Mira Geoscience
...modelling the earth

3D Inversion Modelling, Integration, and Visualization of QUEST Project Airborne Gravity, Magnetic, and Electromagnetic Data

Nigel Phillips

Advanced Geophysical Interpretation Centre

17 September 2009

Outline

- Objectives
- Physical Properties
- Data
- Inversion Methods
- Results
- Deliverables
- Using the Results

Mira Geoscience
...modelling the earth

Objectives

- Useful 3D physical property products
- For direct employment in regional exploration
- Exploration criteria can be applied based on different physical properties.
- Provide guidance to the regional structure
- Help geologic mapping
- Help target prospective geology, alteration, or mineralization.
- Guide detailed follow-up survey design
- Depth of overburden analysis

Mira Geoscience
...modelling the earth

Products

- 3D inversions of potential field data
- Interpolated 3D conductivity model based on 1D EM inversions
- Integrated 3D Physical Property Classification Models
- Accessible deliverables for visualization and quantitative 3D analysis

Mira Geoscience
...modelling the earth

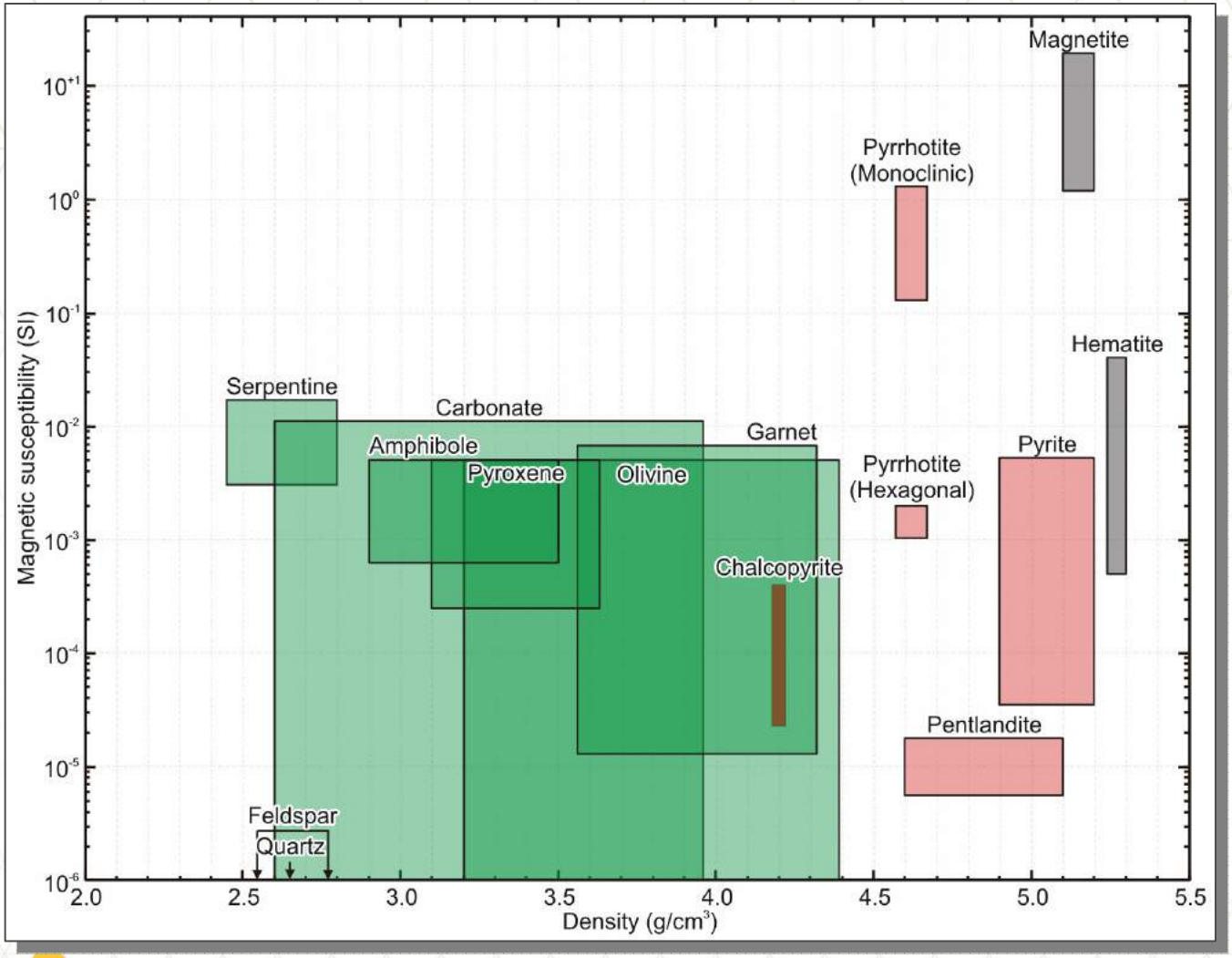
Physical Properties – *the key to relating geophysics to geology*

1. What are the dominant causes of physical properties?
   - Mineralogy
   - Texture
   - Grain size
   - Porosity

2. How do geologic processes change physical properties?
   - Deposition
   - Cooling
   - Metamorphism/Metasomatism
   - Mineralization/Enrichment
   - Alteration
   - Weathering

Mira Geoscience
...modelling the earth

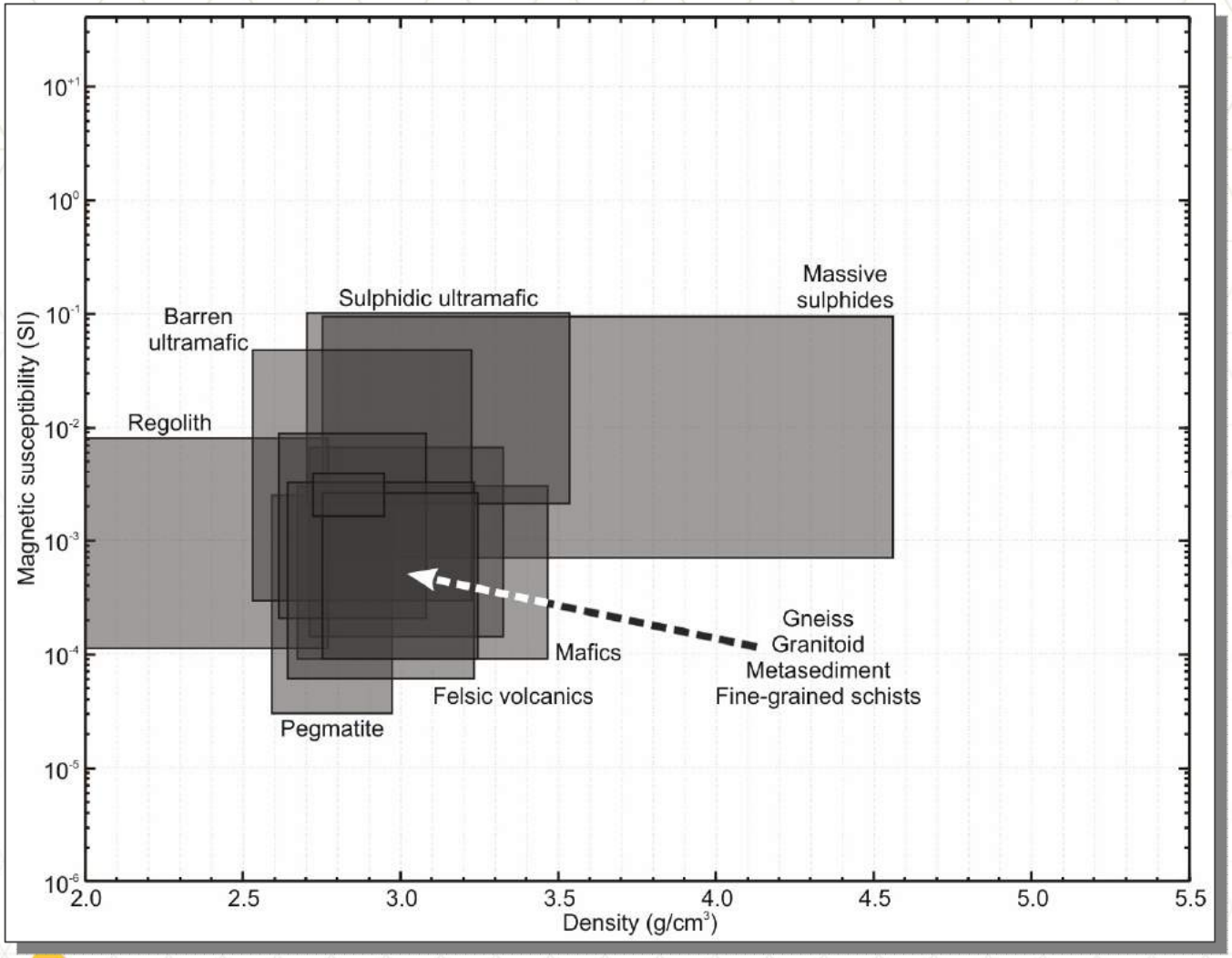
Mineral Physical Properties: density–sus. cross-plot



Mira Geoscience
...modelling the earth

after Williams 2007

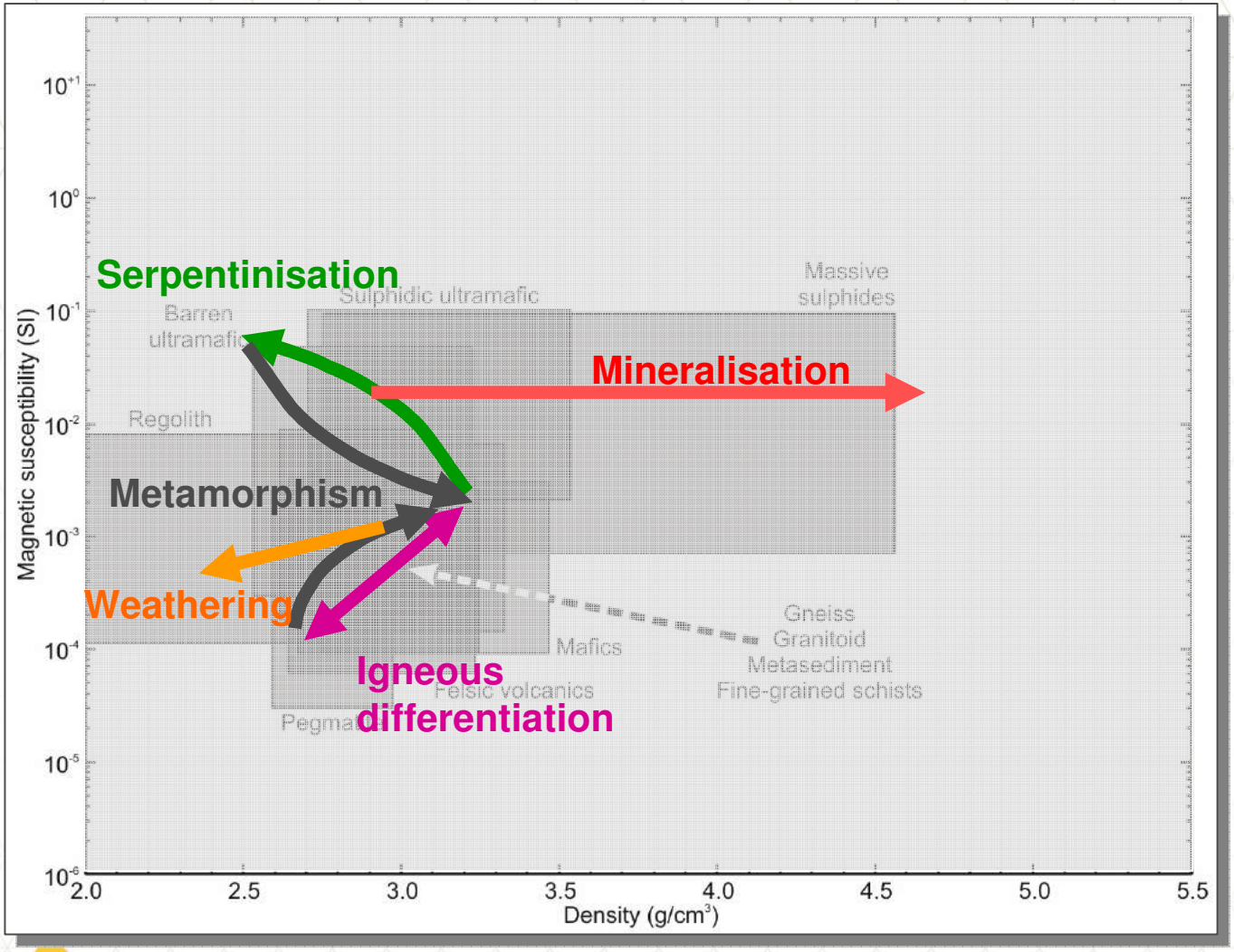
Rock Physical Properties: density–sus. cross-plot



