Terra Resources

ASEG Inversion Workshop: Examples of 3D Potential Field inversions – Low Latitudes and Remanence

B. Bourne, Principal Consultant, Terra Resources, 2nd September 2014

(bbourne70@gmail.com +61 409493485)

Introduction

- Remanence (and Porphyries)
- Alumbre Porphyry Project, Peru
- Geosoft MVI / IRI Inversion
- Regional Mafic Belt, Australia
- Conclusion

Magnetic Remanence - Causes

Terra Resources

- **Mineralogy/Lithology**
  - Fine grained magnetite (<20µm) eg rapidly chilled basalt, oxidised mafic intrusions (titanomagnetite)
  - Monoclinic pyrrhotite
- **Alteration**
  - Skarn
  - Hornfelsing
  - Or any processes resulting in above
- **Magnetisation History**
  - Systems that develop during long periods of consistent geomagnetic polarity much more likely to exhibit remanence-influenced signatures
  - Cretaceous Normal Superchron ~118 Ma to 83 Ma
  - Permo-Carboniferous (Kiaman) Reverse Superchron ~315 Ma to 260 Ma

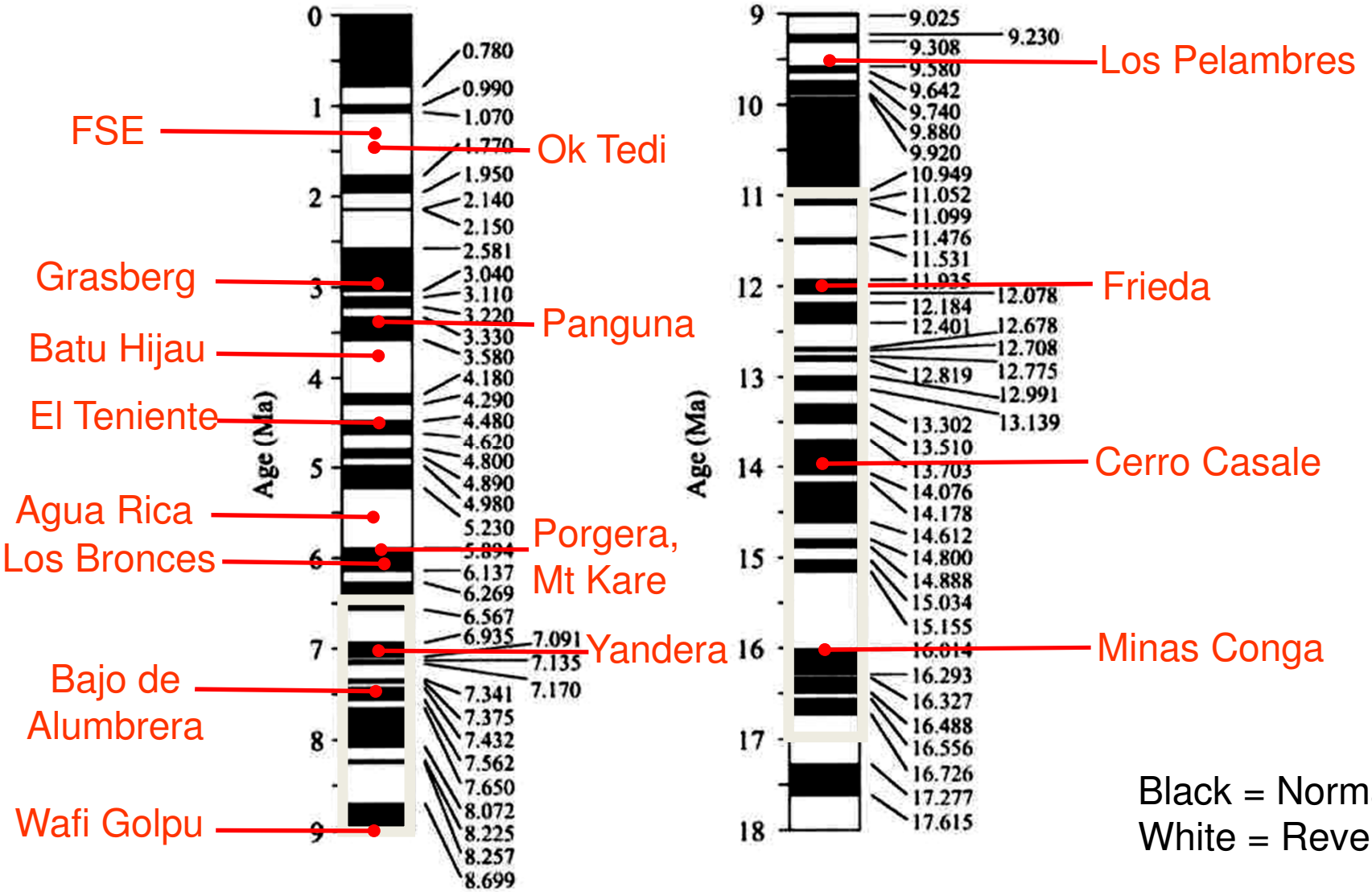
Implications for Porphyry Exploration

Terra Resources

- Most porphyry system magnetite is coarse-grained, therefore remanence < induced
- During age of mineralisation, earth's field direction was changing and multiphase intrusions/thermal events would be overprinted after each event cancelling out any likely effects of remanence
- **No known world class porphyry deposit with dominant remanent effects**
- Only likely source of remanence features in younger terrains are oxidised mafic intrusions and skarns
- Co-magmatic mafic events likely with world class porphyry districts

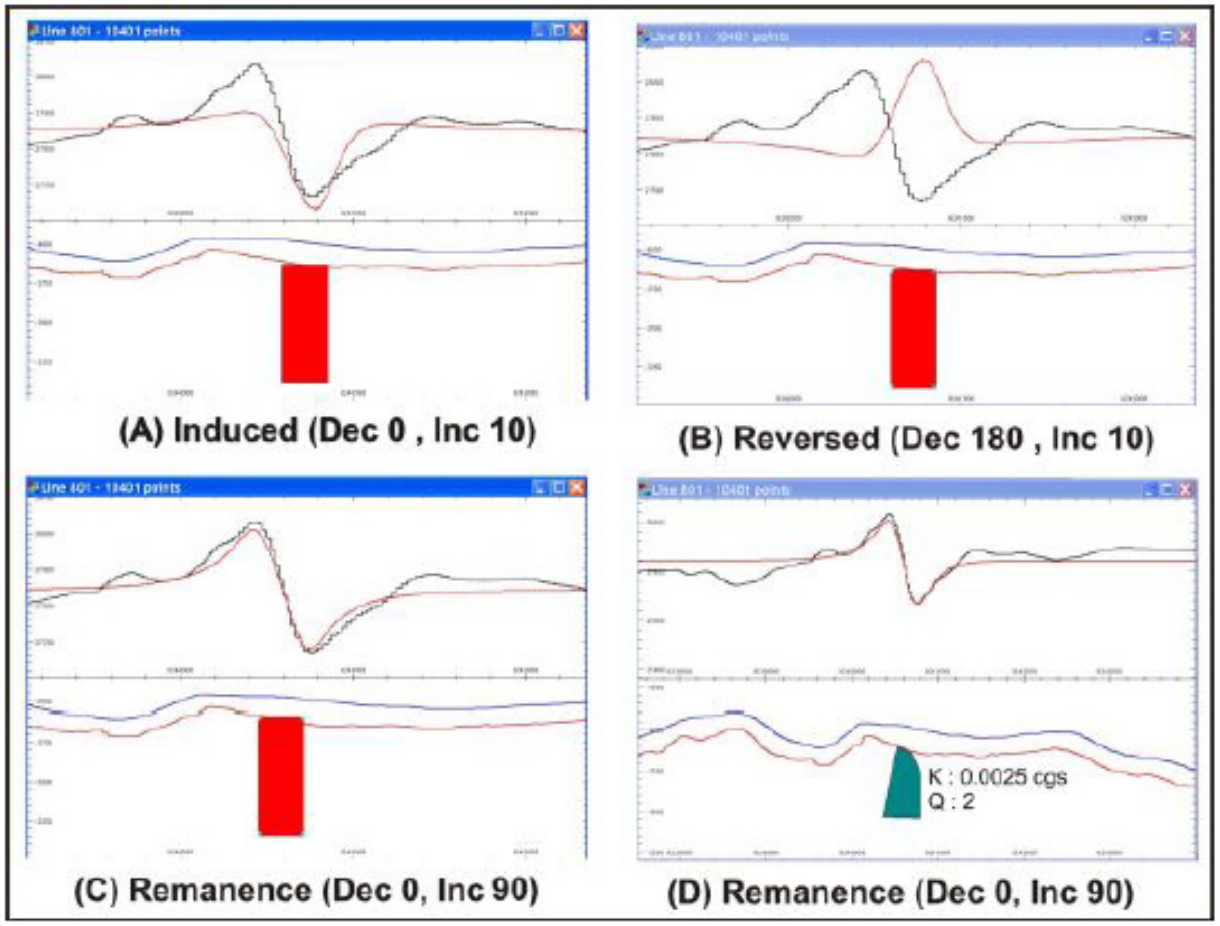
Implications for Porphyry Exploration

Terra Resources



Implications for Porphyry Exploration

Terra Resources



After Hoschke (2013)

- Hosche (2013) showed that porphyry a prospect in South America has significant remanence
- A number of magnetic targets in the surrounding area are thought to have been missed because remanence was not considered
- After trialling new modelling inversion methods (such as MVI) better fits with geology/ susceptibility were being obtained when drilling for porphyries especially at low latitudes

