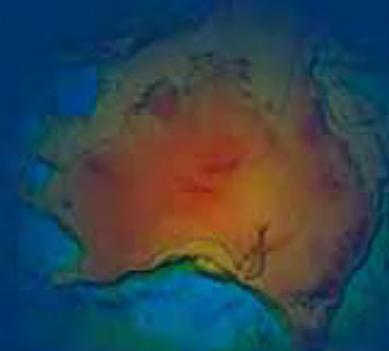
Australian Government

Geoscience Australia

Crustal setting of the Olympic Cu-Au province

Insights from seismic reflection-profiles and inversion of potential-field data

Gawler Minerals Promotion Project



CONTRIBUTORS

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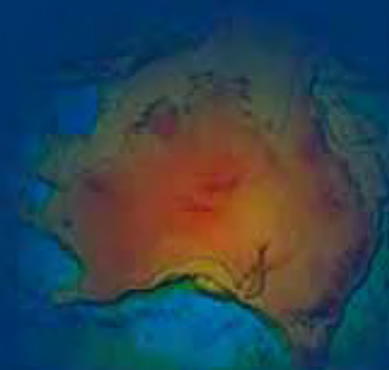
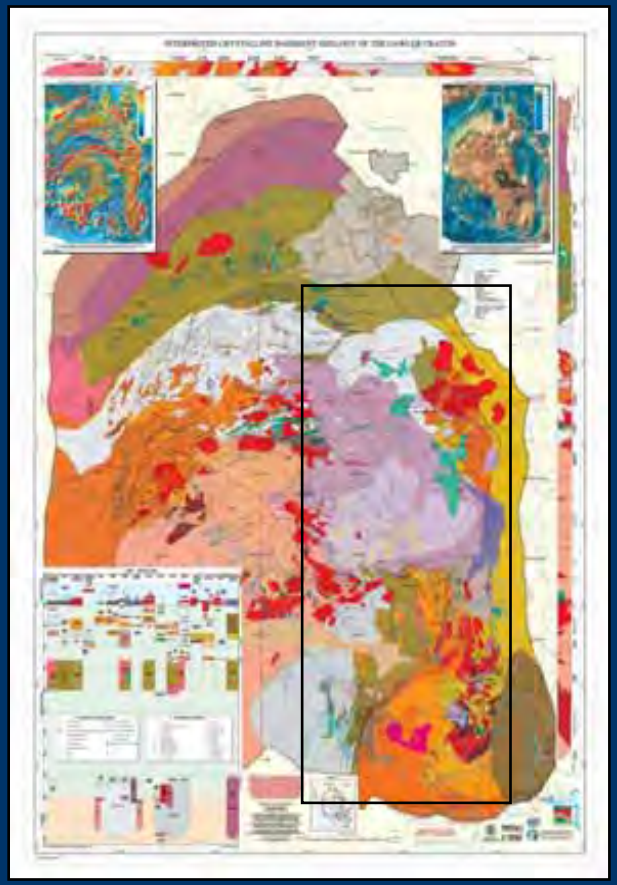
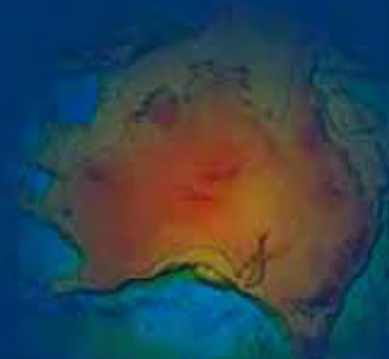
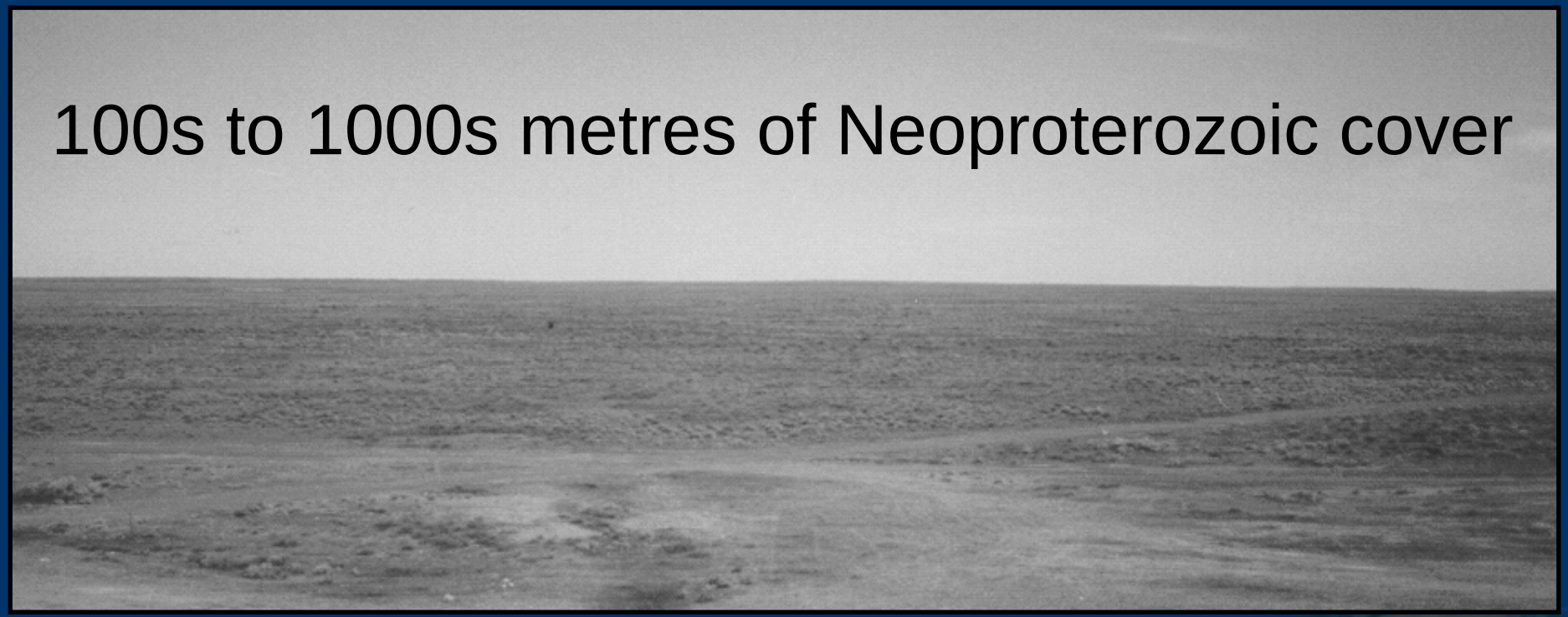




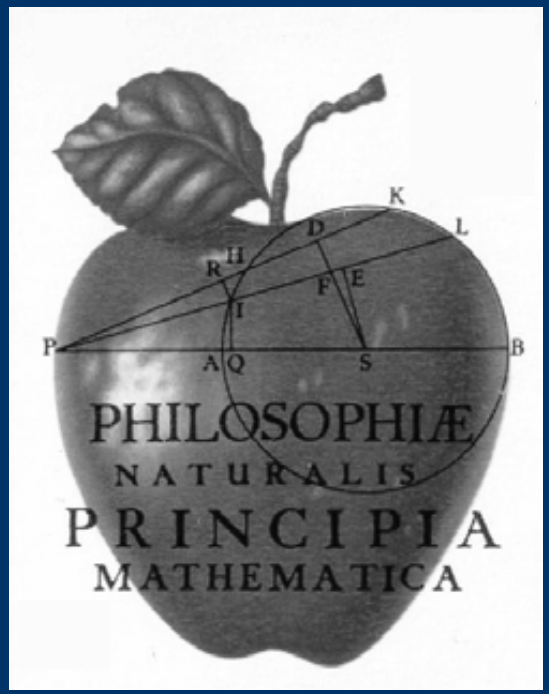
Olympic Cu-Au Province

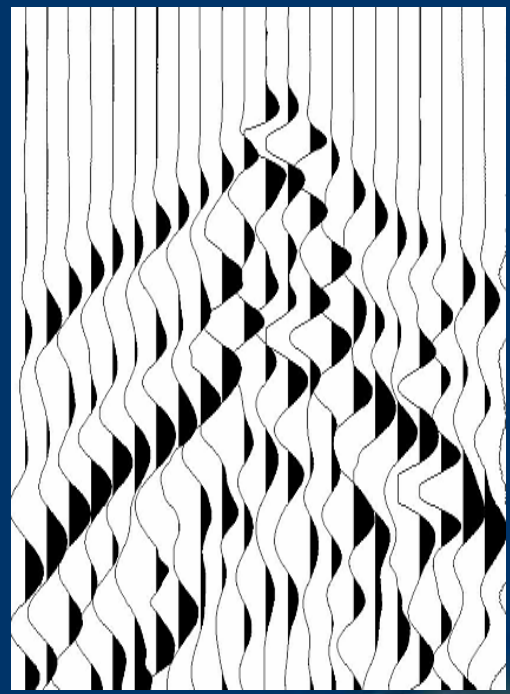


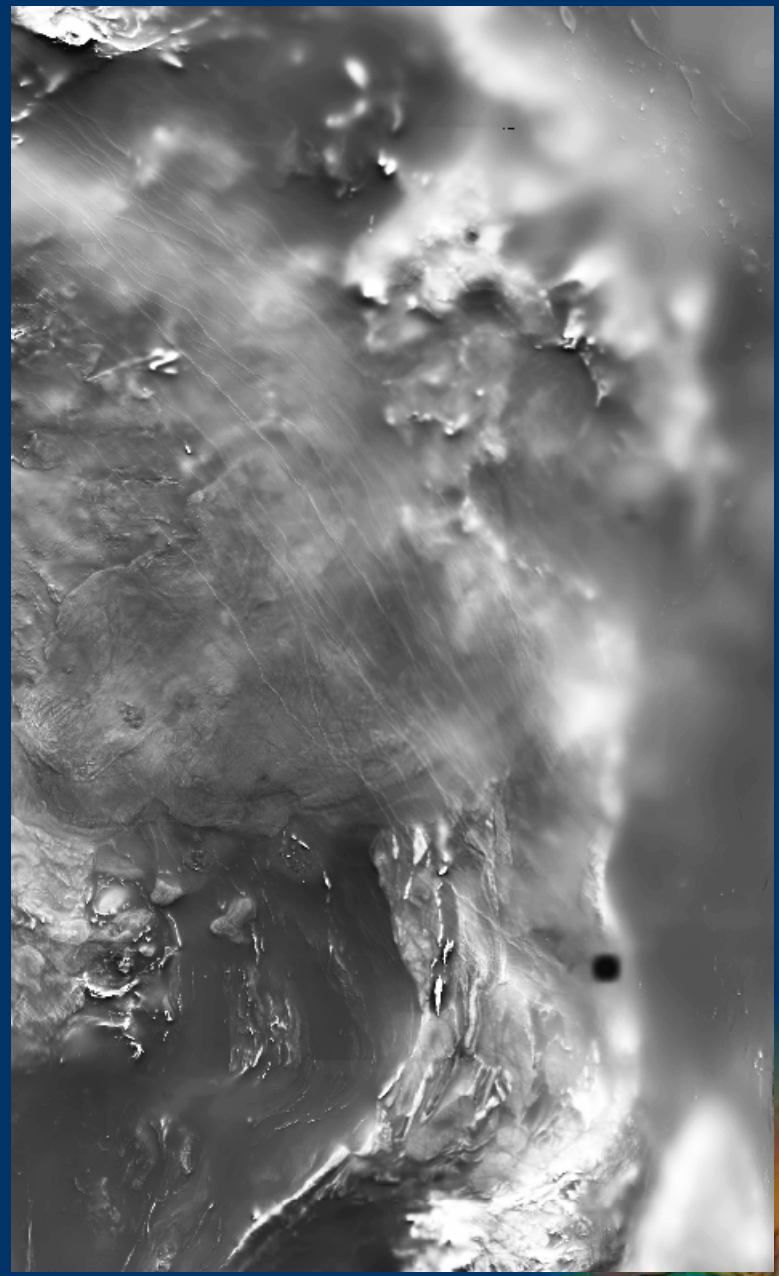
The Problem

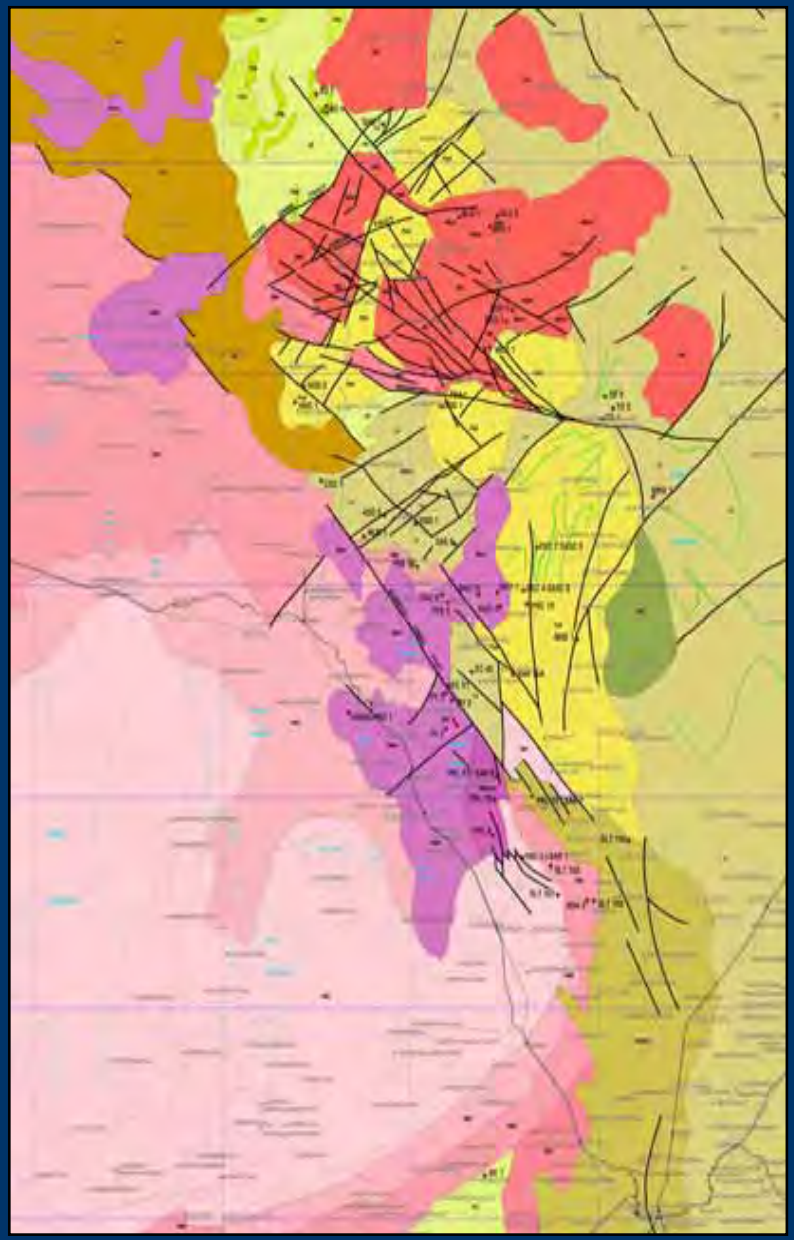


Getting around The Problem







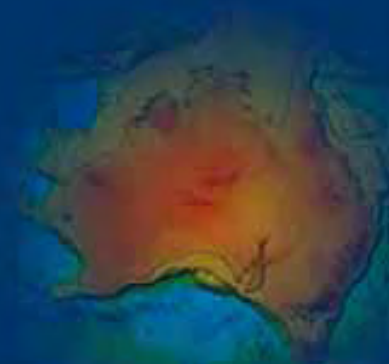


Direen & Lyons 2002

SCALE

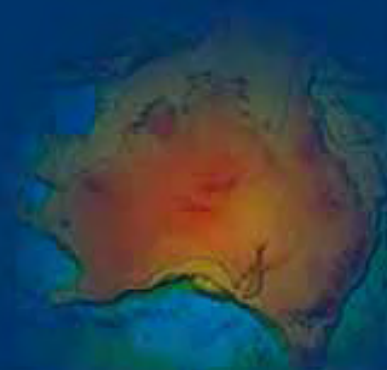
Interpretation of potential-fields in the region of Olympic Dam

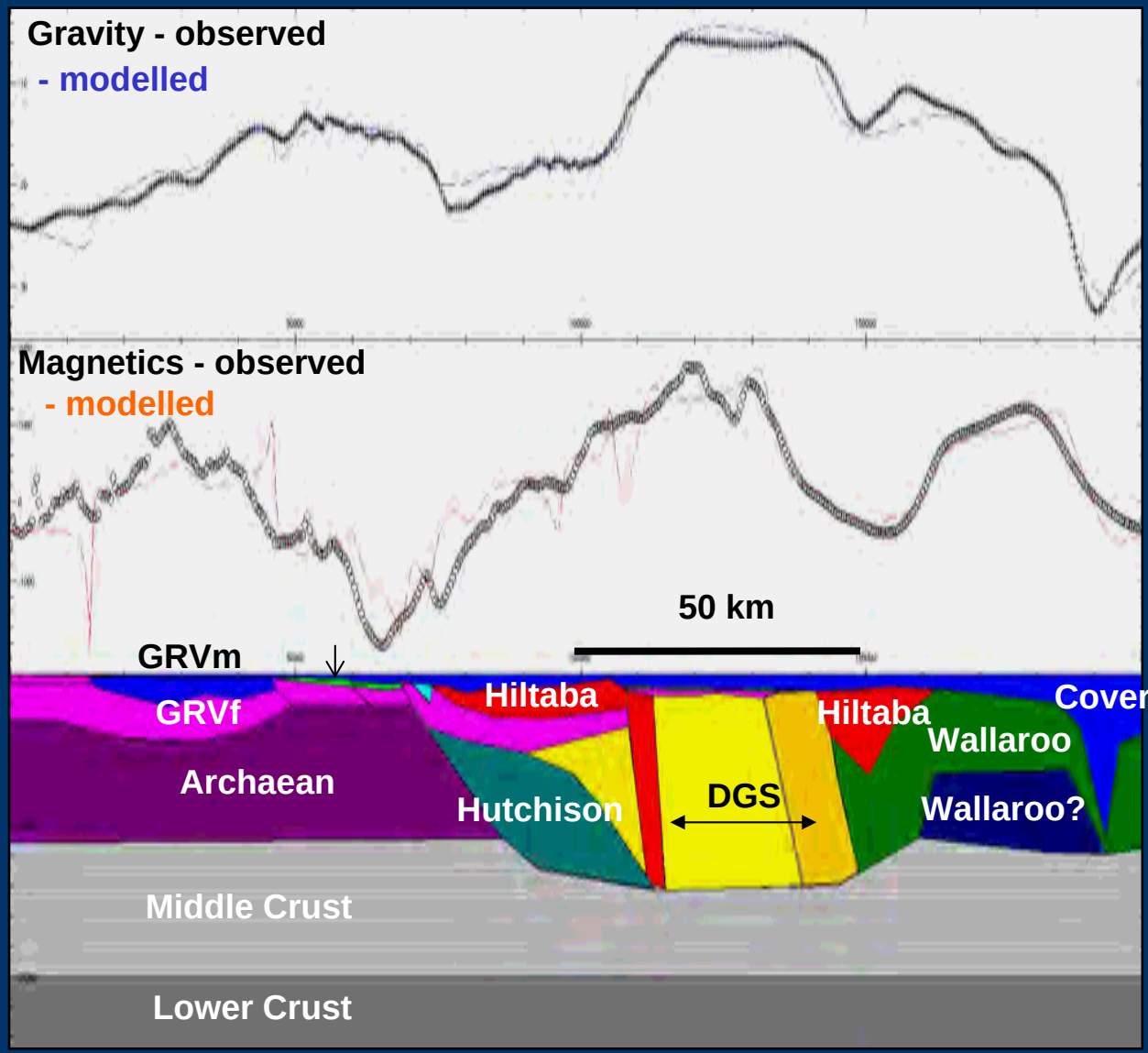
- Gawler Range Volcanics
- Hiltaba Suite
- Wallaroo Group
- Donington Suite
- Hutchison Group
- Archaean basement



FORWARD MODELS

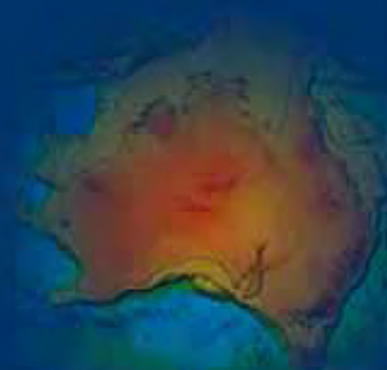
Calculated fields
from a given set of properties





Direen *et al*., 2002

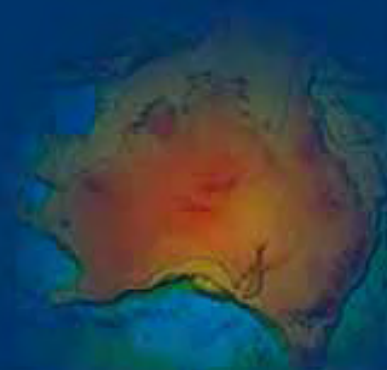
Because the potential-field, at any point,
is the vector-sum of the fields due to all sources,
we cannot know the distribution of the sources



Another problem

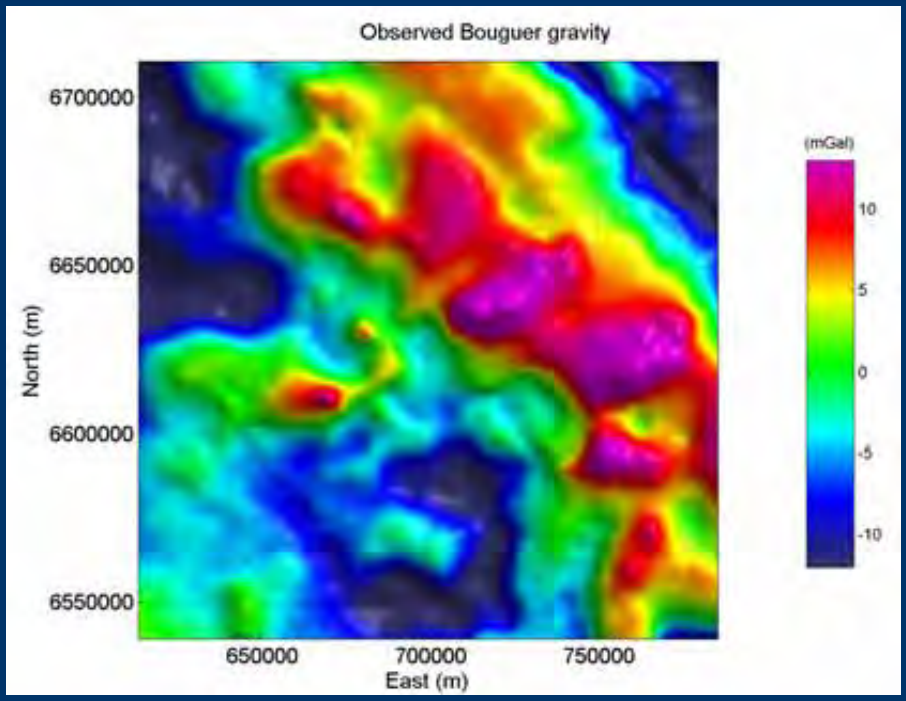
We want to obtain density/susceptibly-distribution from observed fields

