



MEMORANDUM

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CC:	Dr John Bishop, Technical Director, Solution Energy Pty Ltd
FROM:	Nick Direen, Principal Consulting Geoscientist & Fionnuala Campbell, Project Geophysicist, Mitre Geophysics
DATE:	3/07/2025
SUBJECT:	Delineation of Tabberabberan granitoids in eastern Tasmania from gravity inversions.

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1 EXECUTIVE SUMMARY

Gravity inversion studies of isostatic residual Bouguer anomalies in northeast Tasmania challenge the long-standing assumption of a major north–south Devonian granite batholith contact. Previous interpretations relied on subjective, model–driven residual gravity anomaly analyses, which risked circular reasoning. Both unconstrained and constrained inversions, using grid and point data, consistently refute the presence of such a contact, with variations in results primarily attributed to noise in gravity sampling rather than geological differences.

Five low–density bodies in the Lemont area, tentatively identified as deformed granites ("Campbell Town," "Blackman River," "Macquarie River", and "Snaky Creek" granites), are interpreted as east–dipping sheets involved in Tabberabberan Orogeny thrusting, likely intruded between 405–390 Ma as unfractionated or weakly fractionated I–type granites. In contrast, the highly fractionated Royal George and Henbury granites form a significant low–density pluton northeast of Campbell Town. These findings question the role of heat–producing granites in the observed geothermal anomalies in the Lemont area (Holgate, 2013). Further 2.5D modeling of the "Blackman River granite" is recommended to refine these interpretations.



2 INTRODUCTION

In the original conception of Lewis (2005), high heat producing Devonian – Carboniferous granites were 80% likely to be involved in producing anomalously high heat flows in eastern Tasmania (his scenarios A–D) (Figure 1). In 2005, the understanding of the subsurface distribution of these granitoid bodies was based on the work of Leaman and Richardson (2003), which was heavily dependent on 2.5D modelling of gravity data to indicate the locations of granite in the middle crust. Although this 2003 work was considered “provisional” and a “work in progress”, and was subjected to further updates (Leaman, 2007, 2010, 2012), one element of the 2003 interpretation that did not change was the interpretation of a major granitoid batholith trending N–S through the eastern third of Tasmania. The western edge of this interpreted batholith body, colloquially known as the “granite wall”, was thought to follow the strong residual Bouguer gravity gradient in eastern Tasmania (Figure 2; Figure 3). However, in the north around the Tamar river region, the interpretation diverged from this concept, with Leaman and Richardson (2003) considering that some of the Devonian–Carboniferous granites had been caught up in west-directed Tabberabberan thrusting (Figure 3), and thus were not batholithic in form, a concept that had first been postulated by LeClerc (1996) for the Housetop Granite in central northern Tasmania.

Following the acquisition of a significant onshore seismic reflection dataset by Great Southland Minerals / Empire Energy (Bendall et al., 2015), Leaman (2012) radically revised his interpretation of the subsurface granites, suggesting in fact that many of them were detached by thrusting at quite shallow depths (2–6 km).

With subsequent revisions of the geology of the Tasmanian granites including their age relationships and tectonic setting relative to the Tabberabberan Orogeny (e.g. Hong et al. (2017); McClenaghan (2014); Seymour et al. (2014)), the need to test the hypothesis of a major longitudinal granitoid batholith in eastern Tasmania has increased, especially as it impinges on the likelihood (or otherwise) of a heat producing granite contribution to the 118 mW.m⁻² geothermal anomaly at Lemont in southeastern Tasmania (Holgate, 2013).

The report below outlines some tests of the hypothesis of a longitudinal “granite wall” in southeastern Tasmania passing near Lemont, using unconstrained and constrained gravity inversions.

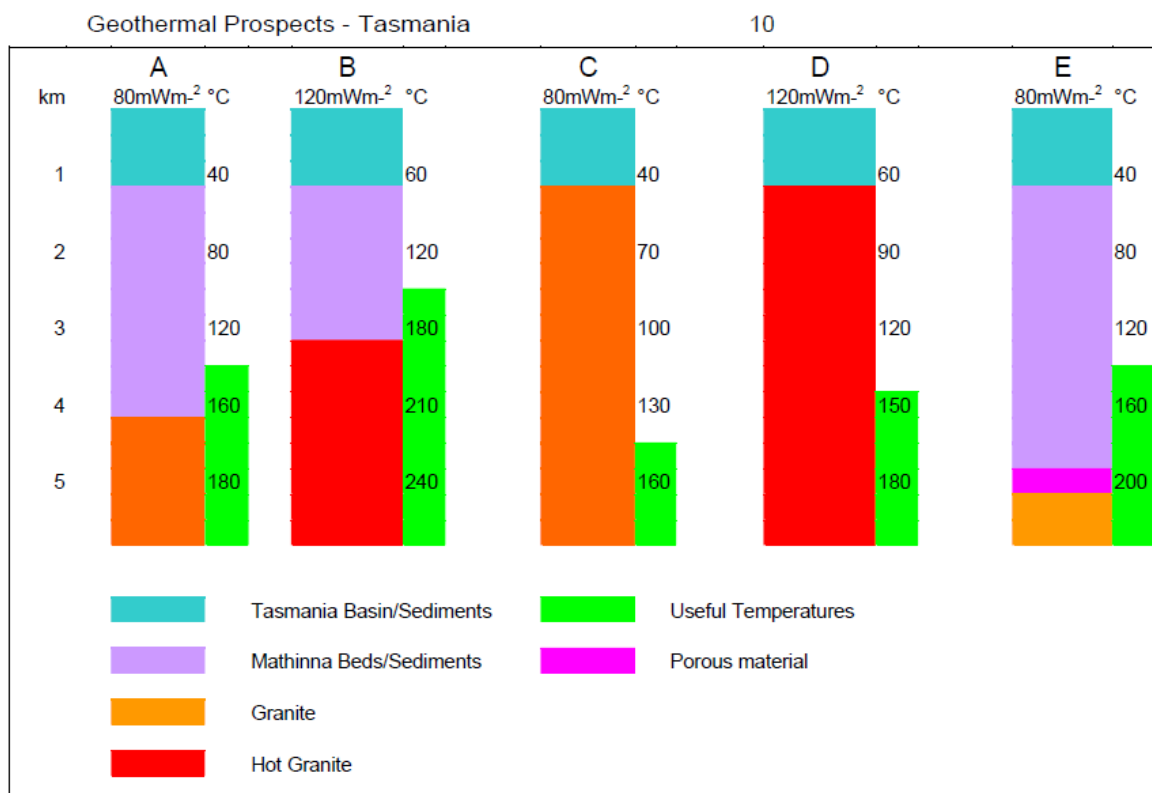


Figure 1: Scenarios for generation of anomalous geothermal gradients in eastern Tasmania (Lewis, 2005).

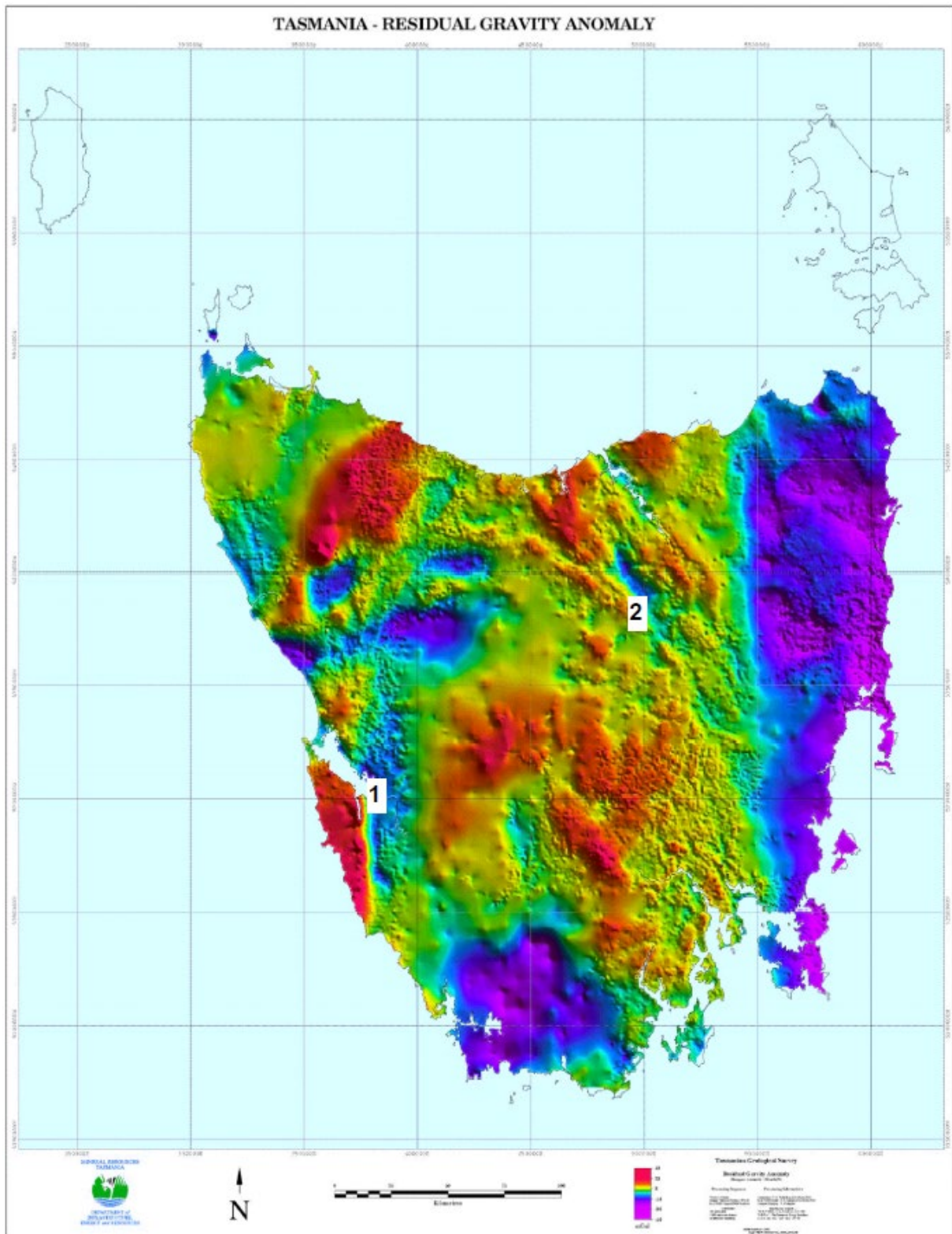


Figure 2: Residual Bouguer Gravity map of Tasmania from Lewis (2005). 1 & 2, mark the Bouguer Anomaly lows associated with the Tertiary Macquarie Harbour and Longford grabens, whereas the remainder of the Bouguer Anomaly gravity lows in blue–purple were interpreted as due solely to Devonian–Carboniferous granitoids





3 REGIONAL GRAVITY INVERSION

3.1 UNCONSTRAINED MODEL INVERSION

Given the necessity of testing for the presence of subsurface granitoid bodies in the area of interest, and the established knowledge that these granites have an average density of 2.60–2.62 g/cc relative to the crustal density of 2.67 g/cc (Leaman, 2012), gravity inversion (the recovery of subsurface density distributions directly from gravity data (Oldenburg and Pratt, 2007)) is a viable technique to approach the problem.

The software package MGINV3d (Paine, 2002) was used to create all of the inversions discussed below. The code is an instance of the UBC–GIF gravity inversion scheme created by Li and Oldenburg (1998). These schemes use a depth weighting function $w(z)$ of the form

$$w(z) = \frac{1}{(z + z_0)^{\beta/2}}$$

where the value β is normally set to between 1.5 to 2, and z_0 is a function of the mesh size and observation height of the data, and measured in metres (Li and Oldenburg, 1998). This prevents the inversion from putting all the anomalous density at the topographic surface.

The data used for the initial regional scale inversion herein was the Complete Spherical Cap Bouguer Anomaly reduced to 2.67 g/cc obtained from Mineral Resources Tasmania. These data have been terrain corrected using a digital elevation model out to a distance of 166.7 km from each station, and then isostatically corrected for Moho effects (Duffett, 2016). This differs from previous approaches such as those of Leaman and Richardson (1989); and Roach et al. (1993), who used long wavelength geological models of the Tasmanian gravity field to remove the Moho effect. Note that this means the results from the work of Leaman (2012) and this study may differ due to these differences in the overall long wavelength component of the regional field.

The gravity data were clipped to the AOI (Figure 4).

The topographic surface used as the upper bound of the inversion mesh was the Shuttle Radar Topography Mission (SRTM) 30 m topographic grid (Geoscience Australia, 2009), also clipped to the AOI polygon (Figure 5).

