2D and 3D Potential Field Mapping and Modelling at the Fallon FORGE site, Nevada, USA

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How can we use gravity and magnetic data to improve our understanding of the 3D geologic framework in the subsurface?

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Gravity data + **Magnetic data** + **Other data** = **3D geologic framework**

A Gravity & Magnetics Primer…

- **Gravity** → **Rock Density**
- **Magnetics** → **Rock Magnetic Susceptibility**
  Rock Magnetic Remanence

Measured Geophysical Data

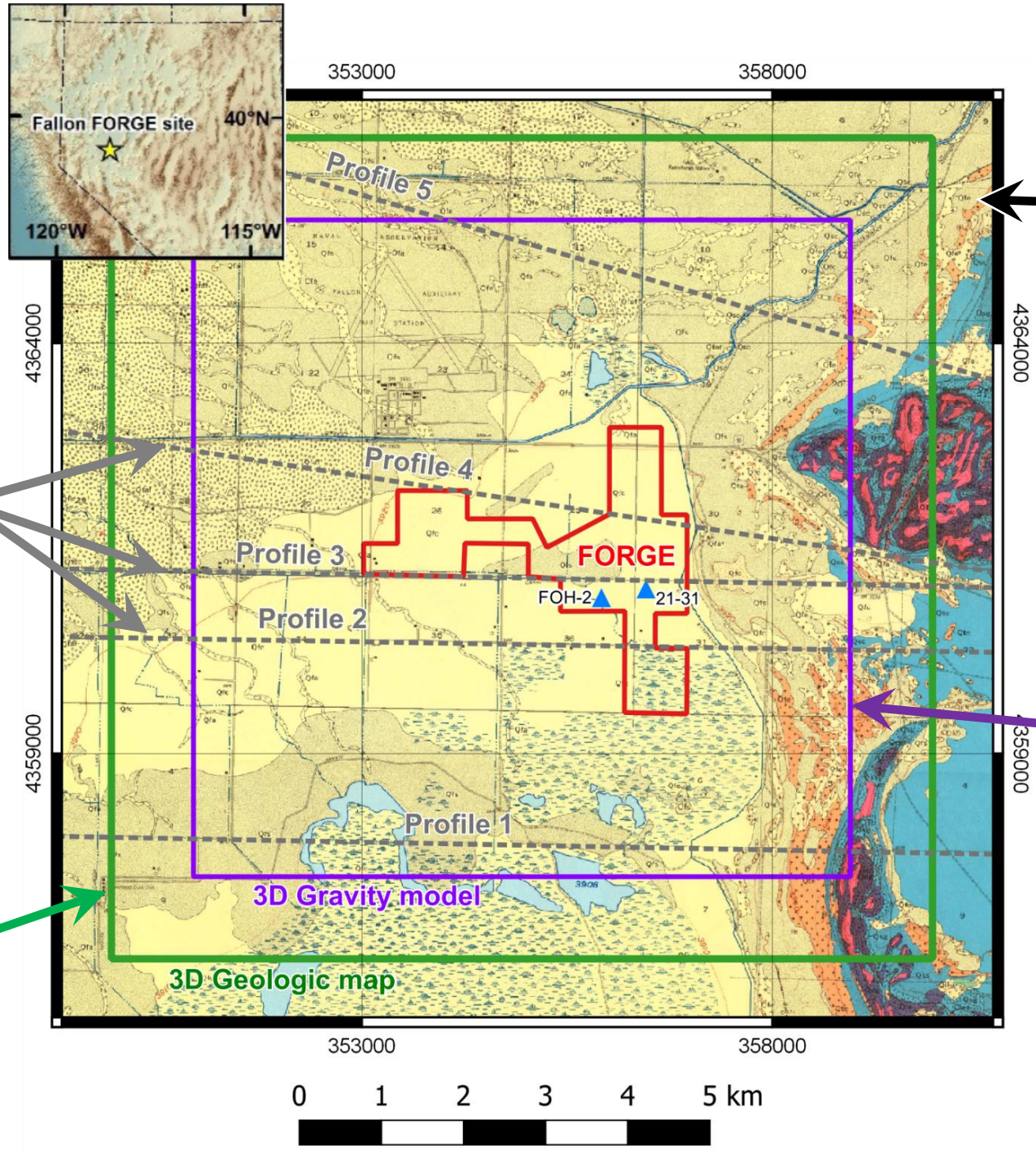
Rock Properties

A Gravity & Magnetics Primer…

- **Gravity & Magnetic map-based interpretation**
  (faults & geologic contacts)

- **2D & 3D modelling of Gravity & Magnetic data**
  (build and test geologic framework)

Study Area



Geologic Map of Morrison (1964) in background

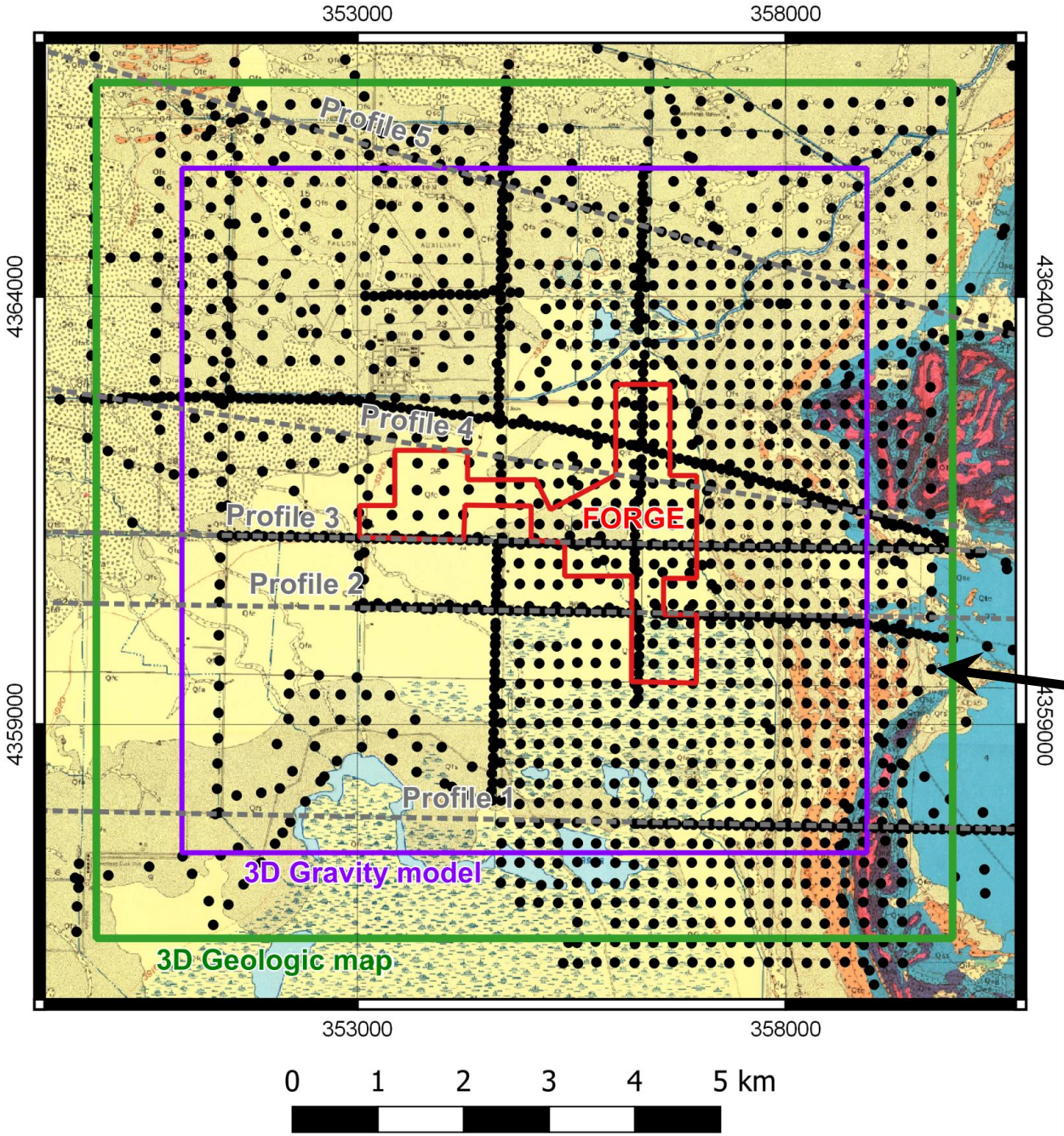
2D Gravity/Magnetic profile models (this study)