Mira Geoscience
...modelling the earth

after Williams 2007

Rock Physical Properties – Processes: density–sus. cross-plot

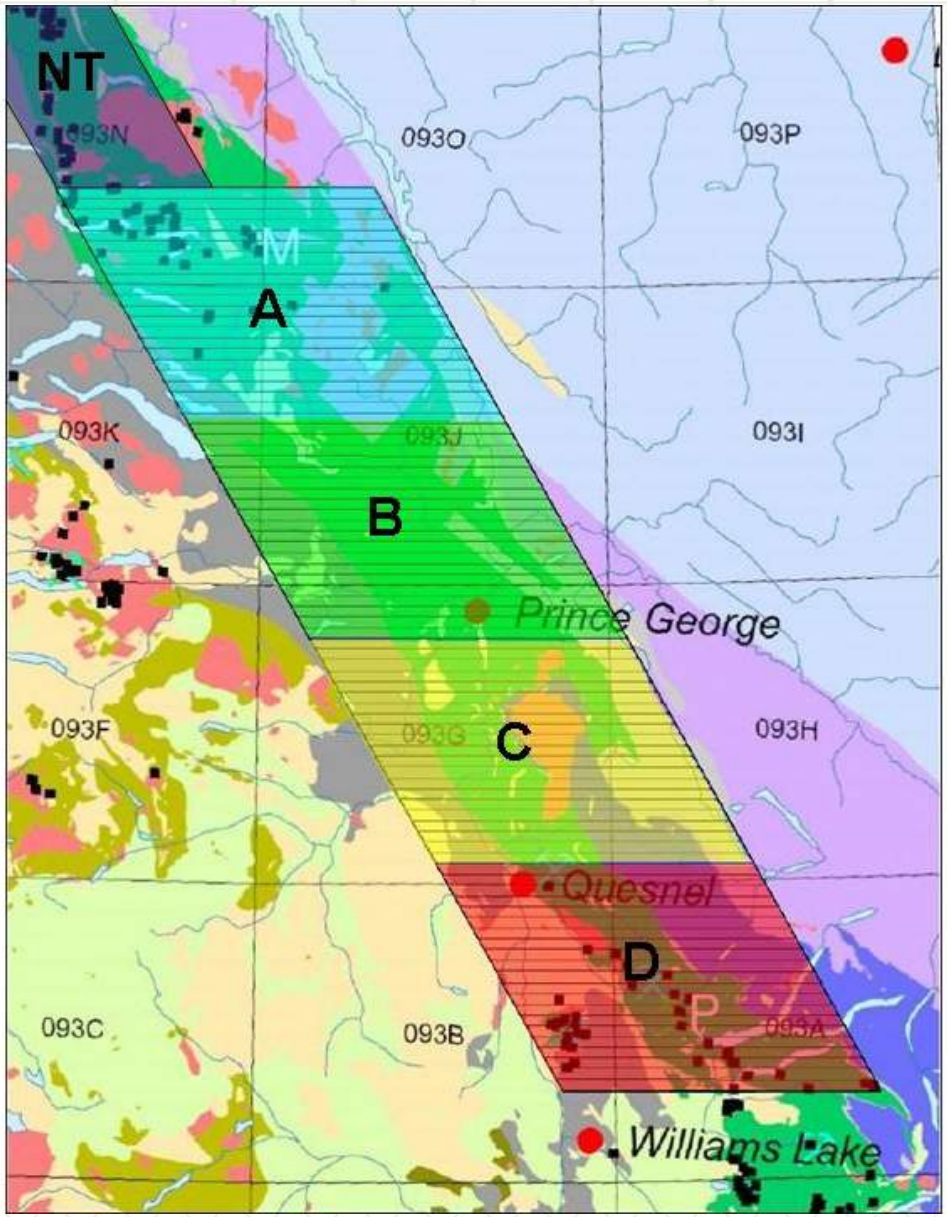


Mira Geoscience
...modelling the earth

after Williams 2007

Data

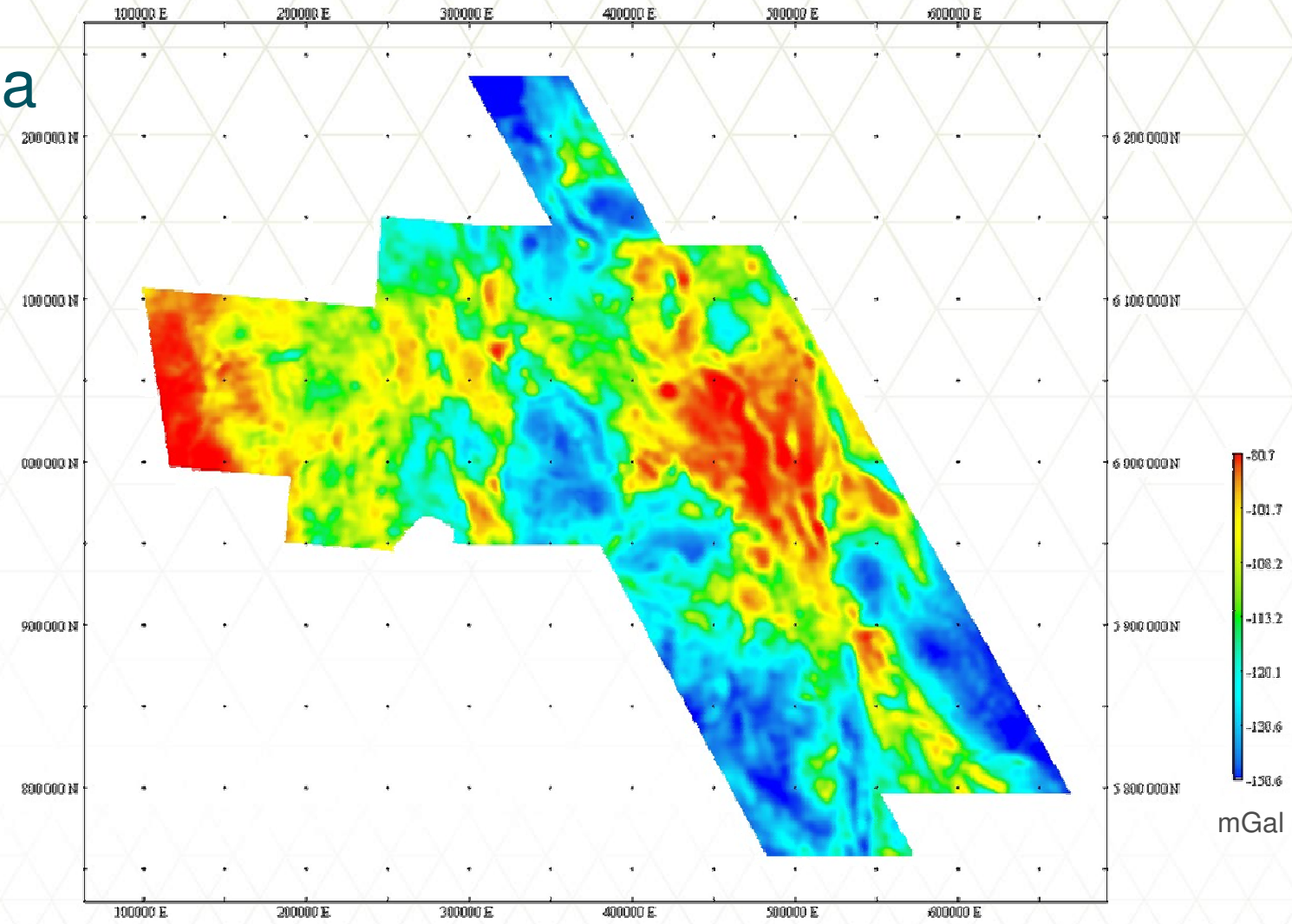
- Airborne Gravity Data
- Airborne Magnetic Data
- Airborne EM Data



Mira Geoscience
...modelling the earth

Gravity Data

Terrain Corrected Bouguer Anomaly (2.67 g/cm^3)



Airborne acquisition by Sander Geophysics

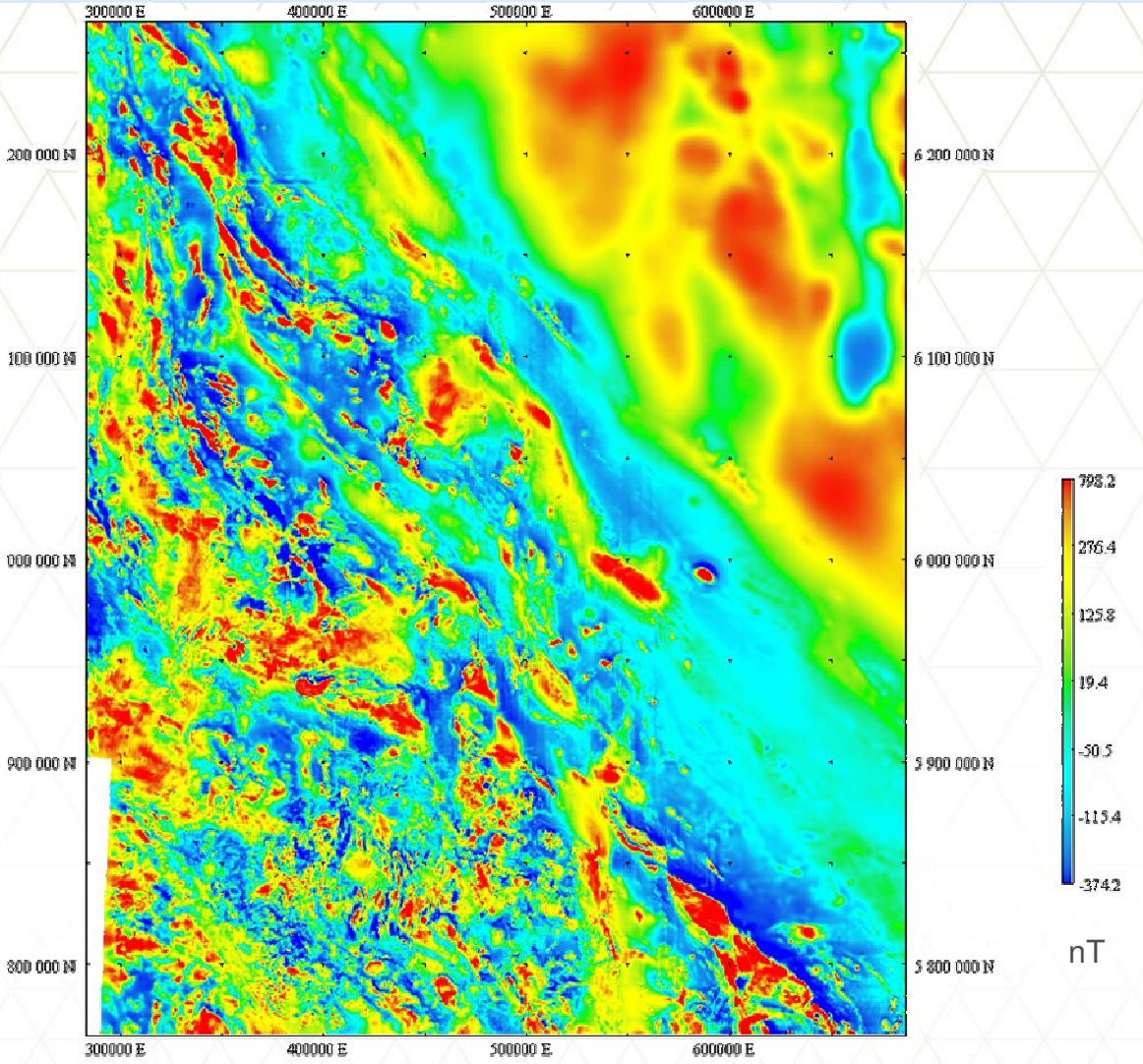
East-West lines with 2000m line spacing

Regional GSC data also used for regional signal

Mira Geoscience
...modelling the earth

Magnetic Data

Total Magnetic Intensity



Airborne acquisition by Geotech

East-West lines with 4000m line spacing

Regional GSC data also used for regional signal

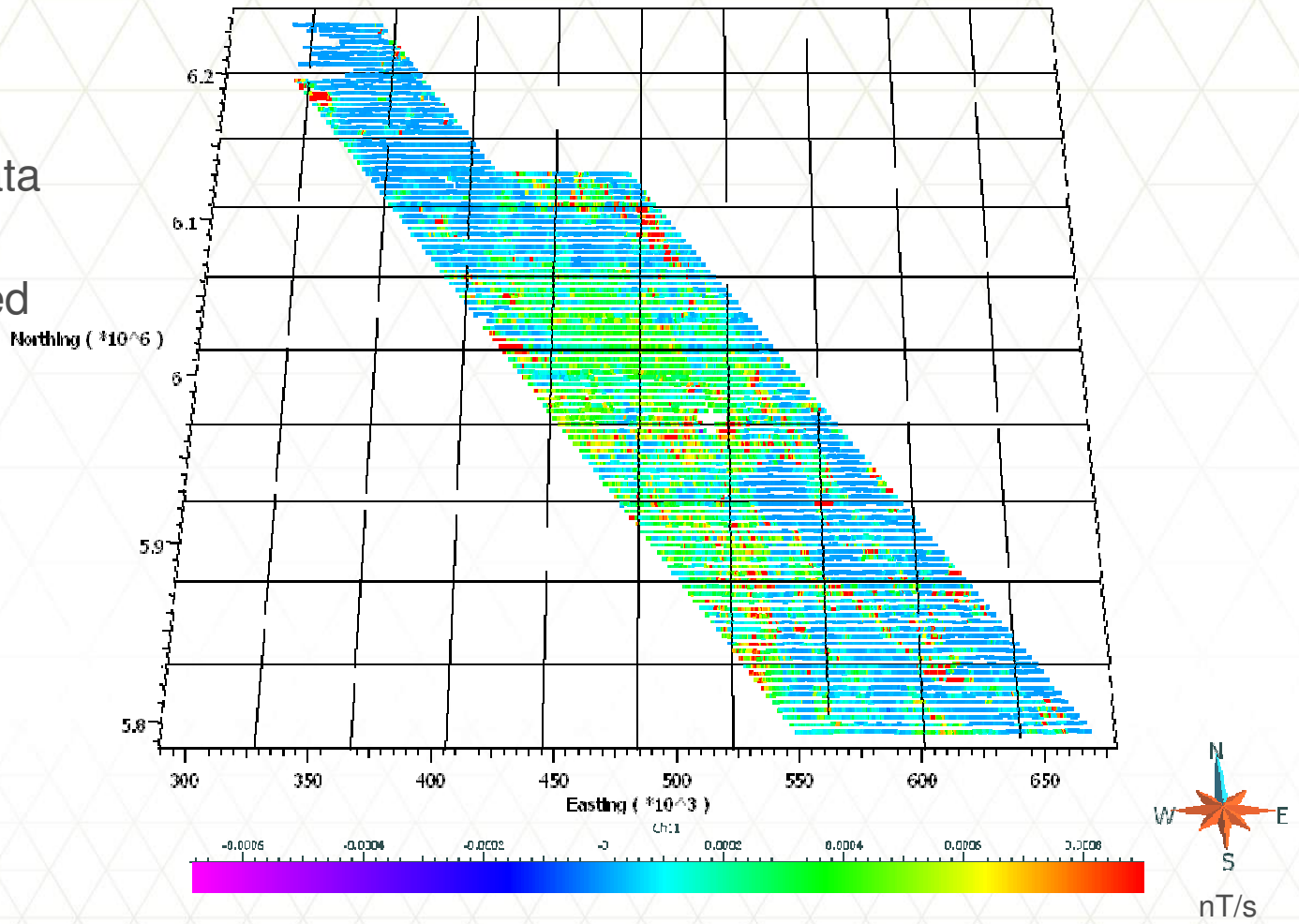
Mira Geoscience
...modelling the earth

Electromagnetic Data

Channel 19 dB_z/dt data

27 time channels used

~78m flight height



Airborne acquisition by Geotech (VTEM system)

