A GRAVITY SURVEY OF THE SOUTHERN ESK TROUGH, SOUTHEAST QUEENSLAND

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(with 5 Text-figures)

ABSTRACT

Simple Bouguer gravity anomalies, established with an error of ±0.65 mGals at 398 stations in the southern portion of the Esk Trough, have been used to delineate the regional structure of the trough. The fault system which bounds the trough in the east is postulated to be a low angle reverse fault, with its surface expression several km to the west of the mapped location of the Eastern Border Fault. The Western Border Fault System is interpreted as the result of normal-type faulting. It is proposed that wrench-fault tectonics explain most satisfactorily the formation of the Esk Trough.

INTRODUCTION

The Esk Trough is a major structural feature of southeast Queensland; its mode of formation and tectonic relations are clearly important to an understanding of the geological history of eastern Australia. The trough, which trends for over 150 km in an approximately meridional direction, is believed to be a fault feature, bounded to the east by the Eastern Border Fault, and to the west by the Western Border Fault System. However, extensive weathering and poor outcrop in the area have inhibited reliable geological mapping, and the major structural features of the trough are still only imperfectly known.

It was the aim of this gravity survey to eludicate the structure of the Esk Trough in the southern portion. The gravity data were used to investigate the geometry of the basement blocks, with the hope that insight into this, in conjunction with the known geology, would yield further information on the tectonic history of the trough.

The survey extended over a roughly rectangular area, bounded by the meridians 152°20'E and 152°45'E and the parallels 27°00'S and 27°30'S, i.e. roughly that portion of the trough extending from Fernvale in the south to Toogoolawah in the north.

Twenty-nine gravity stations, established by the Bureau of Mineral Resources (BMR) as part of the national regional gravity network, serve to indicate the regional gravity trends, but no other gravity data were available for the area.

The Esk Trough lies between the D'Aguilar and Yarraman Blocks, these consisting essentially of Palaeozoic metamorphic and igneous rocks. The stratigraphic section exposed in the Esk Trough has been divided into the

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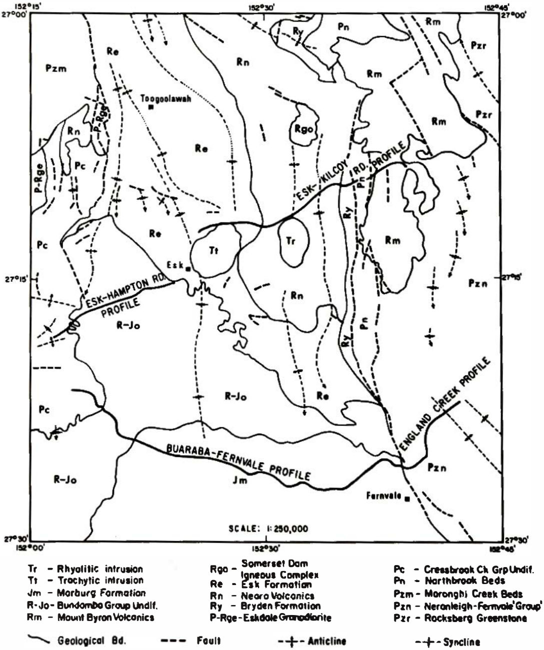


Text-fig. 1 Geology of survey area, showing location of gravity profiles.

Toogoolawah Group and the Woogaroo Sub-group. The Toogoolawah Group consists of the basal Bryden Formation, the Neara Volcanics outcropping mostly in the eastern portion of the trough, and the Esk Formation, occurring mainly in the western section. In the south of the study area, the Toogoolawah Group is overlain by the massive sandstones of the Woogaroo Sub-group. Small inliers of Permian sediments occur towards the sides of the trough, and it is possible that this Permian accumulation is continuous beneath the Triassic sediments of the Toogoolawah Group. Text-fig. 1 shows the broad geology of the survey area; it may be consulted in more detail in Hill (1960); Swindon (1971); Day *et al.* (1974); and West (1975).