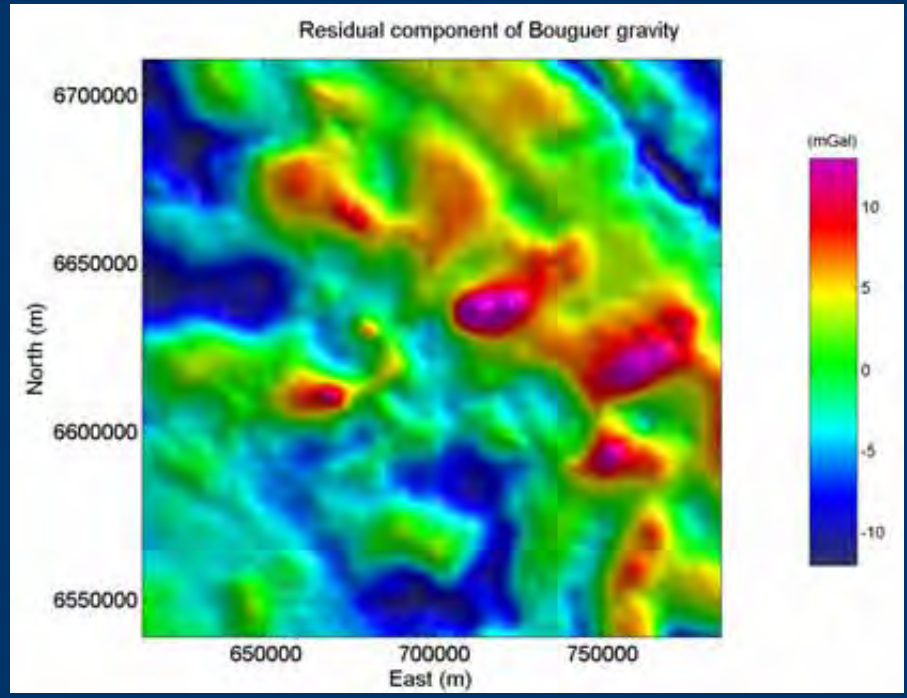
INVERSION

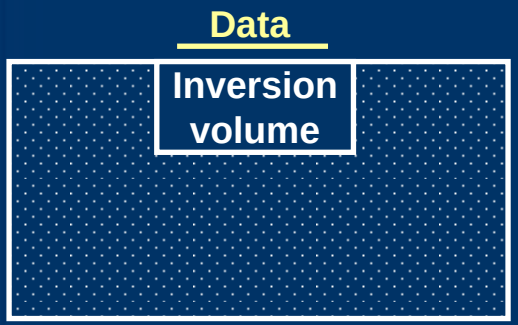


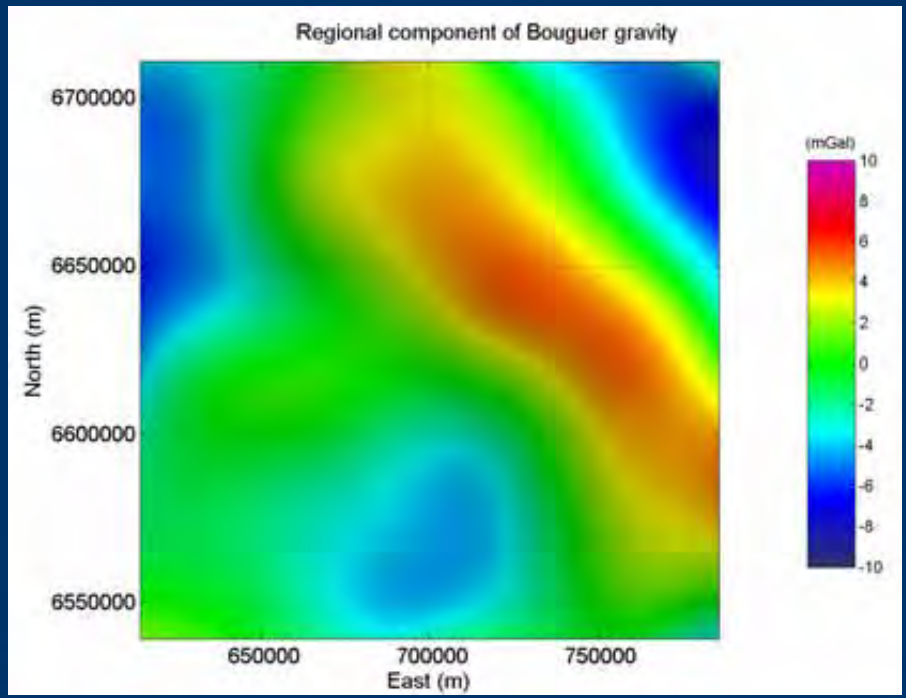
ADVANTAGES OF INVERSION

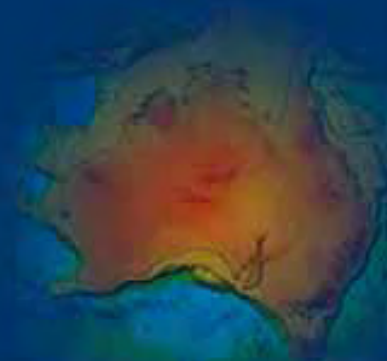
- 3D structure – difficult to connect individual 2D cross-sections
- Can be guided by existing knowledge
- Rigorously and objectively account for all features in the data
- Ensure consistency between models and observations
- Allow for systematic errors in the data
- Show where models are not compatible with data

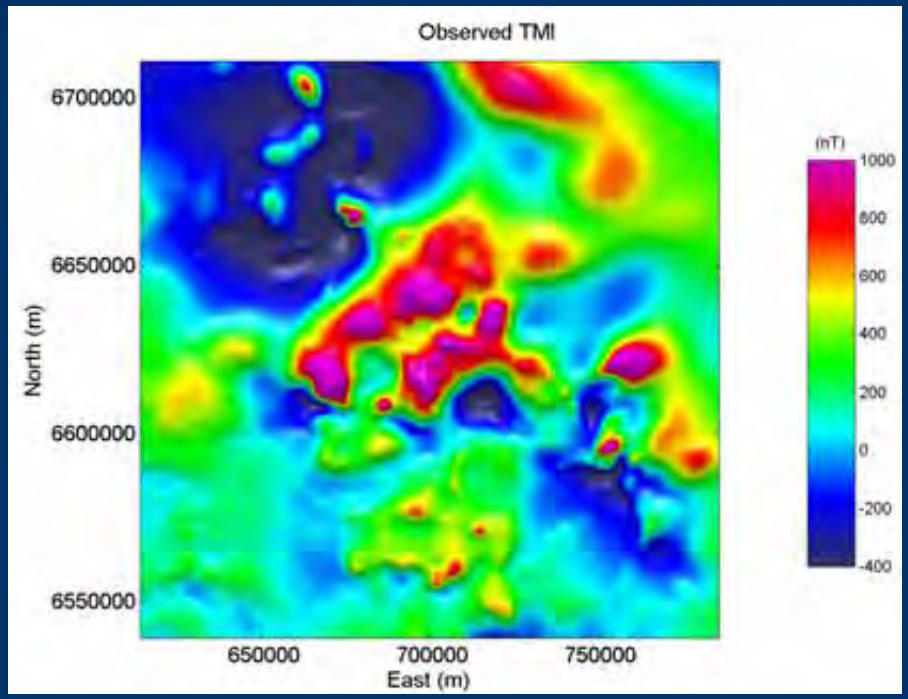

Observed Bouguer gravity
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)
(mGal)
10
5
0
-5
-10

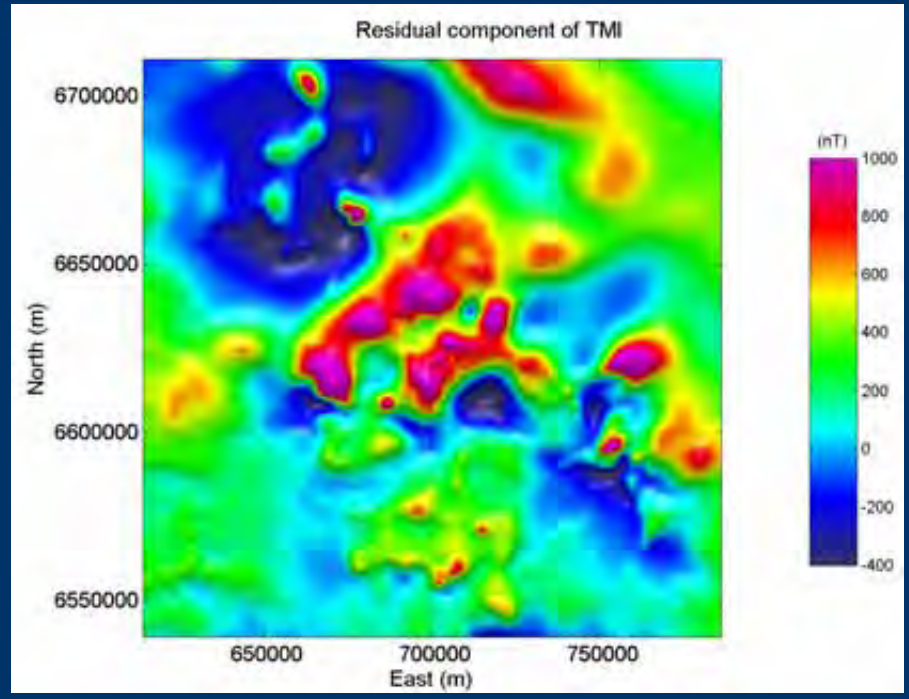

Residual component of Bouguer gravity
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)
(mGal)
10
5
0
-5
-10

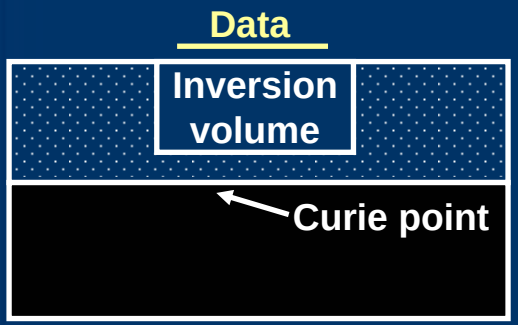

Data
Inversion volume

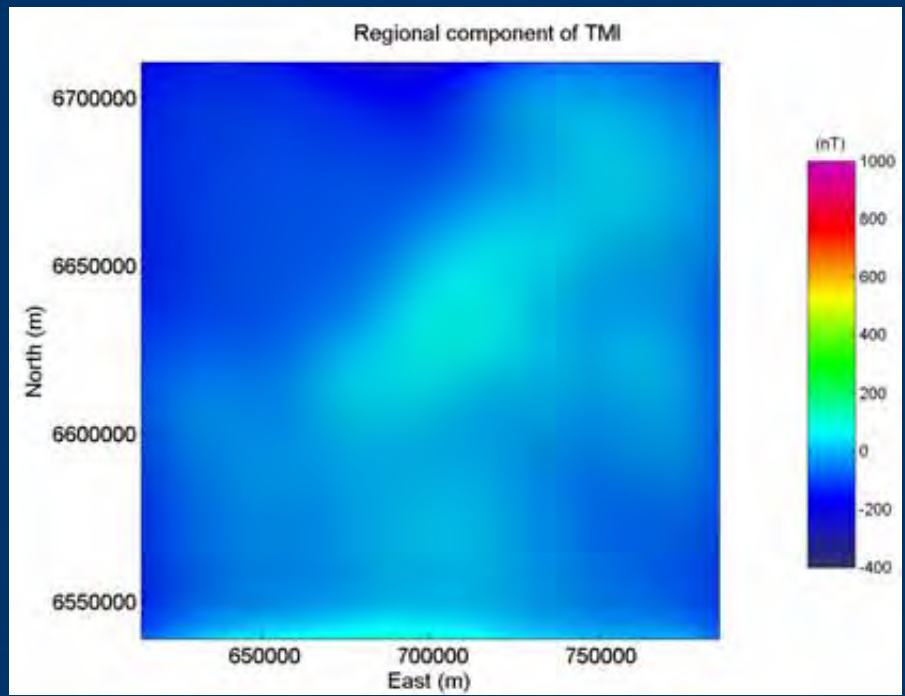

Regional component of Bouguer gravity
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)
(mGal)
10
8
6
4
2
0
-2
-4
-6
-8
-10

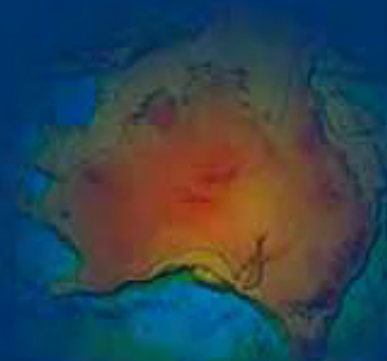



Observed TMI
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)
(nT)
1000
800
600
400
200
0
-200
-400


Residual component of TMI
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)
(nT)
1000
800
600
400
200
0
-200
-400


Data
Inversion volume
Curie point


Regional component of TMI
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)
(nT)
1000
800
600
400
200
0
-200
-400

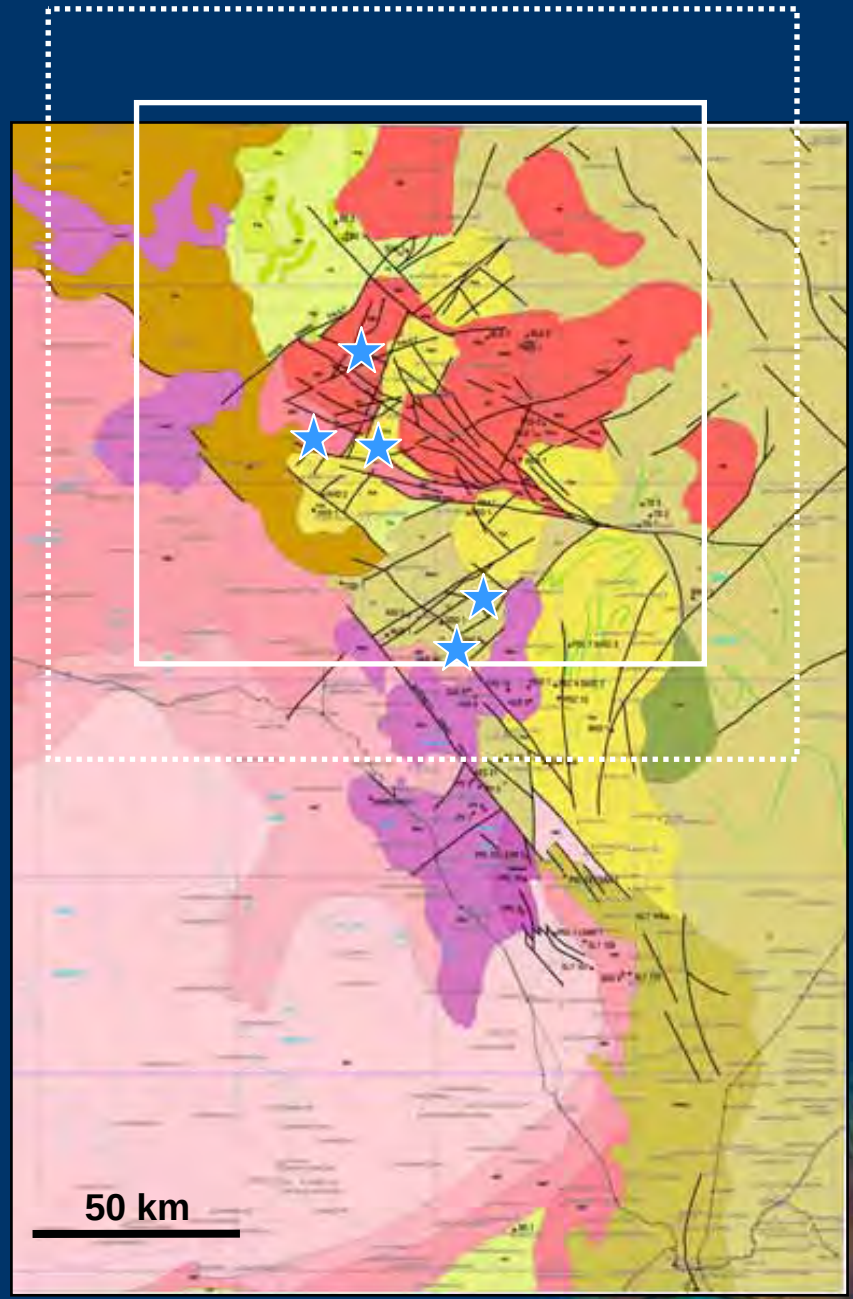


REGION INVERTED

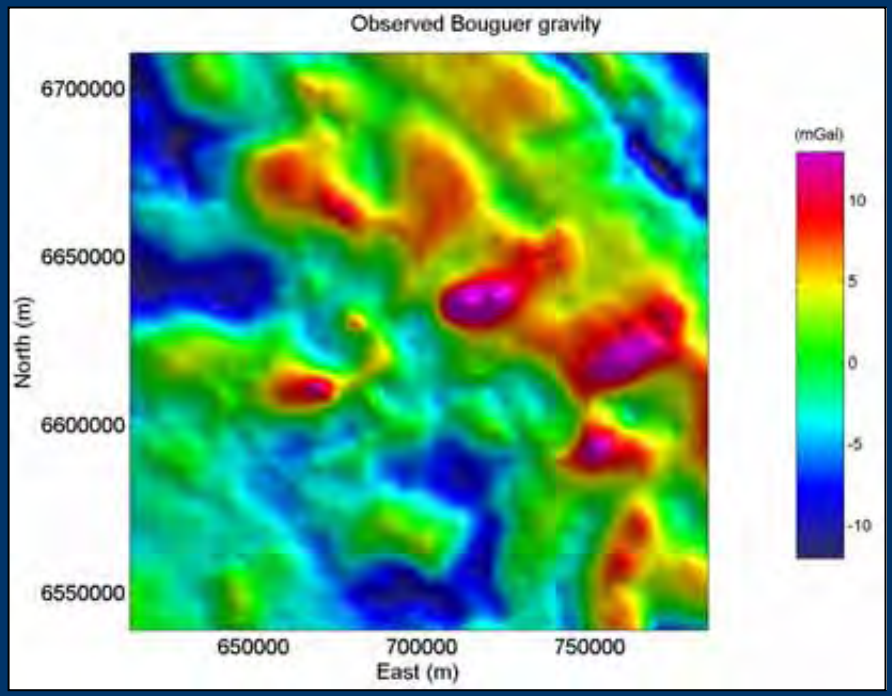
Volume of interest:
150 km × 150 km × 12 km
= 270,000 km³

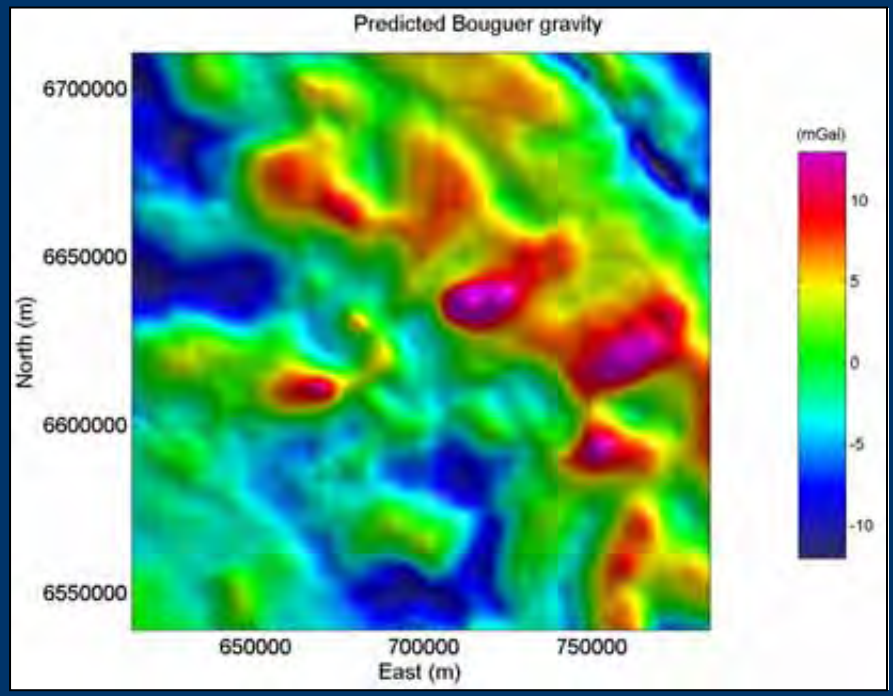
Padded extent:
198 km_X × 198 km_Y × 18 km_Z
= 705,672 km³

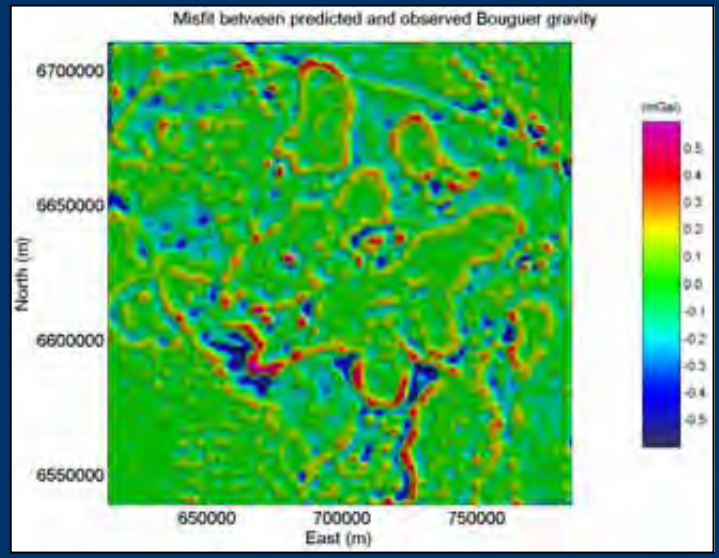
1 km × 1 km × 0.5 km cells
= 1 411 344 cells



