Improved depth distributions by inversion of magnetic surveys collected at different survey heights

Bob Lo, BHL Earth Sciences

Ross Groom, PetRos EiKon

Topics

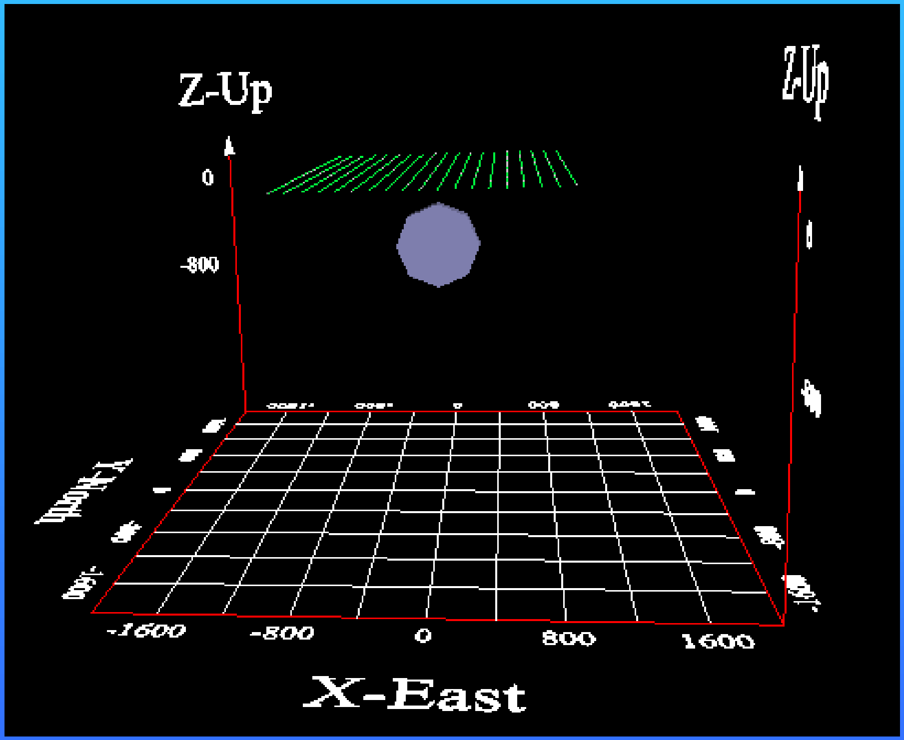
- Introduction - motivation
- simple rationale behind method
- EMIGMA inversion software - its magnetic inversion design
- synthetic models
- Perseverance Case History
- summary

Motivation

- In Canada ,where there is a modern aeromagnetic survey, there should be an older survey at a higher elevation flown for the GSC years before,
- and that survey heights have been decreasing over the past decades.

- Other examples
  - ground follow-up data beneath airborne,
  - OTH Fort Good Hope Survey has magnetics as part of an EM survey at 71 metres, and an aeromagnetic / radiometrics survey at 100 metres
- the data at two different levels should be useful – but no one is making use of it.

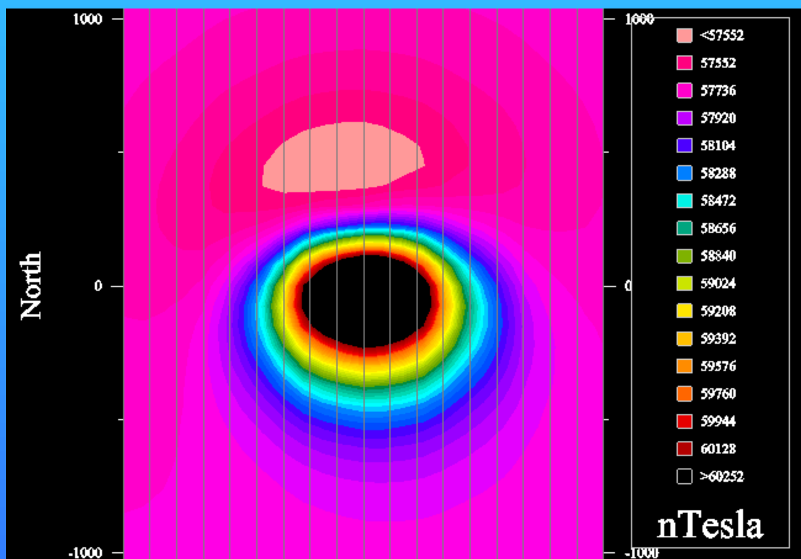
Why would data at two different levels be useful?



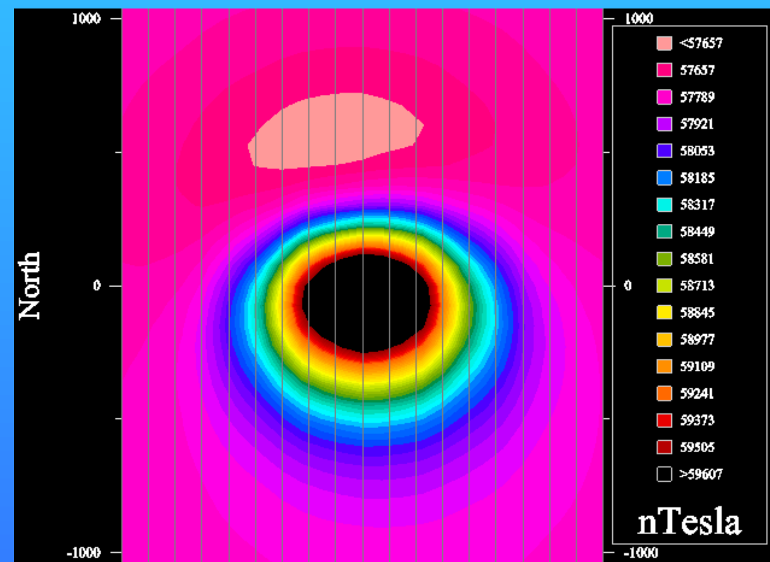
- Demonstrate using forward model of magnetic data collected at 80 and 150 metres above ground
- source: simple vertical disc oriented east-west (axis of symmetry is horizontal and pointing N-S)
- 150 metres thick, 300 metres radius,
- centre of disc is 350 metres below ground
- susceptibility =1 SI units

