Department of Employment, Economic Development and Innovation
Geological Survey of Queensland

Combining seismic interpretation and gravity modelling

Muttaburra, Galilee Basin

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Introduction

Coal measures deposited in the Galilee Basin during the early Permian make interpretation of the Permo-Carboniferous unconformity at the base of the Galilee Basin from seismic surveys difficult. A recent regional gravity survey conducted by the Geological Survey of Queensland showed a distinct gravity high (Figure 1) in the same location as a basement high interpreted from the Bellara and Pendine seismic surveys. This area is also covered by airborne magnetic data but there is no corresponding magnetic anomaly, possibly as a result of the poor resolution of the data. Gravity modelling has limited application in modelling the internal stratigraphy of the sedimentary basins, due to the minor density changes between units. However, the interface between the sediments of the lower Galilee Basin and the basement rocks has a density contrast which is able to be modelled using the gravity data. This is due to the change from sedimentary rocks in the basin to metamorphic and igneous rocks in the basement, which have higher densities. The calculated basement depths from the seismic interpretation were used as the basis for gravity forward modelling and, in conjunction with density values from a nearby well, tested the hypothesis that basement relief is the source of the gravity anomaly.

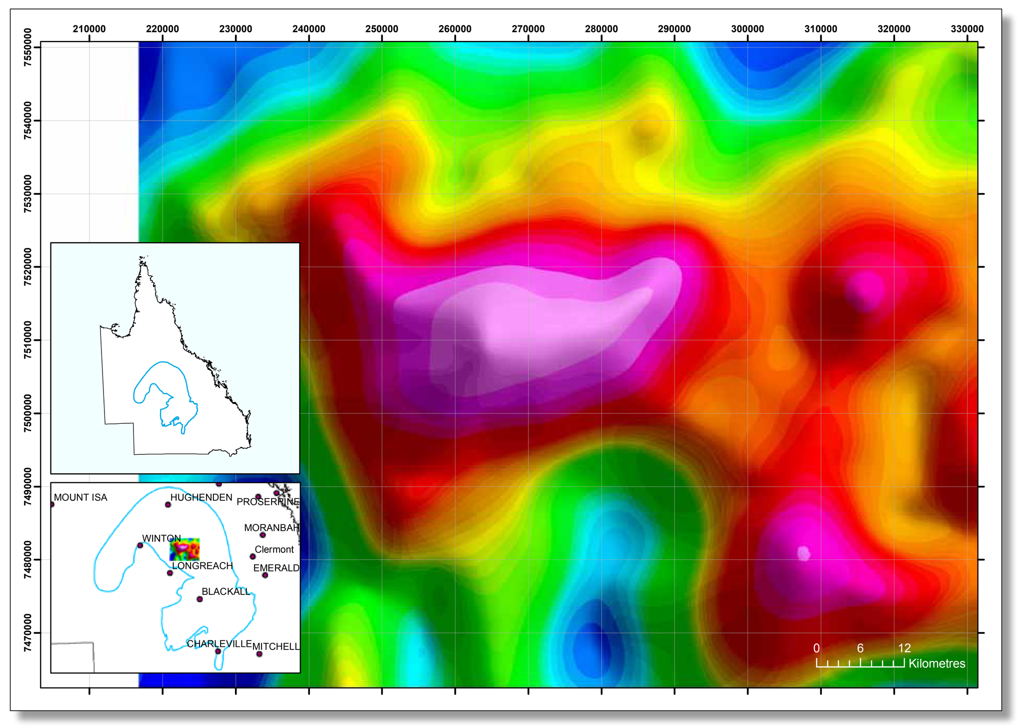


Figure 1. Location of the project area showing the gravity anomaly defined by the Galilee Gravity Survey.