East-West lines with 4000m line spacing

Mira Geoscience

...modelling the earth

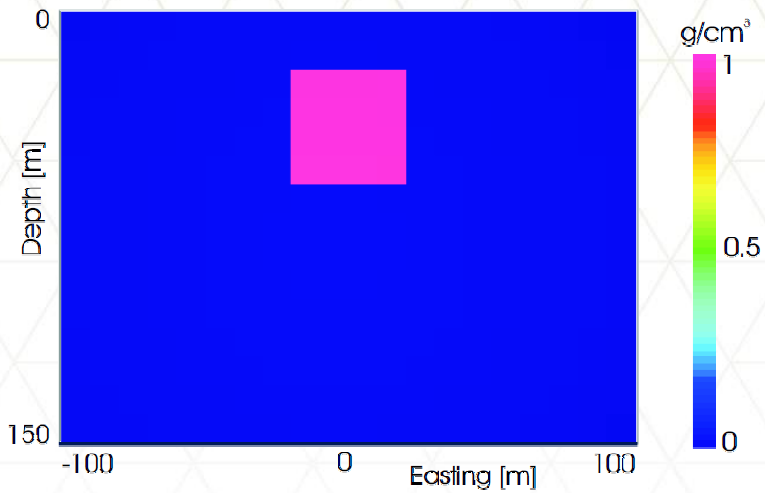
Inversion Methods

Potential Fields

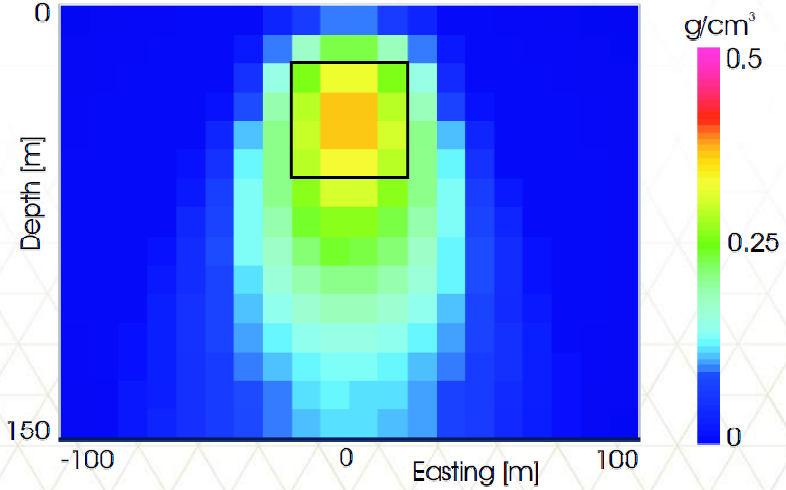
UBC-GIF GRAV3D and MAG3D

Inversion for a smoothly varying heterogeneous 3D physical property distribution

Synthetic Example



True Model



Recovered Model

Mira Geoscience
...modelling the earth

Inversion Methods

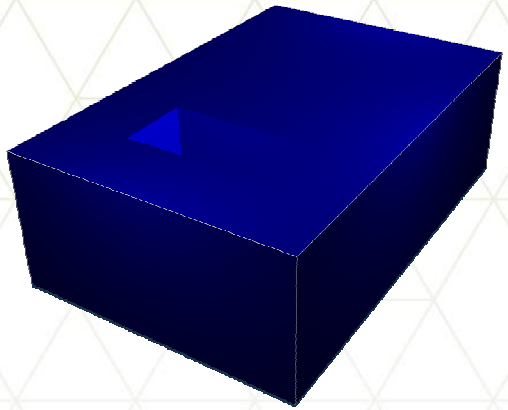
Potential Fields

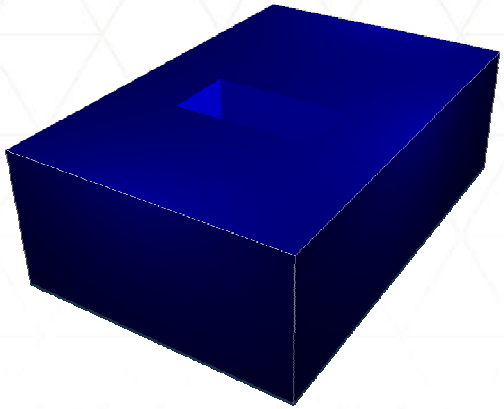
UBC-GIF GRAV3D and MAG3D

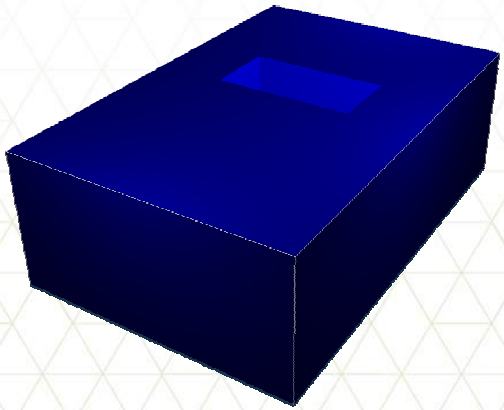
Inversion for a smoothly varying heterogeneous 3D physical property distribution

Data Preparation
- Model-based levelling
- Upward continuation

Large-scale tiled inversions
- Regional Separation for each tile







Mira Geoscience
...modelling the earth

Inversion Methods

Potential Fields

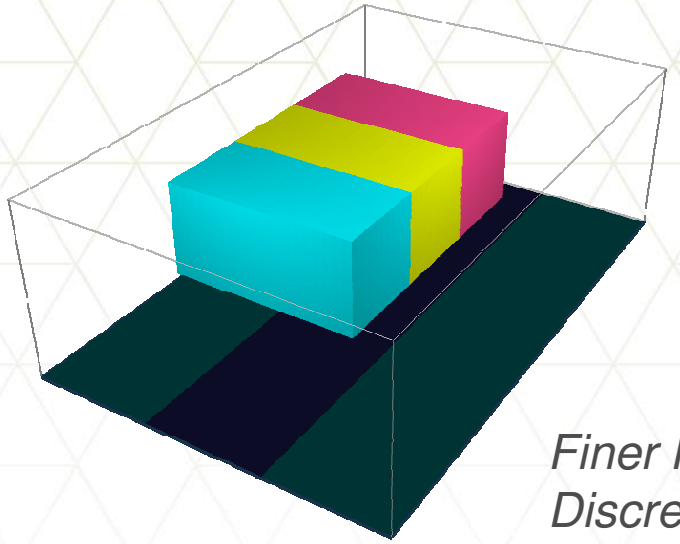
UBC-GIF GRAV3D and MAG3D

Inversion for a smoothly varying heterogeneous 3D physical property distribution

Data Preparation
- Model-based levelling
- Upward continuation

Large-scale tiled inversions
- Regional Separation for each tile
- Modelling with 500m x 500m x 250m cells
- 3D Model Merging → 32 million cells

Data misfit analysis



Finer Model Discretization And Merging

Mira Geoscience
...modelling the earth

Inversion Methods

Airborne EM

UBC-GIF EM1DTM

Inversion for a smoothly varying heterogeneous 1D conductivity distribution

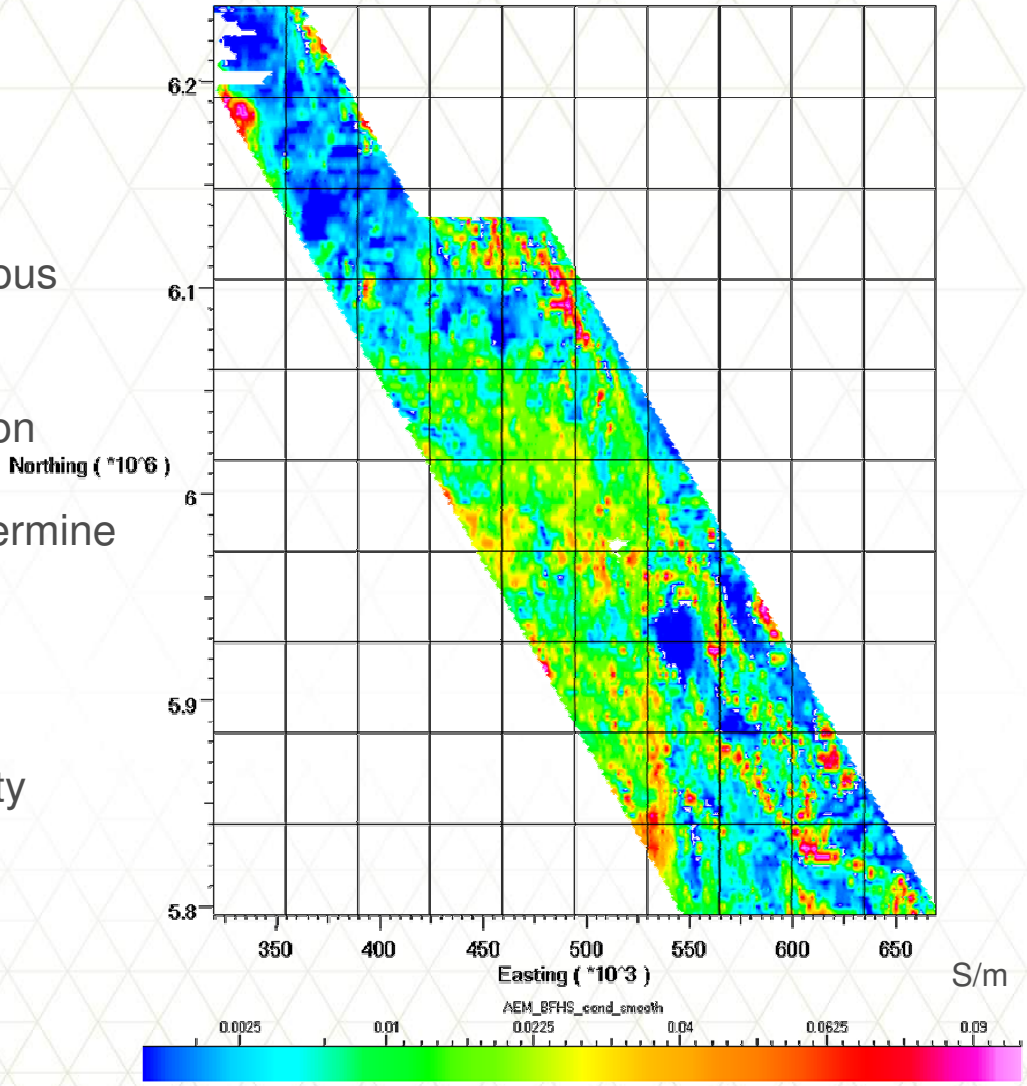
Laterally Parameterized/Constrained Inversion

