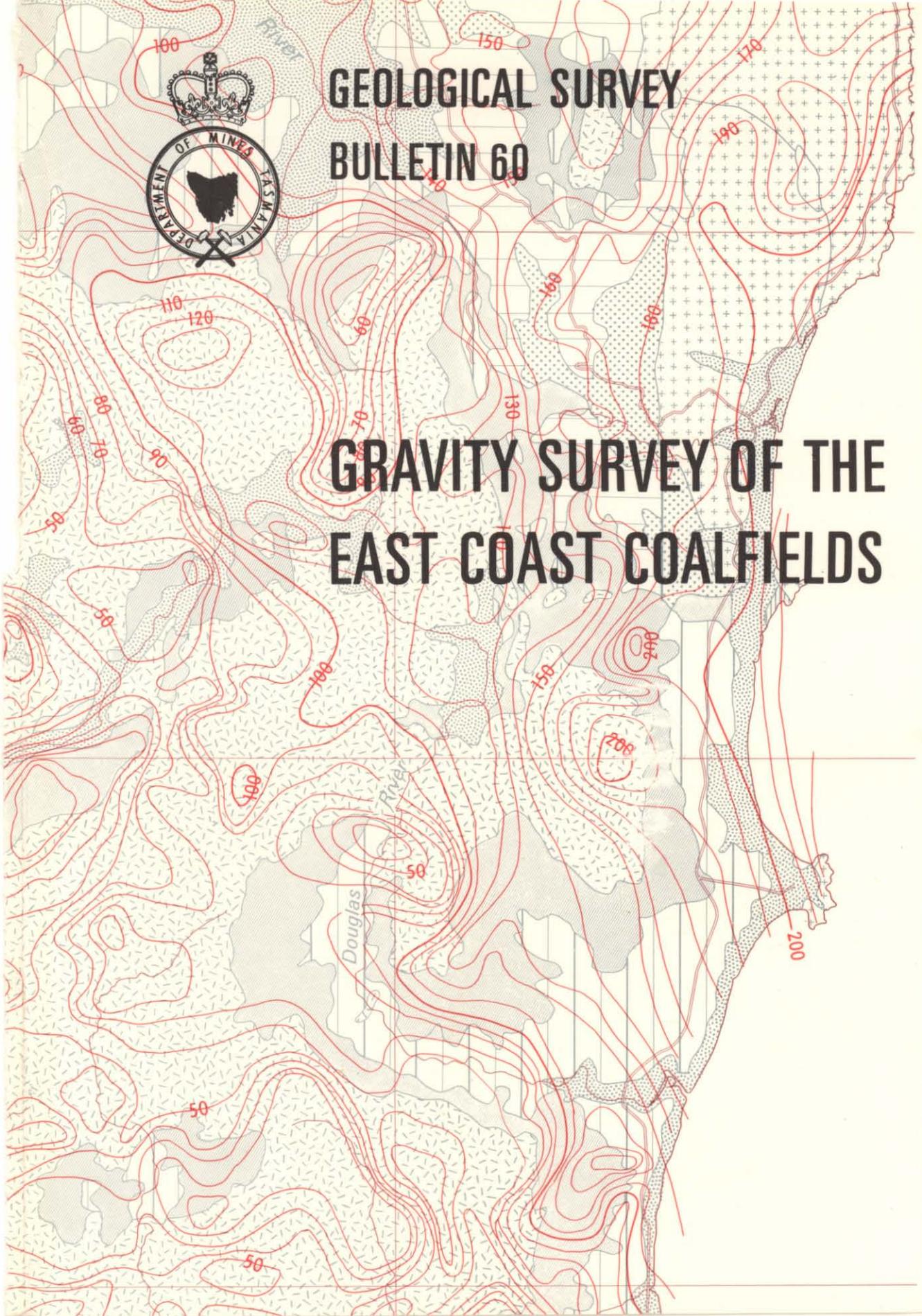




# GEOLOGICAL SURVEY BULLETIN 60

# GRAVITY SURVEY OF THE EAST COAST COALFIELDS



G5B60



TASMANIA DEPARTMENT OF MINES

GEOLOGICAL SURVEY  
BULLETIN 60

Gravity survey of the  
East Coast coalfields

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## ABSTRACT

A regional gravity survey between Swansea, Lake Leake, Rossarden and Falmouth in eastern Tasmania has confirmed that the coal and limestone-bearing Permo-Triassic rocks are deposited on a varied basement with high relief, revealed some major faults and a number of Jurassic dolerite feeders. Prime areas for coal assessment, where the coal measures are thickest, are Nicholas Range, St Marys-Dalmayne, central to east Fingal Tier, Apsley-Douglas Rivers interfluvium and Lynes Sugarloaf-Llandaff. In all other areas basement relief or dolerite intrusion has foreshortened or terminated the section.

A detailed survey of the Fingal Tier State Reserve (1964/167) has defined dolerite feeders, dolerite cap thickness variations and specified definite exploration target zones.

## INTRODUCTION

A reconnaissance exploration programme directed at coal resources has been underway in eastern Tasmania for two decades. Drilling has been the only technique utilised for most of that period. In later years, from about 1972, as drilling and site selection problems mounted and as demands to accelerate reserve estimation, or at least identify promising areas, increased it became obvious that additional methods must be used. Budgetary and manpower considerations were limiting factors in any proposals to develop the exploration programme.

Gravity or seismic reflection methods, in association with detailed geological mapping, offered the only chance of an advance in the difficult terrain and geology of the region. In 1973, when these options were considered, only the first and last were possible. The gravity survey was begun immediately. Whole area and detailed Fingal Tier coverages were completed late in 1978 and March 1980 respectively.

Problems of access, vegetation, manpower and priority affected both surveys. Experiments with magnetic methods were also begun about the same time in order to improve boundary location, as the presence of substantial talus deposits makes reliable mapping of dolerite-coal measures-talus boundaries difficult.

Reflection methods, which offer the greatest promise for overall structural resolution and definition within the coal measures, have now realised pre-production status. Evaluation of magnetic and reflection surveys will appear in separate unpublished reports. It should also be noted that both the gravity and reflection methods have application - resolution deficiencies which are largely overcome when the techniques are combined. The strength of the gravity survey rests in its areal coverage and its weakness in consequent ambiguity, whereas the reflection data is line controlled and lateral effects may hinder interpretation.

This report details both the primary gravity survey undertaken over an area in central eastern Tasmania, which includes every major east coast coalfield (refer Hills *et al.*, 1922) and the only operating mines, and a secondary survey on the Fingal Tier core area adjacent to the Duncan mine.

The surveys were intended to provide information about:

- (a) basement structures
- (b) dolerite structures
- (c) sedimentary basin structures

Perhaps the most important of these objectives is the second, as dolerite sheets cap or transect the coal measures in every coalfield zone. Gravity surveys are proven in dolerite applications (e.g. Leaman, 1972). If areas with concordance, transgressions or feeders could be located, the drilling programmes could be revised to yield results more economically and with minimised drilling of dolerite. The whole area is known to have some basement relief and in some extreme cases the Triassic coal measures may rest on pre-Permian basement rocks. Thus information on the entire sedimentary basin and the sedimentary sandwich contained between a variable basement and an unpredictable dolerite capping can be provided.

The area covered by the primary (or regional) survey includes the Mount Nicholas-Fingal-Dalmayne coalfield, the Seymour-Douglas River-Denison Rivulet-Mt Paul coalfield and the Avoca coalfield (see Hills *et al.*, 1922 for subdivisions). The survey extends to exposed pre-Permian rocks, in all but the south-west corner, in a region characterised by high relief, often dense vegetation and, until the advent of wood-chipping, poor access. Some previous surveys have included this area (Cameron, 1967; Johnson, 1972; Zadoroznyj, 1975), but in each case the coverage was very coarse and uneven. No previous data are included in this presentation.

Qualitative and quantitative interpretations are provided for each survey.

## SUMMARY

### GEOLOGY

A summary of the available geological mapping is presented in a simplified form in Figure 1. This information has been drawn from incomplete mapping by R.H. Castleden, N.J. Turner, C. Calver, D.E. Leaman, D.J. Jennings and the Launceston and Oatlands 1:250 000 map sheets. The compilation is rather uneven as a result.

Several materials of economic interest occur within the area covered; Triassic coal, Permian limestone, Devonian tin-tungsten and gold deposits.

For the purposes of this report, basement rocks are the folded sandstone, shale, quartzite and slate of the Ordovician-Devonian Mathinna Beds, which have been intruded by a range of granitic rocks. These are unconformably overlain by Permian rocks, and sometimes by Triassic rocks, and all are intruded by large sheets of Jurassic dolerite, although most dolerite has intruded the Triassic succession. Some significant Tertiary basin deposits occur in the Swansea region. Faulting is ubiquitous, but not readily located or specified.

## GRAVITY FIELD

### Survey details

	<i>Regional coverage</i>	<i>Detailed coverage</i>
Station spacing	750-1000 m	250-400 m
Elevation accuracy	<1-2 m	1 m
Bouguer accuracy	<3-4 $\mu\text{m/s}^2$	<3-4 $\mu\text{m/s}^2$
Location accuracy	<50-100 m	<20-50 m
Terrain correction	calculation radius 19 km	
RMS accuracy	<4 $\mu\text{m/s}^2$	<4 $\mu\text{m/s}^2$
Bouguer density	2.67 t/m <sup>3</sup>	2.67 t/m <sup>3</sup>
Base station	6491.9136 St Helens airport; 9.8030235 m/s <sup>2</sup> (10 $\mu\text{m/s}^2$ = 1 mgal)	

### Bouguer anomalies

The observed Bouguer anomalies are shown in Figures 4 and 5 and include a substantial regional component. Attempts have been made to establish the most reasonable separation compatible with project aims, and a 4 km grid average separation has been used for the regional survey. The interpretation is thus based on a 4 km residual (fig. 8). Contrast of regionals calculated for 4 and 16 km grids has allowed a review of upper crustal basement structures and, in particular, the definition of granite stocks and sheets (fig. 11).

However assessments for the detailed survey have been more refined and a 3 km separation appears to provide the best residual data, especially for an evaluation of dolerite/coal measures interactions on Fingal Tier. Two or four kilometre separations might be appropriate in other regions, depending on section scale and rock proportions.

### Interpretation

Three distinct interpretations have been provided. The first deals with gross upper crustal features and is directed particularly at granitic forms. The southern extension of the Scottsdale Batholith is shown to close and trend south-westward, while a separate substantial stock has been located west of Bicheno. The extent and form of these intrusions is shown in Figure 11, where they appear as marked negative anomalies.

The two other interpretations relate especially to the dolerite/coal measures problem. The first assesses the entire area, while the second is focussed on Fingal Tier. In each case qualitative and quantitative evaluations have been made, the latter being as extensive as funds permitted.

### Bulk wet densities

Quaternary talus	: 2.20-2.40 t/m <sup>3</sup> (estimated)
Tertiary sediments	: 1.92
Jurassic dolerite	: 2.83
Triassic coal measures	: 2.35
Permian sequence	: 2.47 (average estimated)
Devonian granite/adamellite	: 2.62
granodiorite	: 2.70
Ordovician-Devonian Mathinna Beds	: 2.57-2.81

### Useful anomaly contribution rates

The following table refers to the absolute contributions made by various materials to the observed or residual Bouguer anomalies. Summation of various components can provide an estimate, assuming two dimensional conditions, of the anomalies to be anticipated at any point.

Quaternary talus	- 17.6 $\mu\text{m/s}^2$ per 100 m
Tertiary sediments	- 31.4
Jurassic dolerite	+ 6.7
Triassic coal measures	- 13.4
Permian sequence	- 8.4
Devonian granite	- 2.1
Devonian granodiorite	+ 1.3
Ordovician/Devonian Mathinna Beds	- 4.2 to + 5.9

Thus a section containing 100 m of talus, 150 m of dolerite, 350 m of coal measures and 100 m of Permian rocks would yield a residual value of  $(- 17.6 + 10 - 46.9 - 8.4) - 63 \mu\text{m/s}^2$ , which can be compared with other values (presuming a consistent basement, if excluded from the calculation).

### The regional survey

The major anomalies may be summarised as follows:

#### Positive anomalies

- (a) Significant anomalies of + 40 to + 60  $\mu\text{m/s}^2$  occur near Cranbrook [EP885487], King Bay [EP935420], Moulting Lagoon [EP970470], south Mt Henry [EP810625], West Swan River [EP770630], Swan River [EP900605], Mt Puzzler [EP900780] and Fingal south [EP750810].
- (b) Lesser anomalies occur in Fingal Rivulet [EP830870], south of St Marys [EP955880], west of Seymour [FP060778], west of Bicheno [FP070615], in the headwaters of the Elizabeth River [EP660565] and along the dolerite-capped divide between the Apsley and Douglas Rivers.

#### Negative anomalies

- (a) Several major anomalies in excess of - 50  $\mu\text{m/s}^2$  have been noted. Two transect the line of Nine Mile Beach [FP000390, EP892380], others correlate closely with the Nicholas Range [EQ920005], near Gray [FP015912], Douglas River [FP000785], south Royal George [EP730650], West Swan River [EP798610], Cygnet River [EP810576], Rossarden [EP620860].
- (b) Lesser anomalies occur north of Mt Henry, on Fingal Tier, north-west of Merrywood, Mt St John and Gilbert Dick Hills.

Consideration of the contrasts and contribution rates presented above will show that substantial negative anomalies can only be derived from the geology of this area if there are thick talus or Tertiary deposits, or if the Permo-Triassic section is very thick, especially the Triassic part. The anomalies at Nine Mile Beach can be directly related to Tertiary basins (seismic control). Other anomalies represent thick sections and it is in such sections that coal will be present (if at all) and to be free of disruption by intrusion. Such zones are therefore prime

targets for exploration.

Where large positive anomalies occur, large accumulations of dolerite are implied with concomitant absence of sedimentary section.

Where the anomaly range is - 20 to + 10  $\mu\text{m/s}^2$  the situation may be confused, since it is possible to have many combinations of dolerite and coal measures which could yield such values. For example:

200 m Jd	+ 13.4	400 m Jd	+ 26.8	350 m Jd	+ 23.9
100 m R	- 13.4	200 m R	- 26.8	250 m R	- <u>33.5</u>
100 m P	- <u>8.4</u>	100 m P	- <u>8.4</u>		- 9.6
	- 8.4		- 8.4		

Values in excess of 0 imply much dolerite, thin sedimentary sections over-all or much dolerite and much sedimentary section. Each area has to be examined individually in relation to its anomaly distribution.

Figure 13 summarises the qualitative interpretation within the ambiguous constraints indicated above. The available spread of drilling control, though sparse, is sufficient to suggest that the indications are reasonably reliable. The unhatched area inside the basin extent boundary is likely to contain a substantial Permo-Triassic section. The gravity survey cannot easily discriminate those regions where local and extreme accumulations of Permian rocks may bias the interpretation. But, in general, it does show those areas in which a thick Triassic section is present and where, therefore, the likelihood of finding coal bearing rocks is enhanced. The qualitative assessment indicates the major dolerite feeders and substantial sheet thickenings, but no faults have been certainly identified by such a treatment.

The original version of this figure (fig. 7 in Leaman, 1978) carried a similar legend but gave more detail about basement and section thicknesses. It also showed exploration zones described as 'prime' and 'good' target areas, or regions where the dolerite cap was very thick. The present figure (13) is simpler because the residual separation on which it is based largely excludes basement influences. A 4 km grid average has been used to derive Figure 13 whereas a 16 km grid average was used to derive the old Figure 7. Consequently basement details are discussed separately (fig. 11, pp 16). In addition, the change of regional grid filter improved the resolution of feeders and thick sheets since these are relatively shallow high contrast features. Several such features may integrate to produce a false impression. Consequently the qualitative interpretation provided in Figure 13 is more accurate but still conservative. The general picture for the northern part of the coal-bearing region, north of grid 700 (5370000mN), of a thick sedimentary section with several feeders and variable sheets is certainly supported by the quantitative interpretation. It may be expected that all the unhatched areas on Figure 13 contain a substantial, potentially coal-bearing, sequence. The refined Fingal Tier interpretation suggests that much of the hatched areas may also be coal-bearing. The actual type or extent of intrusion, and whether the coal-bearing part of the section has remained unaffected, is indicated by the absolute value of the residuals. Values in excess of + 10  $\mu\text{m/s}^2$  imply a high risk of section loss and Figure 13 is drawn on this basis.

Previous discussions (p. 9) have shown, however, that misleading values are possible for the range - 20 to + 10  $\mu\text{m/s}^2$ , depending on the

proportions and substance of a particular section. Thus some geological controls must also be applied. Considering the few available sections and drill holes it may be concluded, in association with the unhatched areas of Figure 13, that the best coal potential lies east of grid 850 (585000mE) and probably north of 650 (5365000mN). This does not imply that mineable coal is present, merely that the Triassic section is substantial. This is clearly not so north of Royal George and west of grid 850, although a portion of this area contains a section, which though thin overall, is dominated by sedimentary rocks. It is not likely to offer much potential for coal exploration. Similar comments apply to the zone south of Royal George but north of the West Swan River and west of grid 850. South and immediately north of the West Swan River the position is unknown. The survey suggests a section dominated by sedimentary rocks, but the Triassic or coal measures content of this section is unknown. The exploration potential cannot be assessed without some drilling being sited on key negative anomalies within the region.

Figure 13 also shows the extent of Triassic rocks, which in the north-east of the area are coal-bearing. This situation cannot be expected to persist south-westward since the Triassic succession in the Midlands is known to contain a substantial basal component lacking coal units. Consequently only those zones in which the section appears thickest will be attractive for coal exploration. These will be associated with the larger negative anomalies.

The provisional interpretation provided is limited by the current levels of geological knowledge and the constraints of the gravity survey. Some ambiguity is inevitable where control points are very widely spaced or are not correlated with established units or features. Particular refinements are made possible by quantitative assessments or more detailed coverages. Comparison of the regional and detailed interpretations of Fingal Tier indicates the relevance of the latter factor.

Figure 20 offers a quantitative assessment of a large core area centred on Fingal Tier. It confirms the presence of a substantial and general thickness of Triassic rocks (average 300 m) and shows that the feeders are smaller than the distribution and scale of positive anomalies might imply qualitatively. In addition, some major faulting, including grabens, is implied with significant disruption of the sedimentary succession. Disturbance of the dolerite cap is not as certainly indicated and much of the faulting may be Jurassic in age. Major faulting appears to be restricted to the region east of Bare Rock to Mt Puzzler (or outside the State Reserve).