Footprint of 3D Gravity model (this study) 8 km x 8 km

Footprint of 3D Geologic Map of Siler et al. (2018) 10 km x 10 km

Gravity Data Coverage

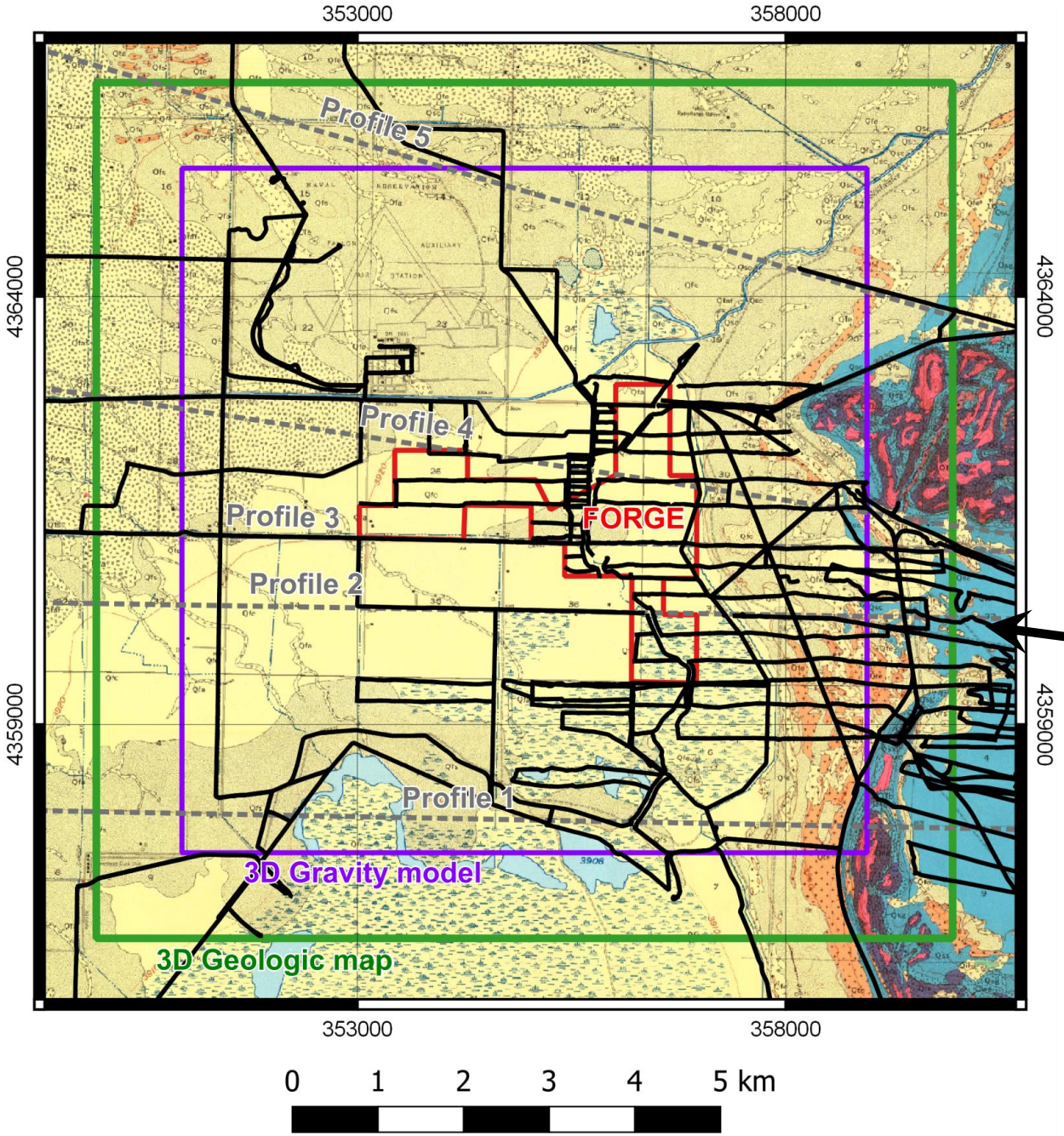
- ~8000 existing gravity stations in Carson Sink
- 900 new gravity measurements
- Station spacing 150 – 300 m
- Tight gravity spacing along profiles
- Coverage sparse in SW



Gravity measurement stations (black dots)

Magnetic Data Coverage

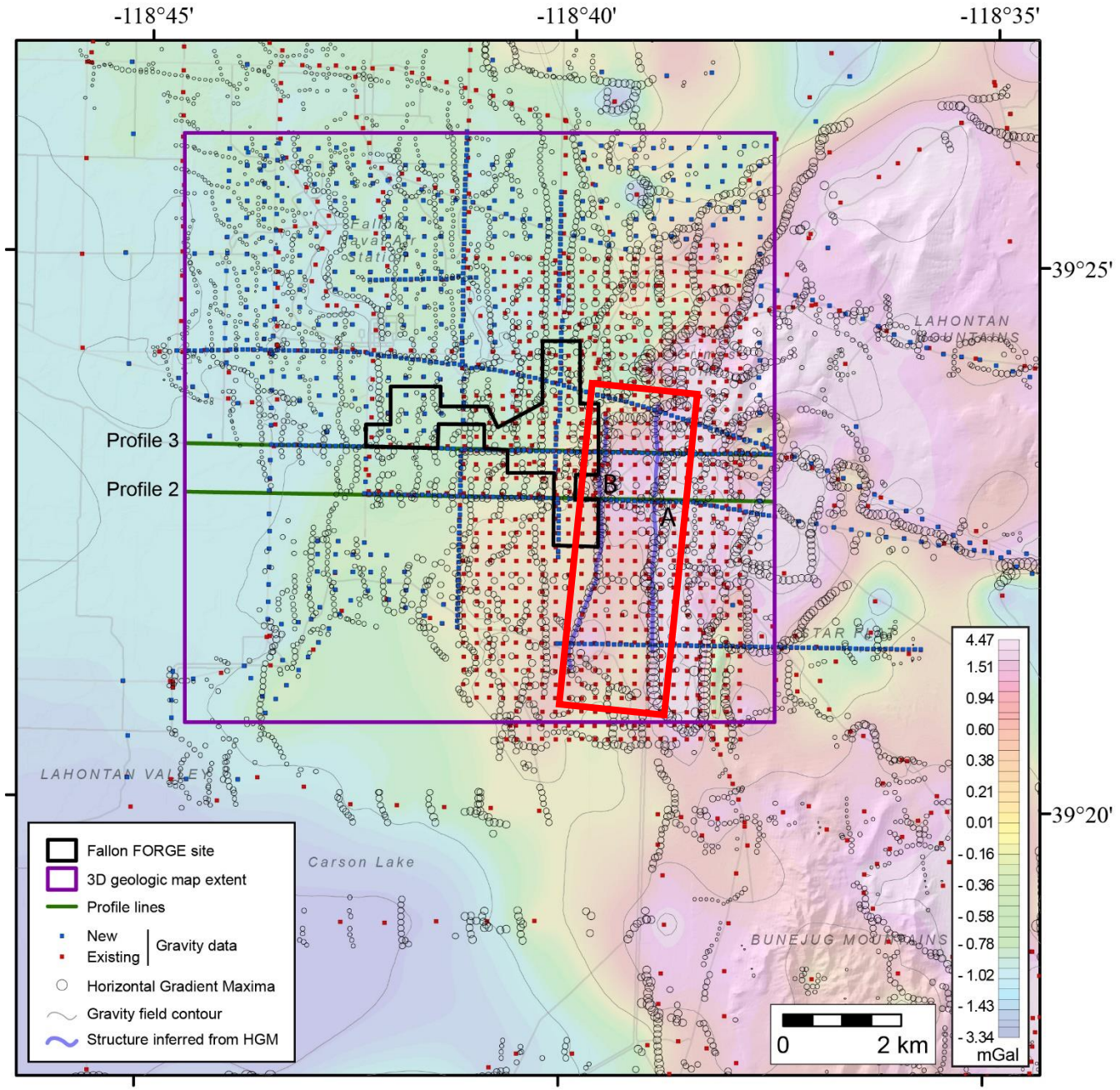
- 475 km new magnetic survey data
- Focused on E half of Fallon FORGE area
- New data merged with existing ground magnetic data
- Overall line spacing ~200 m



Magnetic survey lines for new data (black)

Gravity Map Interp

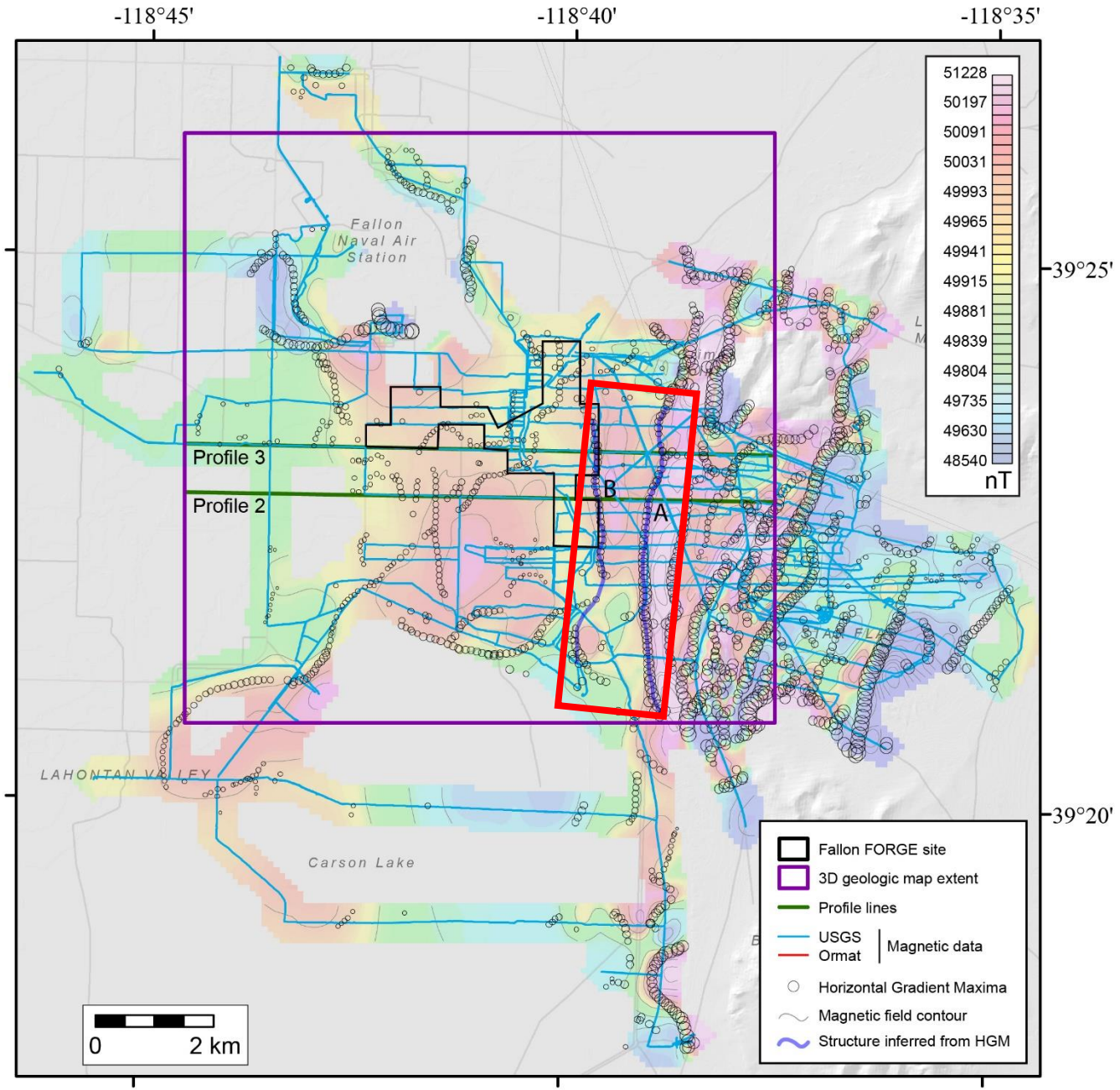
- Isostatic residual gravity map
- Horizontal gradient maxima identified from isostatic residual data (open circles)
- Infer structural features