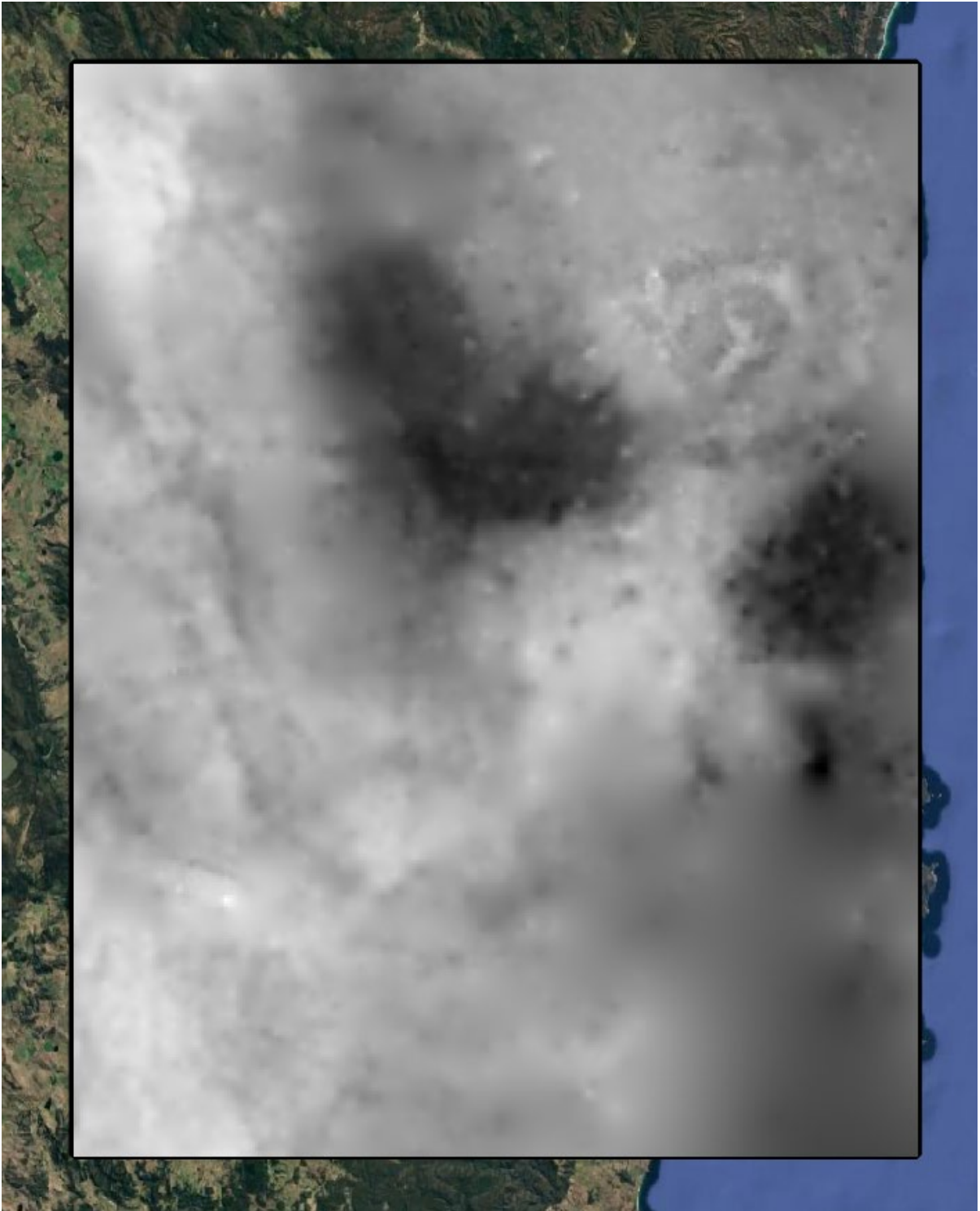


Figure 4: Clipped isostatic CSCBA 2.67 g/cc data used for the regional inversion

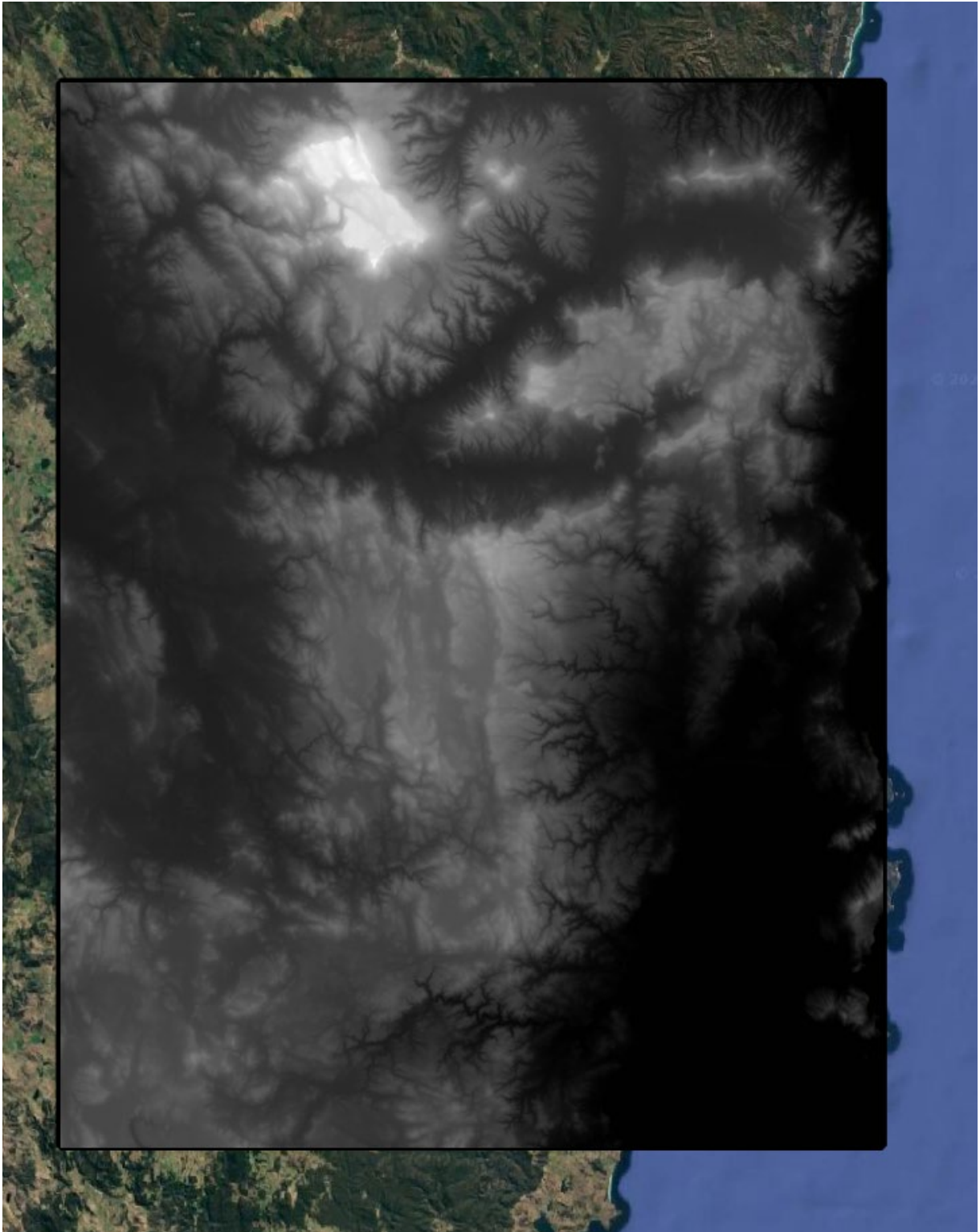


Figure 5: SRTM topographic grid for the AOI

3.1.1 PARAMETERS

The initial model was run on the gravity grid (as opposed to the point data) for a maximum 250 iterations using a 1km x 1km x 500m mesh down to a depth of 10km. The calculation level was set at 0.5m above the SRTM topographic surface. Positivity of the resulting cells was set to unconstrained, meaning that cells could be solved with a positive or negative density contrast. The depth weighting parameter β was set to 1.8, and the z_0 value at 0. The misfit tolerance of the objective function was set at 0.02 mGal, which approximates the noise level in the



data in areas of subdued topography, although this may be overfitting in areas of topography where height and terrain errors may be ≥ 0.05 mGal (Duffett, 2016).

3.1.2 RESULTS

This model ran to 250 iterations and produced a result. However, the errors between the inverted field of the model and the observed data were significantly patchy (Figure 6), reflecting the highly irregular station distribution in the grid (Figure 7).

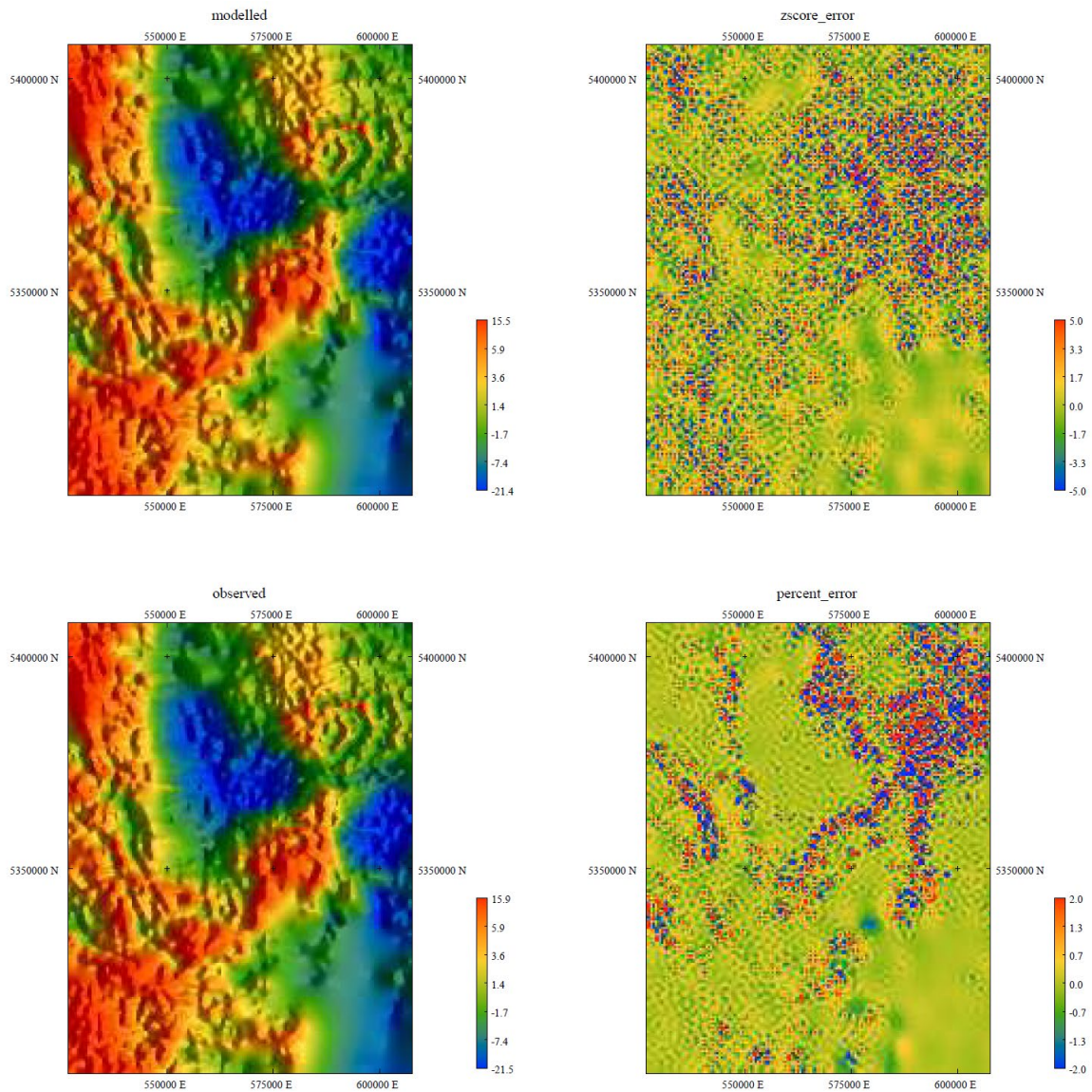


Figure 6: Error Plot, initial regional unconstrained inversion. TL: modelled field of the inversion result. BL: observed CSCBA dataset. TR Z score error scaled $-5 - +5$. BR Percent error difference scaled from $+2\%$ to -2% .

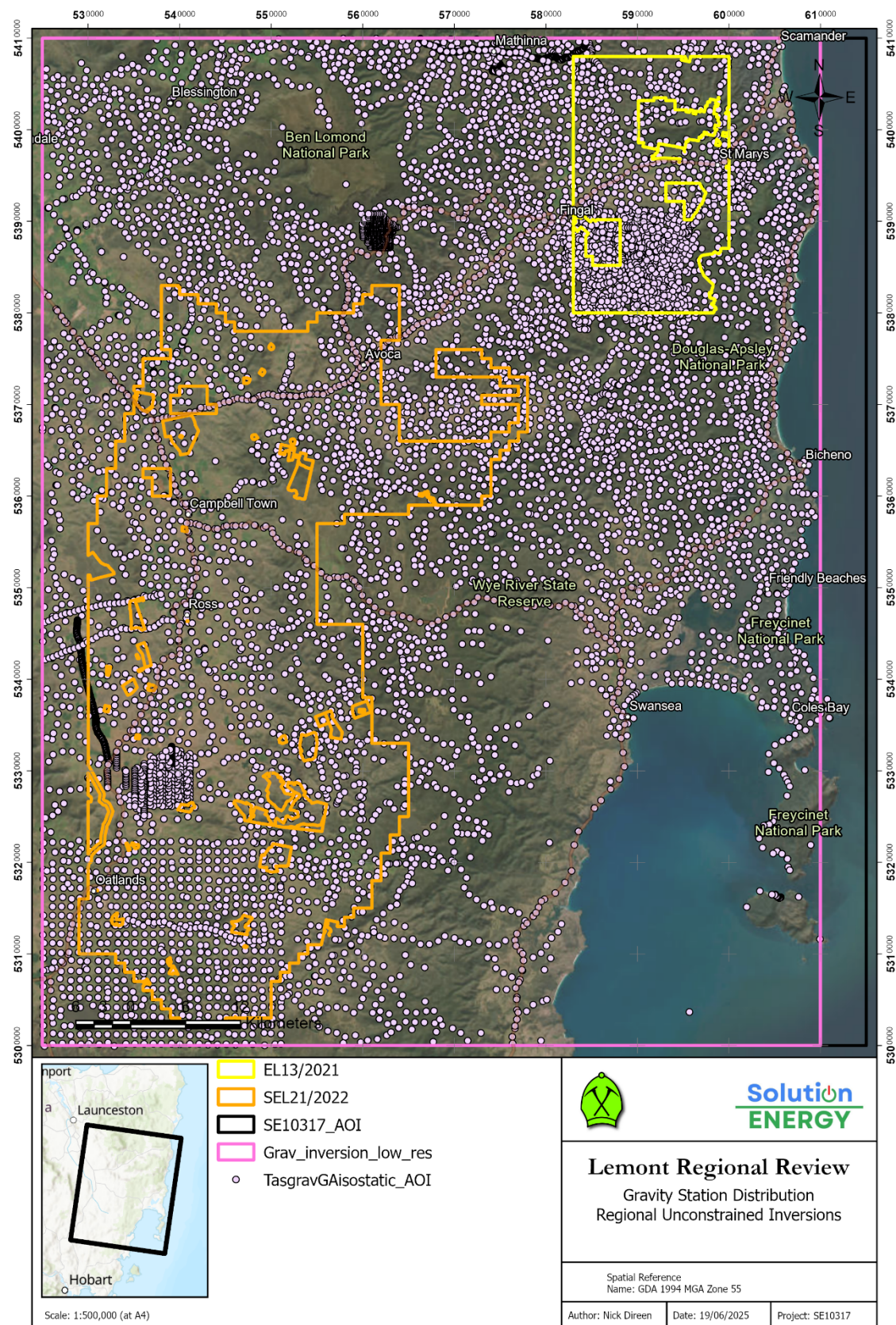


Figure 7: Gravity station distribution



Because of the patchiness of the result, we determined to run a second model using an upward continuation of the isostatically corrected CSCBA grid as the input; upward continuation acts as a low pass filter (Jacobsen, 1987), thus removing high spatial frequency noise due to gradients between stations of different vintages as well as surficial and incompletely terrain corrected responses (cf. Direen (2001); Duffett (2016)), and retaining more of the longer wavelength field response due to the deeper granite bodies.

3.1.3 ITERATION 2: 1KM UPWARD CONTINUED GRID

In this inversion, the observed data inverted was the isostatic CSCBA 2.67 grid, upward continued grid to 1km above its previous level. All other parameters were unchanged from the initial inversion.

3.1.4 RESULTS

This attempt produced a similar result to the initial model, but with less noise. This was deemed an acceptable result, and used for further analysis.