Quantitative methods used have been based on a complex equivalent mass - continuation procedure. Since many of the anomalies occur in the topography, above the reference geoid, a means of balancing and sorting sources had to be found. This was done by calculating a set of masses which could yield the observed field. By forming them at some depth below the geoid (a depth set by computer speed algorithms) they could then be used to provide a field distribution above the land surface. Thus the geology could be modelled with an upper horizontal surface and an irregular, but known, first layer of air. Model procedures require a horizontal surface, usually the geoid. Models can be compared with the continued field using three dimensional functions. Two dimensional functions are clearly invalid generally and are only useful as rough guides.

### Detailed survey, Fingal Tier

The observed Bouguer anomalies are shown in Figure 5 and have been analysed by filter methods and continuations. The most relevant filter, on theoretical and observed practical grounds, for the principal aims of the survey, is that based on a 3 km grid. It is shown as part of a set in Figure 24, separately in Figure 31, and describes the form of the capping dolerite sheet. A 50 m variation in sheet/sedimentary section thickness is equivalent to one contour if the variation is extensive or two dimensional. For the major part of the area, the rule

$$\text{dolerite thickness} = 5 \times \text{anomaly} (3-0, \text{ in } \mu\text{m/s}^2) + 310 \text{ m}$$

applies given these conditions or allowance for them. For the far eastern part of the area, across the faults implied in the regional coverage, the rule is modified to

$$t = 5 \times A + 200$$

These rules are intended for use as guides only.

The filter treatment and the residuals obtained, especially 3-0, 3-1 (figs. 23, 24, 31) define the feeders, major accumulations of sedimentary rocks and regions where the capping sheet is thinnest. These are summarised in Figure 30.

Faulting is also implied. However, analysis of feeders and faulting is best made by consideration of continuations and the distribution and proportion of the equivalent masses. Although these are biased toward the observation points, there is an improved definition of feeders and the large 'feeders' are shown to be multiple structures. Several smaller anomalies may represent small pipes and certainly the sites of possible location of such features is established (fig. 30). Faulting may be inferred from some of the gradients or anomaly distributions.

### CONCLUSIONS

The regional survey has identified a number of exploration targets (coal-bearing rocks) in the east coast coalfields. Some were previously unsuspected, while others are more substantial than suggested by earlier workers. It has also indicated major dolerite and basement structures. Prime coal exploration targets are south-east of the Duncan mine, south of Dalmaine, west of the Douglas River, around Lynes Sugarloaf, around Mt St John and south-west of Mt Henry.

On Fingal Tier, the detailed coverage has defined feeder systems, potential producing areas, major faults and may now serve as a principal guide to exploratory drilling and optimum hole siting.

The interpretation presented is not considered by the authors to be final. It does, however, represent a qualified guide for future exploration of all kinds. Clearly, regional mapping and additional drilling will enable future revisions and refinements. Control across large tracts is certainly required, including some definition of pipe or dyke sizes which would allow more direct use of the continuation residuals.

Detailed regional mapping, with deep spot drilling, of the entire area is recommended.

## GEOLOGY

A summary of the available geological mapping is presented in a simplified form in Figure 1. This information has been drawn from incomplete mapping by R.H. Castleden, N.J. Turner, C. Calver, D.E. Leaman, D.J. Jennings and the Launceston and Oatlands 1:250 000 map sheets. The compilation is rather uneven as a result.

Several materials of economic interest occur within the area covered; Triassic coal, Permian limestone, Devonian tin-tungsten and gold deposits. Geographic locations are shown in Figure 10.

### STRATIGRAPHY

#### *Ordovician-Devonian*

The Mathinna Beds, a series of sandstone, shale, quartzite and slate possibly more than 5 km thick, range in age from Early Ordovician to Early Devonian. The major exposure is north and west of Fingal-St Marys, although significant exposures occur south of Bicheno. Metamorphic effects are generally slight unless a major intrusive boundary is within about a kilometre.

Granitic rocks of late Devonian age occupy large tracts around the periphery of the area near Avoca, Royal George, St Marys and Bicheno.

For the purposes of this discussion all the above-mentioned rocks have been termed basement rocks and they form an irregular base for Permo-Triassic deposition, especially south of the Break O'Day valley.

#### *Permian*

Fossiliferous sandstone, shale, limestone and unfossiliferous siltstone, grit and conglomerate unconformably overlie the basement rocks. The best sections are in the Mount Elephant region (McNeil, 1965). The thickness of these rocks varies from nil to about 250 m.

#### *Triassic*

Quartz and feldspathic sandstone and mudstone overlie, usually disconformably, the Permian succession. In some areas Triassic rocks rest unconformably on basement. The Triassic sequence, which may contain lithic arkose, also includes several coal seams which occasionally exceed two metres in thickness. The succession may exceed 400 m in thickness.

#### *Jurassic*

Dolerite has intruded the Permo-Triassic sedimentary rocks as large dykes and sheets. Some small dykes have also been mapped. Mapping by the senior author suggested, but could not confirm, the presence of feeders at St Marys-Gray, Fingal Rivulet, Seymour and Lochaber. Most intrusion has occurred in Triassic rocks.

#### *Tertiary*

Sand, clay and laterite deposits occur in the Swansea region. The thickness of the deposits probably exceeds 300 m. No basalt is known to be associated.

## Quaternary

Alluvial deposits occur in all river valleys and in some cases braided gravels may be found. Most slopes, in those parts of the area where dolerite caps the highlands, have valley sides covered in a variable but often thick veneer of talus. Block sizes may locally exceed ten metres across. Marsh deposits are also common above 500 m.

## STRUCTURE

The structure of the region is dominated by the igneous intrusions of Devonian and Jurassic age. The western margin of the surveyed area is provided by the Scottsdale Batholith and its extension to Royal George. The eastern margin, the coast, is marked by a series of topographically dominant lesser intrusives. Inland, Jurassic dolerite disrupts and caps the coal-bearing sequence and dominates the entire area.

The Mathinna Beds are intensely folded but no consistent structural pattern is evident due to disruption and subsequent cover. A clear unconformity occurs at the base of the Permian rocks and, although it appears to occur at a consistent level north of Fingal, it is very irregular to the south. The extent of faulting cannot be appraised since faults are not easily identified. Several faults have been inferred (e.g. by Threader, 1968) but few have been confirmed. Three structural trends are evident; east-west, north-south and north-west - south-east (Williams, 1967, 1969).

Two major features (faults presumed) define the area; the Castle Cary Fault to the west of Avoca and the coastal structure which extends north from Freycinet Peninsula to Seymour. In each case granitic rocks are juxtaposed with coal measures. The precise form of these features has not yet been established.

## GRAVITY FIELD

### SURVEY DETAILS AND ACCURACY

The gravity surveys presented here were intended to provide a general semi-detailed coverage of central eastern Tasmania and a specific coverage of the Fingal Tier region.

It was essential that the primary survey cover a large area in order that full appraisal of the coal-bearing areas and basement influences be possible. Adequate detail was also necessary if dolerite structures were to be recognised and if areas were to be selected for further detailed work. A nominal station spacing of 750-1000 m was chosen as a reasonable compromise between these objectives and to allow the work to be completed in a reasonable time. Access and manpower restrictions resulted in a five year project.

The more detailed Fingal Tier coverage is based on a nominal station spacing of 250-400 m and required an additional year to complete.

The base station for both surveys is at St Helens Airport (Bureau of Mineral Resources 6491.9136;  $9.8030235 \text{ m/s}^2$ ). A tie station network consisting of nineteen points was established and corrected for loop errors by the methods of Gibson (1941) and Green (1961). All other observations have been tied to this network and corrected for drift. No specific tidal correction has been included. The accuracy of the tie

station network is considered better than  $0.2 \mu\text{m/s}^2$  and of all other stations  $0.3\text{--}0.5 \mu\text{m/s}^2$ . Details of the tie stations are provided in Appendix 1.

Stations have been sited, where possible, on State Permanent Marks or Lands Department spot heights. About one half of the stations are based in this way. Elevations at other stations are based on high water mark or microbarometer ties to spot heights. Where loop times are short, spot control is available and check readings can be made during the traverse; an accuracy of  $1\text{--}1.5$  m is possible. The elevation of stations is accurate to one metre in many instances or better than two metres in nearly every case. The accuracy of the Bouguer anomaly is better than  $3\text{--}4 \mu\text{m/s}^2$  for more than 95% of each coverage.

All stations have been located within  $50\text{--}100$  m and several stations have been located to within  $20\text{--}50$  m. Stations of the detailed coverage are located within  $20\text{--}30$  m. The maximum positional error in the Bouguer anomaly is about  $0.5 \mu\text{m/s}^2$ .

All stations have been terrain corrected to a radius of  $19$  km using the method of Hammer (1939). The accuracy of the correction made is estimated at 5% for most stations. The maximum resultant error is estimated at  $0.2\text{--}1.0 \mu\text{m/s}^2$ .

The RMS accuracy of the reduced observations is thus less than  $4 \mu\text{m/s}^2$  and the Bouguer anomaly has been plotted with a contour interval of  $10 \mu\text{m/s}^2$  (1 mgal).

The station numbering and distribution is shown in Figure 2 (full coverage) and Figure 3 (Fingal Tier). Acknowledgment is due to G. Benn, D. Wyatt, T. Andrews, P. Lennox, G. Hodge, R. Munro, J. Knight, J. Lister, E. Johnson, J. Richardson, M. Triffitt, C. Harris and G. Humphries for their contribution as observers and assistants during this survey.

## BOUGUER ANOMALIES

### *Specification and presentation*

The results of each survey have been expressed in terms of the extended Bouguer anomaly with an assumed density value of  $2.67 \text{ t/m}^3$ . The reduced values have been contoured and are shown in Figure 4 (primary cover), and Figure 5 (Fingal Tier) with a contour interval of  $10 \mu\text{m/s}^2$ .

### *Regional separation*

The Bouguer anomalies plotted in Figure 4 show a general increase in the gravity field from west to east which reflects a thinning of the crust toward the continental shelf. The term regional may be applied to that component of the field derived from the core, mantle and lower crust. Alternatively, given the wide spectral range of the anomalies, it could be applied so as to include all but the uppermost part of the crust.

Previous gravity surveys (Leaman, 1972; Leaman *et al.*, 1973; Leaman and Symonds, 1975) have examined residuals after extracting a coarse regional and this has proven adequate. However, in view of the considerable economic importance of this survey, two regionals have been calculated; they are shown in Figures 6 and 7. The regional shown in Figure 6 is based on a maximum grid size of  $4$  km units while that in Figure 7 uses  $16$  km units. The grid-average process is a crude but effective filter and comparison of

Figures 6 and 7 will confirm this (see also St John, 1967; Leaman, 1977 and page 47). A uniform distribution of points is desirable for effective filtering and two other problems may be noted; selection of an appropriate grid size, and edge effects. The BMR regional survey coverage (Zadoroznyj, 1975) offers some control of the latter and thus the regionals presented here cover the entire surveyed area.

Experience has shown that the 16 x 16 grid is adequate where interpretations to around 5-10 km are undertaken. The problem of extreme basement variations and the need to evaluate only the upper 500-1000 m suggests that a 4 x 4 grid is more appropriate for this survey.

#### *Description of residual anomalies*

Figures 8 and 9 present the residual Bouguer anomaly obtained from the total field for the full survey (fig. 4) by removal of the regional contributions calculated with 4 x 4 and 16 x 16 km grids (figs. 6, 7). There are substantial differences between Figures 6 and 7 and it will be noted that the separation using the 4 x 4 km grid has removed much shallow basement interference and improved definition of all features marginal to the Permo-Triassic basin. In particular, it will be observed that the negatively attracting crustal feature west of Bicheno has been minimised, allowing near surface features to be identified (compare features figs. 6, 7, 8, 9).

The following discussion and subsequent interpretation is based on the residual Bouguer anomaly (4 x 4) (fig. 8).

#### *Positive anomalies*

- (a) Significant anomalies of + 40 to + 60  $\mu\text{m/s}^2$  occur near Cranbrook [EP885487], King Bay [EP935420], Moulting Lagoon [EP970470], south Mt Henry [EP810625], West Swan River [EP770630], Swan River [EP900605], Mt Puzzler [EP900780] and Fingal south [EP750810].
- (b) Lesser anomalies occur in Fingal Rivulet [EP830870], south of St Marys [EP955880], west of Seymour [FP060778], west of Bicheno [FP070615], in the headwaters of the Elizabeth River [EP660565] and along the dolerite-capped divide between the Apsley and Douglas Rivers.

#### *Negative anomalies*

- (a) Several major anomalies in excess of - 50  $\mu\text{m/s}^2$  have been noted. Two transect the line of Nine Mile Beach [FP000390, EP892380], others correlate closely with the Nicholas Range [EQ920995], near Gray [FP015912], Douglas River [FP000785], south Royal George [EP730650], West Swan River [EP798610], Cygnet River [EP810576], Rossarden [EP620860].
- (b) Lesser anomalies occur north of Mt Henry, on Fingal Tier, north-west of Merrywood, Mt St John and Gilbert Dick Hills.

### INTERPRETATION

The interpretation for each survey is given in two parts, a qualitative outline leading to generation of the initial quantitative model. The quantitative interpretation is based on analysis of the initial model

and its variants.

The evaluation of the regional or primary coverage has been used to guide the treatment of the Fingal Tier detailed survey. In each case the qualitative treatment is adequate to identify feeders and provide immediate guidelines for drilling targets. It is not adequate to specify feature scale, faulting, section thickness and similar details, and the quantitative treatment is aimed at these aspects. Due to the complex interplay of structural features a comprehensive continuation - three dimensional interpretation process has been used. It must be noted that the interpretations provided need further control (drilling or reflection seismic) and possibly iteration before optimum resolution is obtained.

#### FULL COVERAGE

##### *Regional Bouguer anomaly - interpretation*

Two principal features are apparent in each regional separation (figs. 6, 7). The first, a significant west-east gradient, is apparent across the entire area with an abrupt sharpening in the region of Royal George-Rossarden. The bulk of the gradient must reflect lower crustal features and indicates a gradient of about 1 in 5 for the Moho. This increase in gradient occurs near the surface exposure of the Scottsdale Batholith and presumably reflects a dipping edge with a base level of no more than 9-10 km. This estimate is based on assumptions that the section east of the batholith is devoid of intrusives and that the relevant densities are 2.62 and 2.72 t/m<sup>3</sup> for granite, and sedimentary section respectively.

The second feature is the large closed negative anomaly west of Bicheno. Although offset from all known granite alignments, this anomaly indicates the presence of a relatively small discrete but deeply rooted granitic mass. A very shallow depth is suggested to the roof of the body (compare figs. 6, 7). Holes 1 and 2 at Llandaff (Hills *et al.*, 1922, see Appendix 3) and DOM DDH 963/546 at Apslawn, even though offset from the centre of the anomaly, confirm this interpretation.

Comparative analysis of the two regional estimates enables some resolution of the structural components to be made. A residual derived from the two regionals is given in Figure 11. This figure also represents the difference in the residual Bouguer anomalies shown in Figures 8 and 9. The two-grid separation clearly reveals those areas where granite is dominant by yielding zones of negative anomaly up to - 50  $\mu\text{m/s}^2$ . Part of the effects displayed may also reflect high relief on the basement materials and contacts. The zone, in the north of the area, where Mathinna Beds are exposed contains low-relief anomalies, suggesting a consistent basement with a density around 2.67 t/m<sup>3</sup>. West of Tower Hill, and in a belt south of Fingal to Great Oyster Bay there are obvious basement variations and denser or metamorphosed rocks may be implied. Figure 11 should only be used as a guide to basement composition in the 1-6 km depth range. The sign convention used has been arranged to correlate with the prevailing density contrasts and implies subtraction of the 4 km grid regional from that of 16 km. Clearly, the larger grid includes more basement contribution and, in the case of granite, overstates their effect - but only in relative interest since the survey targets are very shallow (surface to 700 m depth).

In consequence the residual extraction shown in Figure 8 (4 km cell) has been used for all interpretation related to dolerite and coal measures

structures. Figure 11 may be used as a guide to basement content (sometimes very shallow) and Figure 9 provides an upper crustal summation.

#### Density determinations

The following bulk wet density values have been assumed throughout the interpretation.

Quaternary talus	: 2.20-2.40 t/m <sup>3</sup> estimated
Tertiary sediments	: 1.92 t/m <sup>3</sup>
Jurassic dolerite	: 2.83 t/m <sup>3</sup>
Triassic coal measures	: 2.35 t/m <sup>3</sup>
Permian sedimentary sequence	: 2.47 t/m <sup>3</sup>
Devonian granite/adamellite	: 2.62 t/m <sup>3</sup>
Devonian granodiorite	: 2.70 t/m <sup>3</sup>
Ordovician-Devonian Mathinna Beds	: 2.57-2.81 t/m <sup>3</sup>

The values for Tertiary sediments, Devonian granite etc. and Mathinna Beds are based on the published results of Leaman (1972), Leaman et al. (1973) and Leaman and Symonds (1975). New determinations have been made for the local dolerite, coal measures and part of the Permian sequence. The results obtained differ significantly from previously published observations from other areas, most of which are more than 100 km distant.

The values quoted for talus are estimates, since it is virtually impossible to reliably sample or use field techniques to obtain good results. The estimates are based on likely values for totally decomposed material where the mass is effectively uniform (2.0-2.2 t/m<sup>3</sup>). The typical condition where large fresh blocks are fairly close packed and the interstices contain air, soil, weathering products or clay could yield values of 2.1-2.5 t/m<sup>3</sup> depending on filling and block size. An estimate using a clay-soil filling and fresh blocks about 300 mm in diameter is 2.2-2.3 t/m<sup>3</sup>. In consequence a value of 2.25 t/m<sup>3</sup> has been used in interpretation.

Ninety-four new determinations were made of coal measures material (many others disintegrated during the soaking process, usually of mudstone lithology). Sandstone exhibited a range of 2.19-2.51 t/m<sup>3</sup> (average 2.36 t/m<sup>3</sup>); mudstone/shale 2.12-2.54 t/m<sup>3</sup> (average 2.35 t/m<sup>3</sup>); sandstone with coal stringers 1.84-2.43 t/m<sup>3</sup> (average 2.34 t/m<sup>3</sup>); coal, carbonaceous mudstone 1.50-2.15 t/m<sup>3</sup> (average 1.94 t/m<sup>3</sup>). The average of all results was 2.31 t/m<sup>3</sup>, but a weighted average allowing for lithologic proportion is 2.35 t/m<sup>3</sup>. All determinations were based on material from DOM DDH 41, Fingal Tier.

