GEOPHYSICAL STUDIES OF AUSTRALIA'S REMOTE EASTERN DEEP-WATER FRONTIER: RESULTS FROM THE CAPEL AND FAUST BASINS

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INTRODUCTION

The Capel and Faust basins are located in a frontier part of offshore eastern Australia, about 800 km east of Brisbane in 1000–3000 m of water (Fig. 1). These basins are being evaluated for their petroleum potential as part of the Australian Government's Offshore Energy Security Program. This article outlines the current status of integrated interpretation of 2D seismic reflection, sonobuoy refraction and potential-field data acquired during Geoscience Australia marine survey GA-302 conducted between late 2006 and early 2007. This survey collected 5920 km of high-quality 106-fold seismic reflection data using an 8 km streamer to 12 s two-way time at 37.5 m shot interval and a line spacing of 20–50 km. A subsequent swath-bathymetry and geological sampling survey (GA-2436), completed in late 2007, also collected potential-field data in the north-west of the study area with a 3–4 km line spacing (Fig. 1). These data have been integrated in 3D to help constrain the geometry and thickness of sediment depocentres in the region.

SEISMIC DATA

Prior to the GA-302 survey, seismic data coverage over the Capel and Faust basins was limited to regional reconnaissance surveys, some of which were completed for Geoscience Australia's Law of the Sea data acquisition program (Fig. 1). These existing seismic reflection data (Van de Beuque et al., 2003) provide evidence of depocentres that correlate with lows in residual Bouguer gravity computed from satellite-altimeter data. On the basis of the residual gravity map, survey GA-302 was planned as a series of 2D seismic lines, 20–50 km apart, to further delineate depocentre geometry and sediment thickness variations.

Interpretation of GA-302 seismic reflection data suggests a complex pattern of depocentres separated by probable basement highs. The depocentres attain a maximum thickness equivalent to ~3 s two-way time (Fig. 2), or about 6 km. The estimated sediment thickness is based on velocity data from sonobuoys and stacking velocities, and is supported by 2.5D gravity modelling (Petkovic, 2008).

Interpretation of the seismic reflection data suggests the presence of pre-rift basement, two syn-rift megasequence packages and two post-rift sag packages (Hashimoto et al., 2008) (Fig. 3). The syn-rift packages probably span the Early Cretaceous to Santonian, while the post-rift sag packages represent the Early Campanian to the present (Hashimoto et al., 2008). These age ranges are directly constrained only by the DSDP 208 drill hole at the northern edge of the study area (Fig. 1) and only to depths of about 600 m below the sea floor (Burns and Andrews, 1973; Van de Beuque et al., 2003). The interpretation shows that some seismic horizons are not continuous between adjacent depocentres and that there are large variations in the thickness of interpreted packages. This means that correlating sediment packages between depocentres and across the survey area is difficult. Despite these difficulties, potential-field data are proving useful as an aid to interpreting the continuation of structures between the 2D seismic lines.