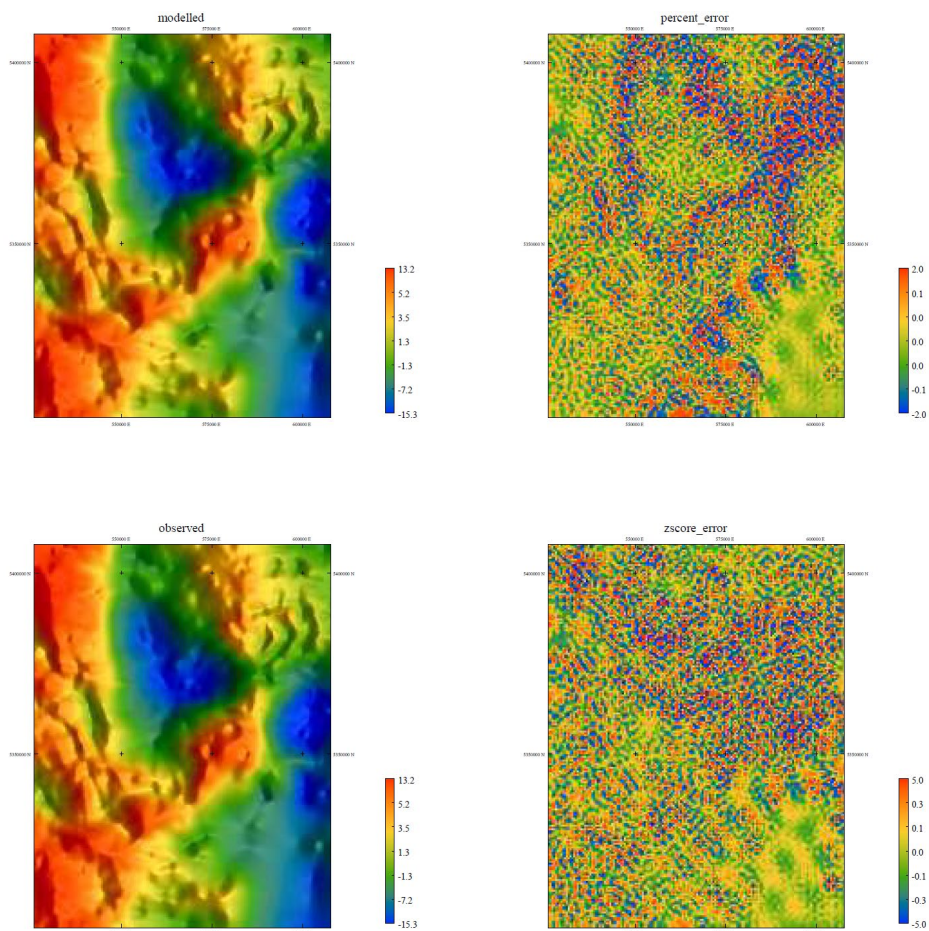


Figure 8: Error Plot, regional unconstrained inversion using upward continued 1km CSCBA 2.67 g/cc gravity grid. TL: modelled field of the inversion result. BL: observed CSCBA dataset. TR Z score error scaled $-5 - +5$. BR Percent error difference scaled from $+2\%$ to -2% .

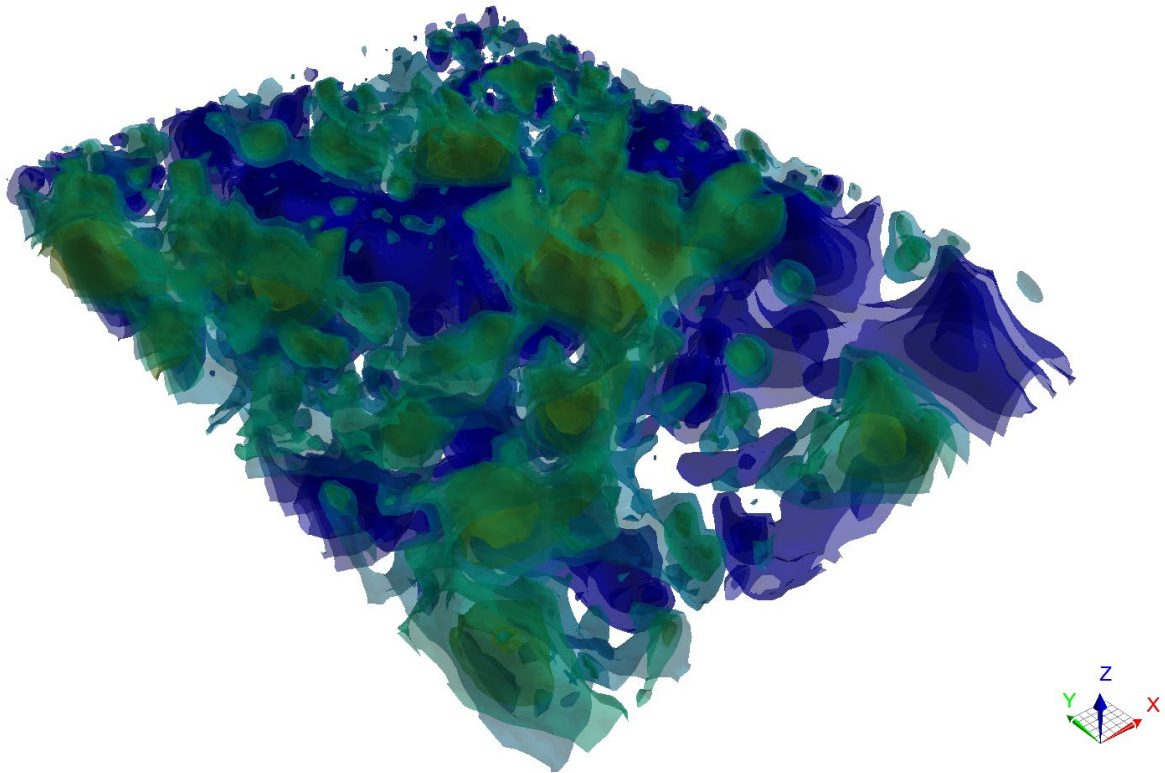


Figure 9: Positive and negative isosurfaces for the 1 km upward continued inversion model. Oblique view looking towards the northeast.

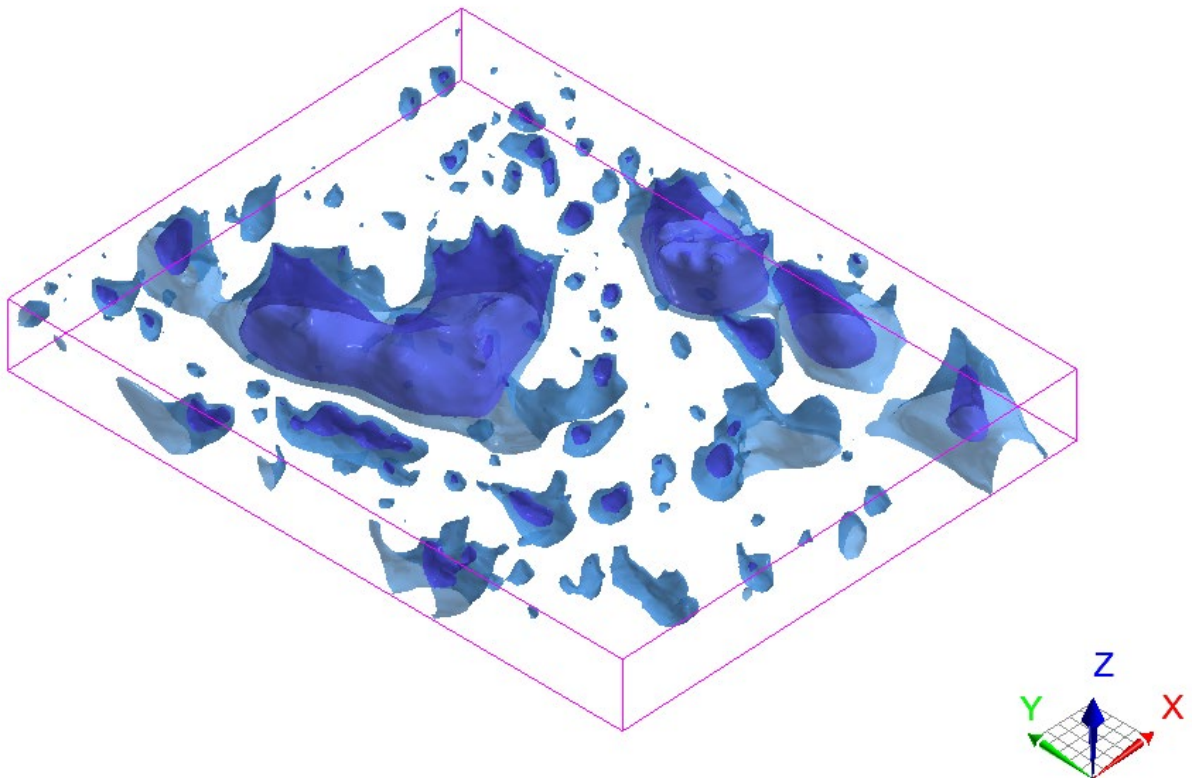


Figure 10: Negative (-0.02 and -0.04 g/cc contrast) isosurfaces, reflecting densities of 2.65 to 2.63 g/cc in the crust that are likely to correspond to granitoids. Oblique view looking towards the northeast.

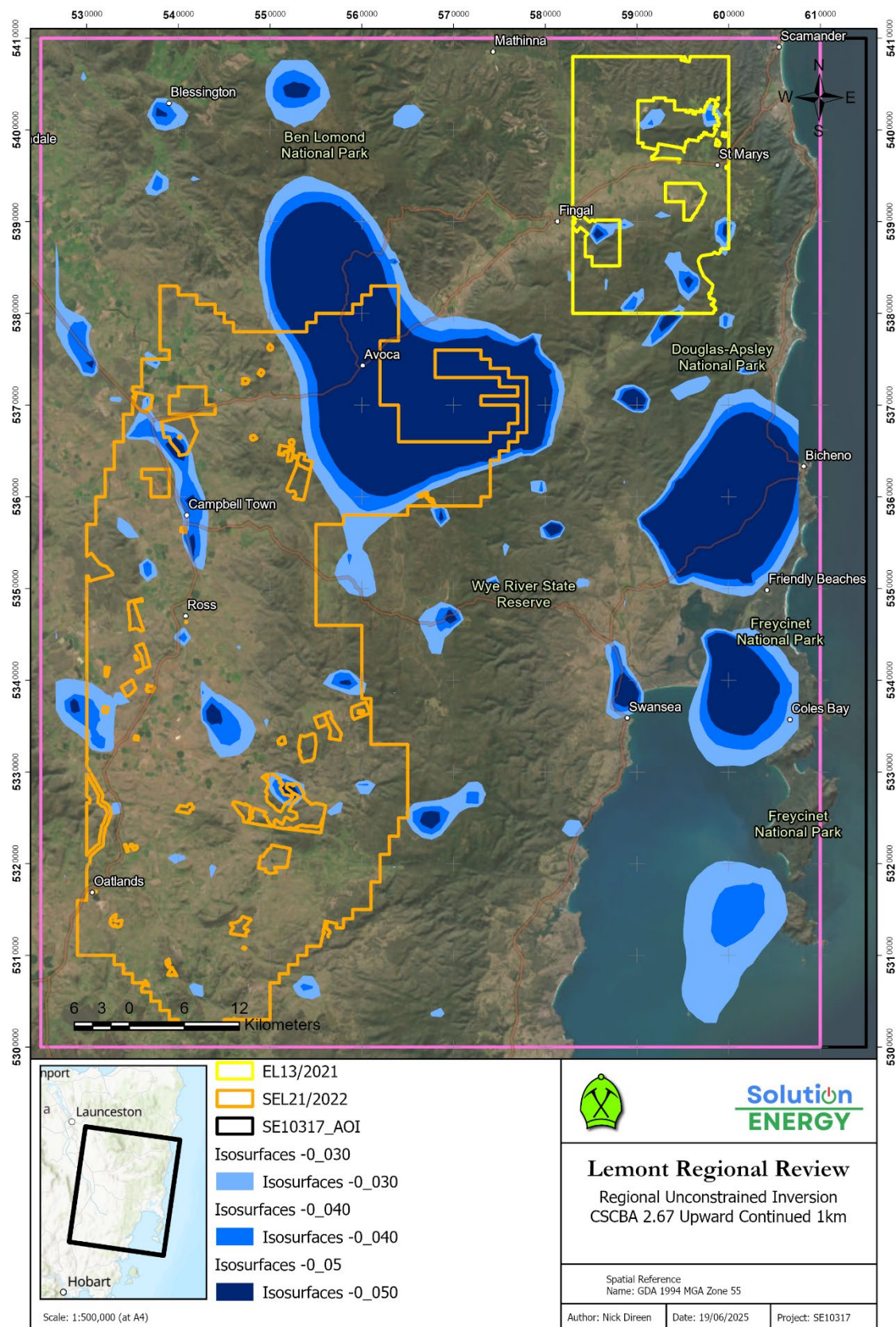


Figure 11: Plan view, unconstrained inversion results, -0.03 , -0.04 and -0.05 g/cc contrast isoshells, corresponding to densities of 2.64–2.62 g/cc, and likely to be granitoids.



What is immediately obvious from the inversion results in Figs. 9–11 is that the granite “wall” of Leaman (cf. Fig 3), is not reproduced by the inversion process.

Comparing the results to geological mapping (Forsyth et al., 2024; McClenaghan et al., 2011), significant plutons appear to be associated with known granites such as the southern end of the Ben Lomond Batholith, the Royal George granite near Avoca, the Bicheno, Coles Bay, and The Hazards granites, and the Schouten Island granite. Interestingly, the Freycinet Granite does not appear to create a large subsurface body, but this may be due to the very poor distribution of gravity stations in this part of the map, essentially restricted to a coastal strip on the western side of the Freycinet Peninsula.

In place of the granite “wall”, most model results south and west of the Royal George Granite that have negative density contrast, are small ($<10 \times 5$ km), ellipsoidal features, several of which have NNW–trending strikes of their long axes.

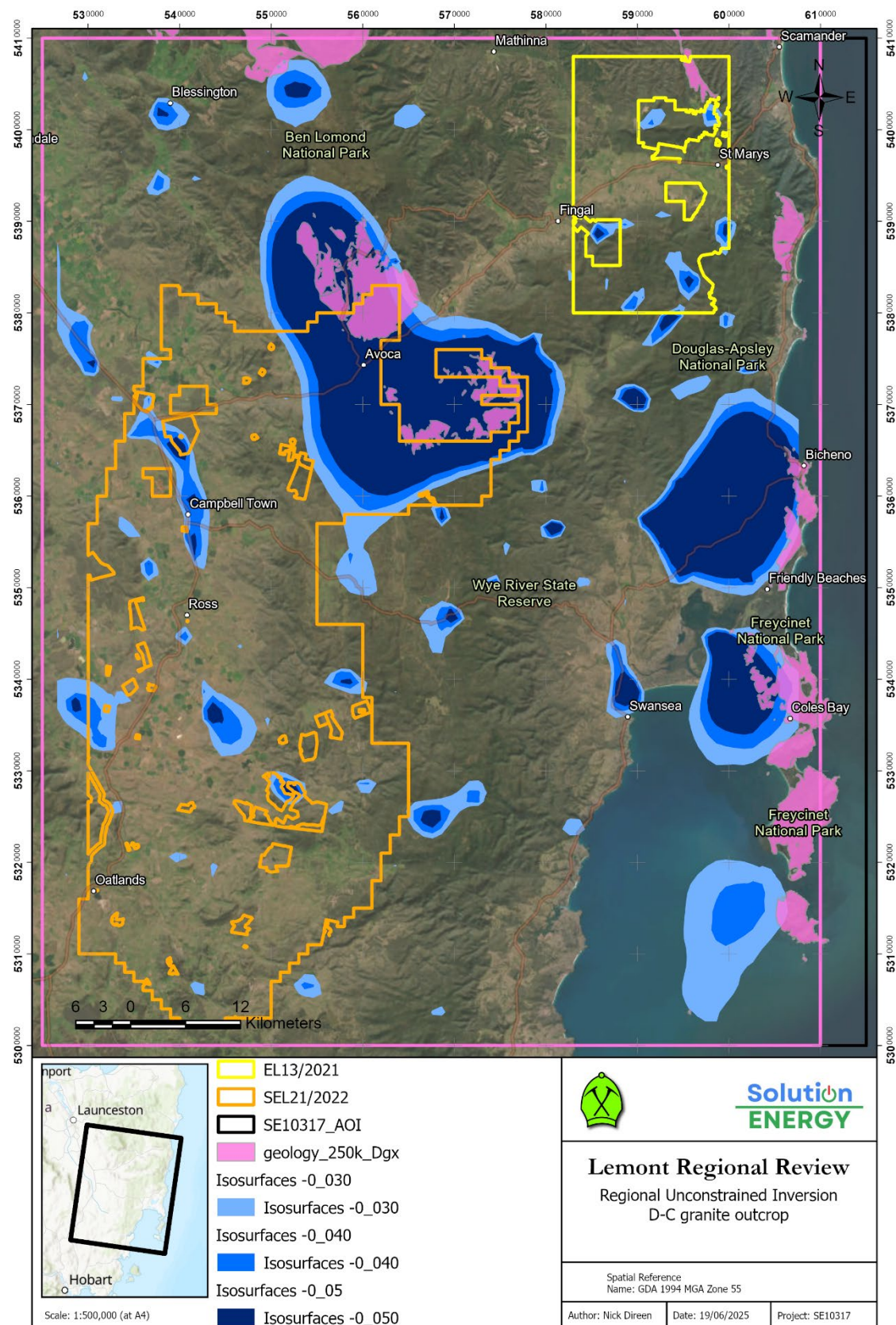


Figure 12: Unconstrained regional inversion result compared to mapped Devonian–Carboniferous granite outcrop (Forsyth et al., 2024; McClenaghan et al., 2011)



3.2 GRANITE OUTCROP CONSTRAINED INVERSION

An attempt was also made to improve the inversion by constraining it to honour outcropping granites.