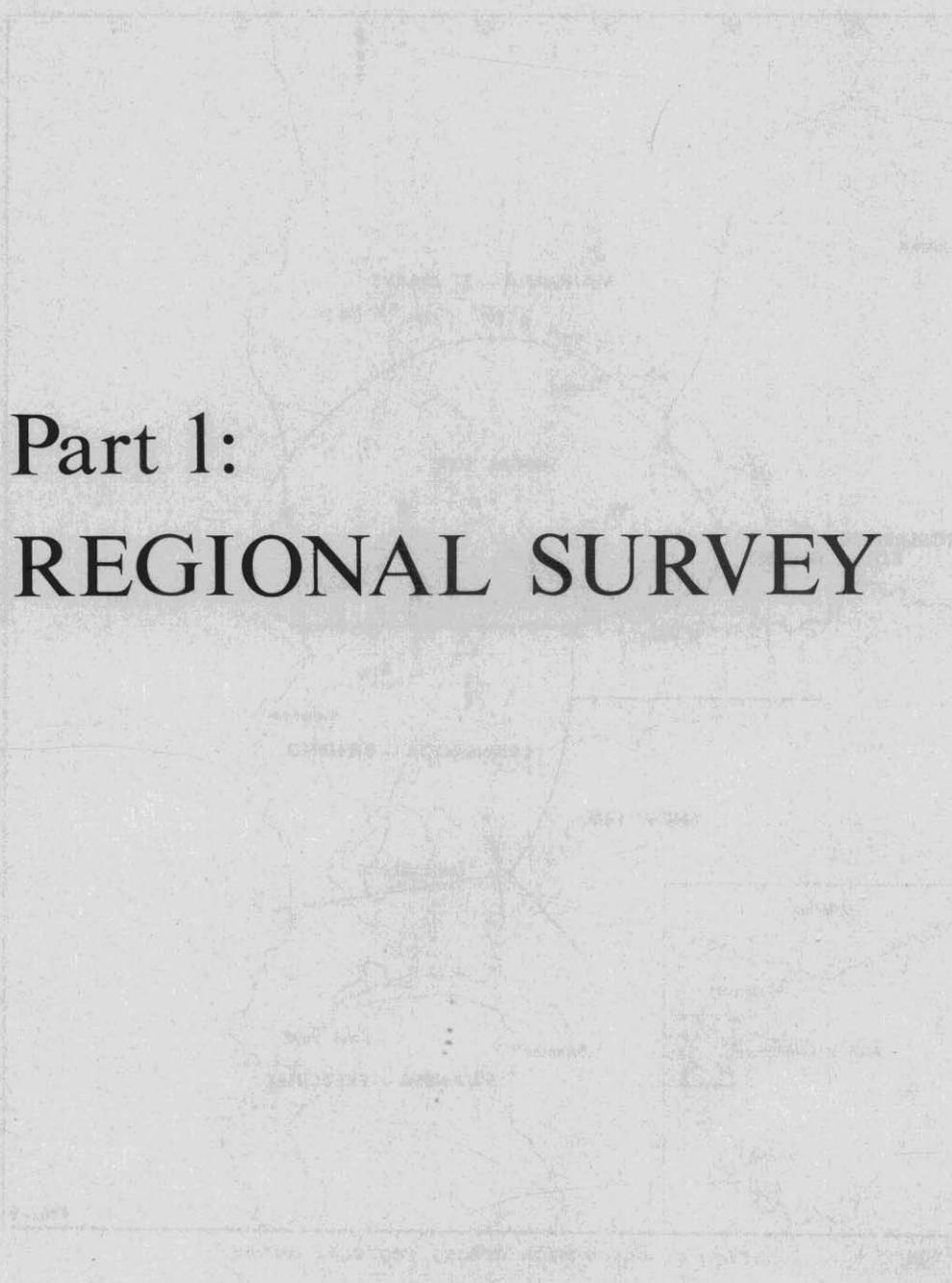
One hundred and twenty-three new dolerite determinations have been made, about half from DOM DDH 17 and the remainder from DOM DDH 20 and 23. Values range from 2.65-2.93 t/m<sup>3</sup> and average 2.83 t/m<sup>3</sup>. Most values fall in the range 2.80-2.90 t/m<sup>3</sup>. Density results throughout more than 320 m of dolerite in DOM DDH 17 did not reveal any pattern or the presence of a higher density lower zone. All values are generally less than recorded for dolerite on the Central Plateau or in southern Tasmania.

New determinations have also been made of the upper part of the Permian sequence. The upper siltstone has a density range of 2.39-2.42 t/m<sup>3</sup> (average 2.41 t/m<sup>3</sup>). The density estimate used in this interpretation (2.47 t/m<sup>3</sup>) is based on equal proportions of siltstone/mudstone:limestone:grit/conglomerate. The Permian sequence is extremely variable, but due to the relative thinness of the section any errors will be small.

The values quoted for the Mathinna Beds represent the limits for unmetamorphosed and metamorphosed materials but there is a range of values depending on actual composition and grain-size.

The remainder of the interpretation is presented in separate parts, respectively dealing with the regional and detailed coverages. Each represents a summation of data at June 1, 1980, from which time a coherent assessment was provided for exploration control. The principal factor contributing to uncertainties is the uneven quality and coverage of geological mapping. In addition, substantial areas lack any other form of control - whether drilling or other geophysical work.

Consequently it must be stressed that the interpretation provided here is intended as an exploration guide which should not be read too literally; just as the authors have resisted a temptation to overinterpret the data. Future revision will certainly be possible but not necessarily essential or desirable if more specific methods - drilling or seismic reflection - can be guided effectively by the current interpretation. Such interpretation can be considered adequate and successful if it has located thinner cappings, fault and feeder zones, and thick successions reliably. The interpreted specifications cannot be so certain.



Part 1:  
**REGIONAL SURVEY**

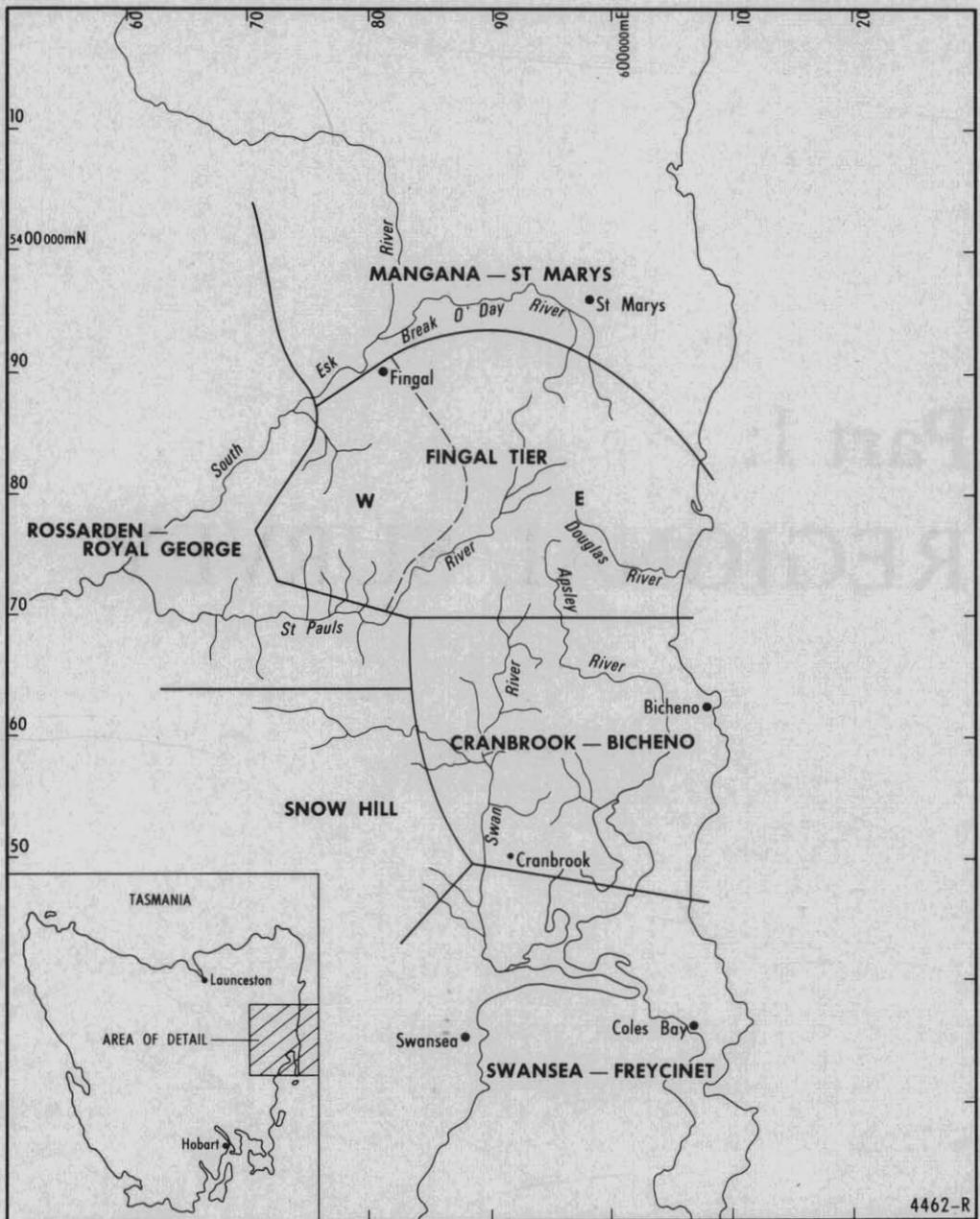
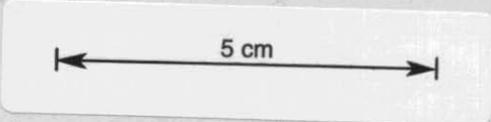


Figure 12. Location of discussion areas, regional survey



## QUALITATIVE INTERPRETATION

As the density value used for the Bouguer reduction was  $2.67 \text{ t/m}^3$  the anomalies to be expected in areas of exposed basement rocks should be very nearly zero. In general, granite will be slightly negative and the Mathinna Beds either slightly negative or positive. The exact magnitude of the anomaly depends on the reliability of the regional separation and the contribution to the anomaly of mass discrepancies above sea level but excluded from the Bouguer reduction. The type of anomaly pattern expected is observed north of Coles Bay, south of Falmouth and in the Fingal-Mangana region. Larger anomalies ( $> 20 \mu\text{m/s}^2$ ) south and east of Rossarden, in the belt of Mathinna Beds between granite exposures, suggests denser metamorphosed materials near the surface. The substantial negative anomalies ( $\sim 50 \mu\text{m/s}^2$ ) associated with the Rossarden-Royal George granite are due to local contrasts and spines, reduction exclusions between the geoid and the surface, edge effect deficiencies in the separation and failure of the separation to cope with the very deep root of the batholith.

Similar smaller scale effects may be noted for the adamellite east of Gray and the granite at Cape Lodi [FP093578] south of Bicheno.

In general, large negative anomalies should only be related to deeply-rooted granitic bodies or thick accumulations of Permo-Triassic rocks. A 300 m succession of Triassic coal measures overlying a 150 m succession of Permian rocks would contribute at least  $-52 \mu\text{m/s}^2$  to the local Bouguer anomaly. About 170 m of Tertiary sediments could produce a similar anomaly. Since Tertiary materials are relatively rare in the area under discussion most large negative anomalies are related to granite-coal measures combinations.

A typical dolerite sheet, 300-350 m thick, can contribute about  $23 \mu\text{m/s}^2$  to the local anomaly. Thus sedimentary successions capped, or intruded by, a thick sheet yield a variable negative or near zero resultant anomaly. A substantial ( $>20$  to  $30 \mu\text{m/s}^2$ ) positive anomaly in an area containing dolerite and coal measures implies a predominance of dolerite content and a very thin sedimentary sequence. Very large positive anomalies ( $40$  to  $60 \mu\text{m/s}^2$ ) imply that much dolerite is present, either in the form of multiple sheets, large dykes or feeders. The precise character of the anomalies will indicate which.

The area has been subdivided for ease of discussion (fig. 12). Each zone is discussed individually and all anomalies are identified by grid co-ordinates.

To assist comprehension of the interpretation the following table provides the relevant density contrasts and the gravitational impact of 100 m of material (contrast versus Bouguer density,  $2.67 \text{ t/m}^3$ )

Material	Contrast ( $\text{t/m}^3$ )	Attraction per 100 m ( $\mu\text{m/s}^2$ )
Quaternary talus	- 0.42	- 17.6
Tertiary sediments	- 0.75	- 31.4
Jurassic dolerite	+ 0.16	+ 6.7
Triassic coal measures	- 0.32	- 13.4
Permian sequence	- 0.20	- 8.4
Devonian granite/adamellite	- 0.05	- 2.1
Devonian granodiorite	+ 0.03	+ 1.3
Ordovician/Devonian Mathinna	- 0.10	- 4.2
Beds	to + 0.14	+ 5.9

Arithmetic using these values as a rule of thumb can provide estimates of the content and attraction of a section. The estimate will be reliable only if the assumptions of uniformity and two-dimensionality are met. Three dimensional or edge effects may modify estimates substantially.

#### Mangana - St Marys

This zone (fig. 12) covers the low-lying country in the valleys of the South Esk and Break O'Day Rivers, includes the Nicholas Range, Mt Elephant [FP038916], St Patricks Head [FP029968] and the granitic coastal intrusives south of Falmouth [FQ0600040] and east of Gray. Lower Palaeozoic Mathinna Beds or Devonian intrusives crop out over a large portion of the area and a relatively thin veneer ( $\sim 100$  m) of Permian rocks is present along the Break O'Day valley. Only on the Nicholas Range, Mt Elephant and St Patricks Head are Triassic rocks and definitely *in situ* Jurassic dolerite to be found. Most dolerite exposures in the valley appear to be talus remnants.

The gravity field eastward from Mangana generally reflects this simple geological pattern. There are broad swells of anomaly ranging from  $-20$  to  $+20 \mu\text{m/s}^2$  and most lie in the range  $0$  to  $+20 \mu\text{m/s}^2$ . This suggests that the density used in the Bouguer correction ( $2.67 \text{ t/m}^3$ ) is lower than the average bulk density for the Mathinna Beds. A density of  $2.8 \text{ t/m}^3$  overall might be more realistic if all the above geoid discrepancy is derived from inadequate correction. This is unlikely to be the case as some anomaly will be contributed by sub-geoid materials. The overall density of the Mathinna Beds is probably a little more than  $2.7 \text{ t/m}^3$  and hence  $2.8 \text{ t/m}^3$  would be a maximum value. The presence of Permian rocks in the Fingal - St Marys area, which would include a negative Bouguer contribution, reinforces this conclusion. The discussion presumes no other positively contributing features (see below).

A broad negative anomaly may be correlated with the exposure of granitic rocks south of Falmouth and north of Chain of Lagoons [FP067862]. Some of the anomaly noted around Mt Elephant may reflect a contribution from the Permian and Triassic cover, although both are relatively thin. Some strong gradients have been observed in this region and it would appear that considerable variation of content exists within this granitic block. The pattern of anomalies is suggestive of a substantial sheet with localised sources [FP080920, FP030970] which thins eastward or dips abruptly westward. The small positive anomaly north-west of Wardlaws Point [FP058980] implies either little granite or a much denser rock, perhaps comparable to a diorite or granodiorite. Groves *et al.* (1977) have recognised no such distinction, but more recent mapping, as published in the 1:500 000 and 1:250 000 series, does indicate that granodiorite might underlie this region and a small inclusion is indicated at FP080910. Generally southerly dips have been observed for the margin of the body. The disposition of the positive values suggests an overall dip to the south-west (McNeil, 1965). If the contribution of Permian and Triassic rocks is removed from the broad anomaly in the region north of Mt Elephant [FP050940] (estimated at  $-10 \mu\text{m/s}^2$ ), then a maximum sheet thickness of about 1100 m is implied (assuming a density of  $2.62 \text{ t/m}^3$ ). No density determinations have been made and it is possible that the St Marys biotite-hypersthene-adamellite porphyry is slightly denser than the normal adamellite. At  $2.63 \text{ t/m}^3$  the thickness would be 1300 - 1400 m.

The broad area of negative anomaly is terminated south-east of Gray by further gentle positive anomalies which may be correlated with rocks of

the Piccaninny Point Pluton (Groves et al., 1977). Rocks of this pluton, which include granodiorite, are denser and the pattern is similar to that observed elsewhere in north-east Tasmania (Leaman and Symonds, 1975). No great thickness of 'pluton' may be assumed from the anomaly values and the body is probably sheet-like. Similar anomaly values occur near Gray and west to Mangana as discussed previously. It is possible that a sheet of granodiorite is universal and that the positive anomalies reflect it. Detailed examination of the relationships between the St Marys porphyry to the north of Chain of Lagoons and the western contact of the granodiorite at Piccaninny Point may resolve the structure and distribution of this material.

The most significant anomaly in the zone ( $-60$  to  $-80 \mu\text{m/s}^2$ ) correlates closely with the coal bearing sequence, as mapped, around the Nicholas Range. The anomaly is always confined to areas of Permian or Triassic cover, and it may be inferred that it is directly related to the coal measures. Summation of the maximum possible thicknesses at Mt Nicholas (150 m for Permian, 400 m for Triassic;  $\sim 65 \mu\text{m/s}^2$ ) can account for all but the peak anomaly values ( $-80 \mu\text{m/s}^2$ ). Any discrepancies may be related to the thick talus deposits which drape most slopes, 20-50 m being adequate to account for the bulk of the anomaly discrepancy.

Within the Mt Nicholas region three small areas of positive anomaly have been noted ( $+10$  to  $+15 \mu\text{m/s}^2$ ). These may be broad residual basement effects, although shown in Figure 13 as dolerite features. Comparison with Figure 11 suggests that upper crustal contributions are not relevant.

Two similar positive anomalies have been noted along the valley of the Break O'Day River; one south of St Marys and the other north-east of the Duncan mine at Fingal. No obvious source is apparent in either case although a basement influence is possible south of St Marys (compare Figure 11). The feature near Fingal may be a small dolerite plug; Figure 13 shows both as dolerite-caused.