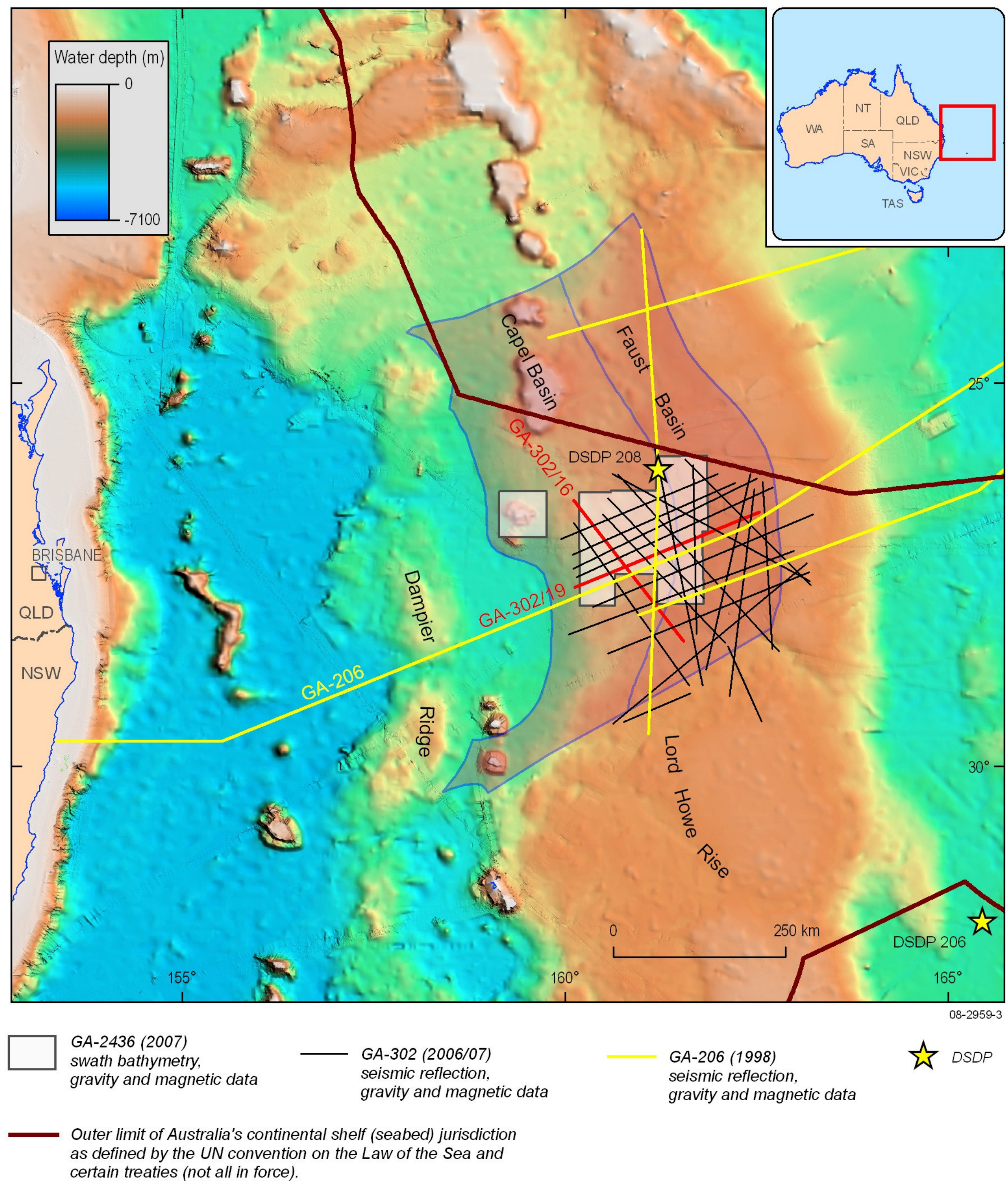

Figure 1: Map showing bathymetry of the northern Tasman Sea and the location of marine geophysical surveys covering the Capel and Faust basins (as defined by Stagg et al., 1999).