Forward models

TMI @ 80 m elevation



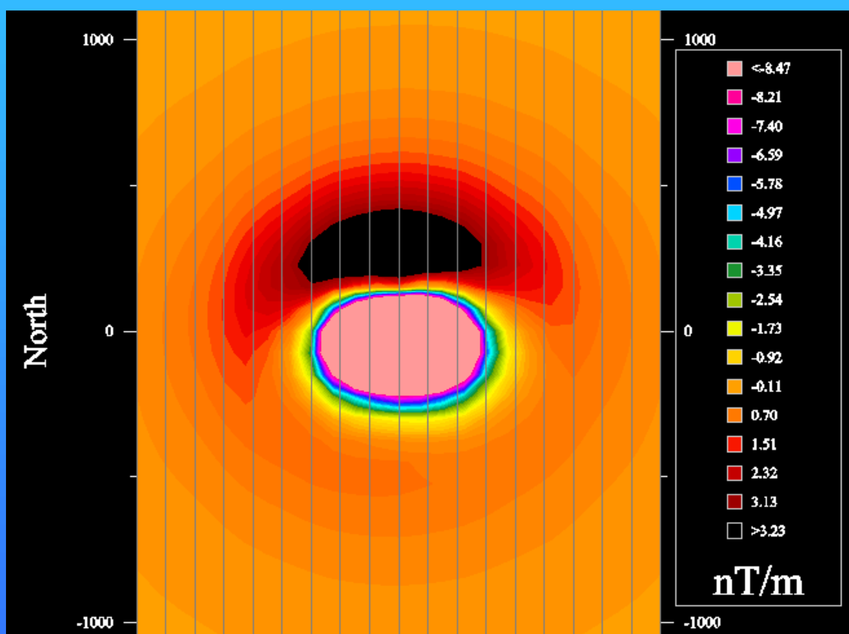
TMI @ 150 m elevation



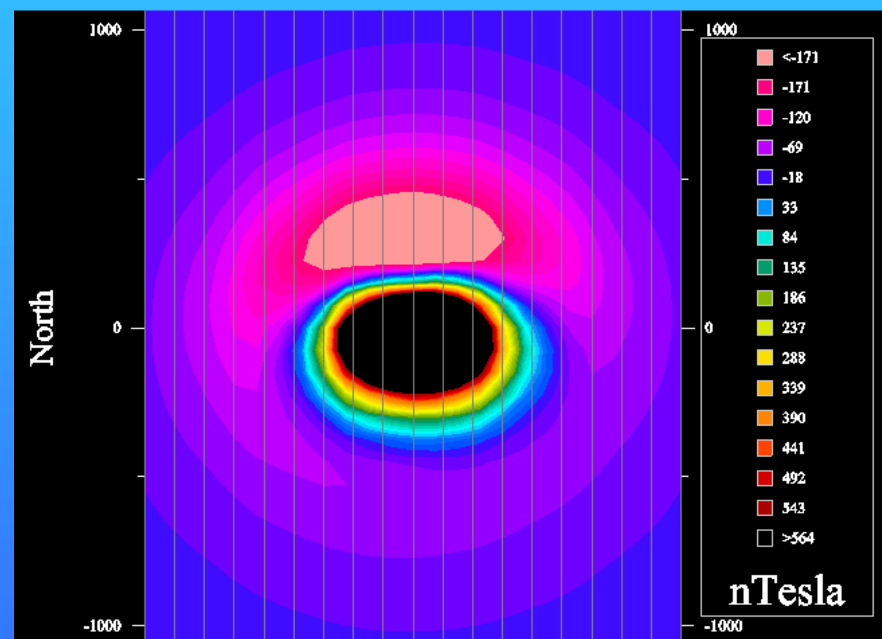
Broader anomaly, lower amplitude

Vertical gradient vs vertical difference

Vertical gradient

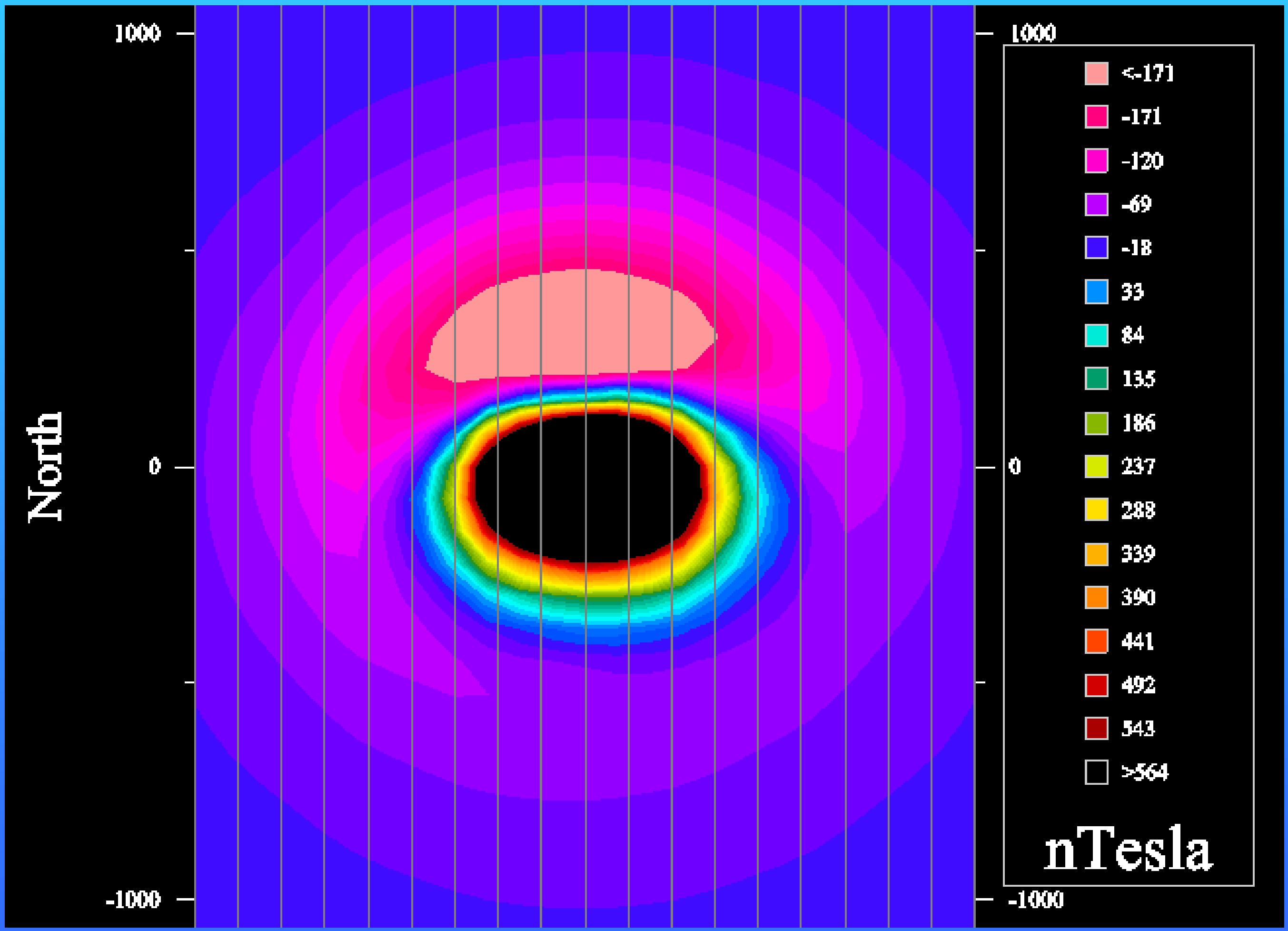


Difference of 150m and 80m data



Anomaly shapes look similar - zero contour on both is more or less the body outline except that difference data is in nT and a sign change.

Vertical difference data



- the difference data of the magnetic signatures are related to the difference in distance between the two surveys to the magnetic source
- hopefully, this difference in signatures can be used to yield a better estimate of the depth.