OBSERVED AND PREDICTED GRAVITY

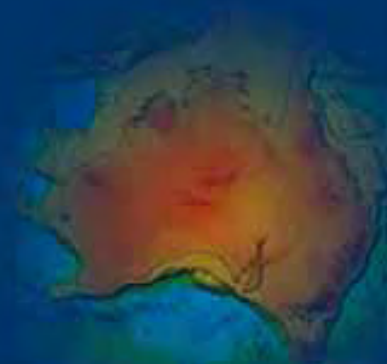




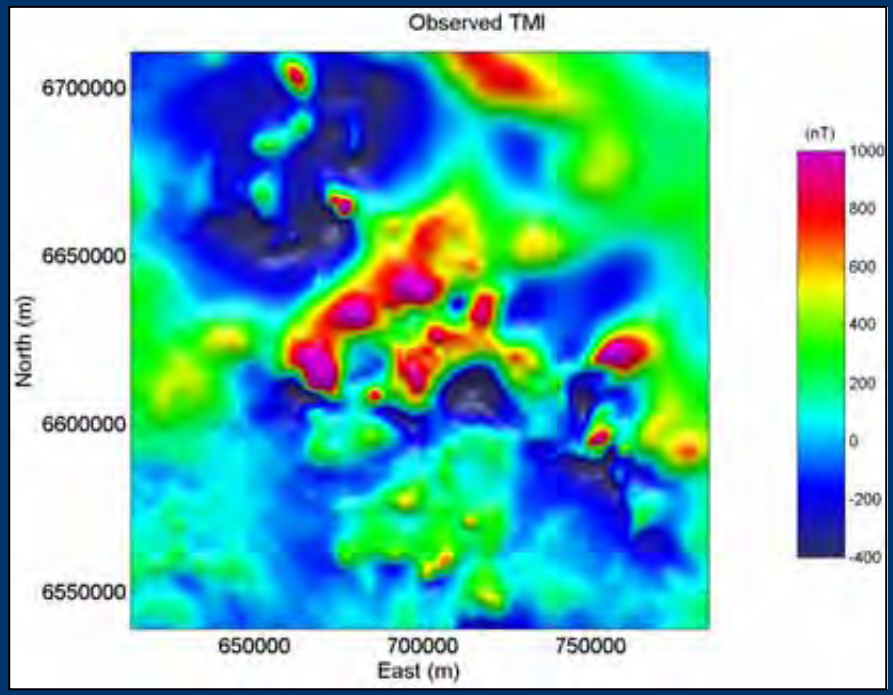


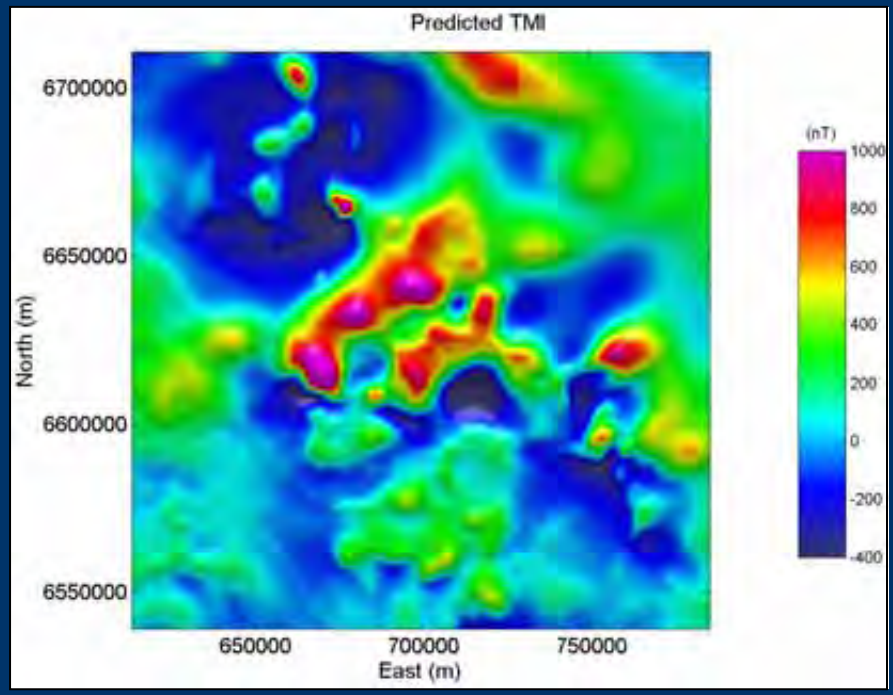
Misfit

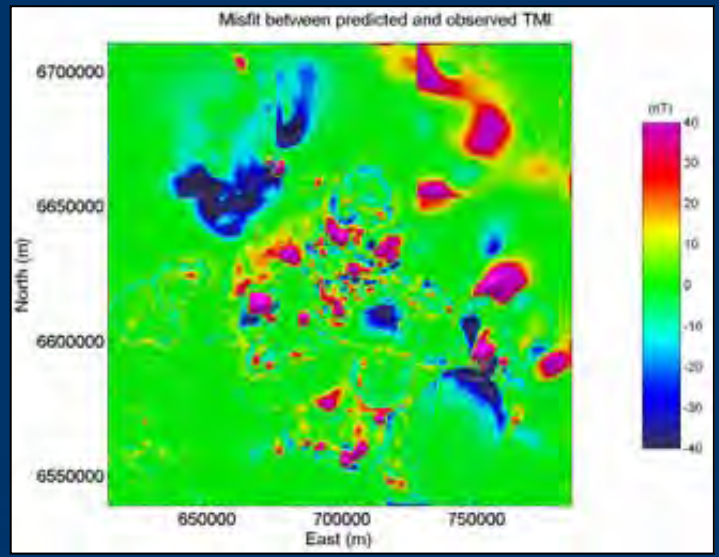
~5% of data range



OBSERVED AND PREDICTED MAGNETICS

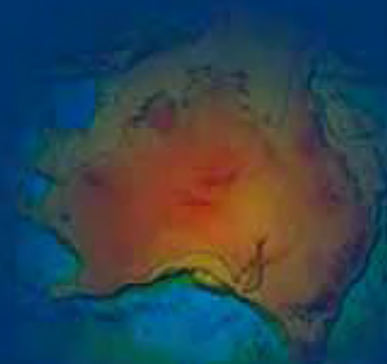






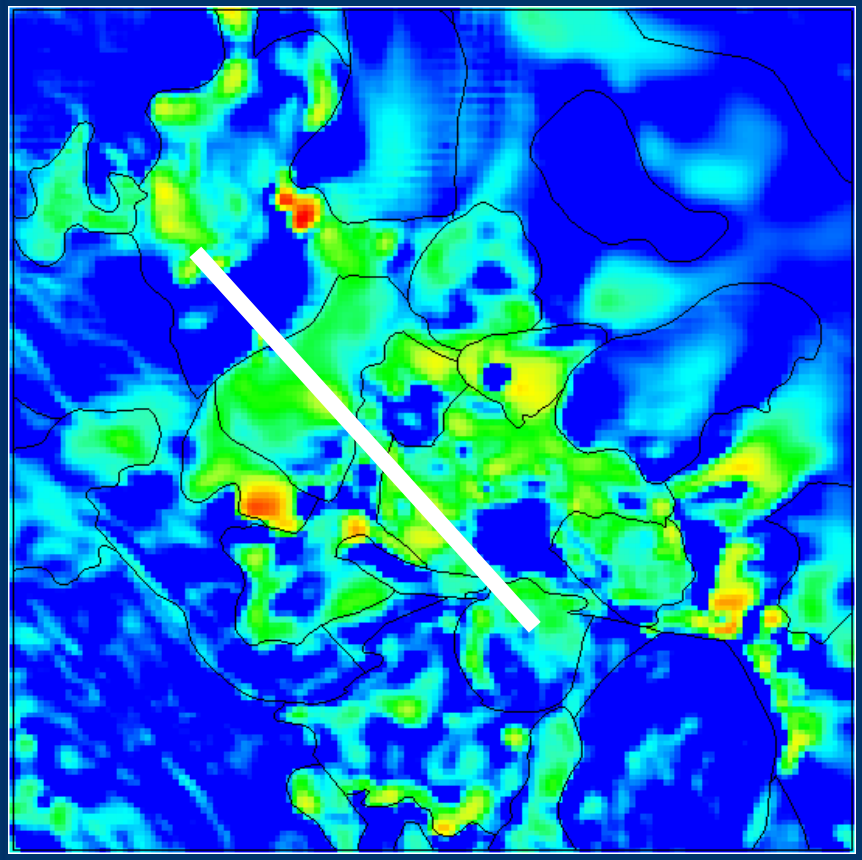
Misfit

~6% of data range

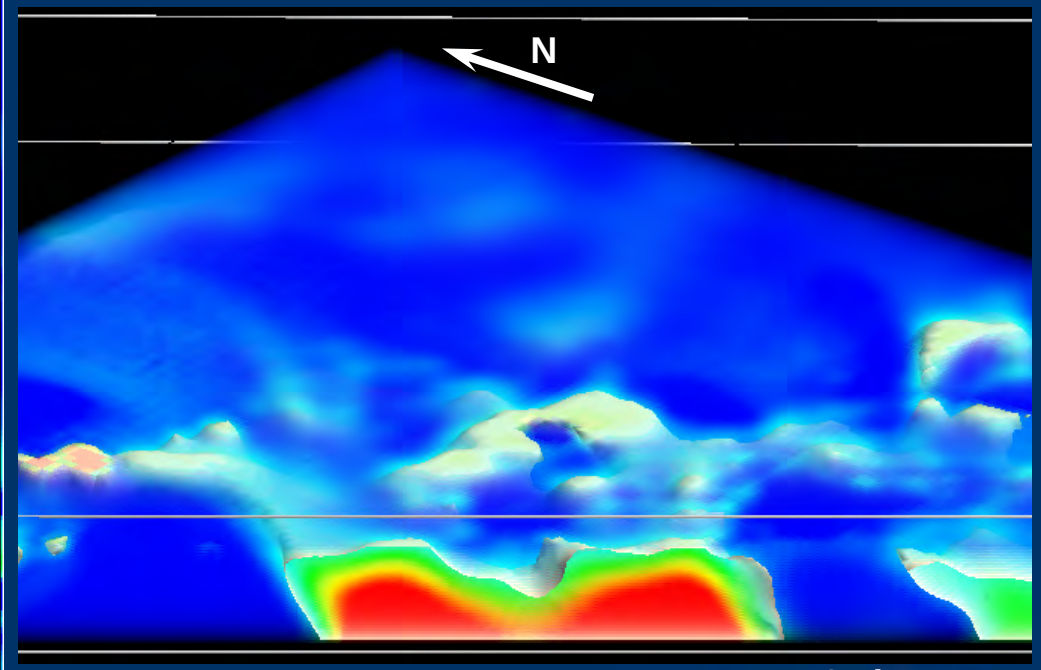


UNCONSTRAINED MAGNETIC INVERSION

-1000 m slice



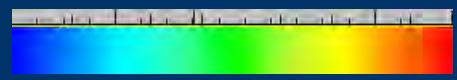
50 km



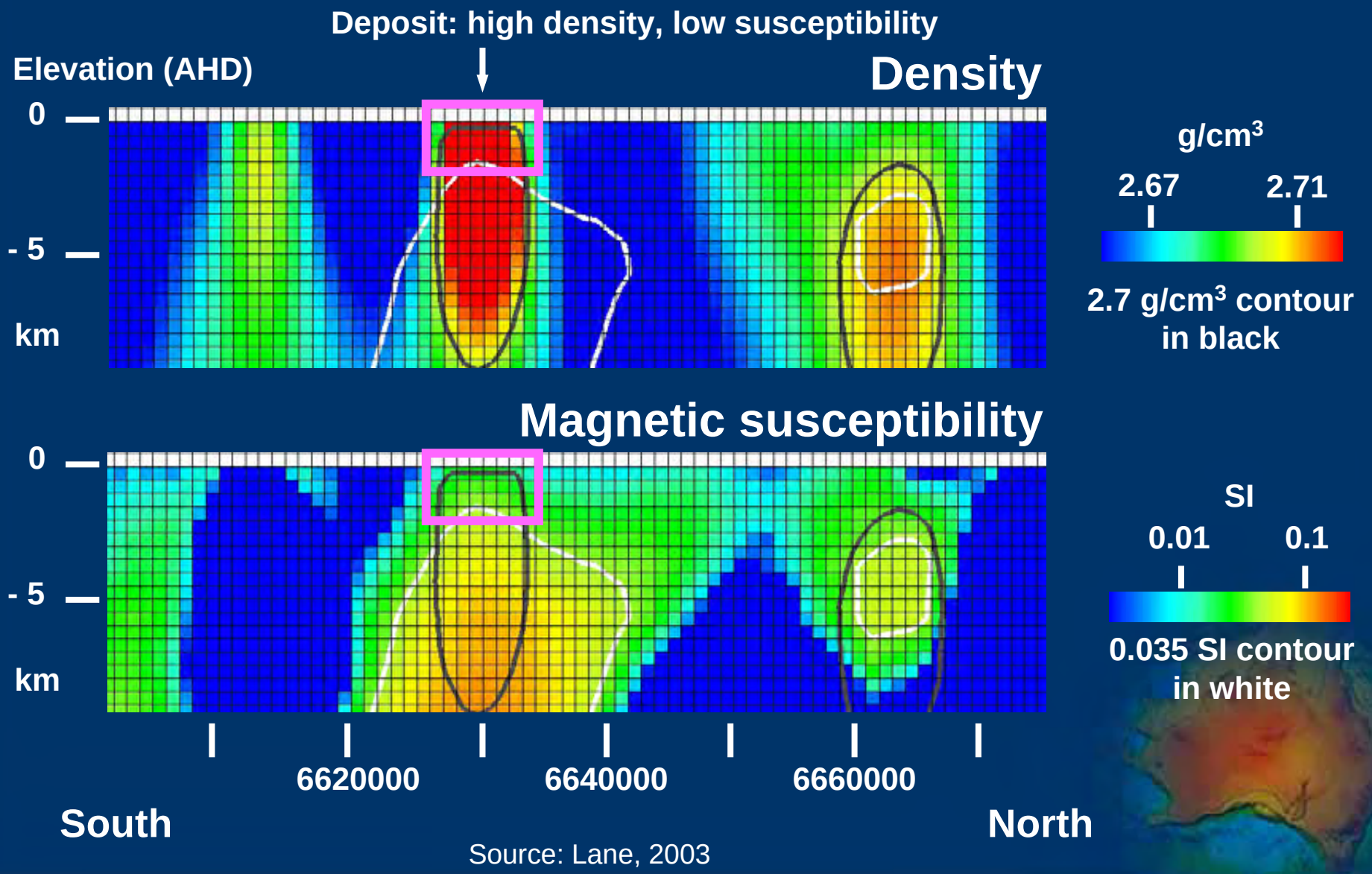
25 km

Susceptibility (SI)

0.002 0.01 0.05

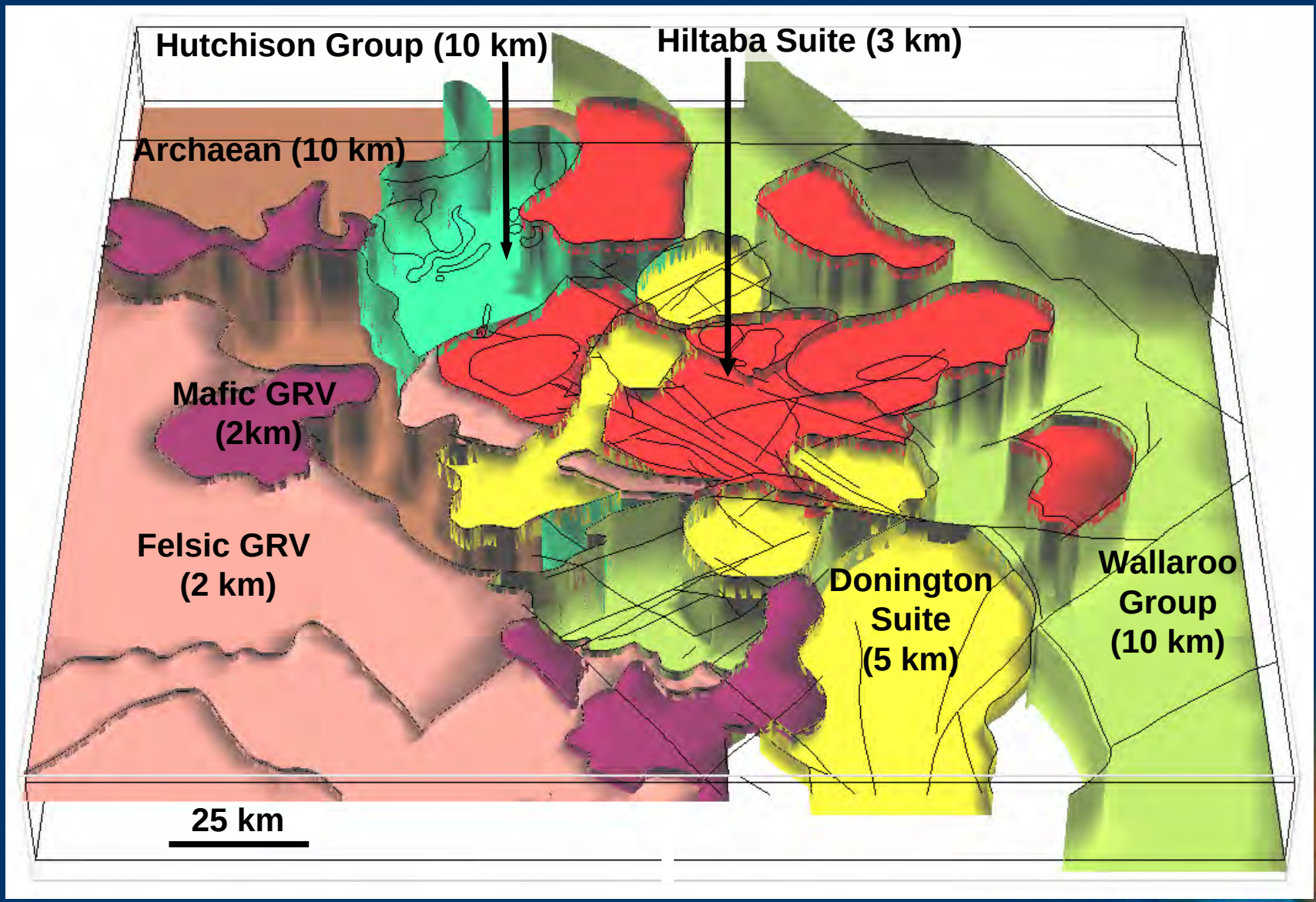


UNCONSTRAINED INVERSION SECTION OLYMPIC DAM 681500 mE



Source: Lane, 2003

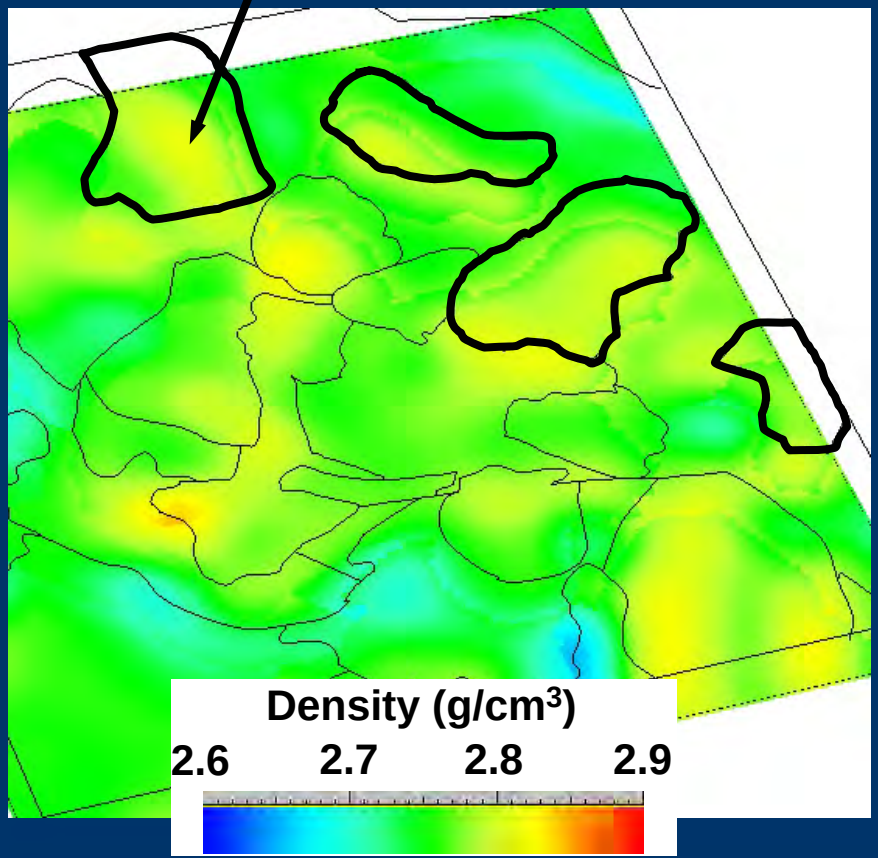
SIMPLE REFERENCE MODEL

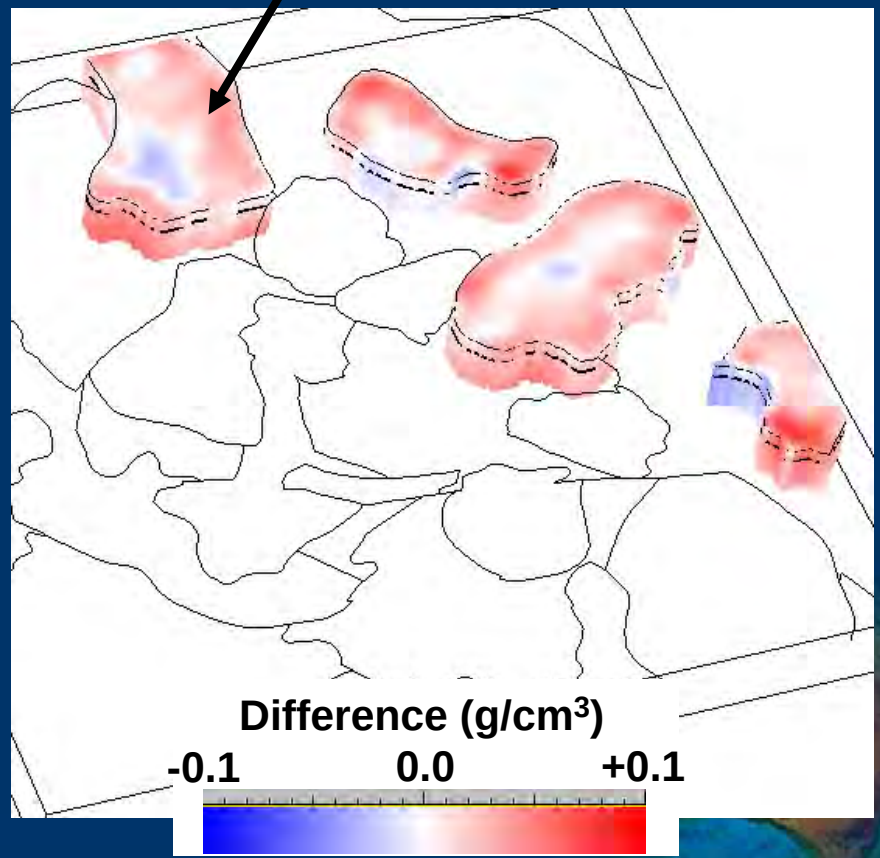


EXCESS MASS

	Reference density (g/cm³)	Inversion density (g/cm³)	Difference (g/cm³)
1 km Cover	2.60	2.61	+0.01
3 km Hiltaba Suite	2.63	2.65	+0.02
6 km Hutchison Gp	2.75	2.78	+0.03