A polygon layer was created from the MRT digital geology of Tasmania, selecting only the mapped areas of Devonian–Carboniferous granitoids (granites, granodiorites, adamellites, porphyrite) within the AOI (Figure 13). This was merged with the SRTM topographic surface to create a surface granite layer. Cells below the granite were continued to a depth of 200m below the surface to give a sufficient vertical extent, and then merged into the starting inversion mesh.

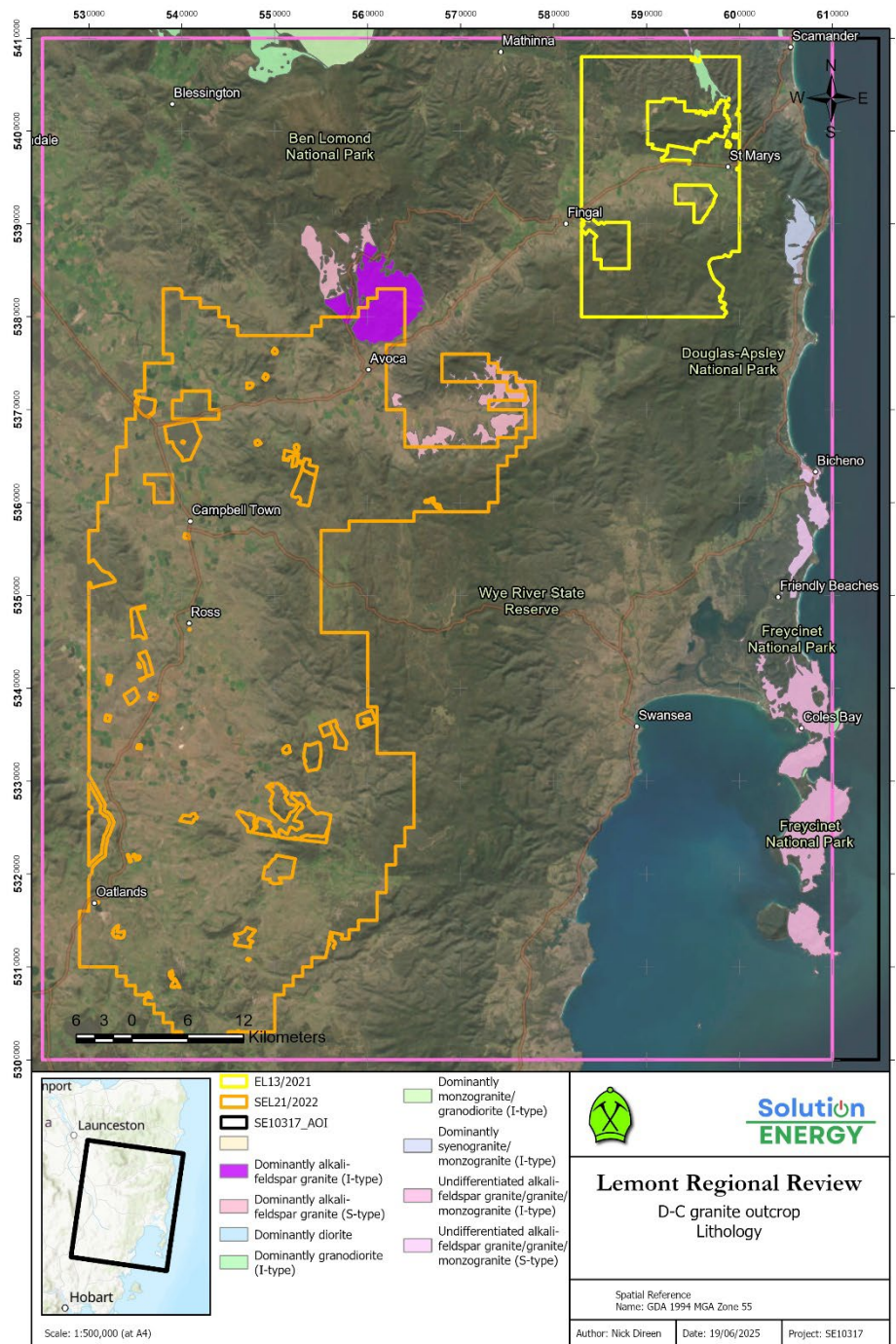


Figure 13: Granite polygons within the AOI, extracted from the geology.

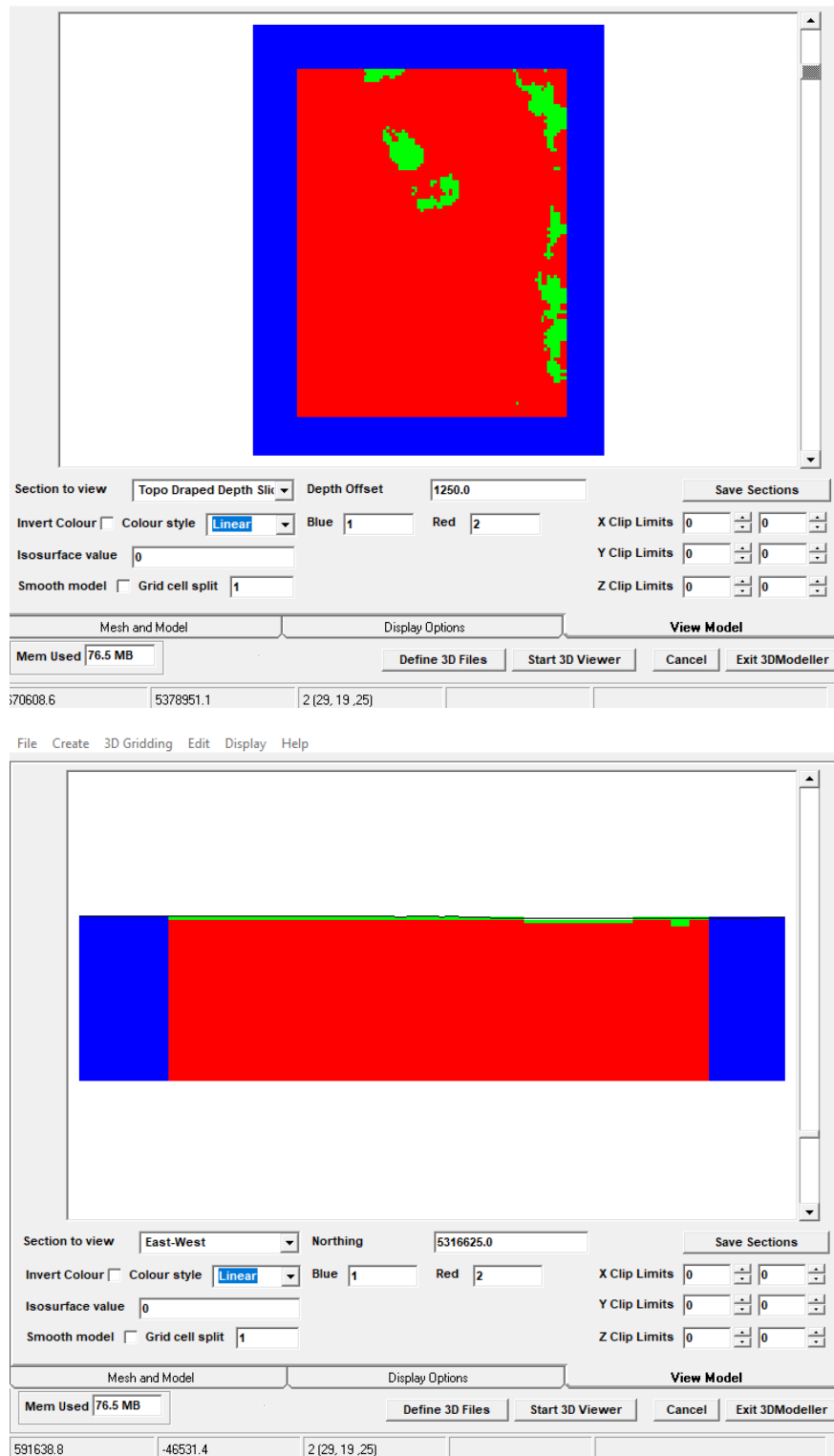


Figure 14: Realisation of the granite outcrop constraint on the inversion starting mesh, in plan view (top) and E-W section (below).

A bounds model was then created from this mesh, with three classes of cells:

Class 1 (padding – blue in the mesh above) had constrained values of –9999 9999

Class 2 (all non–granitic cells: red in the mesh above) had non–constrained values of –9999 9999, i.e. free to vary in the version to any value.

Class 3 (granites – green in the mesh above) had constrained values from –0.07 to –0.05 i.e. starting densities of 2.60 – 2.62 g/cc.



All other parameters were left the same as the unconstrained model.

3.2.1 RESULTS

The unconstrained and the constrained inversion results matched each other very closely (Figure 15), indicating that constraining the model to outcrop did not generate either new / unexpected results, nor any major improvements. If anything, errors in the constrained model are higher (Figure 16), perhaps because the blocky nature of the constraint prevents the model from smoothly varying to fit the field more accurately.

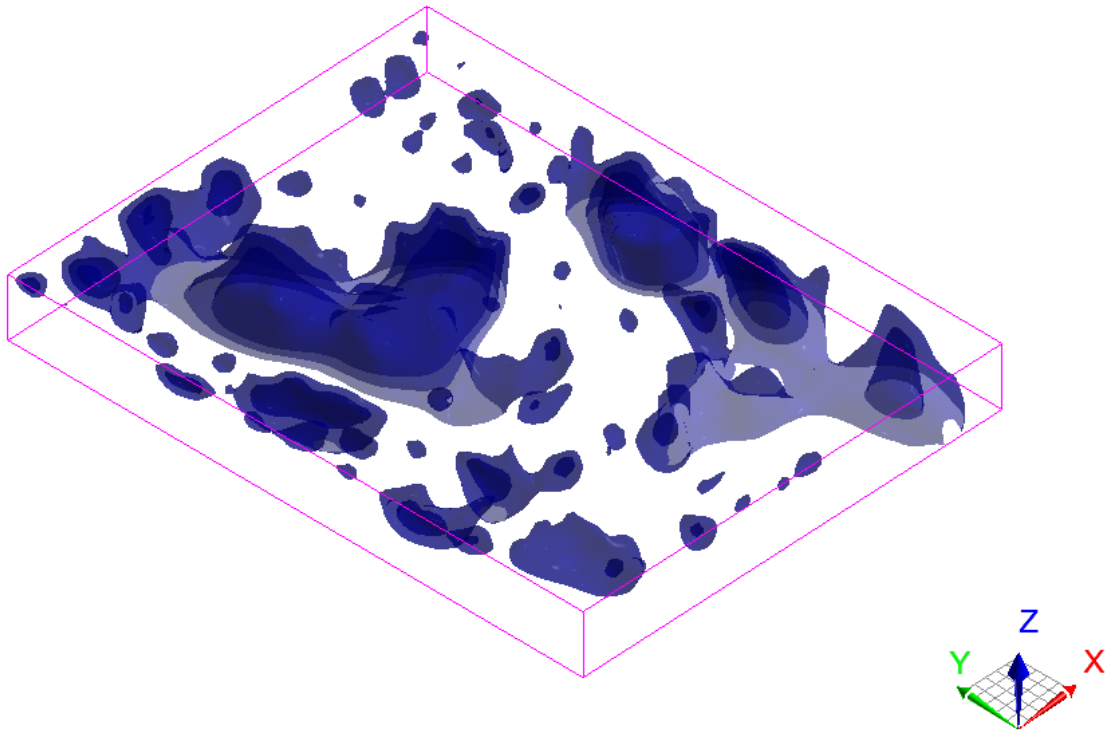


Figure 15: Outcrop constrained inversion result, negative isosurfaces (-0.02 , -0.04 and -0.06 g/cc)

One interesting feature of this result is that several bodies including the Russells Road Granite/ Granodiorite, Upper Blessington Granodiorite, Picaninny Creek Granodiorite, and the Scamander Tier Granodiorite do not produce any subsurface features in the inversion. It is inferred that this is because these granodiorites have much higher densities than the granites (2.69 – 2.71 g/cc) (Leaman, 2012), and thus do not produce an associated gravity low. This result validates the approach.