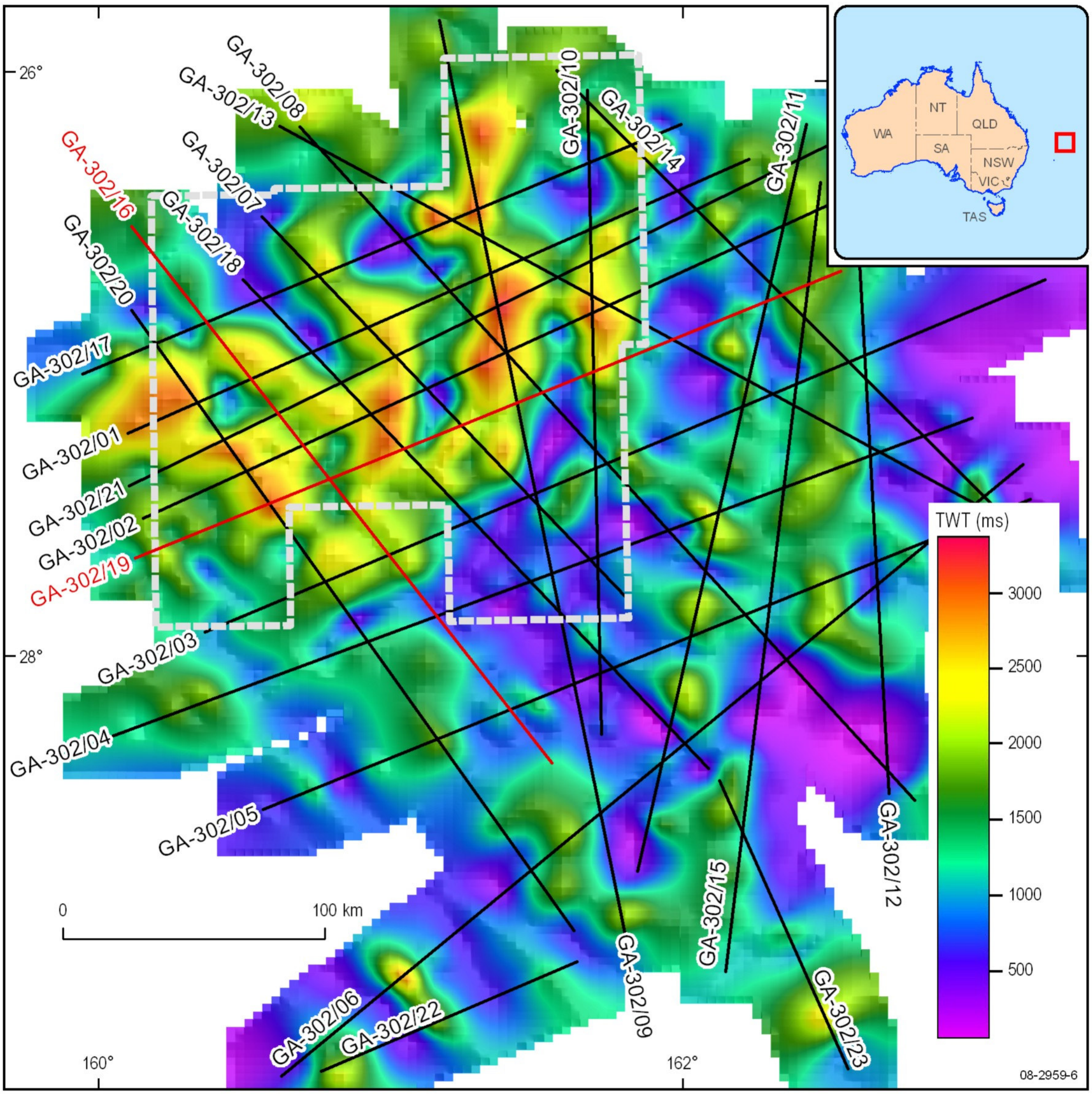

Figure 2: Map of total sediment thickness (in two-way time) based on preliminary interpretation of Survey GA-302 seismic data (black lines, red lines are shown in Fig. 3), gridded using a 3×3 km cell. The thick dashed line outlines the GA-2436 survey area.

POTENTIAL-FIELD DATA

Gravity data were obtained along the GA-302 seismic reflection lines and along the closely-spaced lines of survey GA-2436. Figure 4a shows simple Bouguer anomalies gridded to a 1 km square cell and band-pass filtered to preserve wavelengths between 7.5 and 100 km. The anomalies show a strong correlation with basin depocentres (gravity lows) and basement highs (gravity highs) interpreted from the seismic reflection data (Fig. 5). The anomalies highlight elongate, roughly N–S-trending or arcuate depocentres, generally with limited strike extent, that are best developed in the north and northwest of the survey area (Fig. 4a). The correlation between gravity anomalies and subsurface structure allows features evident in individual 2D seismic lines to be linked between lines or for their inter-line terminations to be mapped. Multi-scale edge-detection techniques are also being applied to constrain this process.

