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MANTLE-09

A NEW CRUSTAL GRAVITY MODEL FOR TASMANIA

Report by D.E. Leaman

March 2009

MANTLE-09 is a gravity model designed to act as an equivalent source which accounts for the general form of the gravity field across continental Tasmania. The model, when applied to observed Bouguer anomalies, allows extraction of an effective and essentially un-biassed residual gravity field suitable for detailed modelling of geological structures in the upper crust.

MANTLE-09 represents a modern replacement of the previous generation of models (MANTLE88, MANTLE91, MANTLE07). It was also generated in a very different manner and the approach reflects the lessons of the previous two decades and the considerable increase in the data base.

The original mantle separation model, known as MANTLE88 (Leaman, 1988; Leaman & Richardson, 1989a), was created from the detailed local modelling undertaken for the Mt Read Volcanics Project (see Leaman, 1986; Leaman & Richardson, 1989b). A large number of intersecting sections and profiles were used to estimate long wavelength (mantle) source elements and these were accumulated and then shaped as a 3D model. The initial model was well developed in NW Tasmania but weak elsewhere due to lack of data and analysis. This situation was transformed between 1989 and 1991 due to data acquisition in various areas and related analysis for Conga Oil. Much of this development applied to northern and north central Tasmania. Not all of this work was reported but some summaries were provided: e.g., Leaman, 1990; 1991a, b. Further extracts were included in Leaman (1992). As a result of these interpretations the mantle model was revised (MANTLE91).

MANTLE91 proved to be a viable and reliable regional separator and was used for sixteen years, during which time a large number of interpretations dealing with structures and intrusions in western Tasmania were generated. It must be noted that most usage was for features in the core area of highest reliability for the first mantle model: northwest Tasmania.

Although much data accumulated in the period between 1991 and 2007, again mainly in central and northern Tasmania, no adjustment was made to the model. However, during 2007 a block of data was acquired by Kuth Energy in the Eastern Highlands south of Lake Leake and an improved assessment of granites was requested. Modelling led to a revision of the mantle model (MANTLE07).

In all cases, including the 2007 revision, the model was adjusted in a modest manner using regional analysis and no comprehensive state-wide testing (coast to coast) was completed. The model had grown piece-meal and was variable in quality.

The crustal separation models have always been in two parts: oceans and mantle, and the water model was derived from mapping data available in 1975-1980.

There was, therefore, a clear need to revise both parts of the crustal model, that is, to update the bathymetry and then revise and check the entire mantle model. Further, acquisition of substantial data sets on Flinders and King Islands, demand a northward extension of both parts in order to derive residuals for those islands and, perhaps, across Bass Basin.

With the experience of the value of this type of regional-residual separation process, and the importance of a uniform and reliable model, a new approach was taken to create MANTLE-09.

A new water model has been generated (WATER3) from recent national maps using published contours. This water model is most reliable for the Tasmania region and less detail was inserted along the Otway and Gippsland coasts of Victoria. Any further extension of the present model should increase the detail adjacent to Victoria and south of Pedra Branca, south of the Tasmanian mainland.

The new mantle model has been derived solely from analysis of very long profiles (500 to 800 km) which extend from ocean (Southern Ocean) to ocean (Tasman Sea) or Southern Ocean to Bass Strait. The reliability of this analysis depends on the quality of Bouguer data offshore and early phases of the review revealed problems which appear to be related to absence of terrain corrections in available data south of 5350 000 mN. This issue does not seriously affect conclusions drawn about the model, or for its creation, across mainland Tasmania and, in any event, it does not apply north of 5350 N. Further, profiles and calculations are not affected in any clear manner where water depth is less than 200 metres. The offshore data used for this study was taken from early MRT compilations (south of 5350 N) and more recent compilations undertaken for the Victorian government.

The model, based on an array of profiles, selected with no regard to surface geology and with the single objective of best regional fit which is internally consistent, depends on the criteria established by Leaman (1994). The initial evaluation was made with 2D methods and then tested and refined with 3D methods. This approach effects a major transformation of the model in terms of consistency and integration.

The new model extends 150 to 200 km north of Devonport and thus involves the structures of Bass Strait. This is the weakest portion of the model and will be revised once some appreciation of the basin sequence has been derived from seismic data and drilling. This is a significant project study but some preliminary estimates were made in order to check the likely range of depth to mantle in the centre of Bass Strait. The present model thus makes a reasonable estimate of shape in the Bass Strait region but lacks the detail of all other parts of the model.