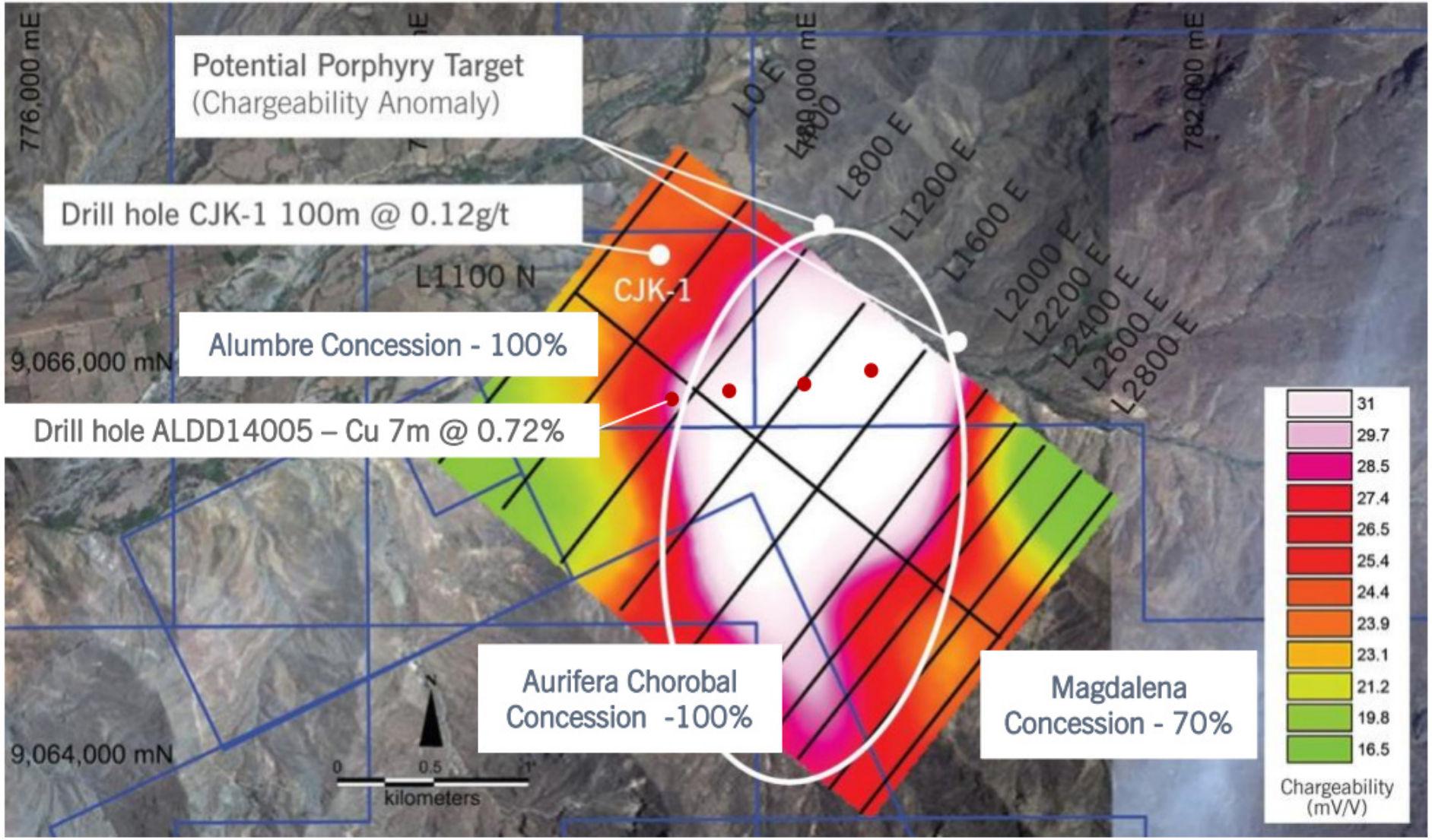
Alumbre Project – Peru Deposits

Terra Resources

PROMESA

Alumbre Project – Induced Polarisation

Terra Resources

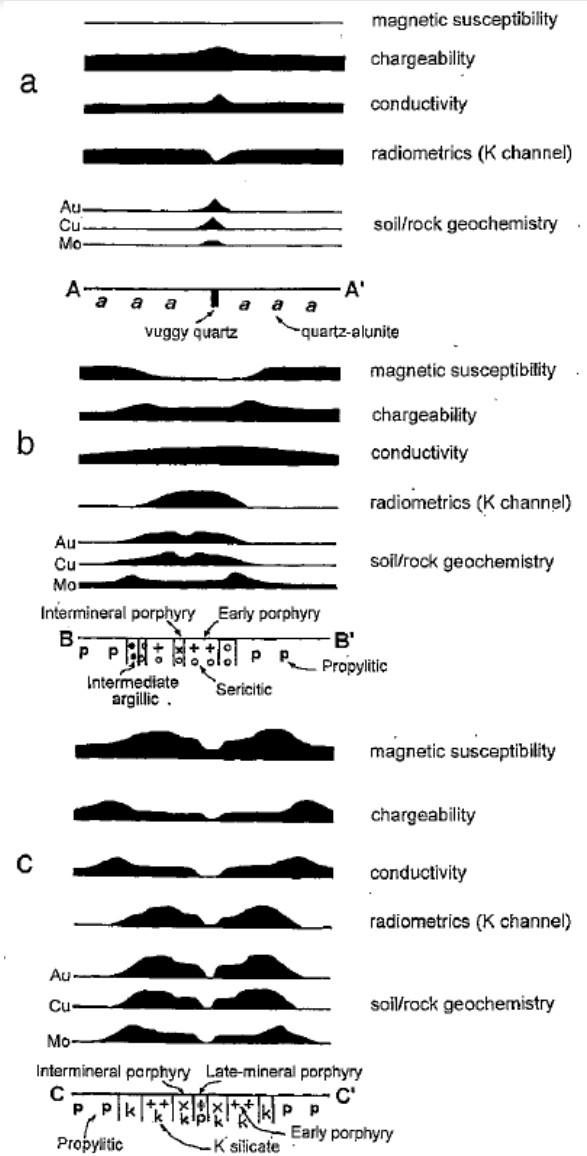


Geophysics Chargeability Results at 400m depth

PROMESA

Au Rich Porphyry Geophysics

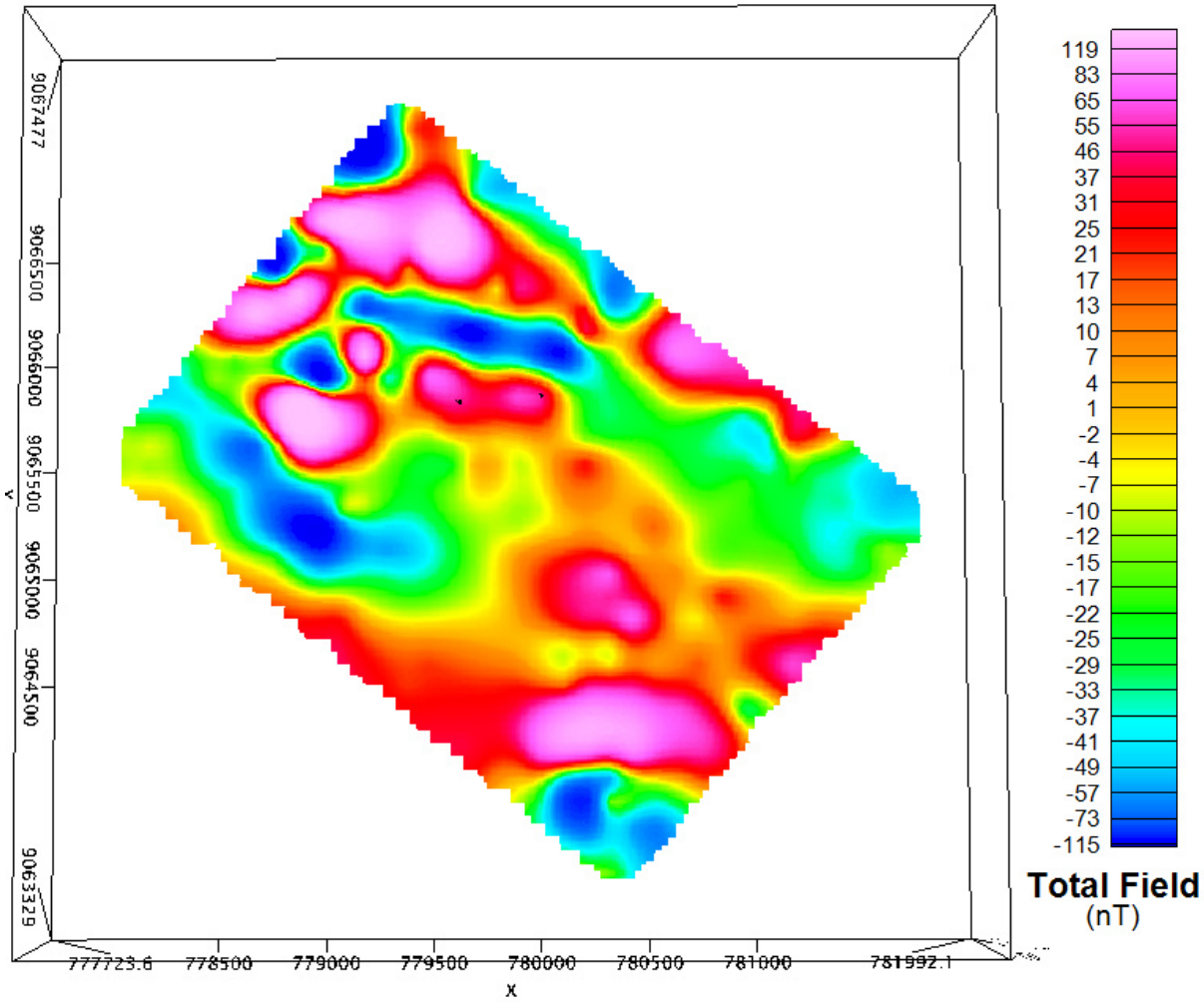
Terra Resources

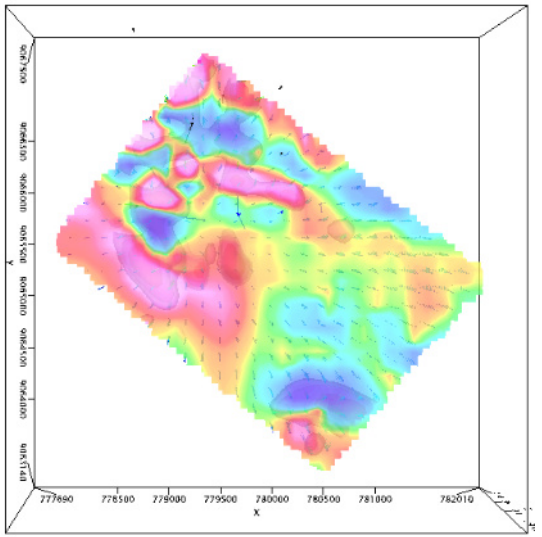


After Silitoe (2000)

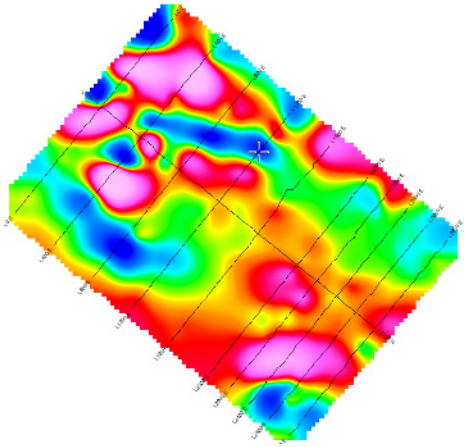
Alumbre Project - Ground Magnetics

Terra Resources





Residual Magnetics – RTP (amplitude correction 70 applied)



Residual Magnetics – TF (400m line spacing in NW and 200m in SE)

Residual Magnetics – Total field data used for magnetic inversion from ground data