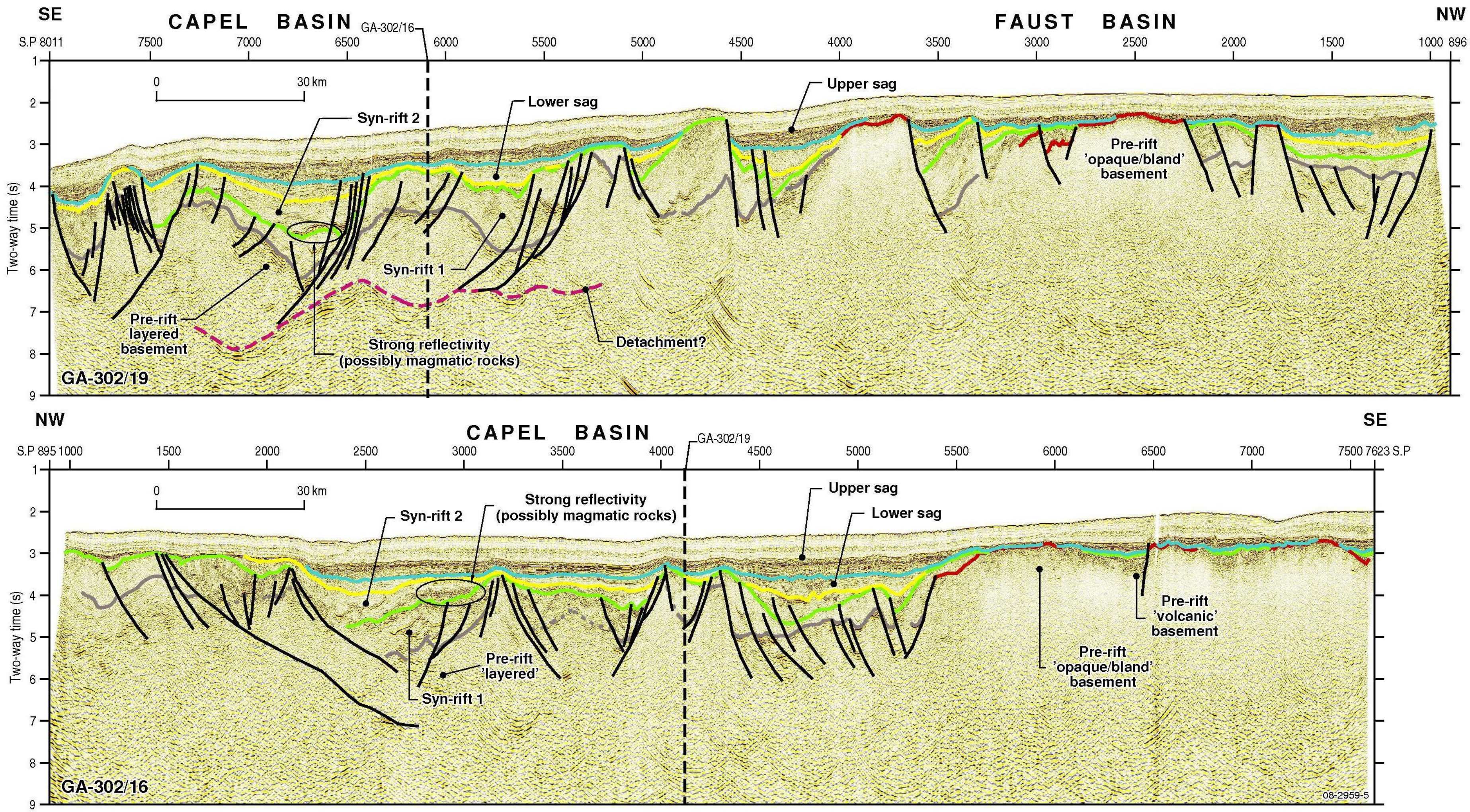
SE
CAPEL BASIN
GA-302/16
FAUST BASIN
NW
S.P 8011
896 S.P
Two-way time (s)
0
30 km
Upper sag
Lower sag
Syn-rift 2
Syn-rift 1
Pre-rift 'opaque/bland' basement
Pre-rift layered basement
Strong reflectivity (possibly magmatic rocks)
Detachment?
GA-302/19
NW
CAPEL BASIN
GA-302/19
SE
S.P 895
7623 S.P
Two-way time (s)
0
30 km
Syn-rift 2
Strong reflectivity (possibly magmatic rocks)
Upper sag
Lower sag
Pre-rift 'layered'
Syn-rift 1
Pre-rift 'volcanic' basement
Pre-rift 'opaque/bland' basement
GA-302/16
08-2959-5

Figure 3 (opposite): Representative seismic reflection data for Survey GA-302 showing preliminary interpretation of major faults (black lines) and megasequence package boundaries (grey/red – green, syn-rift 1; green – yellow, syn-rift 2; yellow – blue, lower sag; blue – seafloor, upper sag) (Hashimoto et al., 2008). Several types of pre-rift basement are indicated. Line 19 is a dip line and Line 16 is oriented along strike (cf. Figs 1 and 2).

