Forward modelling and inversions for IP survey design

ExploreGeo Technical Note 6

Explanation

Thanks to modern acquisition systems, many choices of dipole and electrode design are available. However, the resulting cost, resolution, and depth may be very different according to the design selected.

An effective way to choose the best array design beforehand, and thus to maximise the return on investment, is to use a modelling and inversion process.

This technical note will investigate the cost effectiveness of multiple array designs on manto-style mineralisation in Chile. Manto-style mineralisation is generally structurally controlled and stratabound within permeable host rock.

In the example modelled here, a thrust fault has superimposed prospective lithologies against younger, barren rocks. Mineralisation was modelled as a stack of stratabound lenses against the fault.

Modelling results

The information presented in this introductory PDF pertains to all modelling and inversion undertaken, details of which can be found in the two PDF files:

- Technical Note 6 - Appendix 1 - Effect of Dip
- Technical Note 6 - Appendix 2 - Effect of Depth

Details

The model contained three mineralised zones which were distributed along the fault. Two of the zones were placed in close proximity to each other to determine the horizontal resolution capability of each array design.

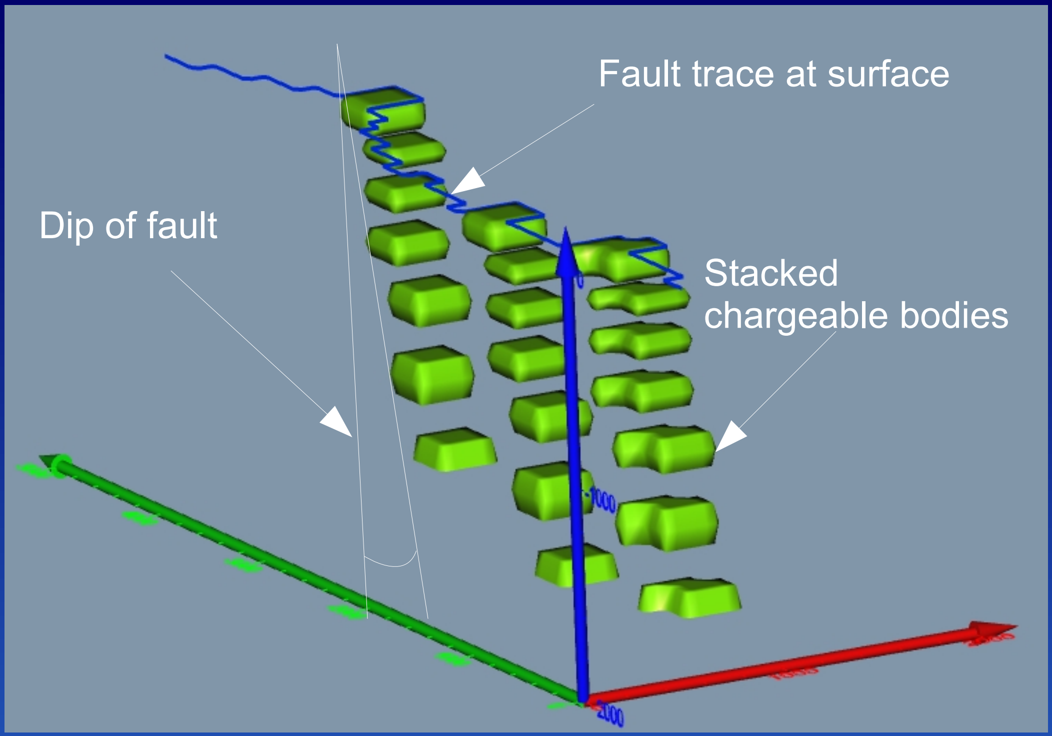
The dip of the fault was varied to determine the vertical resolution of each array.

One of the stacks of mineralisation was reduced to a single lens and was placed at various depths to both determine the depth of investigation and ability of the array to resolve a small discrete body beside a larger mineralised system.