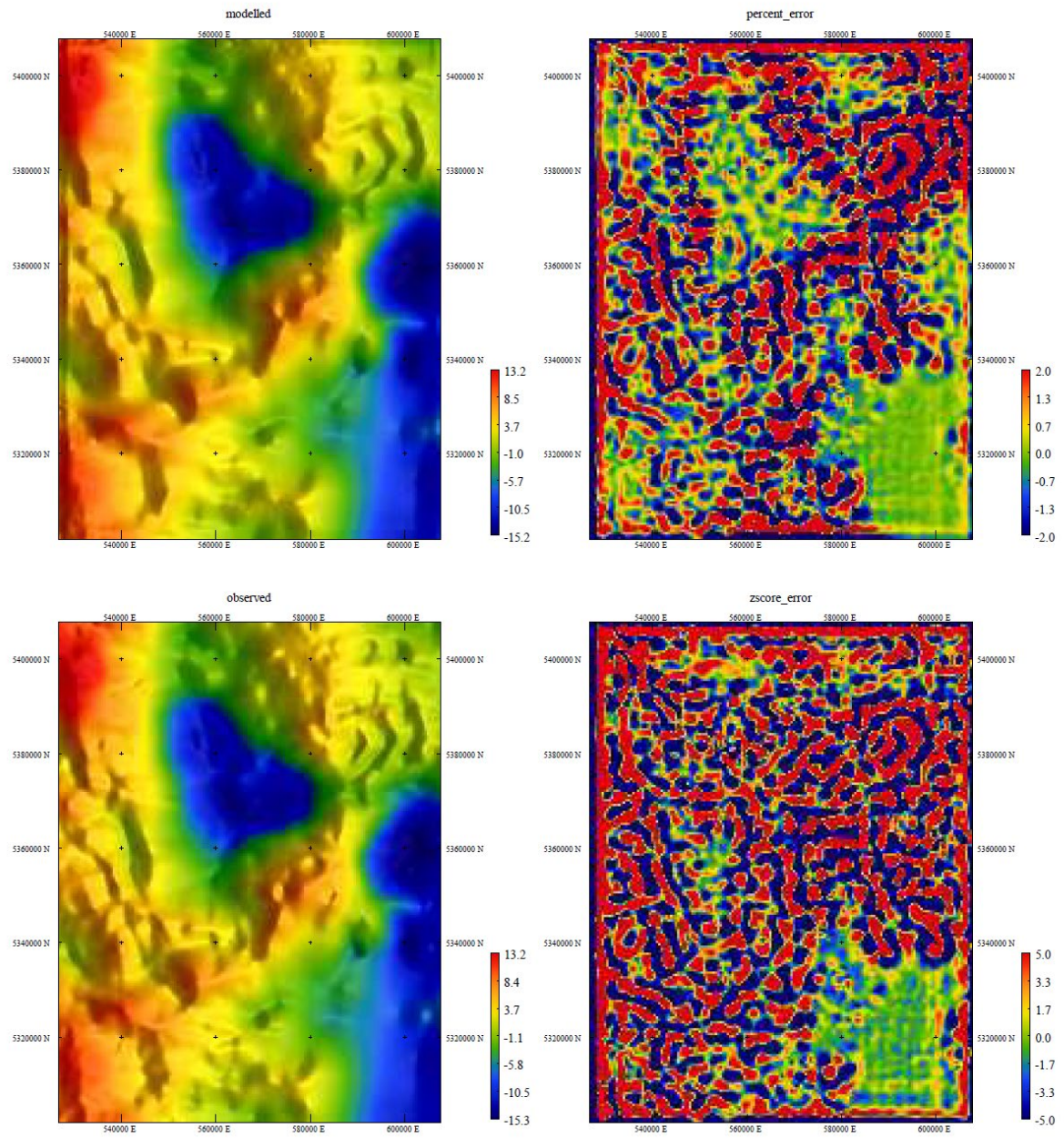


Figure 16: Error plot for granite outcrop constrained inversion. TL: modelled field of the inversion result. BL: observed CSCBA dataset. TR Z score error scaled $-5 - +5$. BR Percent error difference scaled from $+2\%$ to -2% .

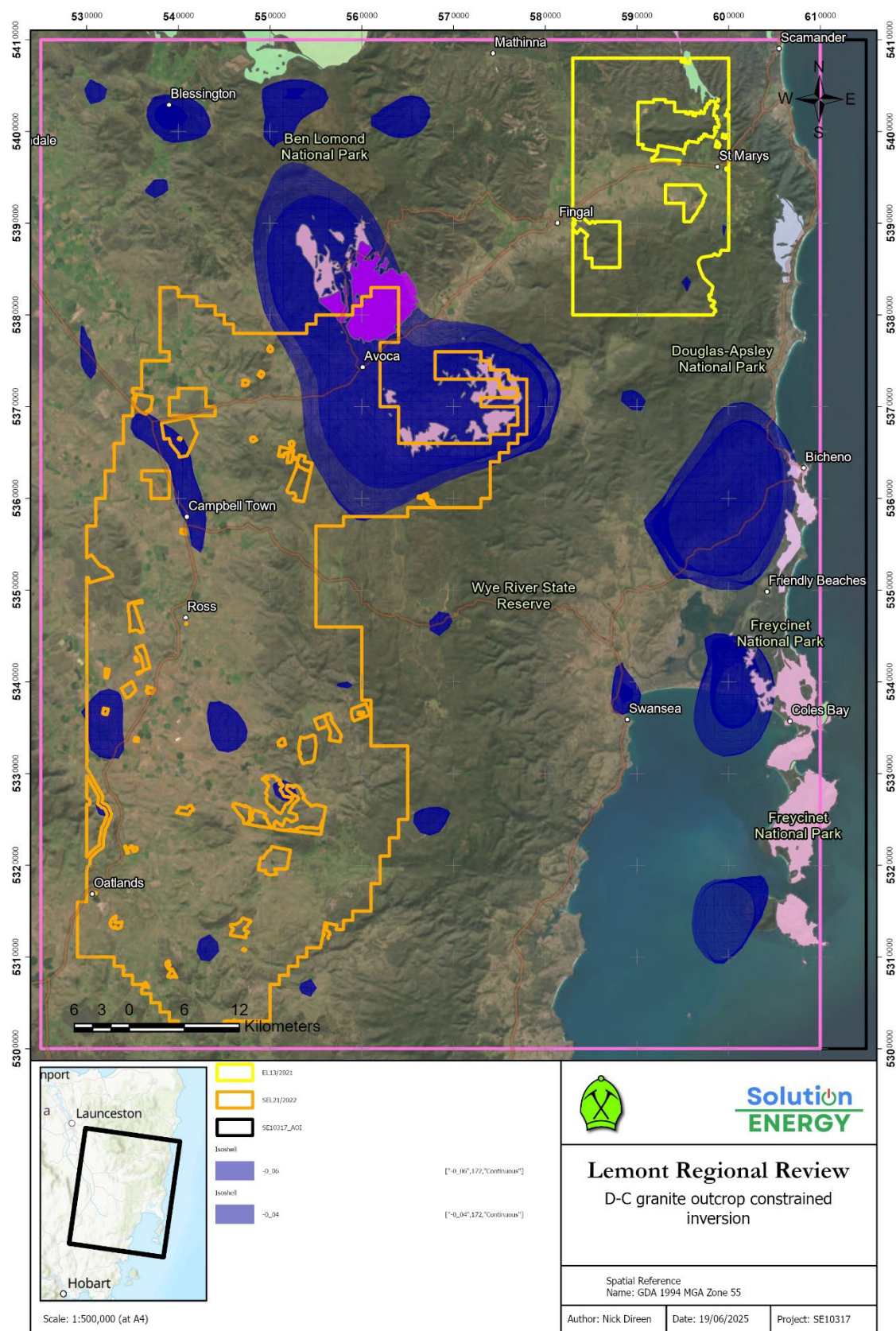


Figure 17: Results of outcrop constrained inversion in map view, with outcrop constraints shown. -0.04 and -0.06 g/cc contrast isoshells shown.



3. HIGH RESOLUTION MODEL AT LEMONT

Solution Energy also requested Mitre construct a more detailed inversion model in the Lemont area, in the SW corner of the broader AOI. This area is shown in the map below, along with the gravity station distribution therein, and the seismic line that crosses into the area (see also Mitre's earlier report (Direen, 2025) for details on the seismic reinterpretation and structure).

In this area where a denser coverage of gravity stations has been observed, we created inversions using both the grid and the point data.

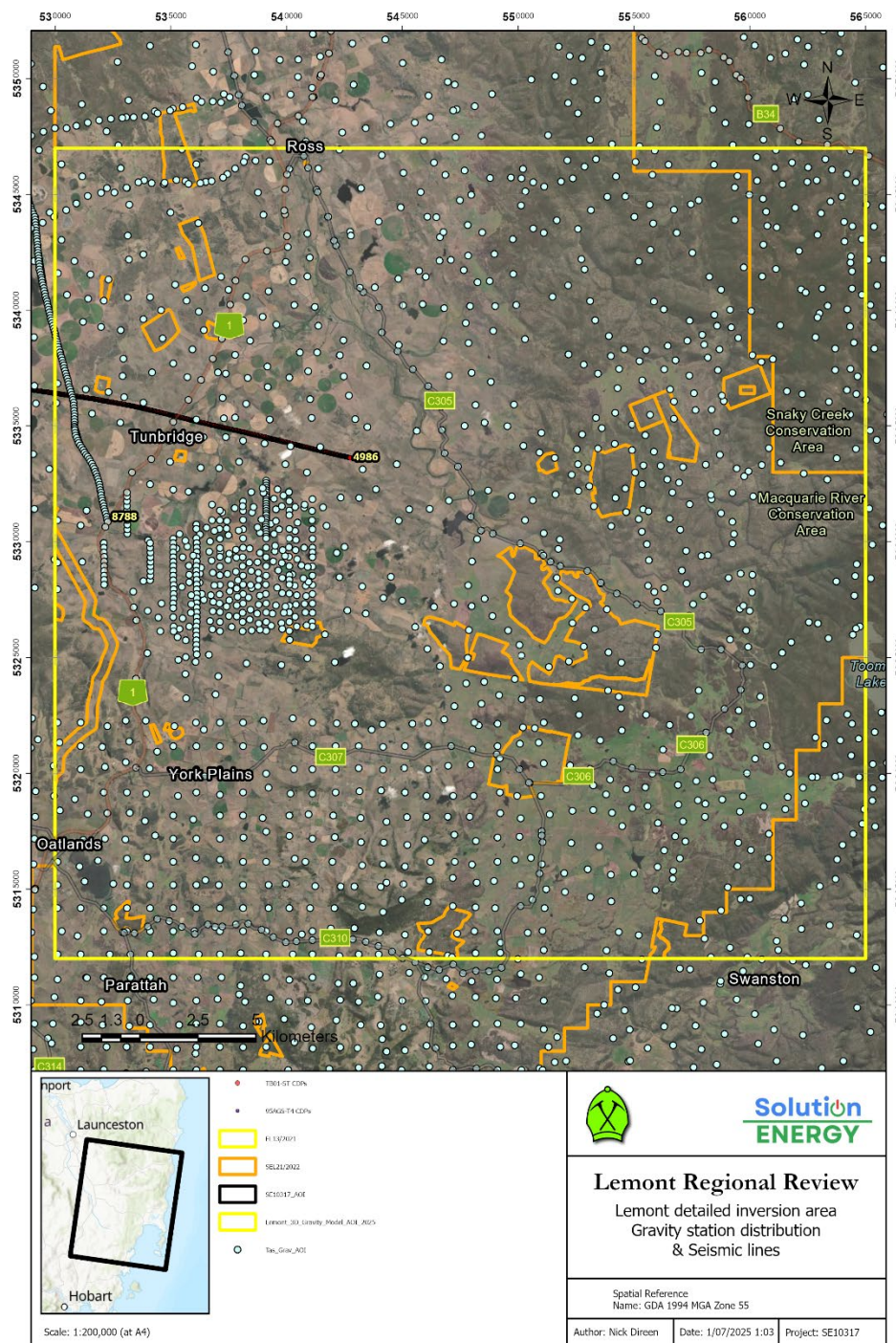


Figure 18: Lemont detailed inversion are with gravity station distribution



3.1 GRAVITY GRID INVERSION

The input dataset used was the same isostatically corrected Complete Spherical Cap Bouguer Anomaly reduced to 2.67 g/cc, obtained from Mineral Resources Tasmania, described earlier. This was gridded to a 250m cell size, which was then smoothed using a 2 cell (500m) convolution averaging filter.

3.2.2 PARAMETERS

The following parameters were used in the inversion of the grid:

- 350m x 350m x 175m mesh in X, Y and Z
- Depth extent of 10km
- Stations located 0.5m above the SRTM topographic surface, clipped to the new area
- 200 iterations
- $\beta = 2$, $z_0 = 0$ were used in the depth weighting function
- Unconstrained positivity for the density contrast

3.2.3 RESULTS

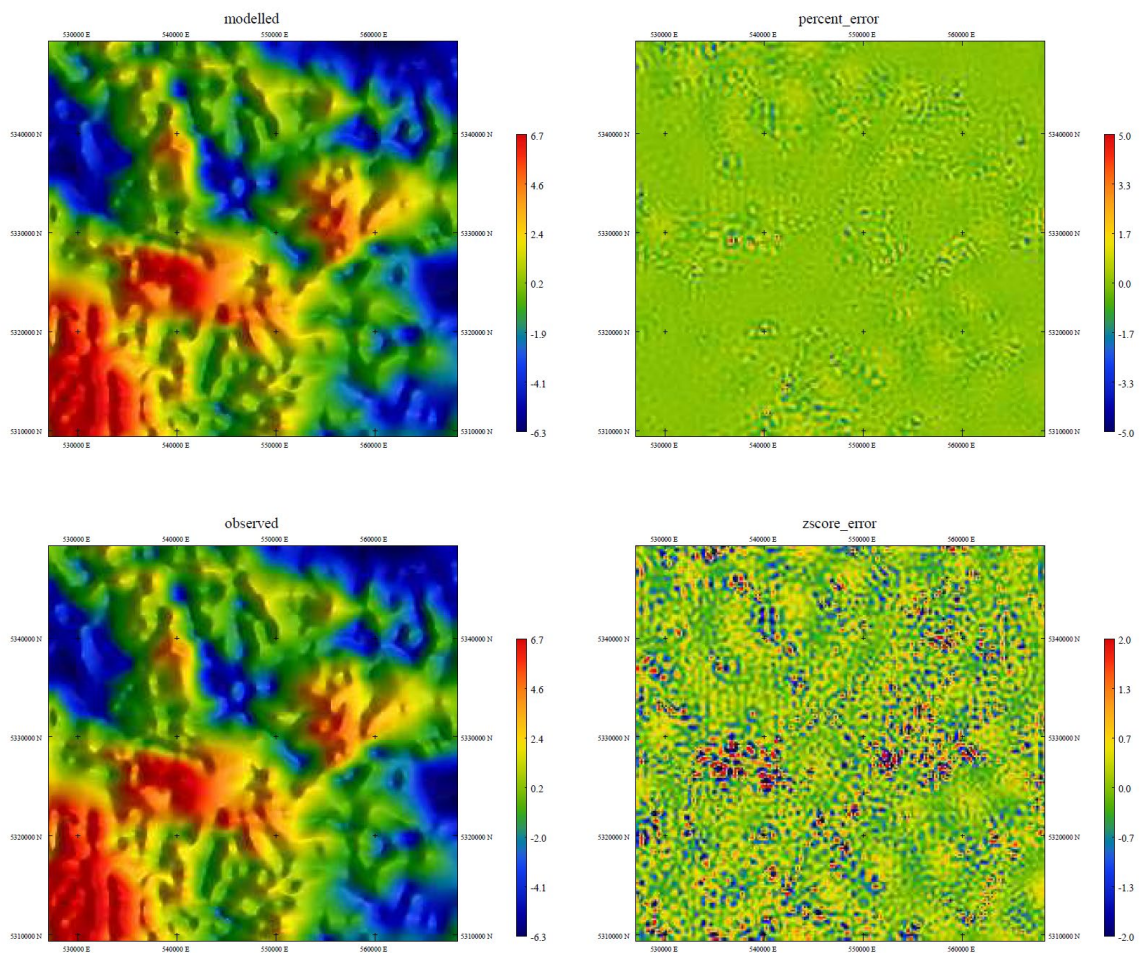


Figure 19: Error Plot, Lemont unconstrained inversion CSCBA 2.67 g/cc gravity grid. TL: modelled field of the inversion result. BL: observed CSCBA dataset. TR Z score error scaled $-5 - +5$. BR Percent error difference scaled from $+2\% - -2\%$.