Neighbouring stations used to determine appropriate inversion parameters

Reduces modelling artefacts

Background/Late-Time Conductivity

Background Conductivity: Plan View



Mira Geoscience
...modelling the earth

Inversion Methods

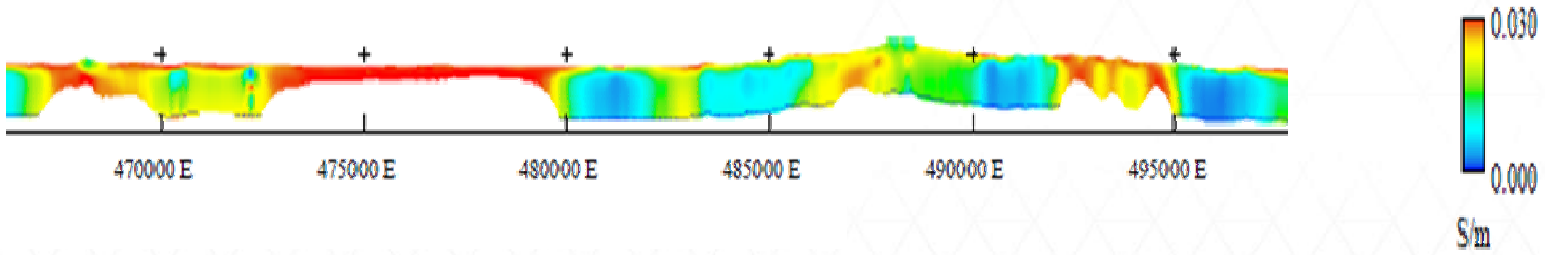
Airborne EM

UBC-GIF EM1DTM

Inversion for a smoothly varying heterogeneous
1D conductivity distribution

Laterally Parameterized/Constrained Inversion

Conductivity Flight-line Section



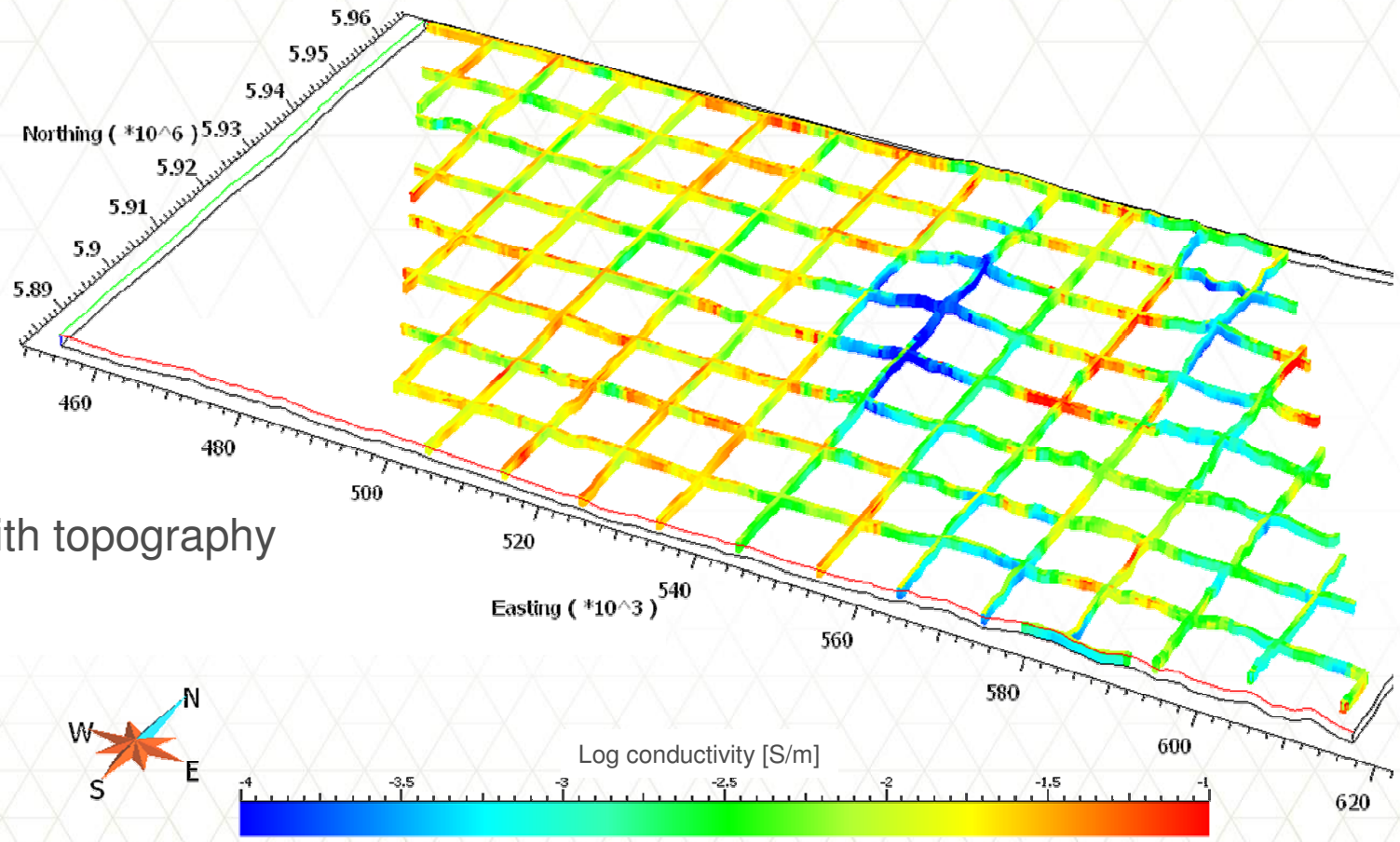
Depth of Investigation based on cumulative conductance

Mira Geoscience
...modelling the earth

Inversion Methods

Airborne EM

3D Interpolation



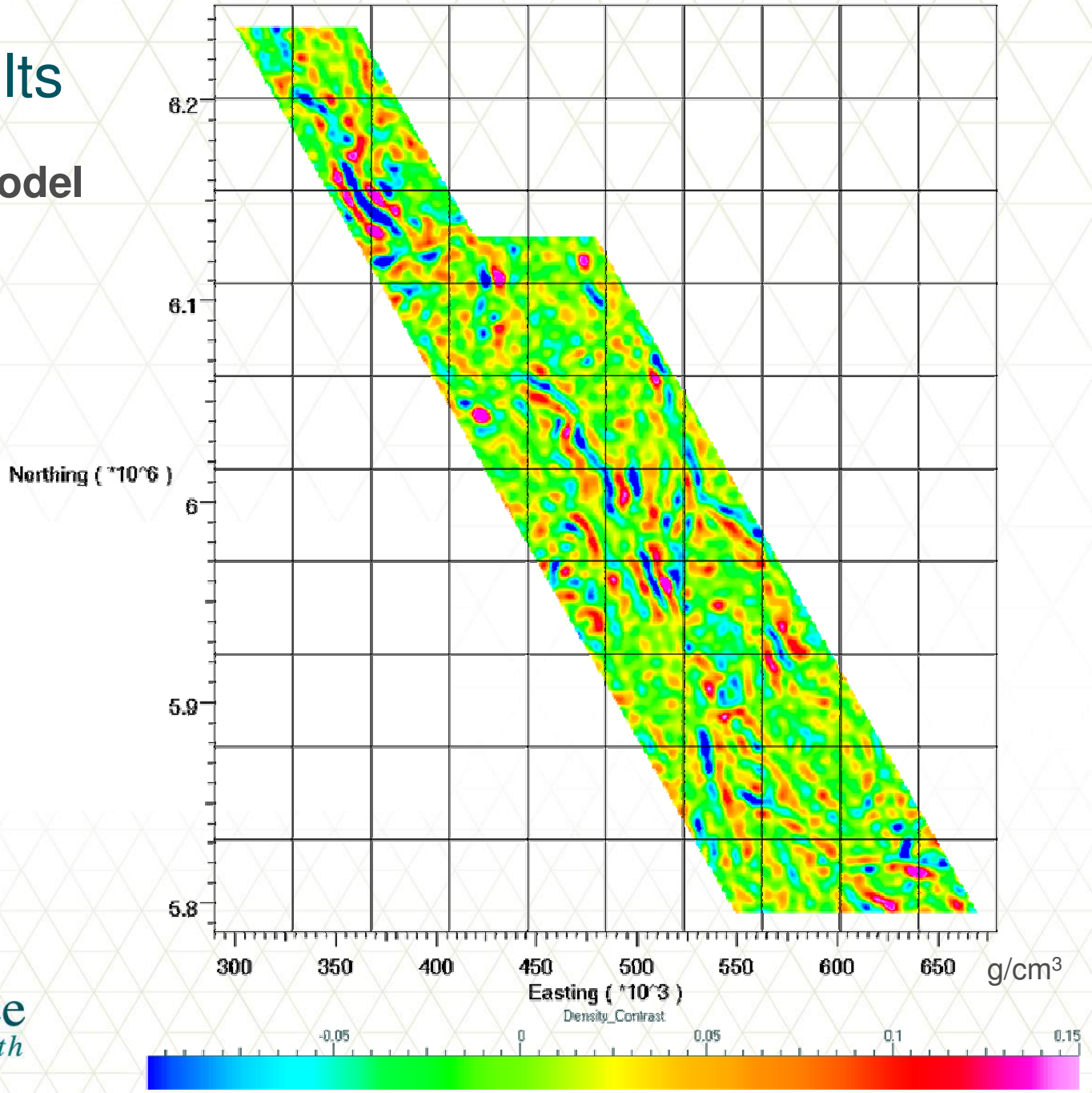
Conformable with topography

Mira Geoscience
...modelling the earth

Inversion Results

Density Contrast Model

Plan slice at sea level.

