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Potential field methods prove effective for continental margin studies

Another option for offshore geology mapping

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Remote geophysical data acquisition tools, such as gravity and magnetic surveys, have proved very successful in mapping the underlying geology of the Australian continent. Similarly, these geophysical methods can also be applied in Australia's offshore areas for mapping the continental margin using marine vessels (surface and submarine) and aircraft. The use of airborne magnetic surveys in these environments provides a cost-effective means of mapping large areas of offshore geology. These datasets greatly contribute to the assessment of the petroleum potential of offshore basins through providing an understanding of regional geology, basin architecture, and crustal discontinuities, as well as showing the distribution of igneous rocks. Two simple potential field methods that have proven effective in the offshore environment are the Upward Continuation Residual (UCR; Jacobson 1987) and the Analytic Signal (AS) Phase (Tilt) filters (Nabighian 1972, 1974; Miller and Singh 1994). These filters are readily available in common commercial and open-source geophysical data processing packages. The UCR and AS methods have been extensively and successfully applied to basin studies carried out by Geoscience Australia in the Capel and Faust basins off eastern Australia, the Bight Basin in the Great Australian Bight, and basins off southwestern Australia (Morse, Gibson and Mitchell 2009). This paper uses examples from the deepwater Otway Basin and the Sorell Basin off western Tasmania.

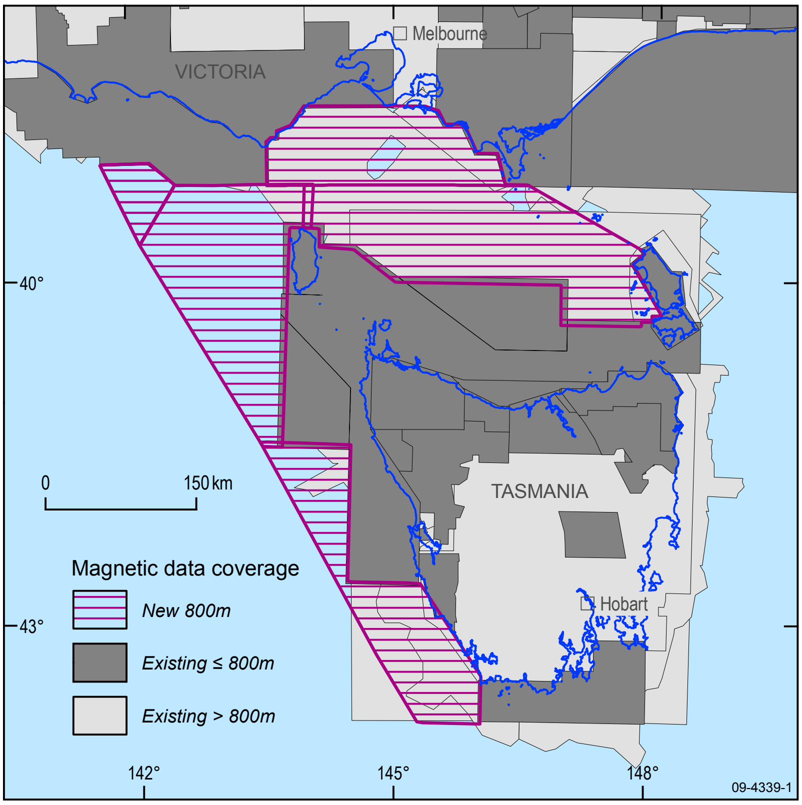

Figure 1. Recent aeromagnetic acquisitions across the Bass, southern Otway, and Sorell basins and Torquay Sub-basin.