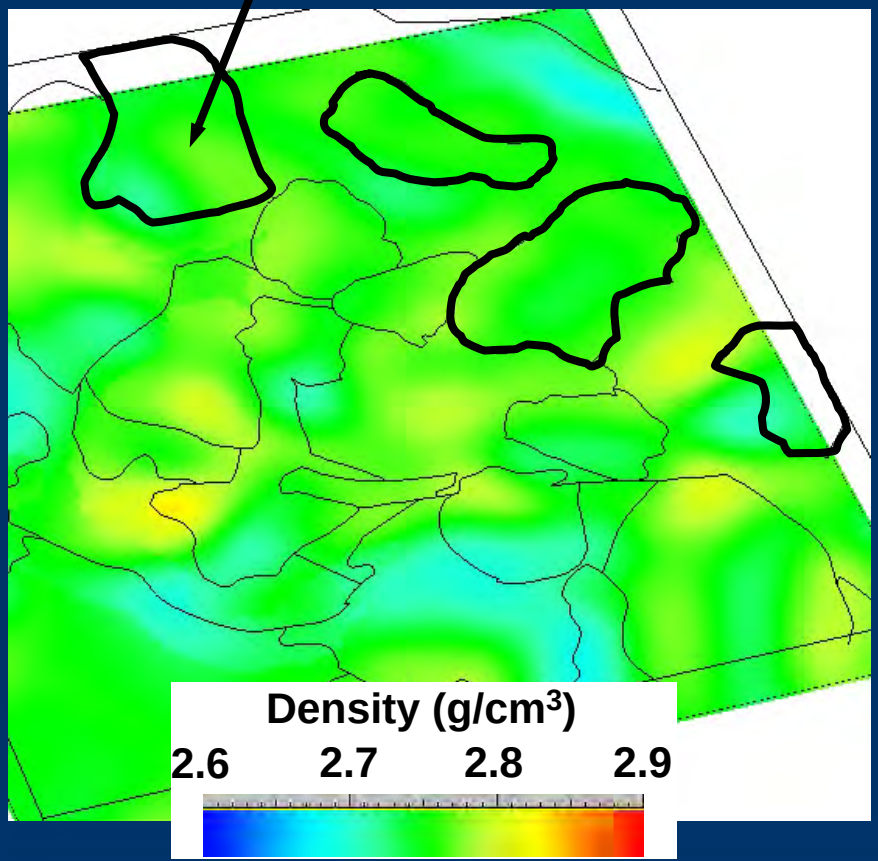
Excess mass ≈ 2.3×10^{14} kg

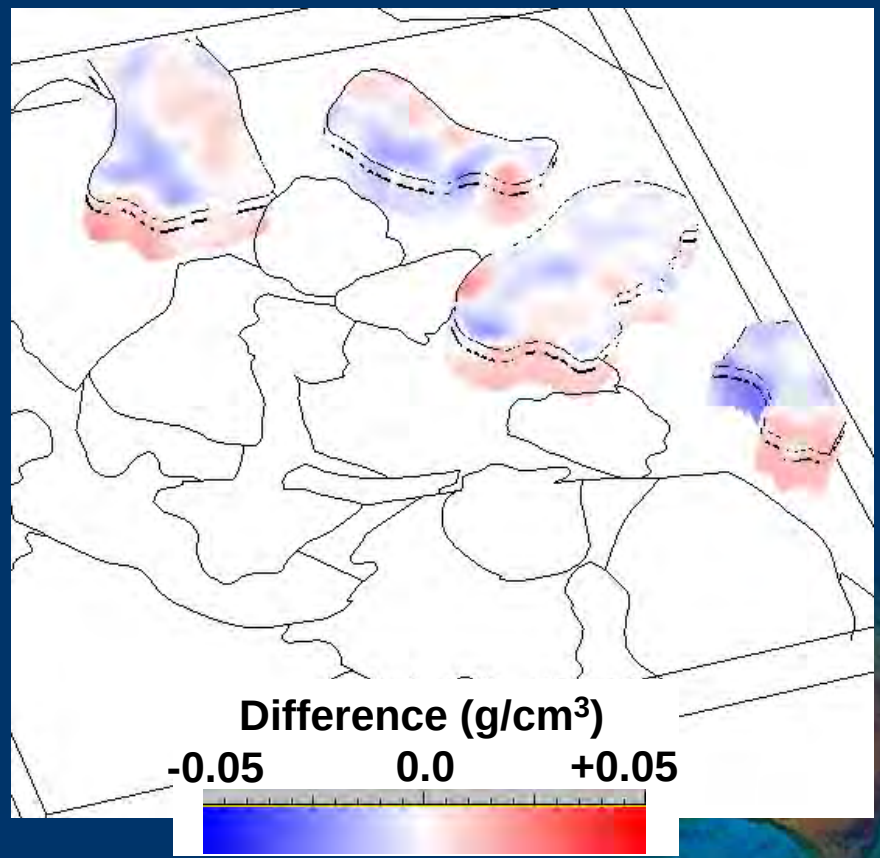




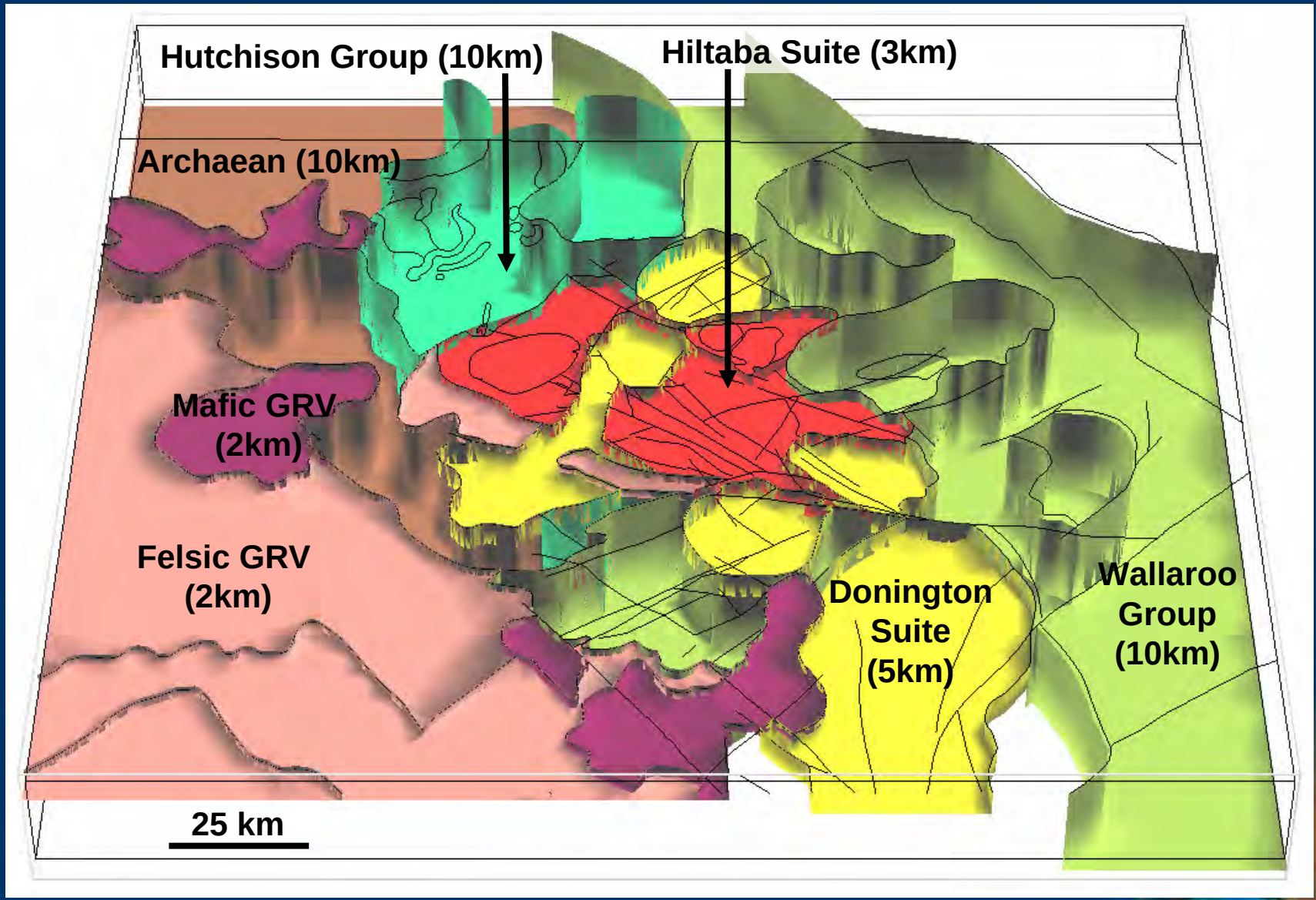
EXCESS MASS COMPENSATION

	Old ref. density (g/cm^3)	Inversion density (g/cm^3)	New ref. density (g/cm^3)	Difference (g/cm^3)
1 km Cover	2.60	2.61	2.60	+0.00
3 km Hutchison Gp	2.63	2.65	2.75	+0.12
6 km Hutchison Gp	2.75	2.78	2.75	+0.00

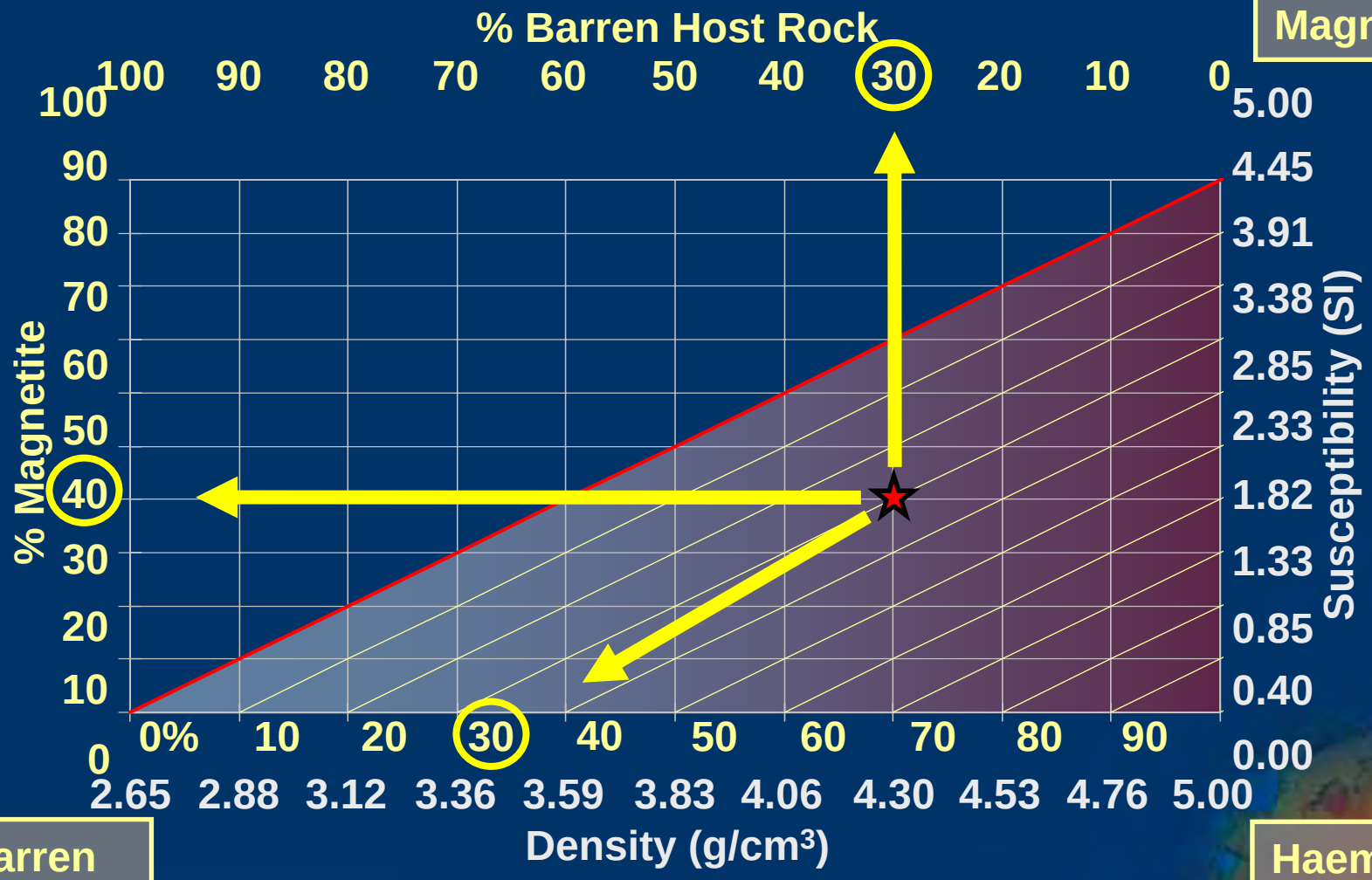




REVISED REFERENCE MODEL



SUSCEPTIBILITY + DENSITY = GEOLOGY?



Magnetite

Barren felsic rock

Haematite/ Sulfides

Source: Hanneson, 2003

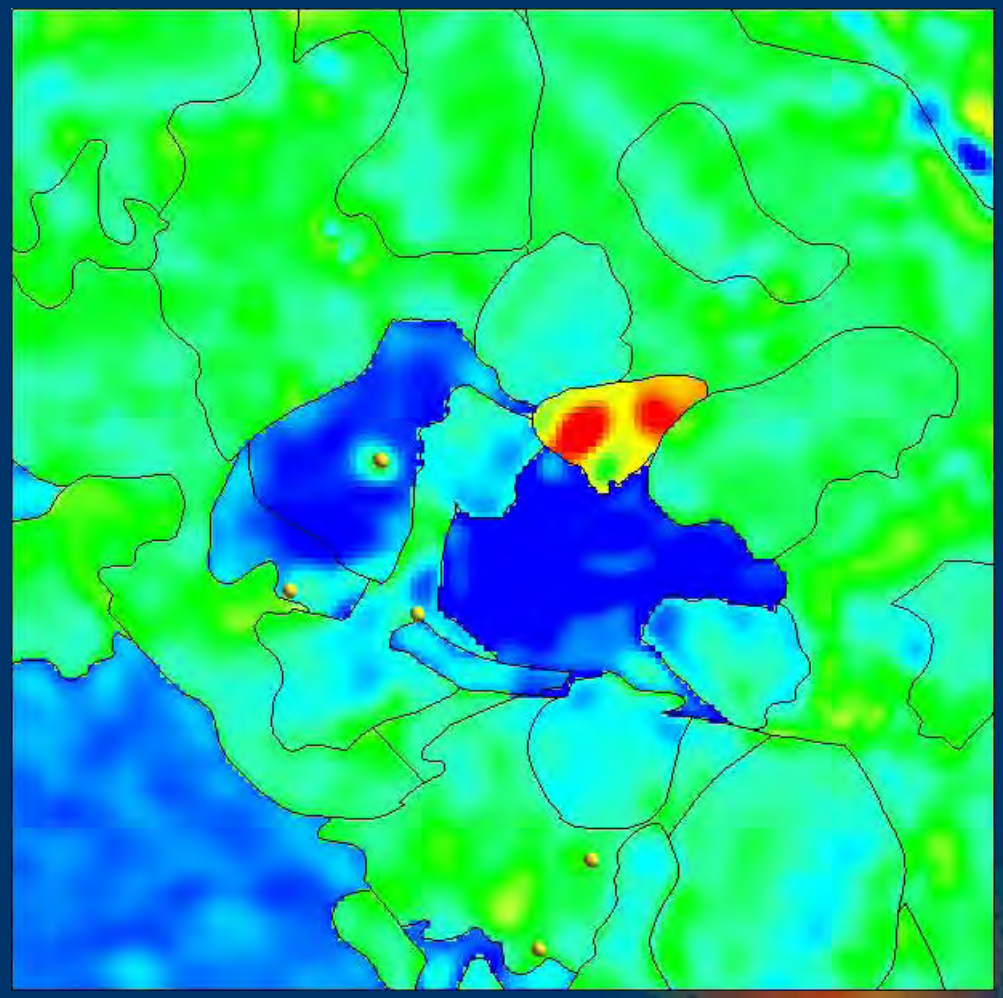
DENSITY OF BARREN HOST ROCK

Can subtract magnetite from the model to determine the density of the host rock

$$\rho_{host} = \frac{Mass_{cell} - Mass_{mgt}}{Vol_{cell} - Vol_{mgt}}$$

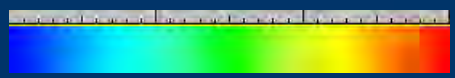
$$= \frac{\rho_{cell} - (\rho_{mgt} \times \%_{mgt})}{1 - \%_{mgt}}$$

-1000 m slice



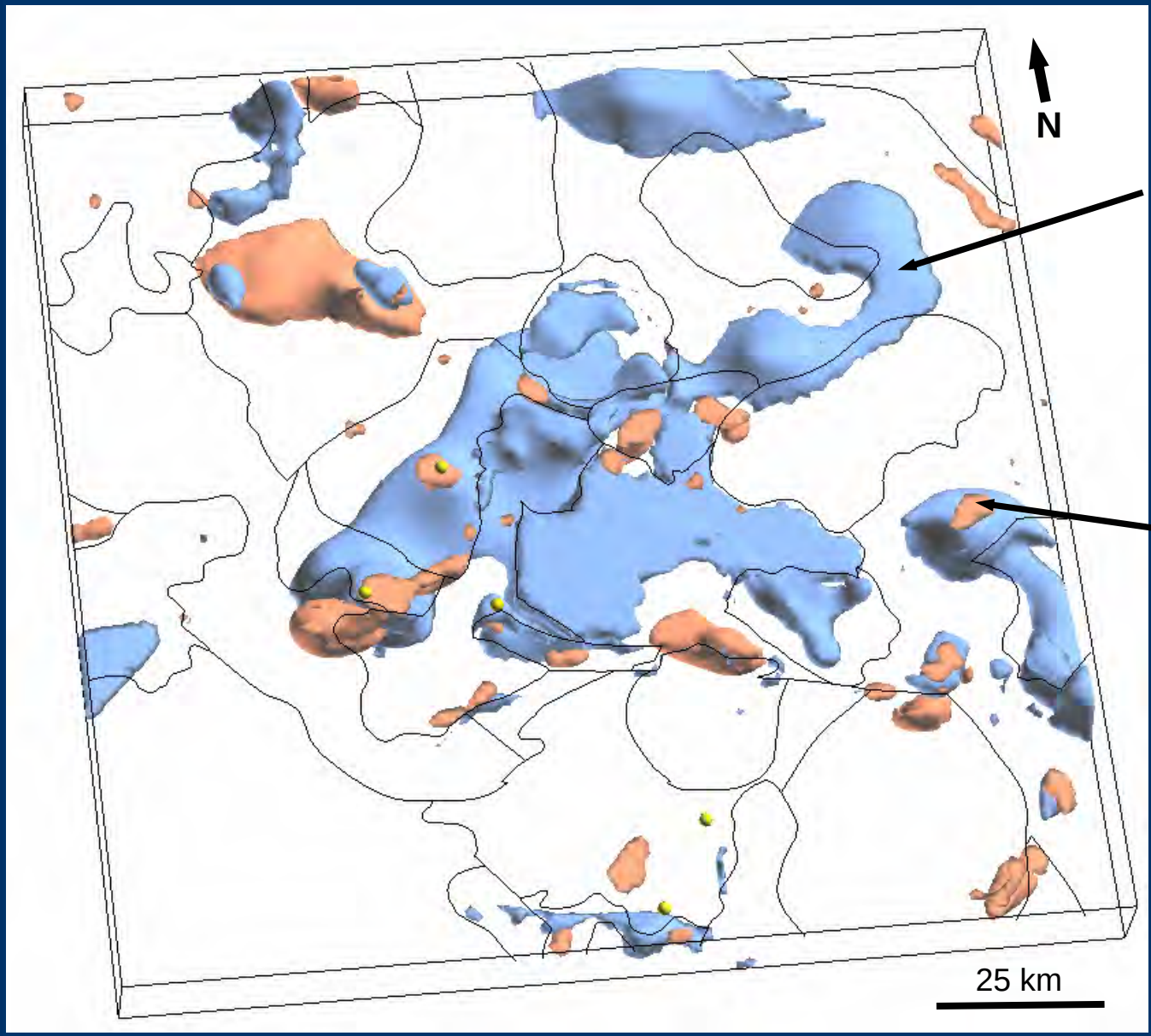
Density (g/cm^3)

2.6 2.7 2.8 2.9



50 km

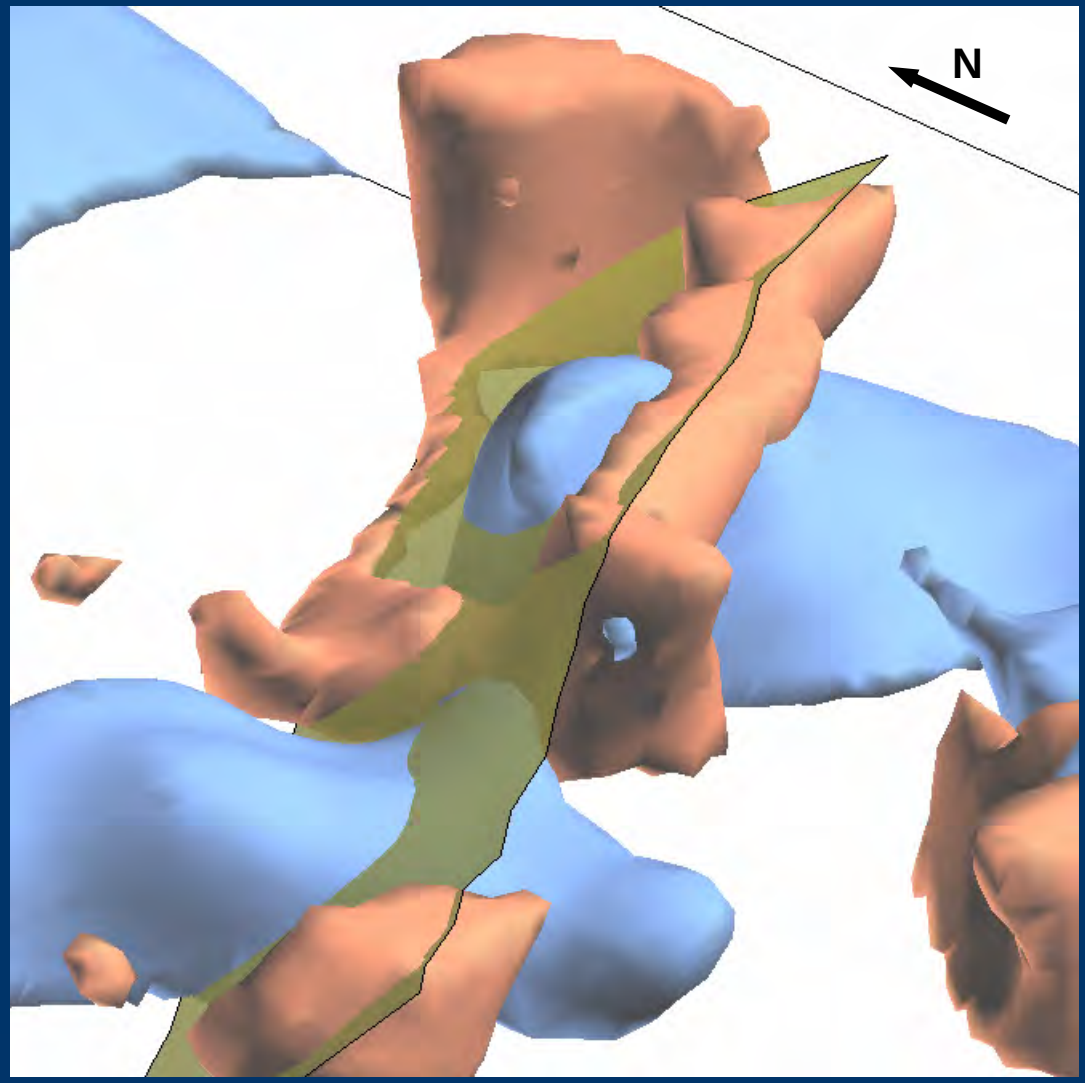
MAGNETITE & HAEMATITE MAP



1.5% "magnetite"
Includes all susceptible minerals as their magnetite equivalent

0.5% "haematite"
Includes haematite, sulfides, gold!, other dense minerals, and remanent magnetisation