3D magnetic inversion

- Test the hypothesis via 3D magnetic inversion using the EMIGMA modelling and inversion software by EiKon Envirotec (*PetRos EiKon*)
- EMIGMA has implemented the ability to use data from different elevations - all as part of the data input of the inversion

3D Magnetics Inversion

$$d = F(m)$$

$d \rightarrow$ ***data vector of dimension N***

$m \rightarrow$ **model vector of dimension M**

- F - physical relationship describing the data as a function of the earth model - *In practice an approximation*

Approaches

- Direct Matrix Inversion - historical

$$\mathbf{d} = \mathbf{F}\,\mathbf{m}$$

$\mathbf{d} \rightarrow$ **vector of** $\mathbf{N}-$ **dimension**

$\mathbf{F} \rightarrow$ **Matrix of** $\mathbf{N} \times \mathbf{M}-$ **dimension**

$\mathbf{m} \rightarrow$ **vector of** $\mathbf{M}-$ **dimension**

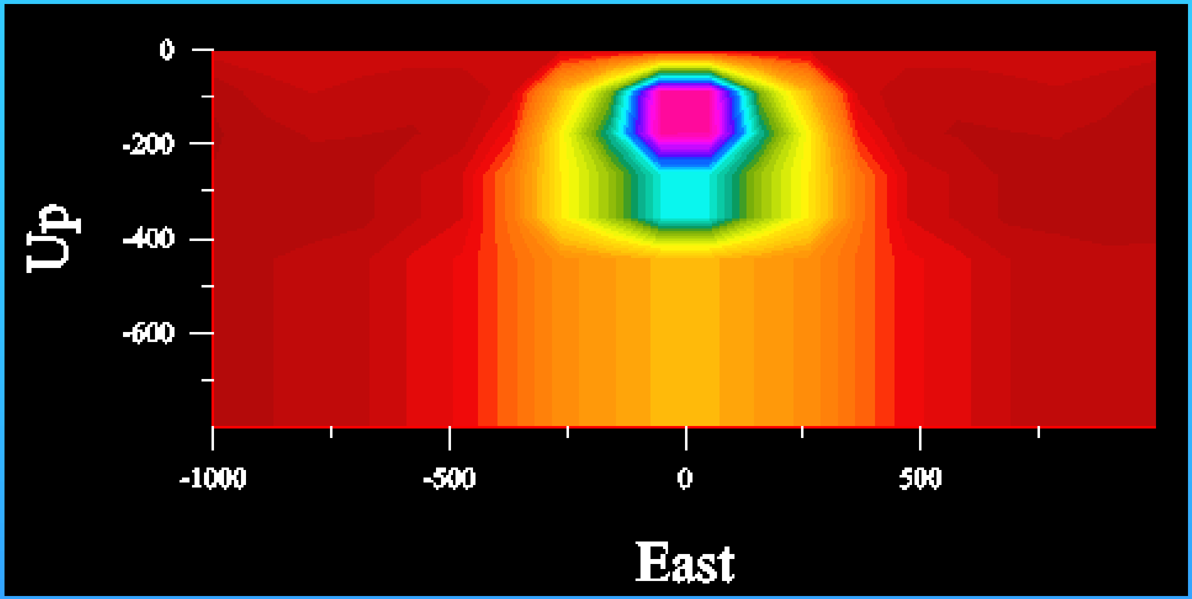
- Optimized Inversion - modern practical approach

  General concept is to start with an initial guess and go looking for the best fitting model by minimizing a given function using an iteration process.

- Critical factors to Optimization Results:
  - Good forward simulation algorithm
  - Good minimization technique
  - Good starting model
  - Good data

Synthetic aeromagnetic example

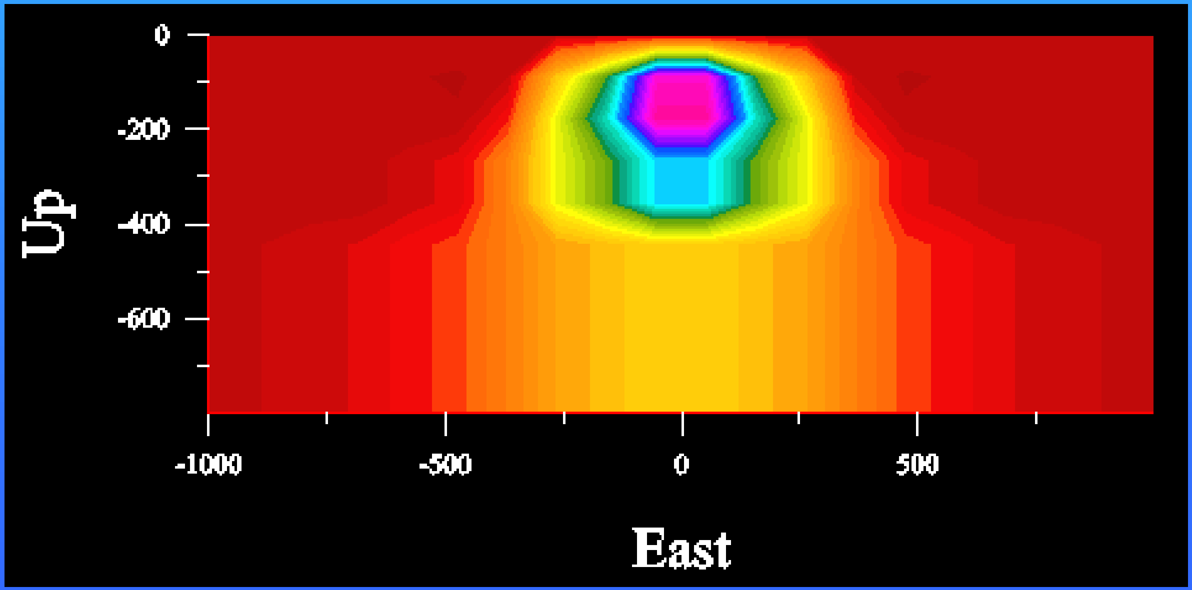
- Same disc model as previously - but lower susceptibility
- “surveys” at 80 metres and 150 metres above surface