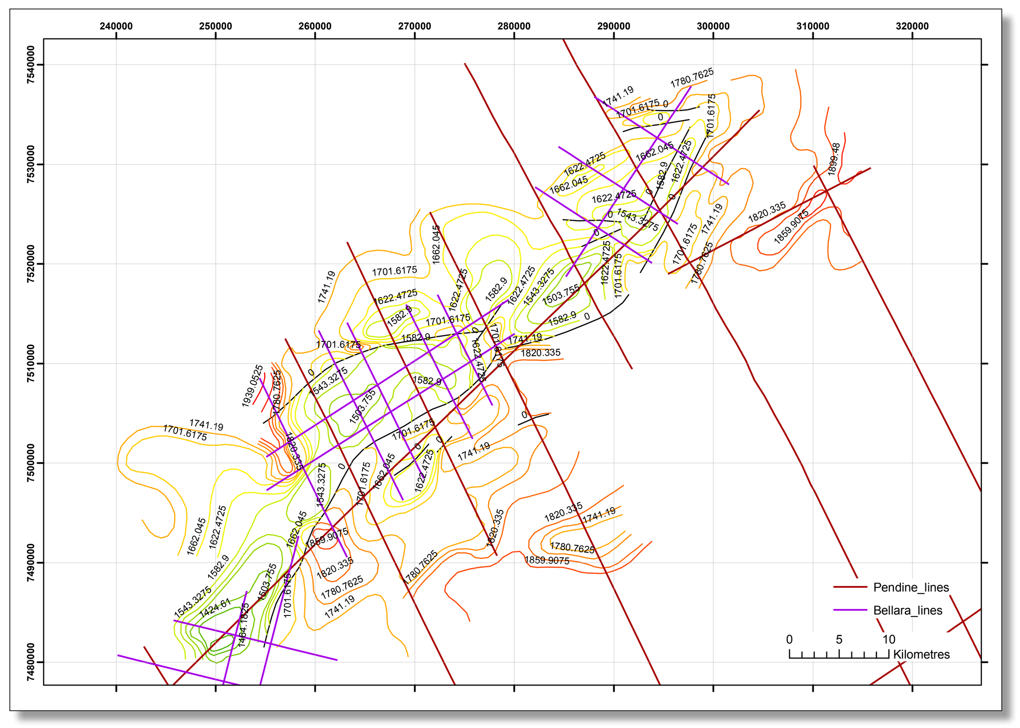


Figure 2. Digitised two-way time contour interpretation of the base of the Permo-Carboniferous based on the Bellara and Pendine seismic surveys (CR11871). Contour labels are the converted depths in metres. The contours are coloured by depth with red being deep and green shallow.

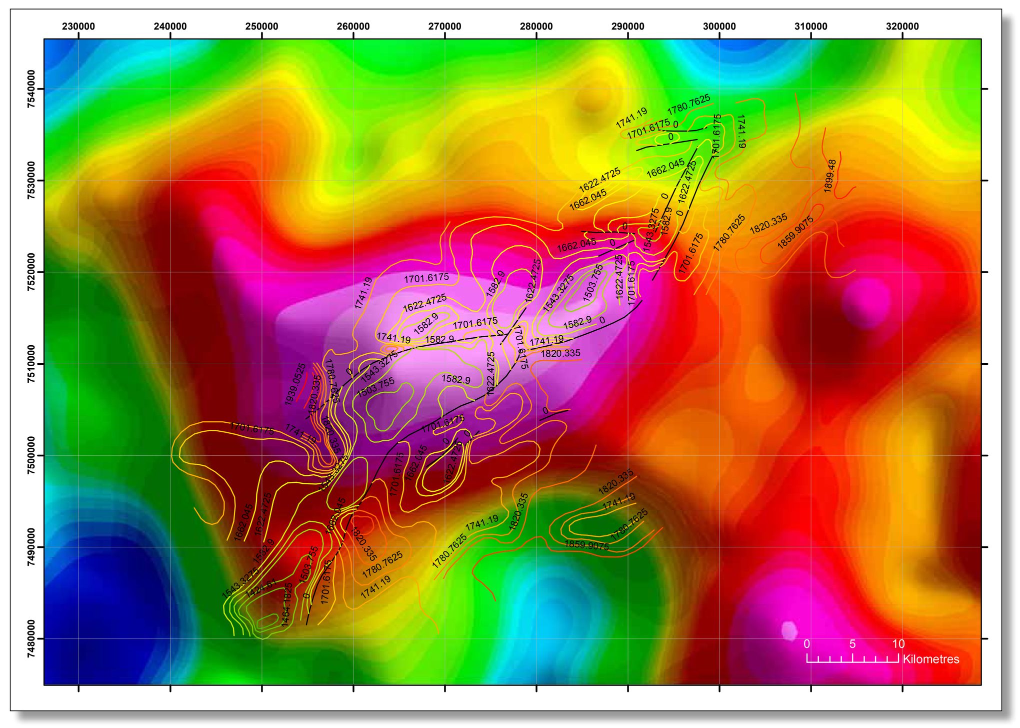


Figure 3. Digitised contours overlain on new Galilee Gravity Survey data showing the coincident gravity and basement high. Contour labels are the converted depths in metres. The contours are coloured by depth with red being deep and green shallow.

