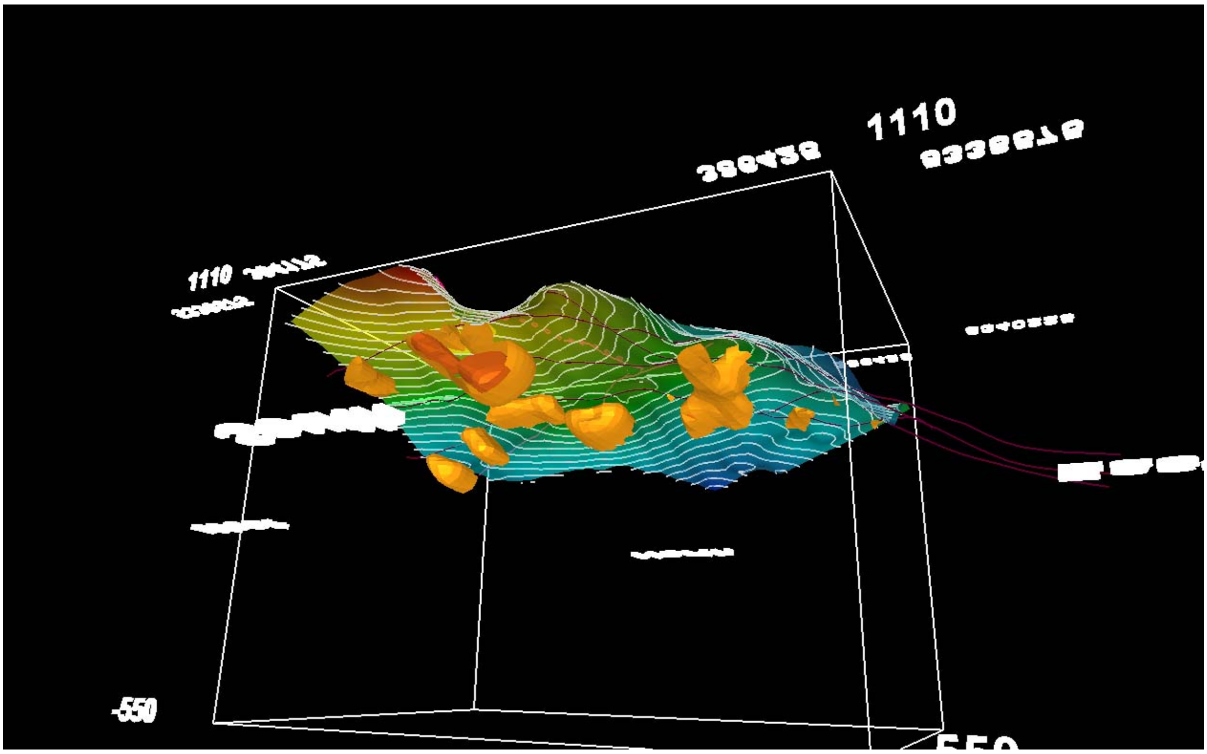
Plan 2b: 3D model view vertically down, sliced at 677 m elevation, showing chargeability isosurfaces at 14 (green), 16 (yellow), 20 (orange) and 25 (red-orange) mV.s/V.