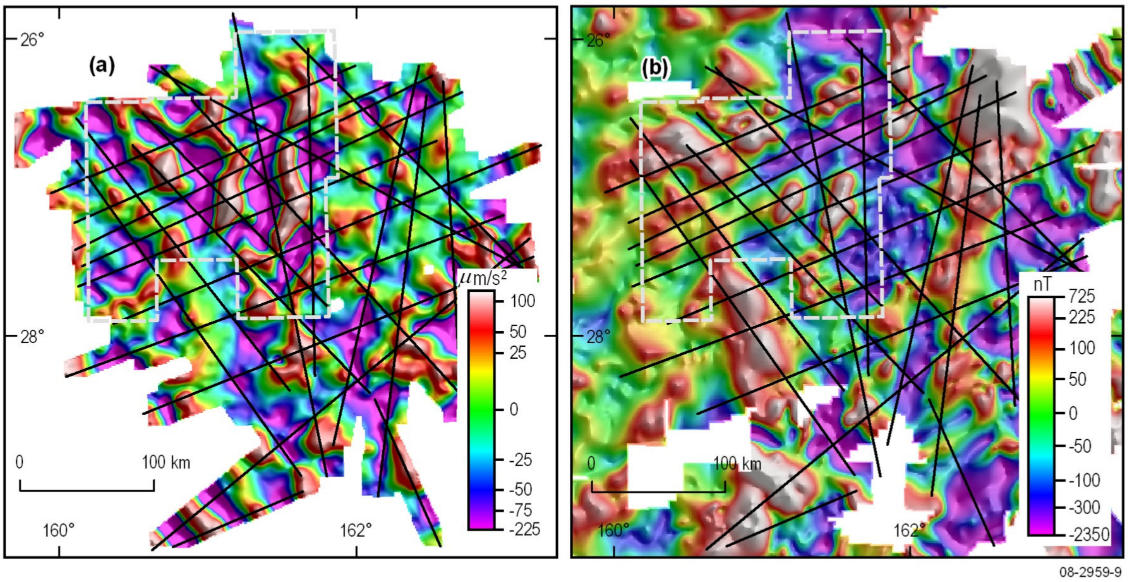

Figure 4: (a) Band-pass filtered (7.5–100 km) simple Bouguer gravity image based on gridded ship-track data. (b) Reduced-to-pole magnetic anomaly image. Both images cover the same area as shown in Fig. 2. Black lines show Survey GA-302 seismic lines and the white dashed line outlines the GA-2436 survey area where line spacing is ~4 km for both gravity and magnetic coverage.

Reduced-to-pole magnetic anomalies are shown in Fig. 4b. This image represents data merged from GA-302, GA-2436 and other marine surveys and gridded to a 1 km square cell. Unlike the gravity data, these data do not have a strong correlation with basin geometry. Instead, it is inferred that magnetic anomalies reflect the distribution of volcanic rocks interpreted in the seismic data. In the central region of generally-subdued magnetic anomalies (< -50 nT), where the elongate gravity anomalies are most prominent and depocentres are best developed, there is less evidence for volcanic rocks in the seismic data. However, two NNE-trending anomalies in the eastern part of the GA-2436 survey area do correlate with inferred dykes intruded along faults that bound basement highs. High-amplitude, sub-horizontal reflectors interpreted as sills, as well as strong reflectivity within interpreted basement, are commonly associated with regions characterised by more positive magnetic anomalies (> 50 nT).

3D MODELLING AND VISUALISATION

An example of the correlation between basement highs and positive gravity anomalies is shown in Fig. 5. This figure also highlights how 3D visualisation aids the interpretation of structural continuity between the widely-spaced seismic lines.