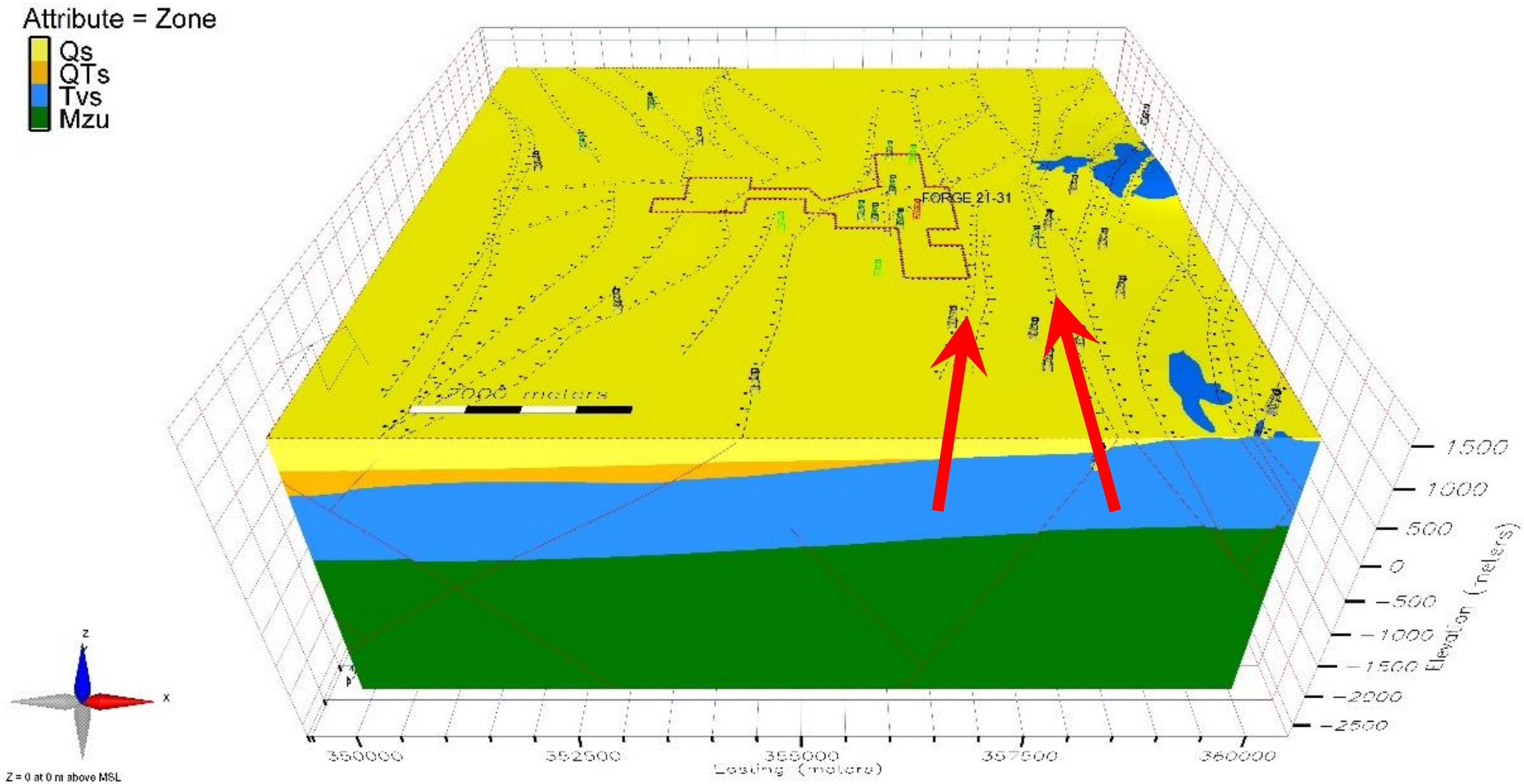
Magnetic Map Interp

- Residual reduced-to-pole magnetic map
- Horizontal gradient maxima identified from processed magnetic data (open circles)
- Infer structural features

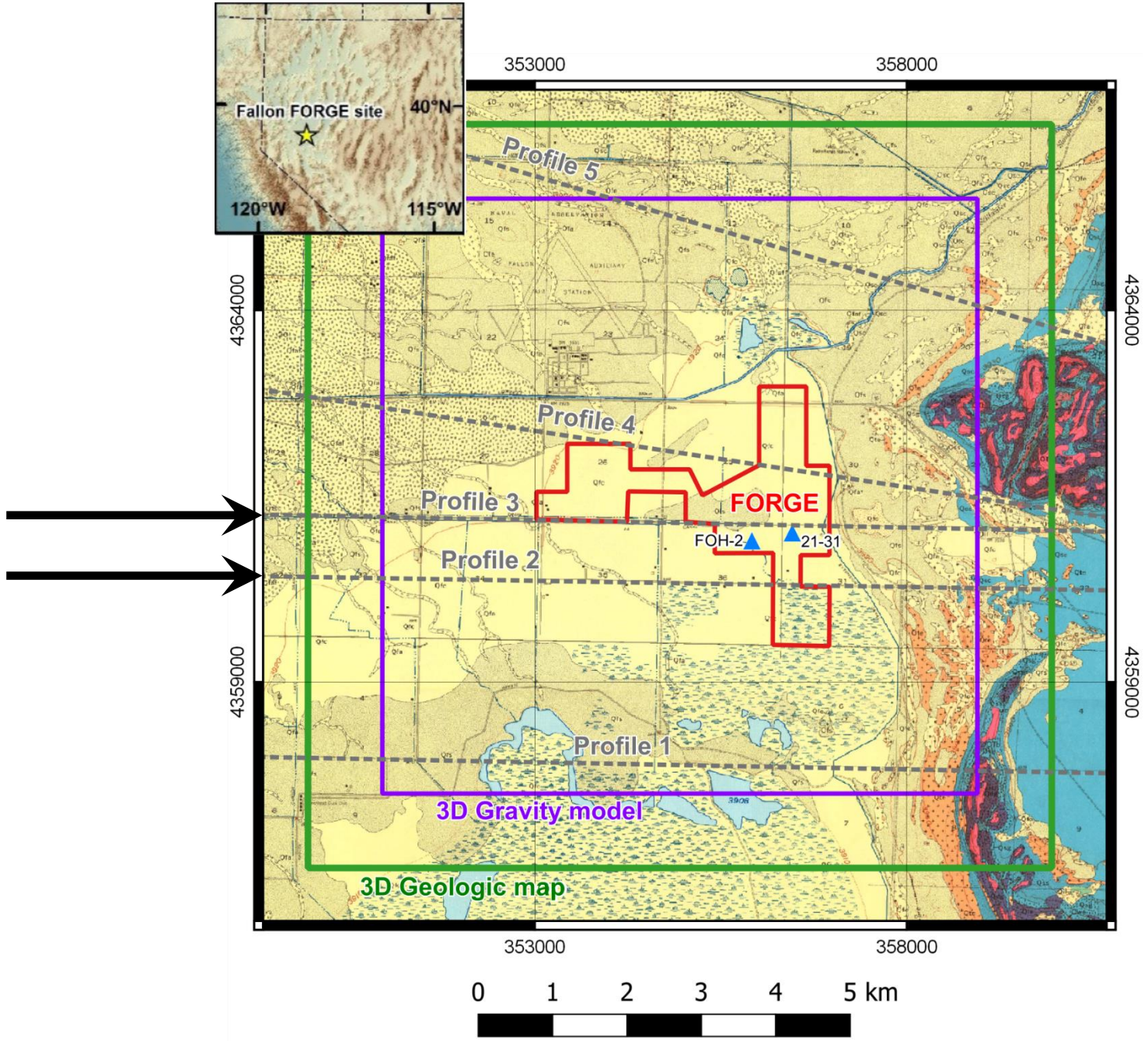
Same ones!