PROMESA

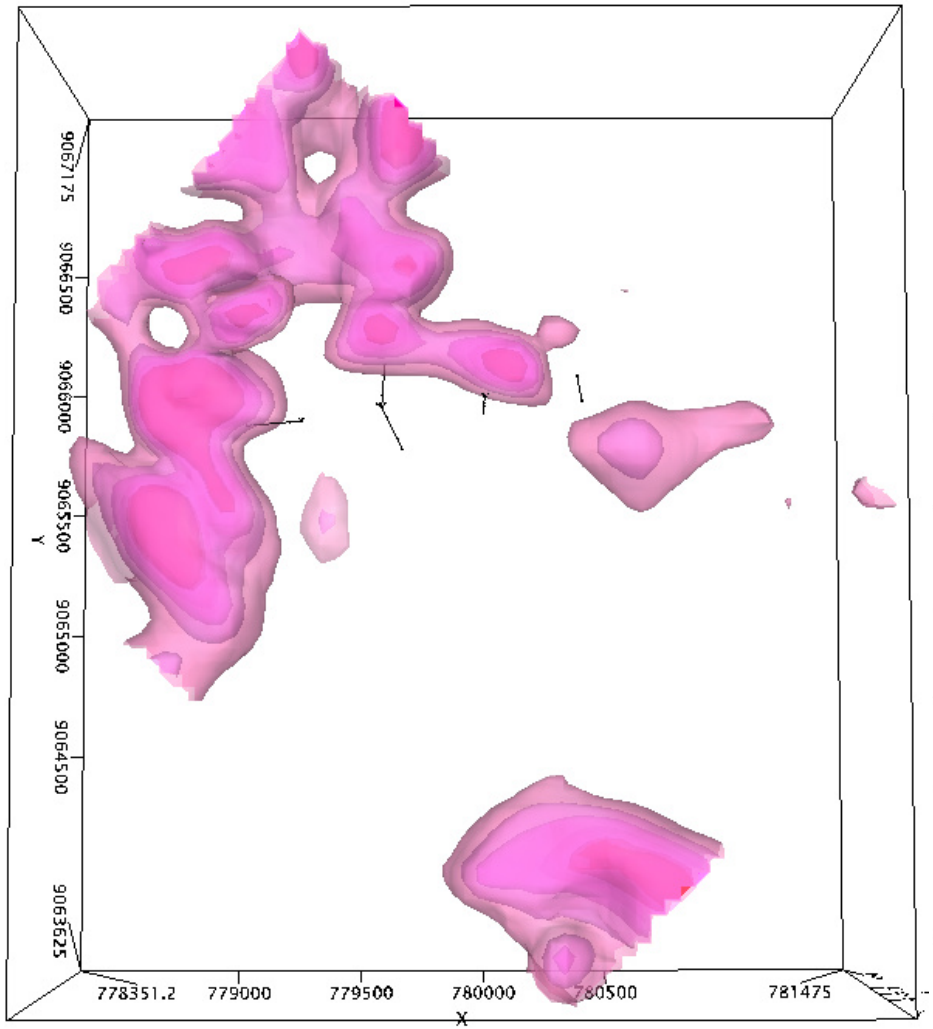
Magnetic Vector Inversion Modelling

Terra Resources

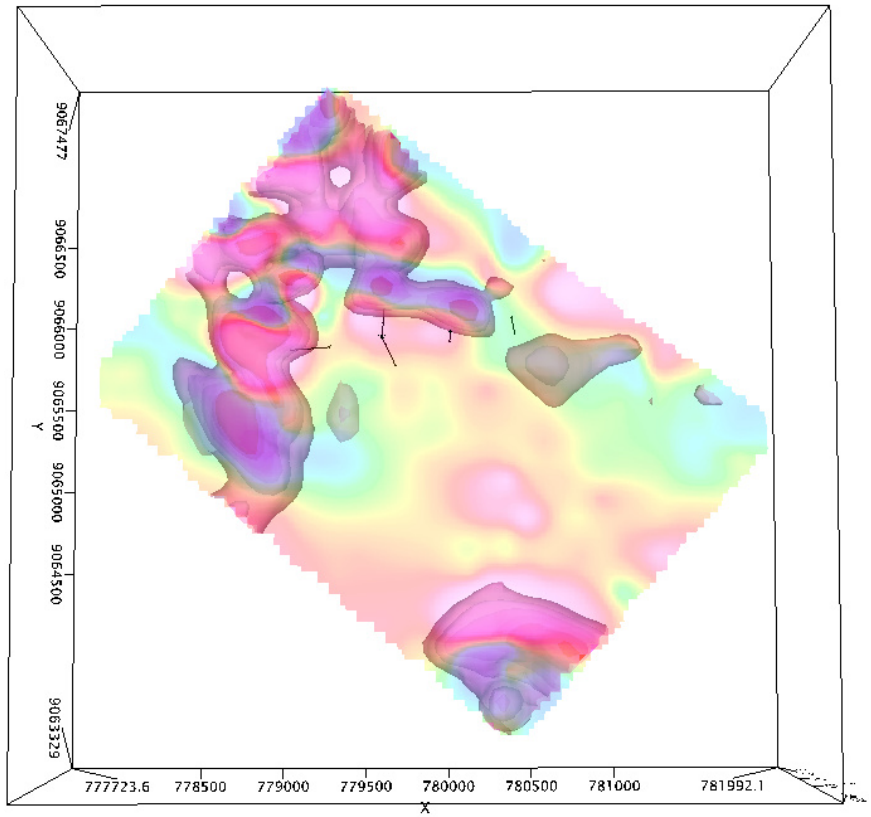
- Detailed magnetic modelling using Magnetic Vector Inversion (Ellis, 2012)
- MVI directly models the vector of magnetization based only on anomalous TMI data
- The method allows the modelling optimization process the freedom to orient the direction of magnetization to best fit the observed data
- Allows the interpreter to model features that may contain combination of remanent magnetization, demagnetization or anisotropic magnetic minerals
- MVI allows modelling of the different orientation of the magnetic field caused by porphyry intrusion at Alumbre
- Typical MVI modelling using 50 x 50 x 25m voxel, on 200m/400m ground magnetic data (single tie line)

Alumbre Project – Magnetic Vector Inversion

Terra Resources



Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink.

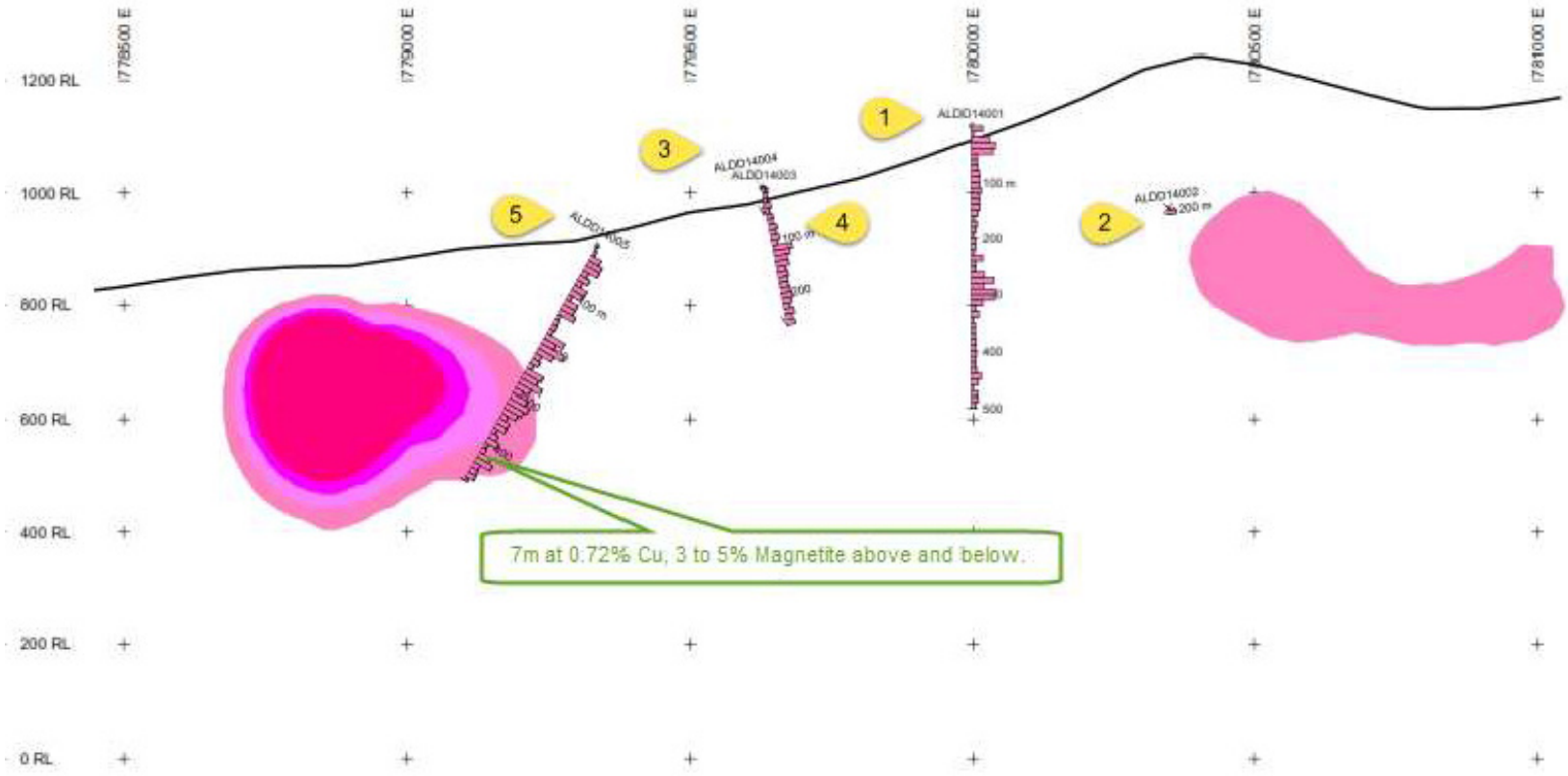


Total field magnetics with +10x10-3 SI* isosurface from the 3D MVI inversion in grey underneath.