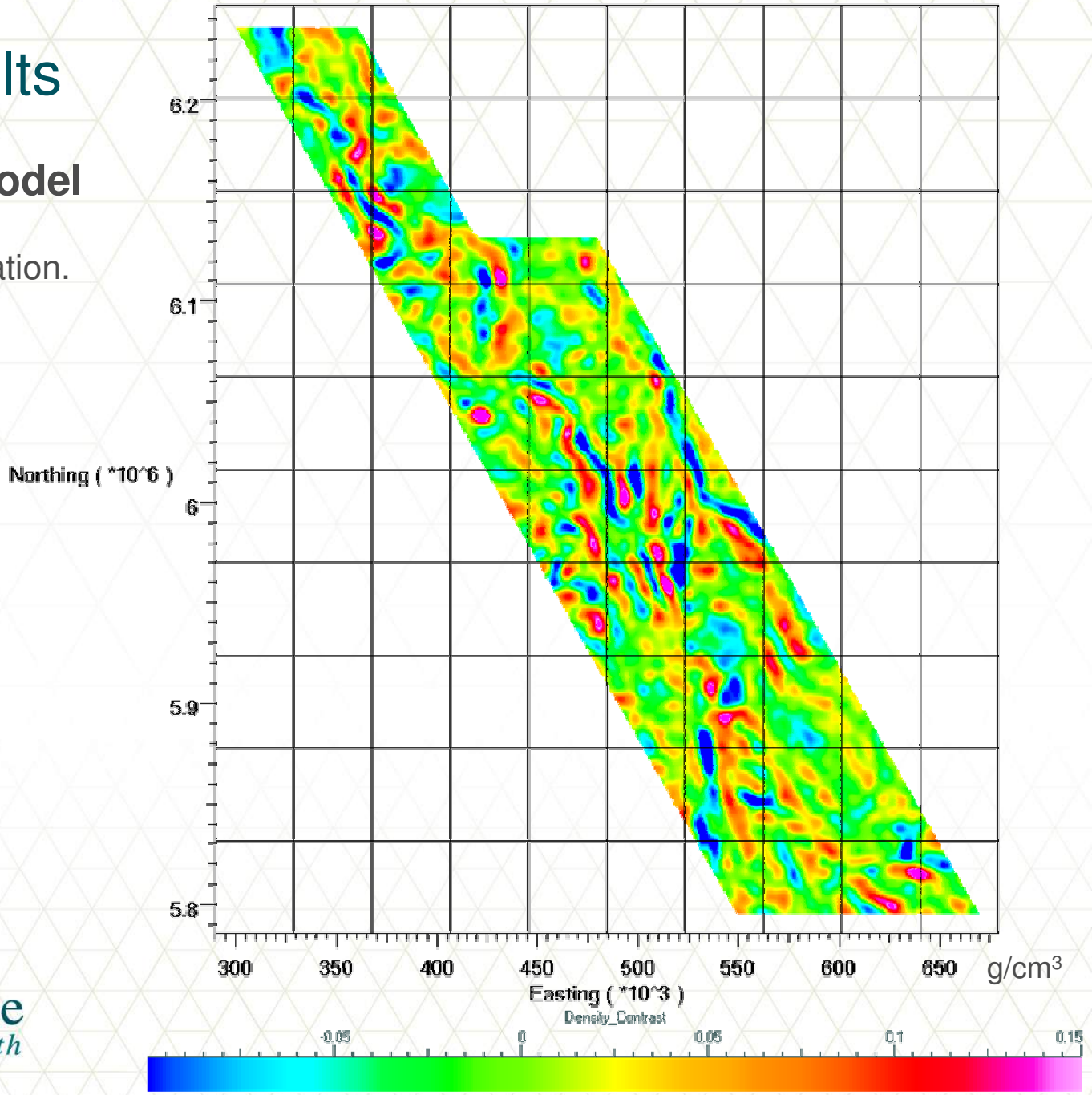


Mira Geoscience
...modelling the earth

Inversion Results

Density Contrast Model

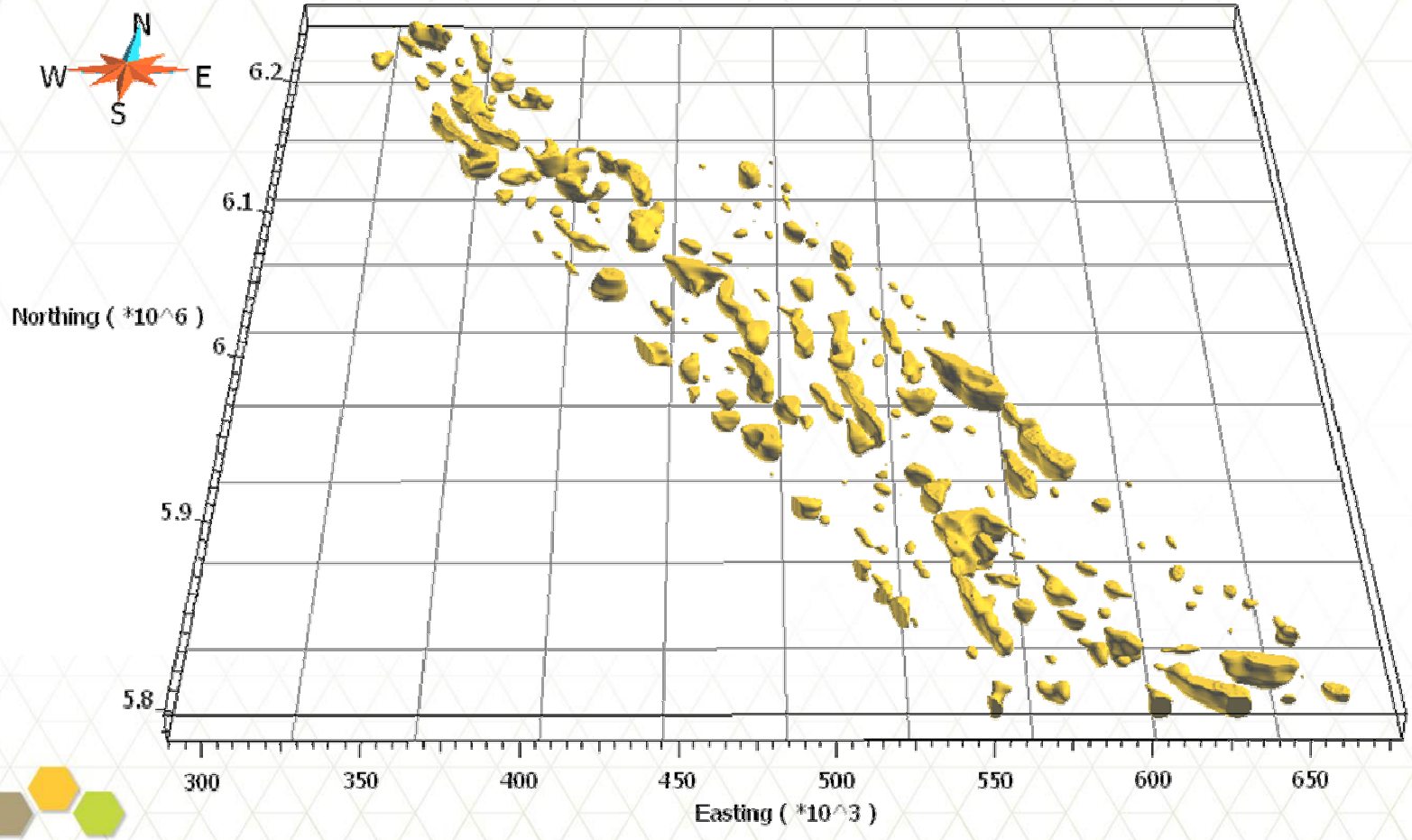
Plan slice at -2500m elevation.



Mira Geoscience
...modelling the earth

Inversion Results

Density Contrast Model - iso-surface cut-off at 0.05 g/cm^3

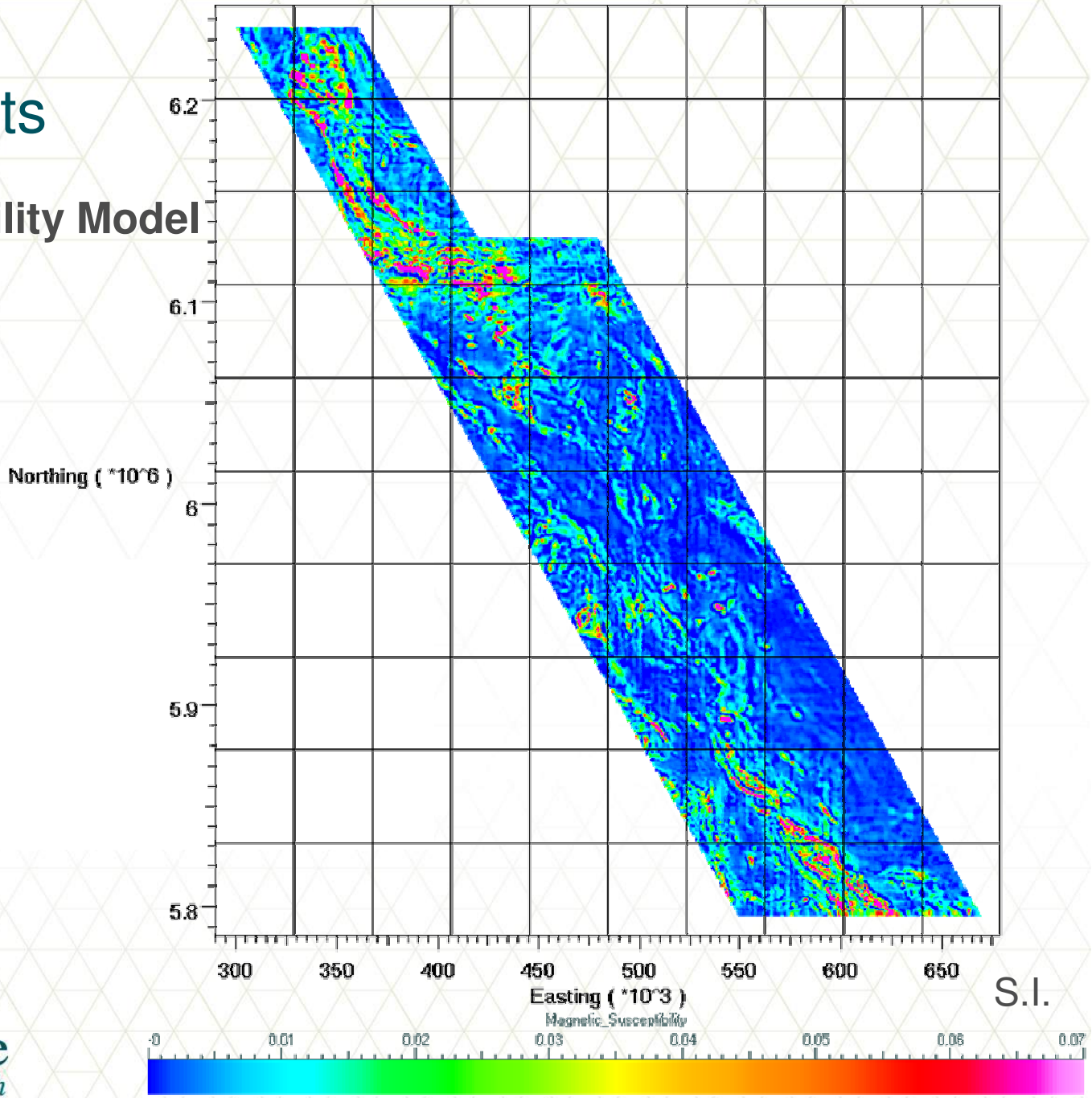


Mira Geoscience
...modelling the earth

Inversion Results

Magnetic Susceptibility Model

Plan slice at sea level.

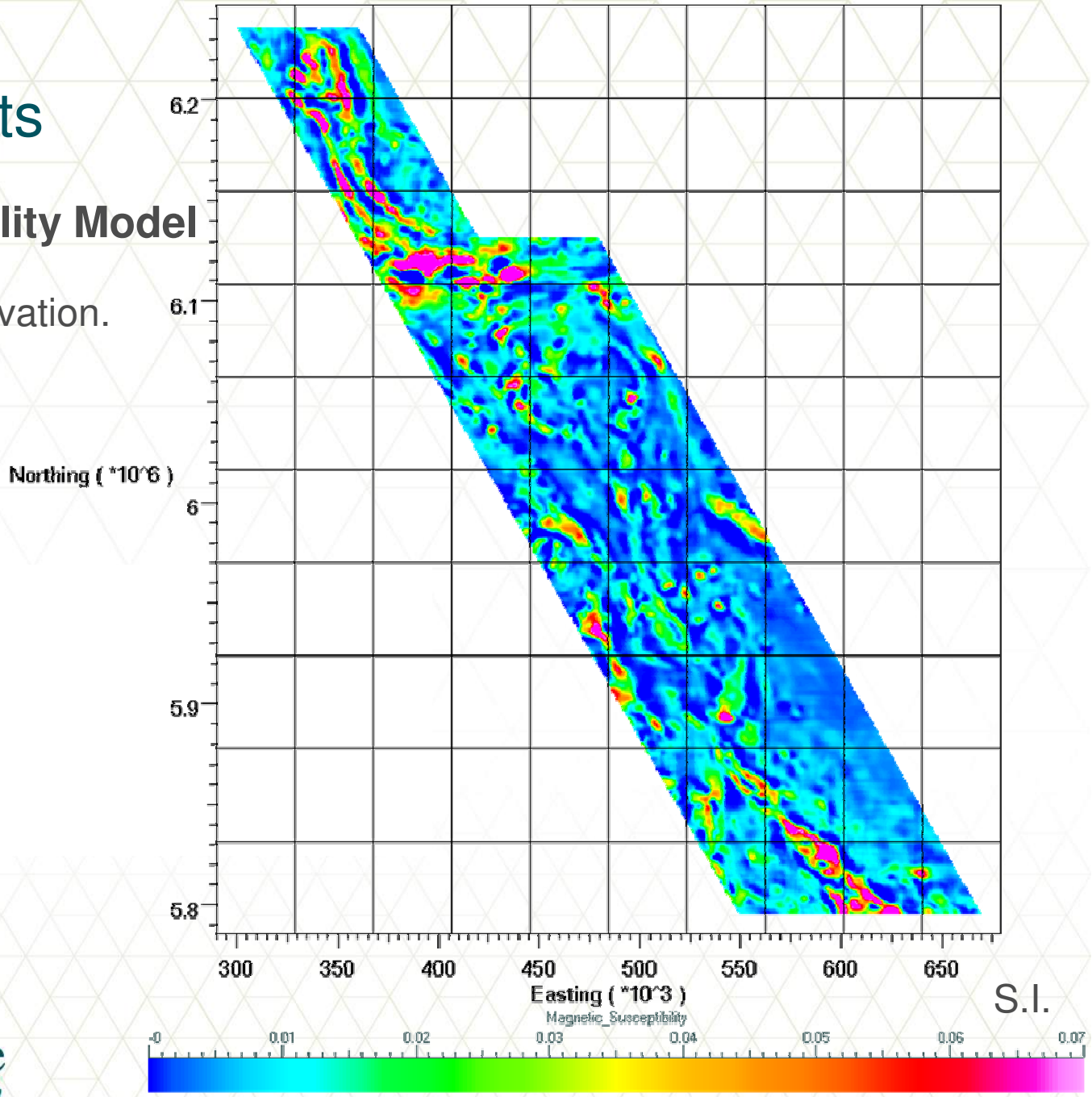


Mira Geoscience
...modelling the earth

Inversion Results

Magnetic Susceptibility Model

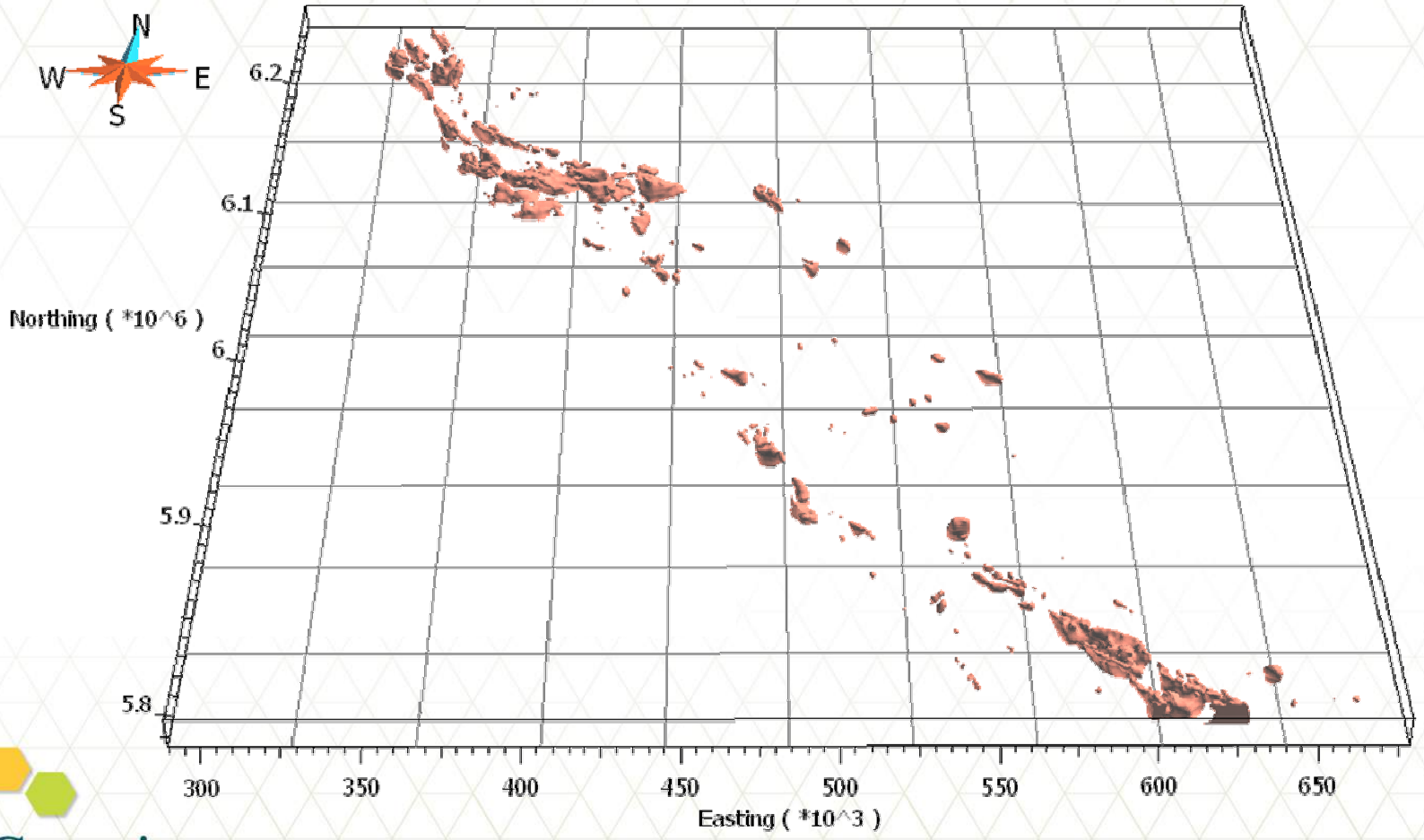
Plan slice at -2500m elevation.