Longitudinal views of the inversion results

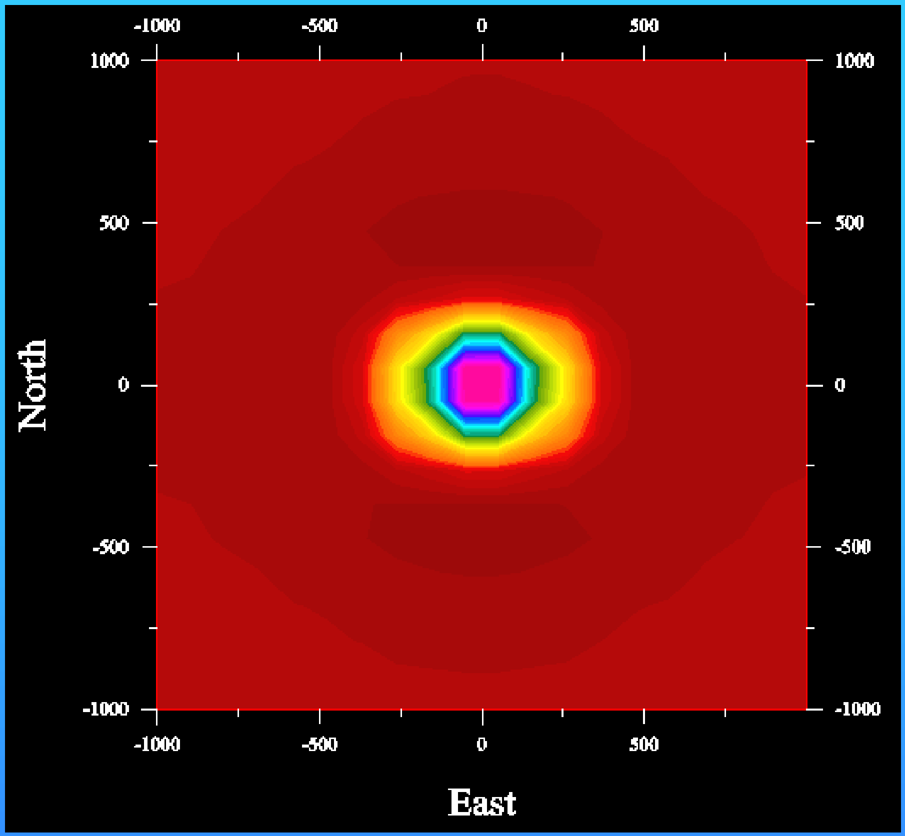
80m data

-good resolution of the top



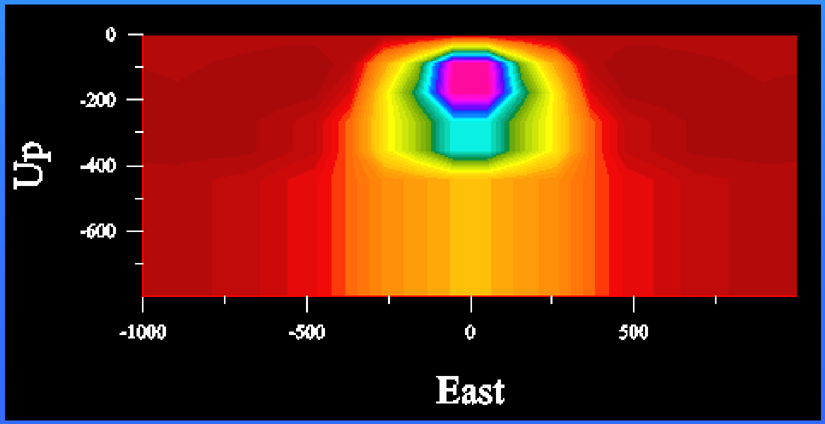
150 m data

- better resolution of bottom



3D magnetic inversion on both 80 m and 150 meter datasets

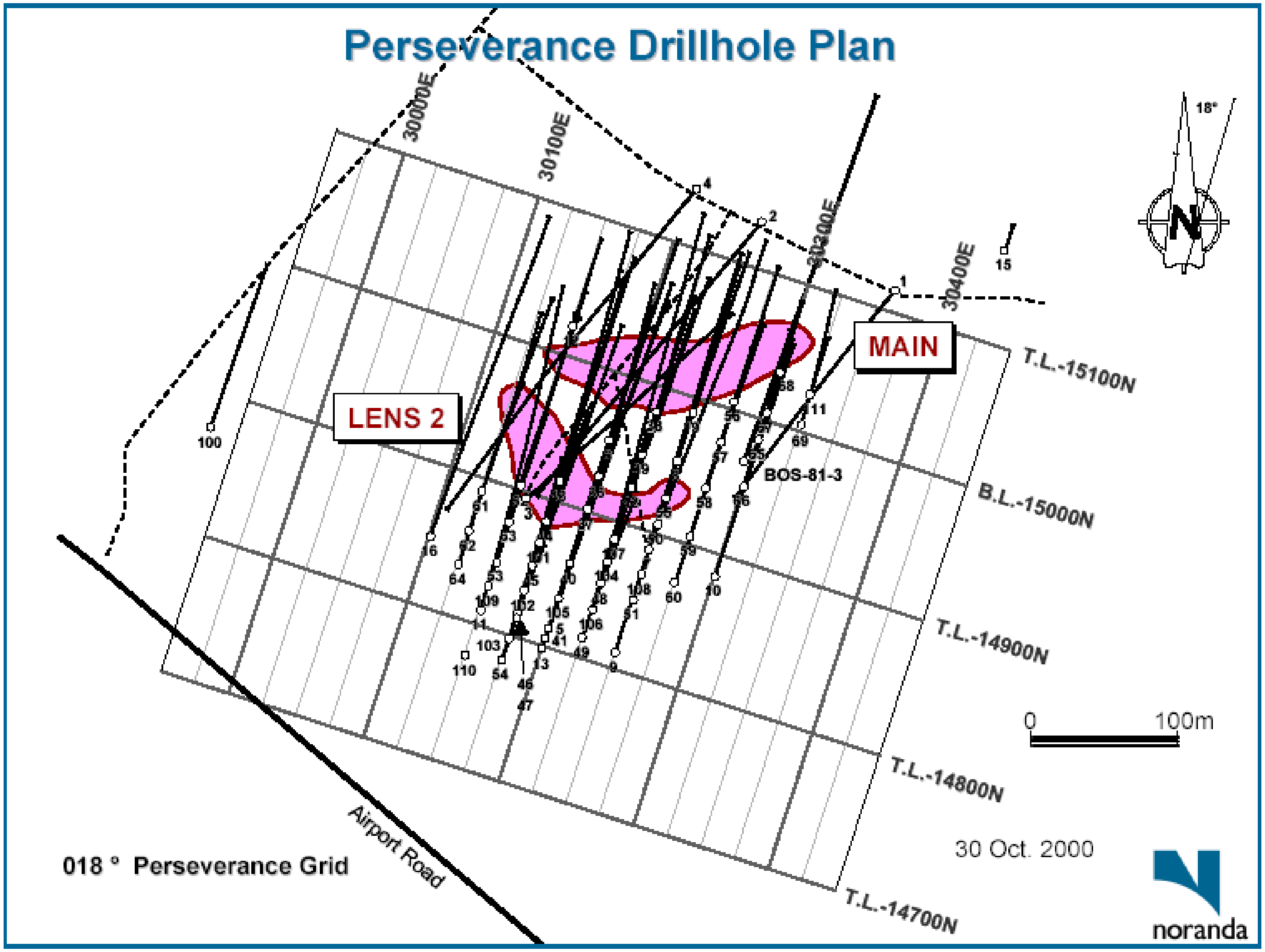
Level view at -168 metres - shows strike length estimate



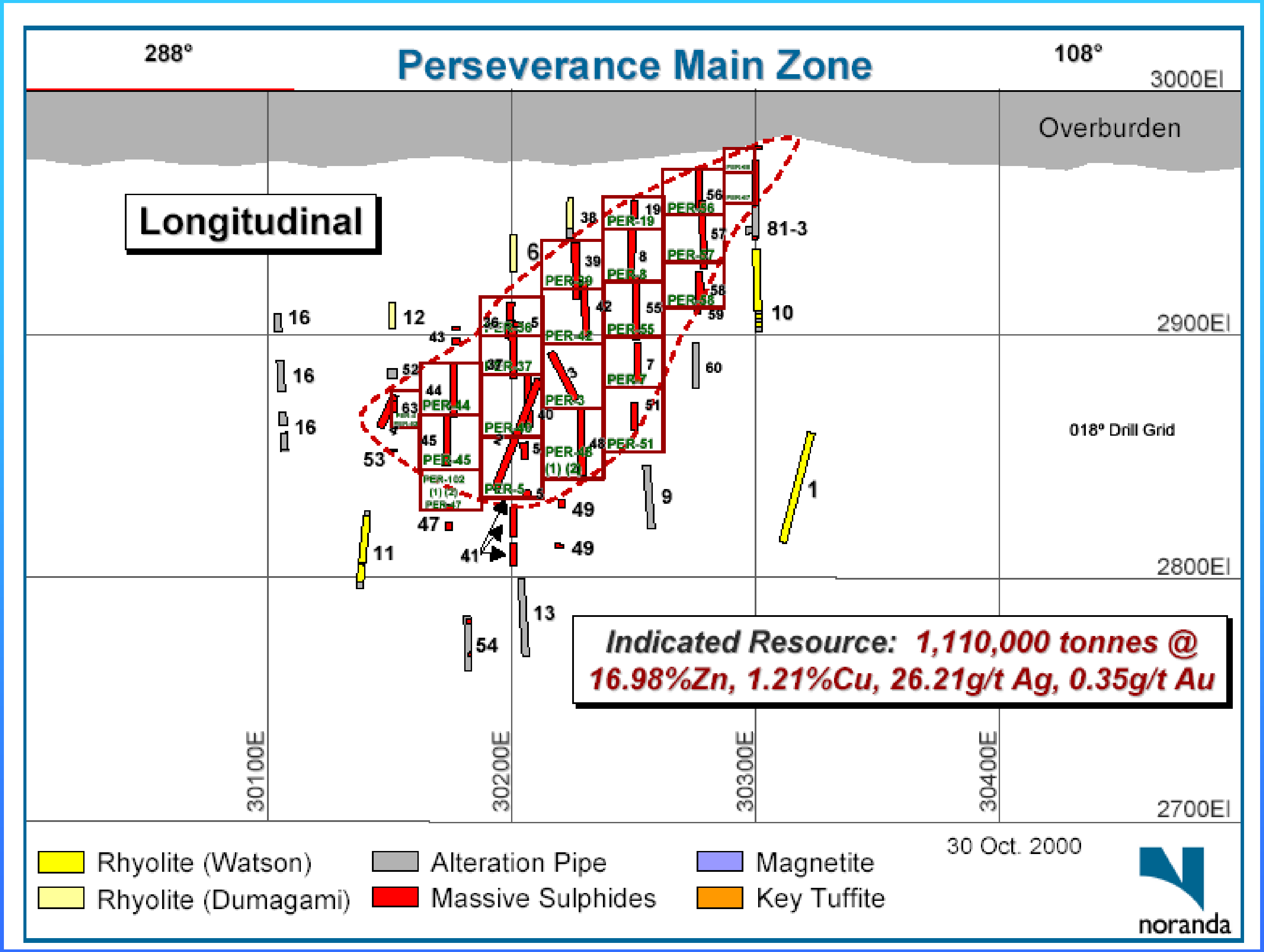
Longitudinal view - slightly better top and bottom estimates