Alumbre Project – Susceptibility Sections

Terra Resources

Section 9065750N

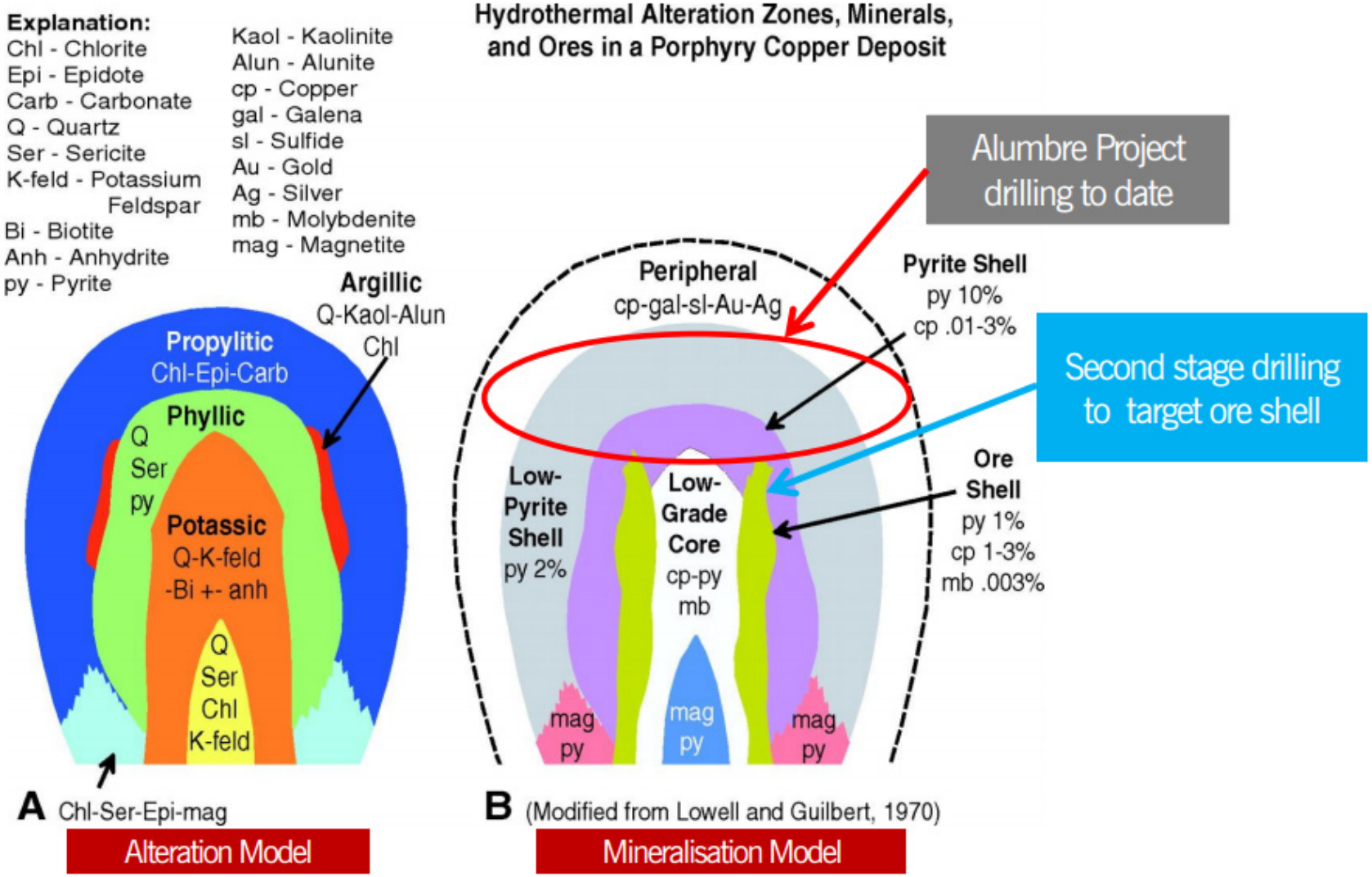


Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink. Centre +15 x 10-3 SI* in red, equivalent to +0.5% magnetite.

PROMESA

Alumbre Project - Geological Model

Terra Resources

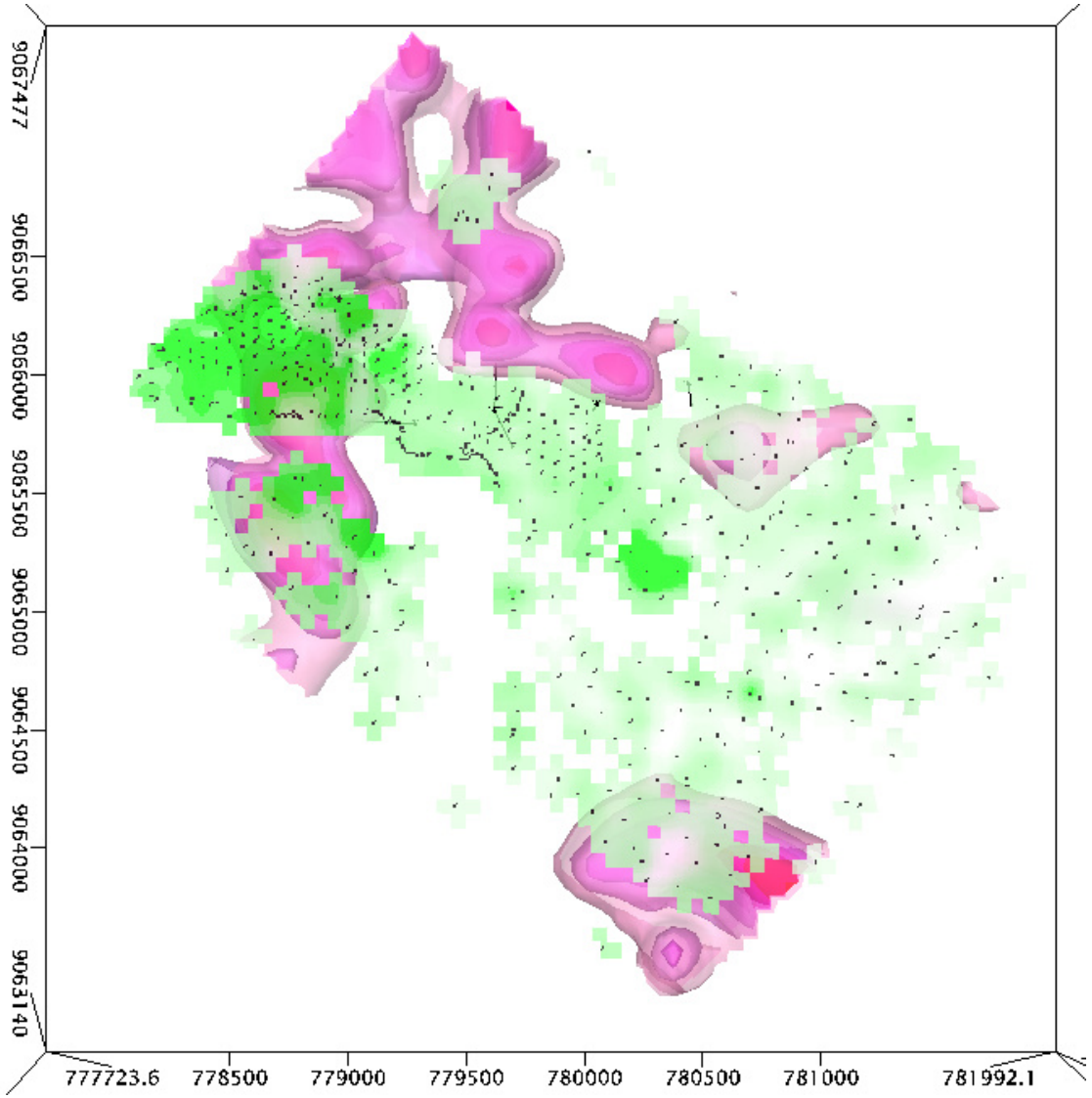


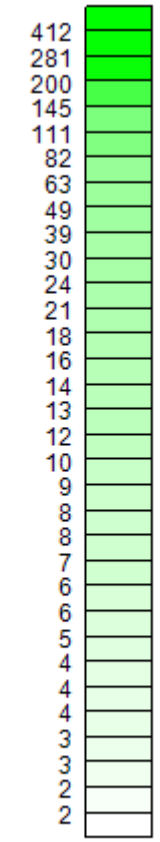
Section View - Illustrated deposit model of a porphyry copper deposit (modified* from Lowell and Guilbert, 1970).** * Geosphere May 2006 vol. 2 no. 3 161-186 **Lowell, J.D., and Guilbert, J.M., 1970, Lateral and vertical alteration-mineralization zoning in porphyry ore deposits: Economic Geology, v. 65, p. 373–408

Alumbre Project - Modelling / Copper

Terra Resources

Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink. Centre +15 x 10-3 SI* in red, equivalent to +0.5% magnetite.