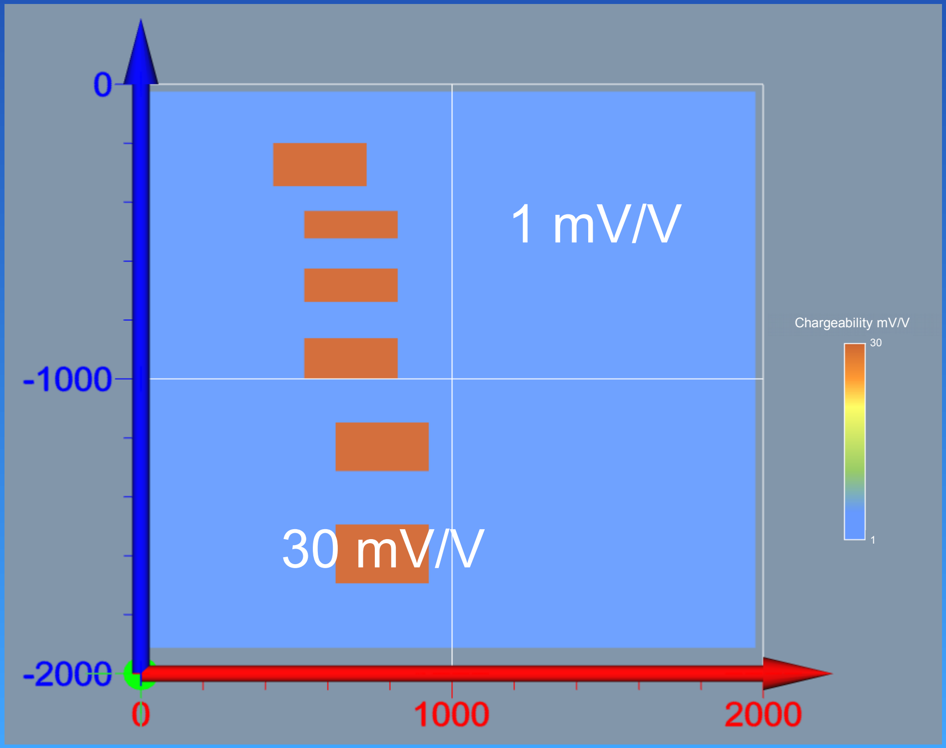
In the 430m depth model, the uppermost lens was removed with the remaining deeper lenses kept in place.

Finally, all three stacks of the 430m depth model were truncated so that the tops of all the stacks were at 430m.