Otway Basin and the Sorell Basin

The geology and petroleum potential of the western Tasmanian offshore basins is poorly understood. To improve explorer understanding of these basins, aeromagnetic data was acquired by Geoscience Australia and Mineral Resources Tasmania in 2008 as part of a cooperative National Geoscience Agreement project. Geoscience Australia's contribution was provided as part of its Offshore Energy Security Program. The survey acquired 141 234 line kilometres of high quality aeromagnetic data with a line spacing of

800 metres across the Bass, southern Otway and Sorell basins and Torquay Sub-basin (figure 1). The aim of this survey was to acquire new aeromagnetic data to help delineate the structural architecture of the basins and underlying basement, and the distribution of igneous rocks. These data filled gaps in the existing aeromagnetic coverage of the area between Tasmania and mainland Australia. It provided fresh insights into basement structure and the structural controls on basin architecture and sedimentation patterns during the breakup of Gondwana and separation of Australia from Antarctica. The UCR and AS filter methods discussed below were used to analyse these data in combination with seismic and geological data.

Benefits of the Upward Continuation Residual filter

The Upward Continuation Residual (UCR) filter manipulates the magnetic and gravity data to enhance the shallower source anomalies by minimising the dominant large deep source anomalies. The UCR method provides a robust method of frequency separation in potential field data (Jacobson 1987) that is locally adaptive and produces a visualization of the data that is arguably more geologically interpretable than a fixed frequency or band-pass filtered image. The method also provides a more interpretable image than total horizontal derivative methods. The UCR method is based on the upward continuation filter which calculates the potential field that would have been recorded at a higher level above the source. Calculating the potential field at this higher level filters out the anomalies of smaller and shallower sources from the original data (figure 2a), and results in a smoother, longer wavelength for the potential field dataset (figure 2b). The useful high frequency signal (figure 2c) can be accessed by subtracting the upward continued signal from the original data, where the upward continuation dataset is acting as a nonlinear, locally adaptive long wavelength filter.

The resultant data effectively images anomalies from shallower sources. In the case of continental margin areas, this method removes the dominant effect of the thinning crust (shallowing Moho) and enhances basins and other upper crustal density features (figure 2). As with all filtered data grids, some artefacts of the process—such as edge effects— remain and need to be considered when interpreting the results.

The UCR filter approach can also be used to separate small amplitude short wavelength anomalies from magnetic signals dominated by high amplitude anomalies to extract source signals from within the sedimentary basin (figures 3a, 3b).

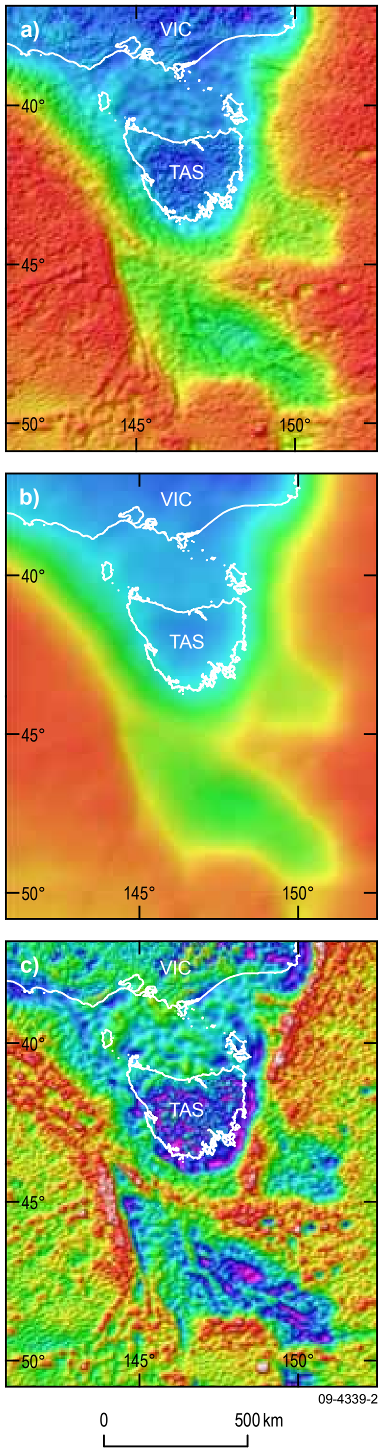

Figure 2. Upward continuation residual filter applied to Bouguer gravity anomaly data for southeastern Australia. The Bouguer gravity anomaly grid at sea level (0 metres; shown at figure 2a) minus the Bouguer gravity anomaly data calculated at 25 kilometres (figure 2b) gives a filtered residual grid of the Bouguer gravity that images the high frequency content of the original data (figure 2c).