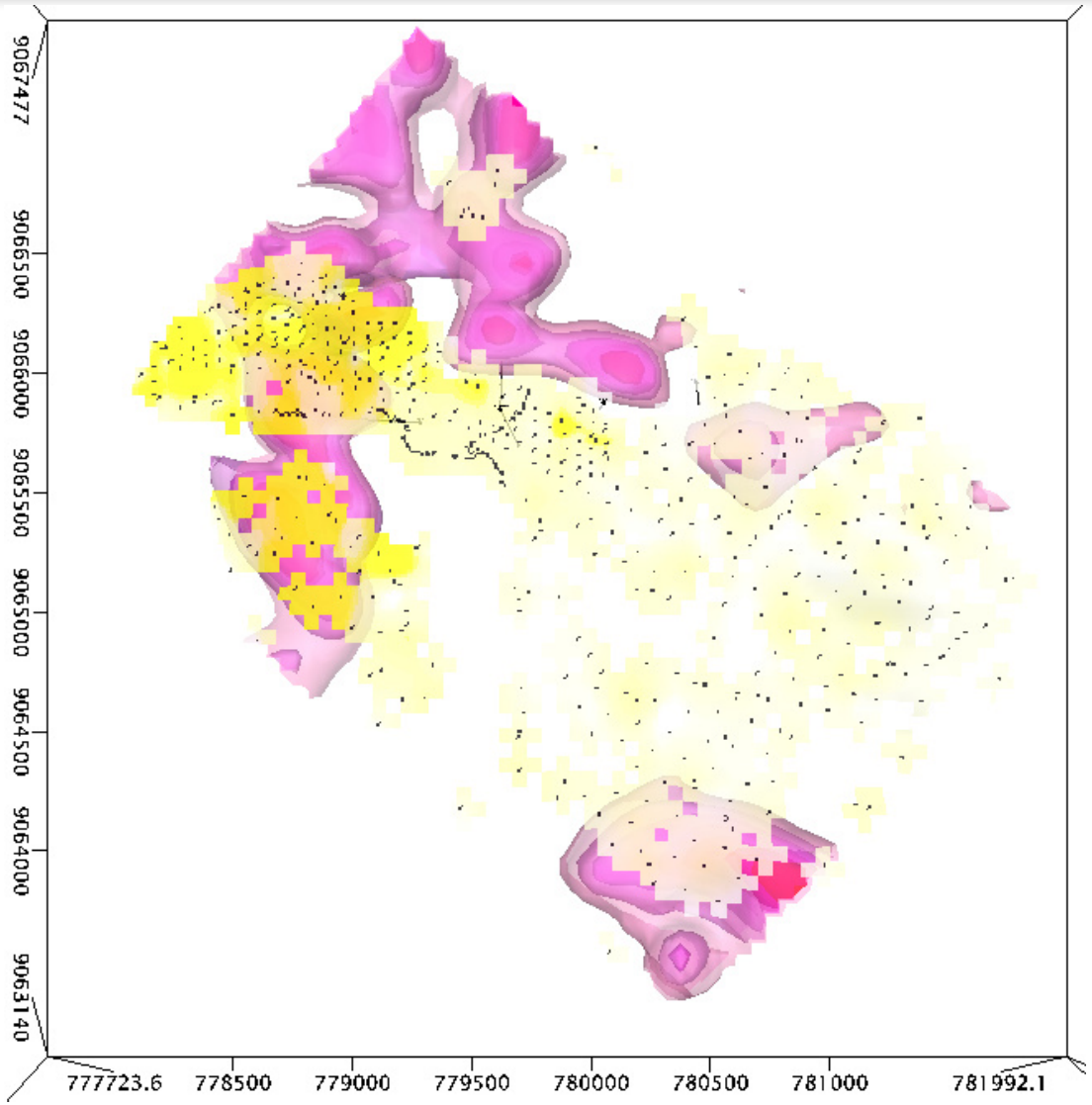


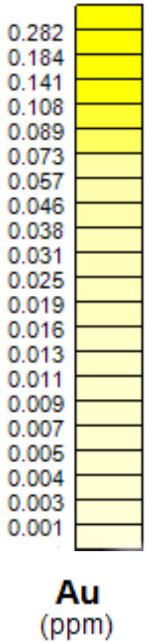


PROMESA

Alumbre Project - Modelling / Gold

Terra Resources





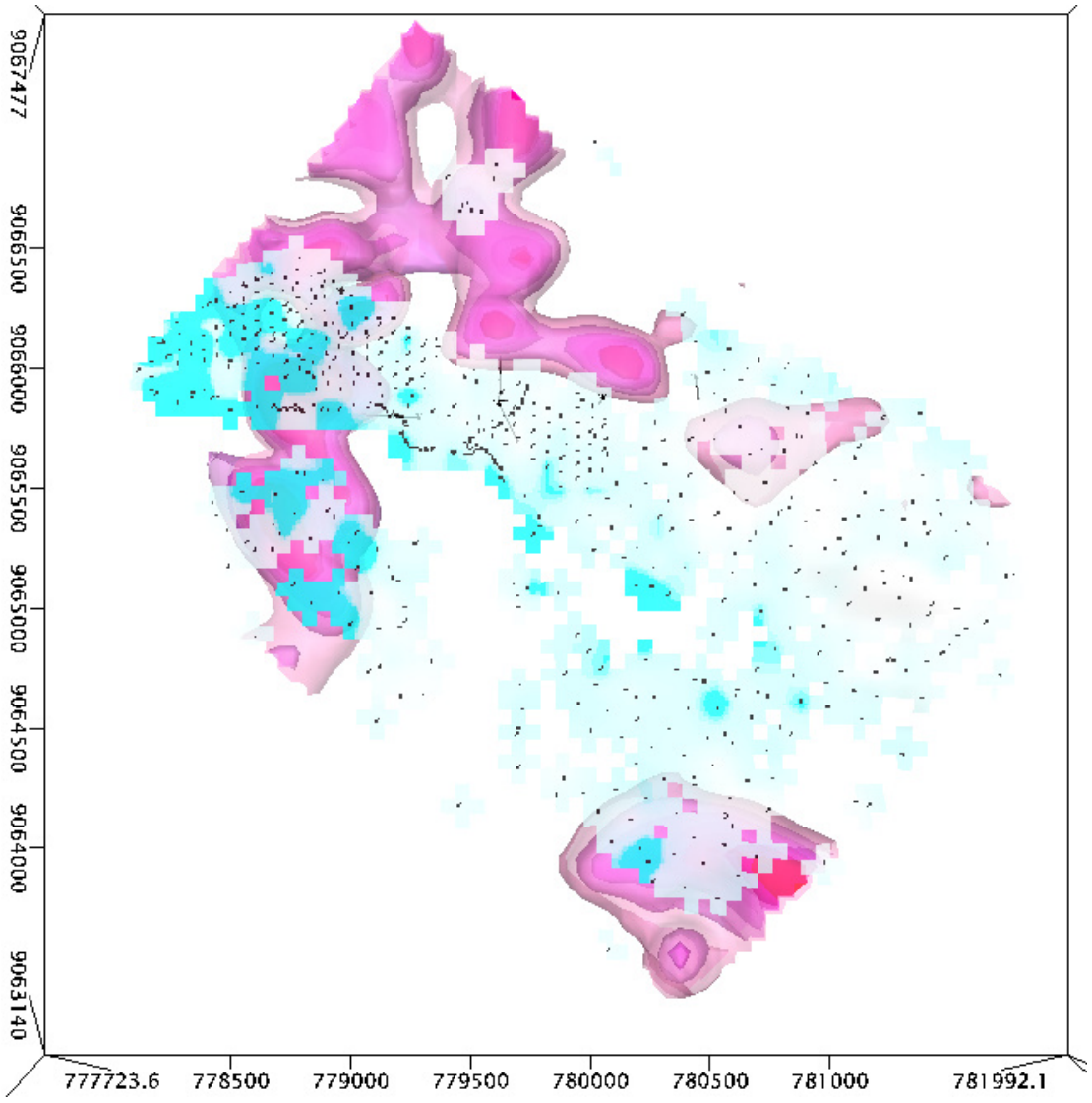
Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink. Centre +15 x 10-3 SI* in red, equivalent to +0.5% magnetite.

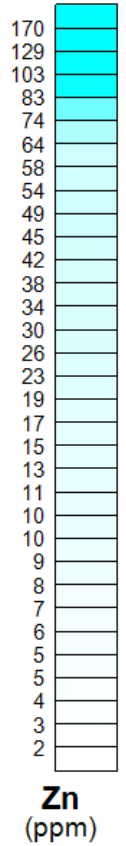
PROMESA

Alumbre Project - Modelling / Zinc

Terra Resources

Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink. Centre +15 x 10-3 SI* in red, equivalent to +0.5% magnetite.



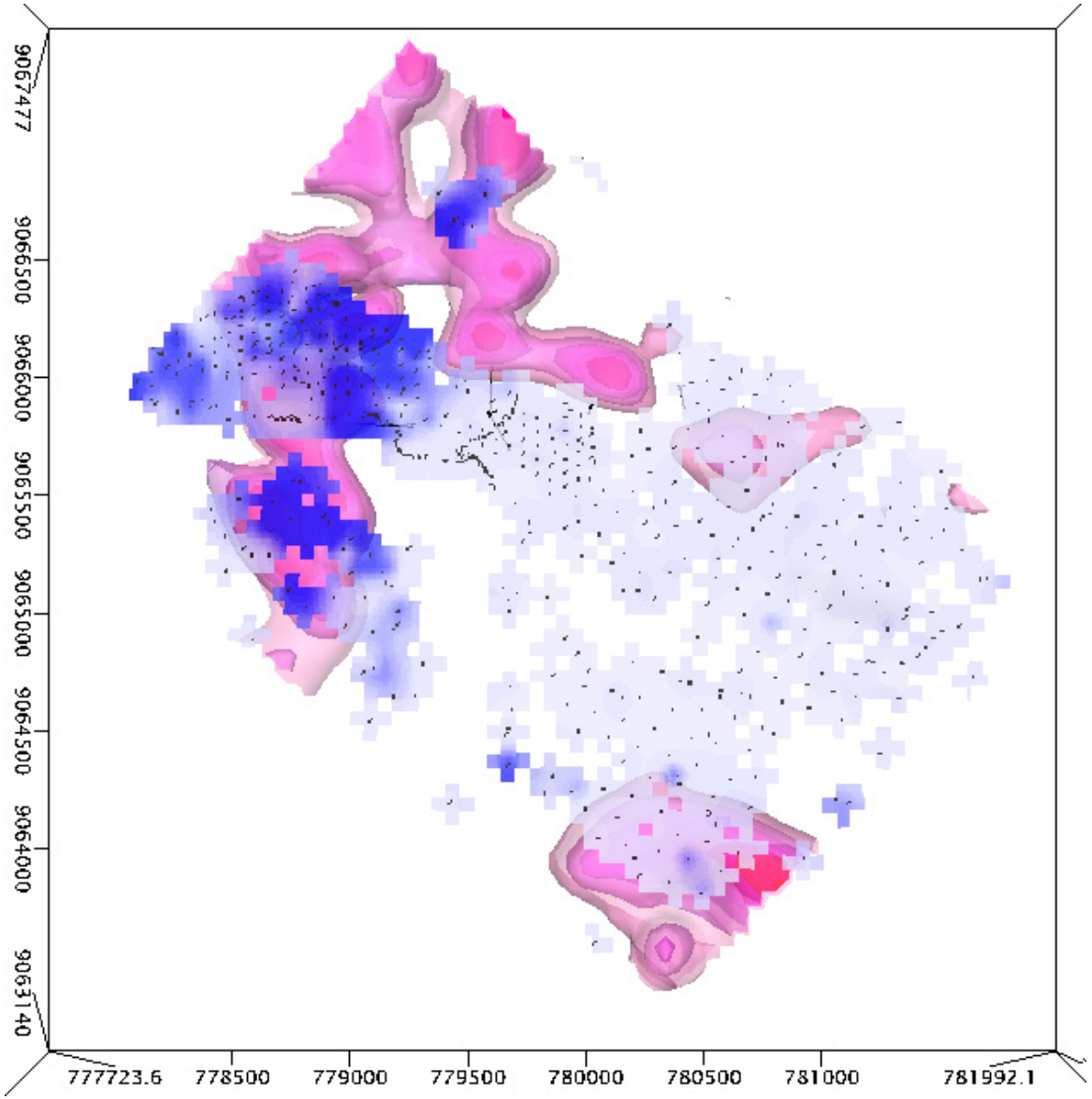


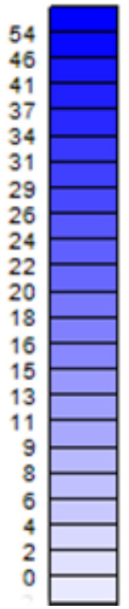
PROMESA

Alumbre Project - Modelling / Mo

Terra Resources

Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink. Centre +15 x 10-3 SI* in red, equivalent to +0.5% magnetite.