3D Geologic Framework from Phase 2B



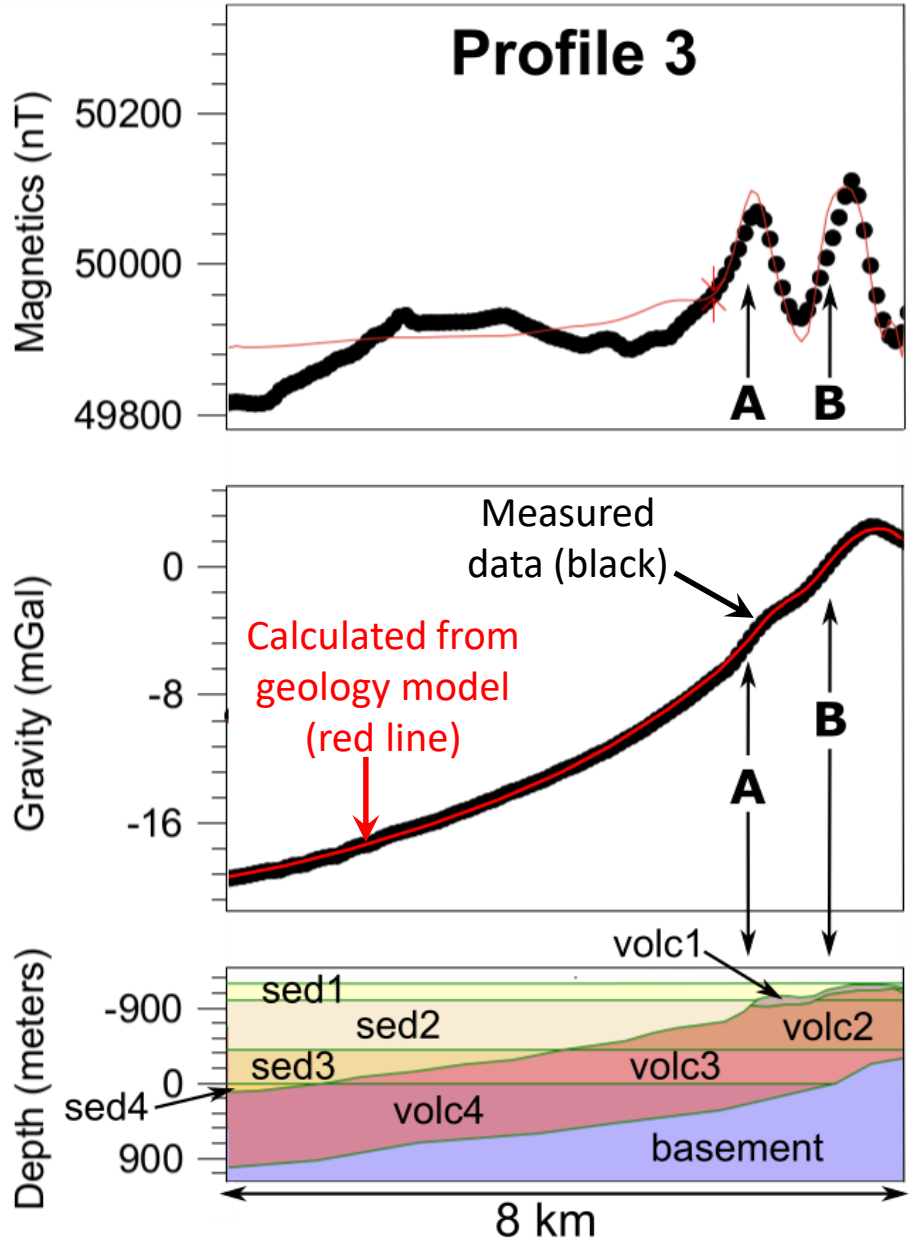
What about 2D Gravity/Mag profile modelling?

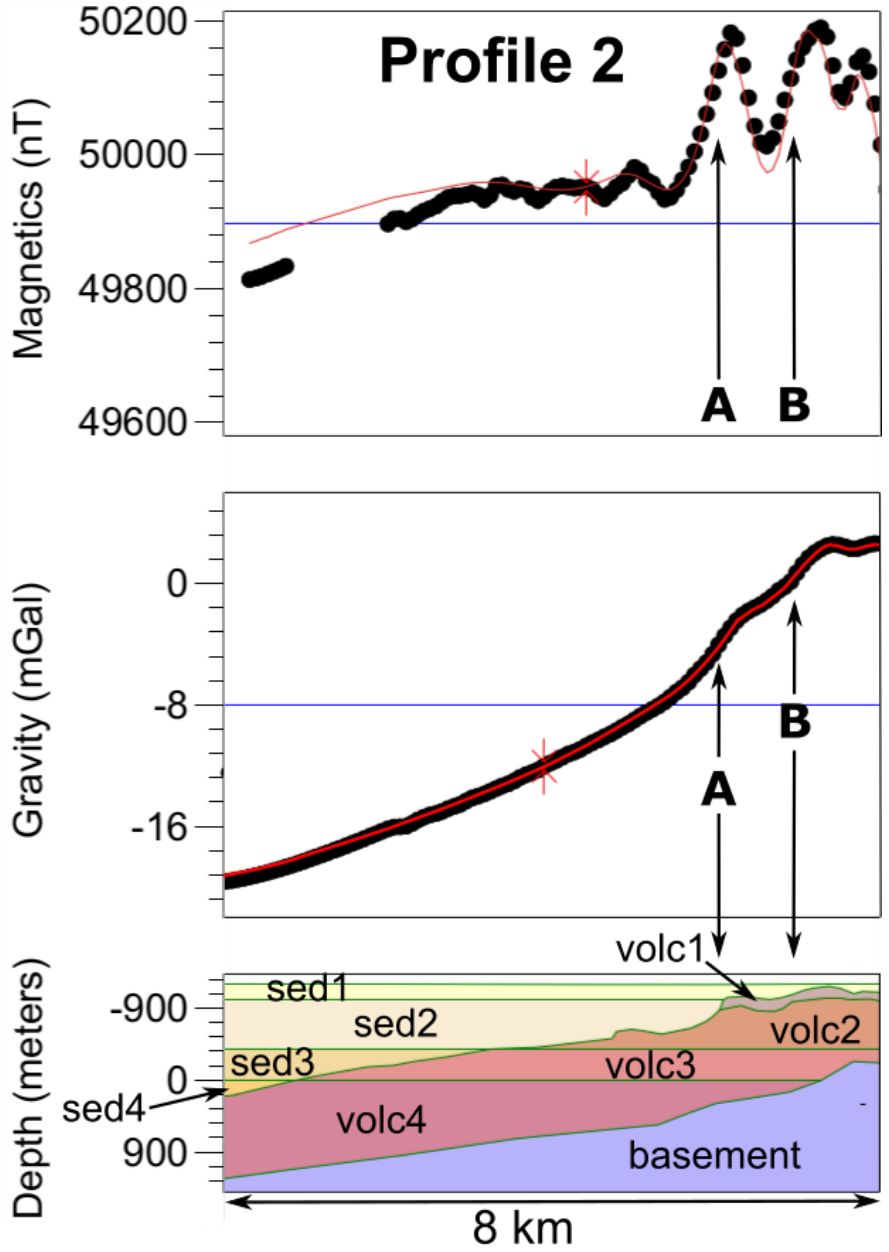


Magnetic profiles

Gravity profiles

Geology model profiles

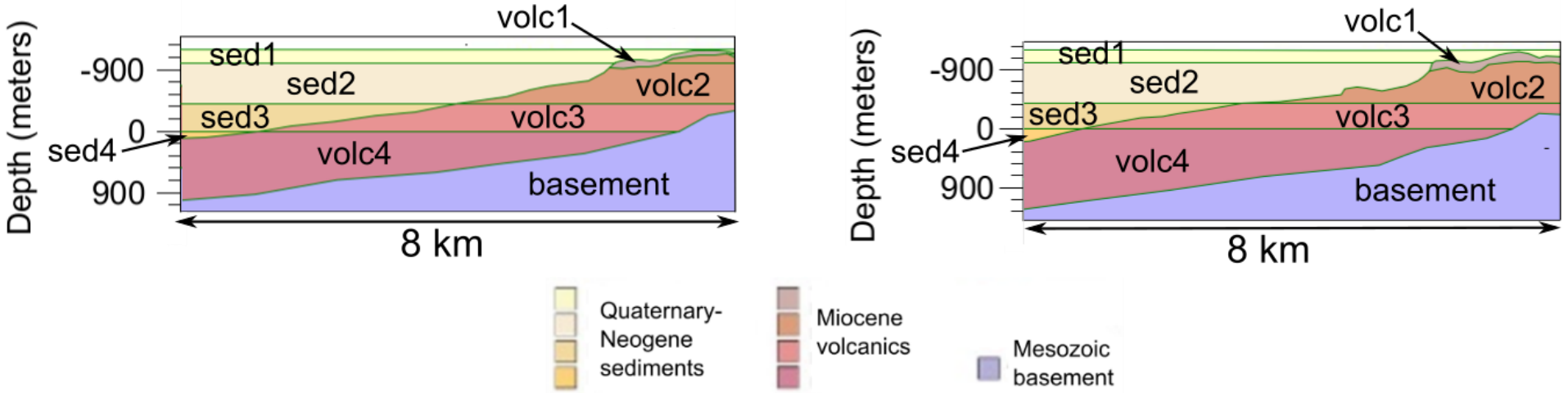




2D profile modelling performed using GM-SYS Oasis Montaj

Model Rock Property values

Model blocks	Density (g/cm^3)	Susceptibility (SI)	Remanence (A/m)	Declination (deg)	Inclination (deg)
sed1	1900	0.002	0		
sed2	2000	0.007	0		
sed3	2200	0.005	0		
sed4	2300	0	0		
volc1r	2300	0.02	2	157	-30
volc1n	2300	0.02	2	0	60
volc2	2350	0.02	2	0	60
volc3	2400	0.02	2	0	60
volc4	2420	0.02	2	0	60
basement	2670	0.01	0		



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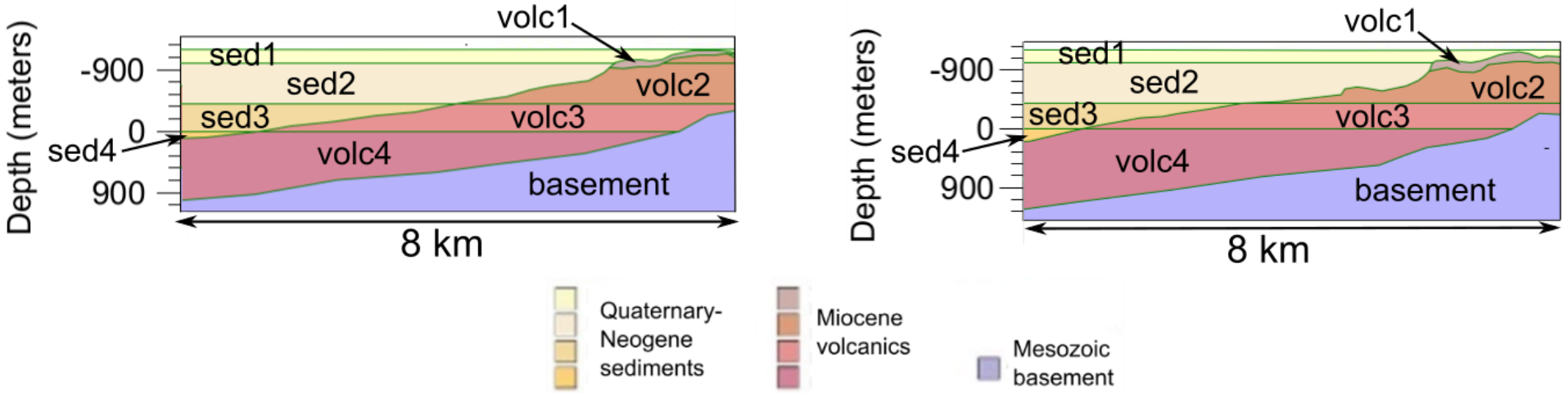