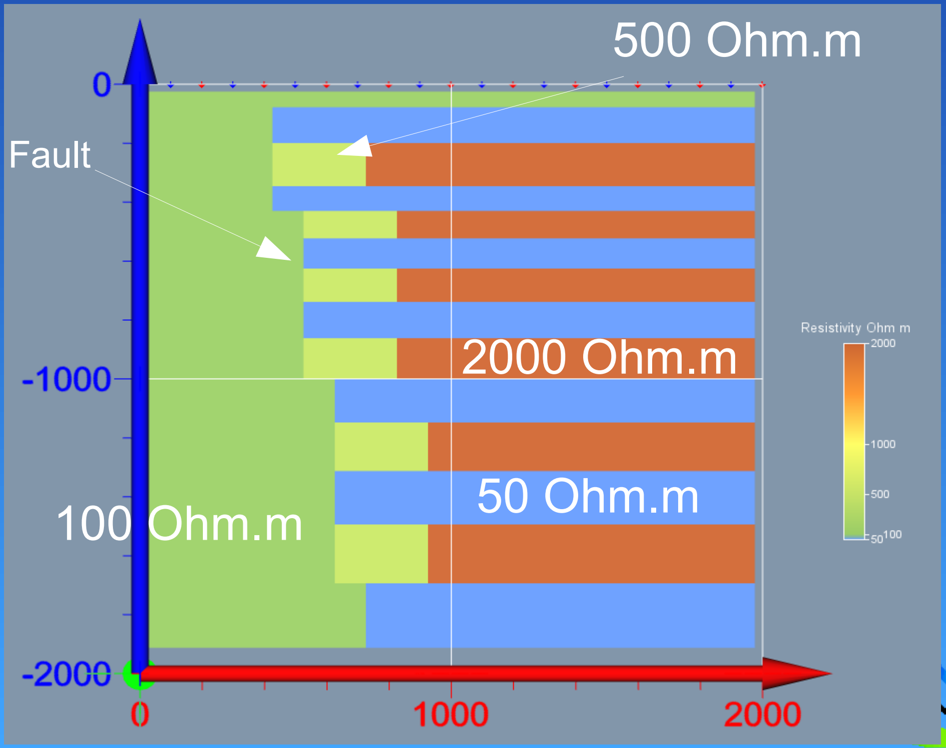
Model description



Chargeability section



Resistivity section



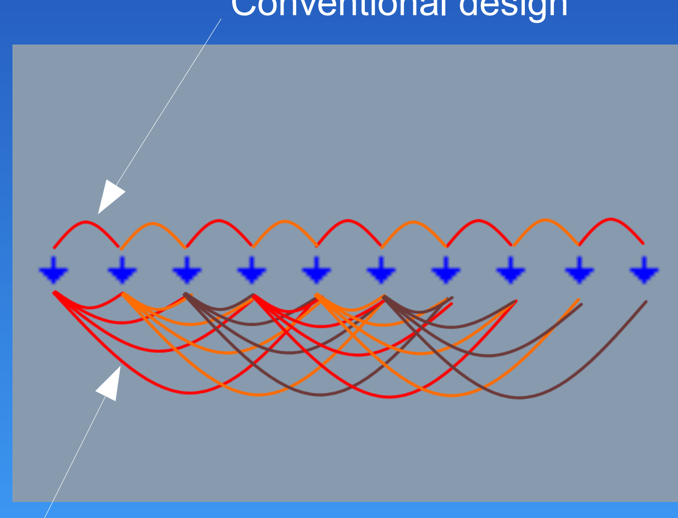
Arrays modelled

- 2D Dipole-Dipole
- 2.5D Quad Offset Dipole-Dipole
- 2.5D Quad Offset Dipole-Dipole with multipoles
- 3D Pole-Dipole (old Orion array)
- 2.5D Double Offset Dipole-Dipole parallel to strike
- 2.5D Double Offset Dipole-Dipole with multipoles parallel to strike

Difference between conventional and multipole arrays

In a conventional array, the same pair of current electrodes are associated with just one receiver dipole spacing. For example, Tx of 200m and Rx of 100m. For the multipole design, dipoles are made by summing the electrode spacing to produce dipoles at any size. For example, Tx of 200m and Rx of 100m, 200m, 300m and 400m.

A greater depth of investigation is expected for the multipole design.

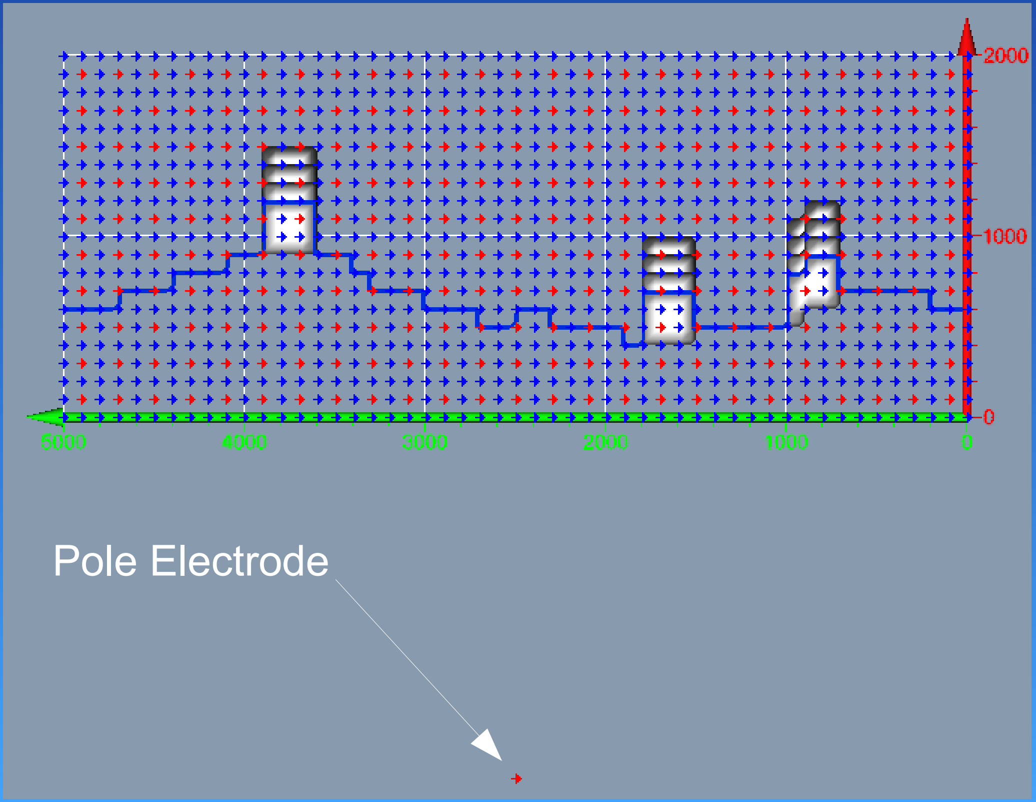


Electrode layout

All arrays used 100m electrode spacing on receiver lines. Offset arrays used 200m transmitter dipoles.