FIELD METHODS AND THE REDUCTION OF DATA

The gravity stations were sited in the field at easily identified features which appeared on the Caboolture, Cressbrook, Crows Nest, and Samford Sheets of the 1:63360 Military Maps, which were used as base maps for the survey. Station grid references from these maps were converted to latitude and longitude during the gravity reduction programme. Elevation control was obtained by making use of whatever points of known elevation were available, and extending the control by barometric levelling, employing sets of Baromec barometers and Wallace and Tiernan altimeters. The 398 gravity observations were made with a Worden Prospector Gravity Meter No. 818, using standard reading methods and field procedures. The meter was calibrated on the Brisbane Calibration Range, taking the gravity interval as 58.25 Soviet mGals (Wellman *et al.* 1974). The scale factors determined at the beginning and end of the survey were 0.08649 mGals/scale unit and 0.08643 mGals/scale unit respectively. The former figure was used throughout the survey, which occupied the period from January to July, 1975. Twenty-one base stations established during the survey were tied absolutely to the BMR base station BMR 6402.5312 at Toogoolawah, for which an absolute gravity value of 979106.96 mGals was adopted (Australian National Gravity Respository, BMR).

The reduction of the gravity followed accepted procedures. A Bouguer density of 2.25 g/cm^3 was adopted, and all elevations were with respect to Australian Height Datum. No topographic corrections were applied, and the reduced data for the survey are in the form of simple Bouguer anomalies. However topographic corrections were calculated for selected stations in order to confirm that the neglect of the correction was justified in relation to the prescribed total error. The error in the absolute gravity determinations was found by re-occupation to be ±0.10 mGals, and that of the Bouguer gravity values to be ±0.65 mGals plus the error introduced by the failure to apply terrain corrections (estimated to be generally below 0.20 mGals).

INTERPRETATION OF THE BOUGUER ANOMALIES

The fundamental assumption made in the interpretation of the survey is that each gravity anomaly is associated with a single anomalous mass distribution, and that this arises from a density contrast everywhere constant. The data have not been subjected to filtering, as it was felt that this was unnecessary, the anticipated regional field changes being small with respect to the anomalies. The magnitude of the overall error of the Bouguer anomalies and the generally inadequate knowledge of the geology of the region do not permit detailed modelling of the anomalous mass distributions, and the interpretation presented here has, of necessity, been limited to an expression of the broad tectonic geometry.

The densities adopted for the interpretation were obtained by applying the well-known empirical velocity-density relations of Nafe & Drake (1963), to the seismic P-velocities determined by the Gatton-Caboolture Refraction Seismic Survey (Phillips 1965). To estimate representative densities for major lithological units, the individual densities corresponding to the observed refractor velocities were averaged over the section by weighting in proportion to the appropriate refractor thickness. In this way, the average density of the trough sediments was estimated to be 2.45 g/cm^3, that of the basement rocks at 2.70 g/cm^3, giving a density contrast of 0.25 g/cm^3.

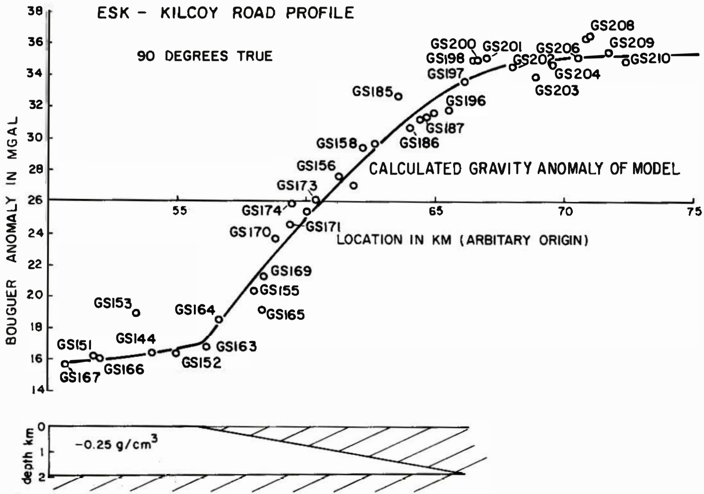
The technique employed for the interpretation of the anomalous profiles followed a curve matching procedure. A programme, based on the algorithm given by Talwani *et al.* (1959), was used to calculate the gravity effect of a polygonal two dimensional distribution of anomalous density, and the polygon was adjusted to give the best match between the observed and calculated gravity effects for a particular profile.