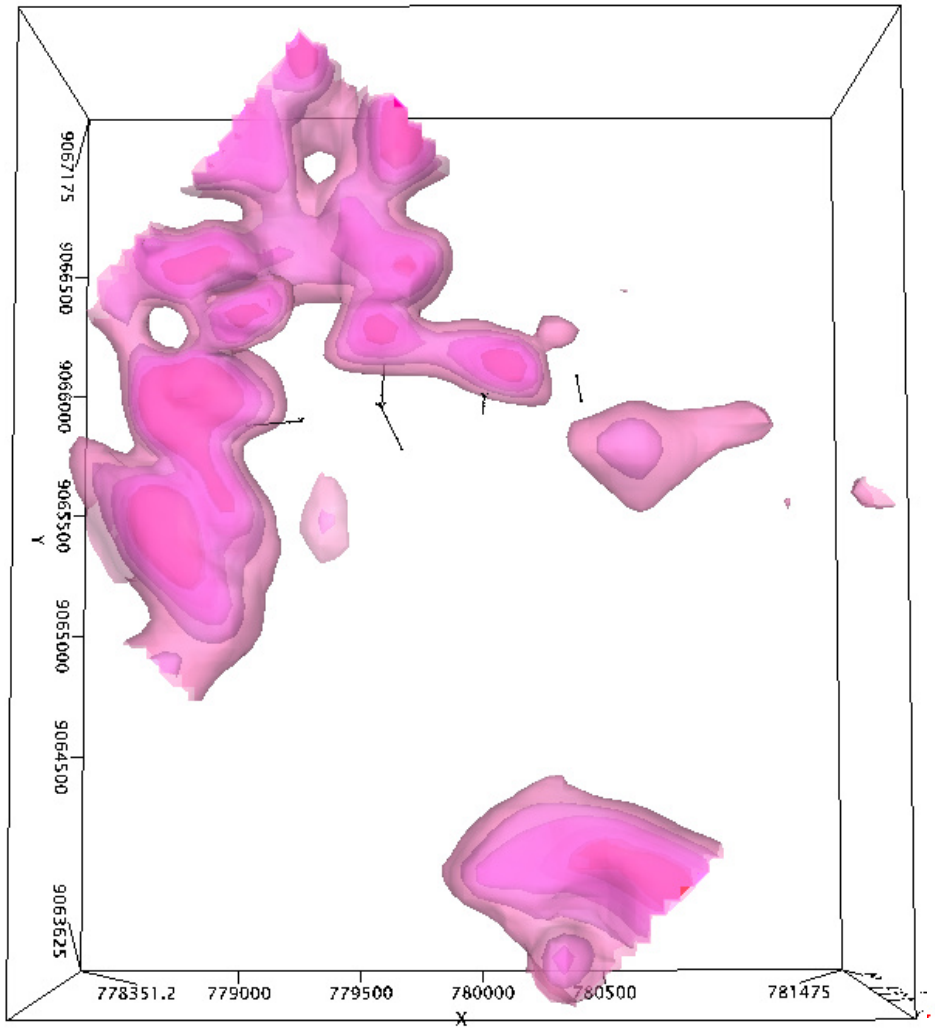




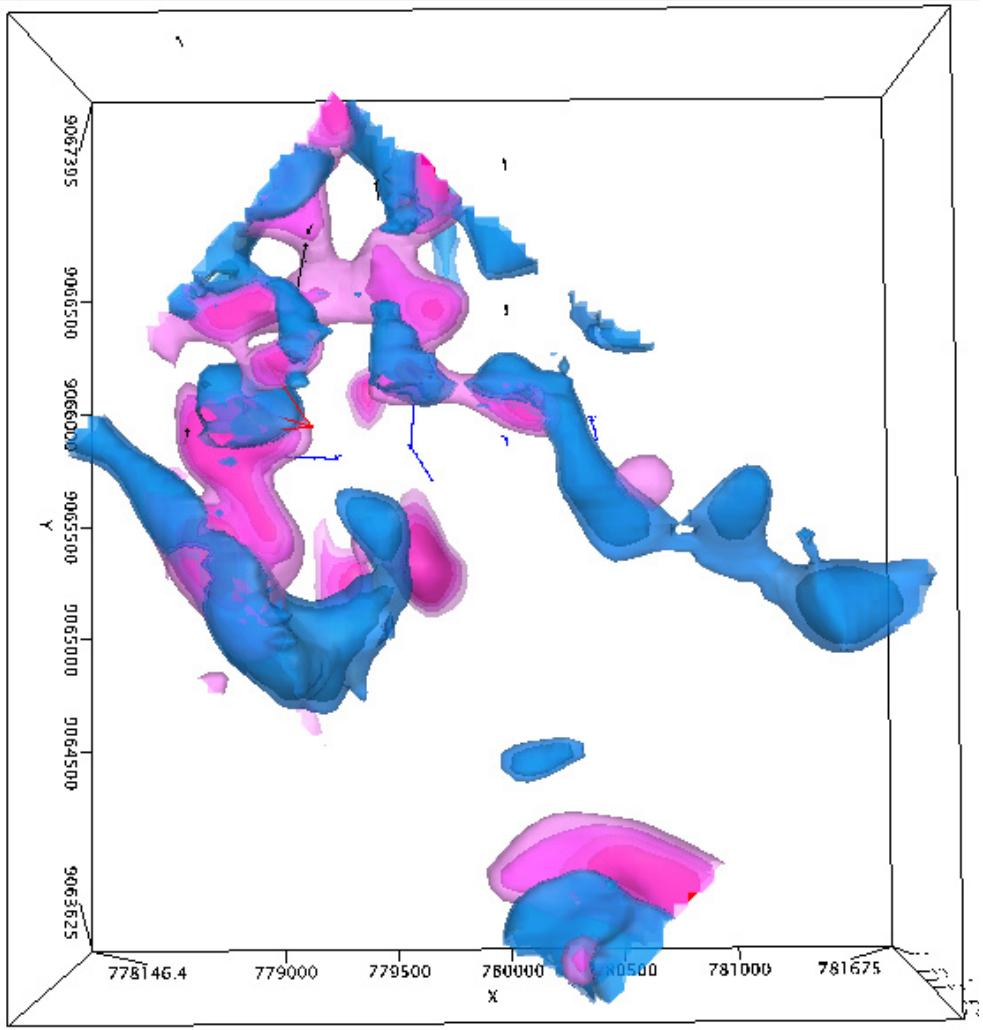
PROMESA

Alumbre Project - Magnetic Inversion

Terra Resources



Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink.

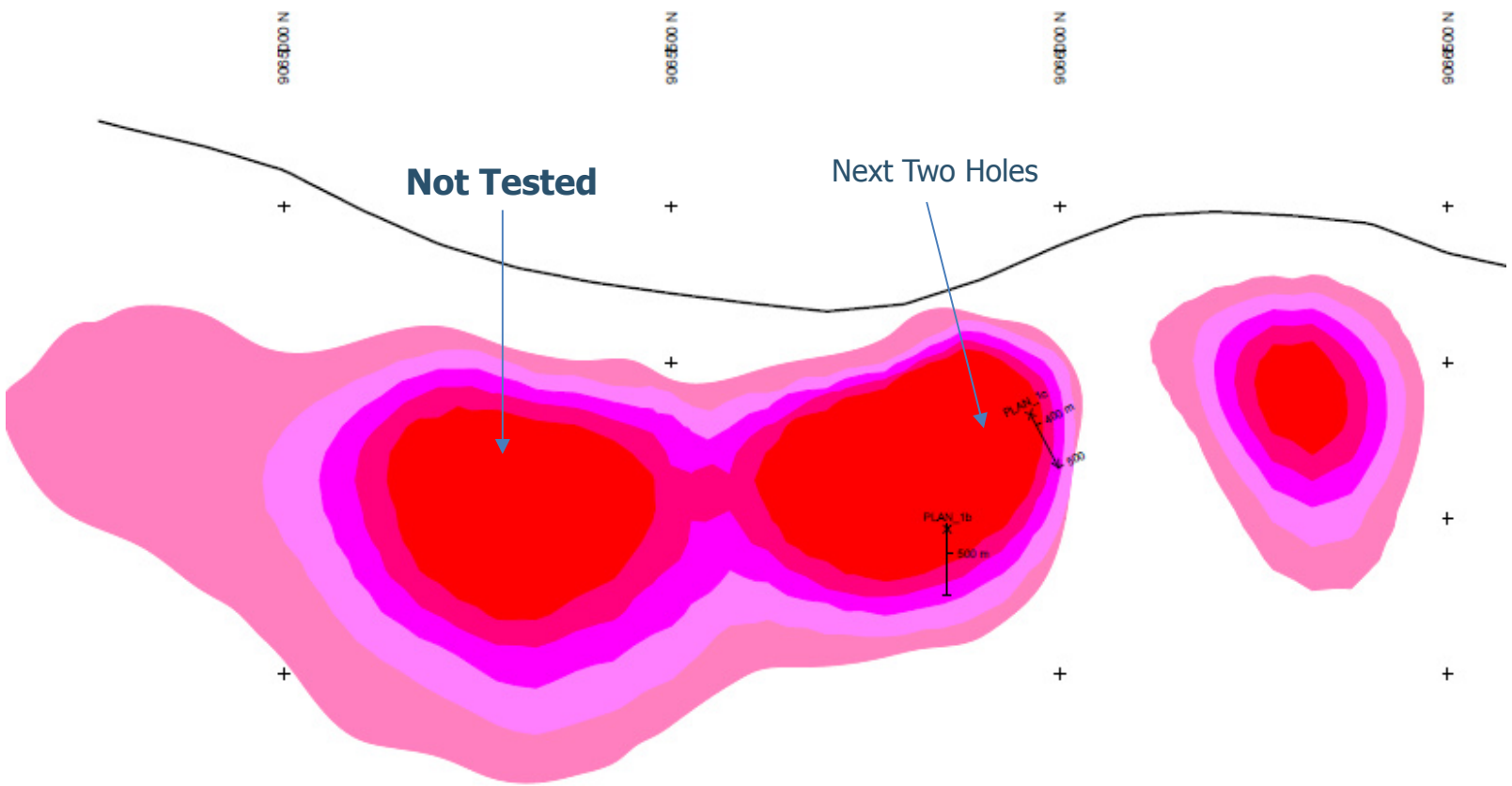


Modelled magnetics with +10x10-3 SI* isosurface from the 3D MVI inversion in pink and IRI standard inversion in blue.

Promesa – Alumbre Sections

Terra Resources

Section 778900E

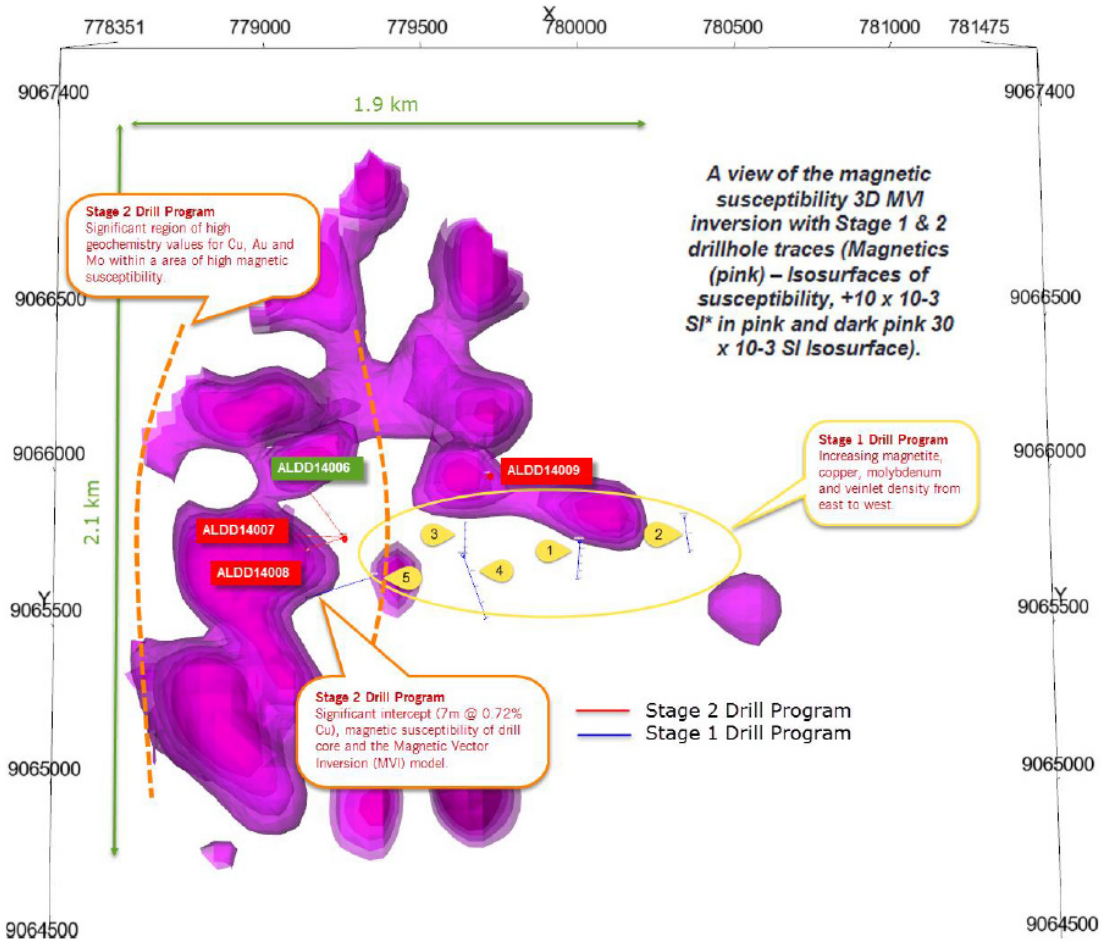


Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink. Centre +15 x 10-3 SI* in red, equivalent to +0.5% magnetite.