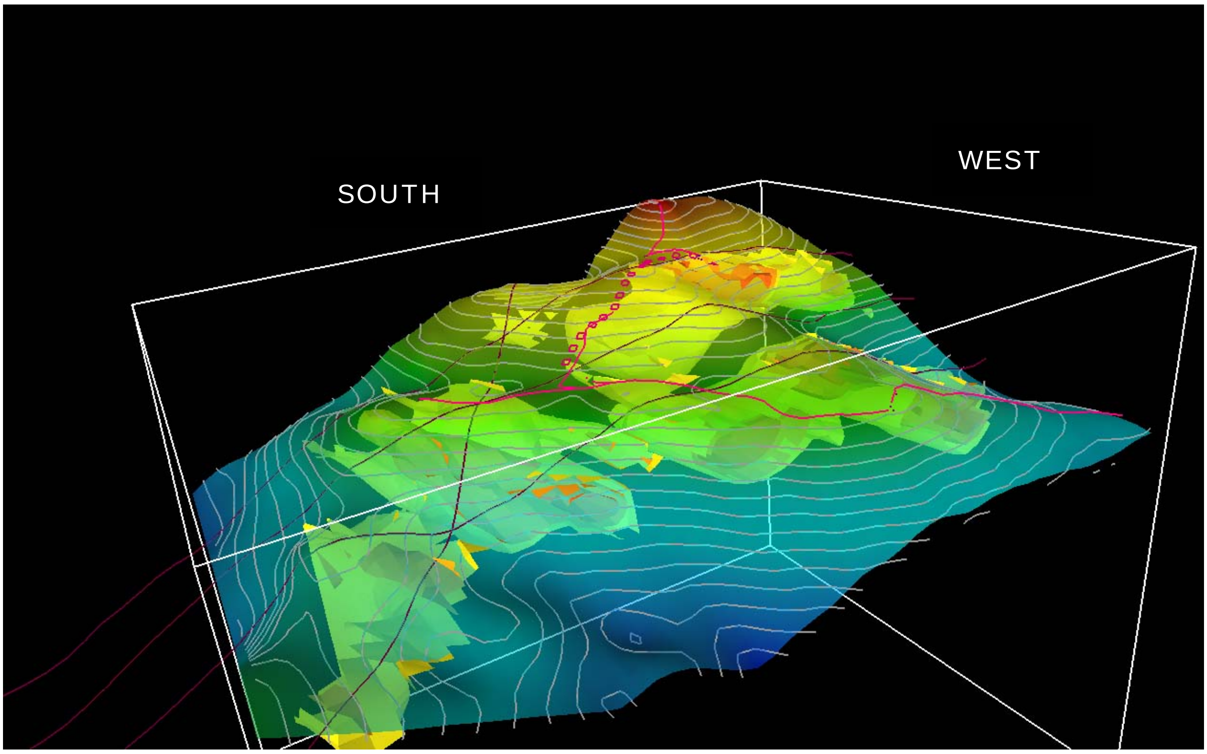
Plan 2c: 3D model view down toward the west-northwest, showing topographic surface and isosurfaces of chargeability at 20 mV.s/V.



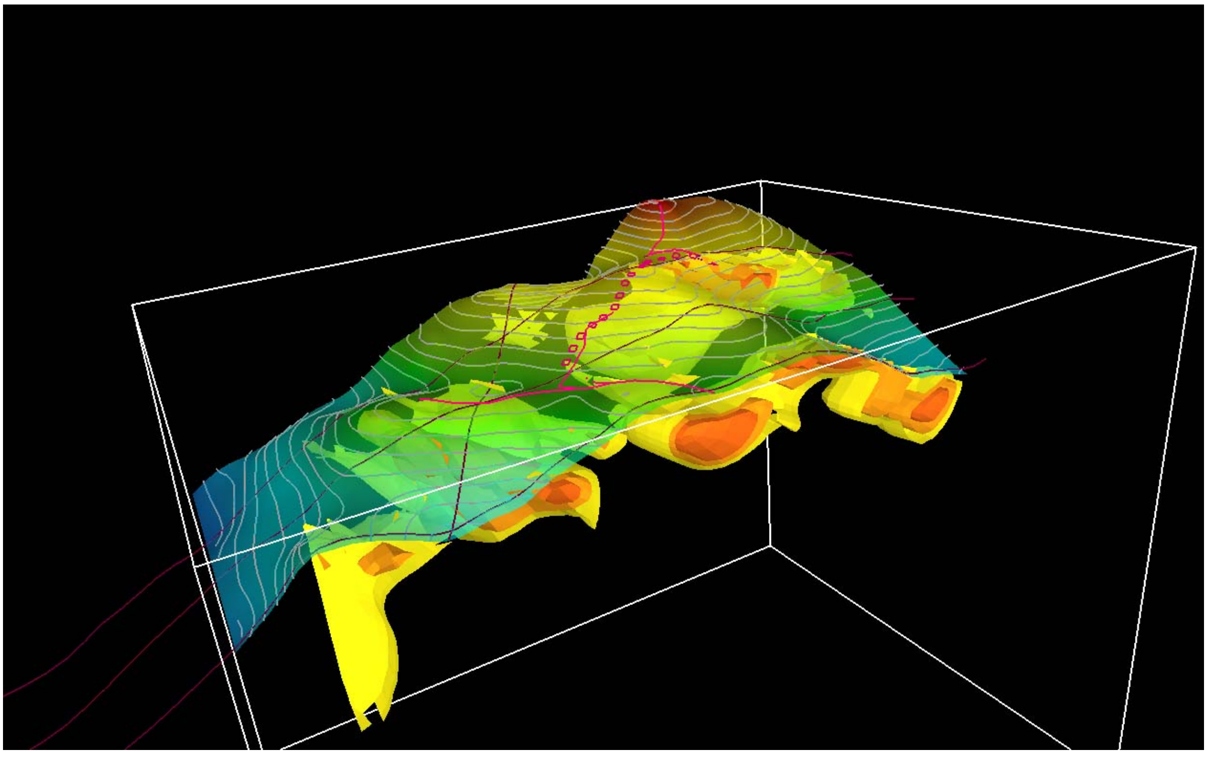
Plan 2d: 3D model view up toward the north-northwest, showing isosurfaces of chargeability at 20 mV.s/V and higher, with topographic surface above.