Where the observations are made at low level, or near the basement interface, the basement contribution to such readings will be more pertinent than for observations in the same small area at much higher elevations. This is a basic dilemma for interpretations of high quality in areas of high relief.

#### Rossarden - Royal George

This zone (fig. 12) covers the western margin of the area. This area is dominated by major exposures of the southern extension of the Scottsdale Batholith, with granite cropping out around Avoca, Royal George and Rossarden. The boundaries of the zone are drawn so as to specifically exclude the western end of Fingal Tier at Mt Foster [EP737792].

Negative anomalies of up to  $-60 \mu\text{m/s}^2$  occur south of Rossarden and around Royal George. In each area, large portions of the anomaly exceed  $-35 \mu\text{m/s}^2$  and each anomaly has strong marginal gradients. Deeply rooted plutons are implied in each case. The belt of positive anomaly extending from Avoca along the South Esk River valley to Ormley [EP690805] and then north of Ormley reflects a substantial screen of Mathinna Beds. The two bodies probably connect at a depth of more than two kilometres. Gradients associated with the Rossarden intrusive can be closely correlated with the known geology, whereas those associated with Royal George and Avoca intrusions have more complex relationships.

Typical anomaly values near Royal George are -10 to +15  $\mu\text{m/s}^2$ . Such values are recorded on granite exposures at low elevation in the valley of the St Pauls River. These values increase and then terminate along a line from Mt Henry to Mt Foster. The actual termination is irregular with abrupt and irregular gradients, but there is good correlation with the dolerite-capped south-west face of Fingal Tier. Permian and Triassic rocks underlie the dolerite cap and contribute to the increased negative anomalies on the slopes around St Pauls Dome [EP692755] and overlooking Royal George.

A similar situation has been observed on the escarpment south of Royal George. As the amount of Permian and Triassic rocks increases the anomaly reduces from about 0  $\mu\text{m/s}^2$  on granite in the valley floor to -60  $\mu\text{m/s}^2$ . The difference can be accounted for entirely by the succession and some talus. The persistence of such large negative anomalies in dolerite-capped areas around Royal George implies locally thin cappings. Strong gradients bound all such caps and confirm abrupt changes in sheet thickness. Similar gradients are never observed where granite-Mathinna Beds contacts are free of the covering materials (e.g. north of St Pauls Dome).

With the exception of an area south-west of Tower Hill [EQ700010], the anomaly pattern north-east of Ormley is very similar to that east of Mangana. However the cells of positive anomaly are slightly smaller and contain some stronger gradients. The sizeable negative anomaly south of Tower Hill (up to -25  $\mu\text{m/s}^2$ ) presumably reflects a sizeable cupola projection at moderate depth.

No part of the anomaly pattern recorded for the valley of the South Esk River from Avoca to Mathinna or for the valley of the Break O'Day River from Fingal to St Marys provides any firm support for concepts of structural control for these valleys. Only one tenuous possibility may be noted. Along a line from Avoca to Falmouth [EP600740 - FQ060040], the eastern marginal gradient for the Rossarden and Royal George intrusions is offset about 7 km to the south and east. The anomalies are not definitive, but the possibility of dextral displacement remains. No other features can be included in the correlation due to the substantial geology-anomaly differences north and south of the alignment indicated. In addition to the dextral notion suggested above, it is also possible that the southern side is downthrown, accounting for the more impressive expression of the granite around Rossarden, as contrasted with that at Royal George.

The Castle Cary fault structure can also be traced in the residual anomalies, but only south of Avoca where a distinctive south-trending negative anomaly may be observed with an appropriate orientation. The feature terminates a large east-west trending dyke before diffusing west of Lake Leake (see also section discussion, Snow Hill). North of Avoca, the coverage is inadequate to define the structure.

### *Fingal Tier*

The Fingal Tier zone (fig. 12) is large and includes all the elevated plateau region south of Fingal and St Marys. Dolerite dominates it. For this discussion it has been divided into two parts, one north-east of the St Pauls River but west of Fingal Rivulet, the second east of Fingal Rivulet (fig. 12). The zone has been terminated on an east-west line approximately coinciding with grid line 5370000 mN due to the presence of significant east-west anomalies. Such a line also marks a geomorphic change from high plateau to a series of major valley dissections and lower elevations. The coastal strip at Seymour has been included to allow integration of discussion.

*Western region.* As mentioned in the previous section, severe gradients are associated with the south-west face of Fingal Tier above Royal George. The presence of a substantial capping (>200 m) of dolerite is largely responsible. Gradients on the north-west face from Mt Foster [EP737792] to Hogg Hill [EP787850] are less severe, due to the absence of contrasting granite, but a strong dolerite correlation persists. In both cases the positive contribution due to a normal sheet thickness is equalled. A normal sheet 300 - 350 m thick contributes a Bouguer anomaly of about  $23 \mu\text{m/s}^2$  and the average anomaly on the western part of Fingal Tier exceeds  $+20 \mu\text{m/s}^2$ . Anomaly peaks of 30 - 60  $\mu\text{m/s}^2$  have been observed in three places [EP770810, EP795855, EP805840]. The first locality is not well defined due to irregular station coverage, but all anomalies fall on the dolerite cap. Feeders may be directly presumed as sources for such large, localised anomalies, since there is no evidence near the Tier escarpments for large multiple cross-cutting sheets which could result in unusual dolerite thicknesses. The second and third localities listed above are associated with the highest portion of the western plateau, although there is no indication of an abnormal sheet thickness from surface mapping.

A broad area of anomaly, exceeding  $+15 \mu\text{m/s}^2$ , extends southward towards the southern face of Fingal Tier. Such values over a large area also suggest a massive capping sheet. Drilling north of Merrywood (DOM DDH 18) confirmed a substantial increase in sheet thickness under the Tier from predictions made at the escarpment. Much of the coal-bearing section has been removed by dilation. The belt of positive anomalies follow the exposure of a large dolerite dyke to the floor of the valley of the St Pauls River at EP860750. The correlation confirms the proposition made further north that the positive anomalies directly relate to the dolerite. In the latter case, the dyke observed would appear to be either a finger from a large feeder, a part of a feeder or an offshoot from a group of feeders. The broad anomalous zone thus represents the sum of effects of several feeding dykes and a very thick sheet. The whole area could not be recommended as worthy of coal investigation.

This conclusion is based as follows. The exposed geology suggests a thick sheet cap (>200 m), an irregular partly granitic basement and thin Permian and Triassic successions. Since all negatively attracting components are clearly terminated the resultant positive anomaly can mean either a very thick capping able to swamp the negative effects or a normal cap and negligible thickness of Permo-Triassic rocks. In either case the coal measures will not provide good targets. The two calculations below indicate how the components of attraction interact.

Typical observed (residual) field: $+15 \mu\text{m/s}^2$			
$+ 16.7 \mu\text{m/s}^2$	250 m dolerite	$+ 16.7 \mu\text{m/s}^2$	250 m dolerite
$- 27 \mu\text{m/s}^2$	200 m coal measures	$- 6.7 \mu\text{m/s}^2$	50 m coal measures
$- 7 \mu\text{m/s}^2$	80 m Permian sequence	$- 4.1 \mu\text{m/s}^2$	50 m Permian sequence
<hr/>		<hr/>	
$- 17.3 \mu\text{m/s}^2$		$+ 6.6 \mu\text{m/s}^2$	
<hr/>		<hr/>	

In each case, more dolerite or less succession is implied. The predominantly granitic and therefore negatively attracting basement in this region reinforces this conclusion.

It might be argued that a large part (10 to 15  $\mu\text{m/s}^2$ ) of the positive anomalies could be related to a metamorphosed screen of Mathinna Beds along the margin of the Royal George granite and under the western part of Fingal Tier. However, while some screens do yield such values, all produce

small patchy anomalies which do not approach the area involved on Fingal Tier West. Further, the values north of the escarpment are less than  $10 \mu\text{m/s}^2$  and when the obvious overall anomaly-dolerite correlation is considered, any contribution by the underlying rocks must be minimal. Furthermore, examination of Figure 11 will show that an effect equivalent to  $+30 \mu\text{m/s}^2$  has already been extracted and which was most certainly contributed by the screen of Mathinna Beds. It is therefore unlikely that any effect as large as  $10 \mu\text{m/s}^2$  could persist.

Apart from the negative anomalies around the western end of Fingal Tier only one significant negative anomaly has been recorded on this part of the Tier [EP825840]. This anomaly was confirmed by additional surveys and then drilled (DOM DDH 29). On the basis of the then partially complete survey, it was believed that values of  $50 \mu\text{m/s}^2$  less than the surrounding region represented a section with negligible dolerite cap. This proved not to be the case with one important qualification. The hole was drilled within the anomaly but on the eastern margin where gradients are relatively gentle. The preferred site was central to the anomaly. It is quite possible that the hole encountered a transgressive sheet dipping eastward. Such a structure is wholly compatible with the massive column of dolerite dissected by Fingal Rivulet immediately to the east and the gently rising eastward gradient. Although the station coverage in the region of Fingal Rivulet is relatively poor, on a regional scale, values in excess of  $+25 \mu\text{m/s}^2$  have been observed and both geological observations and gravity results indicate the presence of a small feeder. Whether or not the above interpretation is correct, the implication of massive amounts of dolerite west of Fingal Rivulet is certainly justified if a hole drilled on the  $-10 \mu\text{m/s}^2$  contour revealed more than 300 m of dolerite. (This feature is further discussed in the section dealing with the detailed survey, with an improved coverage).

Another smaller anomaly relates to the most obvious landmark in the Fingal area - The Vertical Acre [EP823866], a massive dolerite exposure. An east-west anomaly trend extends from the centre at EP795855 toward The Vertical Acre, diminishing in intensity toward it. A dyke is clearly indicated for part of the distance, but the anomaly at the landmark is compatible with about 200 - 250 m of dolerite sheet. However, the anomaly rolls over in this region and if the results of hole 29 were to be directly accepted, a dyke would certainly be implied as well. However as there is still some doubt about the exact meaning of observations at hole 29 this cannot be assumed, as a similar roll-over of anomaly could be produced by sheet(s) transgressing upward from the north-west, east or south-west, where centres most certainly exist. Comparison of results from holes 28 and 29 drilled on either side of this anomaly indicates no significant displacement or dilation. Thus any dyke present must be a separate feature at this level of intrusion and embody no uplift component.

The marked gradients associated with all anomalies within a 4 km radius of Fingal Rivulet certainly suggest that features within 500 m of the surface have produced these anomalies. Yet, if one considers the anomaly at EP825840 which has a value of  $-32 \mu\text{m/s}^2$  and assumes a 200 m cap of dolerite with 200 m of Triassic and 100 m of Permian rocks, the anomaly should be an absolute maximum of  $-23 \mu\text{m/s}^2$  but more probably about  $-15 \mu\text{m/s}^2$  allowing for three dimensionality of the structure. A discrepancy of  $-10$  to  $-20 \mu\text{m/s}^2$  is implied. If there is 100 m less capping the discrepancy reduces to about  $-5$  to  $-10 \mu\text{m/s}^2$ . It was on this basis that the region was drilled and a surprising 346 m of dolerite revealed. The core log notes an inclined basal contact which is compatible with the conclusion outlined earlier.

It remains possible that drilling in the centre of this anomaly may reveal a considerably thinner cap, or conversely, a thicker coal measures section.

*Eastern region.* A significant negative anomaly correlates with the region currently being worked at the Duncan mine ( $-70 \mu\text{m/s}^2$ ). Such an anomaly is difficult to account for given the known materials unless much talus is included. The anomaly correlates closely with the block of Triassic rocks enclosed by a feeder along Fingal Rivulet (previous section), a small dyke wall to the north, a major sheet transgression to the south and the main body of the capping sheet to the east. On the regional coverage, the anomaly is centred at EP850890 within this block. Strong gradients to the west, north and north-east suggest that this block is largely confined by dolerite. A major problem relates to the magnitude of the anomaly. If a section comprising about 200 m of Triassic coal measures and 100 m of Permian rocks is assumed, the absolute value of the deficiency should be around  $-30$  to  $-35 \mu\text{m/s}^2$  allowing for problems of equidimensionality and coal removal. The problems of a lesser discrepancy to the south-west was discussed in the previous section and no firm solution can be offered on the basis of the regional survey. The maximum known thickness of coal measures is about 350 m and the maximum anomaly should therefore not exceed  $-50$  to  $-55 \mu\text{m/s}^2$ . (The detailed follow-up survey, discussed later in this report, found that the three stations largely responsible for this feature were in error by about  $20 \mu\text{m/s}^2$ . There is a significant negative anomaly in the region but it is of lower amplitude).

The negative anomaly described above is closed abruptly to the west, north and east. To the west, a prong of positive anomaly extends along Fingal Rivulet where a significant mass of dolerite is exposed (see previous section). The sheet on the end of the eastern Tier around the drilled grid appears to have been derived from this source, since transgressions from the west may be observed near EP845860. Such an eastward transgression appears to dominate the entire central portion of the Tier and a general north-south gradient crosses the Tier south of this point. Anomaly values reduce eastward and a broad zone of negative anomaly occupies much of the Tier (e.g. between EP860820 and EP920880).

To the north a thin dyke, probably occupying a fault, terminates the coal measures, uplifts the Permian rocks and forms the boundary to the anomaly. To the east, the dyke ends in a large boss-like intrusion [EP860900]. A  $10 \mu\text{m/s}^2$  anomaly is associated with this feature but it is poorly defined due to limited station coverage. Faulting does not appear to account for the relationships observed in this area and the dolerite body gives the impression of being a moderate sized pipe. A much reduced positive anomaly may be observed on the Tier proper and there is probably no connection between the two features. On the Tier, values of  $-5$  to  $+5 \mu\text{m/s}^2$  are associated with a substantial thickening in the capping sheet; DOM DDH 23, 24, 17 and 31 lie within this zone and on its axis. The cap, as observed in these holes, is 60 to 140 m thicker than noted in surrounding holes. This topic is expanded in the section dealing with the detailed survey. It cannot be positively established on the basis of the regional survey that only a substantial sheet thickening is present in this part of Fingal Tier. Preliminary calculation indicates that the anomalies noted are also consistent with a model containing a thickened sheet, as specified by existing drilling, and a dyke up to 150 m wide. Such a model has important mining ramifications.

The anomalies noted in the region of holes 23/24 are about 0 to

-5  $\mu\text{m/s}^2$ . The section, as noted in these holes, could be expected to produce about -5  $\mu\text{m/s}^2$ . This is an acceptable agreement for hole 23. The section at hole 24 should yield about +5  $\mu\text{m/s}^2$ . The anomaly seems slightly displaced but this may be due to problems of scale. The large areas of negative anomaly to the north, east and south clearly reflect areas in which the dolerite cap is thinner. Estimates of cap thickness for each zone are listed below and are for the central point in each area. The estimates apply only with the proviso that levels relate to the higher elevations in the region and sheet thickness will be reduced appropriately in depressions and incisions.

<i>AMG reference</i>	<i>Anomaly (<math>\mu\text{m/s}^2</math>)</i>	<i>Thickness (m)</i>
EP900890	-35	~150
EP915860	-20	~320
EP875840	-15	~350
EP865835	-32	~150
EP955830	-35	~100

The above estimates assume some multiple source interference and no base-ment contributions to the residual anomalies. The estimates are variable and the areas may need improved definition, but the cap thickness for some of these areas is likely to be as much as 100 m thinner than the average drilled around the present grid at about EP875870.

Two large areas of significant positive anomaly are included in this generally negative area, which should be contrasted with the substantial positive area west of Fingal Rivulet at the same elevation. The two parts of Fingal Tier are structurally distinctive. The two positive anomalies are at EP960880 and EP925820. Both are closed and both can be related to a major dolerite column. The anomaly centred at EP960880 coincides with a large dolerite body which is coarse grained (exceptional in this area) and which is associated with a number of faces plunging to a low elevation. A plug is suggested by its appearance at the escarpment south of St Marys. The substantial anomaly of +35  $\mu\text{m/s}^2$  confirms this inference. A feeder and associated thick sheet is implied in this area. Drilling inside the 0  $\mu\text{m/s}^2$  contour is likely to prove a cap thickness in excess of 300 m. Drilling inside the +20 to +30  $\mu\text{m/s}^2$  contour is not recommended. Similar comments apply to the anomaly centred at EP925820. In this case the anomaly follows a spine of dolerite which plunges into the gorge of the St Pauls River. A further feeder, dyke and thick sheet are implied. The substantial gradients associated with each anomaly suggest that the basal surface of the sheets about each centre and any associated dykes has a significant dip.

A smaller centre may be reflected in the increased anomaly at EP980845. Many anomalies on Fingal Tier suggest a relatively irregular pattern of sheet intrusion with minimal concordance. Many sheet troughs appear to be present, spanning upward and outward from the centres with the result that the basal surface of the sheet is quite wavy. Amplitude variations of 150 m are to be anticipated.

With the exception of some relatively small areas, the residual anomalies are negative east of the two principal centres. Around Mount St John [EP890710; EP930785], Gray [EP990890] and the Douglas River [EP995820] values exceed -50  $\mu\text{m/s}^2$ . The major anomaly near Gray may be correlated with exposed coal measures sequences and the anomaly is reduced southward due to the influence of capping dolerite and thinner successions resulting from faulting and dilation differences. The anomalies of around -5 to -20  $\mu\text{m/s}^2$  in the headwaters of the Douglas River south of Thompsons Marshes suggest

about 350 m of cap. At the local base level in the marsh areas this estimate can be reduced by the average relief (60 - 120 m). The local positive anomaly (+5  $\mu\text{m/s}^2$ ) at FP000815 suggests a localised thickening of the sheet by up to 100 m. However estimates are uncontrolled and it is likely that excessive estimates of dolerite thickness (200 m) are possible due to lateral influences.

The negative anomaly at Gray is very similar to that observed south-east of Fingal near the Duncan mine. A thick Triassic sequence may be presumed, although some of the anomaly may be the result of a general local negative trend extending to the north-west.

The substantial anomalies occurring in an arc about Mount St John [EP910737] may be correlated with exposed coal measures successions to the north and thick talus deposits, presumably concealing coal measures, to the south. The belt of negative anomaly extends east-west from Lochaber [EP837706] to near the coast and the mouth of the Denison Rivulet. Positive anomalies of less than +30  $\mu\text{m/s}^2$  are associated with the divide between the Douglas-Apsley and St Pauls Rivers. The average anomaly is about 0  $\mu\text{m/s}^2$  which is consistent with a general cap thickness of more than 600 m.