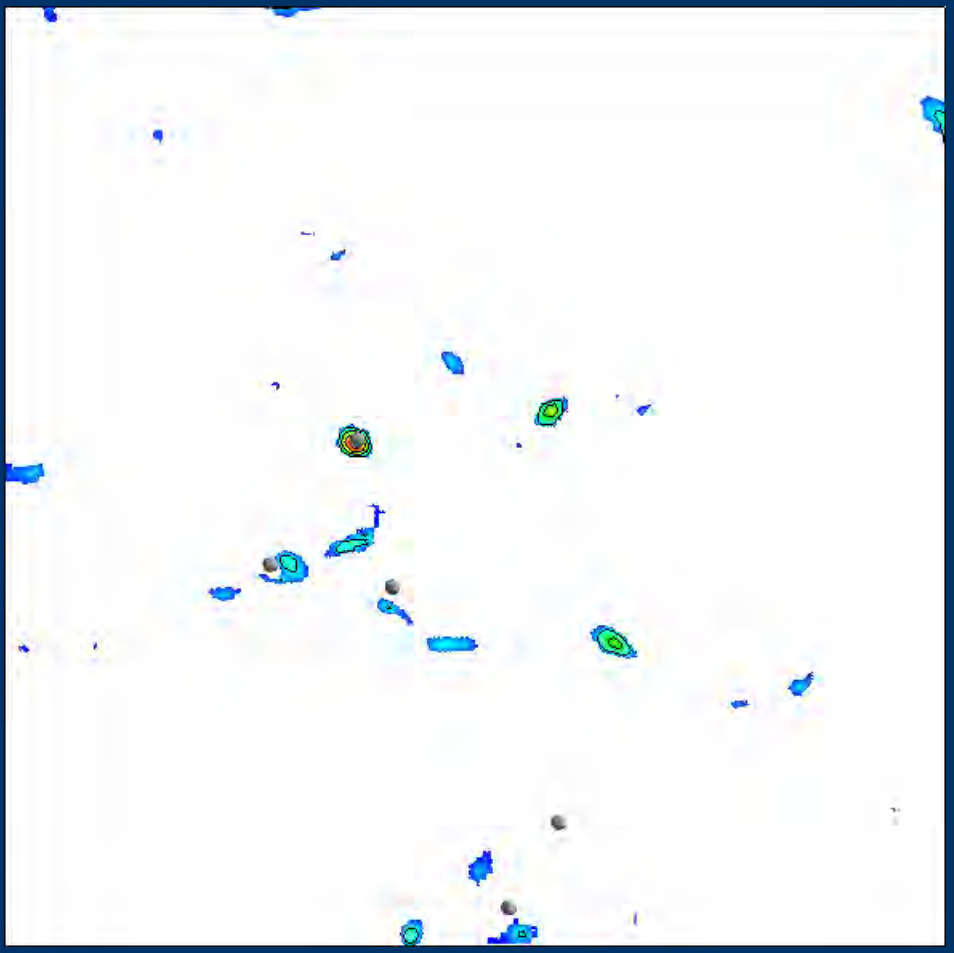
MAGNETITE & HAEMATITE MAP

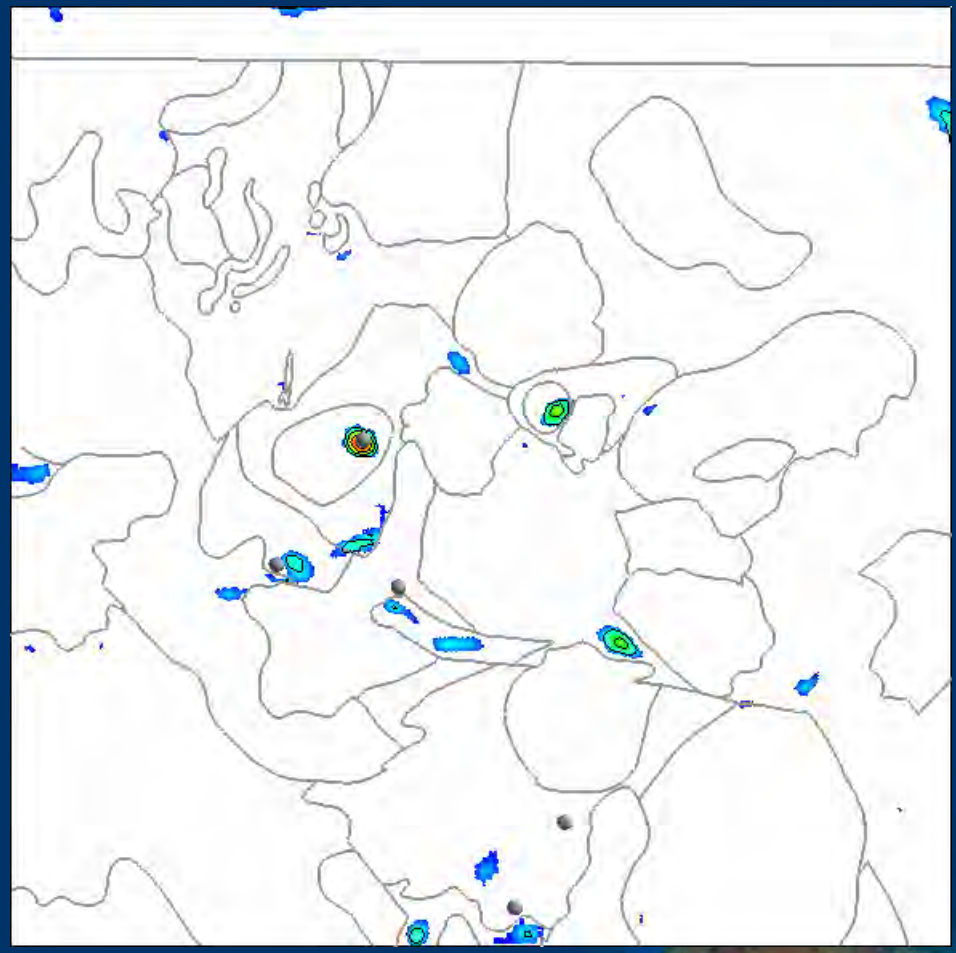


1% "magnetite"
Includes all susceptible minerals as their magnetite equivalent

1% "haematite"
Includes haematite, sulfides, gold!, other dense minerals, and remanent magnetisation

BASEMENT MAPS OF PREDICTED HAEMATITE/SULFIDES





0.5% haematite/sulphide contours

25 km

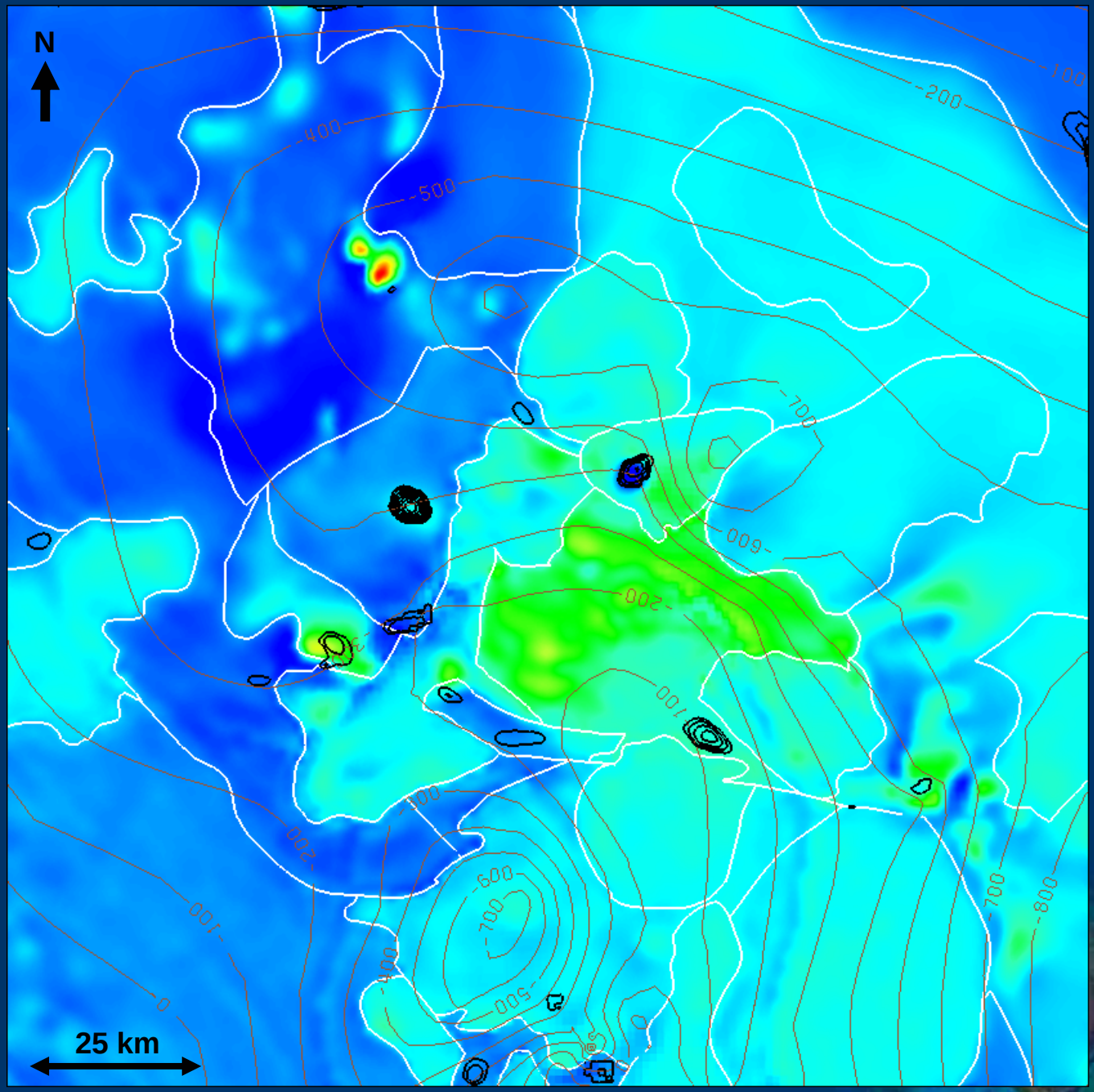
Undefined

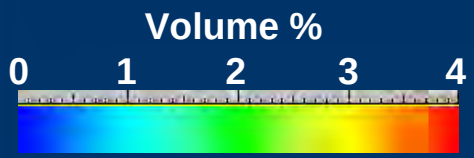
Volume %

0 1 2 3 4

Basement Alteration Map

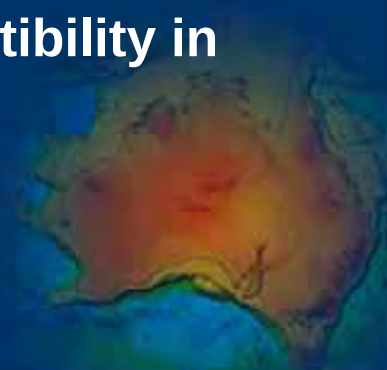
- Coloured by magnetite
- 0.5% contours of haematite/ sulfides (black)
- Contours of depth-to-basement



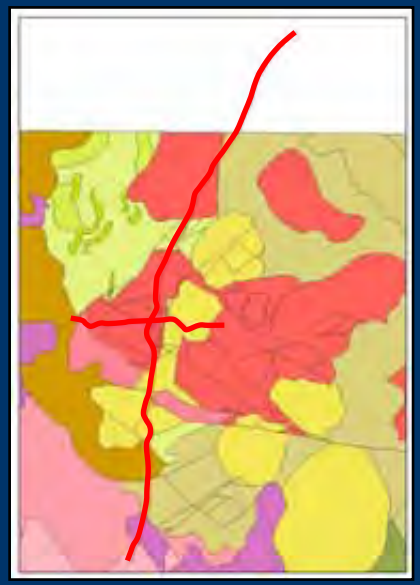


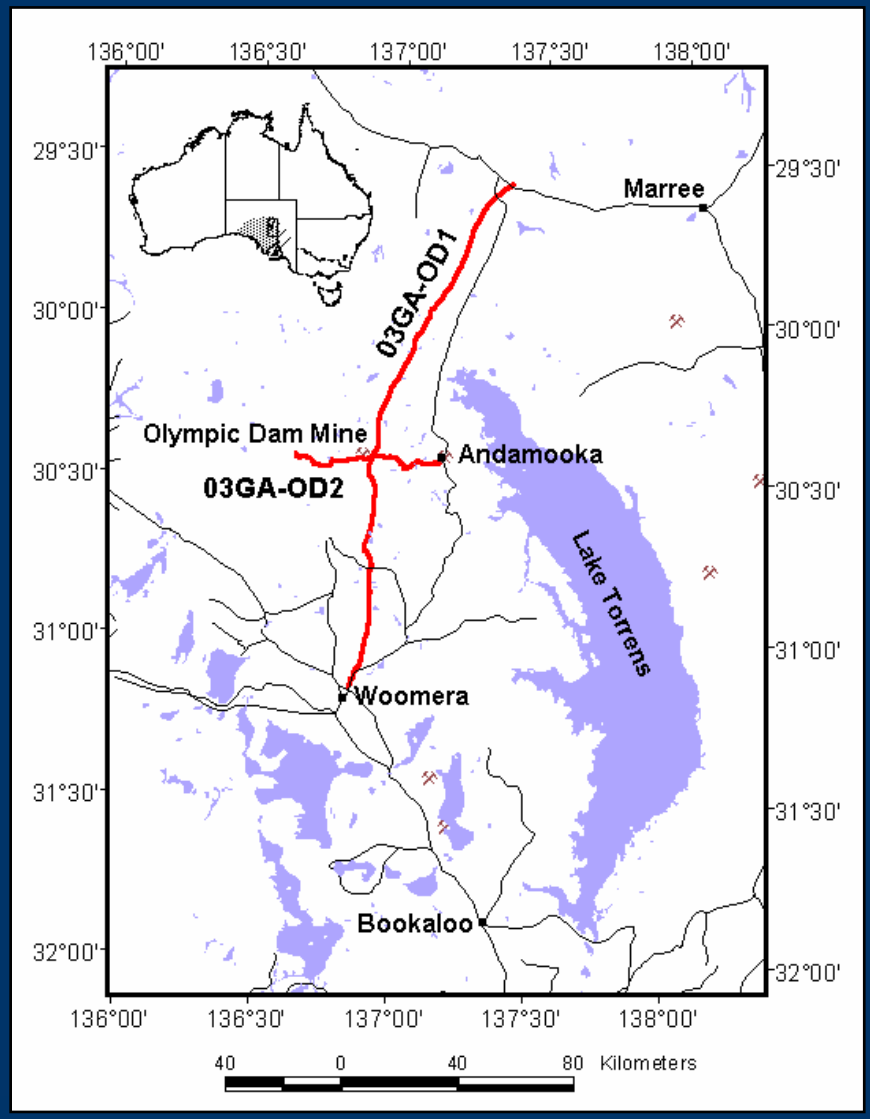
BETTERMENT

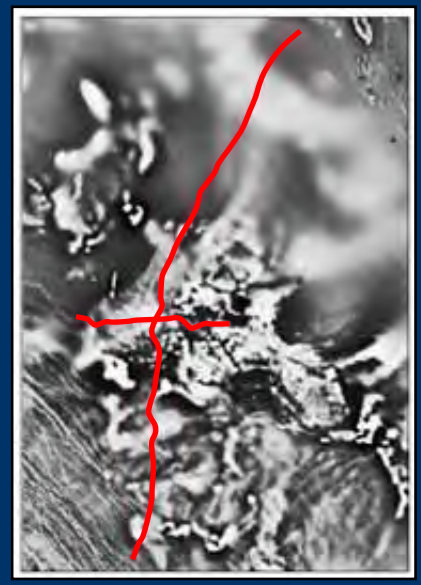
- Depth-to-basement (seismic, drillhole data)
- Better geological constraints (seismic, drillholes, company data)
- More physical property measurements for each unit:
  - Characterise each unit type by its density
  - and susceptibility
- Treat known volumes of alteration separately from their host:
  - Isolate Olympic Dam, Acropolis, *etc*.
  - Use characteristic alteration density and susceptibility in reference model
- Spatial constraints (seismic)