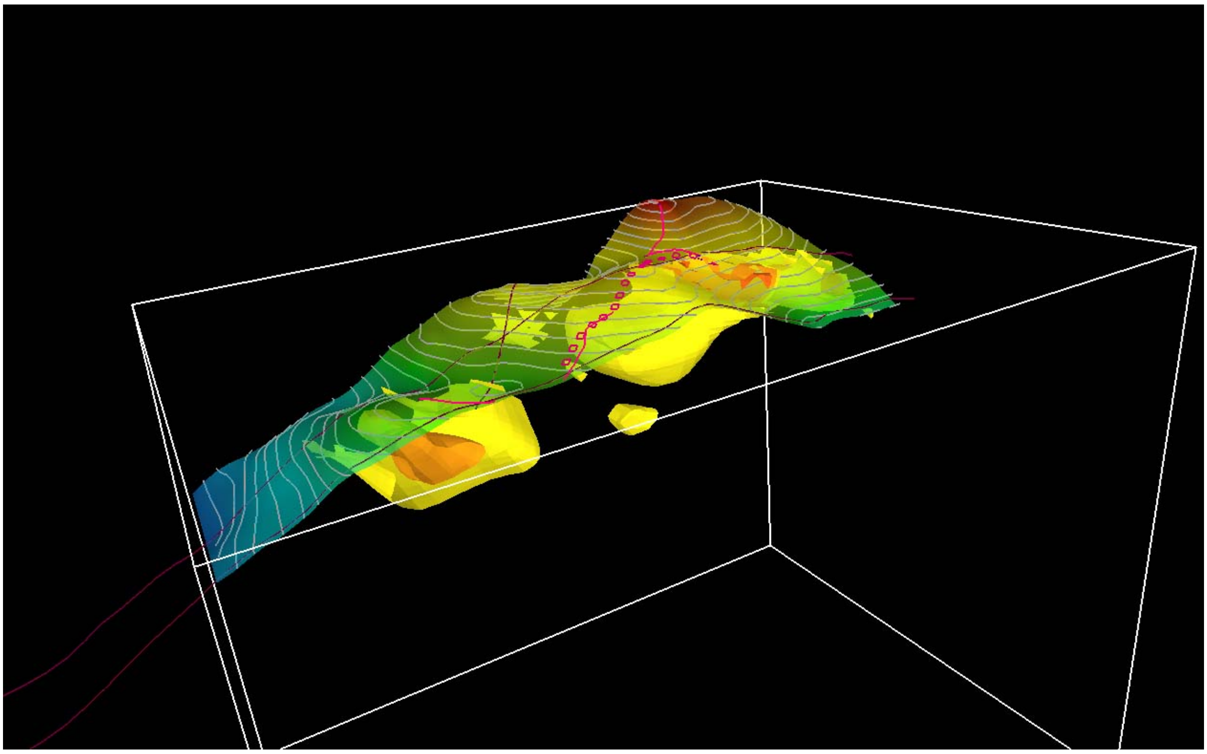
Plan 2e: 3D model view down toward the south-southwest, showing topographic surface, pipes etc. and chargeability isosurfaces at 16 mV.s/V and higher.



Plan 2f: 3D model view down toward the south-southwest, showing topographic surface, pipes etc. and chargeability isosurfaces at 16 mV.s/V and higher. Model cut at 5339625N.



Plan 2g: 3D model view down toward the south-southwest, showing topographic surface, pipes etc. and chargeability isosurfaces at 16 mV.s/V and higher. Model cut at 5339325N.



Plan 2h: 3D model view down toward the south-southwest, showing topographic surface, pipes etc. and chargeability isosurfaces at 16 mV.s/V and higher. Model cut at 5339025N.