Mira Geoscience
...modelling the earth

Inversion Results

Magnetic Susceptibility Model - iso-surface cut-off at 0.05 S.I.

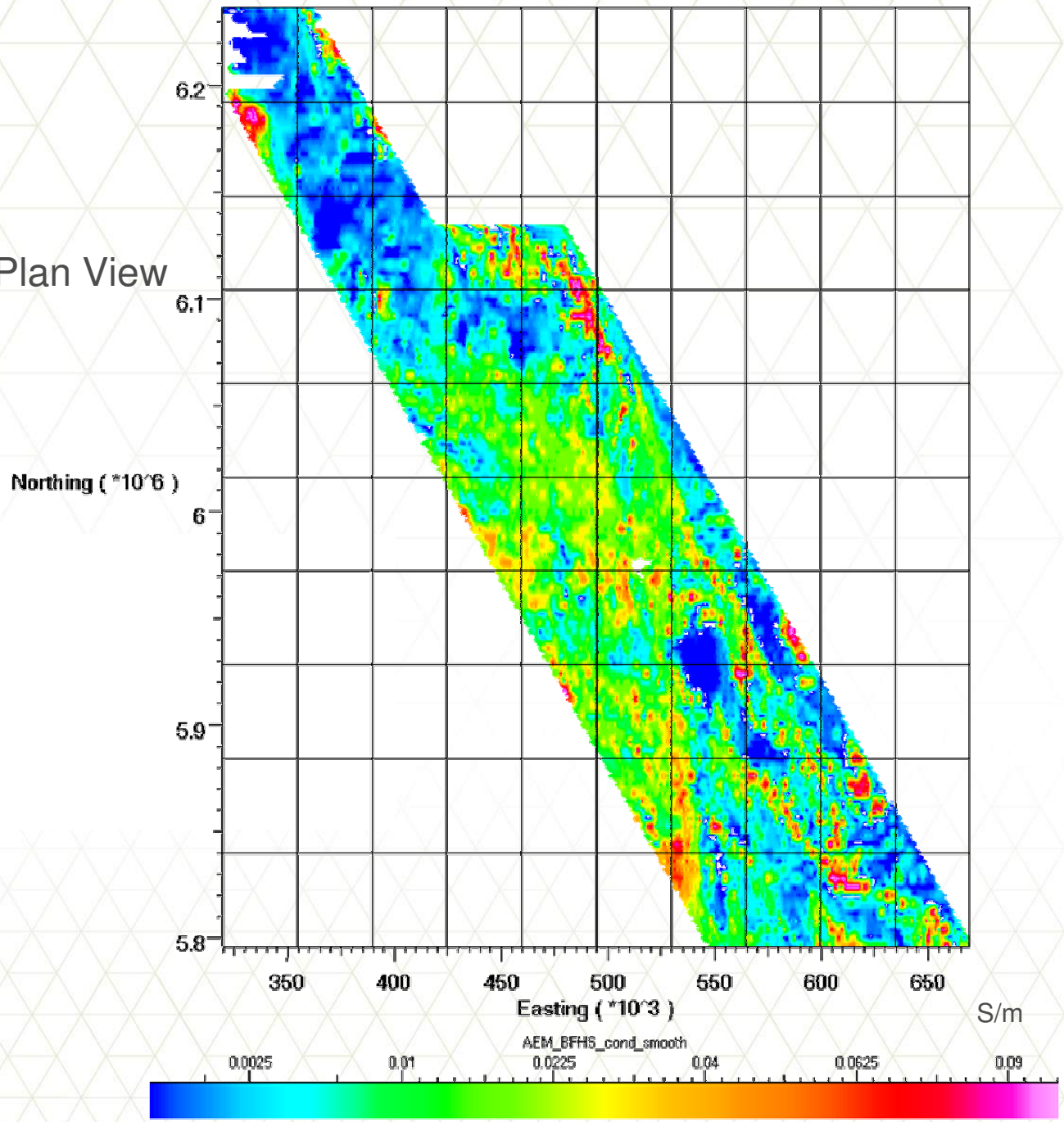


Mira Geoscience
...modelling the earth

Inversion Results

Conductivity Model

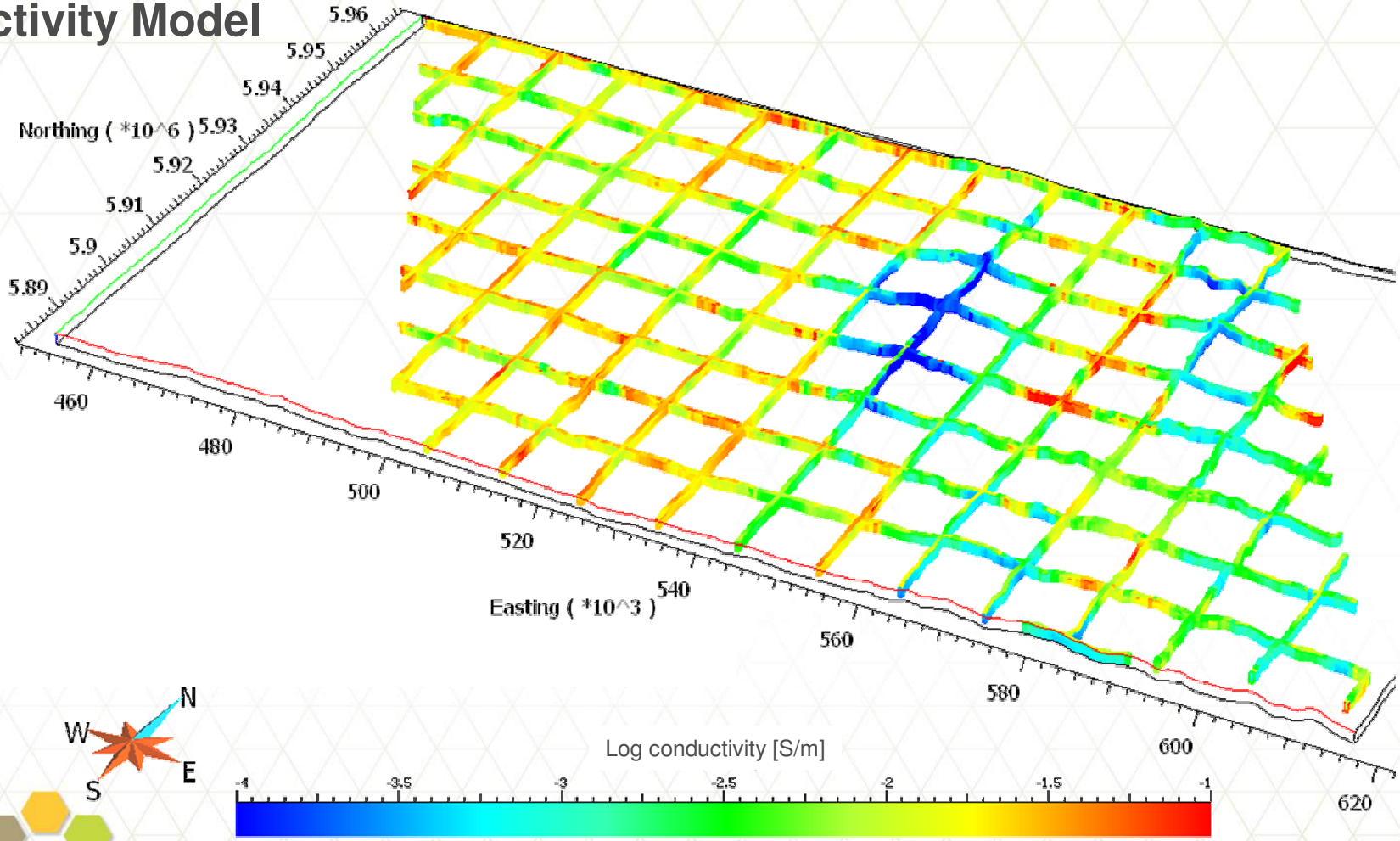
Background Conductivity: Plan View



Mira Geoscience
...modelling the earth

Inversion Results

Conductivity Model

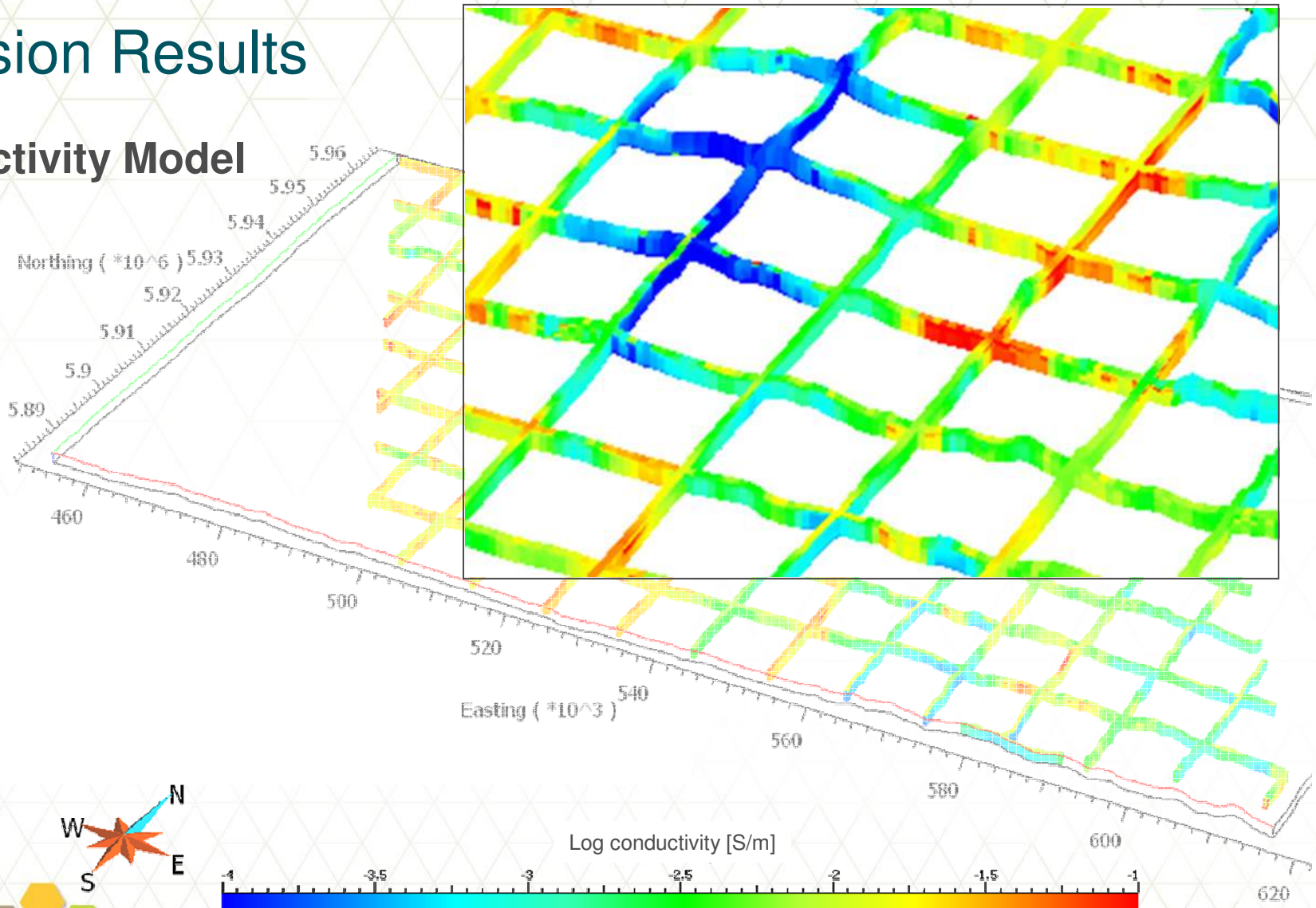


Mira Geoscience
...modelling the earth

Inversion Results

Conductivity Model

Zoom



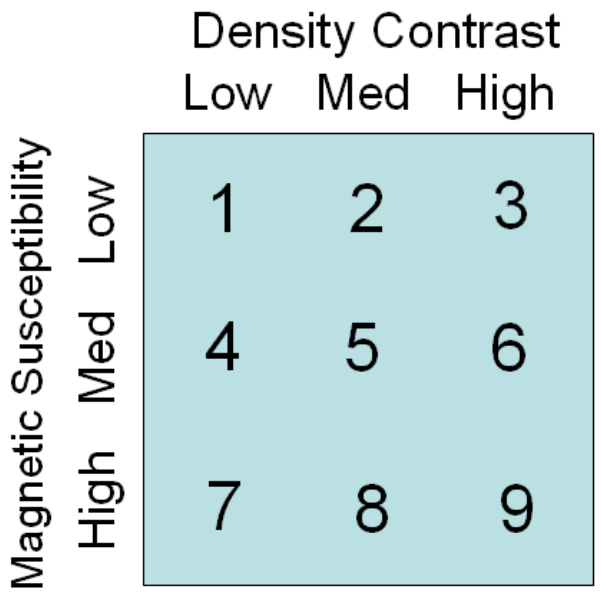
Mira Geoscience

...modelling the earth

Inversion Results

Physical Property Classification

- Common 3D Discretization Mesh
- Each Physical Property classified into High, Medium, and
- Density Contrast and Magnetic Susceptibility
  Two-phase system → 9 classifications