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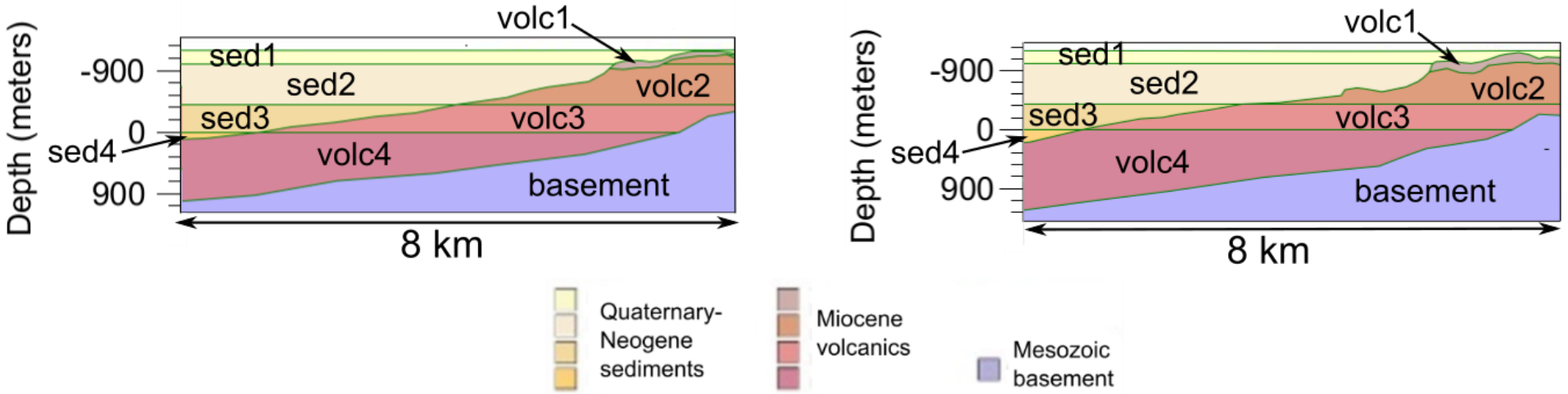


Rock Property Measurements

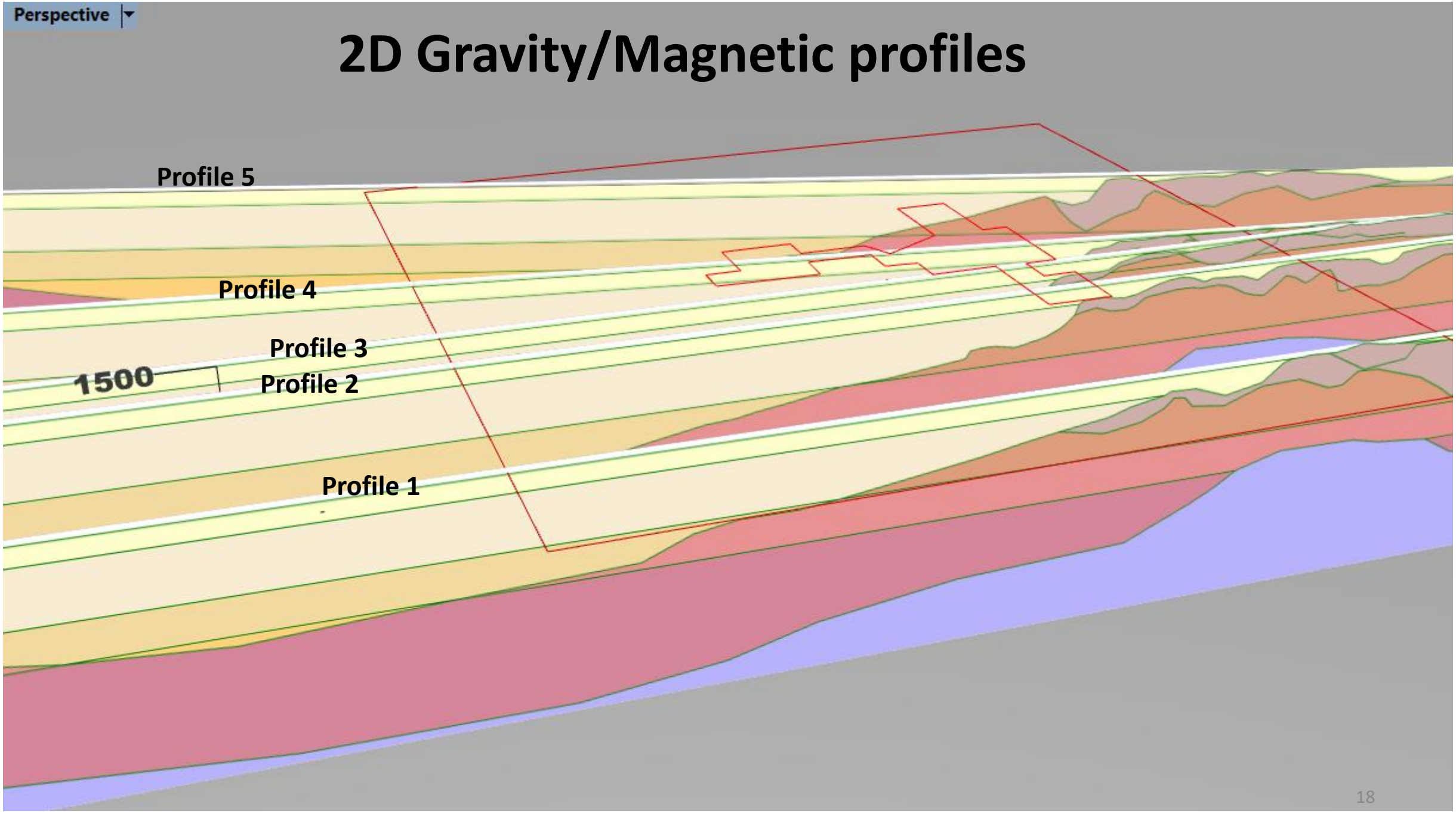
Density

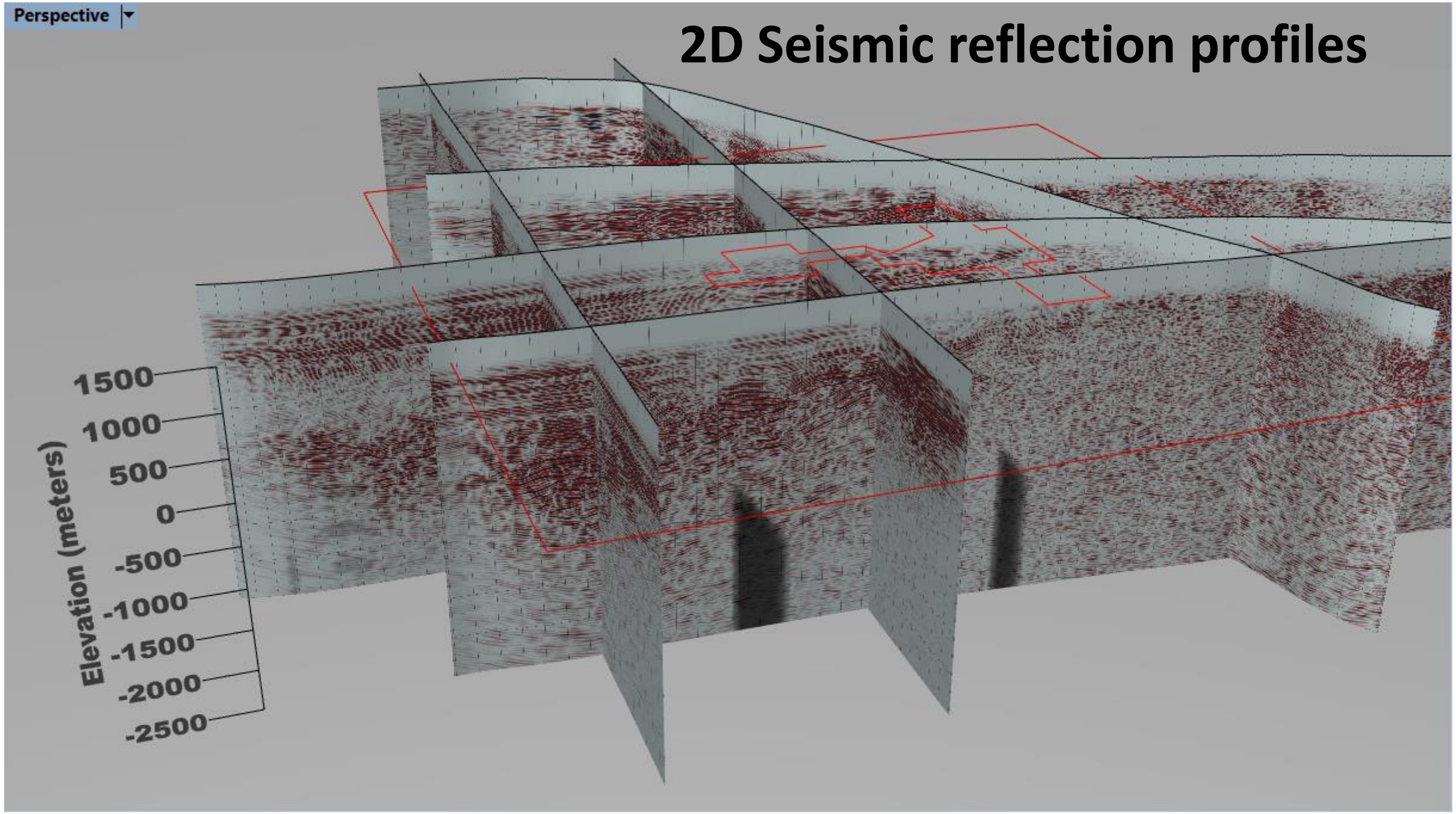
Well	Rock unit	Number of measurements	Average Saturated Bulk Density (± 1σ SD)
51-20	Tvs	33	2.419 ± 0.138 g/cm^3
FOH-2	Tvs	172	2.410 ± 0.127 g/cm^3
BCH-3	Tvs	54	2.390 ± 0.123 g/cm^3
BCH-3	Mzu	42	2.630 ± 0.40 g/cm^3