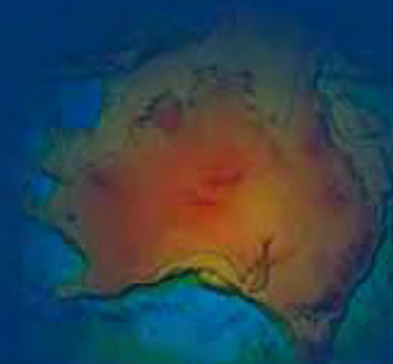


SEISMIC LINES



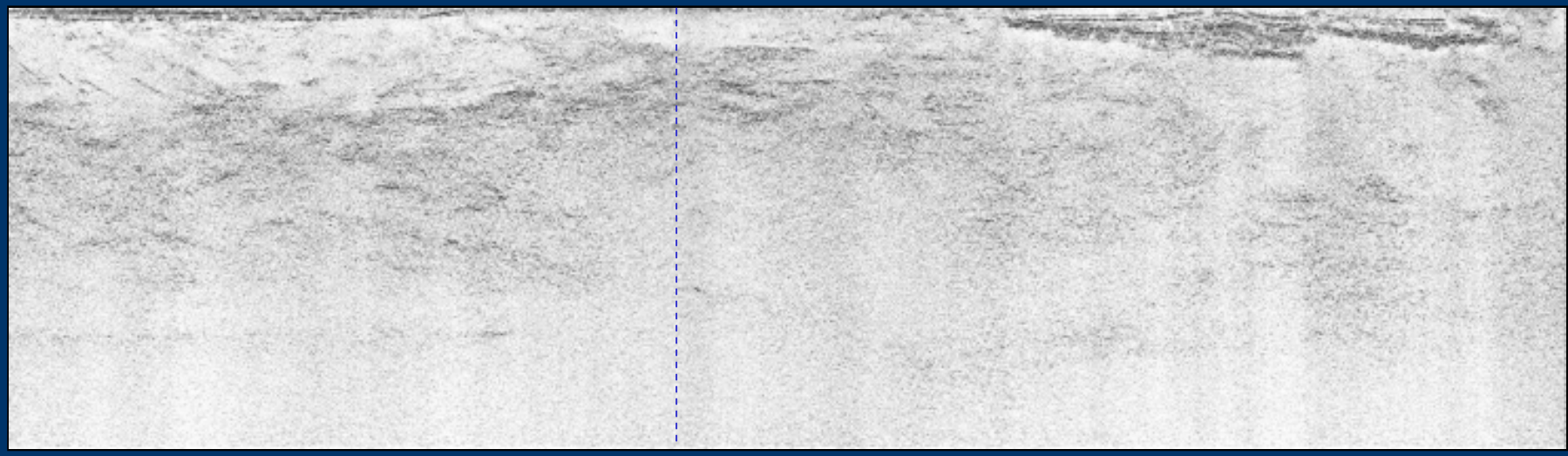




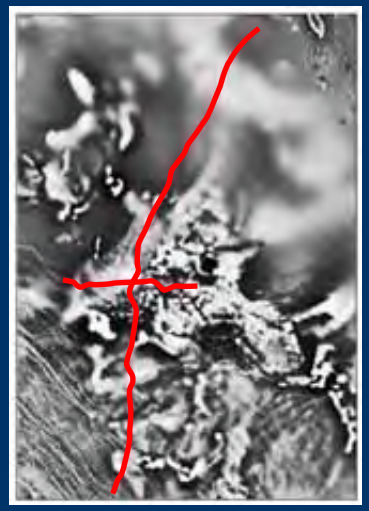


S

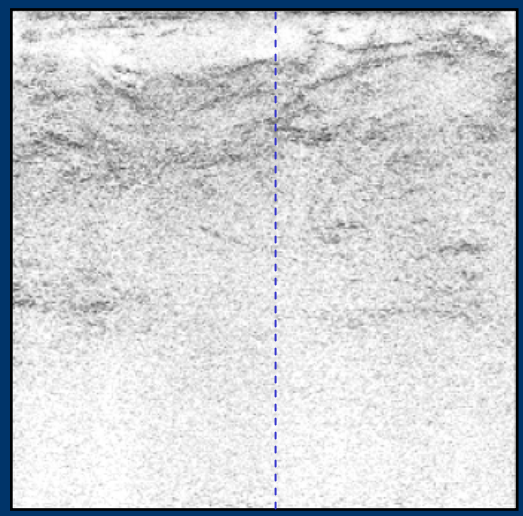
N



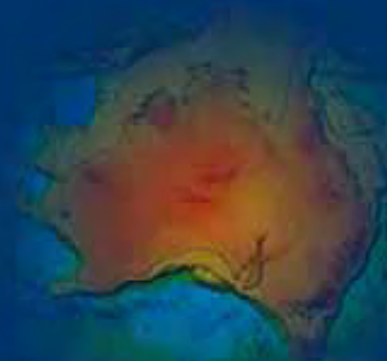
50 km



W



E

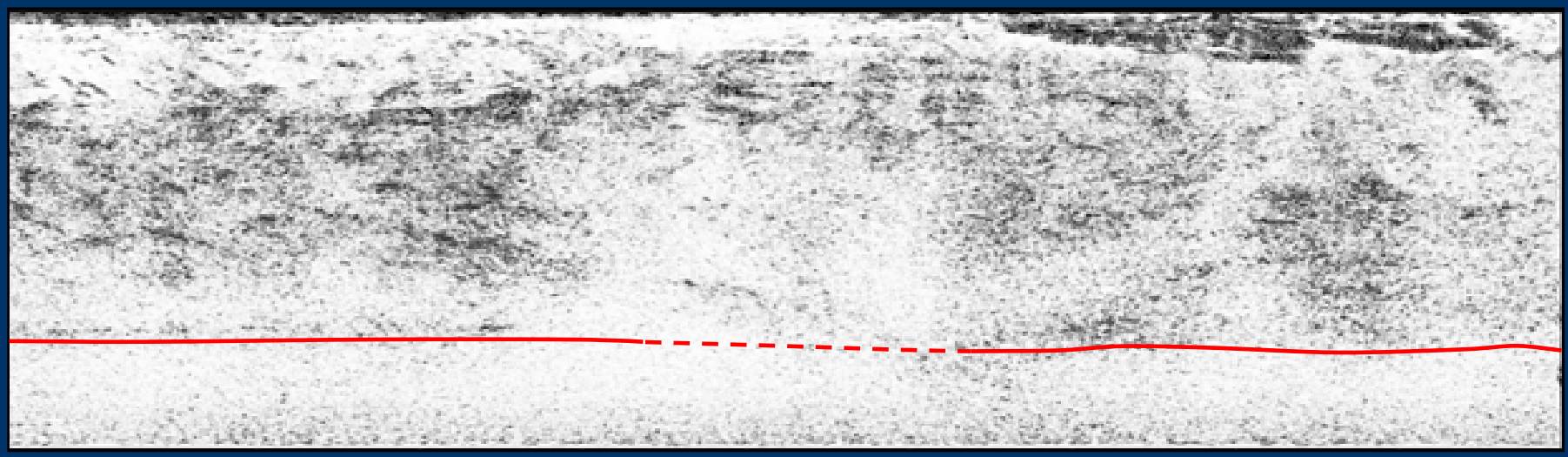


MOHOROVIČIĆ DISCONTINUITY

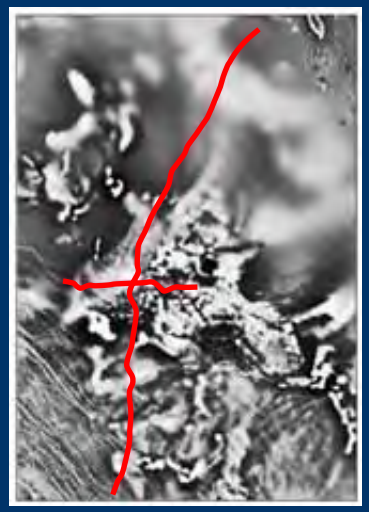
~40 km depth

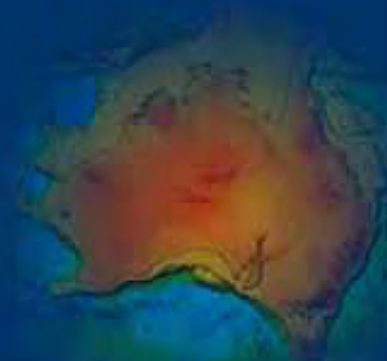
S

N



50 km



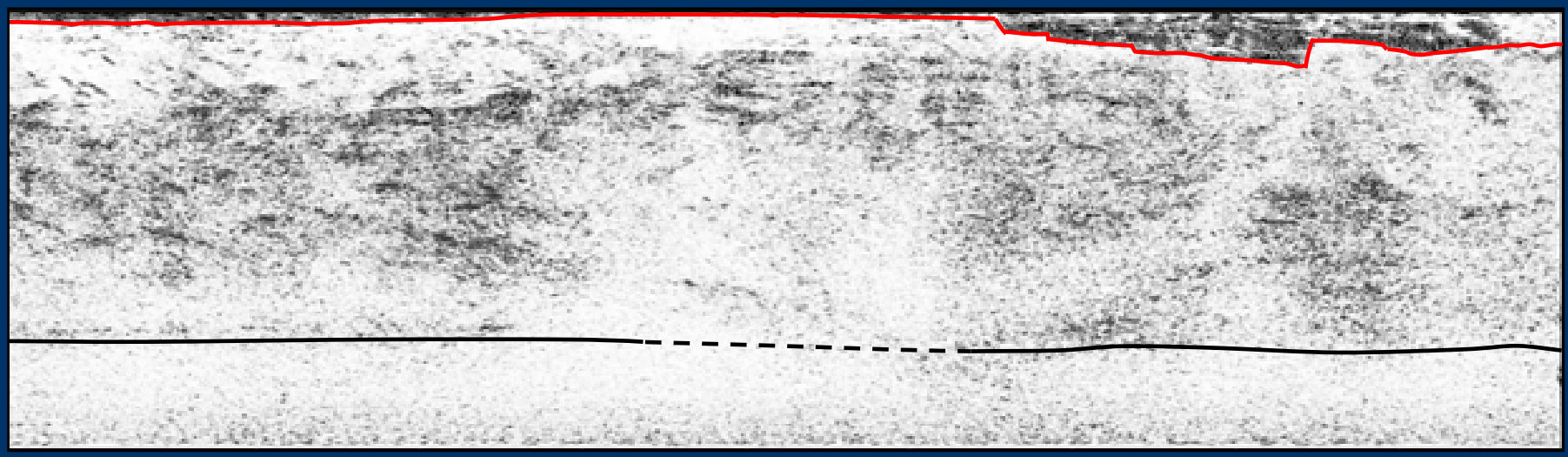


NEOPROTEROZOIC COVER

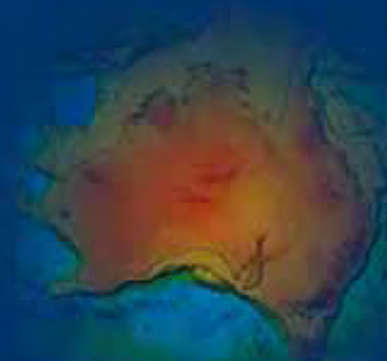
300 m to 6 km thick

S

N



50 km

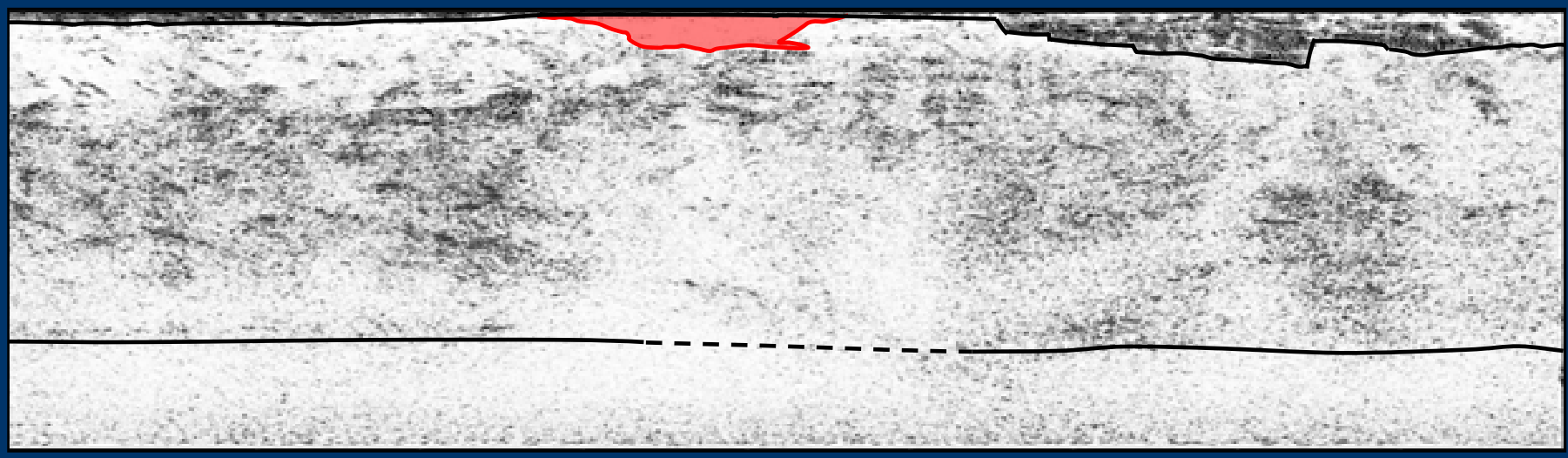


BURGOYNE BATHOLITH

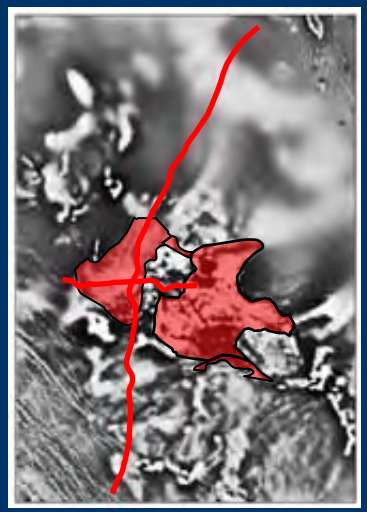
5 km thick

S

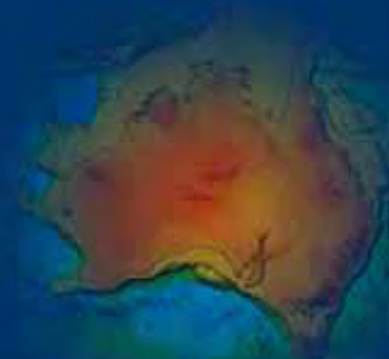
N



50 km



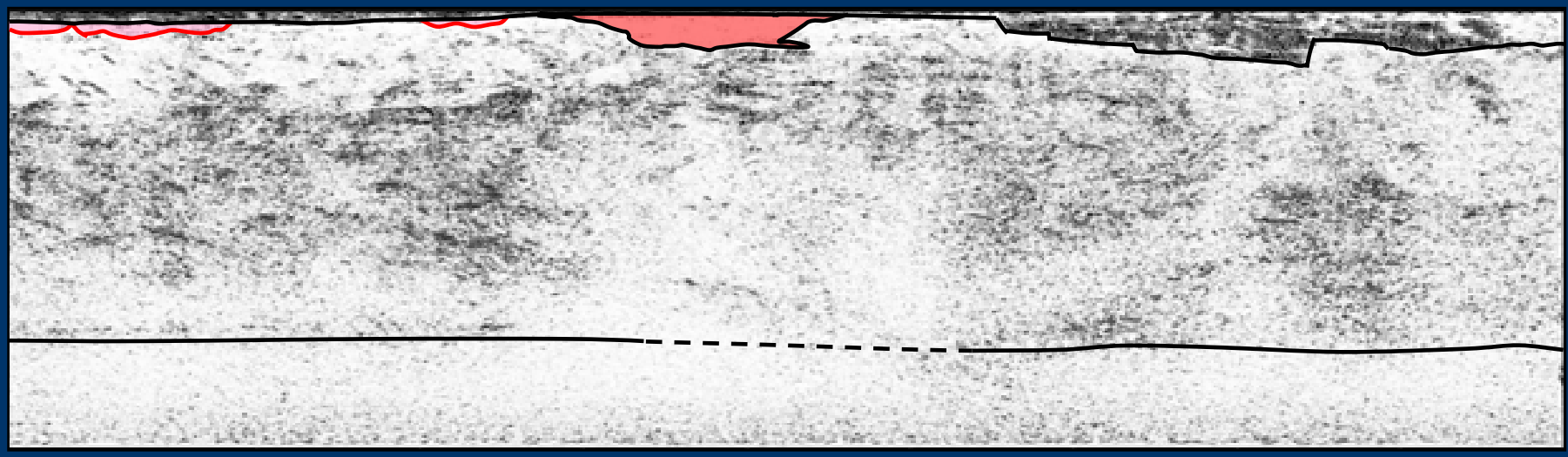
1590 Ma



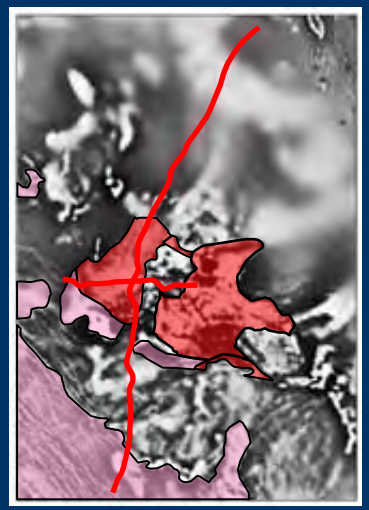
GAWLER RANGE VOLCANICS

S

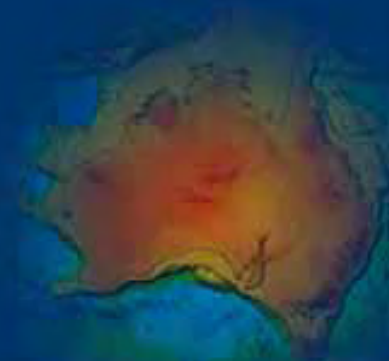
N



50 km

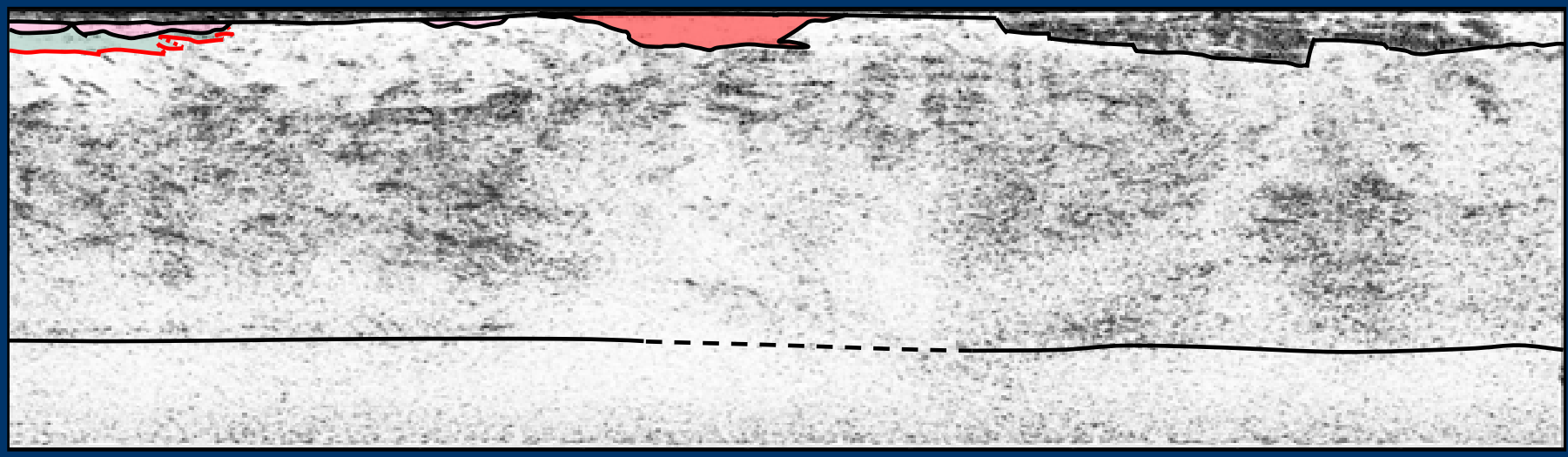


1590 Ma

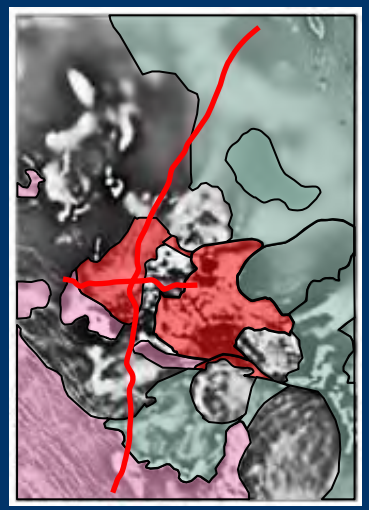


WALLAROO GROUP

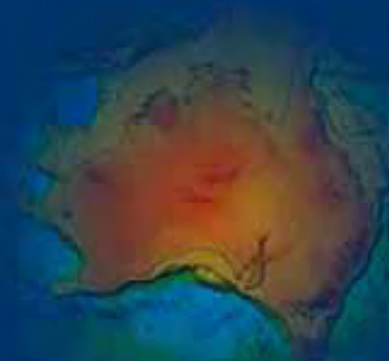
S N



50 km



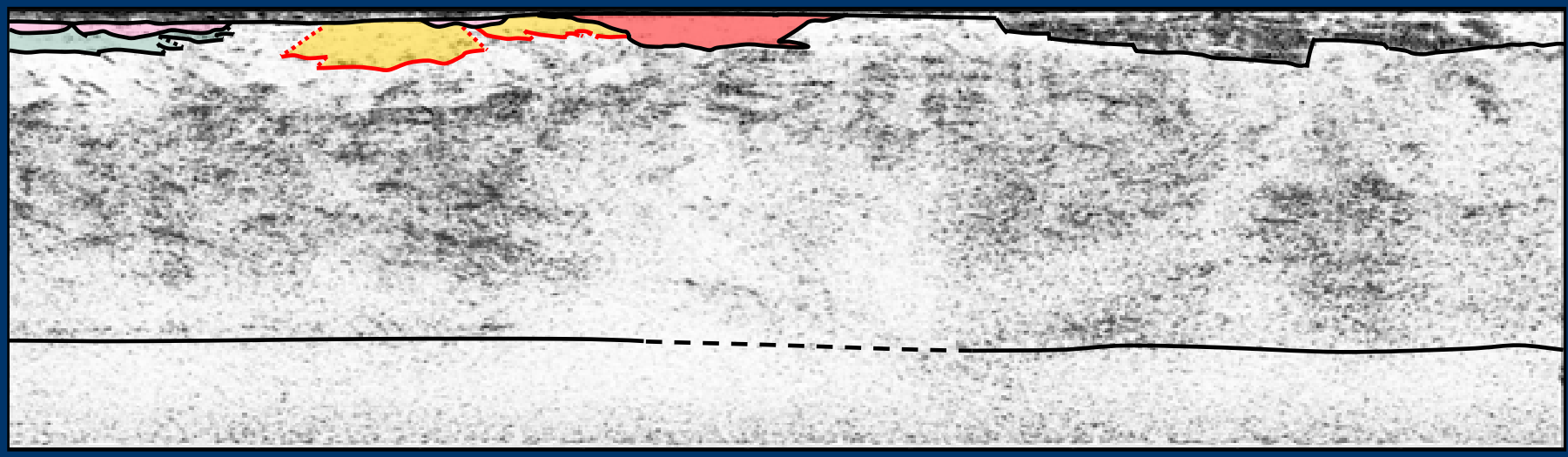
1760 Ma – 1720 Ma



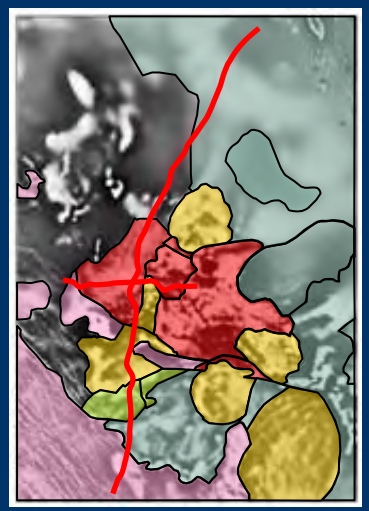
DONINGTON SUITE

S

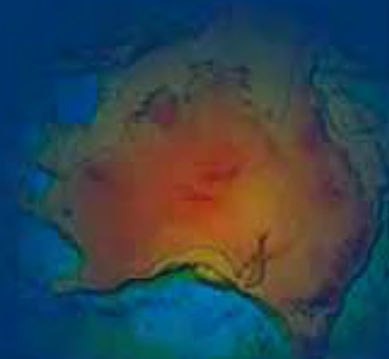
N



50 km

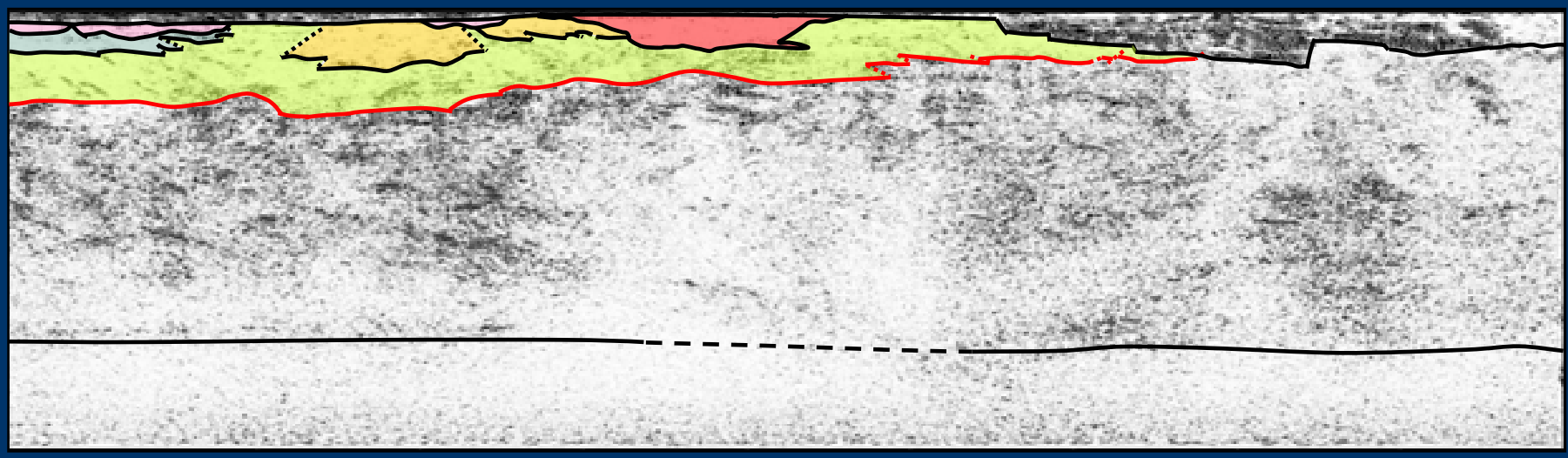


1850 Ma

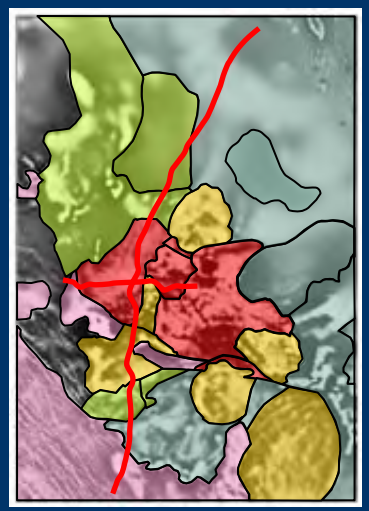


?HUTCHISON GROUP

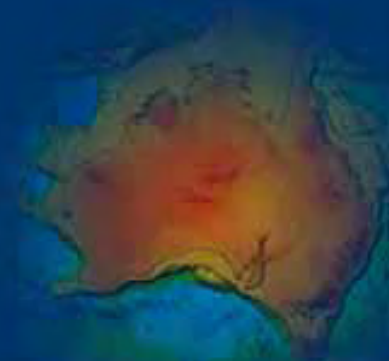
S N



50 km

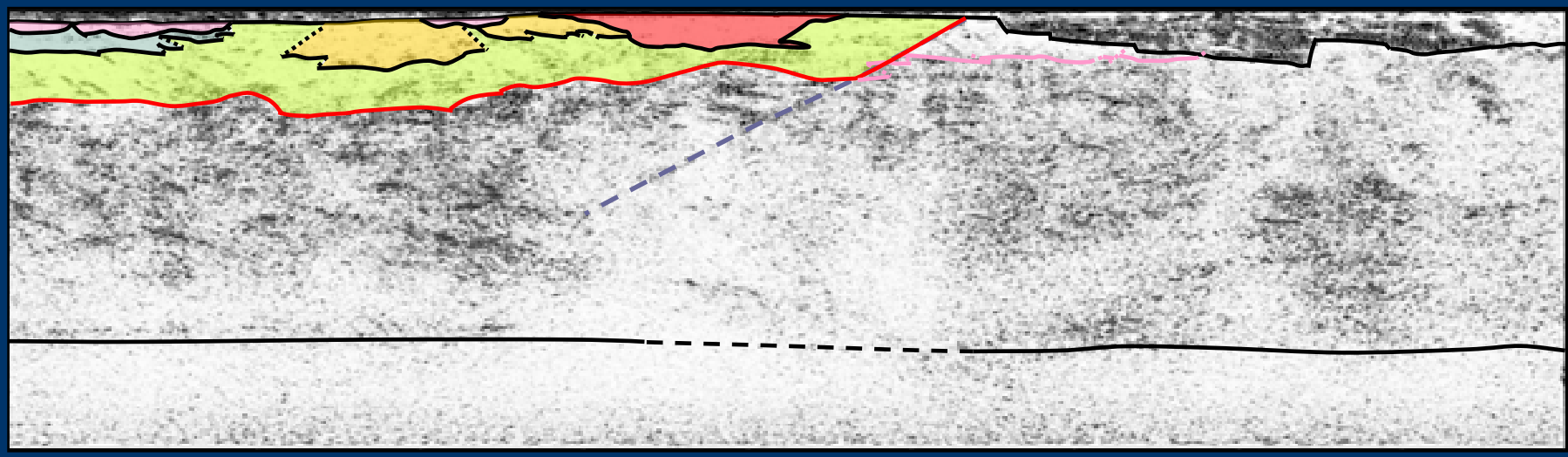


2000 Ma – 1850 Ma