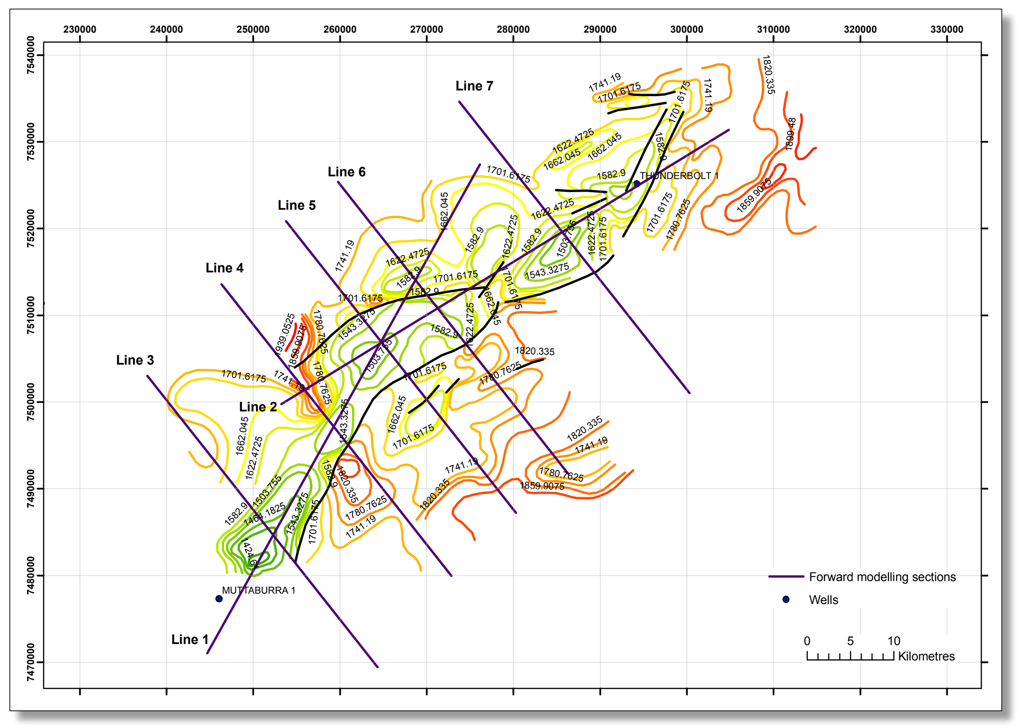


Figure 4. Location of the sections that have been forward modelled. Contour labels are the converted depths in metres. The contours are coloured by depth with red being deep and green shallow.

Seismic interpretation

A two-way time contour interpretation based on the Pendine and Bellara Seismic surveys was used as the initial starting model for the 2D gravity forward modelling (Figures 2-4). The two-way time contours were converted to depths using the seismic velocities and the Dix formula. The results of the conversion from time to depth were checked against the wells in the area. There was a 2-3% error in the calculated basement depths when compared to the actual depths from APC Thunderbolt 1 and PON Muttaburra 1. This error is the result of using an average velocity to calculate the depths from the two-way time contours and is not large enough to be significant in the forward modelling. The depth to basement ranged from approximately 1450m to 1900m.

Forward modelling

The initial forward models, based only on the basement depth from the seismic interpretation and the model densities derived from RPN Hughes 1 well, show that the gravity anomaly is not explained by the basement relief interpreted from the seismic sections (Figure 5). The change in topography that the basement interpretation displays would need unrealistic density values (less than 2g/cm³ for basin sediments and more that 4g/cm³ for basement) to even come close to matching the observed gravity response. The other option is to modify the depth of the interpreted basement surface to match the gravity anomaly. However, the changes again would have to be quite significant, raising basement up to 1km higher, which is definitely in contradiction to the shallower parts of the seismic interpretation (Figure 6).

As the existing seismic interpretation was not able to explain the gravity anomaly, an attempt was made to reinterpret the seismic data in conjunction with the gravity data (Figure 7). The model constructed from the reinterpretation was able to provide a match for the gravity anomaly. However, the features that generated the gravity anomaly were not delineated by the seismic, but rather, were based on current geological understanding. The density values used were estimated from theoretical bulk densities based on rock type. These interpreted sections also displayed basement depths significantly deeper than nearby drill holes. The long period and smoothness of the gravity anomaly (both good indicators of deep sources) prompted investigation of the possibility that the source is basement heterogeneity.