Perseverance data set

- Discovery announced by Noranda in 2000 near the Matagami airport
- airborne and ground data are shown over the Main zone
- data will be inverted individually and then combined

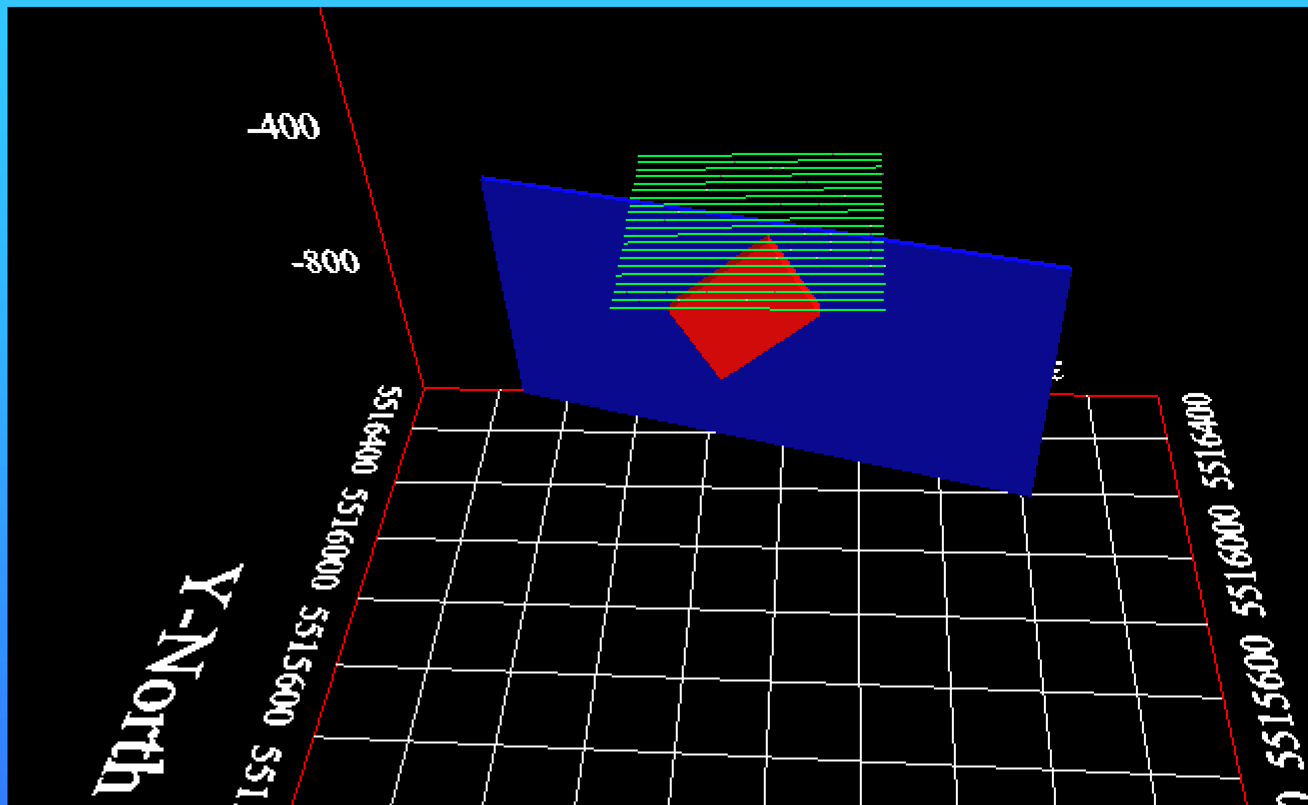


Information from Noranda's website



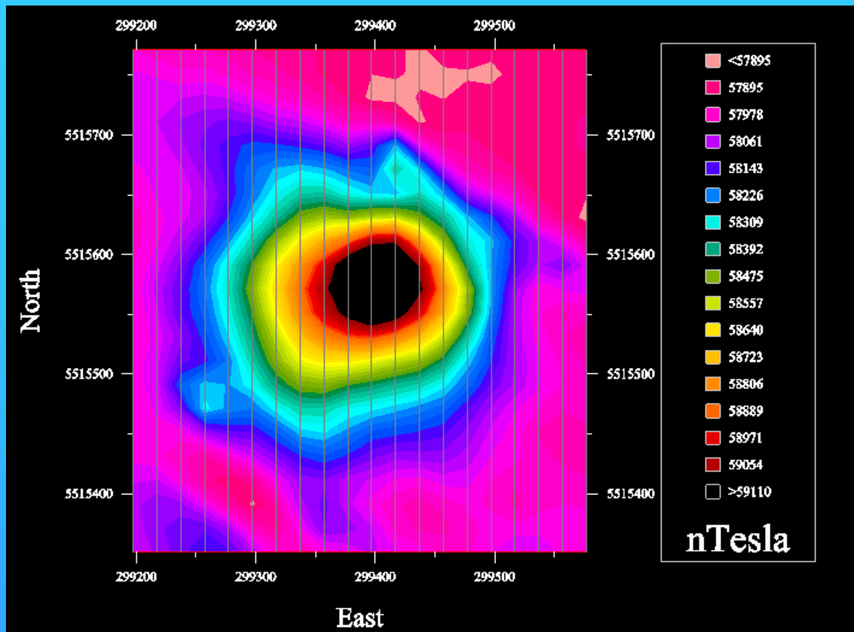
From Noranda's website

Forward model to understand physical parameters

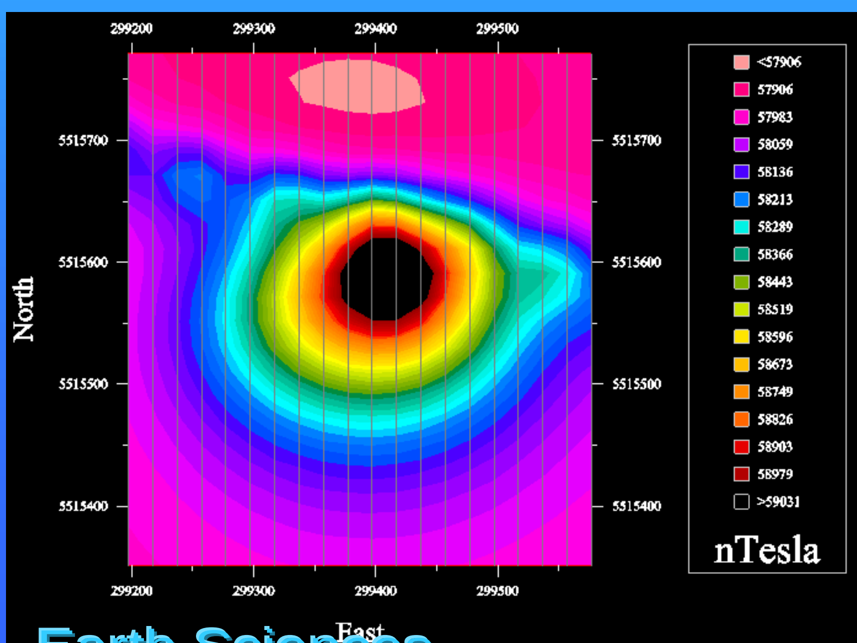


Dyke to the north, and a 200 X 150 X 50 metre body of susceptibility 0.25 SI units was used to model the anomaly. Depth to top corner ~30m, depth to bottom corner ~220m.