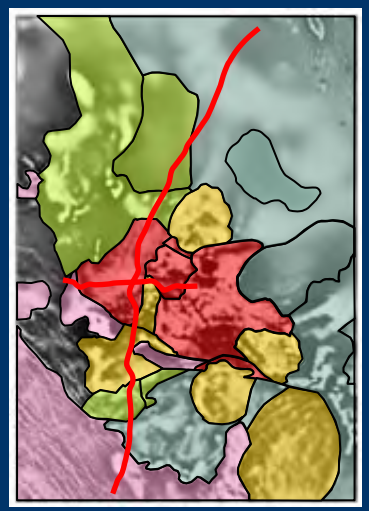


?HUTCHISON GROUP

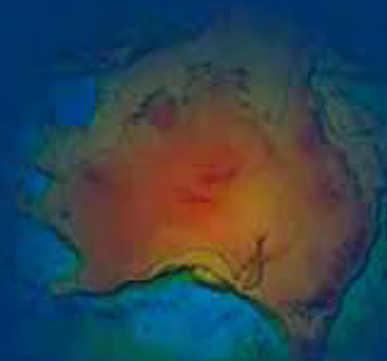
S N



50 km



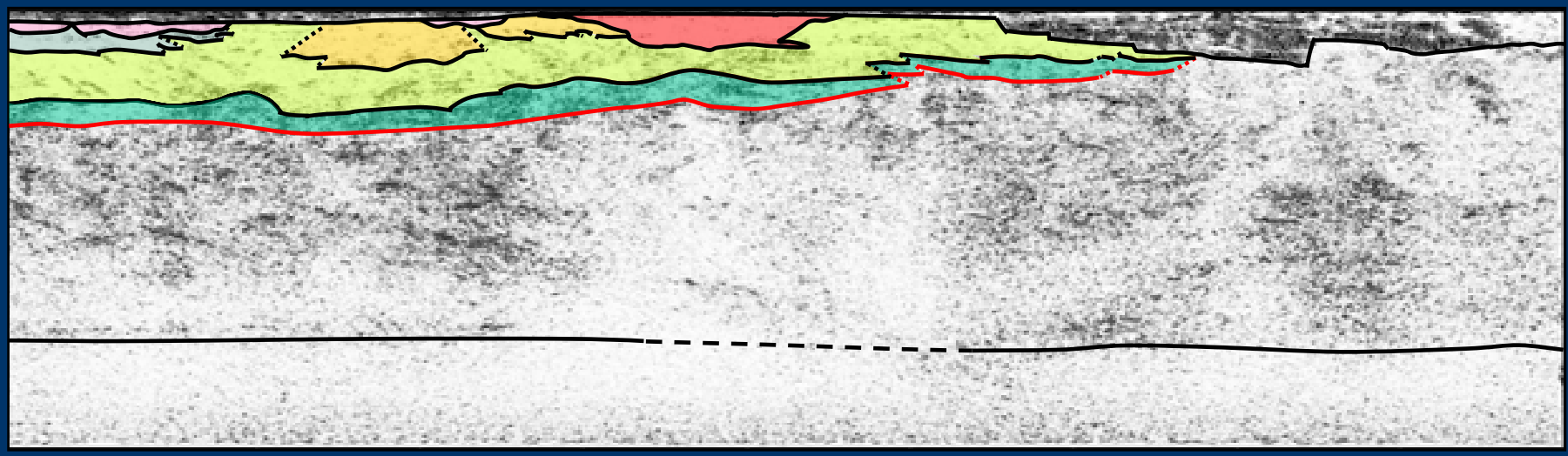
2000 Ma – 1850 Ma



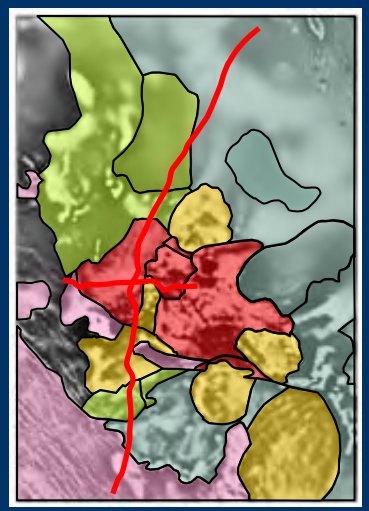
MID-CRUSTAL LAYER

S

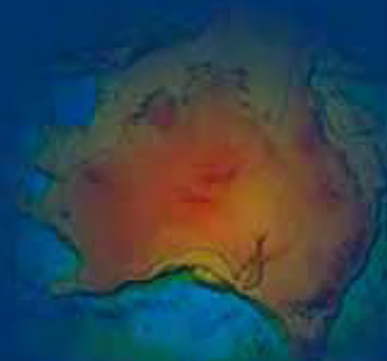
N



50 km



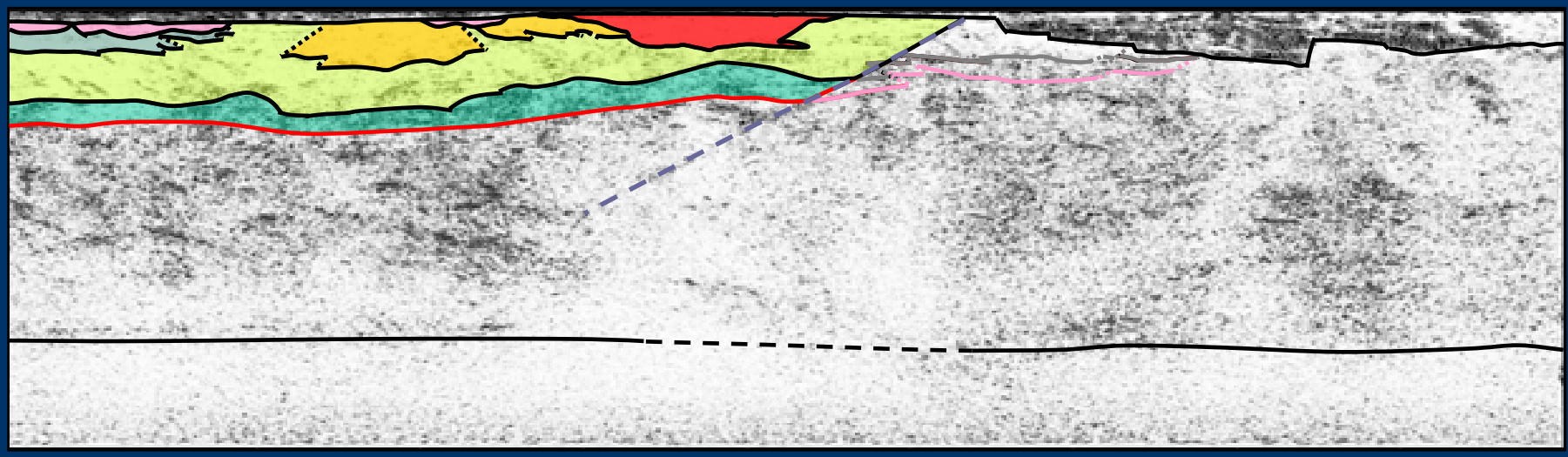
>2000 Ma



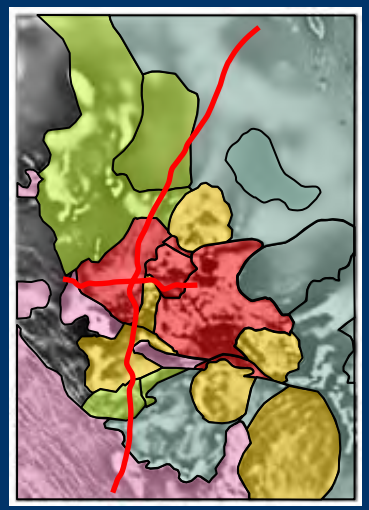
MID-CRUSTAL LAYER

S

N



50 km



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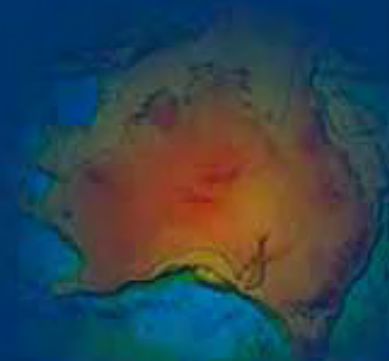
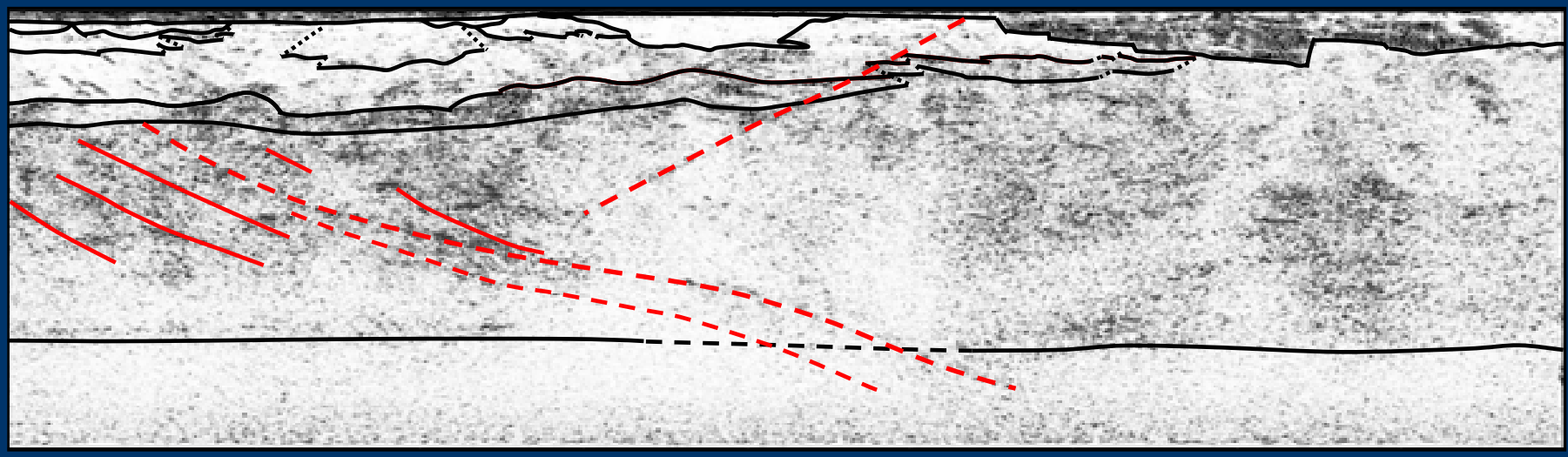


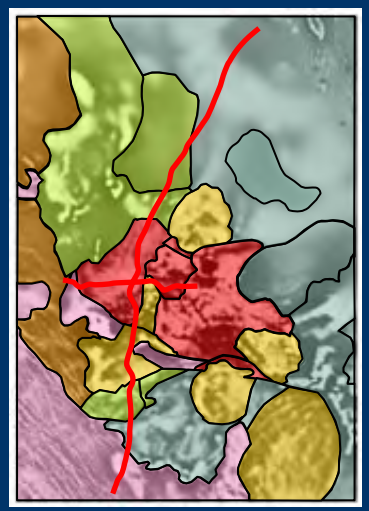
DEEP CRUSTAL STRUCTURE

S

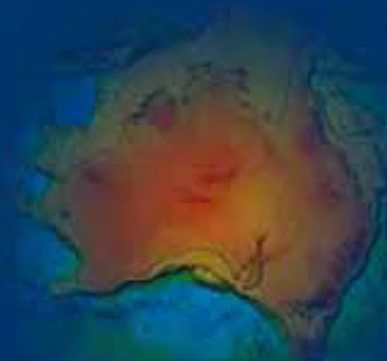
N



50 km



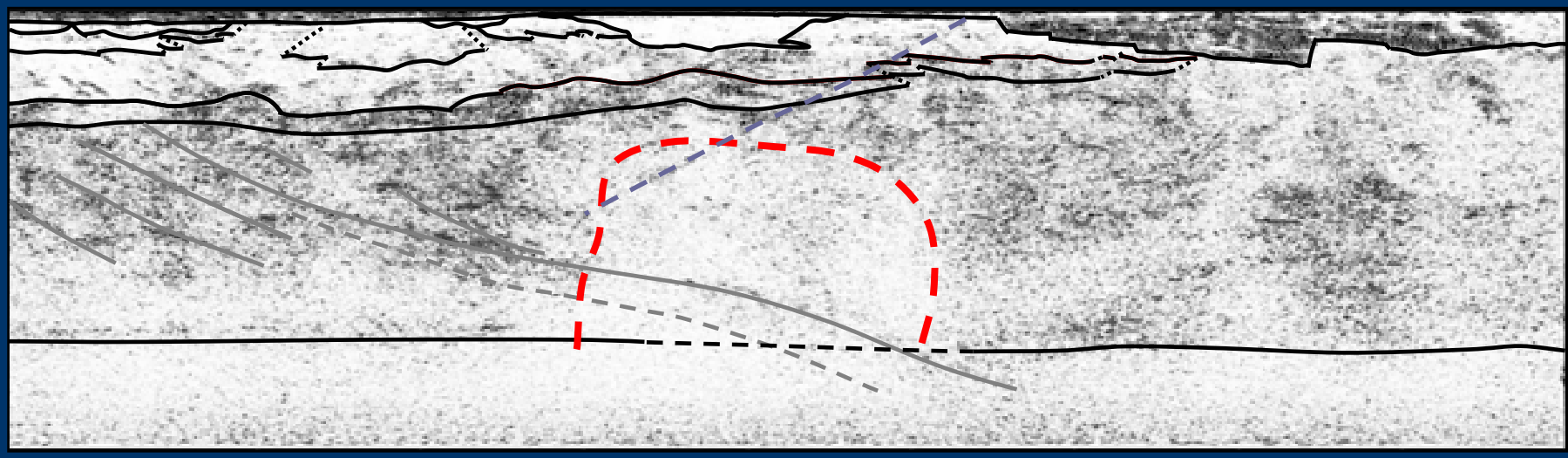
>2000 Ma?



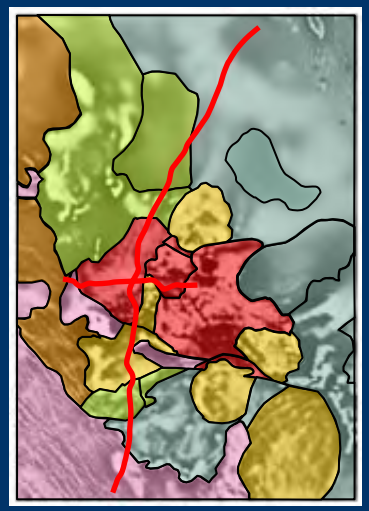
BLAND ZONE

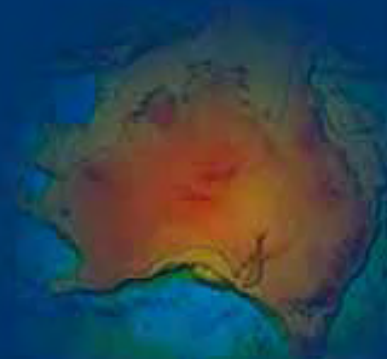
S

N



50 km



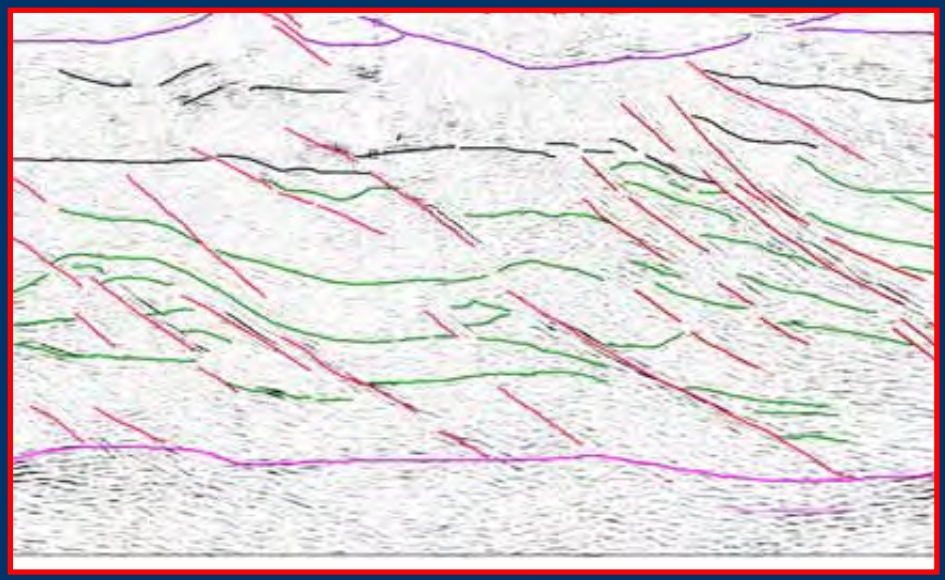


ELIZABETH CREEK THRUST-COMPLEX

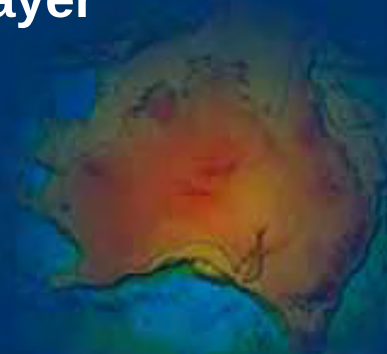
S

N

50 km



1720 Ma thrusts in ?Hutchison & Wallaroo Groups detaching on mid-crustal layer



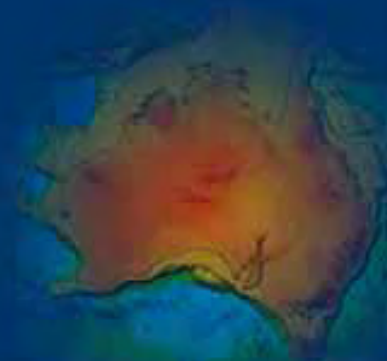
ELIZABETH CREEK THRUST-COMPLEX

S

N

50 km

Back-thrust of fault complex

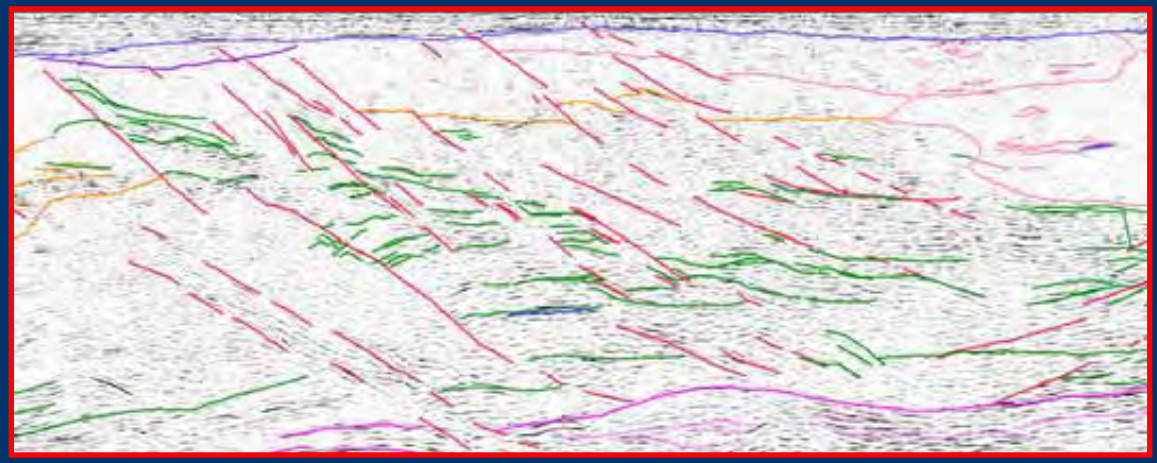


WIRRDA THRUST-COMPLEX

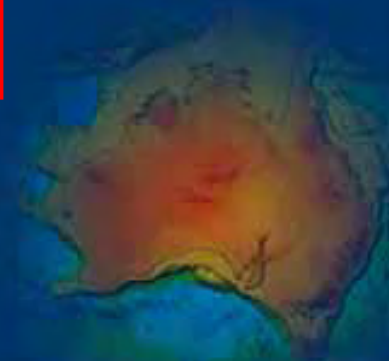
S

N

50 km



Thrusts detaching on mid-crustal layer



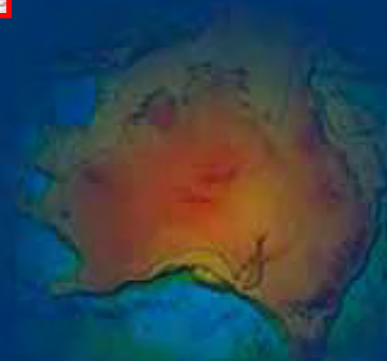
WIRRDA THRUST-COMPLEX

S

N

50 km

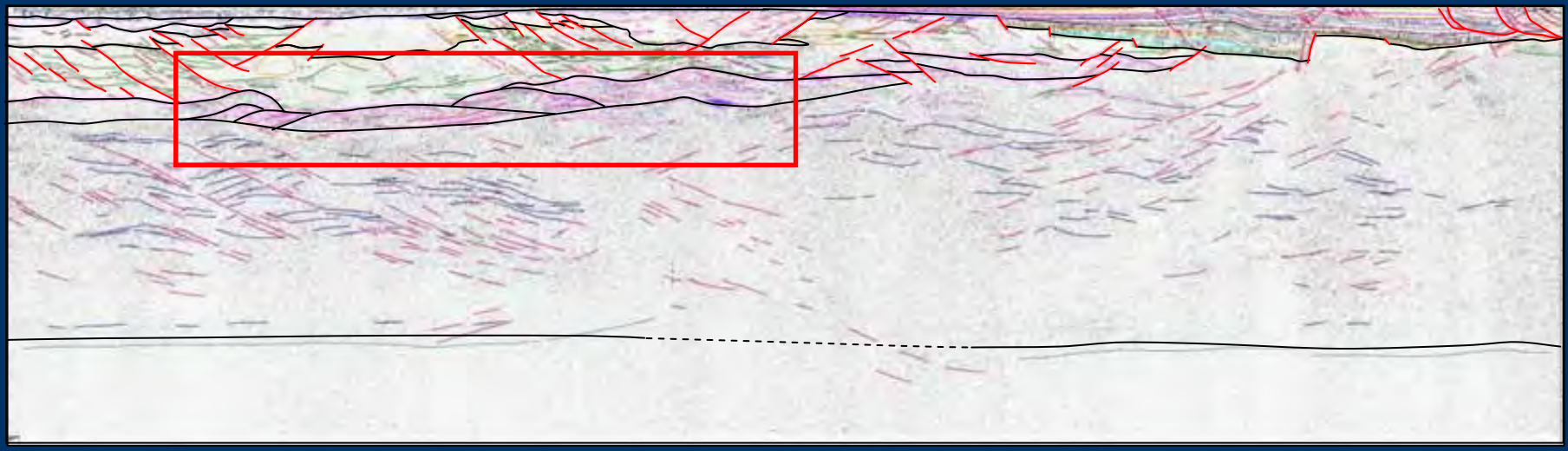
Possible back-thrusts cutting host granite of Olympic Dam