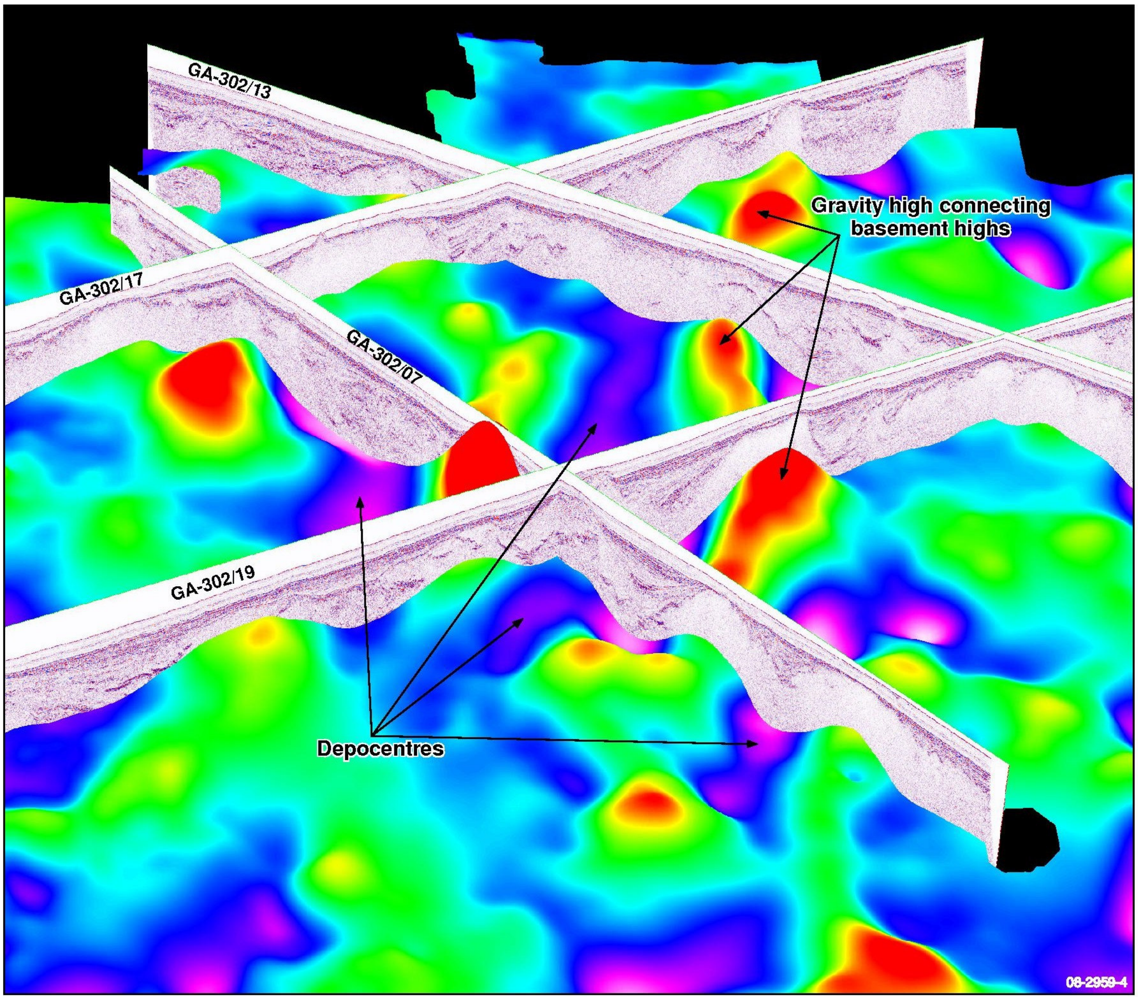

Figure 5: 3D view looking to the north showing selected seismic lines and the band-pass filtered Bouguer gravity anomaly. This image highlights the continuity of depocentres, basement highs and faults between the widely-spaced GA-302 seismic lines.

Figure 5 convincingly illustrates the presence of off-line structures close to every line. This in turn highlights the inadequacy of 2.5D gravity modelling in this region. To address this inadequacy, 3D gravity modelling, using the GeoModeller software from Intrepid Geophysics, is being applied in order to validate and test the interpretation of sedimentary sequence boundaries and depocentre thickness. Current gravity models use a five-layer configuration divided at the water bottom, base of early Miocene (onset of strong reflectivity above the blue horizon in Fig. 3), top of Syn-rift 1 package (green horizon in Fig. 3) and top of pre-rift section (i.e. 'basement', grey line in Fig. 3). Densities for each of these layers are inferred from refraction data and stacking velocities and take on values of 1.03, 1.95, 2.4, 2.5, 2.67 t/m^3, respectively. Variations from these values are also being tested.