Magnetic Susceptibililty ⇨ **> 300 measurments from core** + **40 measurements from surface samples (Bunejug Mtns)**

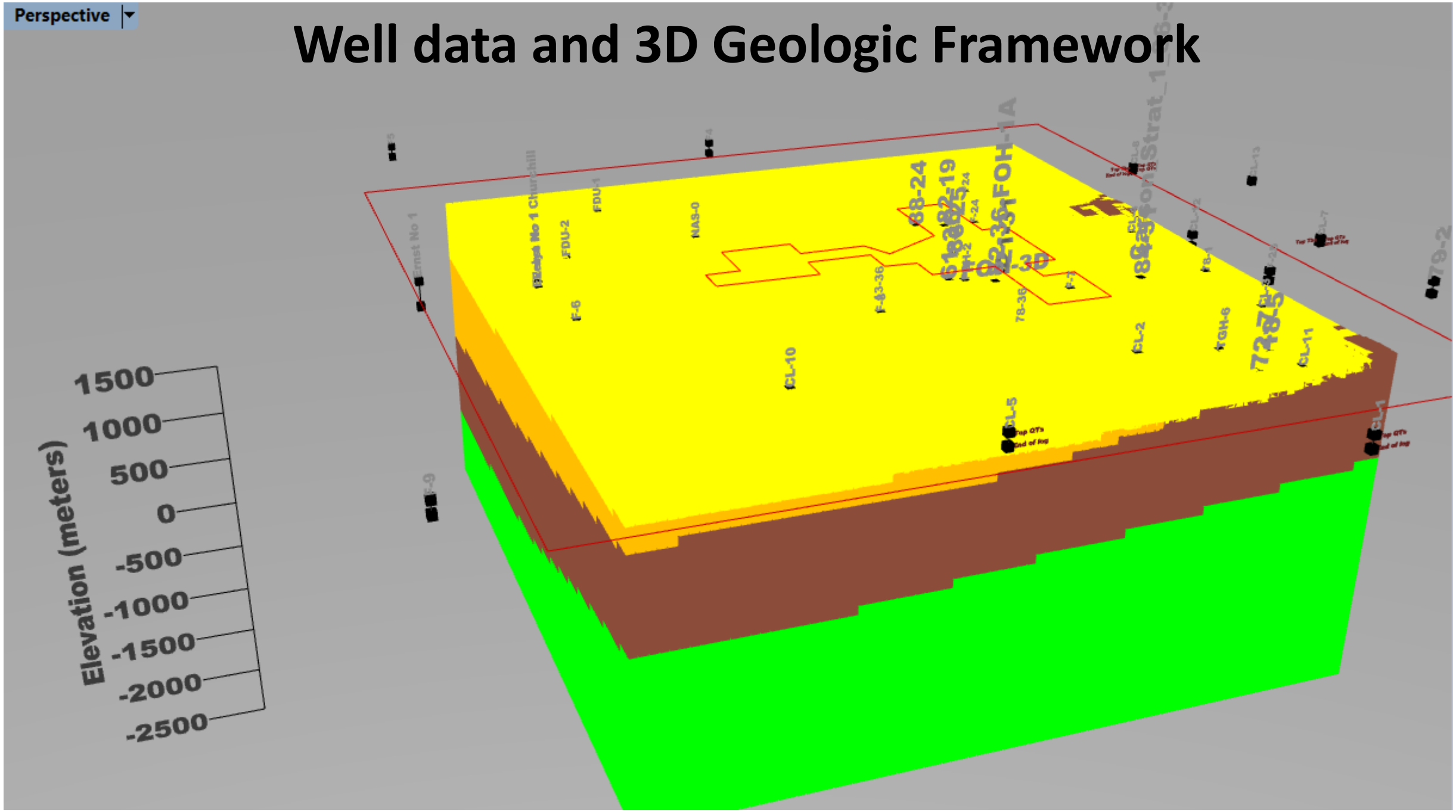
Magnetic Remanence ⇨ **93 samples from Tertiary volcanic rocks exposed in Bunejug Mtns**

2D Gravity/Magnetic profiles




Perspective
2D Seismic reflection profiles
Elevation (meters)
1500
1000
500
0
-500
-1000
-1500
-2000
-2500

Well data and 3D Geologic Framework



How can we test the entire 3D model?

…to reduce uncertainty

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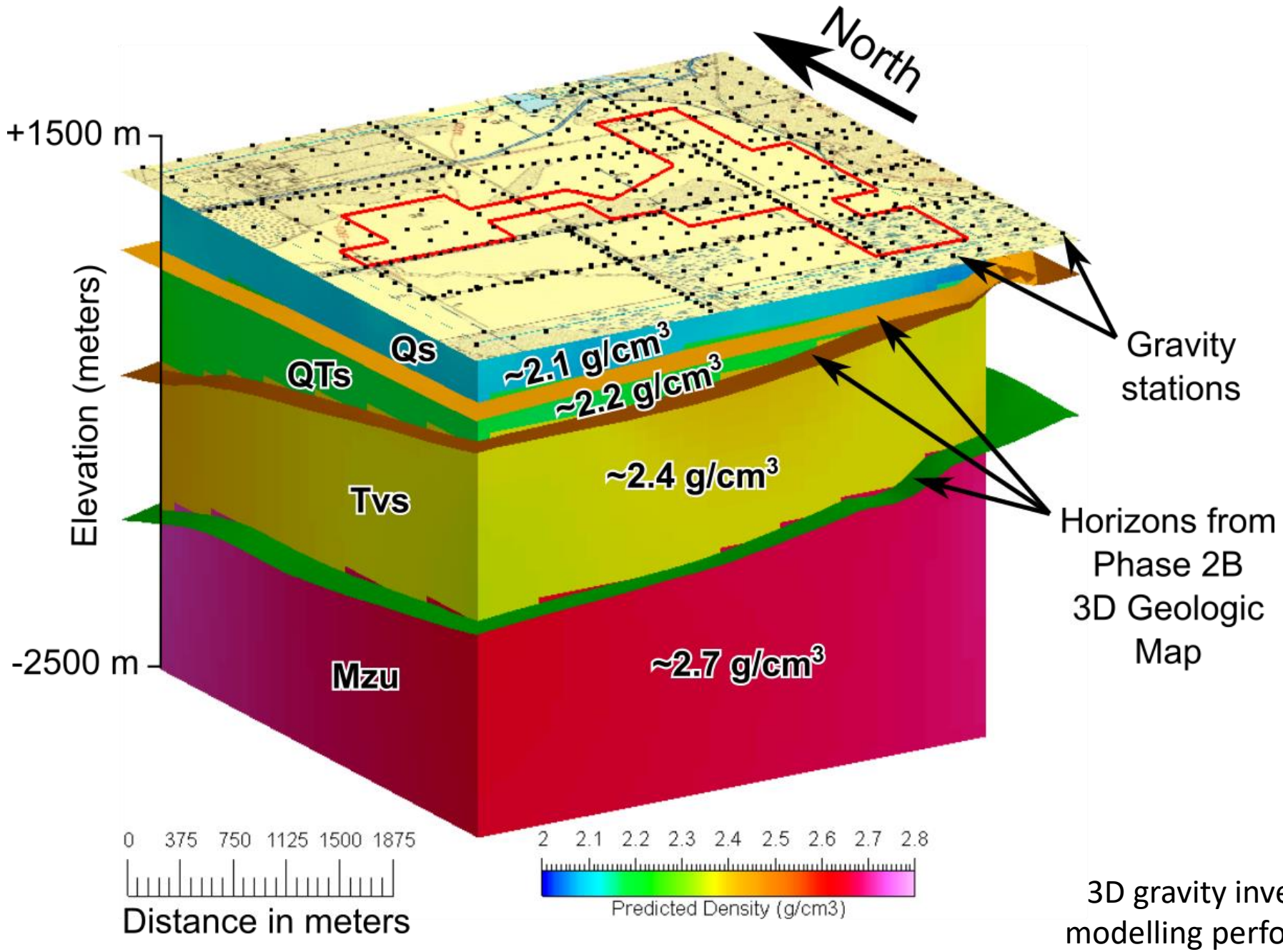
…to reduce uncertainty