PROMESA

Alumbre Project - Drilling

Terra Resources



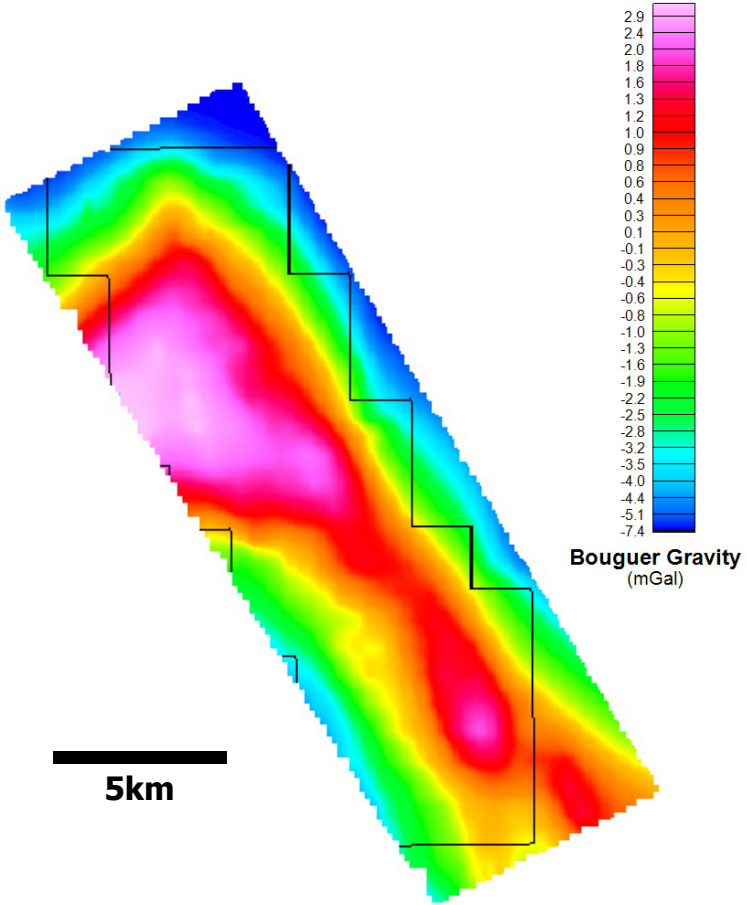
"The first drill hole, ALDD14006 has progressed to 303m with chalcopyrite and magnetite observed and increasing with depth" 28/9/14

Magnetics (pink) – Isosurfaces of susceptibility, +10 x 10-3 SI* in pink. Centre +15 x 10-3 SI* in red, equivalent to +0.5% magnetite.

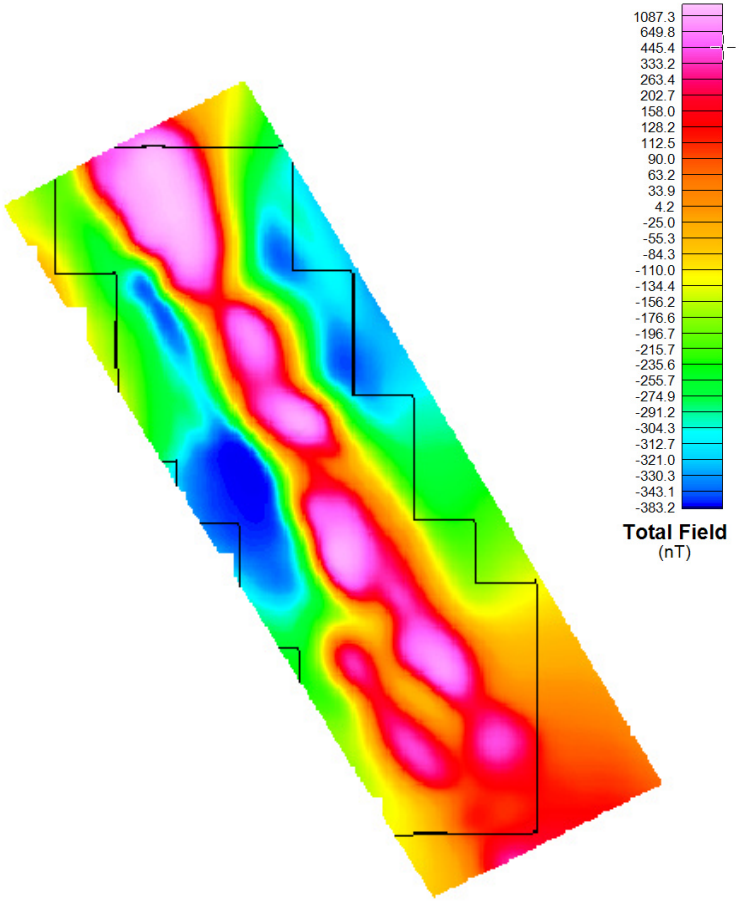
PROMESA

Regional Mafic - Modelling

Terra Resources



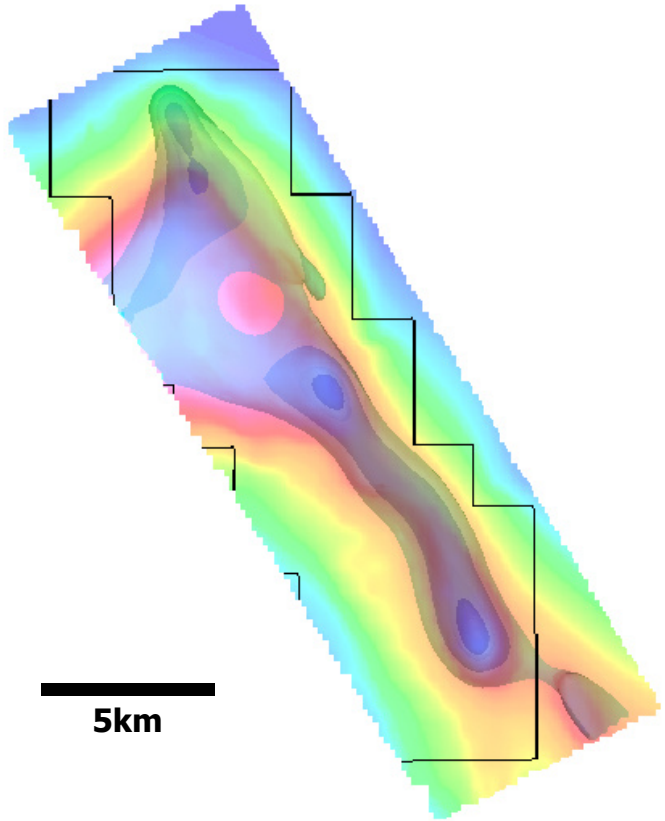
Detailed Bouguer Gravity – Residual gravity image, used for modelling, over the area of interest (200m grid resolution)



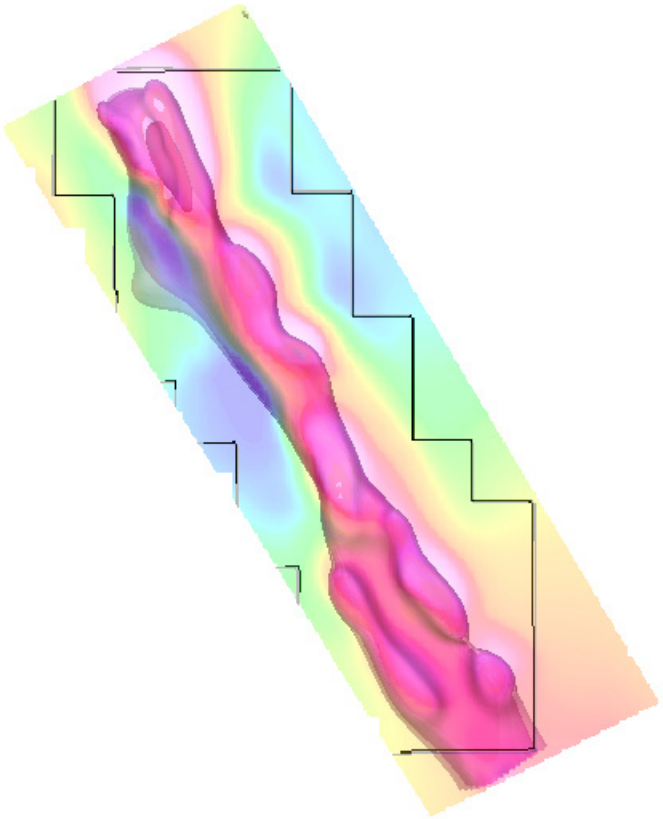
Detailed Magnetics– Residual TMI image over the area of interest (50m grid resolution)

Regional Mafic - Modelling

Terra Resources



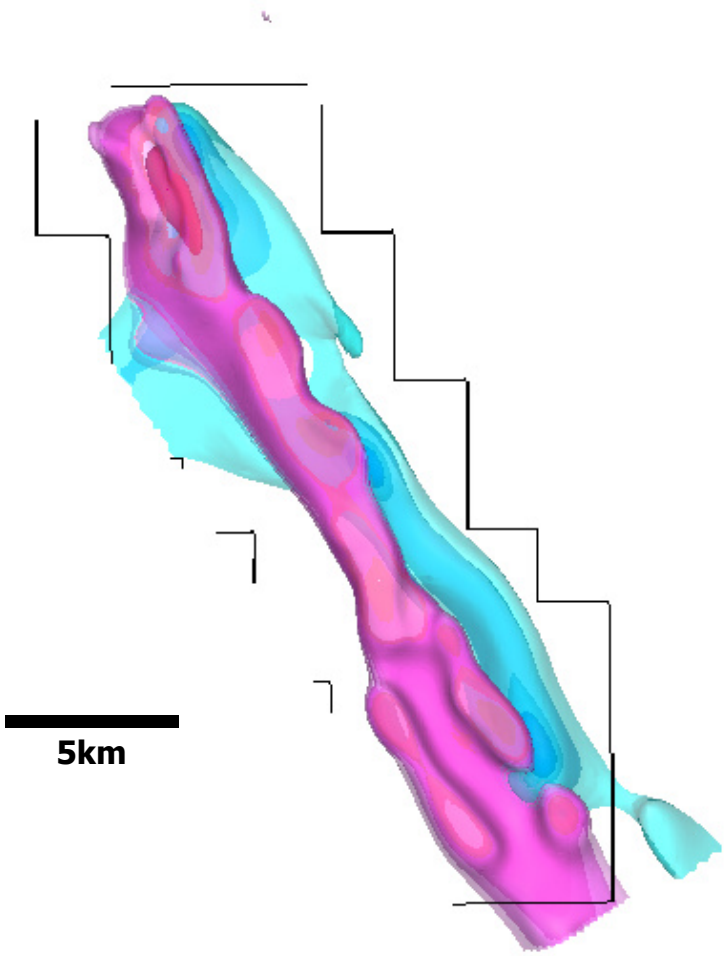
Detailed Bouguer Gravity – Residual gravity image over the area of interest with gravity inversion in blue.