Such a value, though consistent with density assumptions and limited section knowledge, reflects an obvious variation from the acceptable pattern of values further west. Such a massive consistent dolerite thickness would imply multiple sheets or some major background disturbance has not been removed in the regional separation. The alteration in characteristics appear to correspond to the region east of the line of the St Pauls and Dukes Rivers. The anomaly pattern around Thompsons Marshes is similarly affected and a 250 to 300 m reduction in dolerite cap is implied from the simple contrast arithmetic. (This zone has been examined further in the quantitative interpretation and a combination of major basement faulting and relief changes is implied).

Local variations are indicated in the sheet capping the divide between the Apsley and Douglas Rivers (e.g. at EP930730, EP945965, EP970795). Since these have a magnitude of about +25  $\mu\text{m/s}^2$ , small feeders may be implied. The base of a major transgression is exposed at EP955728.

Negative anomalies around the valley of the Douglas River indicate that the sheet exposed to the west at EP970770 is thin, but thickens markedly westward. The sheet around FP010780 is generally a patchy capping, but thickens to the north and north-east where small and large sources are located. The value of +32  $\mu\text{m/s}^2$  at FP010760 related to the southern end of the capping sheet north of the Douglas River probably reflects, in view of surrounding negative values associated with Triassic rocks, a small feeder. The dolerite spines of Nichols Cap to the immediate south are at a lower elevation and the presence of dykes exposed in the river bed nearby support this suggestion. The sheet to the south, at EP990730, is generally less than 150 - 200 m thick, until south of grid line 5370000 mN where substantial thickening occurs.

Positive anomalies at FP045820, FP040800 and FP035720 in the coastal hills probably represent a string of feeders. The coverage around the first two sites is insufficient to determine whether there is any continuity. In each case, massive dolerite bodies are to be found near sea level with marked discordant margins to the west.

Anomalies along the coastal plain near Seymour are small (10 to 20  $\mu\text{m/s}^2$ ) and negative. They are consistent with general background basement

anomalies when Mathinna Beds or granodiorite are predominant with a relatively thin veneer of Permo-Triassic rocks (~200 m).

The anomalies across Fingal Tier, while providing little indication of major structural alignment compatible with currently known geology, do indicate three main trends. All features show trends or margins aligned north-west, north-east or east-west.

#### *Cranbrook - Bicheno*

Anomalies in this zone can be classified into three types. The first is a broad belt of positive anomaly extending from EP955680 to EP860560 and FP000750 and which encloses the second, a generally negative area centred on Lynes Sugarloaf [EP960590] and the granitic stock. The third type consists of small paired anomalies peripheral to the others, especially along the coast.

Dolerite is the ubiquitously exposed material in the belt of positive anomaly. It occurs at all elevations and few windows in which other rocks are exposed are known. The average anomaly value over this entire region is about +20  $\mu\text{m/s}^2$ , with many local peaks of +45  $\mu\text{m/s}^2$ . There is little correlation between magnitude of anomaly and elevation and it is likely that a number of feeders are represented. For example, some increases in anomaly are associated with valley floors at EP955680 and EP895605, when a reduction in elevation should produce reductions in the Bouguer anomaly with the density used (2.67  $\text{t/m}^3$  cf 2.83  $\text{t/m}^3$  necessary) if the intrusions were slab-like. Feeders are definitely indicated at the example sites. Elsewhere, a very thick sheet (or sheets) is implied with other probable feeder sites at EP875680, EP860560, EP885520, FP000750 and EP860490.

The large negative anomaly which peaks at -60  $\mu\text{m/s}^2$  averages -25 to -30  $\mu\text{m/s}^2$  in the residual Bouguer anomaly. This anomaly zone is clearly visible in both regional maps (figs. 6 and 7) and hence the source is a major basement feature not wholly compensated in the residual separation. A sizeable granite stock is the only likely source for such an anomaly. The strong gradients associated with the western and southern margins are partly due to the contrast of granite-dolerite columns in depth and partly to structures which are very near surface. The pinnacles of negative anomaly about the western margin imply local cupolas. The dolerite capping on Lynes Sugarloaf does not modify the pattern in any significant way and it is possible that the wafer of intruded Triassic and Permian materials is very thin west of grid line 597000 mE. This is revealed in the 1888 drilling at Llandaff (see Appendix 3). In holes L1 and L3 no Permian rocks can be deduced in the log and the roof of the granite rises to -100 m. On the northern side of Lynes Sugarloaf hole DOM DDH 992/637 encountered granite at -43 m. The Permian succession in this area is extremely variable in content and thickness but a thick limestone unit is normally present.

An alternate interpretation is suggested by a pilot drill hole south-west of hole 992/637 within the anomaly proper (see Appendix 3, hole 986/620) where the thickness of coal measures was far thicker than could have been predicted on stratigraphic or topographic considerations. Compare the results of holes 992/637 and 986/620.

Site anomaly:	DOM DDH 986/620: -25 $\mu\text{m/s}^2$	DOM DDH 992/637: -20 $\mu\text{m/s}^2$
Section:	30 m dolerite (2 bodies)	3 m coal measures
	321 m coal measures	115 m Permian rocks
	? permian/granite	granite
Attraction:	-42 $\mu\text{m/s}^2$ (minimum)	$\approx 5 \mu\text{m/s}^2$

This table suggests that the residual field contains a positive component and that either major faulting or very irregular deposition is concealed beneath the dolerite cap of Lynes Sugarloaf. Only at Lynes Sugarloaf does the effect of dolerite become obvious and a feeder is implied. The sizeable negative anomalies west of Lynes Sugarloaf do indicate a thin cap and thick sequence although a high relief near surface or low density granitic basement may contribute. No basement variants can simply resolve the problem of the positive deficiency, since the scale required is not possible, most of the basement effects having been deducted by the 4 x 4 km regional. Consequently the bulk of the positive effects must be lateral, three dimensional additions. This would imply narrow downthrown fault blocks and, possibly, a number of dolerite intrusives within the region.

Two groups of small anomalies may be noted along the coast, one at Bicheno and one along the Denison Rivulet valley. At Bicheno, a small discrete negative anomaly ( $-30 \mu\text{m/s}^2$ ) may be correlated with the ridge of outcropping granite. Adjacent, to the west, is a positive anomaly ( $+40 \mu\text{m/s}^2$ ) which may be correlated with exposed dolerite. The correlation is limited, however, since to the north and south, positive contributions due to the presence of dolerite are overwhelmed by the large negative background. A small feeder is thus implied at FP060615.

The positive anomalies along the southern side of the Denison valley are a continuation of the major features described above. They enclose a small pocket of coal measures and produce an anomaly differential of about  $100 \mu\text{m/s}^2$ . Sizeable dykes are considered to be present in this region.

It appears that the granite stock centred beneath Lynes Sugarloaf has dominated sites for dolerite emplacement and it is ringed by feeders.

#### *Swansea - Freycinet*

This zone contains some extensions of the positive anomalies described in the previous zone and includes a large anomaly [EP930435] of  $+42 \mu\text{m/s}^2$  which clearly represents a massive feeder in The Grange Hills north-east of Swansea, or a thick sheet west of Swansea.

Two major negative anomalies run out to the coast along Nine Mile Beach. The largest, of some  $-90 \mu\text{m/s}^2$ , is rather box like and situated toward the eastern end of the beach. The gradients east of this feature are smoothed by the presence of negatively attracting granitic materials. The anomaly at this site and of this scale can only be due to a Tertiary sequence and some Tertiary materials are present around Pelican Island and north of Swansea. Block faulting is suggested. The sediment thickness is likely to be at least 250 m. A similar but smaller structure is present at the western end of the beach and correlates with the large plain north of Swansea. The peak anomaly in this region is about  $-50 \mu\text{m/s}^2$  and about 100 m of sediment is implied. Surface expression of Tertiary materials is terminated near the  $-5 \mu\text{m/s}^2$  contour and the small offset negative anomaly along the Swan River from The Grange to Cranbrook is presumably due to a section of Triassic rocks with minimal dolerite intrusions. The maximum anomaly in this region is about  $-22 \mu\text{m/s}^2$  and rapidly closed to the north.

Three sites for seismic reflection soundings have been occupied along Nine Mile Beach in order to provide an independent guide to the scale of the Tertiary structures. These targets were chosen because previous experience with the method suggested that good analogue results could be expected, so obviating the need for processing.

Site 1: 0.7 km west of road loop at Coles Bay end of Nine Mile Spit  
[EP996392]

Gravity anomaly:  $-70 \mu\text{m/s}^2$

Shot offset: 15 m; geophone spacing (groups of 6) 3 m; 28 Hz

All geophones buried. Best results were obtained (in windy conditions) using LL input filters at 2000 samples/sec.

Interpreted reflectors at 52, 77, 102, 114, 126, 166, 184, 204, 230, 260, 280, 300, 340, possible 390 ms.

Typical shallow refractor velocity: 1800 m/s

The major events at 280, 300 and 340 ms probably represent basal deposits within the Tertiary basin and one or more the base of the deposit. These travel times would be equivalent to depths of 252, 270 and 306 m respectively. If we then assume a section containing 250 m of Tertiary sediments ( $\rho = 2.00 \text{ t/m}^3$ ); 100 m dolerite ( $2.90 \text{ t/m}^3$ ); 100 m Permian rocks ( $2.50 \text{ t/m}^3$ ) the resultant two dimensional anomaly would be  $-69 + 9.5 - 7.1 \mu\text{m/s}^2$  or  $-66.6 \mu\text{m/s}^2$ . Given that the feature is three dimensional and that the peak anomaly value is  $-90 \mu\text{m/s}^2$ , it seems likely that the Tertiary thickness is greater, probably over 300 m even allowing for some variation in the amount of dolerite included:

$$\begin{aligned} \text{e.g. } 300 \text{ m Ts} + 100 \text{ m Jdl} + 100 \text{ m P} &= -80.4 \mu\text{m/s}^2 \\ 300 \text{ m Ts} + 100 \text{ m P} &= -89.9 \mu\text{m/s}^2 \end{aligned}$$

Site 2: On beach at end of short road spur to the access point at the centre of the spit [EP950394]

Gravity anomaly:  $+10 \mu\text{m/s}^2$

Shot offset: 40 m; geophone group spacing 5 m; 28 Hz

All geophones buried. Best results obtained with input filtering (LL) and output filters (LH, HH) at 1000 samples/sec.

Interpreted reflectors at 40, 65, 90, 110, 150, 170, 200, 215, 245, 255, 270, 305, 360 and 410 ms. The event at 90 ms is large and compound and probably represents the base of the Tertiary sediments (at  $\sim 81 + \text{m}$ ). The gravity anomaly could be accounted for by 80 m Ts + 350 m Jd + 100 m P (equivalent to site 1 section total depth) =  $22.4 + 33.2 - 7.1 \mu\text{m/s}^2 = +3.7 \mu\text{m/s}^2$ .

In the seismic section, similar values could be obtained if the 200 ms reflector is the base of the dolerite and the 245 ms reflector the base of the Permian.

Dolerite thickness at 5500 m/s (55 ms half time) = 303 m

Permian thickness at 4500 m/s (22 ms half time) = 99 m

Using these values and a surface corrected upper layer (63 m) the calculated anomaly would be  $+4.5 \mu\text{m/s}^2$ .

Site 3: Swansea end of Nine Mile Beach at end of track to mouth of Meredith River [EP885370].

Gravity anomaly:  $-10$  to  $25 \mu\text{m/s}^2$ , steep gradient.

Shot offset: 40 m; IF = LL; OF = HH best results.

Very windy conditions. Interpreted reflectors at 120, 205, 270, 310 and 370 ms. The reflectors at 120 and 205 ms are compound and probably represent base Tertiary/top dolerite; base dolerite.

With surface corrections, these values yield thicknesses of 90 m and 231 m respectively and a section of 90 m Ts + 231 m Jd + 100 m P =  $-10 \mu\text{m/s}^2$ . Given the gradient conditions and exact anomaly location, these results are certainly consistent.

Relatively low amplitude anomalies may be observed on Freycinet Peninsula associated with the granite, Mathinna Beds and basal Permian rocks. The pattern is comparable with that observed on granitic basement elsewhere,

e.g. Zone 1. The scale and form of the structures north of Coles Bay cannot be estimated qualitatively. There is no obvious expression of any anomaly contribution from the major structure which juxtaposes dolerite and granite along the western side of the peninsula.

#### *Snow Hill*

As noted in the discussion for the Rossarden - Royal George zone (fig. 12) interpretation of extended area anomalies of  $-50$  to  $-60 \mu\text{m/s}^2$  south of Royal George, along the West Swan [EP798610] and Cygnet Rivers [EP810576] reflect thick coal measures sections. Triassic coal measures are exposed high on the escarpment south of Royal George from near Lochaber [EP810670] to south of Avoca [EP650630] but not elsewhere. However, the negative anomalies, which exceed  $-30 \mu\text{m/s}^2$ , in the headwaters of the Brushy River [EP740510], the central region of the Cygnet River [EP810560], south-west of Snow Hill [EP690570] and around Gilbert Dick Hills [EP580530] certainly imply a substantial sedimentary section. The capping may also be substantial and comparable with Fingal Tier.

Little drilling information is available, but two holes (AV8, AV9) drilled by the Shell Company have revealed in excess of 300 m of dolerite in the eastern portion associated with anomalies of  $0$ ,  $+8 \mu\text{m/s}^2$ . These results suggest that anomalies of  $+15$  to  $+25 \mu\text{m/s}^2$  reflect thick or multiple dolerite sheets and/or possibly no sedimentary section. Other anomalies, in excess of  $+30 \mu\text{m/s}^2$ , are certainly feeders. Two anomalies exceed  $+60 \mu\text{m/s}^2$  [EP770630, EP810625] and suggest very large feeding dykes. The major east-west alignment of positive anomaly north of Snow Hill suggests a large dyke which dominates the coal measures section south of Royal George. This section has been drilled (Investigator Coal Exploration; 78RGL, 2). South of this structure, the anomaly distribution is similar to that on Fingal Tier and the values generally suggest a capping sheet of at least 250 m and a sedimentary section not less than 300 m.

#### *SUMMARY OF QUALITATIVE INTERPRETATION*

The regional gravity survey of central eastern Tasmania has clearly revealed the location of more than twenty dolerite feeders, thick dolerite sheets, several granite plugs and identified several sectional problems worthy of further work. Combination of observations on dolerite feeders and sheets with granite highs severely limits the areas liable to contain thick sections of coal-bearing rocks. In general, the prime target areas lie in the eastern and southern parts of Fingal Tier and around Lynes Sugarloaf. No other parts of the area covered by this survey, with the sole exception of the Nicholas Range, can be expected to contain significant reserves of coal. The prime target areas (see fig. 13) may be specified as

- i) South-east of the Duncan mine, Fingal
- ii) South of St Marys, west of Dalmayne
- iii) Lochaber to the Douglas River
- iv) East Lynes Sugarloaf to Llandaff
- v) Between the West Swan and Cygnet Rivers

Most of the first area lies within State Reserve 1964/167, which also includes two major feeder systems, while the second, fourth, fifth and most of the third are presently held under exploration licence 5/61 (Gray) by Industrial and Mining Investigations Pty Ltd and 18/77 (Avoca) by the Shell Company of Australia. The interpretation is summarised by Figure 13.

The original version of this figure (fig. 7 in Leaman, 1978) carried

a similar legend but gave more detail about basement and section thicknesses. It also showed exploration zones described as 'prime' and 'good' target areas, or regions where the dolerite cap was very thick. The present figure (13) is simpler because the residual separation on which it is based largely excludes basement influences. A 4 km grid average has been used to derive Figure 13 whereas a 16 km grid average was used to derive the old Figure 7. Consequently basement details are discussed separately (fig. 11, pp 16). In addition, the change of regional grid filter improved the resolution of feeders and thick sheets since these are relatively shallow high contrast features. Several such features may integrate to produce a false impression. Consequently the qualitative interpretation provided in Figure 13 is more accurate but still conservative. The general picture for the northern part of the coal-bearing region, north of grid 700 (5370000 mN), of a thick sedimentary section with several feeders and variable sheets is certainly supported by the quantitative interpretation. It may be expected that all the unhatched areas on Figure 13 contain a substantial, potentially coal-bearing, sequence. The refined Fingal Tier interpretation suggests that much of the hatched areas may also be coal-bearing. The actual type or extent of intrusion, and whether the coal-bearing part of the section has remained unaffected, is indicated by the absolute value of the residuals. Values in excess of  $+10 \mu\text{m/s}^2$  imply a high risk of section loss and Figure 13 is drawn on this basis.

Previous discussions (p. 9) have shown, however, that misleading values are possible for the range  $-20$  to  $+10 \mu\text{m/s}^2$ , depending on the proportions and substance of a particular section. Thus some geological controls must also be applied. Considering the few available sections and drill holes it may be concluded, in association with the unhatched areas of Figure 13, that the best coal potential lies east of grid 850 (5850000 mE) and probably north of 650 (5365000 mN). This does not imply that mineable coal is present, merely that the Triassic section is substantial. This is clearly not so north of Royal George and west of grid 850, although a portion of this area contains a section, which though thin overall, is dominated by sedimentary rocks. It is not likely to offer much potential for coal exploration. Similar comments apply to the zone south of Royal George but north of the West Swan River and west of grid 850. South and immediately north of the West Swan River the position is unknown. The survey suggests a section dominated by sedimentary rocks, but the Triassic or coal measures content of this section is unknown. The exploration potential cannot be assessed without some drilling being sited on key negative anomalies within the region.

Figure 13 also shows the extent of Triassic rocks, which in the north-east of the area are coal-bearing. This situation cannot be expected to persist south-westward since the Triassic succession in the Midlands is known to contain a substantial basal component lacking coal units. Consequently only those zones in which the section appears thickest will be attractive for coal exploration. These will be associated with the larger negative anomalies.

The provisional interpretation provided is limited by the current levels of geological knowledge and the constraints of the gravity survey. Some ambiguity is inevitable where control points are very widely spaced or are not correlated with established units or features. Particular refinements are made possible by quantitative assessments or more detailed coverages. Comparison of the regional and detailed interpretations of Fingal Tier indicates the relevance of the latter factor.