Comparison of ground data - measured and forward modelled



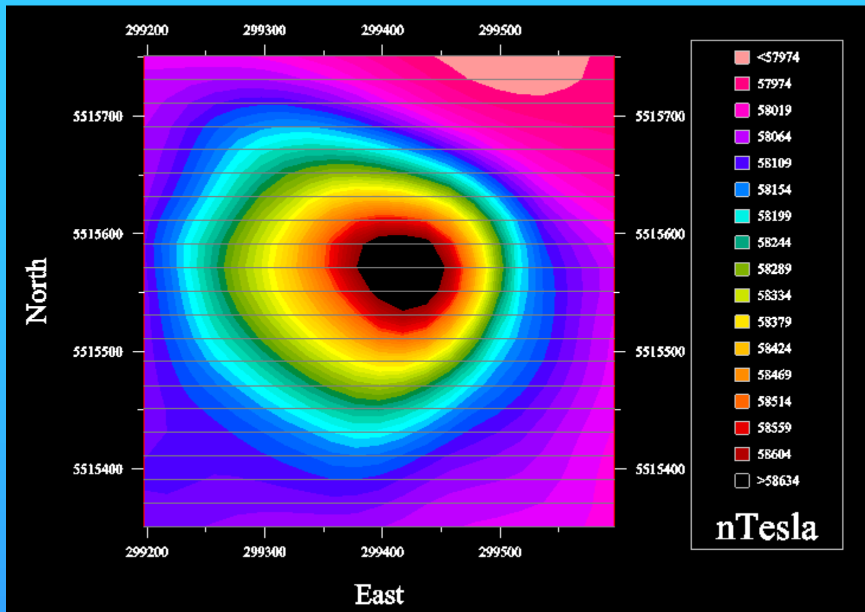
Measured ground data



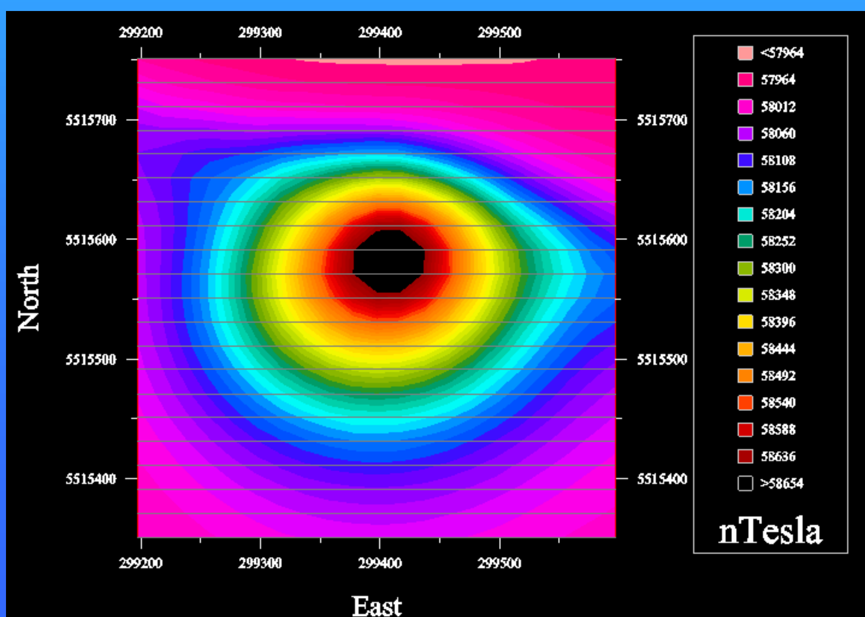
Forward model of ground data

BHL Earth Sciences

Comparison of ground data - measured and forward modelled



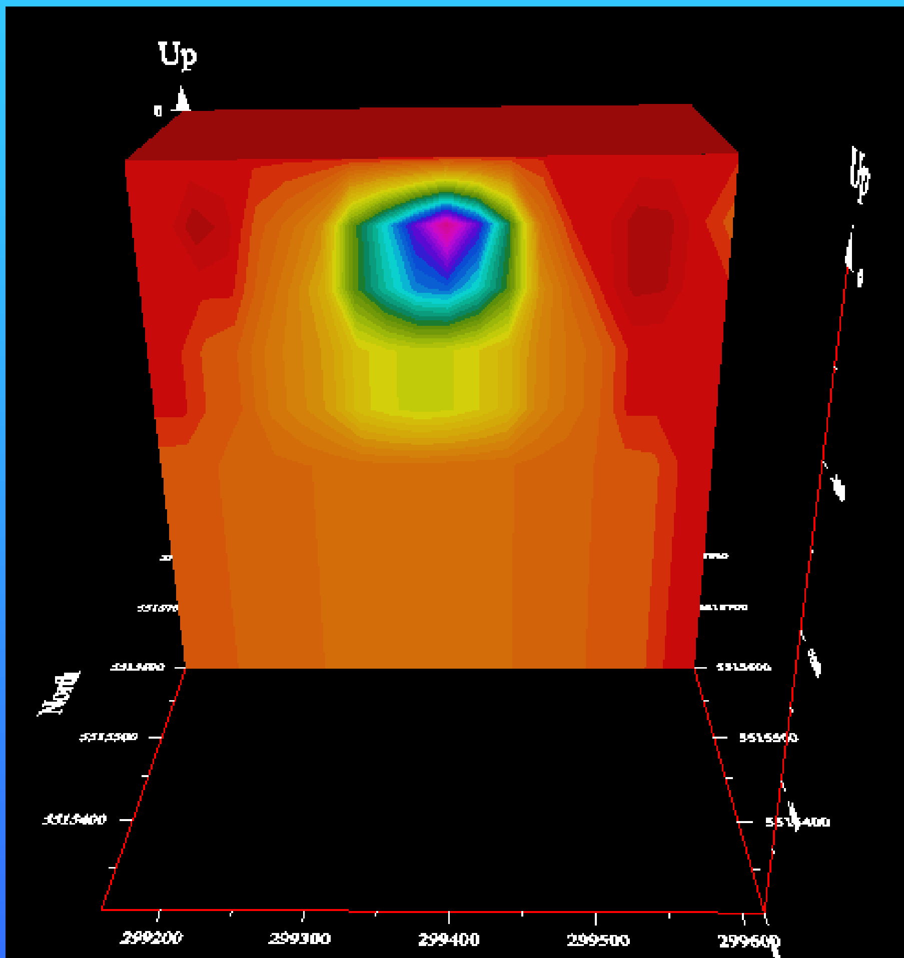
Measured airborne data



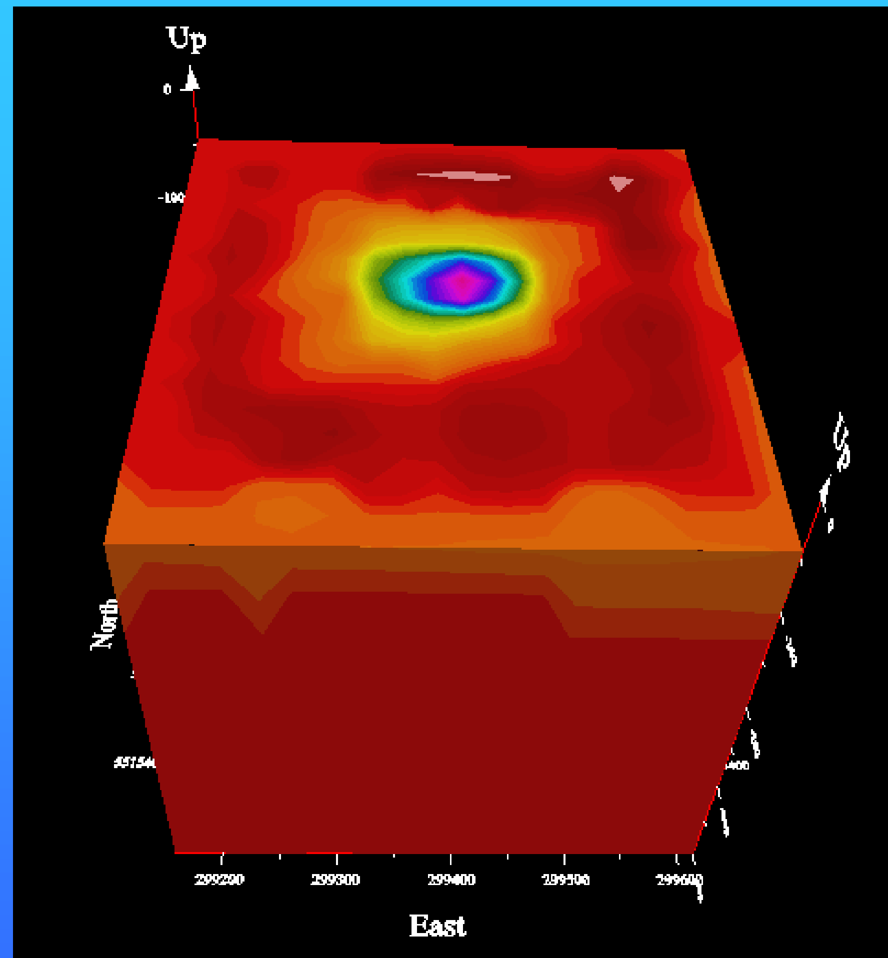
Forward modelled airborne data

Optimised inversion of ground magnetics only

Longitudinal view



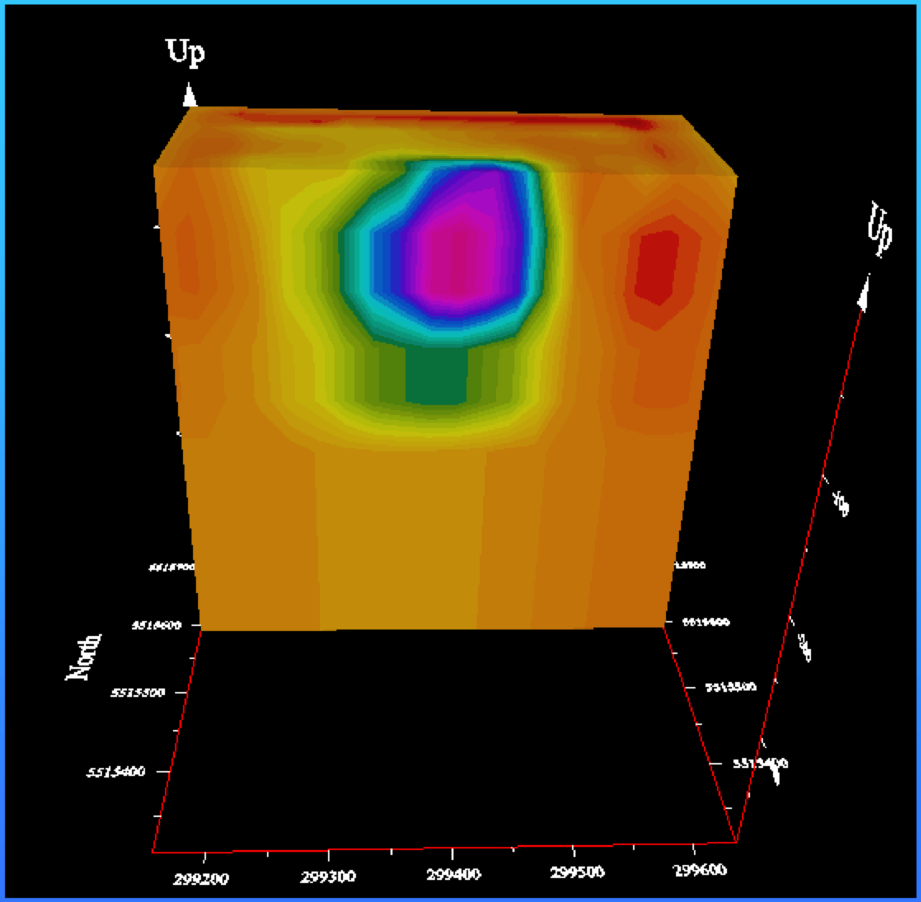
Level view at -44 metres



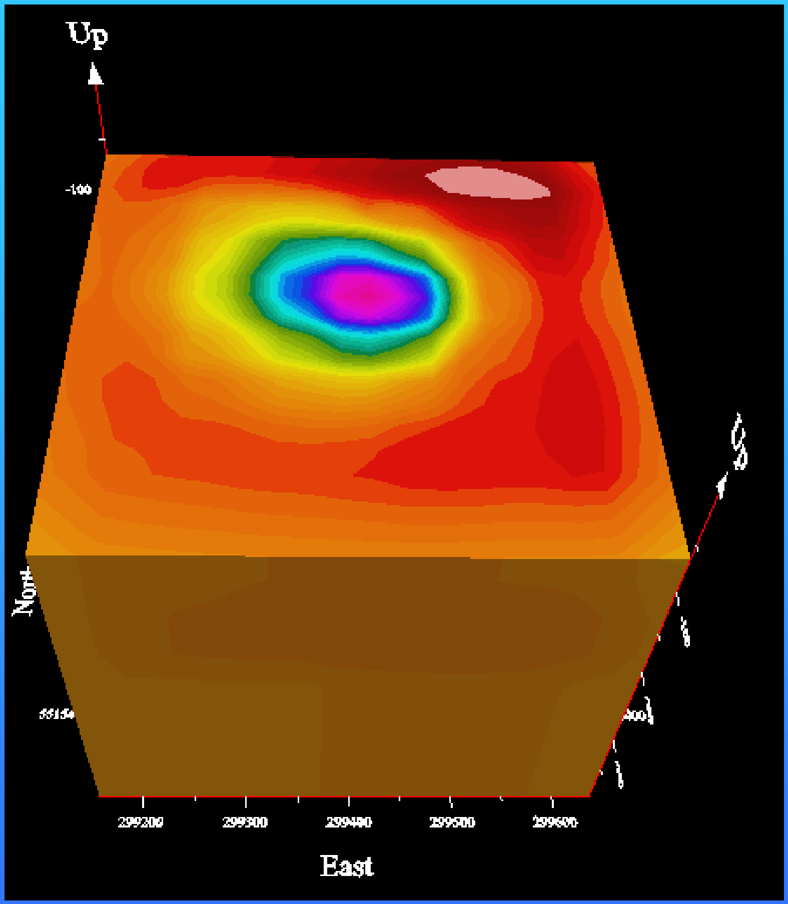
Top of magnetic material ~17m, bottom of core magnetic material ~126, bottom of magnetic material ~184. Depth to top OK, depth to bottom is slightly off.