Mapping potential field data

Analytic signal phase filters provide a simple method to map the estimated positions of magnetic source bodies (Miller and Singh 1994). The analytic signal of magnetic or gravity field data is an alternative mathematical representation of the data (Nabighian 1972, 1974). It can be used instead of the Reduce to the Pole (RTP) filter to locate magnetic anomalies over source bodies, and in low latitudes is more stable than the RTP filter. The analytic signal has two parts, amplitude and phase. In two-dimensional cases the analytic signal has a number of attractive properties that simplify the interpretation of the magnetic field. In three-dimensional cases this simplification does not occur but the analytic signal is still a useful approach to retrieving geological information from the geophysical signal.

The combination of the analytic signal's amplitude and phase data provides a powerful alternative means to visualise potential field data. This combination proved useful in mapping the fabric of the magnetic data over the deepwater Otway and the Sorell basins and clearly displays the structural fabric of the western Tasmanian margin (Morse et al 2009).

The analytic signal phase data can be used to directly map the approximate position of the anomaly source bodies. Miller and Singh (1994) showed that the analytic signal phase is positive over source bodies and negative otherwise. A geographic information system (GIS) layer of the approximate source body positions can be produced by:

- Calculating the analytic signal phase of the gridded potential field.
- Converting the resultant grid into a binary grid: +1 for positive phase values and –1 for negative phase values.
- Using a raster-to-polygon utility to convert the positive areas to polygons.

Where there are shallow sources, the polygons will tightly map the lateral extent of the source bodies. For deeper sources the source body polygons will be wider, and the deeper the source body the wider the polygon. The method is therefore dependent on the quality of the gridded data used.

The advantage of this method is that it objectively determines the source positions from the magnetic anomaly data with more detail than can be manually interpreted. Figure 4a shows how this method extracts geological detail that could not be manually extracted from the data. Given the limitations of this method, the polygons produce a map that correlates with the known geological features and allows these geological features to be confidently mapped offshore (figure 4b). This method extracts one of the essential information attributes of the magnetic anomaly data—the location of the magnetic source bodies—and provides geological information that can be integrated with other geological datasets (figures 4a, 4b).

The potential field methods described above are just two of a number of methods used to interpret potential field geophysical data. They have proven useful in Geoscience Australia's frontier basin studies and show how geological information can be extracted from geophysical datasets in studies of the continent's southern margins.

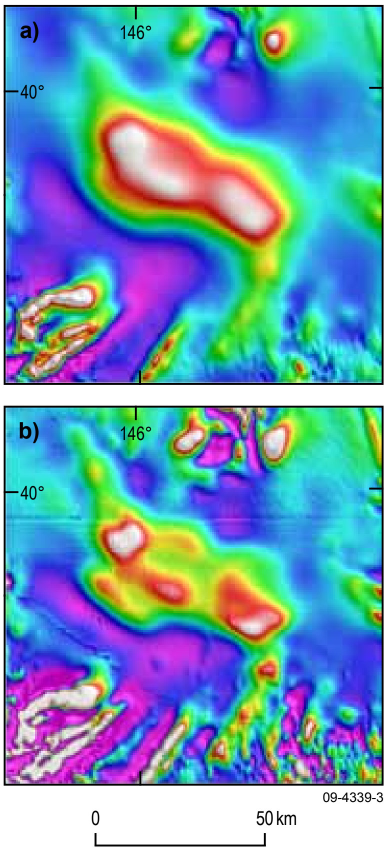

Figure 3. Visualisation of detailed structure of the large total magnetic intensity anomaly located in the middle of the Bass Basin (figure 3a). The UCR filter (0 metres minus 500 metres upward continuation) shows that this large anomaly is made up of a number of separate anomalies which correlate with shallow sills imaged in reflection seismic data (figure 3b).