The sheet-like character of the St Marys porphyry and the stock-like

character of the granite at Rossarden and Royal George is confirmed. The nature and extent of the granodiorite north of Piccaninny Point is uncertain without model calculation. An additional large stock west of Bicheno, below Lynes Sugarloaf, has been located and limits placed on its extent. The present interpretation does not offer any solutions for the nature of the bounding structures which juxtapose dolerite and granite, although at least one feeder occurs in such a zone. Many small feeder systems are likely to be concealed in the broad areas of positive anomaly south of Lochaber and south-west of Fingal.

The common north-west, north-east and east - west trends are reflected by the gravity anomalies. The interpretation given above represents a limiting view of the survey and establishes guidelines for the first quantitative model. A number of difficulties have been raised; what is the contribution to each anomaly of basement influences?, how three dimensional and interactive are the anomalies?, and the limited whole section drilling control (most holes are shallow and few penetrate to Permian rock or basement) and its uneven distribution.

Most of the anomalies result from an interplay of dolerite and coal measures influences. Anomalies range from about  $-60$  to  $+60 \mu\text{m/s}^2$  with most features in the range  $-30$  to  $+20 \mu\text{m/s}^2$ . Given the information on density contrasts, negative anomalies imply minor cappings and a substantial sedimentary section but any positive value, especially those in excess of  $+10$  to  $+15 \mu\text{m/s}^2$  should be regarded with exploration caution.

#### QUANTITATIVE INTERPRETATION

As noted above, much information is contained in the Bouguer anomaly maps and cannot be accessed simply. This is largely due to the target anomalies being confined between a high relief surface for the observations and the geoid. Normal reduction and interpretation procedures presume all anomaly contributions arise below the reference surface and cannot reliably or accurately cope with the actual situation. In addition, the interpretation must be three dimensional in order to evaluate the form and interference of likely source masses.

The solution to these problems requires four stages of processing. First, the actual observations are examined and a set of imaginary masses is created at some new reference level, so avoiding the effect of anomalous masses in the topography. These masses must be able to generate the total field as measured. The reference level in this case will be lower than the geoid since some stations are at sea level. Second, when the equivalent masses have been calculated the derived gravity field may be produced for any other reference level. Thus the effects may be continued upward to a reference level which is above the highest point of the topography and hence above the observed data. Third, a residual may be calculated at the new level by continuing the field to a much higher level and then subtracting it from the continuation at the lower level. Fourth, since the new field (or residual) is for a level above the terrain, standard interpretation procedures may be applied with the first layer - variable but precisely defined - of air. The geology of the model then constitutes the remainder of the model. Unfortunately, with a large number of irregularly spaced data points, this process is expensive in terms of computer time but still relatively cheap when compared with the cost of wasted drill holes. The cost of the entire quantitative interpretation for the regional coverage presented here is equivalent to that of a single 500 m deep hole (computer time costed at the commercial rates paid).

5 cm

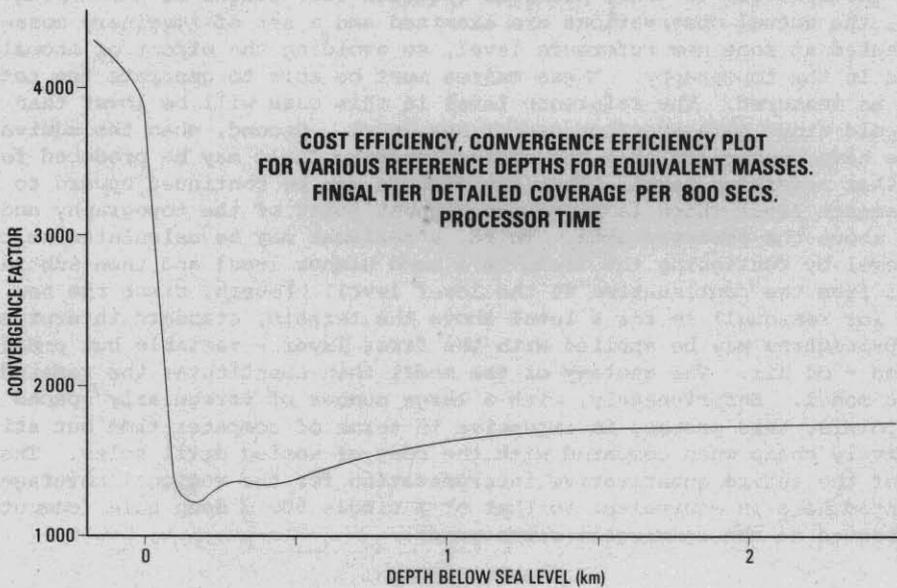
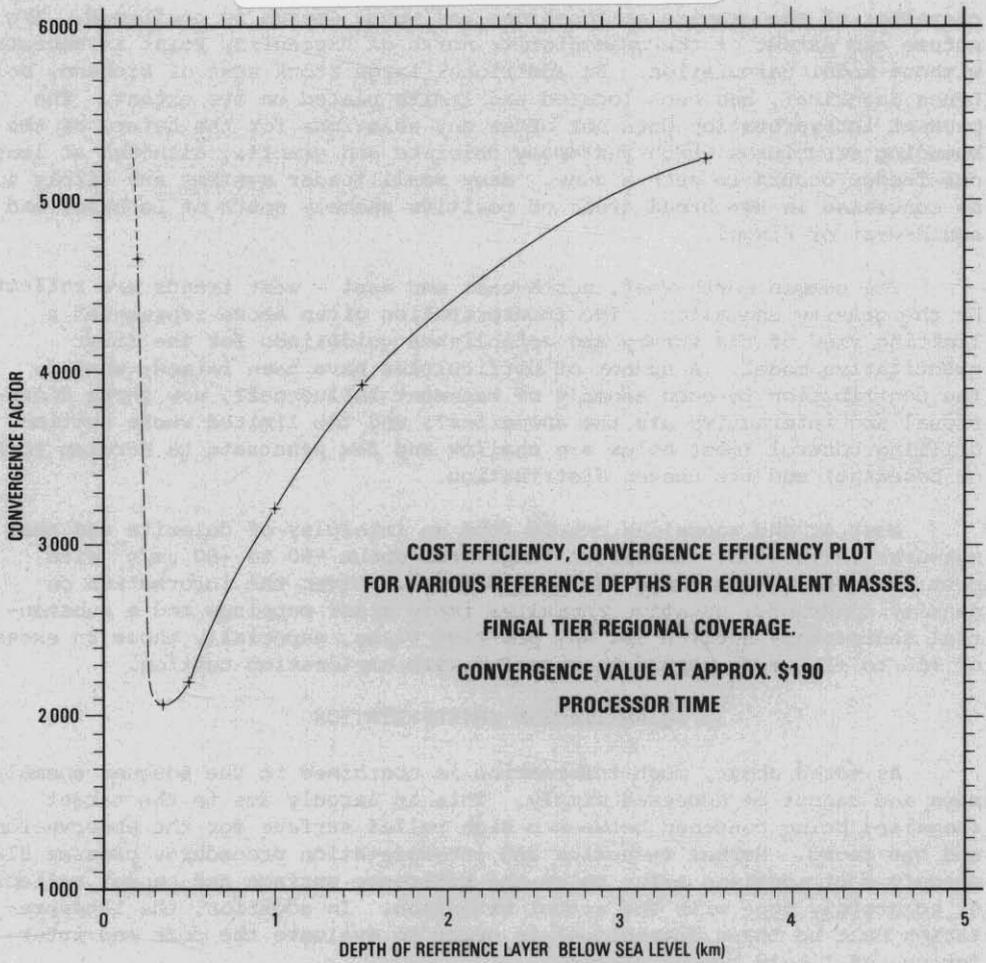


Figure 14.

Therefore, in order to make the process fit the budget, the area corrected was reduced from the full survey to the core area centred on Fingal Tier. This meant that the investment based on the regional data could provide some immediate guidelines and indicate the best procedures and starting model for the detailed survey when completed (discussed in next section). Decisions related to the first stage of processing - the level of the equivalent masses - and the problems of the relationships of topographic and geographic distribution were very difficult. Inspection of Appendix 2 will show how critical some of these factors are to efficient processing. (Appendix 2 summarises the programmes used and their mathematical basis).

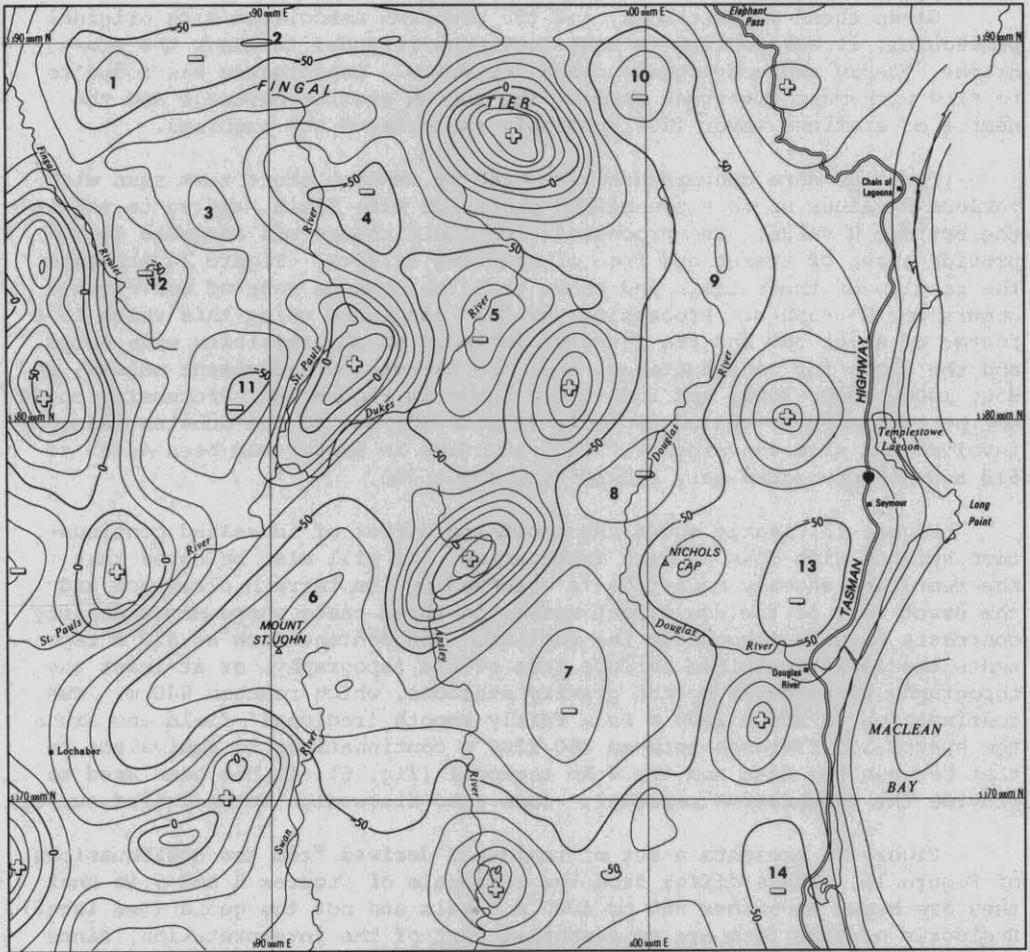
Given these restrictions, and the problems associated with original procedures, it was decided to make test runs in order to check the programme, theory and convergence characteristics. Convergence was found to be slow with many divergent steps. The uneven station coverage and the number of stations (over 1200) probably exacerbated the problems.

Tests of data convergence were made by running short test runs with various H values up to a prescribed processor time limit, and so to select the optimum H value. The processor time limit chosen was adequate to provide a set of iterations free of starting effects. Figure 14 presents the results of these tests and shows that the maximum rate of convergence occurs for  $H \sim 350$  m. Processing was then continued using this value to a factor of about 500 and the results plotted. No abnormalities were noted and the plots for continuations, from the calculated equivalent masses, at 850, 1000, 1500, 2000, and 2500 m are shown in Figure 15. Processing could not be continued to the ideal limit (about 200) due to the substantial cost involved and slow convergence. The reduction in factor had been 44495 to 518 and had proceeded very slowly from about 700.

Figure 15 clearly shows the smoothing effect of increased continuation heights with loss of high frequencies. It will also be noted that the resultant anomaly magnitude is affected by its terrain clearance and the exact form of the equivalent masses in those cases where major density contrasts persist throughout the section. The continuation at 850 m represents the lowest possible surface free of the topography, or at least the topography represented by the gravity stations, which reaches 848 m. The continuation to about 2500 m is a fairly smooth 'regional' field and since the spectral difference between 850/2500 m continuations is equivalent to that between the data and the 4 km regional (fig. 6), it has been used to provide the comparative residual. (See also discussion for detailed survey).

Figure 16 presents a set of residuals derived from the continuations of Figure 15. These differ from the residuals of Figures 8 and 9 in that they are based on either 850 or 1000 m levels and not the geoid (sea level). Residuals of this form are an essential part of the interpretation, since any model calculations must allow for the topography and maintain all parts of the model below the calculation surface. Spectrally, the 850/2500 m residual is comparable to the 4 km separation but somewhat smoothed by the 850 m continuation.

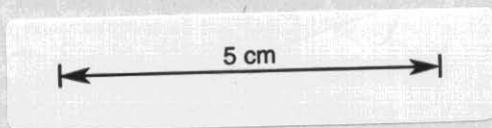
Some significant features may be noted in the set of residuals. Comparisons will show that certain anomalies are enhanced at certain levels of separation. For example, the major positive anomalies (due to feeders at EP960870 and EP920800) are not seen in the 850/1000 m separation since the cap of dolerite is fairly uniform and generally more than 100-200 m thick. The anomalies are more evident when contrasted at 1500, 2000 or 2500 m and increase with greater separation. This confirms the feeder character of



**MODEL 1: CALCULATED FIELD AT 850m**

CONTOUR INTERVAL  $10\mu\text{m}/\text{sec}^2$

FIGURE 17



these features and pinpoints several others [e.g. EP920670, EP950760, FP030725].

Many negative anomalies behave in a contrary fashion, such as the belt of anomaly north-west and south-west of EP950830 and around EP980750. This suggests that the source of these features is mid section or within the range 200-1000 m and therefore most probably in the coal measures or Permian section.

Each separation reveals traces of a NE-SW lineament extending across the centre of the area. It is just apparent in the 850/1000 separation but a strong gradient is evident in all separations below 1500 m, being weakest in the 1000/1500 m separation. This would imply a basement or near basement dislocation; probably a major fault. The lack of effect at shallow depth suggests non-involvement of dolerite and a (pre-) Jurassic age for the structure. The coal measures is probably disrupted but this is not definitely established in preliminary analysis. This feature was alluded to in the description of the anomalous resolution of residual anomalies in the Gray-Dalmyne-Llandaff region by qualitative analysis. The feature is not obvious in the Bouguer anomaly or conventional residuals but it may correlate with an extension of the Cornwall Fault (McNeil, 1965). The anomalies on either side are consistent with a west side downthrow involving Permian rocks and possibly part of the Triassic coal measures (presuming a Mathinna Beds density of slightly more than  $2.67 \text{ t/m}^3$ ).

However edge effects are possible in both figures east of grid line 605000 mE due to an absence of information immediately offshore.

The interpreted core zone presented in Figures 15 and 16 is centred on Fingal Tier. All calculations have included a 5 km wide extension or marginal strip, designed to minimise edge effects. The extensions are not included in any figure and all figures show only the model and results for the core area.

#### *Model analysis*

Only the first and final models are discussed here in order to simplify this discussion. Each is described in detail by examination of its parts and their effects. Model 1 is a summation of information extant in December 1979, while the final model is a summation of incremented data and resolution of implications based on intermediary models. It cannot be regarded as a complete or ultimate solution since many parts of the area lack any firm controlling information. It may be regarded as a specific quantitative structural guide.

Figure 17 presents the field as calculated for Model 1. In discussion it will be contrasted with the continuation separations for 850/2500 m. Figure 18 presents the specification of the model and Figure 19 the attraction assigned to each part.

The presentation in Figure 18 is awkward due to the complex three dimensional character of the model. Each part is defined by an upper irregular surface layer. Thus part 1 represents all the material from an arbitrary base level (-350 m) to the topography as dolerite. The attraction of this body is shown in Figure 19. Part 2 defines all the material from the base level to the top of the coal measures as coal measures. Since this volume had previously been assigned as dolerite the full dolerite coal measures contrast of  $-0.48 \text{ t/m}^3$  is used to calculate the effective attraction. Similar methods are used for the other parts (3, 4, 5) with partial

replacements of coal measures by Permian rocks, Permian by Mathinna Beds and Mathinna Beds by granite. In part 6 portions of all sedimentary units are replaced by dolerite to equate feeders. All parts are then algebraically summed. The feeders of part 6 have been calculated to a depth of -1000 m. Production of the model exposed many gaps in the general geological knowledge of the area even though the base level is only -350 m. The first part, which includes the bulk of the land surface, was the most complex since dolerite outcrops widely.

Comparison of the most appropriate residual (850/2500 of Figure 16) and the calculated field of the model at 850 m (fig. 17) allows several comments to be made. The actual values or absolute signs cannot be compared. The residual is based on data which has an elevated Bouguer anomaly due to an actual base level much deeper than the -350 m of the model. The model is more negative, by -40 to -70  $\mu\text{m/s}^2$ , implying that the near basement materials have a density slightly in excess of the Bouguer density. Thus any comparison of these figures must be based on gradients or relative amplitudes.

The model shows coarse agreement with the residual in terms of general distribution of positive and negative features. However, most positive features are too large and suggest that the feeder sizes presumed in Figure 18 (part 6) are too large. Some feeders are also misplaced. The body at EP840821 extends too far south, that at EP970875 is too circular and offset to the north-east, that at EP875690 is too elongate, there is little support for that at EP830680 and the twin features in the Apsley-Douglas divide at EP970770 need not be separated in order to produce the necessary western gradients.

The negative anomalies are the more significant economically and physically. Figure 19 (part 2) shows that the contribution of the coal measures outweighs all other components and indeed generates the overall negative effect of the model. Equally, the explanation of detailed variations within specific negative tracts is the primary aim of this interpretation. In general the real and calculated negative tracts (fig. 16) agree, but there are substantial variations in comparative value. The table below shows this. The sites are derived from Figure 17.