Selected Profiles

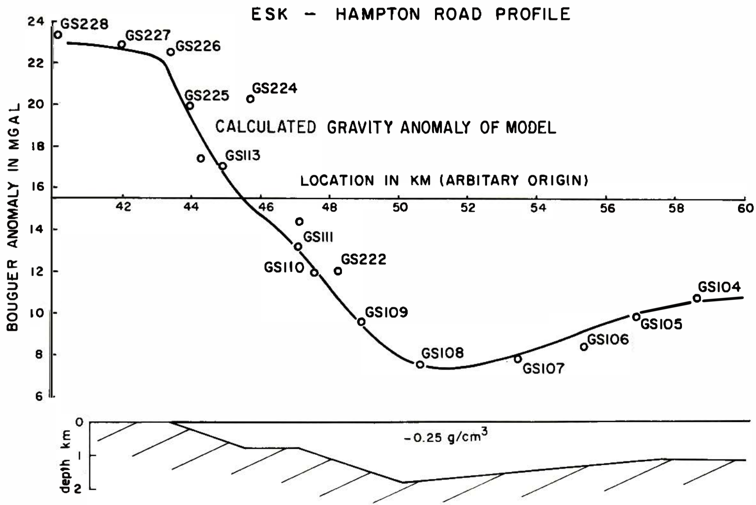
Esk-Kilcoy Road Profile (Text-fig. 2). This east-west profile crosses the eastern margin of the trough south of Somerset Dam. It has the form characteristic of a reverse fault, as the knee with the smaller radius of curvature is on the downthrown, or Esk Trough, side. The model which was fitted to the anomaly infers a ten-degree reverse fault, with an approximate throw of 2 km. The surface expression of this model fault is approximately 5 km west of the previously mapped location of the Eastern Border Fault. (Australia 1:250 000 Geological Series, Ipswich Sheet).

Esk-Hampton Road Profile (Text-fig. 3). This profile transformed to 245 degrees true, crosses the Western Border Fault System. It has been interpreted as the result of normal faulting, the model displaying two normal faults, with an intermediate fault block approximately 1 km in width. The model infers that a particularly deep section of the trough exists immediately east of the Western Border Fault System. The surface position of the westernmost fault given by the model agrees well with the mapped location (Australia 1:250 000 Geological Series, Ipswich Sheet).

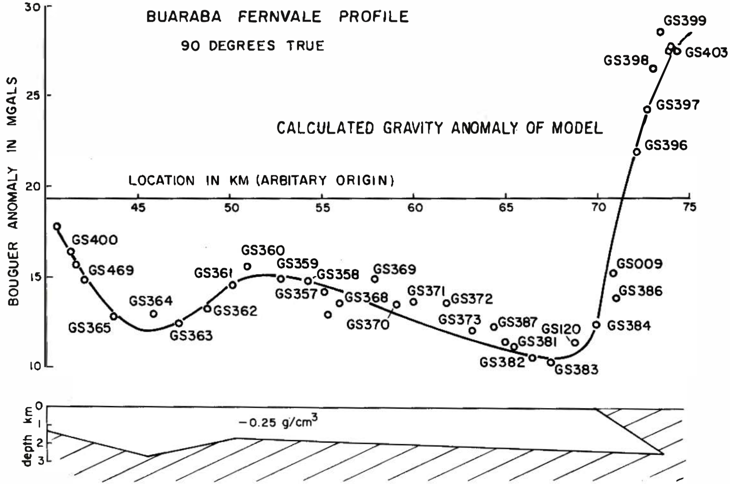
Buaraba-Fernvale Profile (Text-fig. 4). This profile, which runs east-west, displays a regular decrease in the Bouguer anomaly values between GS360 and