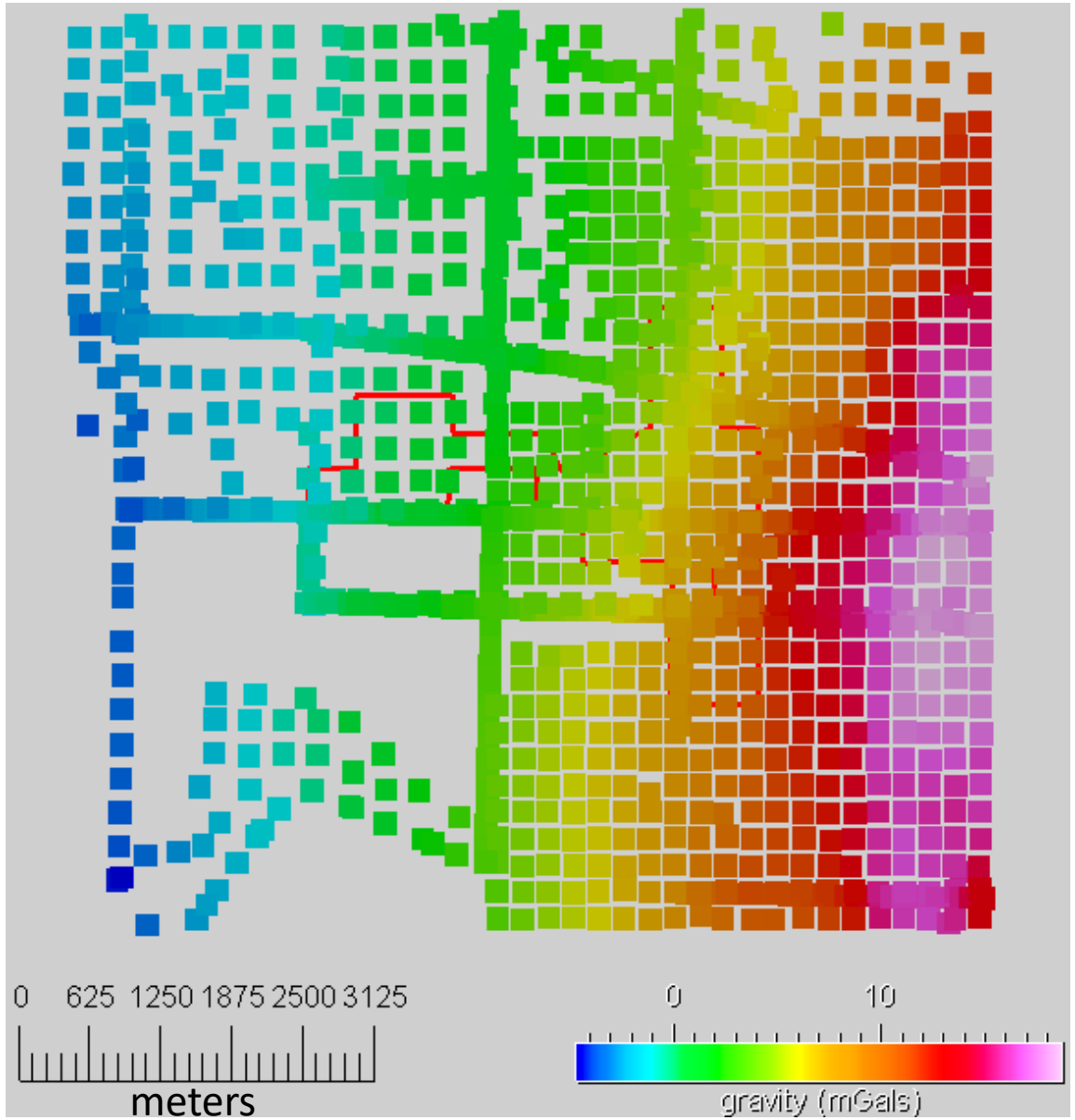
3D Gravity Inversion modelling

Gravity data + **Rock Property data** + **3D geologic framework** ⇨ **Agree??**

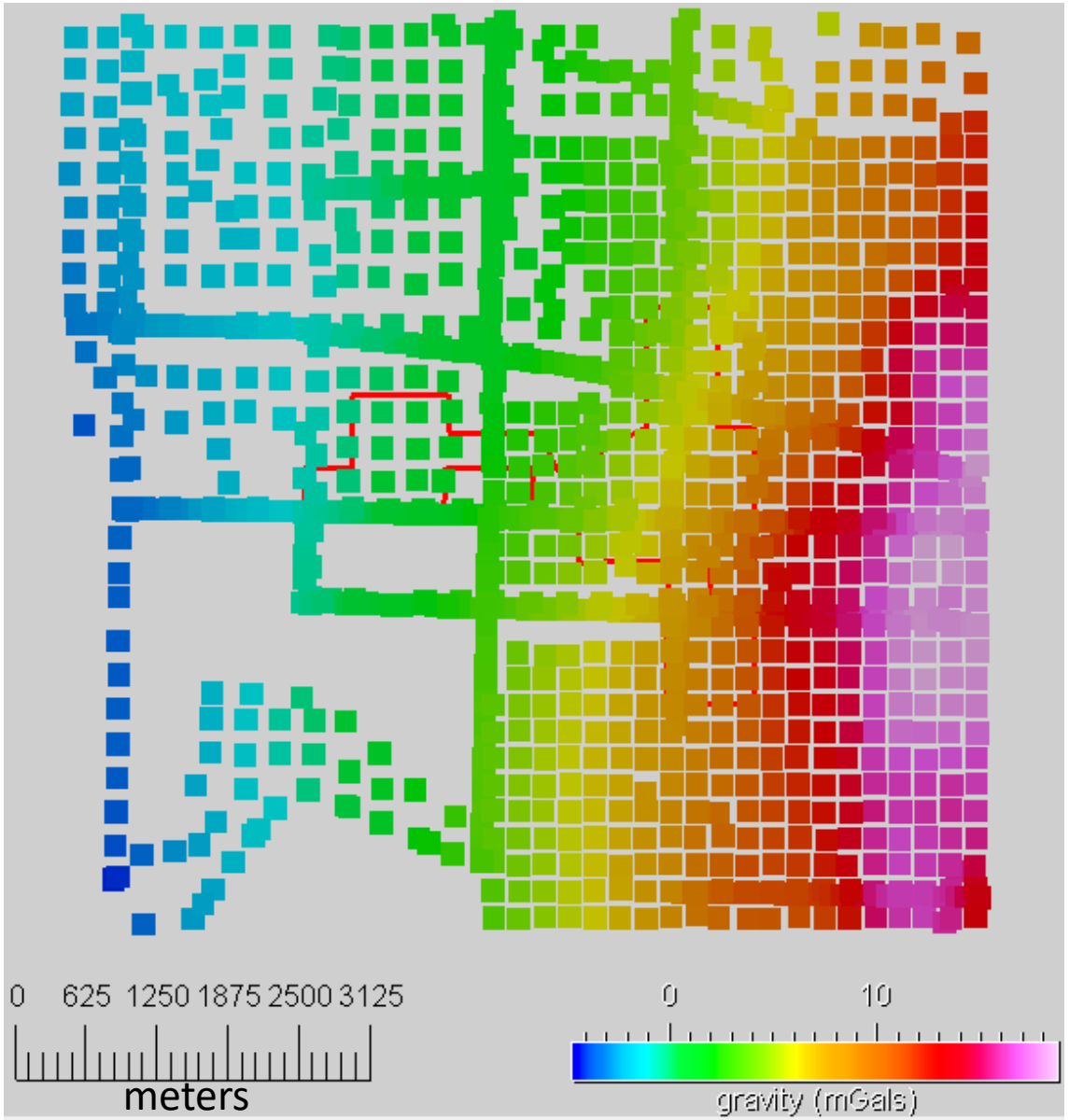
- 3D gravity inversion
- 3D density model
- Constrained by 3D geology
- Guided by rock density measurements



3D gravity inversion modelling performed SIMPEG and Rhino3D



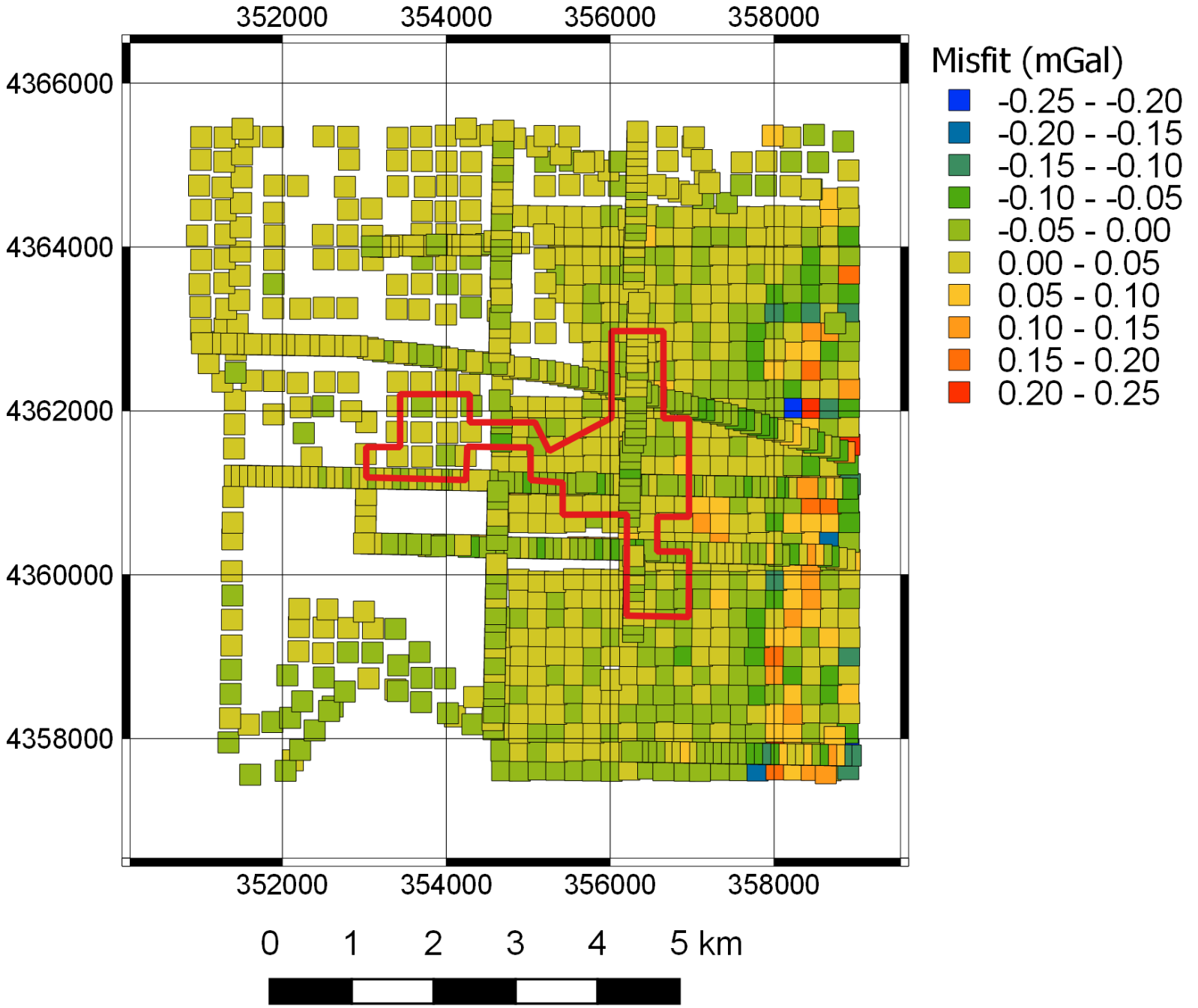
Measured gravity data



Gravity calculated from 3D density model

How good is the match between the measured and calculated gravity?