Site	Bouguer anomaly ( $\mu\text{m/s}^2$ )						
	Peak			Anomaly type	Average values		
	Calculated	Residual	Difference		Calculated	Residual	Difference
1	-60	-25	-35	(-)			
2	-60			(-)	-55	0	-55
3	-18	+15	-33	(+)			
4				(-)	-50	0	-55
5	-70	-6	-64	(-)	-55	0	-55
6	-70	-12	-58	(-)	-55	5	-60
7	-70	-7	-63	(-)	-60	5	-65
8	-60	-5	-55	(-)			
9	-60			(-)	-50	+25	-75
10	-60	-5	-55	(-)	-50	0	-50
11	-50	-10	-40	(-)	-40	0	-40
12	-50	-7	-43	(-)	-40	0	-40
13	-50	5	-55	(-)			
14	-50	10	-60	(-)			

Variations east of FP000800 may be partly ascribed to edge effects, elevated basement or basement variations but all others must be directly related

to dolerite capping or coal measures thickness. Most of the comparisons given above are free of feeder contributions but variations within anomaly sites 6, 8, 9, 13 and 14 especially must reflect changing sections. Even in the region of best control (sites 1, 2, 3 and 4) there are sizeable variations although the detailed survey (page 46) has modified the situation at site 1 by about  $20 \mu\text{m/s}^2$ . Site 3 is unusual and suggests that too much dolerite has been included in the model. Section proposed at 3 is;

granite	:	-350 to -100 m
Mathinna Beds	:	-100 to + 50 m
Permian section	:	50 to 250 m
Coal measures	:	250 to 500 m
Dolerite	:	500 to 820 m

The model at site 3 is strongly three dimensional and any simple evaluation is not possible. It does seem that the overall average thickness of the coal measures should be about 100 m more and that of the dolerite cap 100 m less. Clearly a model interpretation at this scale cannot resolve all such nuances but a detailed treatment can (page 55). Deficiencies of this order are built in to the model since slices of this size were used. A 100 m deviation would introduce a further  $-20 \mu\text{m/s}^2$ . Thus any refinements of this model must be restricted to producing the general pattern of anomalies with appropriate amplitudes (positive to negative) and extended gradients.

The final model accepted as being a reasonable representation of the structure of the area on a broad scale is given in Figure 20. It may be used as an exploration guide and it confirms the extent of coal measures implied in the qualitative assessment. The calculated attraction of the model is shown in Figure 21.

The model presented is final only in the sense that no further iterations are justified with the information available (June, 1980). It will be noticed that there are considerable differences between the specification of the initial model (fig. 18), which is based directly on the sparse geological facts, and that of the accepted model (fig. 20). The accepted model incorporates the experience of more than twenty structural variants used to assess likely structures where control is presently non-existent, as based on the gravity anomalies. In common with all potential field interpretations lacking firm control points (especially outside the Fingal or Gray areas) it must be used with caution. Nevertheless, it offers solutions to many problems and certainly limits the structural possibilities.

Comparison of Figures 16 and 21 will indicate why this combination of structures was accepted; it yields a general field distribution which matches in form and relief that of the residual and is only divergent near the coast where edge effects have distorted the continued field residual. The values given in Figure 21 are not as calculated (compare fig. 19). It was found, however, that removal of a scalar factor of  $70 \mu\text{m/s}^2$  from the resultant would yield values directly comparable with those of Figure 16 (850/2500). This eases comparison and shows the general balance of the model in contrast with model 1. Deviations are generally less than  $\pm 10 \mu\text{m/s}^2$ . Although this is a sizeable variation, it must be evaluated in the context of model specification and geological control.

It was noted above that the Triassic portion of any model contributes the bulk of the anomalies. Consequently the configurations of parts II and III (figs. 18 and 20) are vital to the interpretation. Even at these high

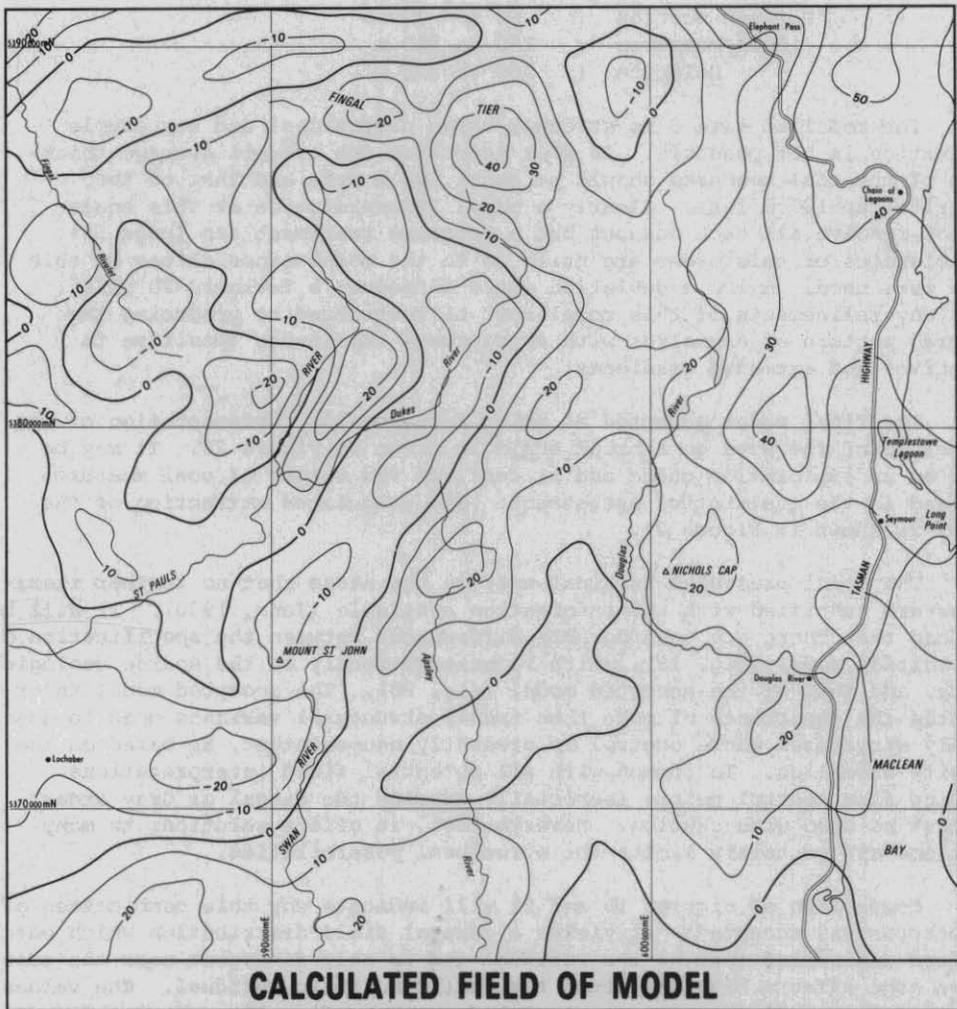
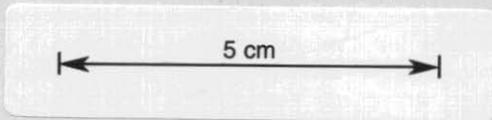


Figure 21.



levels in the structure, overall control is poor (apart from a few peripheral exposures, control on lower surfaces is virtually non-existent). This means that any interpolations involving the wedge of coal measures may bias the interpretation. Unfortunately coarse digitising intervals have been required in the three dimensional modelling process in order to reduce computing costs and these have lowered the resolution of the models. Note that a deviation of  $\pm 10 \mu\text{m/s}^2$  represents  $\pm 50$  m of variation in the dolerite-coal measures interface or  $\pm 250$  m of the coal measures-Permian interface. This shows how sensitive the process is to the placement of the dolerite base interface and also explains why no further refinement is justified given the constraints on the model and the data as a whole.

Within the limits of resolution, however, several key facts have emerged.

- (1) The Triassic coal measures are extensively faulted. Many situations have been recognised in which the coal measures must be thicker than originally suggested in model 1. Many of these structures, which have throws in excess of 100 m, are suggested in parts III and IV of Figure 20 by straight or disruptive segments and firmly indicated in part VI. While the processing may not identify all such structures, or possibly even locate them precisely, it certainly shows that NE-SW, N-S and E-W faulting is common and can be recognised after removal of terrain-dolerite surface effects. A major graben-like structure trends NE-SW across the area with a major downthrown block in the Lochaber region. The E-W anomaly trend from Lochaber to the coast is also fault-controlled.
- (2) The Triassic succession is consistent (averaging 250-350 m) across the entire area.
- (3) The Permian succession is not properly defined but a thickness of 100-200 m seems general.
- (4) Dolerite feeders are more numerous and much smaller than originally thought. Many take the form of thick dykes or dyke extensions from nearby pipes. The major 'feeders' on Fingal Tier are probably clusters of pipes. Several appear to be related to faulting suggesting that some faults are at least Jurassic in age.
- (5) Basement effects generally contribute little to the anomalies calculated at 850 m - the elevation of the model and residual anomalies. Most of these effects are coastal and not easy to assess due to edge effects in the continued residual. However, the models have assessed the possible effects of granite, Mathinna Beds and granodiorite in the important Gray-Dalmaine-Douglas Region (anomaly sites 8-9-10 of fig. 17). In this region the dolerite cap is generally thin (<100 m) and the Permian section is exposed in the coastal hills at a moderate elevation. However, the sedimentary section is faulted (see also parts III, IV, VI - fig. 20) and substantial coal measures sections are possible locally. The main problem noted in interpretation of this region (p. 29) is a positive contrast with the bulk of the area surveyed. Metamorphosed Mathinna Beds are areally limited, but a granodiorite slab as shown in part VII (fig. 20) could provide both the necessary attraction and the localised effect. Contrasted against a general granite

basement such a slab would be no more than 450-550 m thick and less than 300-350 m if intruding lower density Mathinna Beds. Such a body has been included in the calculation plotted in Figure 21.

- (6) Gradients in the region of Mt Elephant-Gray imply some large boundary structures. Geological mapping in the region has revealed a complex of faulting and igneous margins but the structures are not well defined or understood due to overall complexity and various types of cover. Consequently modelling has not been straightforward and has not adequately resolved the features which, gravitationally, have their greatest impact east of Gray. Most faulting is at, or west of, Gray. The principal gradient is clearly related to the margin of granitic rocks.
- (7) The basement materials (pre Permian) are varied. The most common basement is Mathinna Beds but adamellite-granite/granodiorite is present in the north-east and granite in the south and south-west.

#### SUMMARY OF QUANTITATIVE INTERPRETATION

Although the quantitative analysis has been restricted to a relatively small 625 km<sup>2</sup> portion of the survey as a compromise between computation speed, economy and digitisation efficiency it has allowed a considerable increase in the geological understanding of the region. Where the qualitative assessment was able to identify blocks of coal measures, dolerite feeder zones and infer one large fault zone, the quantitative assessment has shown that the sedimentary section is general, the feeders small and multiple and significant faulting common. Resolution of all these features is limited only by the general data coverage and the parameters of the models. These factors limit the degree to which the interpretation can locate or size the structures. Clarification is provided for part of the interpretation by the more detailed survey (next part).

The interpretation has been further restricted in the coastal zone by edge effects in the data and this has made evaluation of the Gray-Dalmayne-Douglas structures difficult. However, it seems certain that there are large faults near the coast and within the coastal hills. Within the limits applied by observations west of Dalmayne it is clear that large faults must be present to account for the overall anomaly levels (no consistent simple structure is possible) and that granodiorite intrudes the local basement rocks. The models calculated have all been based on the limited geological control extended by reasonable extrapolations suggested by the gravity field.

The diagonal, from Lochaber to Gray, largely followed by the St Pauls and Dukes Rivers, is a major fault zone. Although cross faulted with some dropped blocks it is basically a graben structure up to 6 km wide.

The following is a list of the contents of the book as given in the original edition. The book is divided into two parts, the first of which contains the general principles of the survey and the second part contains the detailed description of the survey.

## Part 2:

# INTERPRETATION OF FINGAL TIER SURVEY

The following is a list of the contents of the book as given in the original edition. The book is divided into two parts, the first of which contains the general principles of the survey and the second part contains the detailed description of the survey.

## QUALITATIVE INTERPRETATION

The Bouguer anomaly map for the detailed survey is given in Figure 5. It enables revision and clarification of most of the features observed or inferred in the full primary coverage. Several important interpretive revisions are possible immediately although all features recognised in the regional cover are confirmed. The revisions, with one exception, are a direct result of the increased station density and improved resolution. The features of the map are summarised below:

- (1) Since Figure 5 presents the observed Bouguer anomalies it also includes a regional component which increases the values from west to east. A change of at least  $60 \mu\text{m/s}^2$  is implied across Figure 5, based on estimates of the regional gradient in Figures 6 and 7.
- (2) A trough of low anomalies extends along the north face of Fingal Tier from EP800870 to EP930910 (site 1 of fig. 17). The trough narrows eastward and is disturbed by;
- (3) An abrupt positive anomaly centred on the ravine of Fingal Rivulet. The total anomaly is about  $+100 \mu\text{m/s}^2$ . A tongue of increased values trends southward, rising to  $+70 \mu\text{m/s}^2$  at EP840800. In the interpretation of the regional coverage it was presumed that these features, two peaks and ridge of anomaly, were a single complex feeder or dyke. This is clearly not so.
- (4) The negative anomaly, drilled by DOM DDH 29, is confirmed but it is now clearly shown that the borehole site was marginal to that anomaly.
- (5) A ridge of positive anomaly trends north-eastward across the Fingal end of Fingal Tier. This trend was suggested but unresolved by the coarser station coverage. It has a sharp positive anomaly at EP870850.
- (6) The remainder of the western half of the Fingal Tier survey area is confirmed as a tract of low anomaly values.
- (7) The major feeder anomaly on the north-east section of the tier [EP960870] has been confirmed but revised in form. Its western side is quite abrupt and corresponds to a stream valley linear. More significantly, the anomaly is shown to extend further to the west along the face of the tier until terminated at about EP905880 by a distinct but shallow step anomaly.
- (8) The gradient associated with the step anomaly was not recorded in the regional survey. The feature persists southward to form the western margin to the other major feeder anomaly. This feeder is now seen to be much smaller, narrower and to have a boss at its northern end [EP905855].
- (9) Between the two major feeders is another less extensive tract of low anomalies.

Only one error has been found in the original regional coverage for Fingal Tier and this relates to the amplitude of anomalies in the region of EP855885 where two stations biased the form of this part of the negative anomaly (site 12, fig. 17) above the Duncan mine. The excessively negative resultant 'pimple' anomaly may be noticed throughout all separations and continuations. The correction shows the field to be  $15\text{-}20 \mu\text{m/s}^2$  higher.

## QUANTITATIVE INTERPRETATION

### Filter theory

Before any attempt can be made to interpret the anomalies listed from Figure 5, including detailed nuances relevant to exploration targets and unit thicknesses, it is necessary to assess and remove an appropriate regional contribution from this map. Since any grid averaging process acts as a filter, it is necessary to evaluate which average unit size yields the best side to side balance while still leaving the anomalies of spectral character most appropriate to the aims of the project. This assessment has been undertaken by creating a data file (later to be used for continuation and interpretation purposes), which includes the stations on the Tier and those in a 5-7 km band around it, and then calculating a set of averages with unit sizes of 1, 2, 3, 4, 6, 8, 10 and 12 km. Figure 23 presents a comparative reference for evaluating filter response from these unit sizes. The filter limitation imposed by the field data distribution is plotted in Figure 22, presuming an overall average station spacing of 500 m. Thus the Bouguer anomalies can only reflect higher frequencies (to the right of the data curve) in those small regions where the station spacing is 250-300 m.

Curves related to grid averages are the filter response according to the function  $\text{sinc } x = \frac{\sin x}{x}$  where  $x = \pi s$  and  $s$  is the number of cycles

in unit scaled distance. The sinc function is a reasonable approximation to a low pass filter. If an aperture of  $A$  units is chosen, absence of distortion requires the area under the  $\pi$  function to be unity and the function can be expressed as  $\text{sinc}(A.s) = \frac{\sin A.\pi.s}{A.\pi.s}$ . The function has a

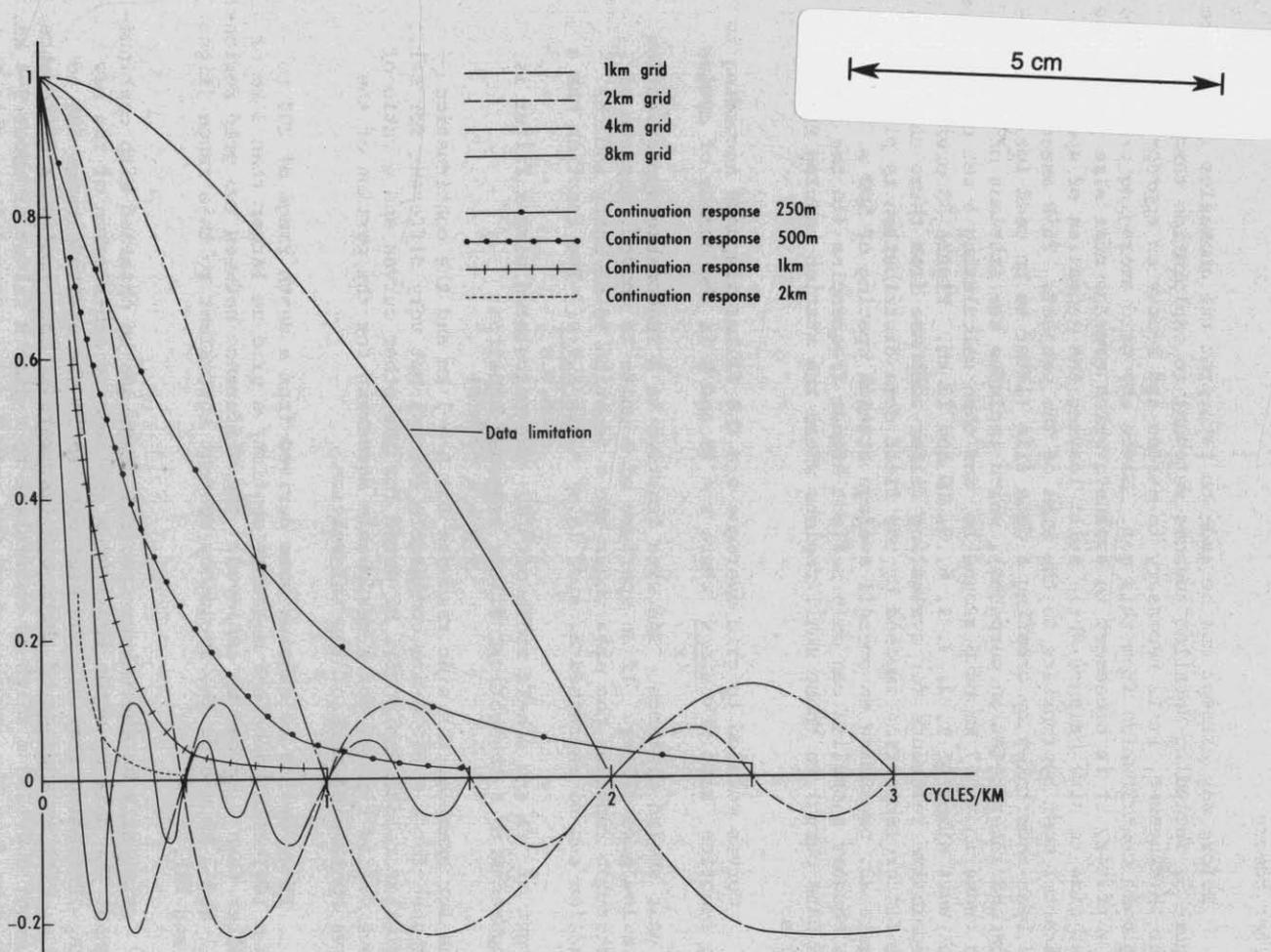
height of  $1/A$  and a half width of  $A/2$ . The calculated sinc  $x$  filter is compared with a theoretical filter response equation

$$\text{F.R} = e^{-2\pi h(s)}$$

Thus for example, the sinc response for  $A = 1$  km and the continuation response for  $h = 250$  m are comparable for  $s < 1$  but very different for  $s > 1$ . A similar relationship will be noted for the other curves and a ratio of about 4:1 is typical for a reasonable agreement for the portion of the curve containing most of the information.