The model elements, known as WATER3 – calculated at a density of -1.64 t/m^3, and MANTLE9F at 0.67 t/m^3, provide the new regional estimates. Both densities are rated against a Bouguer reference of 2.67 t/m^3 for the crust. These values indicate a bulk density of 1.03 t/m^3 for water and 3.34 t/m^3 for mantle.

The 2D and 3D reviews have established that the density contrasts employed are reasonable and likely. Tests of a higher density (2.8) or graded density crust proved unworkable and unable to explain either the corrected offshore values or the crustal profile beneath central Tasmania.

Residuals may be calculated from the TASGRAV data base using the following equation.

residual Bouguer anomaly = observed BA – (WATER3 + MANTLE9F – 210)

WATER3 plus MANTLE9F constitutes model MANTLE-09.
The scalar of 210 mgal is the consistent value required to provide a best fit of the model to the long wavelength elements of the data base and gross gravity field. The value arises from the thickness of the mantle model, which has a base reference depth of 30 km.

The new model, defined as MANTLE-09, is considered to be a more consistent and reliable solution than previous models. It is shown in Figure 1. Two samples of the long line modelling are given in Figure 2.

There does, however, remain scope for further evolution and improvement. This will require

1: greater detailing of the water model between 1 and 3 km depth,
2: greater detail of the water model at all depths adjacent to the Victorian coast.

These details have been beyond the scope of the current brief and general forms have been incorporated. No such allowance (as for 2) was made in any previous model.

3: full terrain correction of all offshore gravity data and acquisition of more gravity data south of 5350 000 mN.

The present model uses uncorrected older data south of this northing but this does not affect its reliability across continental Tasmania. It does affect assessment ocean-ward of the 200 m isobath.

4: comprehensive regional modelling of sedimentation in Bass Basin in order to assess implied residuals and further detailing of mantle shape beneath such sediment and related structures. This will require integration of gravity, magnetic, seismic and drilling data and has been beyond the scope of the present study.

Bass Basin effects do not affect conclusions and residuals across Tasmania but changes in the mantle model in that region will modify assessments around both King Island and the northern part of the Furneaux Group.

The model process could be extended north into Victoria once item 4 has been completed and N-S profiles which extend as far north as the Great Dividing Range are modelled.

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Report provided by

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March 26, 2009

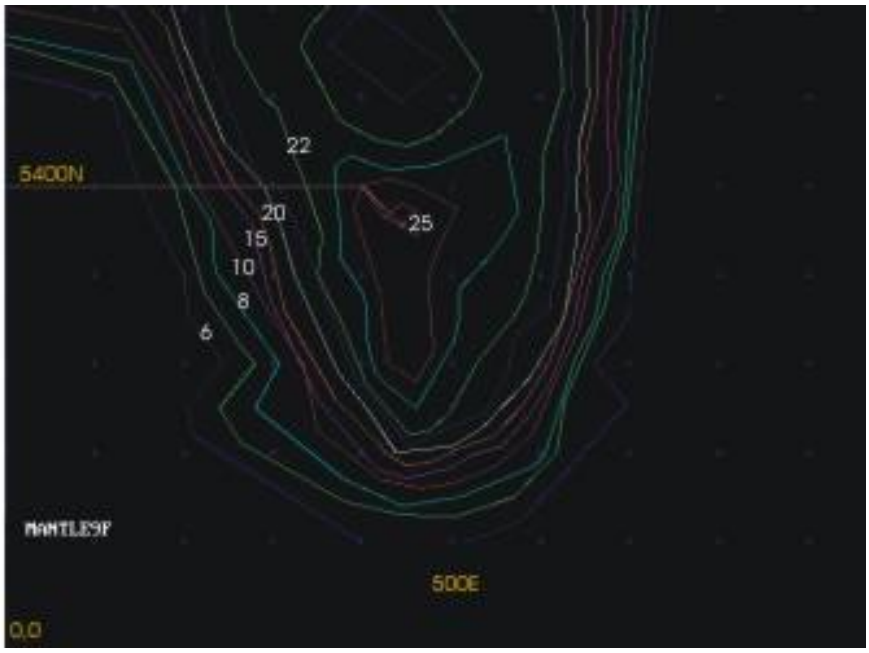

Figure 1
Form of model MANTLE09 for the Tasmania region.
Contours are in kilometres (for depths of 6, 7, 8, 10, 15, 17, 20, 21, 22, 23, 24 and 25 km).
The grid interval is 100 km from an origin of 0E, 0N.