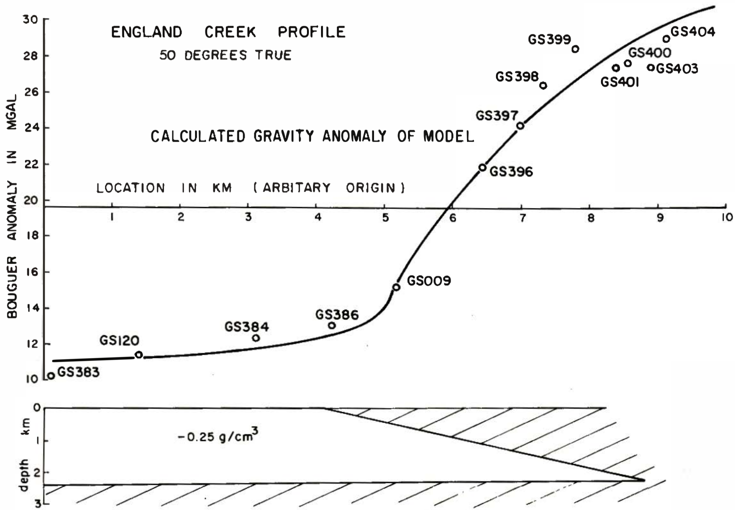
Text-fig. 2 Esk-Kilcoy Road Profile observations (shown as circles) and gravity anomaly of proposed model.



Text-fig. 3 Esk-Hampton Road Profile and gravity anomaly of proposed model.



Text-fig. 4 Buaraba Fernvale Profile and gravity anomaly of proposed model.



Text-fig.5 England Creek Profile and gravity anomaly of proposed model.

GS383, interpreted as indicating a deepening of the trough floor towards the east. This is collaborated by the refraction seismic work done in the area by Phillips Australian Oil Company (1965). To the west, the rise in the floor is terminated in a local gravity high, which has been interpreted as reflecting an arch, designated the Coominya Arch, striking at approximately 060 degrees towards the Eastern Border Fault. It is thought that the arch separates regions in which the basement floor of the trough dips to the east, as shown in this profile, from those where it is either horizontal, or dipping at small angles to the west. The survey did not extend far enough to the west to give an accurate picture of the western border of the trough in the southern region; however, it can be inferred on the basis of extrapolation to be a normal-type fault. The eastern portion of the profile is discussed below.

England Creek Profile (Text-fig. 5). This profile, transformed to 050 degrees true, crosses the Eastern Border Fault in the southern portion of the survey area. It has been interpreted as the result of a reverse fault dipping 31°E. The surface location of the fault model is approximately 3 km to the east of the mapped location of the Eastern Border Fault. This model shows substantial variation from the model for the Esk-Kilcoy Road Profile to the north, and it is suspected that major changes in the character of the Eastern Border Fault occur in the vicinity of Bryden.

GEOLOGICAL INTERPRETATION OF THE MODELS PROPOSED ON THE BASIS OF THE GRAVITY OBSERVATIONS

In the interpretation of the gravity data, emphasis has been placed on those traverses which might be expected to yield information on the nature of the trough boundaries. The Esk-Kilcoy Road Profile was interpreted as indicating a 10° reverse fault, in which the D'Aguilar Block has overridden the sediments of the Esk Trough. While this agrees with the proposal of a thrust fault given by Dunlop (1951), it poses a difficult question if the age of this thrust feature is Late Devonian, as Dunlop suggests. It is therefore thought that a reverse fault, in which the movement occurred either concurrently with, or subsequent to the accumulation of the Triassic sequence, is more likely, although the plane of weakness may have existed since the Late Devonian.

The profile which best defines the Western Border Fault System is the Esk-Hampton Road Profile. The interpretation of this in terms of a system of two normal faults agrees with that given by McDonnell (1956), who stated that the Western Border Fault System is "a system of intersecting vertical and normal faults". Zimmerman (1956) thought that this faulting commenced late in the Permo-Carboniferous, while Dunlop (1951) proposed a Triassic age. Day *et al.* (1974) assert that "continued crustal tension and uplift in the lower Triassic time caused major down faulting", suggesting an Early Triassic age for the normal faulting of the Western Border Fault System.