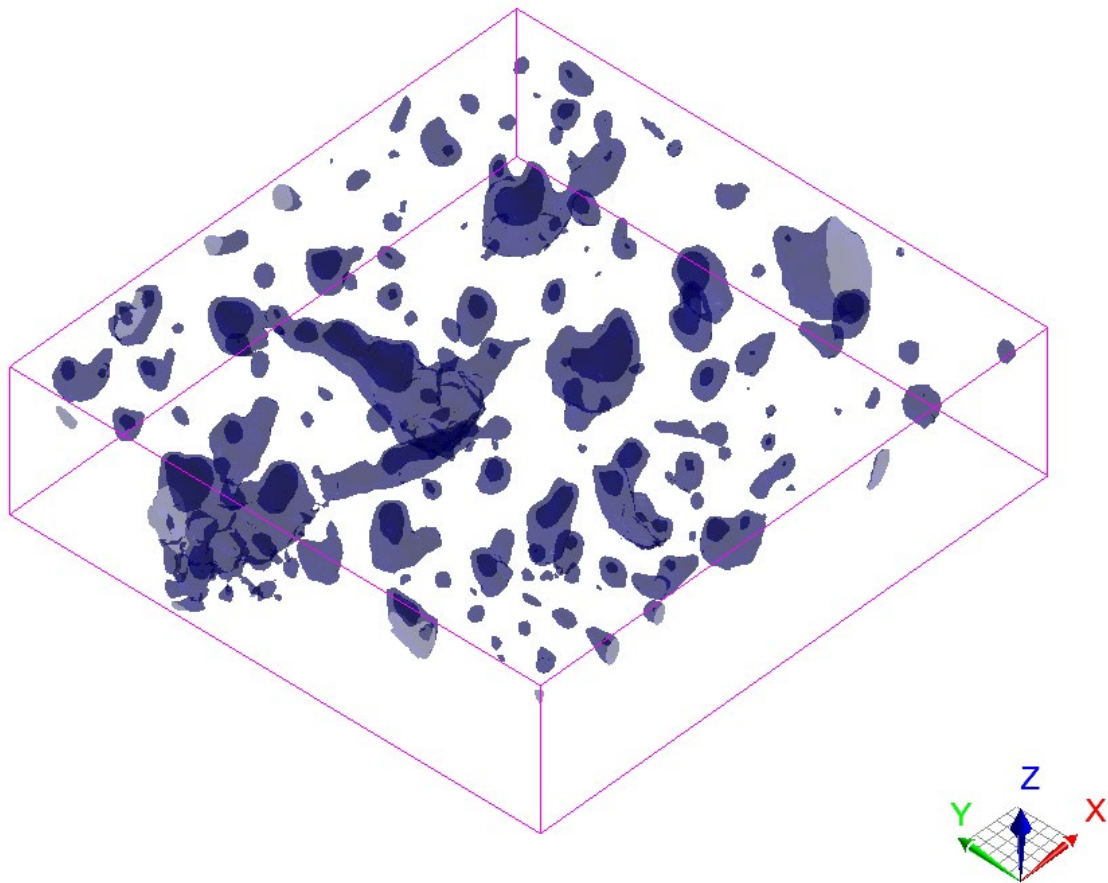
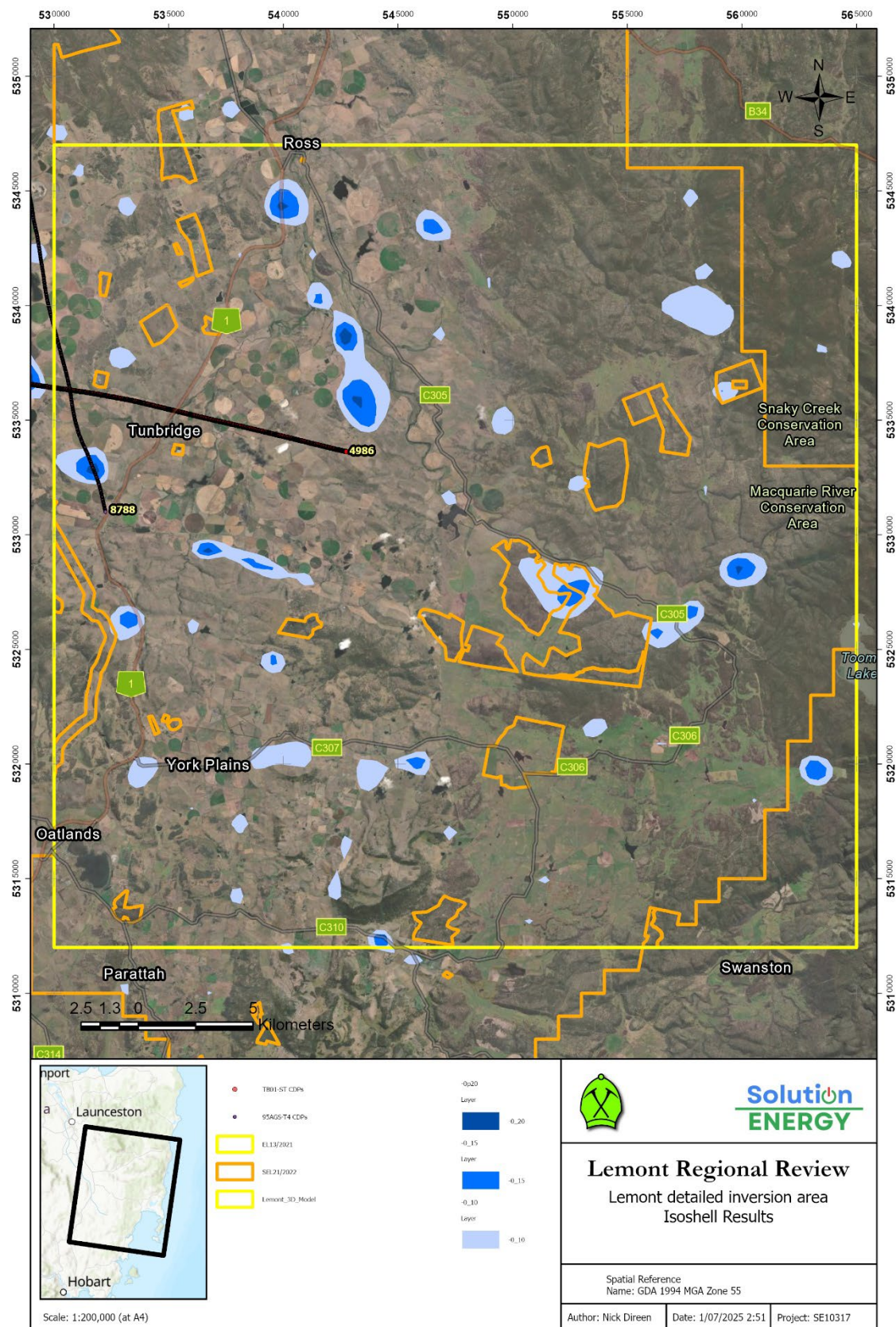


Figure 20: Isosurfaces -0.05 and -0.10 g/cc, corresponding to densities of 2.62 and 2.57 g/cc



Again, no significant plutonic bodies of granite are required by the inversion to fit the denser gravity coverage in the Lemont area. About 10 ellipsoidal bodies larger than 1km in dimension have been created, and the majority



of these are elongated in the NW or WNW direction, which aligns with the Devonian structural fabric (see Direen, 2025). The larger features in the local grid inversion align with the previously delineated “Blackman River granite”, “Macquarie River granites” with another feature to the northeast, which will be informally referred to as the “Snaky Creek granite”.

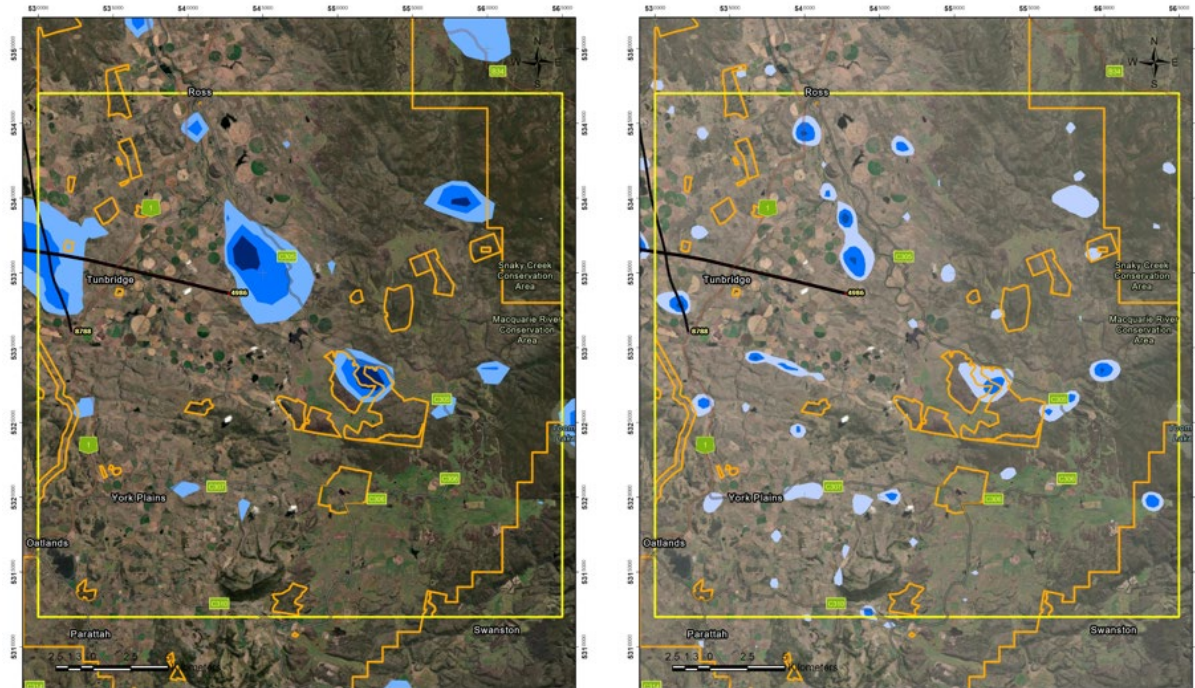


Figure 22: Comparison of regional unconstrained grid inversion isoshells (left) with detailed unconstrained grid inversion (right). The main anomalous low densities are reproduced in both inversions. Differences are due to mesh size relative to the more detailed gravity sampling in the local area, which has also led to more noise being fitted in the model at right.

3.1 POINT INVERSION

The following parameters were used for the point inversion, with the intention of determining whether inverting at the data points gave a better result than the grid inversion which by its nature is interpolative and therefore smoothed. The clipped database was imported and the values posted for the CSCBA isostatic data.

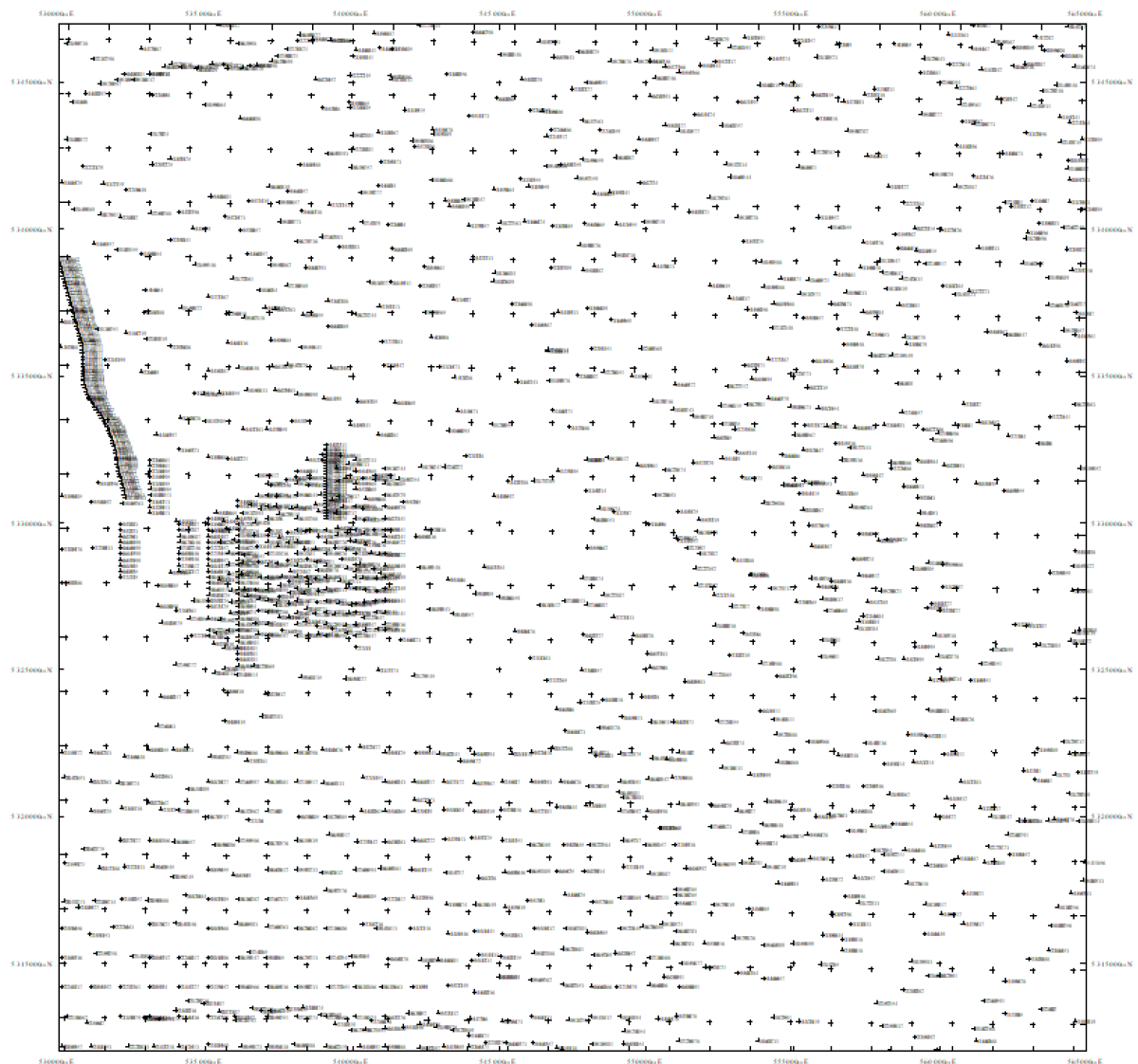


Figure 23: Stations used in the point inversion for Lemont

The following parameters were set for the model:

- Positivity unconstrained.
- $B = 1.8$, $z_0 = 0$.
- 350m x 350m x 175m mesh in X, Y and Z.
- 250 iterations.
- misfit error of 0.02 mGal.
- Stations located 0.5m above the SRTM topographic surface, clipped to the new area.

3.2.4 RESULTS

The result from the point inversion is a very geologically “noisy” model, with most detail in areas where there are more data points. The overall trends are similar to the Lemont detailed grid, but the product is less geologically interpretable, due to the prevalence of small, isolated features that may be associated with clusters of noisy gravity points. This is reflected in the error plots (Figure 25) which show strong noise and errors between groups of stations of different vintages and spacings. For this reason, no further analysis was undertaken on this model, and its use is not recommended.