Detailed Magnetics– Residual TMI image over the area of interest with standard magnetic inversion results in pink.

Regional Mafic - Modelling

Terra Resources

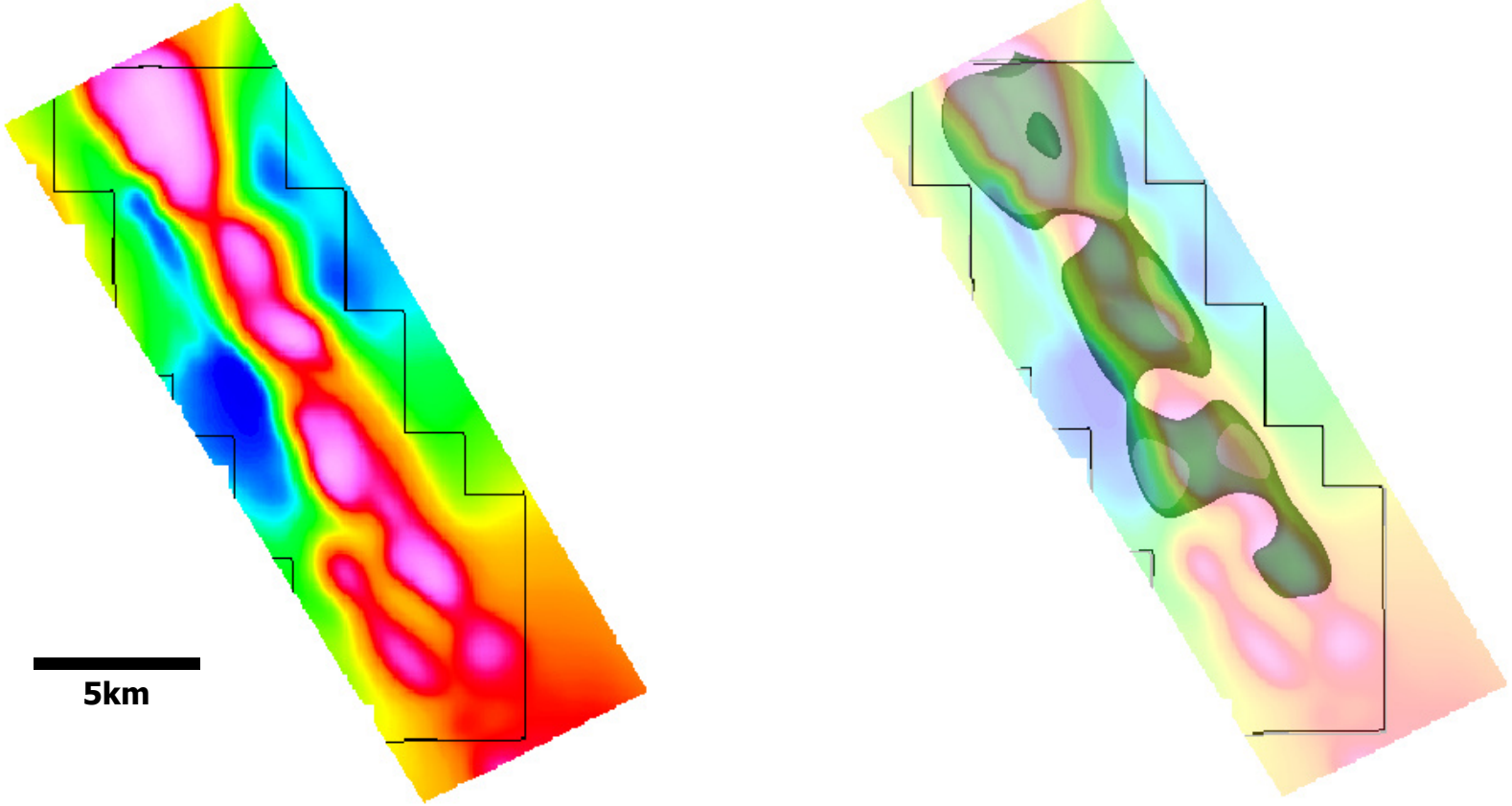


Magnetic Inversion (Pink) – Isosurfaces of susceptibility, +10 x 10-3 SI in pink. Darker pink/red +50 x 10-3SI. (depth to shallowest part of model~150m)

Gravity inversion (blue)– Isosurfaces of density, +0.05 light blue outer shell,+0.15g/cc in dark blue smallest (depth to shallowest part ~400m, but could be shallower as sampling is at 200m along line).

Regional Mafic - Modelling

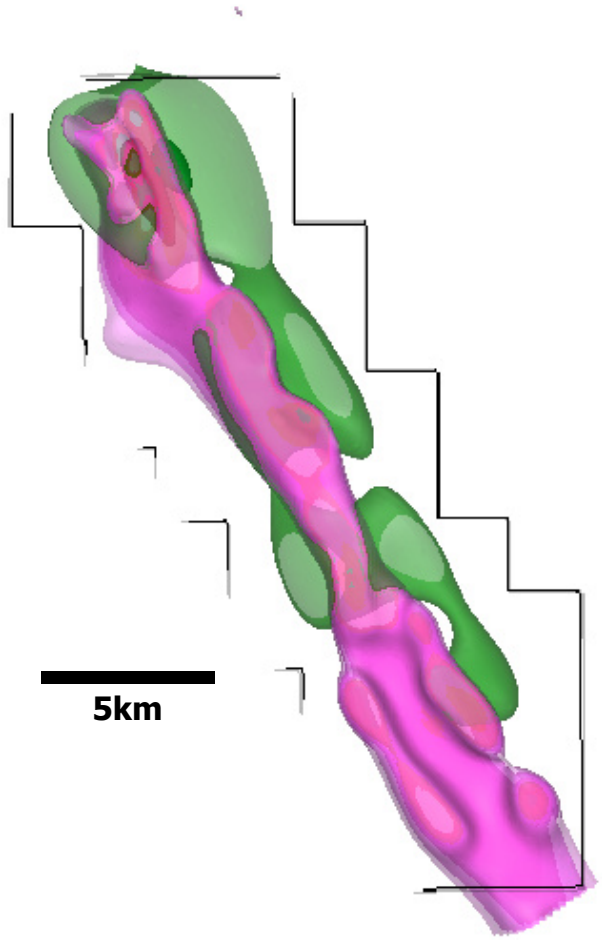
Terra Resources



Detailed Magnetics– Residual TMI image over the area of interest with MVI magnetic inversion results in green.

Regional Mafic - Modelling

Terra Resources

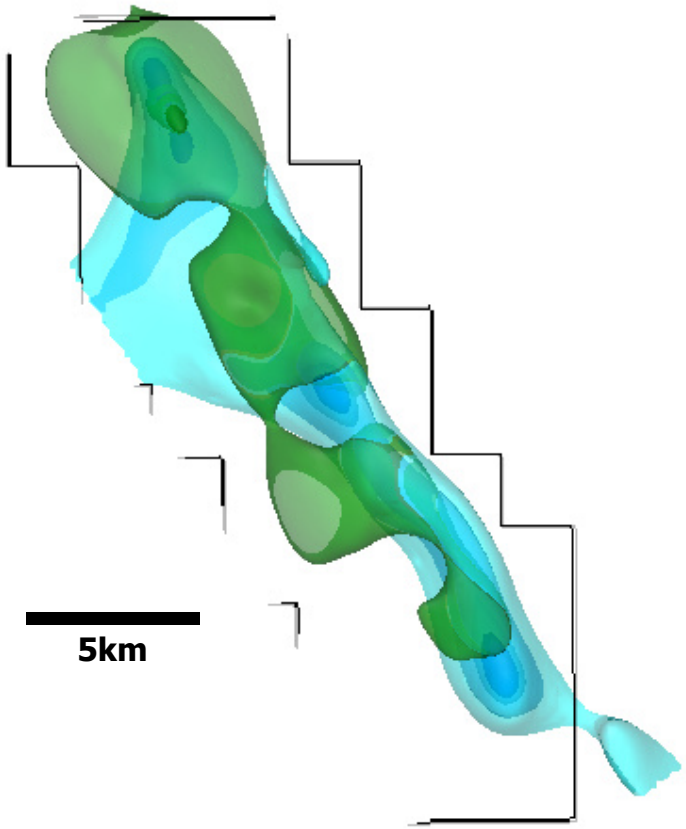


Detailed Magnetic Inversion –MVI magnetic inversion results in green and standard inversion results in pink.

Standard Inversion technique creates a narrower body. The MVI inversion creates a broader anomaly. The MVI inversion puts part of the body further east than the standard inversion. The MVI inversion model is about 100m deeper than the standard model.

Regional Mafic - Modelling

Terra Resources



Detailed Inversion –MVI magnetic inversion results in green and gravity inversion results in blue.

The MVI inversion seems to correlate better with the gravity than the standard magnetic inversion.

Conclusions

- Recent advances in 3D inversion methods have led to the availability of techniques that look to address more complicated geological/ geophysical problems and challenge conventional thinking.
- After trialling new modelling inversion methods (such as MVI) better fits with geology/ susceptibility were being obtained when drilling for porphyries especially at low latitudes
- In addition, at a regional scale, geological features that appear to be normally magnetised may in fact have a remanent component.
- Alternative modelling techniques should be trailed and **all** data considered before planning follow-up exploration.

ASEG Inversion Workshop: Examples of 3D Potential Field inversions – Low Latitudes and Remanence

B. Bourne, Principal Consultant, Terra Resources, 2nd September 2014

(bbourne70@gmail.com +61 409493485)