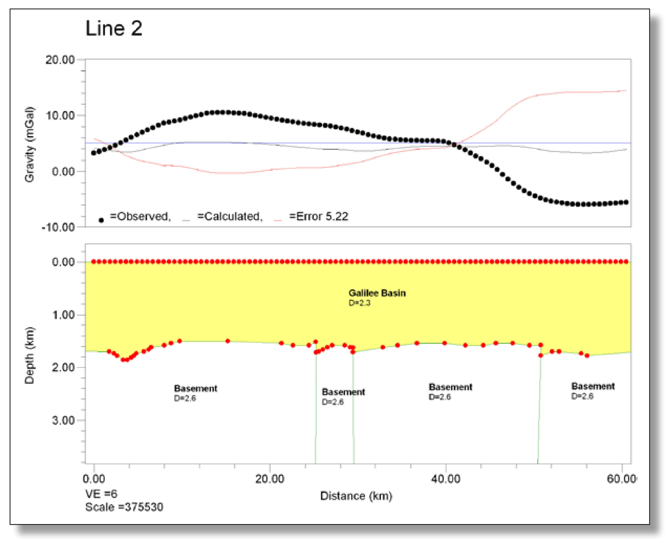


Figure 5. Gravity forward model with basement contact from seismic interpretation and density vales from RPN Hughes 1. Points on the basement interface are directly derived from the seismic interpretation.

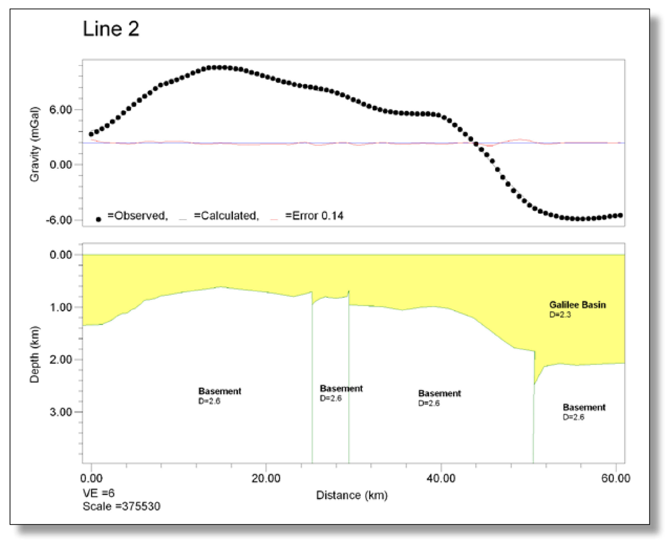


Figure 6. 2D forward gravity model which changes the basement relief to match the observed gravity anomaly. Note the significantly shallower basement that is required.

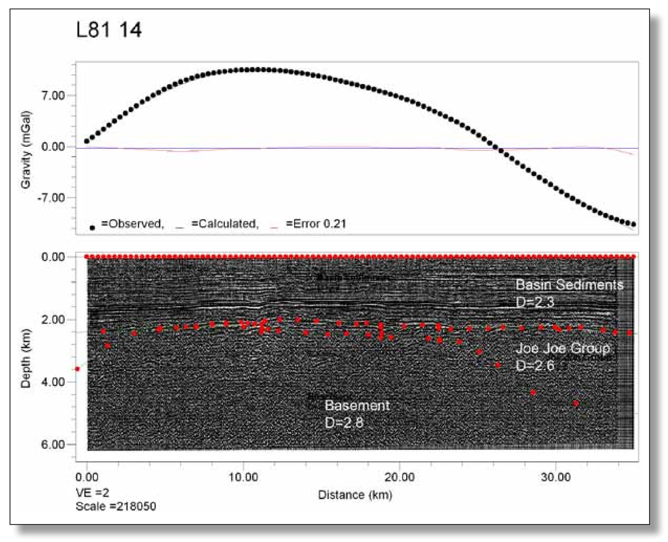


Figure 7. Reinterpretation of seismic line L81 14 from the Pendine seismic survey. Contact between Joe Joe Group and basement not delineated by the seismic.