The attitude of the fault plane for the model of the Esk-Hampton Road Profile is approximately 30°, implying that the planes of this fault and that of the Eastern Border Fault, as shown in the England Creek Profile, are almost parallel, although their sense of displacement is opposite. The Eastern Border Fault is thought to have developed either concurrently with, or after the deposition of the Triassic sediments, though if the deposition preceded the faulting, approximately 2 km of sediments must have been removed from the upthrown D'Aguilar Block. In referring to this fault, but thinking in terms of a very much smaller throw, Zimmerman (1956) stated that ". . . . an enormous amount of erosion would be required to remove them (the Neara Volcanics) from the Esk Beds prior to the deposition of the Bundamba sandstone. There is no trace of andesitic material similar to that of the Neara occurring between the Esk and Bundamba." The possibility that the Bundamba Sandstone, now called the Woogaroo Sub-group, might be the result of the erosion is ruled out on grounds of the extent, constancy of lithology, and mineralogy of this unit. Therefore, it would appear that the reverse faulting could not have occurred after the accumulation of the trough sediments, and that it must have taken place contemporaneously with the Middle Triassic deposition of the Toogoolawah Group.

The difficulty of accounting for the development of major normal faulting in the Early Triassic, followed by major reverse faulting in the Middle Triassic, with the movement on the latter fault having no obvious effect on the former, can be overcome by invoking the hypothesis of wrench faulting. This, however, does not solve all the problems. The deformation of the Triassic sediments does not display the characteristic geometry of the drag folds proposed by Moody & Hill (1956), the folding being dominantly parallel to the margins of the trough. Nor is the upturning of the Triassic and Permo-Carboniferous sediments at the mapped location of the Eastern Border Fault easily explained in terms of this model, as this fault is several km from the postulated surface location of the eastern border fault system of the trough. Furthermore, the 10° reverse fault inferred on the basis of the Esk-Kilcoy Profile is not consistent with the high angle normal-to-reverse faults, thought by Moody and Hill to be associated with wrench faults, or with the sand models of wrench faulting discussed by Emmons (1969).

This last difficulty could be partly avoided if this low angle reverse fault were to be explained as the intersection of the wrench faulting with an older plane of weakness, perhaps that proposed for the Devonian by Dunlop (1951). In these terms the reverse fault could be the result of the trough floor moving down the older weakness during the wrenching movement.

The interpretation of the Esk-Kilcoy Road Profile infers that the surface location of the eastern border fault system of the trough is approximately 5 km to the west of the mapped location of the Eastern Border Fault, and this in turn places the postulated surface location of this fault close to the Caboonbah Fault mapped by Zimmerman (1956). If these two features are identical, then the vertical throw on this fault is of the order of 2 km, not 130 km, as suggested by Zimmerman. It is thought that a thin veneer of Triassic sediments covers the basement block eastwards from the surface location of this fault as far as the location of the Eastern Border Fault.

McDonnell (1956) proposed a basement thrust in the floor of the trough, to explain the localization of the folding in the Colinton Anticline, a median zone of tight folding in the Esk Trough, to the north of the present survey area. A further possibility is that the Caboonbah Fault may, in continuation to the north, correspond to the Stephenson Fault of Jorgenson & Barton (1966). In their photogeological interpretation, these authors advanced evidence to show that the Stephenson Fault separated the Esk Formation and the Neara Volcanics, and was a major median fault which continued over most of the length of the Esk Trough. If this correspondence is correct, then it can be surmised that both these features represent the surface expression of the eastern border fault system. Thus, it is proposed that the "intense zone of median folding" owes its origin to the eastern border fault system, and that the basement "thrust" block proposed by McDonnell is the D'Aguilar Block.

CONCLUSIONS

The speculative nature of the structural analysis proposed on the basis of the gravity data cannot be over-emphasised. It is recognized that further geological and geophysical work will be required in order to either substantiate or modify these ideas. However, it is believed that only by advancing hypotheses, however tentative, can the understanding of the tectonic history of a region be furthered.

In the light of a consideration of the proposed models, and within the framework of the known geology, it is believed that the concept of wrench-faulting (Moody & Hill, 1958; Emmons, 1969; Wilcox *et al.,* 1973) best explains the formation of the Esk Trough. The gravity data give no indication of the sense of the lateral movement of the proposed wrench fault, although Dr M.M. Wilson (personal communication, 1975), on the basis of wider geological observations, suggests that it may be right lateral. The concept of wrench-fault tectonics advanced here for the Esk Trough is in agreement with the theorems of strike-slip faulting proposed by Scheibner (1974). However, it is clear that a full assessment of the feasibility of such a mechanism must await further study of the area, directed in particular towards the identification of geological features characteristic of wrench faulting.

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