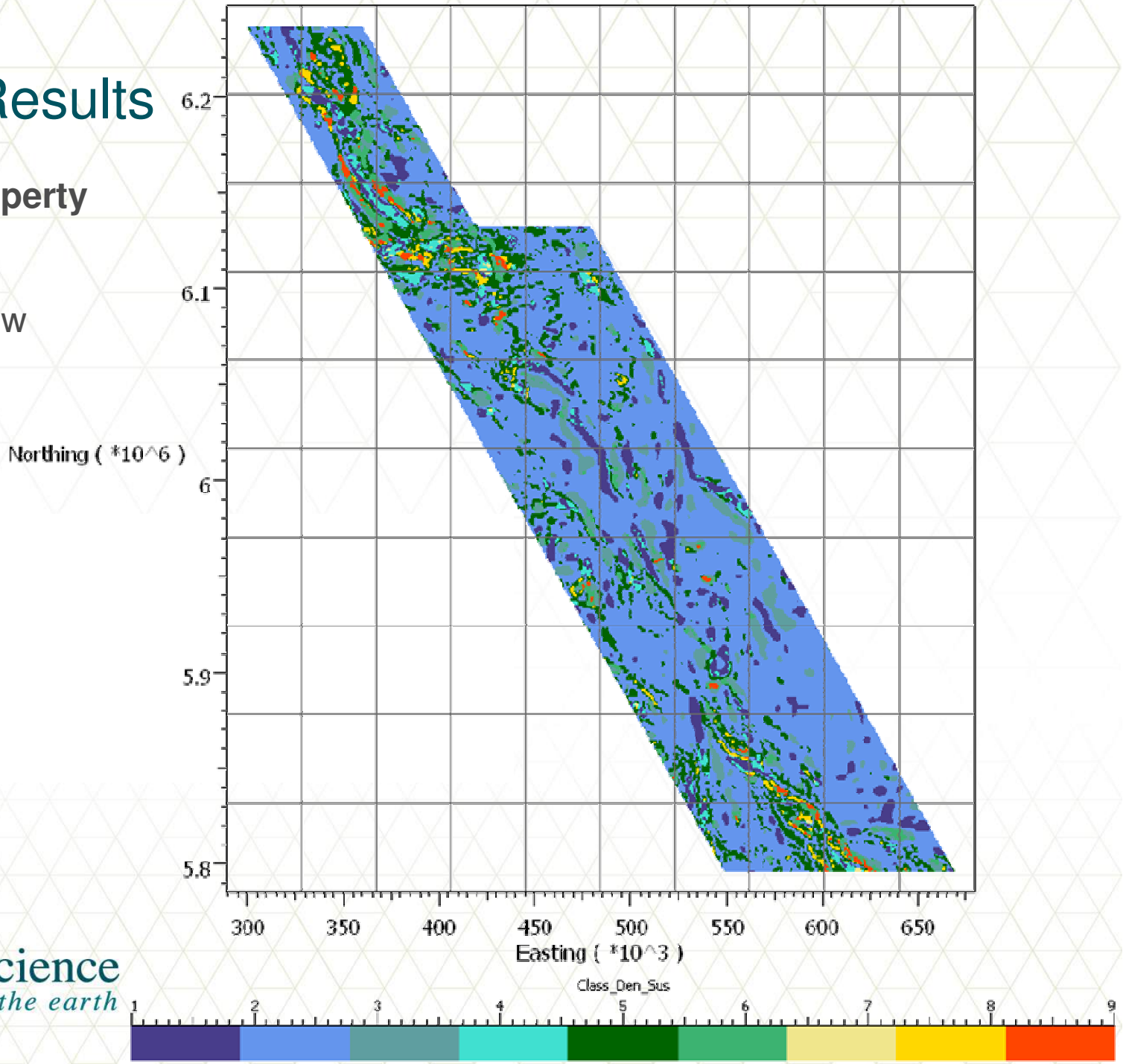
- Density Contrast, Magnetic Susceptibility, and Conductivity Background
  Three-phase system → 27 classifications

Mira Geoscience
...modelling the earth

Inversion Results

3D Physical Property Classification

Surficial Plan View

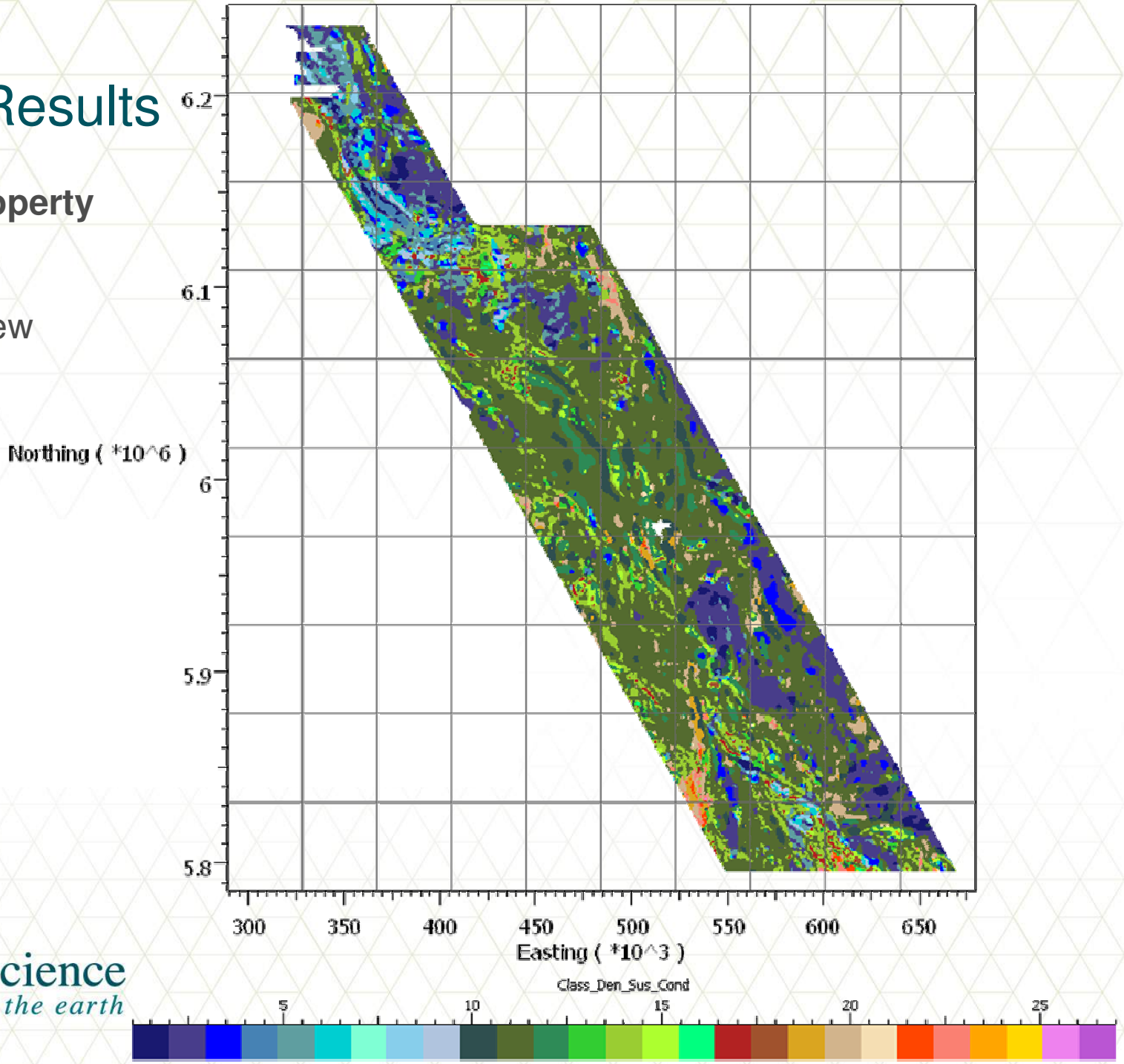


Mira Geoscience
...modelling the earth

Inversion Results

3D Physical Property Classification

Surficial Plan View



Mira Geoscience
...modelling the earth

Deliverables www.geosciencebc.com/s/2009-15.asp

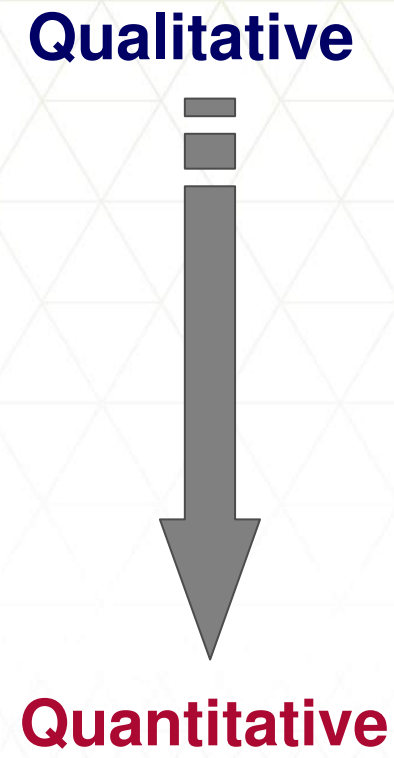
For whole survey, or separated into survey blocks or lines

- Observed and Predicted Data
- Density Contrast Model [g/cm^3]
- Magnetic Susceptibility Model [S.I.]
- Interpolated Conductivity Model [S/m]
- 1D conductivity models
- Conductivity Depth of Investigation Estimate
- Background conductivity map
- Integrated 3D Physical Property Classification models
- Gocad, UBC, Geosoft Grid, DXF, and ASCII formats
- Iso-surfaces for physical property values
- Gocad Projects
- 3D PDF scenes
- Report

Mira Geoscience
...modelling the earth

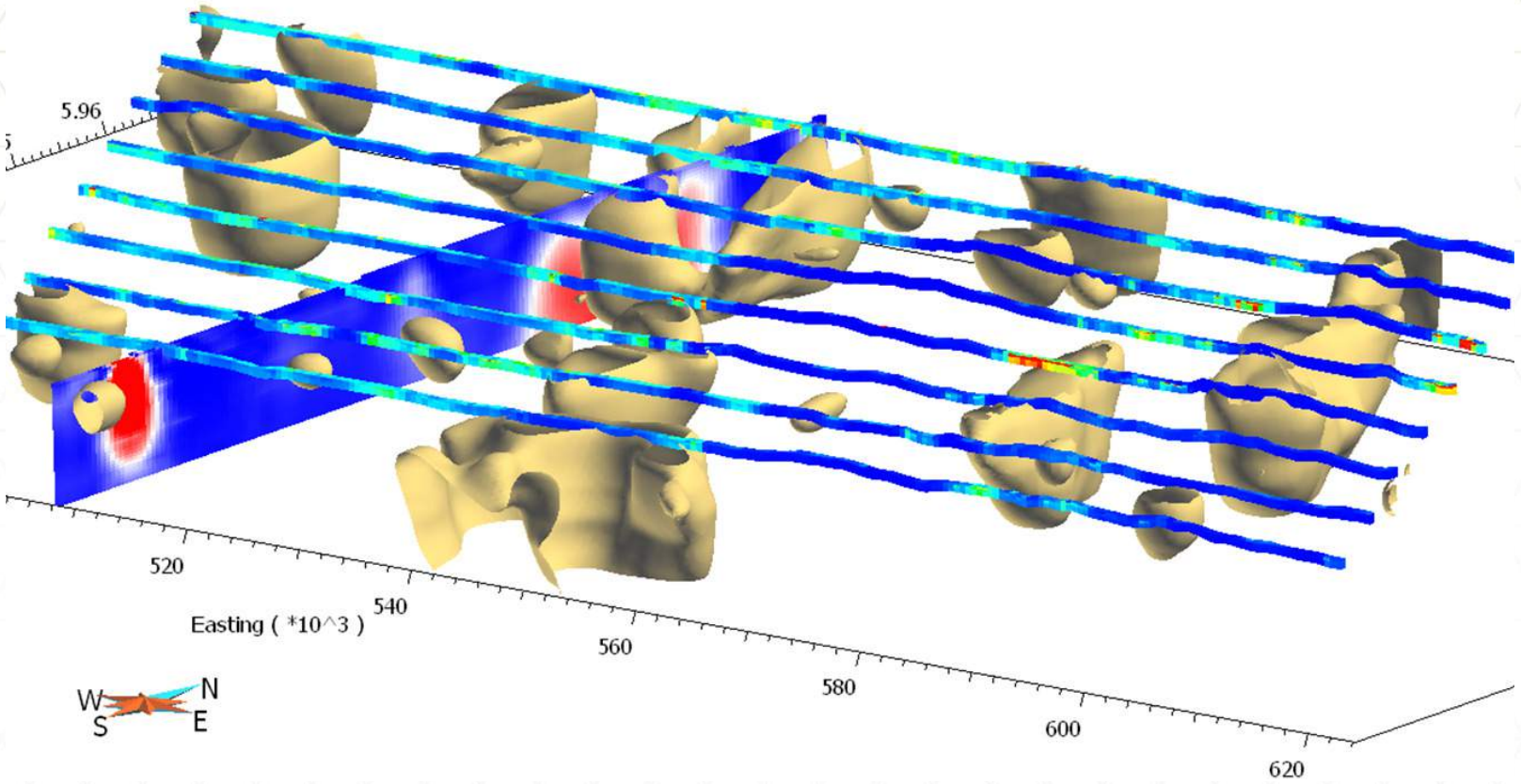
Using the Results

- Regional Interpretation
- Integrated Interpretation
- Interpretation with Physical Properties
- Constraining Information
- Target Customization
- Survey Design
- Integrated Modelling
- Common Earth Model Development
- 3D GIS Regional Targeting