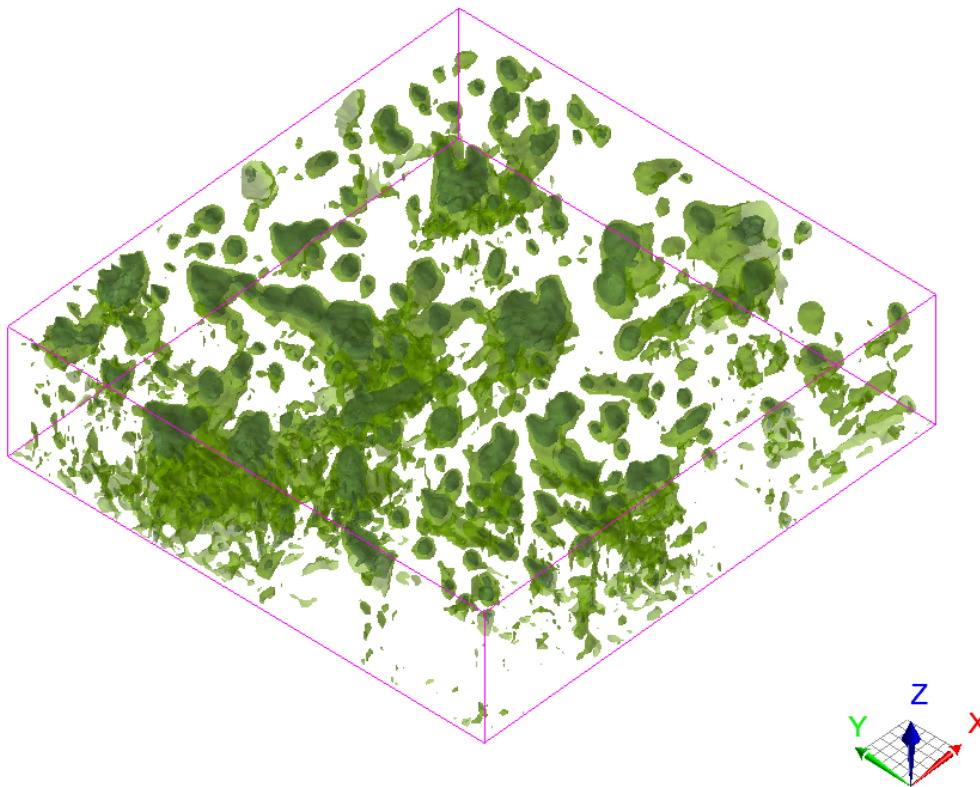


Figure 24: Isosurfaces -0.05 and -0.10

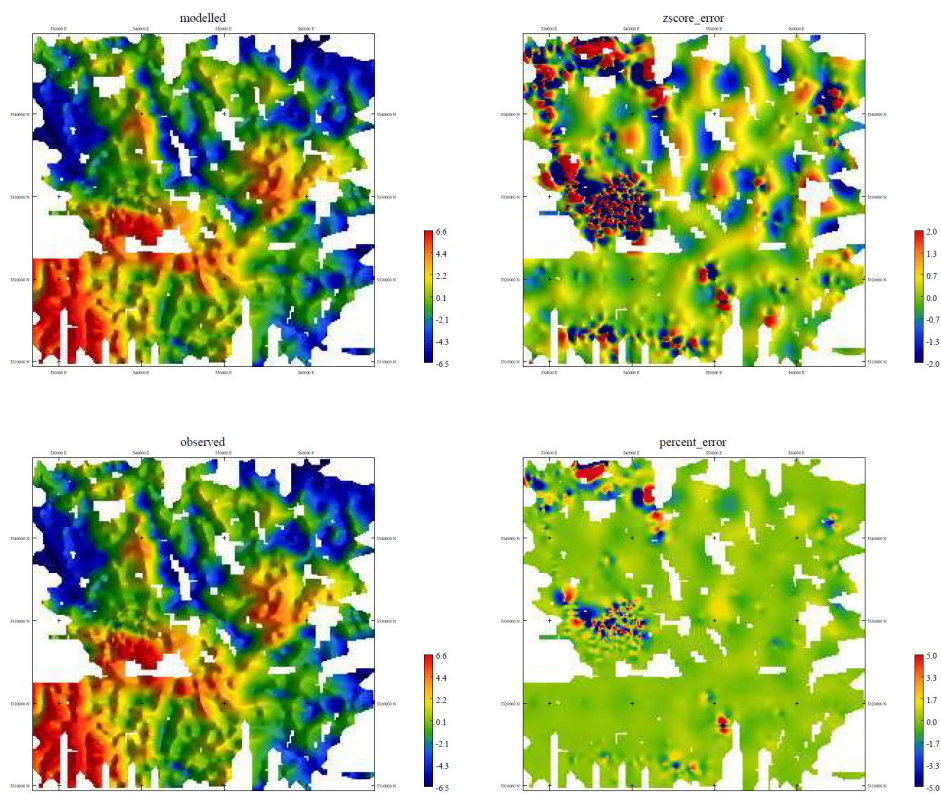


Figure 25: Error Plot, Lemont unconstrained inversion using CSCBA 2.67 g/cc gravity points. TL: modelled field of the inversion result. BL: observed CSCBA dataset. TR Z score error scaled -5 – $+5$. BR Percent error difference scaled from $+2\%$ to -2% .

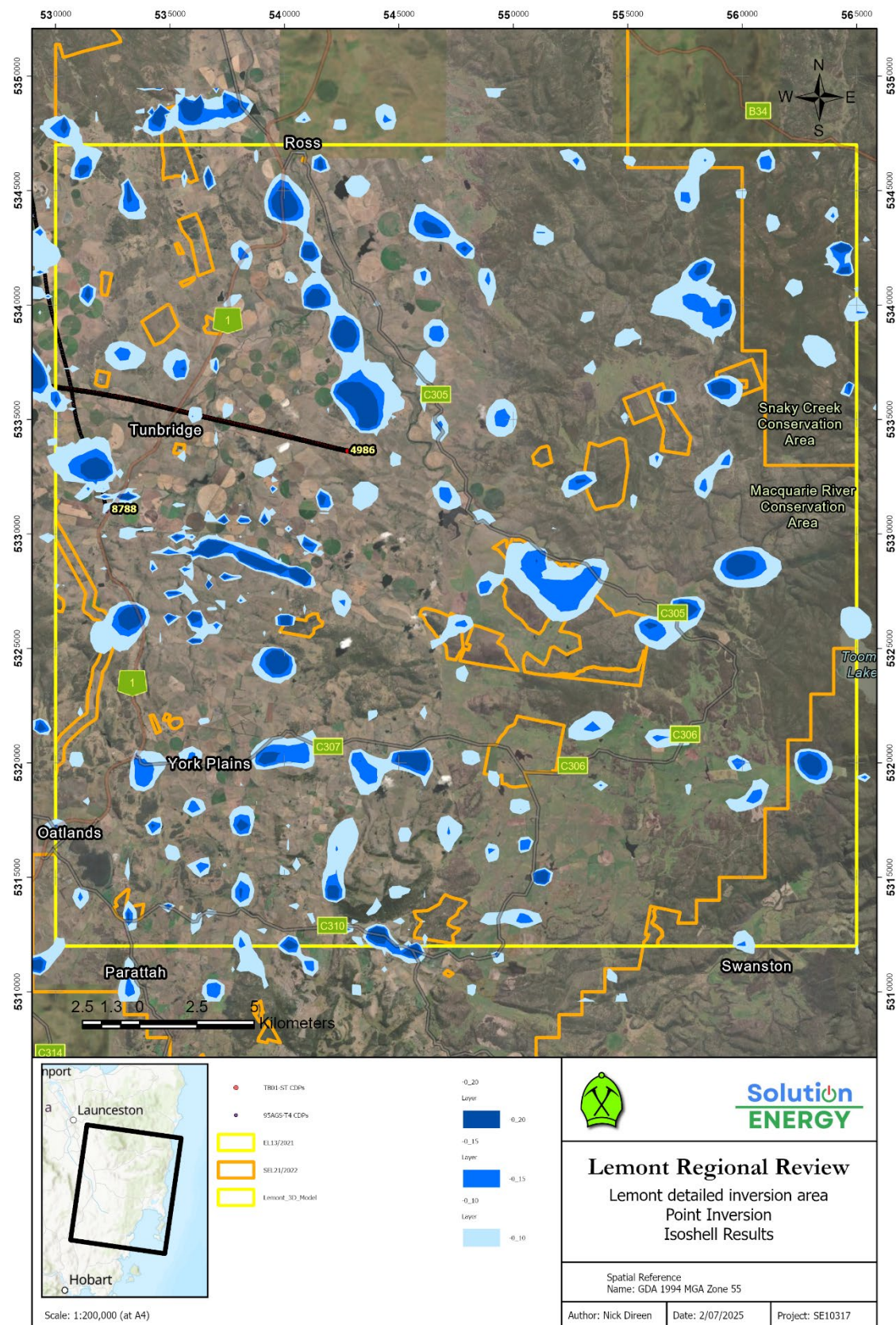


Figure 26: Detailed area point inversion with -0.2 , -0.15 and -0.10 g/cc contrast isoshells shown.

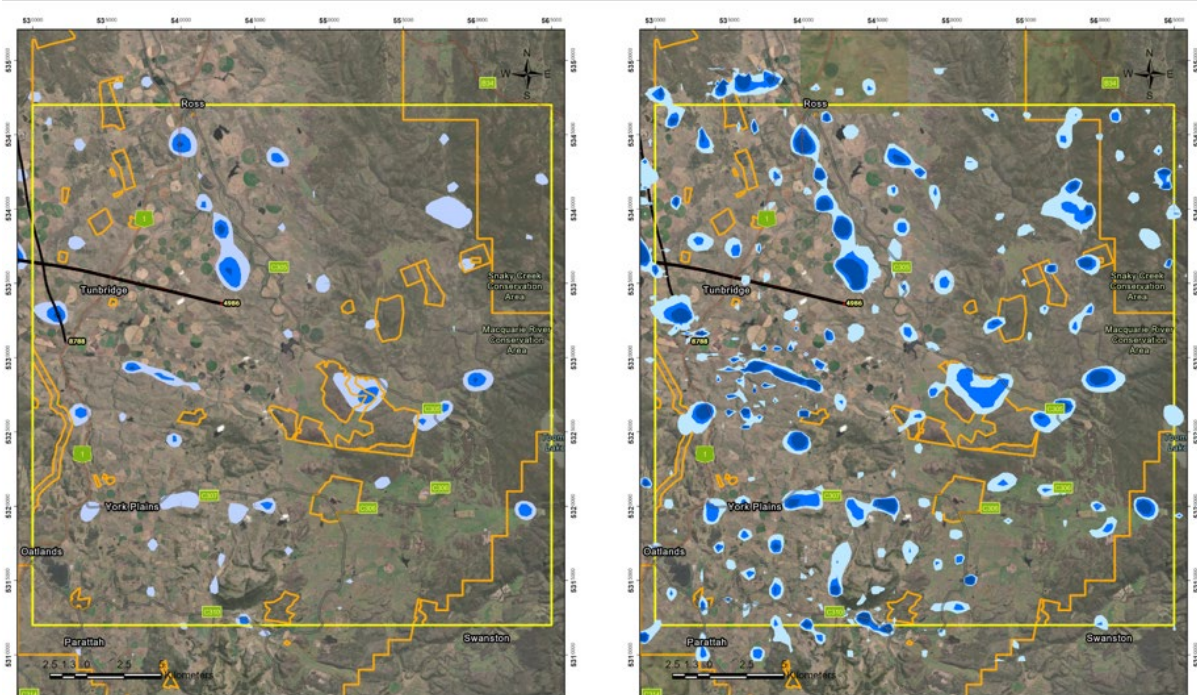


Figure 27: Comparison of Lemont area grid inversion (left) and point inversion (right). The point inversion contains far more small bodies that may be related to noise gradients near single point observations, and are thus unreliable. The version on the left was preferred for analysis.

4 DISCUSSION & CONCLUSIONS

It has been an “article of faith” in Tasmanian geology that there is a major, deep seated Devonian granite batholith margin (often referred to colloquially as the “granite wall”) running from northeast to southeast Tasmania in a roughly N–S line e.g. (Holgate, 2013); Leaman (1990); Leaman and Richardson (1992); McClenaghan (2014); (Roach et al., 1993). This feature is based on residual Bouguer gravity data, and is the feature that was contoured by Leaman (2012) (Figure 3), and modelled by him previously in various iterations and configurations (Leaman and Richardson, 1992; Leaman, 2007, 2010). Leaman himself noted in his 2008 and 2010 reports that the form of the granite “batholith” western contact was highly dependent on the regional field used to create the residual Bouguer Gravity, and showed at least two different versions of the residual gravity, based on his MANTLE91 and MANTLE07 models, which produced variants in the position of the interpreted granite “batholith” margin. Those residual Bouguer maps, were of course model-based (Leaman and Richardson, 1992; Leaman and Richardson, 1989; Roach et al., 1993), and to an extent, based on circular reasoning: a major granite batholith was assumed and modelled into the crust to produce the regional field; the same batholith feature was then found to create a major residual gravity low. However, no further evidence was ever adduced to support the extension of a deep seated granite batholith margin in inland SE Tasmania, beyond the coastal outcrops – it was purely a model-driven feature.

The severing of the link between geologically-driven models for the regional field, and the residual Bouguer gravity was a result of moving to isostatically corrected Bouguer gravity anomalies, pioneered by Geoscience Australia (Nakamura et al., 2010) & Duffett (pers. Comm, 2025). The resulting residual anomalies (which were used in this study) are only dependent on a regional field generated by the USGS AIRYROOT algorithm (Simpson et al., 1983), and the topography/bathymetry, rather than any assumptions about the nature of the crust and its density, (cf Leaman and Richardson (1989)). This is the principal reason for the inversions described here being significantly different to earlier models of the Devonian granite distribution in eastern Tasmania.

The inversions herein show that there is no major N–S-trending granite batholith margin in southeast Tasmania required to fit the isostatic residual Bouguer Anomaly. Instead, the southernmost major plutonic body overlapping the AOI is associated with the highly fractionated S-type Royal George Granite plus I-type Henbury



Granite in the northeastern extremity of Solution Energy’s tenements. Other major plutons are farther to the east around the I-type Bicheno, Coles Bay–Hazards, and Schouten Island granites.

In the Solution Energy tenements, there is an elongate, northwest striking low density body almost parallel to the Midland Highway centred on Campbell Town (informally here: “Campbell Town granite”); another elliptical, northwest striking, northeast–dipping body near the Blackman River, west of Tunbridge (informally here: “Blackman River granite”); and pair of elliptical bodies striking northwest along the thalweg of the Macquarie River (informally here: “Macquarie River granites”), and a body to the northeast of those (informally here: “Snaky Creek granite”).