Basement modelling

Little is known about the nature of the basement in this area. The wells that intersect basement near the model area are PON Muttaburra 1, APC Thunderbolt 1, ENL Brookwood 1 and EAL Norris 1. The basement rocks intersected in these holes are generally described as dacite or metasediments; however, the holes never continue more than 100m into basement. Two different models were tested in an effort to understand possible sources for the gravity anomaly . The first model used the half-width rule to provide an estimate of the depth to the centre of mass of the body generating the anomaly (Figure 8). This provides a depth estimate of approximately 12km. The most likely source for the anomaly in this model is considered to be a mid-crustal intrusion. A generic value of 2.8g/cm³ was chosen because it could represent either a mafic or intermediate body, while still being significantly more dense that the surrounding basement, and thus able to generate the gravity anomaly. The second model tested was an igneous body in the shallow basement (Figure 9). This model was based on the presence of dacite in nearby drill holes. A density of 2.7g/cm³ was first chosen as a representative density for dacite; however, approximately 10km of volcanics was required to match the gravity anomaly. A density of 2.8g/cm³ (a value consistent with andesitic volcanics) provided a better match for the gravity anomaly with a more reasonable unit thickness.

Figure 8. 2D forward gravity model which uses the addition of lower crustal intrusion to model the gravity anomaly. The depth of these intrusions was based on the half-width rule in the absence of all other constraining information.

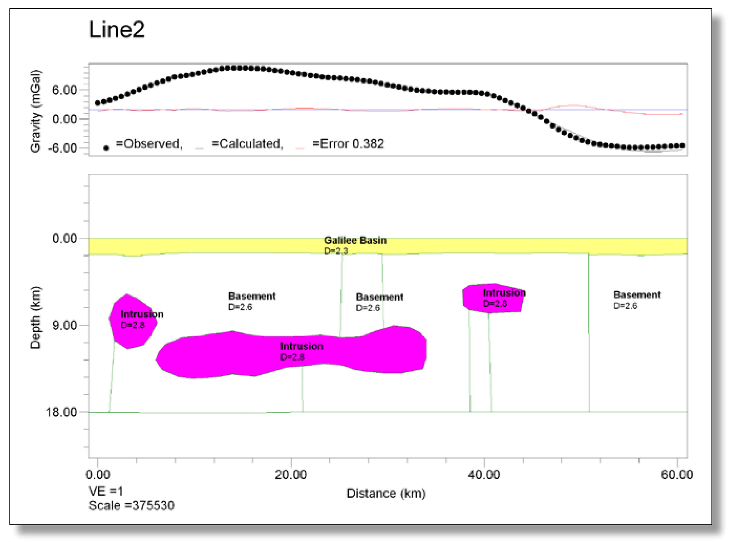
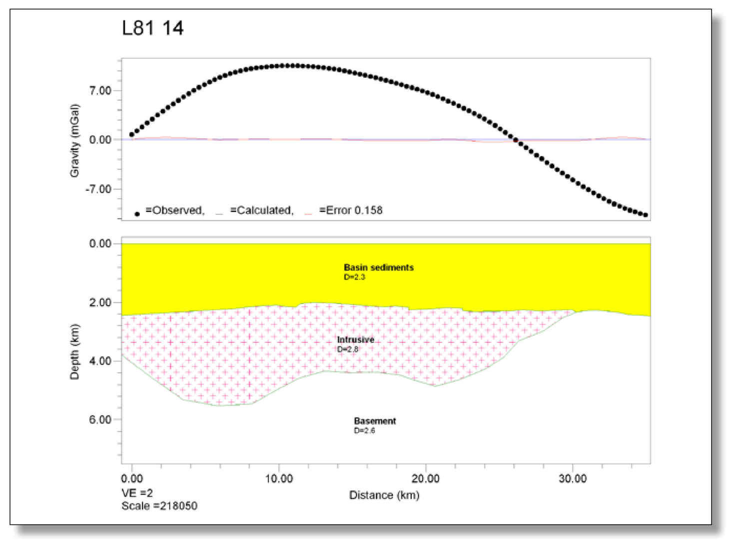


Figure 9. 2D forward gravity model with a dacitic to andesitic body in the shallow basement. The presence of this body is based on the nearby basement cores.



Results and conclusions

This study provides strong evidence that, while the gravity anomaly just outside Muttaburra coincides with a basement high from seismic interpretation, the basement relief is not the source of the gravity anomaly. Analysis of the seismic and the gravity anomaly suggest that the source is most likely the result of basement heterogeneity. Potential field modelling is unable to provide unique solutions to any given anomaly; however, it can be used to ascertain if a hypothesis is plausible. While the absence of constraining data reduce the confidence in the solutions, the two models that display basement heterogeneity are considered to be plausible models for the source of the gravity anomaly.