Forward modelling of the gravity field generated by the simplified 3D model is largely consistent with the seismic interpretation. Shorter-wavelength gravity lows generated by sediment-filled depocentres are reproduced by the model. However, the modelled gravity field in the western part of the area (Fig. 6b) is generally more negative than the observed free-air gravity field (Fig. 6a), suggesting that the model requires more mass in this area. This implies the presence of higher-density magmatic rocks within the sedimentary layers, or that the basement pick on seismic sections is incorrect. These and other alternatives, including Moho depth variations (Goncharov et al., 2007), are currently being explored.

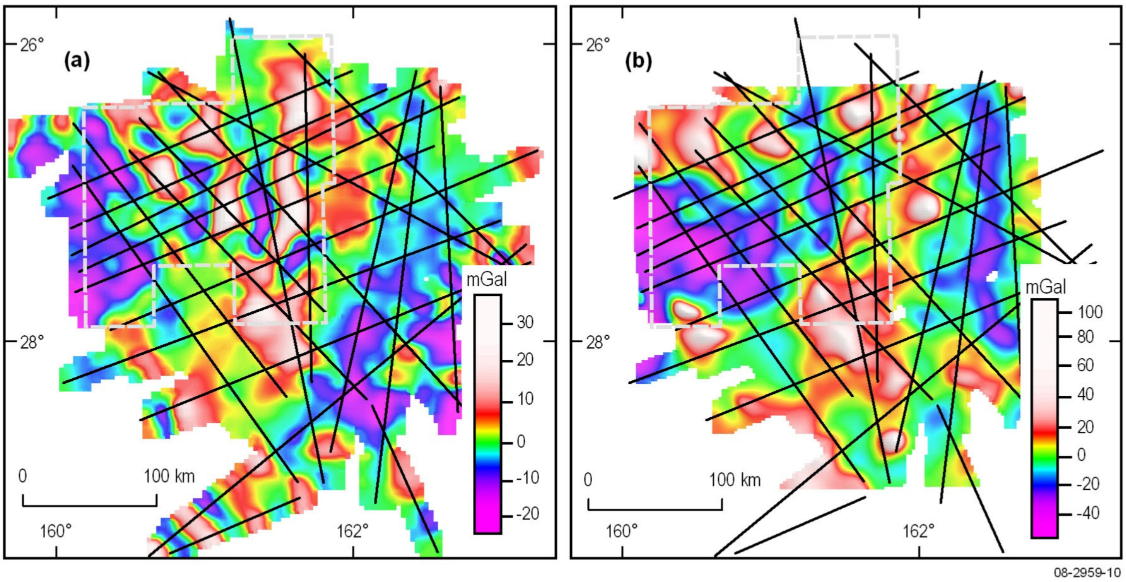

Figure 6: (a) Observed free-air gravity (mGal) and (b) gravity calculated from an initial 3D model. Planar detrending has been applied to both images in an attempt to account for long-wavelength contributions to the gravity field that are not included in the 3D model (e.g. Moho). Note the reasonable fit at shorter wavelengths and the generally more negative calculated gravity associated with the deepest depocentres in the northwest part of the model. The negative calculated gravity could be attributable to missing mass (e.g. magmatic rocks within the middle sedimentary package or incorrect horizon picks).

CONCLUSIONS

Seismic reflection and potential-field data covering the southern parts of the Capel and Faust basins have been combined in a 3D visualisation environment to help constrain depocentre geometry. This integrated 3D approach helps constrain the continuation of structures and the mapping of faults between the 2D seismic lines and to infer the magmatic character of the upper crust. Interpretation of the seismic reflection data suggests up to 6 km of sediment accumulation in the northwest of the study area. This interpretation is generally consistent with preliminary 3D modelling of gravity data. Areas of misfit are attributed to a mass-deficit within the middle or lower parts of the sedimentary section. The approach described here illustrates the integral role for 3D gravity modelling as an aid to interpretation in frontier basins. It also demonstrates an approach that is useful for planning of future investigations of basin architecture and petroleum potential of not only the Capel and Faust basins, but also other basins that make up Australia's remote eastern frontier.

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