Line spacings were allowed to vary from 100m to 500m.

The 3D Pole-Dipole array was modelled with a pole electrode at coordinates 2500, -2000, as shown below:



Forward modelling details – Pt 1

Each array and model were forward modelled using Res3Dmodx64 to generate apparent resistivities and chargeabilities.

Noise was added to the exported chargeability and resistivity values. This was done by back calculating the primary voltage from the modelled apparent resistivity assuming a transmitter current of 20A. Although 20A is a relatively high current and unachievable for many commercial IP transmitters, it is commonly achieved by leading contractors using their own hardware. A random number of between +/- 5% was added to the calculated primary voltage as below.

If $V_p > 0.1$ mV

$$V_{p(noise)} = V_p + RN*V_p*0.1$$

If $V_p \leq 0.1$ mV

$$V_{p(noise)} = V_p + RN*0.1$$

RN = Random number between -0.5 and +0.5

Forward modelling details – Pt 2

The apparent resistivity was then recomputed using the noise added primary voltage, and the chargeability had noise added in the same proportion as the apparent resistivity.

The data were then clipped to remove any readings with a primary voltage of less than 0.1 mV in order to try and mimic real receiver noise thresholds.

Inversion details

All arrays were inverted using Res3Dinvx64 and the 2D dipole-dipole lines were inverted individually using Res2Dinvx64. The results were loaded into a 3D display package and displayed here as sections and plans of resistivity and chargeability overlain on the true model.

Figure details

All chargeability sections and contours use a linear colour scale with a contour interval of 0.5 mV/V.

All resistivity sections and contours use a logrithmic colour scale with a contour interval of 10 levels per decade.

Chargeable bodies are represented in grey.

Electrodes are represented by arrows:

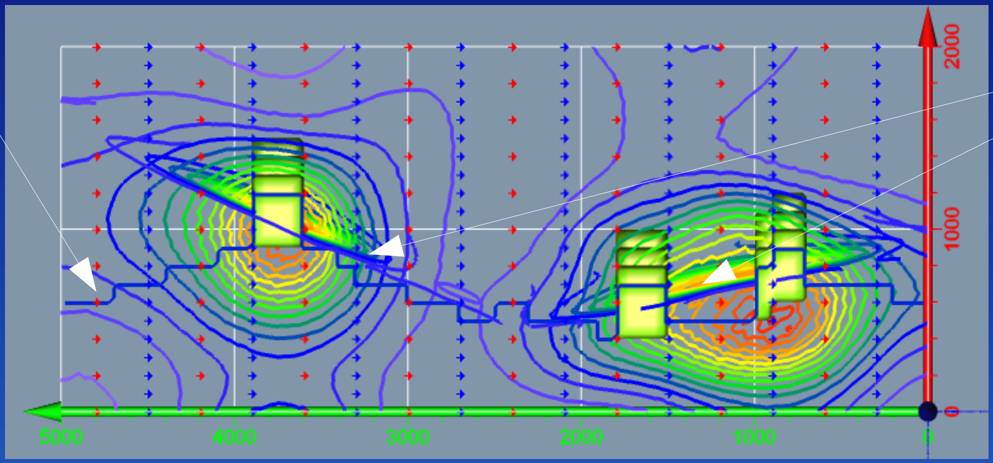
- Red for transmitters.
- Blue for receivers.

Plan sections show the trace of the fault. At the surface this is known as it can be directly observed with satellite imagery.