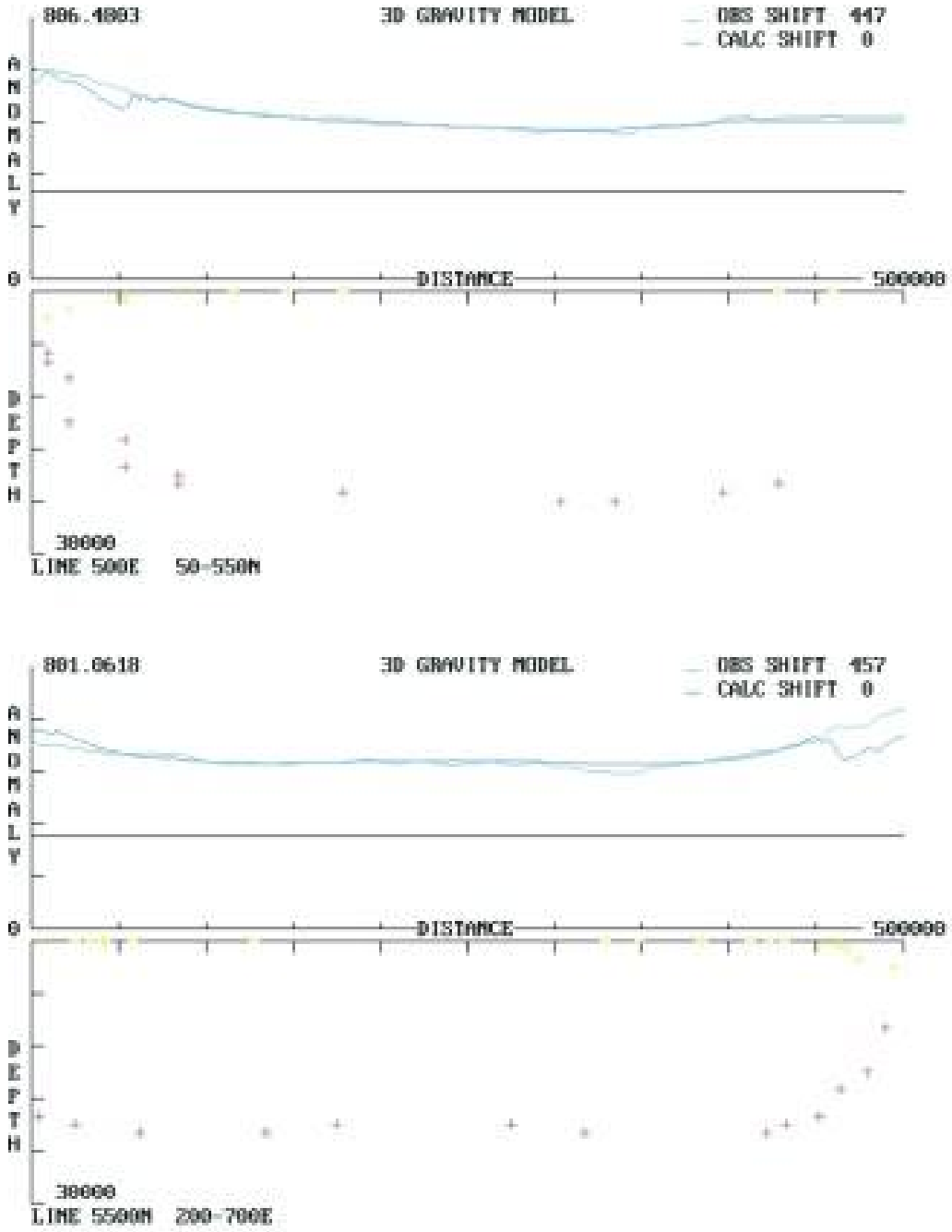

Figure 2.
Two sample sections: at 500 000 mE and 5500 000 mN.
The fit of the model calculation is shown in the upper part of each section and an indication of the shape of the mantle (dark colour) and ocean (light colour) is provided in the lower part.