Mira Geoscience
...modelling the earth

Using the Results



Mira Geoscience
...modelling the earth

Quest Block C:

- Conductivity model: East-West flight line model sections
- Density Contrast iso-surface at a value of 0.05g/cm3
- North-South magnetic susceptibility section

Using the Results

Evaluation of physical property classification based on known mineral occurrences:

1. Compute spatial correlation of physical property classifications with known mineral occurrences in 3D.

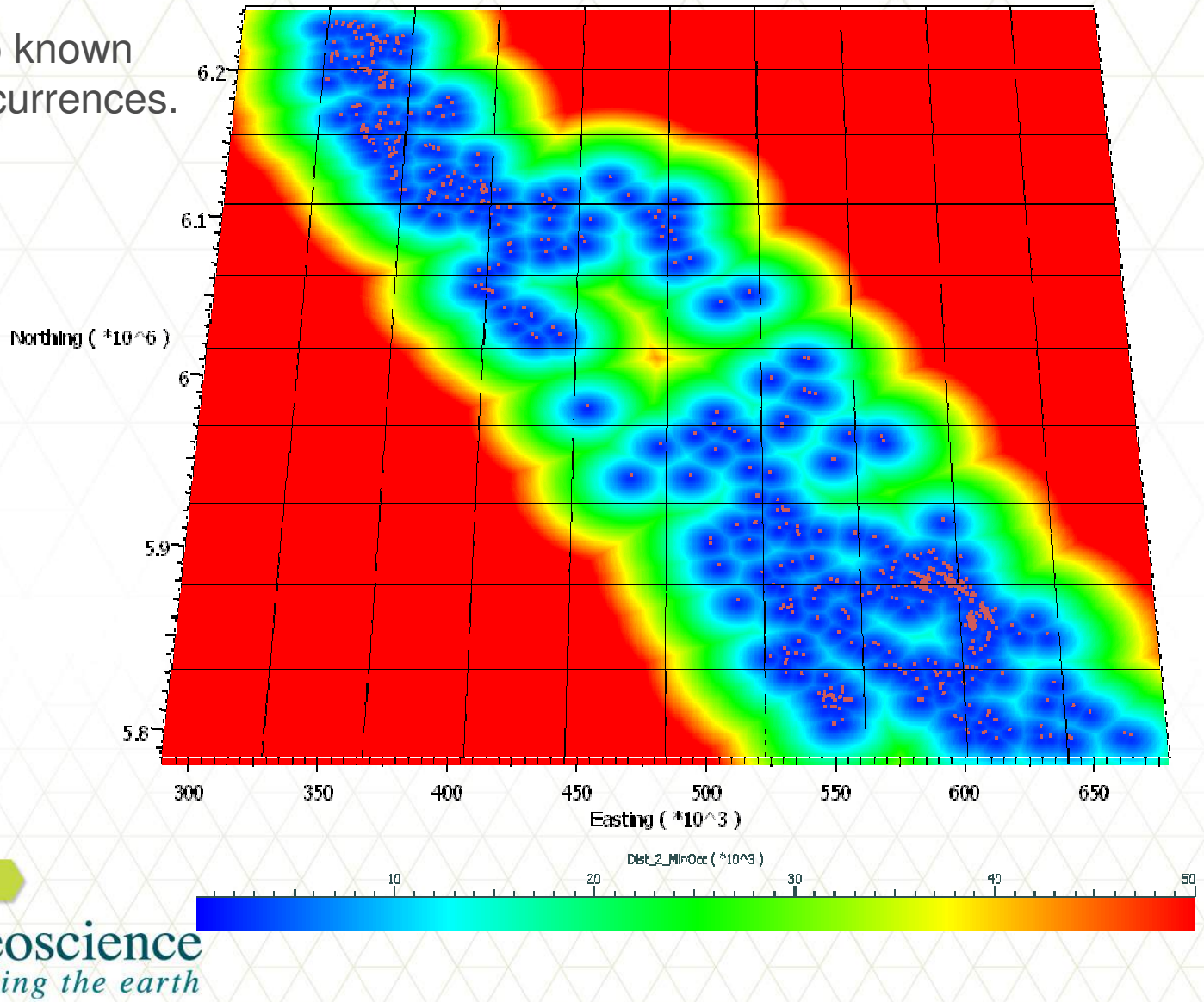
2. Determine which class has the highest correlation.

3. Perform for Density Contrast and Magnetic Susceptibility two-phase system, and Density Contrast, Magnetic Susceptibility, and Conductivity Background three-phase system.

Mira Geoscience
...modelling the earth

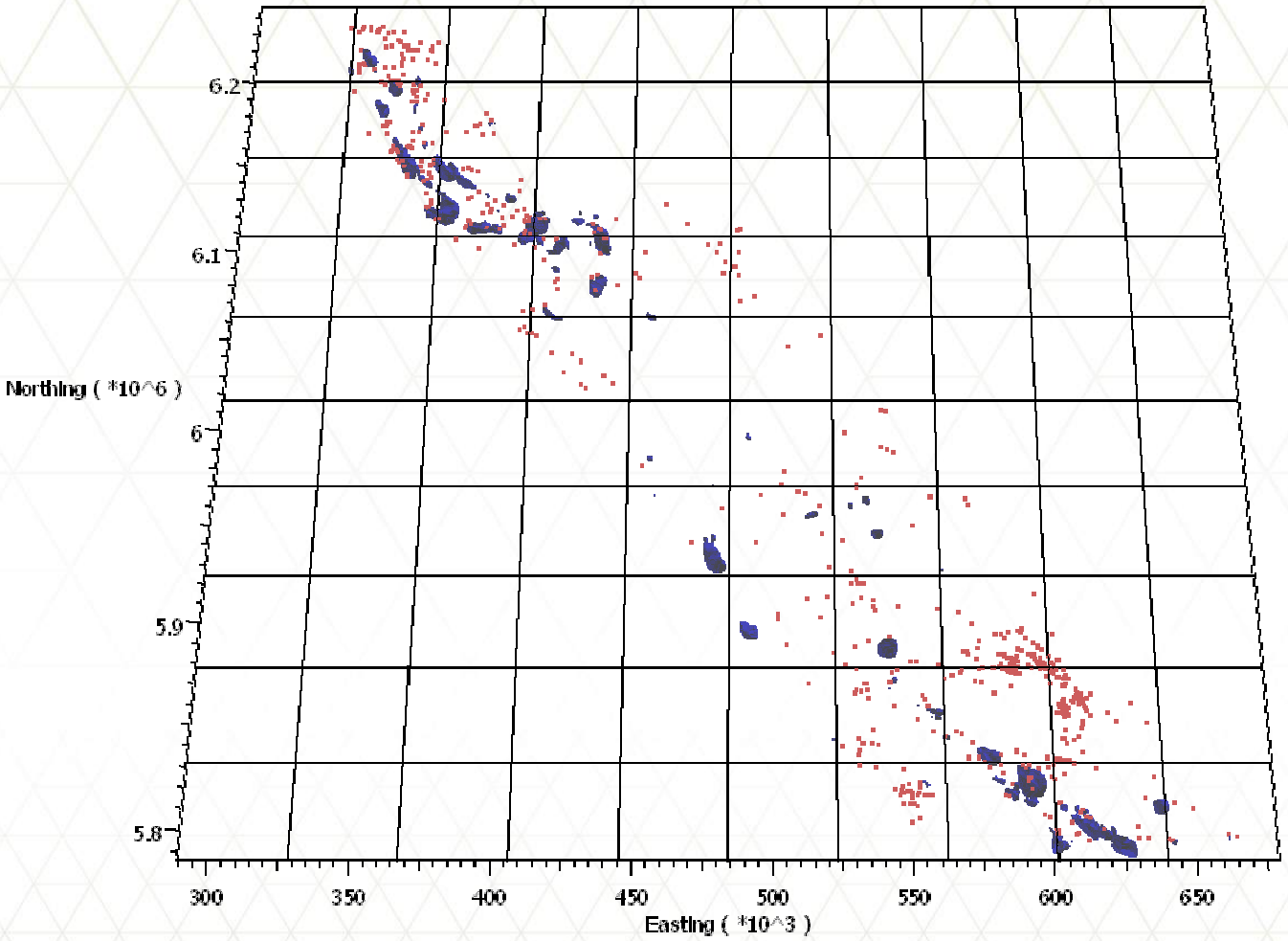
Using the Results – evaluation of physical property classification

Distance to known mineral occurrences.



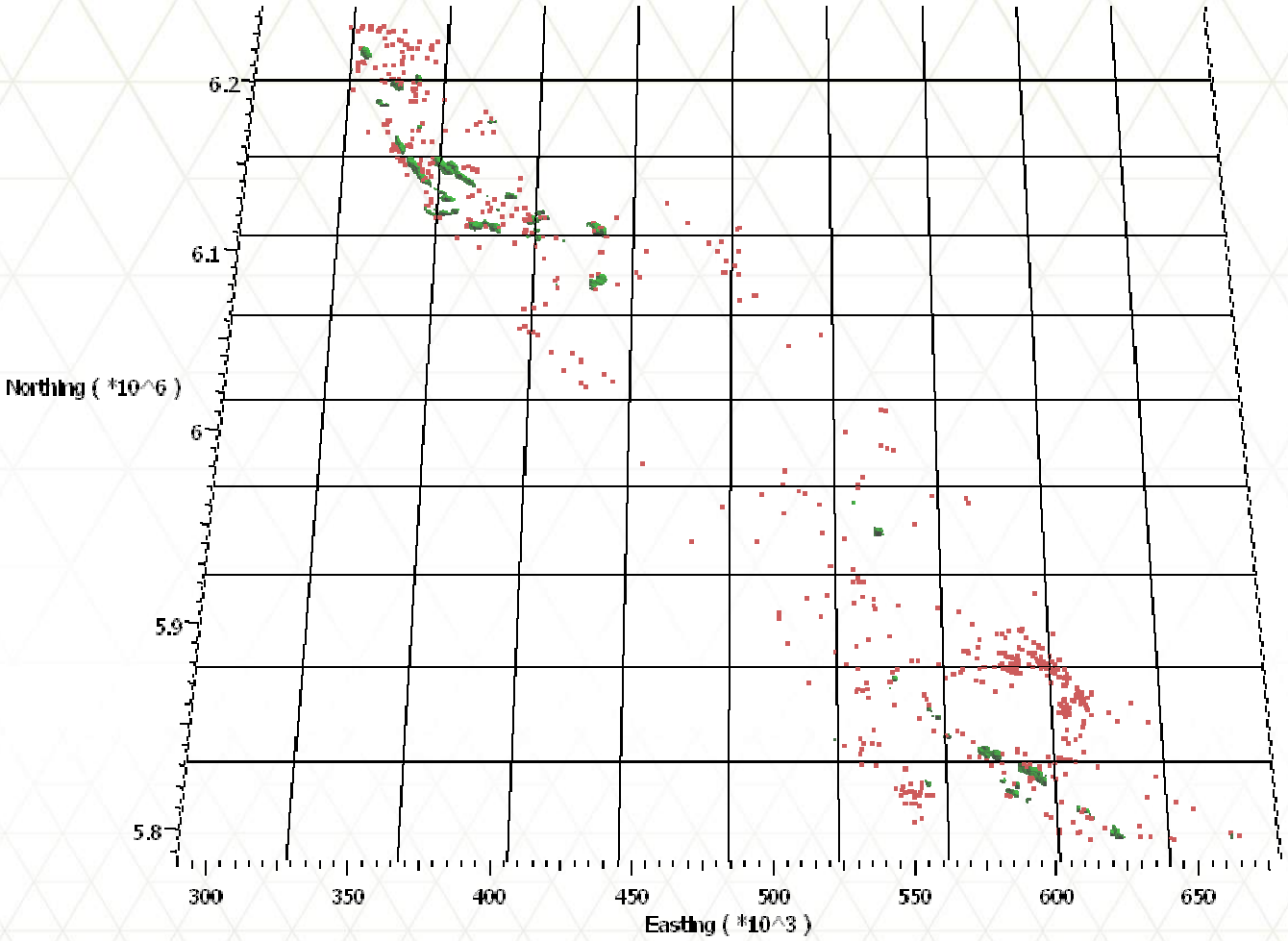
Mira Geoscience
...modelling the earth

Using the Results – Den/Sus: Class 9



Mira Geoscience
...modelling the earth

Using the Results – Den/Sus/Con: Class 9



Mira Geoscience
...modelling the earth

Acknowledgements

Thi Ngoc Hai Nguyen (Mira Geoscience AGIC)
Vicki Thomson (Mira Geoscience AGIC)
Doug Oldenburg (UBC-GIF)
Roman Shekhtman (UBC-GIF)
Peter Kowalczyk (Geoscience BC)

Mira Geoscience
...modelling the earth

Contact Info

info@mirageoscience.com

Gocad Mining Users Meeting

Vancouver, October 6th and 7th

QUEST 3D GIS study by Peter Kowalczyk

Mira Geoscience

...modelling the earth