How to read the IP plans and sections

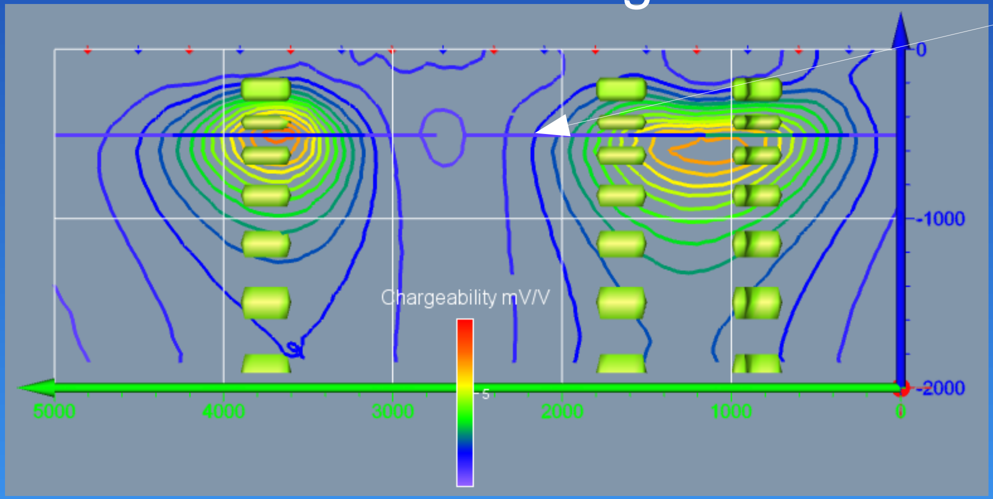
Fault - visible from space

Plan view



(a)
Long sections are bent through the centre of the mineralised bodies and tilted into the plane of the fault

Long section view



(b)
Plan section depth selected from the maximum response on the section, or through the chargeable body, depending on the model studied.

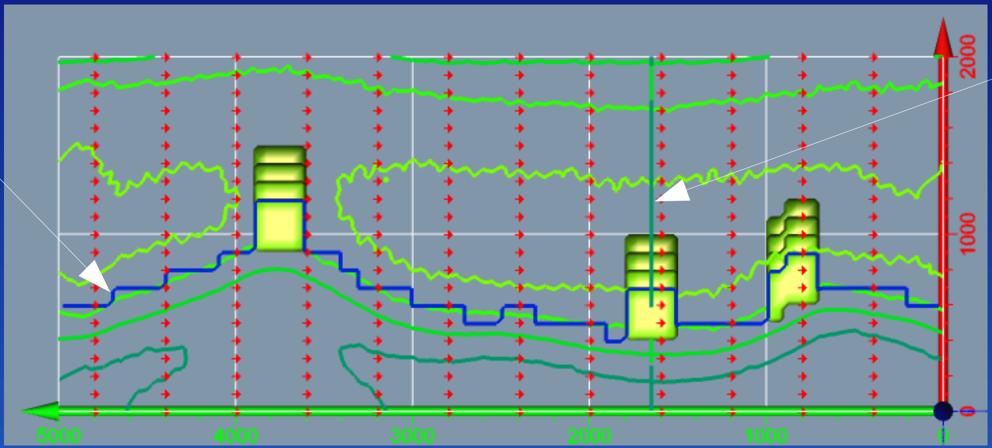
Location of the section can be seen on the plan view (a).
Location of the plan can be seen on the long section view (b).

How to read the resistivity plans and sections

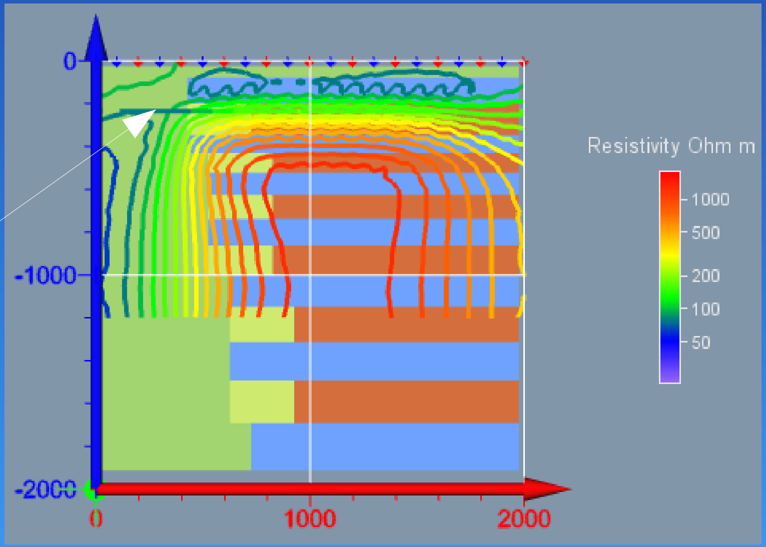
Fault - visible from space

Plan view

Cross-section at 1650m on the green axis, through the centre of the central mineralised body



Cross-section view



Plan section depth set to the centre of the upper chargeable body.