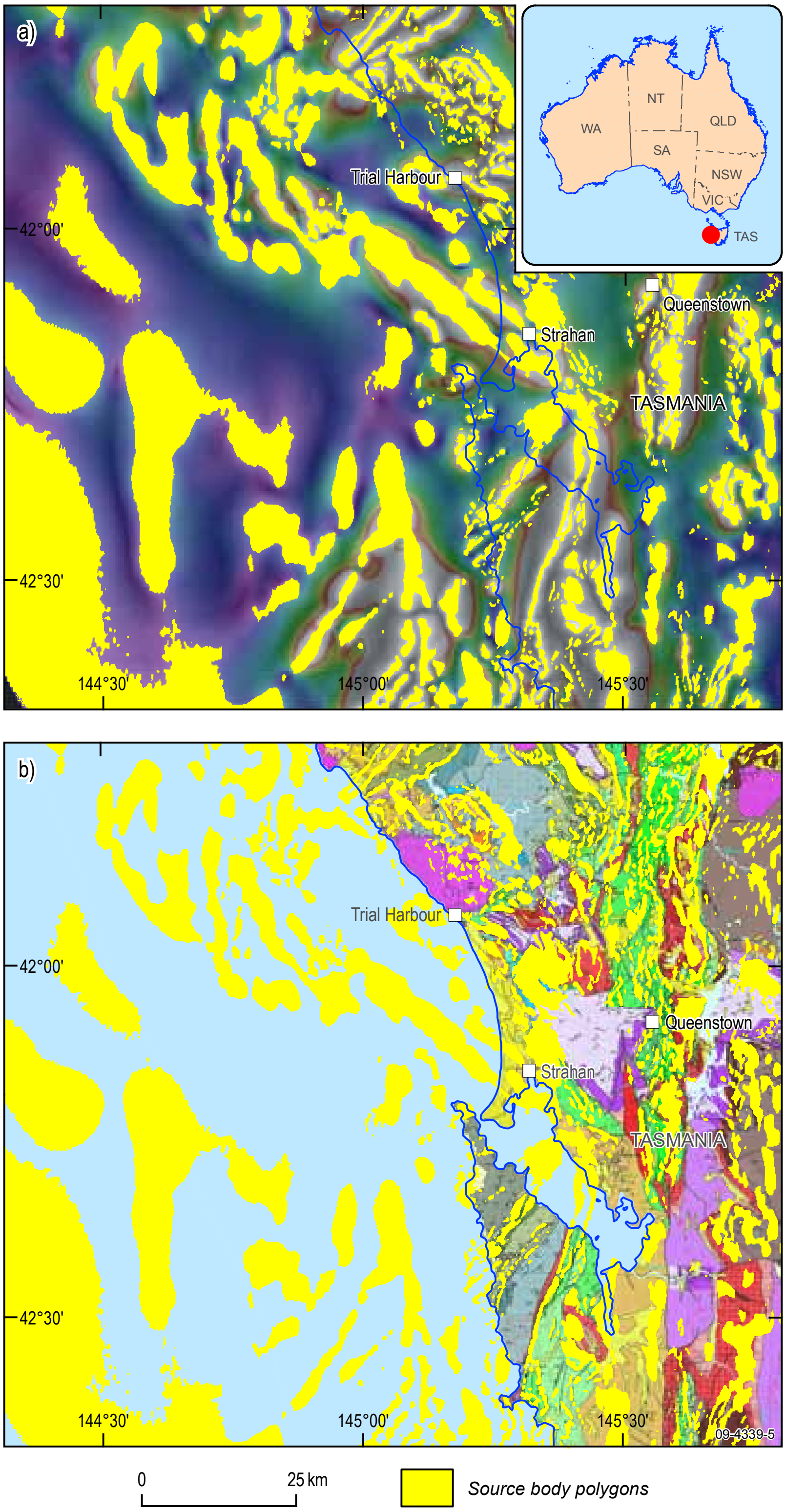

Figure 4. Strahan Sub-basin, western Tasmania: a) source body polygons from analytic signal phase on the analytic signal map; b) source-body polygons on the Tasmania 1:250 000 scale geology map.

For more information

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