Optimised inversion of Airborne data only

Longitudinal view



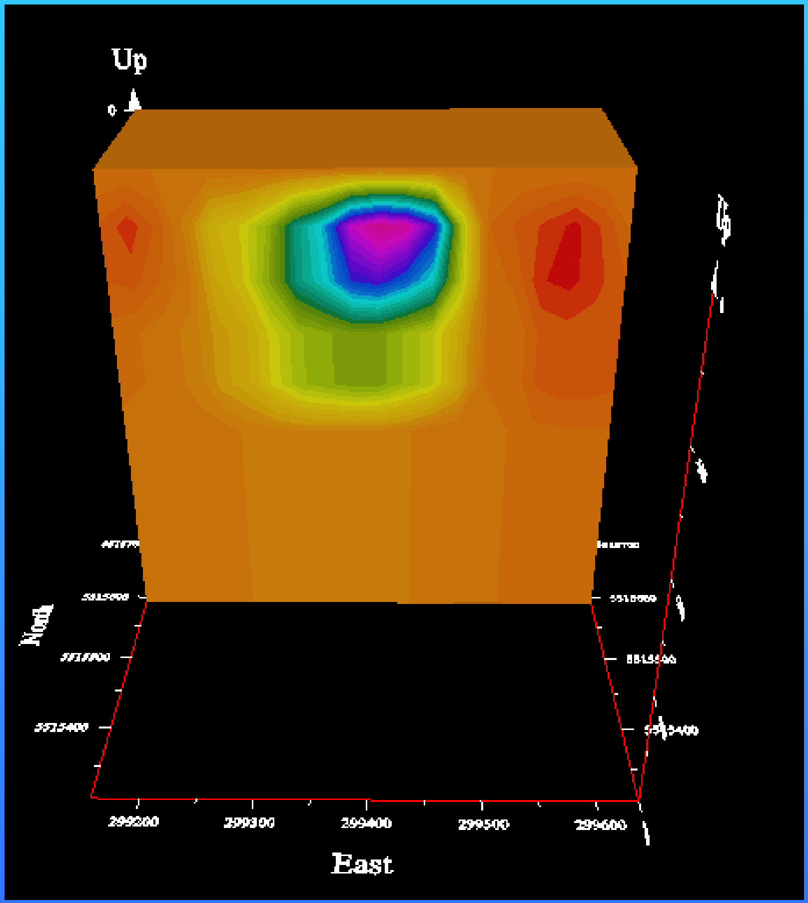
Level view at -44 metres



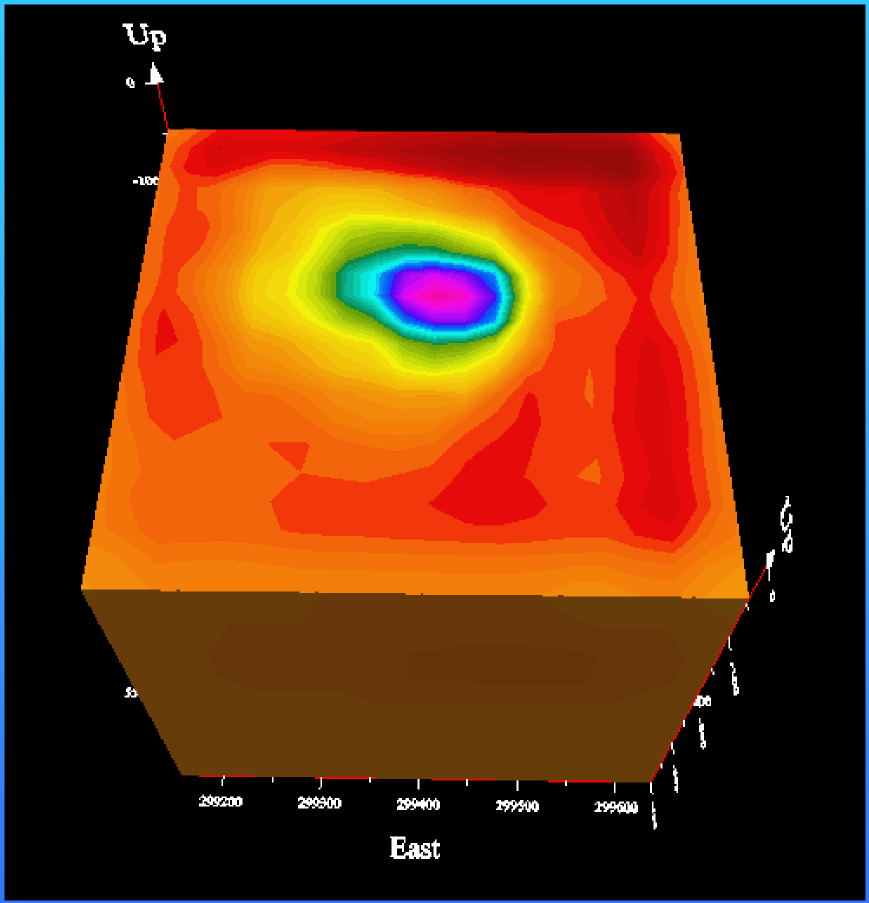
Top of magnetic material - surface, bottom of core magnetic material ~126, bottom of magnetic material ~200. Depth to top is off, depth to bottom is better. Strike and shape look good.

Optimised inversion of both airborne and ground data

Longitudinal view



Level view at -44 metres



Top of magnetic material ~20m, bottom of core magnetic material ~126, bottom of magnetic material ~200. Depth to top and bottom are good. Strike and shape look good.

Conclusions

- Yes, magnetic data collected at different levels can be used in inversions
- having data at two different levels seem to improve the distribution of magnetic material in the models - depth to top and bottom are better estimated.

Future directions

- Study whether the estimate of a susceptibility distribution at a particular level varies with the difference in survey heights - synthetic results give better susceptibility estimates (i.e. higher),
- Get a better feel for this type of inversion - use lots more field data to prove this methodology
- routinely collect aeromagnetic data at different levels!

THANK YOU

- thank you to Noranda for granting permission to use the Perseverance data sets