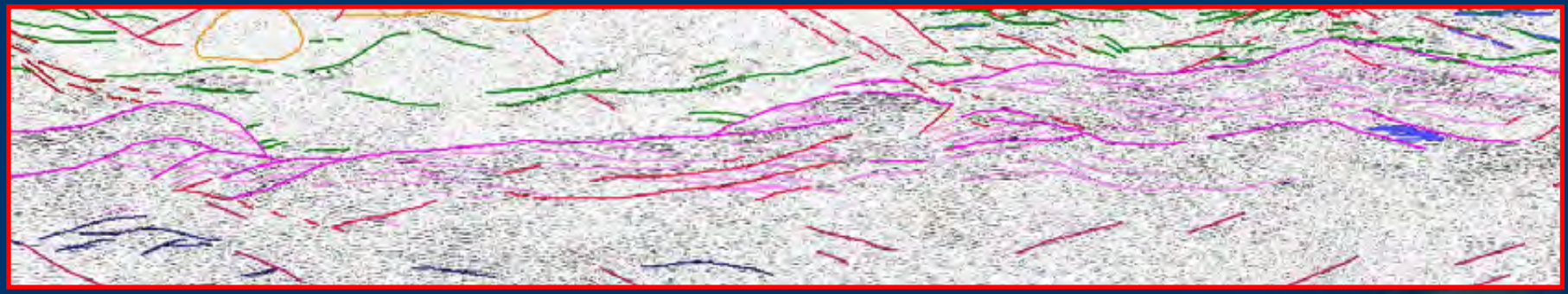
DUPLEXES IN MID-CRUSTAL LAYER

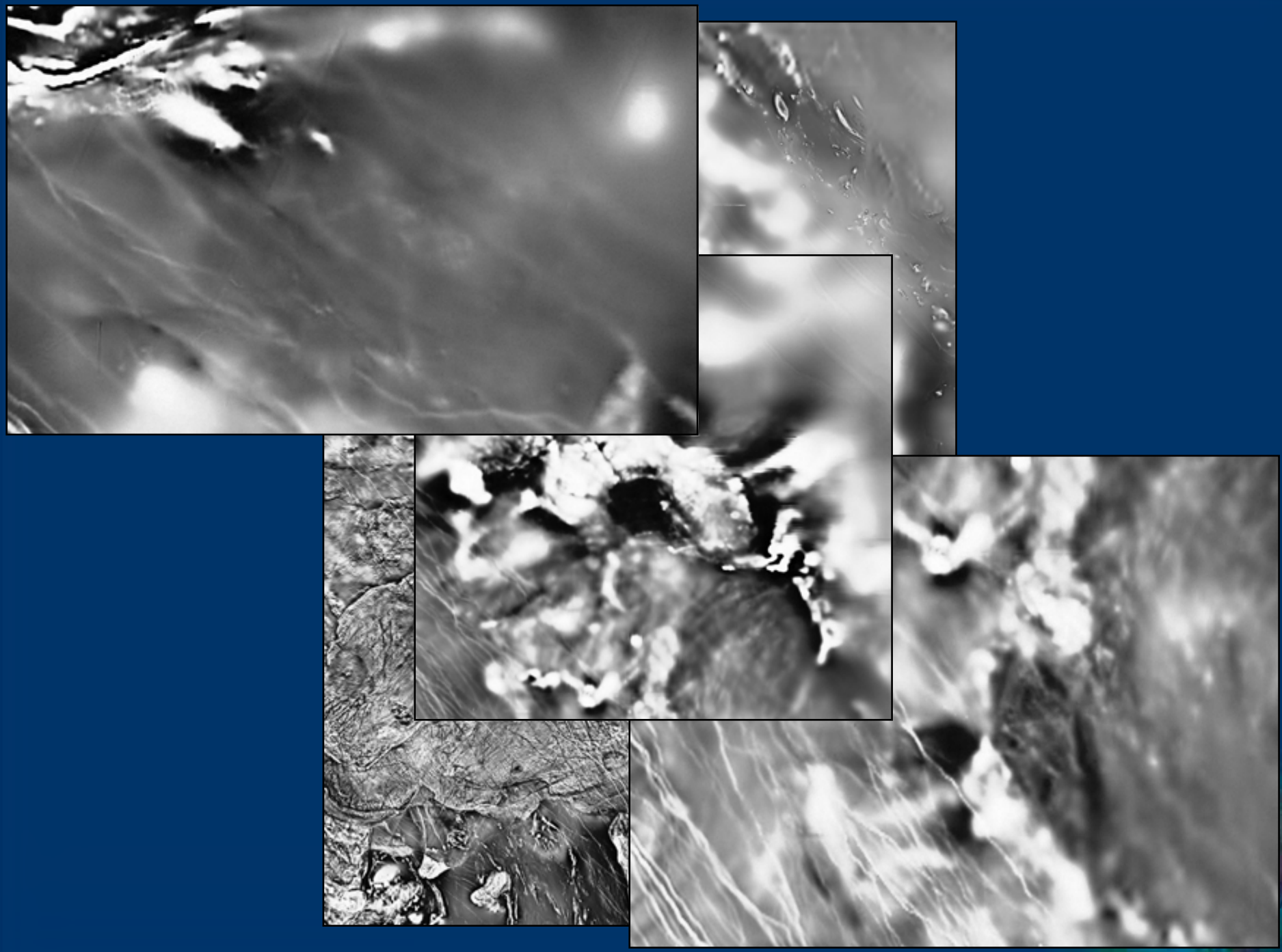
S

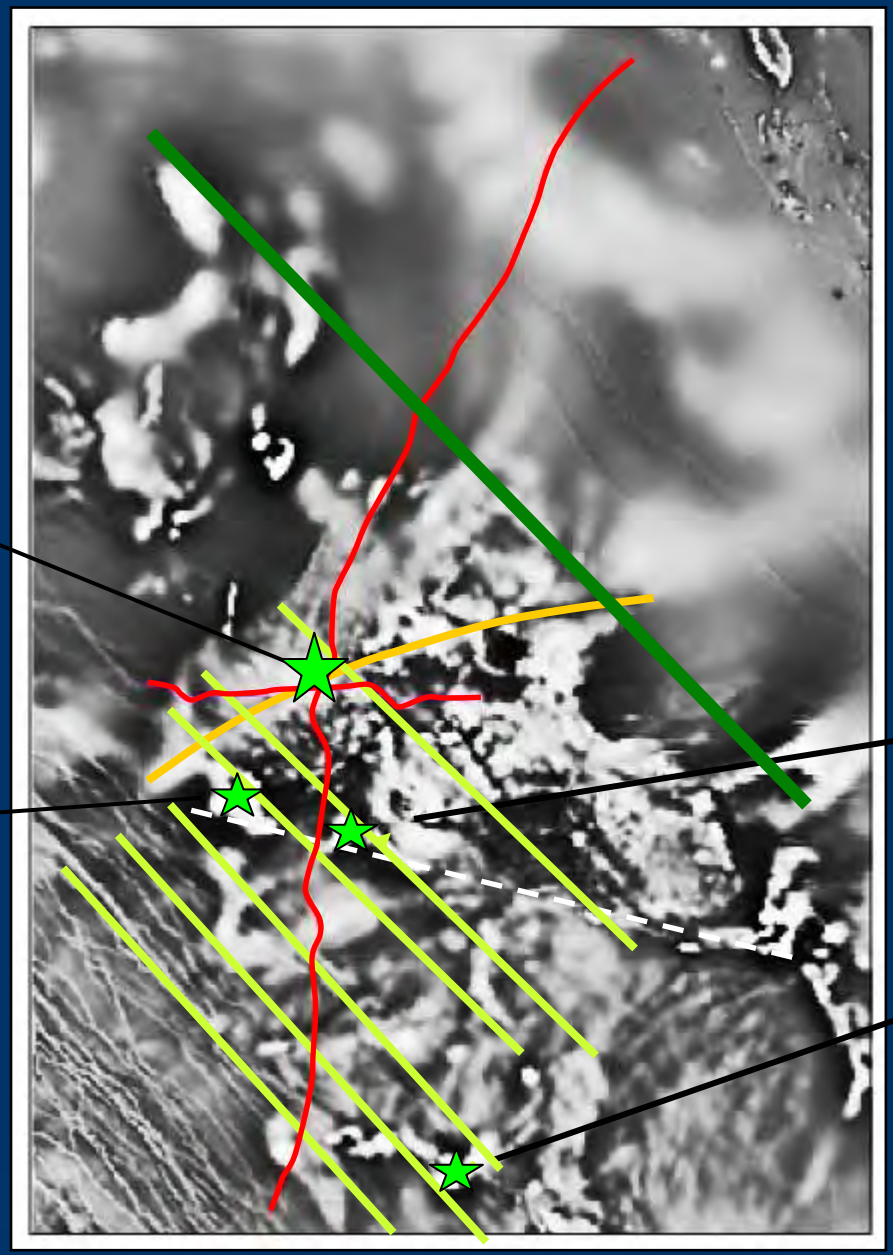
N

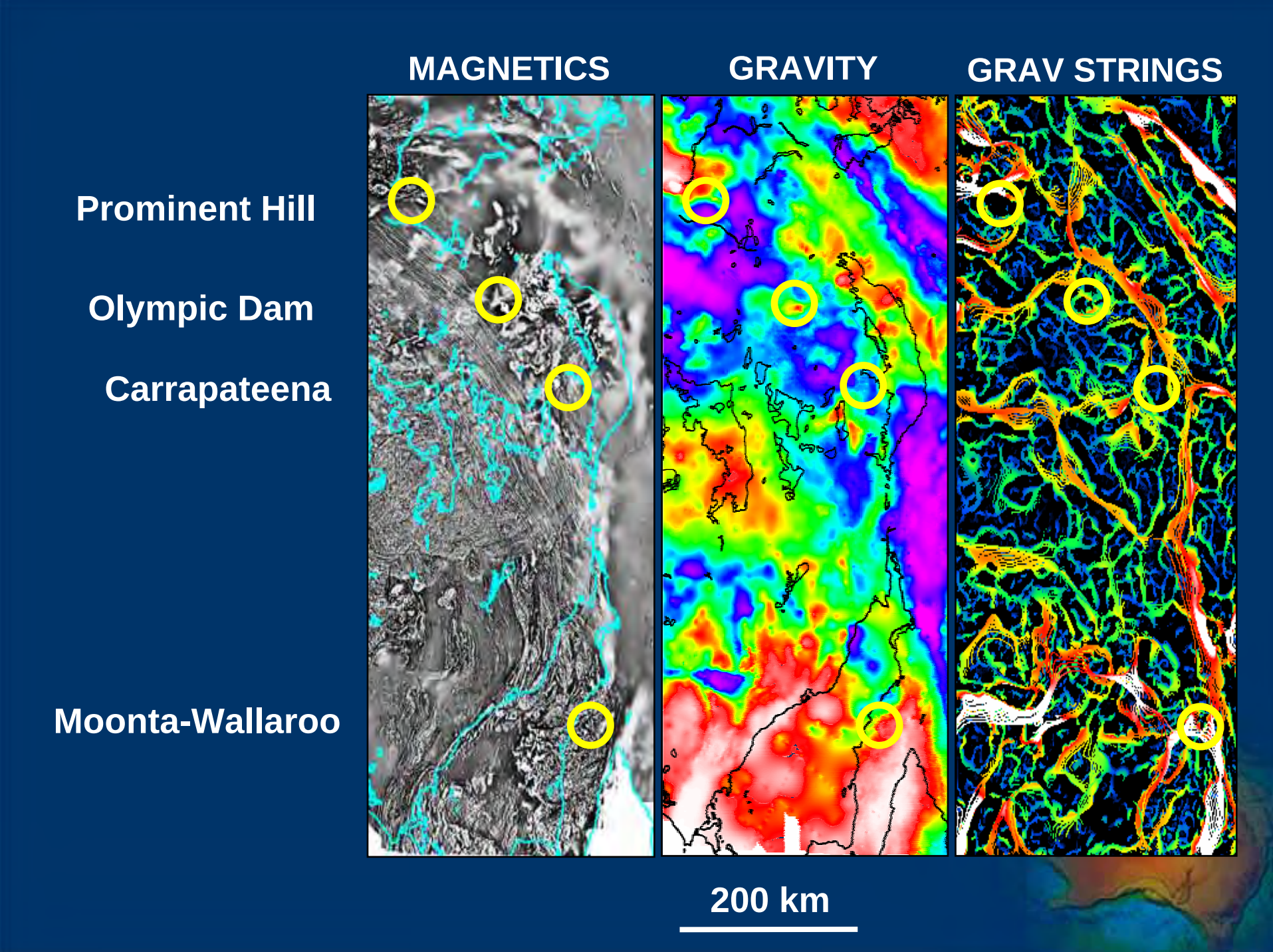


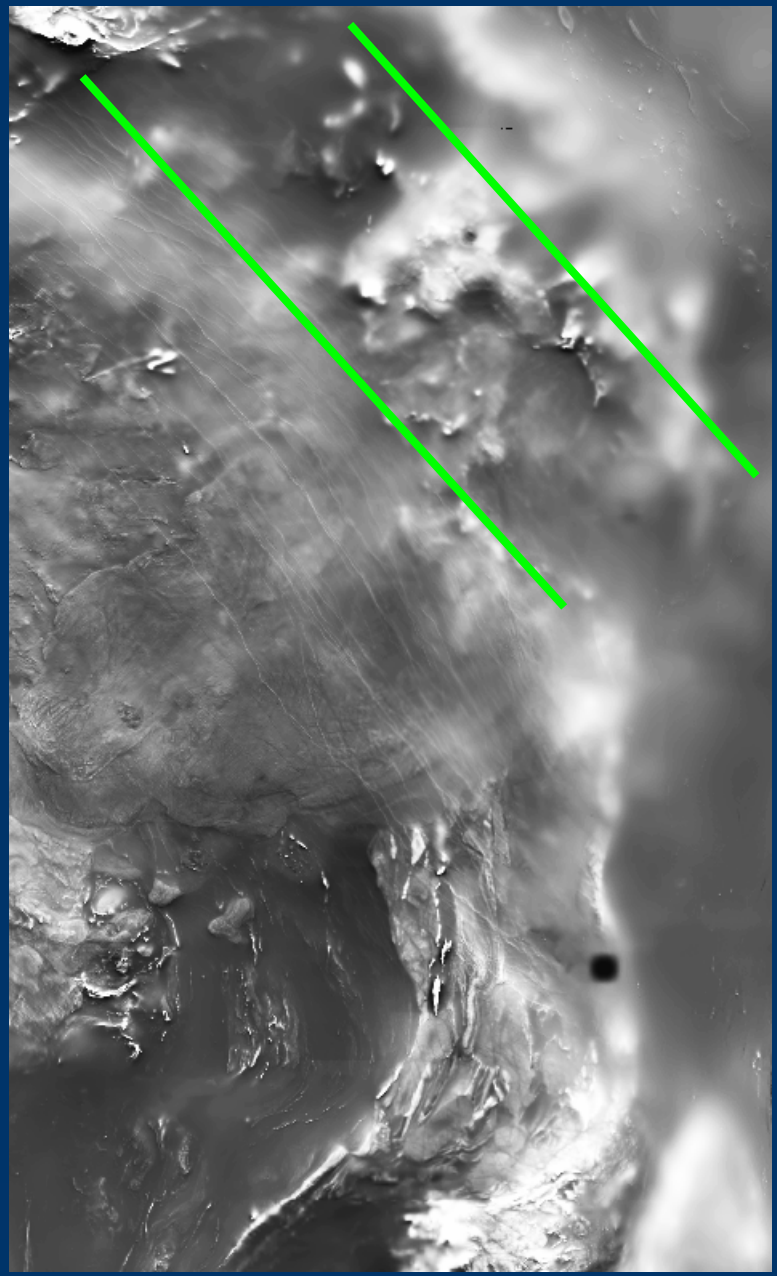
50 km






Olympic Dam
Acropolis
Wirrda Well
Emmie Bluff


MAGNETICS
GRAVITY
GRAV STRINGS
Prominent Hill
Olympic Dam
Carrapateena
Moonta-Wallaroo
200 km

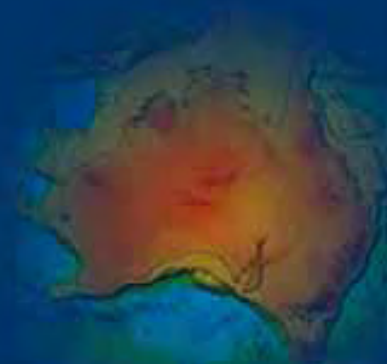


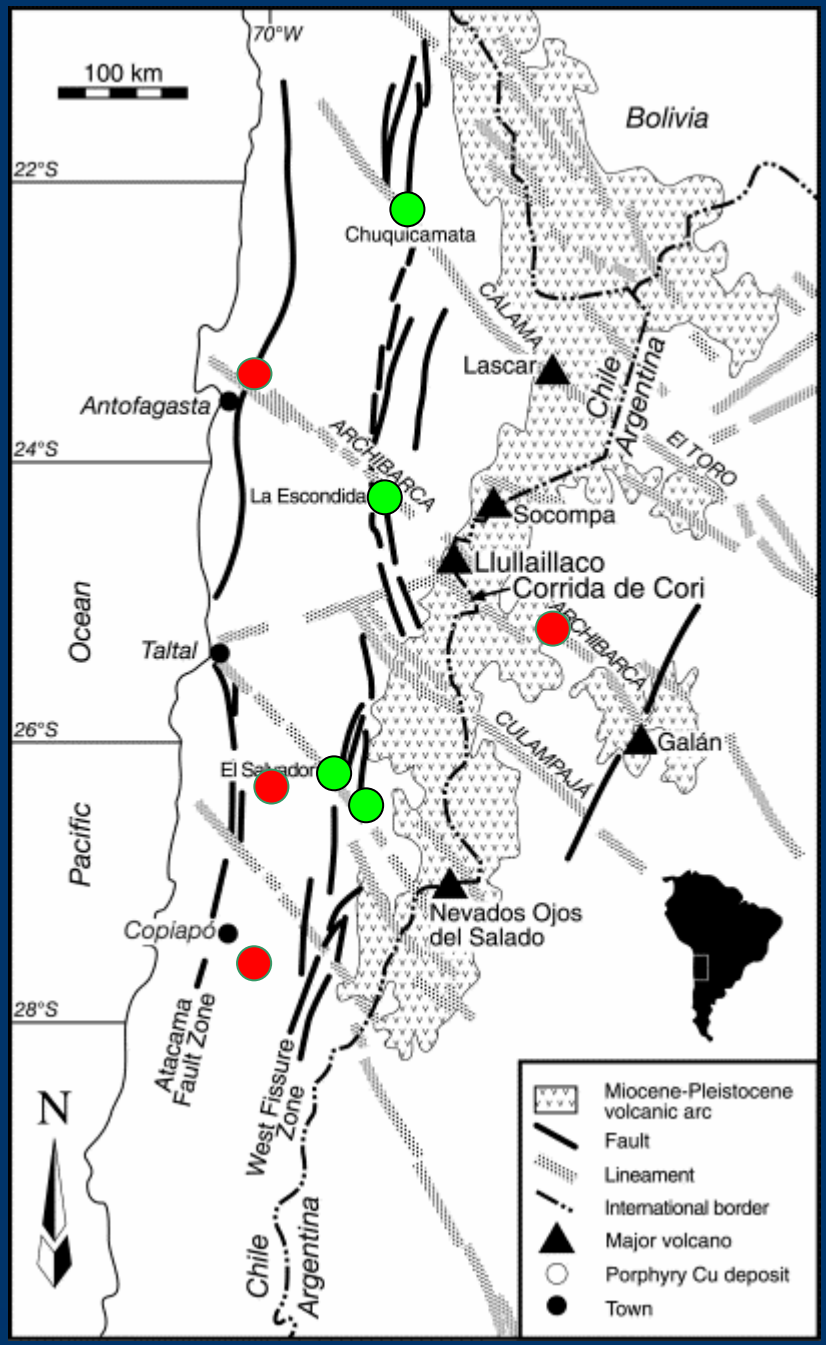
CRUSTAL SETTING

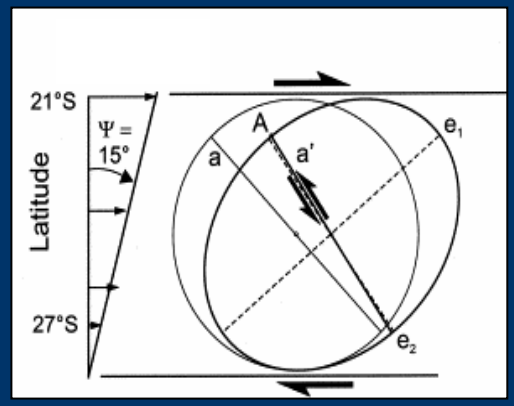
EXTENSIONAL

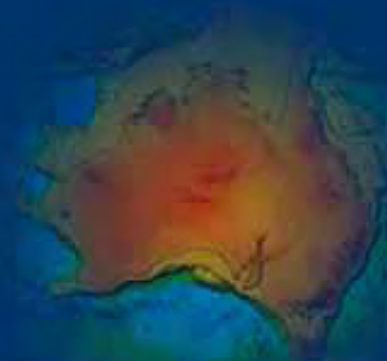
COMPRESSIONAL

?




70°W
100 km
Bolivia
22°S
Chuquicamata
CALAMA
Lascar
Chile
Argentina
Antofagasta
ARCHIBARCA
EL TORO
24°S
La Escondida
Socompa
Llullaillaco
Corrida de Cori
Ocean
Taltal
ARCHIBARCA
26°S
CULAMPAJA
Galán
El Salvador
Pacific
Nevados Ojos
del Salado
Copiapó
28°S
Atacama
Fault Zone
West Fissure
Zone
Chile
Argentina
N
Miocene-Pleistocene
volcanic arc
Fault
Lineament
International border
Major volcano
Porphyry Cu deposit
Town


21°S
Latitude
27°S
Ψ =
15°
A
a
a'
e1
e2



CONCLUSIONS

The Gawler seismic profiles show crustal structure, providing geometric and spatial constraints for interpreting other geophysical datasets

Locations of Fe oxide bodies are structurally controlled

The crustal structure derives from multiple events occurring from 2.5 Ga to 1.6 Ga

Extensional features formed by convergence

Distribution of FeOx alteration can be mapped in 3-D