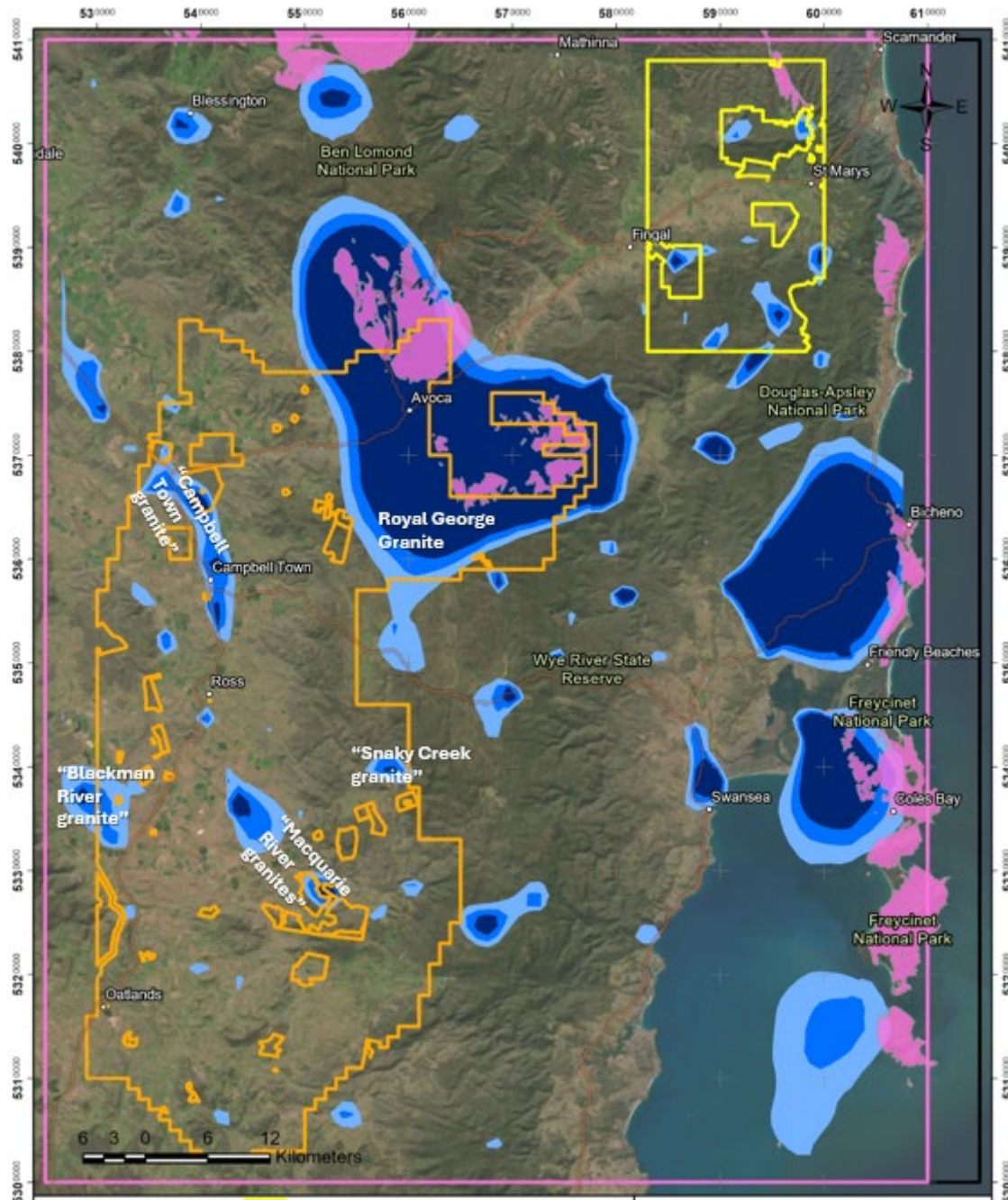


Figure 28: Named low density features likely to be granitoid bodies.

The “Blackman River granite” intersects the seismic reflection line TB01–ST which was previously interpreted by Mitre (Direen, 2025), who found scant evidence for granitic intrusions in the line.

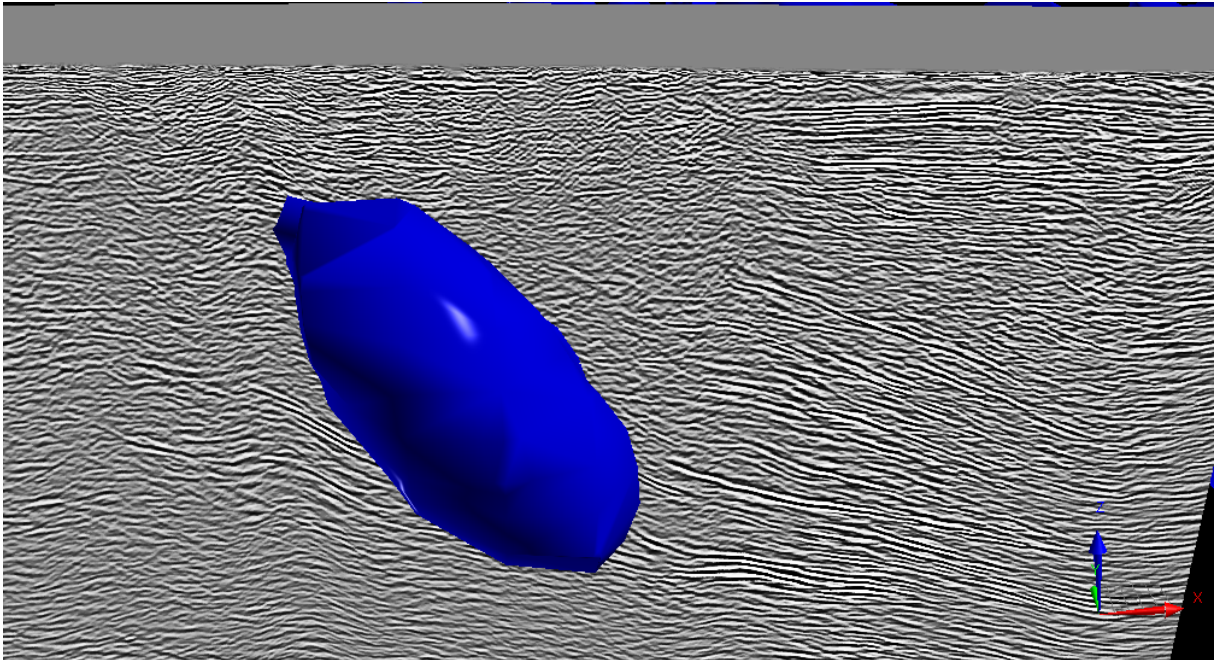


Figure 29: 3D view of the -0.04 g/cc contrast isoshell of the “Blackman River granite” intersecting seismic line TB01–ST

Examining this body further by clipping it in the plane of the seismic section (Figure 30 below) there is a suggestion that the body breaks or disrupts some high amplitude, east-dipping reflections. Its upper contact also appears to align with a strong east-dipping reflector, and internally the body also contains a broken east-dipping reflection fabric. All of these observations suggest that if this low density body is a granite, that it has been caught up in and sheared by the Devonian Tabberabberan deformation; in turn this suggests that if it is granite, it must have been intruded quite early in the Tabberabberan Orogeny.

Black et al. (2005) noted that granitoid intrusion in northeast Tasmania took place over a period of at least 22 million years. They also recognised that some granites (e.g. Pyengana Granodiorite, undated; Diddleum Granodiorite dated 390.4 ± 2.2 Ma) in northeast Tasmania had a northwest-trending foliation present, whereas others are unfoliated, and cross-cut the regional fold trends, and are thus post-tectonic intrusions. The oldest of the unfoliated post-tectonic granites is the Upper Blessington Granodiorite (388.9 ± 1.6 Ma). This very precisely constrains the timing of the Tabberabberan Orogeny in northeast Tasmania to 390–389 Ma. Subsequently, Hong et al. (2017) also recognised several other pre-orogenic granites in northeast Tasmania, namely the George River Granodiorite, Grant Point Granite and Mt. Pearson Granite; the Coles Bay Granite, dated at 388 ± 7 Ma is co-synchronous with the deformation event, which they interpreted to be a slightly longer event, 394–386 Ma, with magmatism spanning a total 55 my period (~ 405 –350 Ma). Notably, all of the pre-tectonic I- and minor S-type granites analysed by Hong et al (2017) were described as unfractionated or weakly fractionated. The most highly fractionated S- and I-types were all emplaced post-tectonically between 380–374 Ma. This potentially has implications for the heat producing capabilities of granite bodies in the Solution Energy tenements, which are small, and likely pre-tectonic, given they appear to be structurally dismembered.

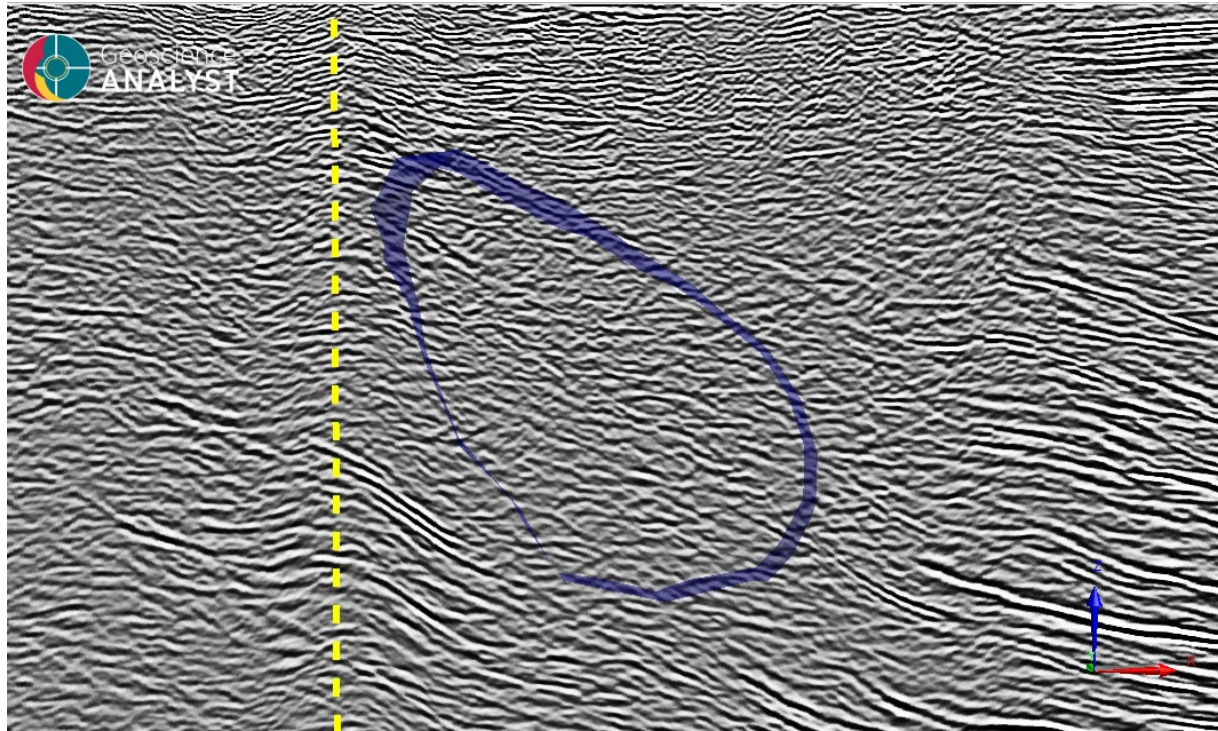


Figure 30: "Blackman River granite" clipped in plane of seismic section

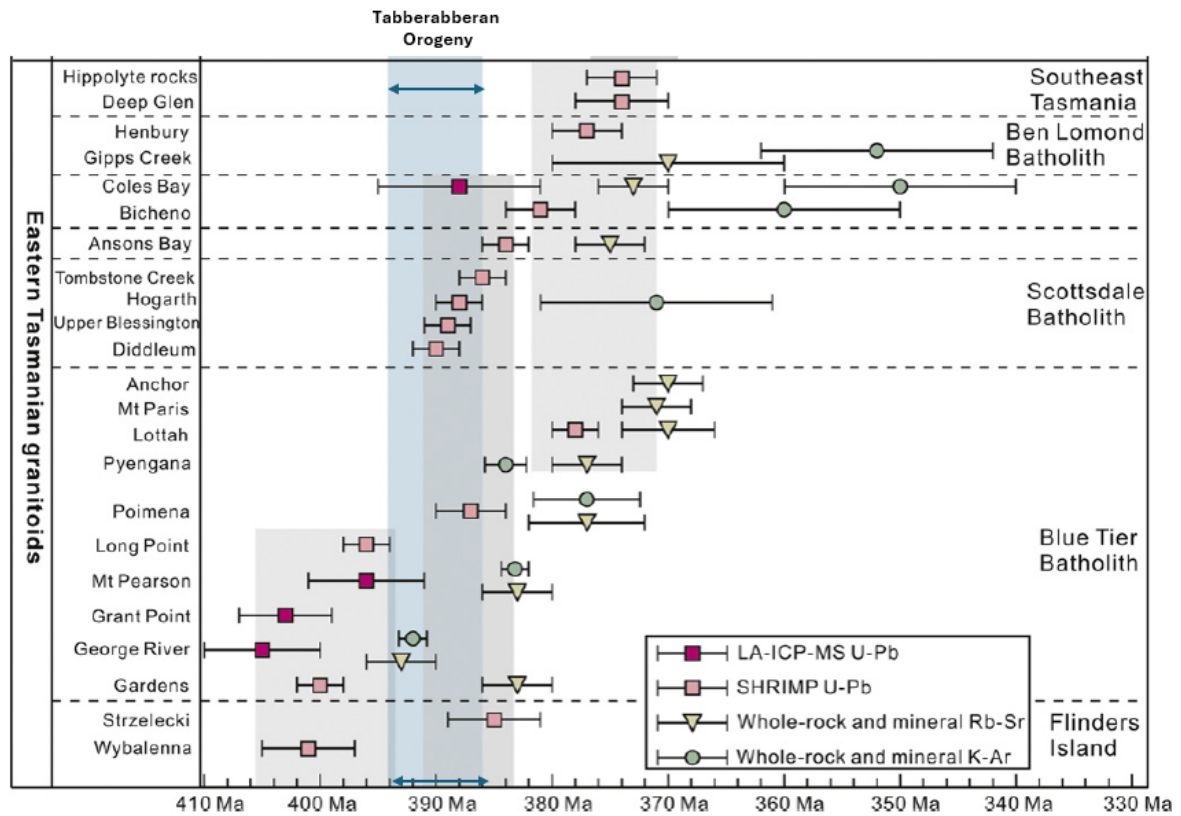


Figure 31: Timing of eastern Tasmanian granitoids relative to the Tabberabberan Orogeny (modified from Hong et al., 2017).

In conclusion, new gravity inversions of isostatic residual Bouguer anomalies over regional northeast Tasmania do not support a long-held belief that there is a major Devonian granite batholith contact running N-S down the island. This interpreted feature was largely based on residual gravity anomalies derived from a model-driven



approach to determining the regional gravity field, a process that is subjective (Roach et al., 1993), and can unwittingly lead to circular reasoning in determining what is contributing to the derived residual field.

Results from unconstrained and constrained inversions, and inversions based on grids vs point data all support the conclusion above, with variations in outcomes mostly related to the level of noise in the gravity sampling, and the mesh size used, rather than any significant geological variance.

Five low density bodies lie in the Lemont area, tentatively interpreted here as deformed granites, the “Campbell Town”, “Blackman River”, “Macquarie River” and Snaky Creek” granites. Some evidence in seismic line TB01–ST suggests these are east–dipping deformed sheets caught up in Tabberabberan Orogeny thrusting. Based on regional geological considerations, these were intruded in the period 405–390 Ma, and are likely to be unfractionated or weakly fractionated I–type bodies. In contrast, the highly fractionated Royal George and Henbury granites are part of a large coherent low density feature interpreted as a major pluton northeast of Campbell Town.

These results have significant implications for the likelihood, or otherwise, of heat–producing granites being the source of observed geothermal anomalism in the Lemont area (Holgate, 2013). Further 2.5D model testing of the “Blackman River granite” feature is recommended.

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