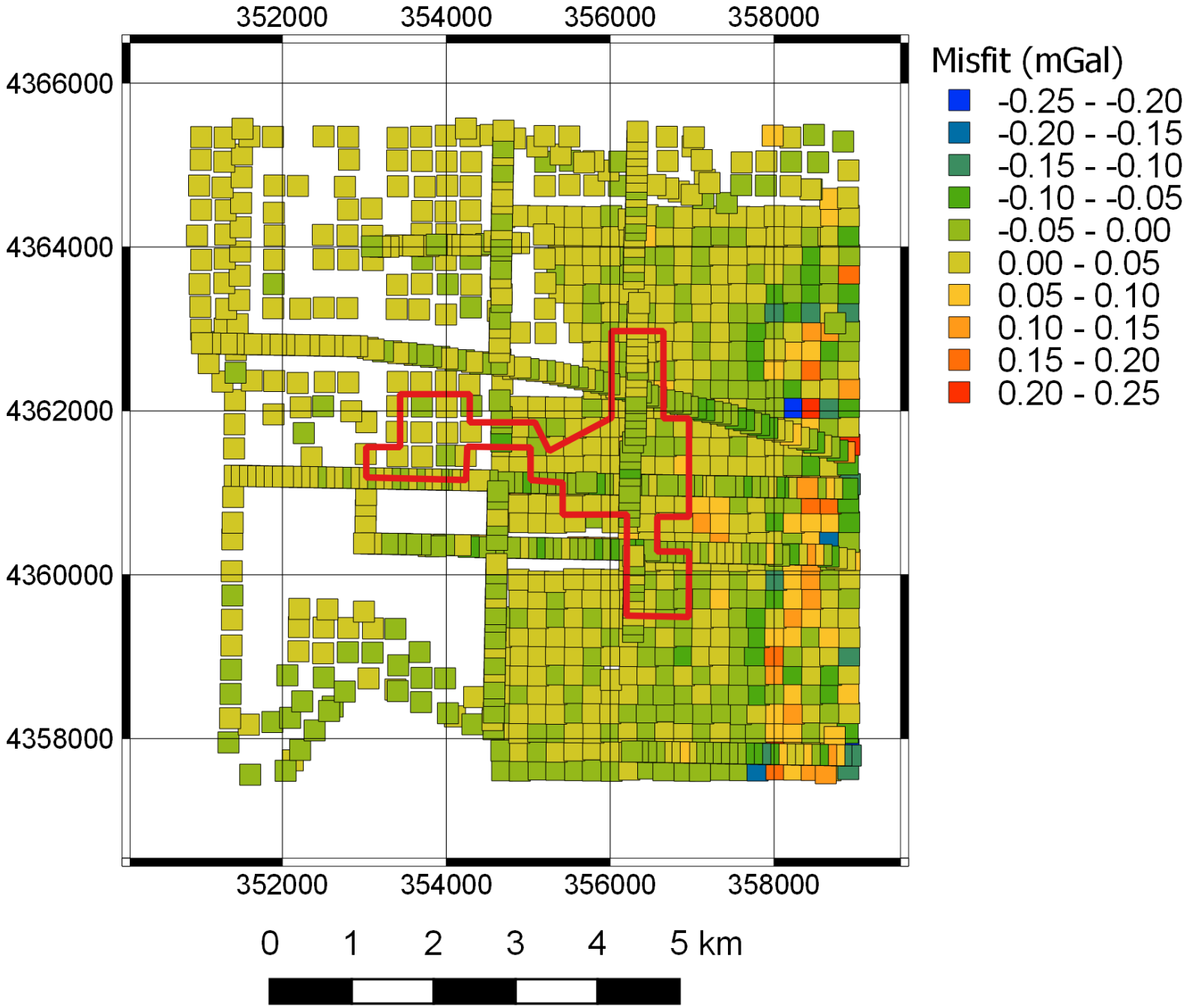
Error in gravity measurements is ~0.1 mGal



How good is the match between the measured and calculated gravity?

Error in gravity measurements is ~0.1 mGal

Majority is within error



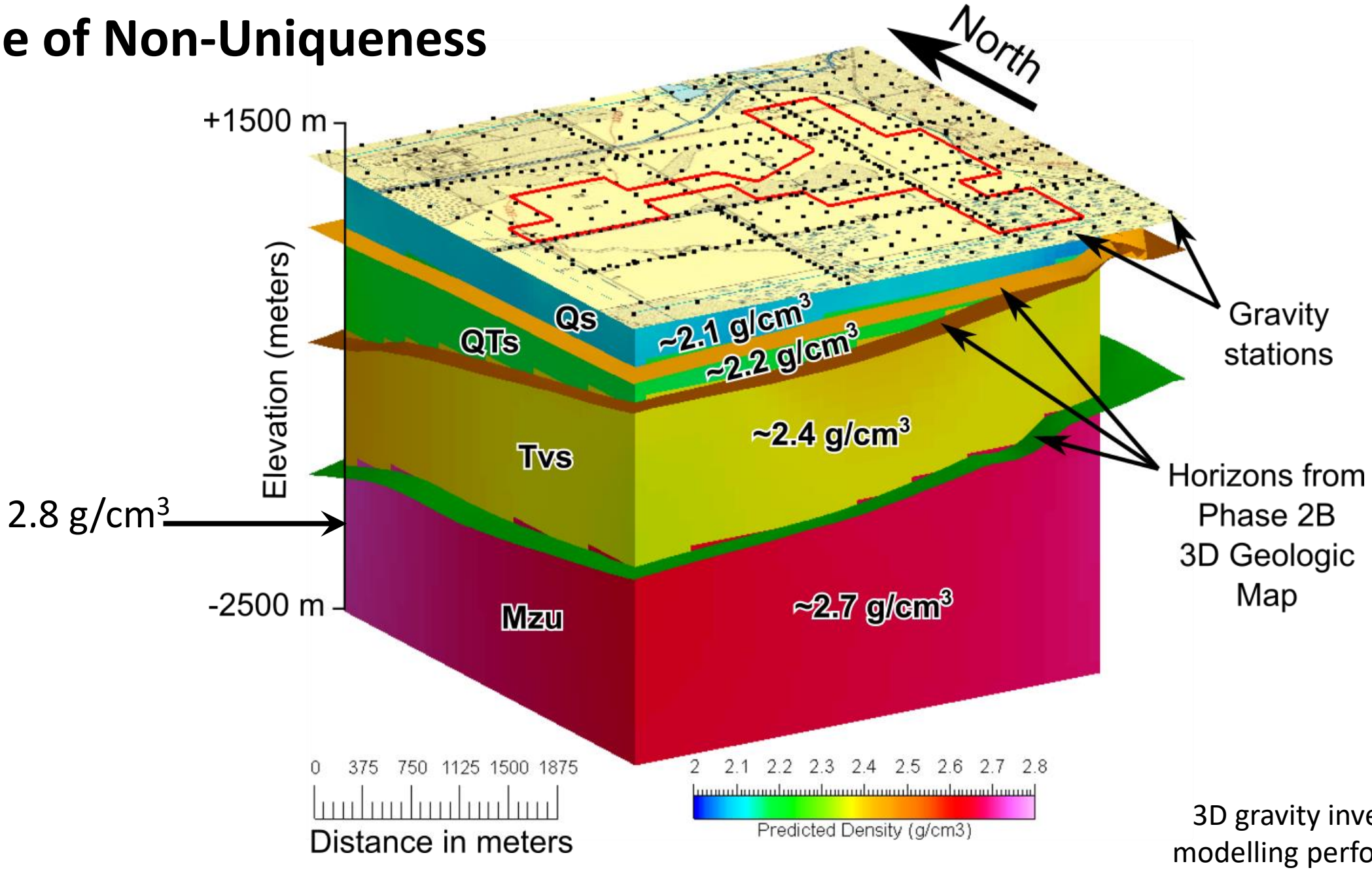
How well does the density model rock density measurements?

Code	Rock Type	Range predicted in 3D density model (g/cm^3; 2σ Std. dev.)	Range of rock density measurements (g/cm^3)
Qs	Quaternary Alluvium	2.04 – 2.16	Geologically reasonable
QTs	Quaternary – Tertiary Sediments	2.13 – 2.29	Geologically reasonable
Tvs	Tertiary Volcanics	2.30 – 2.48	2.28 – 2.54
Mzu	Mesozoic Basement	2.63 – 2.75	2.68 – 2.70

3D Geologic Framework is quantitatively consistent with the gravity data

Caveat: non-uniqueness in geophysical model results

Example of Non-Uniqueness



3D gravity inversion modelling performed SIMPEG and Rhino3D

Conclusions

- Gravity & magnetic map-based interpretation
  → Useful to identify faults & geologic contacts

- 2D gravity/magnetic profile modelling
  → Aids construction of 3D geologic framework

- 3D gravity inversion modelling
  → Useful to test and refine 3D geologic framework