If we desire to examine data derived from a depth range of 200 to 700 m (dolerite base-coal measures section) a grid no larger than 3 km or smaller than 1 km can be employed. The difference between two grid regionals at 1 and 3 km yields the frequency content equivalent to this range (figs. 23 and 24).

Similarly an equivalent spectral range can be obtained with continuation of the data by about 600-1000 m followed by subtraction of the raw data. Presuming that all the stations lie in the altitude range 500 to 850 m, with an average of about 650 (estimated), this implies a difference of about 850-1250 m which is equivalent to a sinc  $x$  filter of about 3-4 km. Some data from the extremities of the height range imply filter equivalents of 2.5-4.2 km. On this basis it is most reasonable to compare a model residual calculated on 850/1750 or 850/2000 continuations and either a residual based on 1/3 km regional separations or data/3 km separations, if information specific to the coal measures is required. These conclusions are based on the general extrapolation of the known depth range of the base of dolerite cap and base of Triassic coal measures as indicated by the drilling control available at 31 May 1980 in the north-western section of the detailed survey area. Consequently these conclusions might not be valid across the entire area or across other areas but it is reasonable

Figure 22. *Filter response*

to expect that a 3-0 filter separation would not introduce significant errors and that a reasonable filter range in any event is 2-0 to 4-0 (contrast latter used for regional survey). The minor differences introduced by the various filters will affect overall reliability and it is for this reason that no final decision on the correct filter should be made in a virgin area without some widespread, if sparse, drilling control.

Data on deeper parts of the section can be enhanced and selectively examined using coarser grid sizes. In each the interpretation can be extended to an 850 m reference level.

#### *Filter results*

The preceding discussion outlined what might be expected on theoretical grounds presuming uniformity of data, topography and reality of processing techniques. Figures 23 to 29 indicate the spectral content of the data at various stages as well as evaluating the veracity of the theoretical treatment.

Figure 29 represents the observed topographic and Bouguer anomaly data as incorporated in the computer analysis and reduction. The two versions reflect differing contouring approaches.

Figure 23 presents the set of regional averages. The high frequency content is rapidly reduced between 1 and 2 km sizes and the classical low frequency form for a data regional is apparent by 6 km. The 2, 3 and 4 km averages reflect mid-level structures, estimated to lie in the range 250 m to 1500 m as based on feature wavelengths.

Figures 24 and 25 show the range of residuals derived by subtraction from the observed Bouguer anomalies or from pairs of regional averages. The set of residuals represented by removal of various regionals from the data are indicated by reference to a zero base level (data). These show an increasing low frequency component and approach the character of the raw data as the grid size is increased. Thus the residuals using the 10 and 12 km averages are very similar to the observed Bouguer anomalies. In contrast, the residuals based on 1 and 2 km averages contain only high frequency information.

The residuals derived by separation of other regionals from the basic residual (referenced to data) yield variously filtered forms. Examples of the effects of such treatment are shown in Figure 25 for the set 8-0, 8-1 and 8-4. As the secondary separation is increased in size the frequencies remaining in the final residual are lowered. Thus the focus of the filtered residual becomes effectively restricted to the depth band represented by the grids used. Thus 8-0 reflects all contributions up to perhaps 2.5 km depth, 8-1 contributions between 250 m and 2.5 km, and 8-4 contributions between about 1.25 and 2.5 km. The depth equivalents stated are estimated on theoretical considerations and examination of residual anomaly wavelengths.

Figures 26 and 27 show the effect of field continuation. Continuations calculated for 650, 750 and 850 m cover the general topographic range and lower levels exclude only dolerite. 850 m has been used as a reference level since it represents the lowest level clear of the topography and observation points. It can therefore be used as a modelling surface.

The zone of greatest geological and economic interest is generally

between 200 and 600 m depth where the Triassic coal measures are sandwiched between an irregular sheet(s) of dolerite and Permian rocks. Thus the most relevant filter residual separation is probably 3-1 (fig. 24). For modelling purposes it is necessary to establish an equivalent continued residual separation. Considering the 3 km base for the filter residual (3-0), rather than 3-1 which excludes some data (the continuations do not), the best match is given by 2000-850 (fig. 28). The residual 2000-850 represents the residual anomalies to be expected at 850 m after removal of a regional effect equivalent to anomalies expected at 2000 m. This is as predicted by the theory and the general agreement is quite good. Models of the structure can be calculated three dimensionally with a reference level of 850 m and directly compared with the 2000-850 residual. The 3-0 and 3-1 filters can be used qualitatively to indicate relative thicknesses of dolerite/coal measures.

The other separations in Figures 24-28 provide a considerable insight into the dimension and distribution of restricted non-horizontal structures, such as faults and feeders. The discussion, as given above, emphasises only the crude horizontal structures or horizontal variations, such as cap or coal measures thickness variations.

#### *Implications of continuation separations*

The relevant continuation separations are shown in Figure 28. Only three features are present throughout the set; these are negative zones centred at EP880890, EP890840, and EP940850. The first zone has an ENE-WSW trend and reflects the escarpment of Fingal Tier with the lower level sedimentary section not capped by dolerite. For this reason there is a contribution from all levels of the section as represented by the continuation (or depth) slices. The other two zones are more significant, each being on Fingal Tier. The coordinates given only roughly indicate the zones. The western zone has a fist-like shape and a north-south 'thumb', while the eastern zone is made up of three semi-detached parts. These zones lie between the feeders clearly identified at EP840870, EP960870, EP920830 and EP840800 in lower separations. The recognition of these negative zones in all separations implies either an original bias in the observed data or appropriate contrasting effects within the dolerite cap. Since the magnitude of the residuals is relatively unchanged until the 1.35/0.85 separation, bias is suspected. With this residual the feeders become more pronounced and other positive variations are emphasised. This suggests that the interface between dolerite and coal measures has been traversed and the positive contrasts of pipes or sheet waves are being noticed. The lesser positive variations, for example at EP860850, are amplified with increased penetration in the range 1.35/0.85 to 1.75/0.85, while the major anomalies continue to enlarge to at least the limit of calculation (2.50/0.85). These observations confirm the status of the feeders and clearly show the high level waviness of the capping dolerite sheet.

The feeder centred in Fingal Rivulet [EP840870] is of particular interest. The Bouguer anomalies associated with this structure are pronounced (fig. 5). However, the continuation differences are only significant beyond the 2.00/0.85 residual. This is interpreted to mean that much of the mass is removed by the ravine of the rivulet, that the pipe is relatively small, and that the high contrast portion of the intrusion (with respect to coal measures) is absent. The latter condition is not applicable to the other feeders which, having avoided severe erosion, persist as pipes to relatively high levels of the section.

The relative sizes of the feeders were also implied in the regional model (fig. 20) where it is suggested that the Fingal Rivulet feeder is a small dyke extension of a larger body to the south [EP840800-EP840770] and that the major feeder is at EP960870. The feeder system centred on EP920830 is not as large, but more two dimensional.

#### *Implications of the continuations*

The continuations of the gravity field (figs. 26 and 27) indicate the relative importance and composition of all principal features. Consider first continuations above the topography (0.85 - 2.50). The 0.85 version is an effectively smoothed version of the data and shows all its essential characters. Following through the continuations several features may be noted.

- (1) The effect of the major feeder at EP960870 persists to at least the 2.00 km continuation
- (2) The feeder at EP920830 is removed by 1.75 km
- (3) The feeder at EP840870 is removed by 1.25 km. (These observations are consistent with the relative sizes and shapes, presumed and discussed above).
- (4) The negative zones on Fingal Tier are removed by 1.35 km
- (5) The negative zone adjacent to the escarpment is removed at about 1.45 km.

Division of these continuation ranges by a factor of 3 or 4 yields an estimate of the depth range for which a substantial density contrast, and hence anomaly source, is extant.

The most significant continuations, however, are those for depths below the topography and surface geology. These reveal very clearly the form and areal extent of transgressive dolerite forms, pipes or dykes, and suggest zones in which minor features not apparent in the normal data reductions might be encountered. Such features are relevant to drilling programmes, reserve estimations or mine planning and may need confirmation by other techniques. The indications of such features should not be ignored.

A number of features emerge from the downward assessment. This discussion is based on the 0.25 km continuation with comment on changing characters seen in other continuations. All potentially relevant features may be recognised at this level. At lower levels there is a risk of single slightly spurious observations or the observation spacing itself biasing the result.

Consider the four primary 'feeders' described above.

- (1) The major feeder in the north-east of the area [actually centred EP960870] is in reality a multiple feature comprising one large dyke [EP955850 to EP965865], three substantial pipes [EP933860, EP970825, EP970848] and six lesser pipes [EP947855, EP945840, EP980840, EP977833, EP967835, EP963823]. Many of these features have a small areal extent and dolerite cannot be expected between them. The patchy form of this structure is not obvious in continuations higher than 0.55 or 0.65 km. This is to be expected after allowing for the normal terrain height of 600-



750 m in this region. The apparent emergence of the pipes from about 0.45 km suggests that the average sheet thickness in this region is no more than 150 m. Below this depth the high density contrast situation (dolerite-coal measures) is present.

- (2) The major feeder in the south of the area [around EP900830] is seen to consist of at least three major pipes [EP910835, EP925825, EP907800], a dyke [EP905840-EP905860] and possibly three smaller pipes [EP936815, EP950810, EP915807]. The entire form of this body varies substantially from that implied from upward continuations or observations.
- (3) The feeder in Fingal Rivulet [EP840870] is shown to be much smaller and relatively poorly defined. The implication of a long thin dyke is confirmed.
- (4) The north end of the feeder system at EP840800 is also clearly visible as a discrete pipe.

Other, smaller, positive anomalies may reflect small dykes or pipes but this cannot be absolutely determined with the data to hand. Such zones are indicated on the predictive structure warning map (fig. 30). Consideration of known structures or geological inferences suggests that 90 to 100  $\mu\text{m}/\text{s}^2$  (9-10 mgal) may be significant. For example, a number of small features may be noted with a NE-SW trend across the western half of the area. Where this trend passes into the region which has been drilled (as at June 1, 1980) this corresponds to a zone of marked downward transgression of the dolerite. Holes DOM DDH 23 and 24, for example, lie on this axis. Dolerite is transgressive upward to both the north and south and, given the hydraulic theory advanced by Leaman (1975), this certainly implies the presence of feeding sources. They therefore appear to be many, but small and apparently isolated. The possible sites for such sources are therefore identified though not all may be necessarily occupied by small feeders. In addition there is no means of establishing the likely size of any feeders present given the absence of more detailed controls or the subsurface proving of any of these anomalies. However, a maximum scale can be estimated. None of these bodies is likely to exceed 75-100 m in thickness or diameter. Consequently, they will not represent major mining problems since planning can ensure that these small high-risk problem areas are totally avoided with minimal dislocation of the operation. Smaller features, such as the ubiquitous five metre dykes, cannot be identified. Local variations in surface sheet capping thickness produce values of -60 to +80  $\mu\text{m}/\text{s}^2$  (-6 to +8 mgal). From current drilling data it may be inferred that values of -20 to -60  $\mu\text{m}/\text{s}^2$  imply up to 100 m of cap, +20 to -20  $\mu\text{m}/\text{s}^2$  200 m of cap, +20 to +60  $\mu\text{m}/\text{s}^2$  300 m of cap and +60 to +100  $\mu\text{m}/\text{s}^2$  400 m of cap. These figures should be considered tentative on present information.

Several trends may be discerned and some of the more obvious are indicated in Figure 30. Faulting has been implied in nearly every case. Not every possible fault-gradient has been so indicated in the figure, although many more may represent faults. This has been done in order to stress those features which appear strongly in many continuations and which, presumably, are more important features. Unfortunately, such an emphasis may be subjectively or structurally biased. The basic difficulty relates to rock contrasts. If a fault dislocates Triassic or deeper units only it must produce a lesser gravitational contrast than if dolerite is in some way involved, either by dislocation (post-intrusion) or by stepping (syn-

intrusion). Consequently, either of the latter possibilities may produce a clearer gradient, although deeper continuations aid the resolution of types. It is not possible with present control to specify the location accuracy of such faults but since many gradients are steep the error is unlikely to exceed 100 m. This reliability estimate is only applicable to the area of the State Reserve where the interpretation is based on a high density station coverage. The area of reliable coverage is more truly indicated in Figures 24 and 25 and is not as extensive as implied in Figures 26, 27 or 30.

Figure 30 also suggests three small zones [EP865835, EP895805, EP910820] in which coal measures may outcrop or nearly outcrop. In each case the field value is less than  $-60 \mu\text{m/s}^2$ . Topographic expression of the dolerite cap in each case tends to support this inference although no non-dolerite (or non-talus) exposures are known in these areas.

The fault pattern and feeder character suggested in Figure 30 is wholly compatible with the coarser deductions based on the regional survey. However most features are specified in detail and more accurately located.

Some other small positive pimples have been identified north of Fingal Tier on the escarpment. These presumably represent small dyke feeder systems, most of which are concealed by the extensive talus deposits.

This discussion was restricted to an appraisal of continuation to only 250 m above sea level for two reasons. Firstly, with greater depth the increasing contour density produces an unclear map (compare 150 m), and even with contour number reduction the effects are not as clear (compare - 50 m). Secondly, the displacement of several hundred metres from the equivalent sources minimises the errors and allows an integration of effect. Continuations at -50, -150 m, which are close to the sources, show spiky localised anomalies not always directly correlated with features at 250 m or the surface. This deviation in continuation character for certain smaller features implies either that the mass distribution is more complex with more integration of effect or that the bodies are discrete but non-vertical. This cannot be resolved but either or both solutions are possible. Note that it is only relevant to those features displaying ten or less units on the 250 m continuation. These, as suggested above, may represent the small plugs, pipes or dykes so common in intruded rocks but which are too small to be apparent in any normal gravity treatment. Equally they may be spurious, but since most are located in the western wedge of thickened dolerite at least some of them must be considered probable sources.

Having established something of the form of vertical variations, using an examination of the continued field, some consideration should be given to horizontal variations.

The reader should note that the calculation of the equivalent masses used to produce continuations is of restricted accuracy due to insufficient computing funds. Convergence was terminated at 700 rather than the desirable 400 and an error, estimated at 5 to  $10 \mu\text{m/s}^2$  may be involved. Convergence was very slow and the results are believed to be, but not confirmed to be, reliable for the purposes of this interpretation.

#### *Use of the 3 km regional filter*

It was established in a previous section that the 3 km filter makes appropriate account of variations in the coal measures sandwich. This is

a gross assessment based largely on two dimensionality and it cannot properly compensate for any feature producing a strong gradient, especially if localised. Filter resolution is also reduced by smoothing and integration of effect; these deficiencies are not present in the continued field (figs. 27 and 30). However it is more readily usable in a semiquantitative way where an indication of the scale of variation is desired.

Using the measured densities for dolerite and coal measures, a 50 m variation in their common boundary results in a  $10 \mu\text{m/s}^2$  (1 mgal) change. This is the effect given two dimensional conditions.

In particular, consider the 3-1 focussed filter. Most of the near-surface variations have been removed and each contour would represent, assuming all conditions are met, about a 50 m variation in the boundary (the 3-0 filter is reproduced in fig. 31).

In broad terms the 3-1 filter picks out the major feeder zones and the significant sedimentary basins. The total variation in contours is 6 units ( $60 \mu\text{m/s}^2$  or 6 mgal) suggesting a total boundary variation of 300 m. This is quite consistent with the likely thickness of the coal measures below the reference depth of about 200-250 m (produced by the one kilometre modulation) and allows full transgression by the dolerite.

However, it is not possible to prepare directly a simple tabulation relating cap thickness to reduced anomaly value. This is simply explained. The same principles apply to other key references - especially low level continuations or the 3-0, 3-2 filters. Values as contoured represent an integration of effect and are not uniquely soluble in terms of body shape. Thus swells of anomaly ranging from +10 to -10  $\mu\text{m/s}^2$  reflect general changes in cap thickness with a total relief of about 100 m. However, if the change occurs rapidly, in less than one kilometre, and a discrete anomaly wave is present, with similar values on either side, then it is possible for the thickness change to exceed 150-200 m. Where the change takes the form of a simple gradient, however steep, the relief remains 100 m. Where similar values extend over substantial areas then gross comparisons can be made according to the density algorithm. Where gradients are curved, anomalies circular or elliptical, or contours close showing cols then three dimensional effects are implied and the indicated value may be meaningless for simple interpretation.

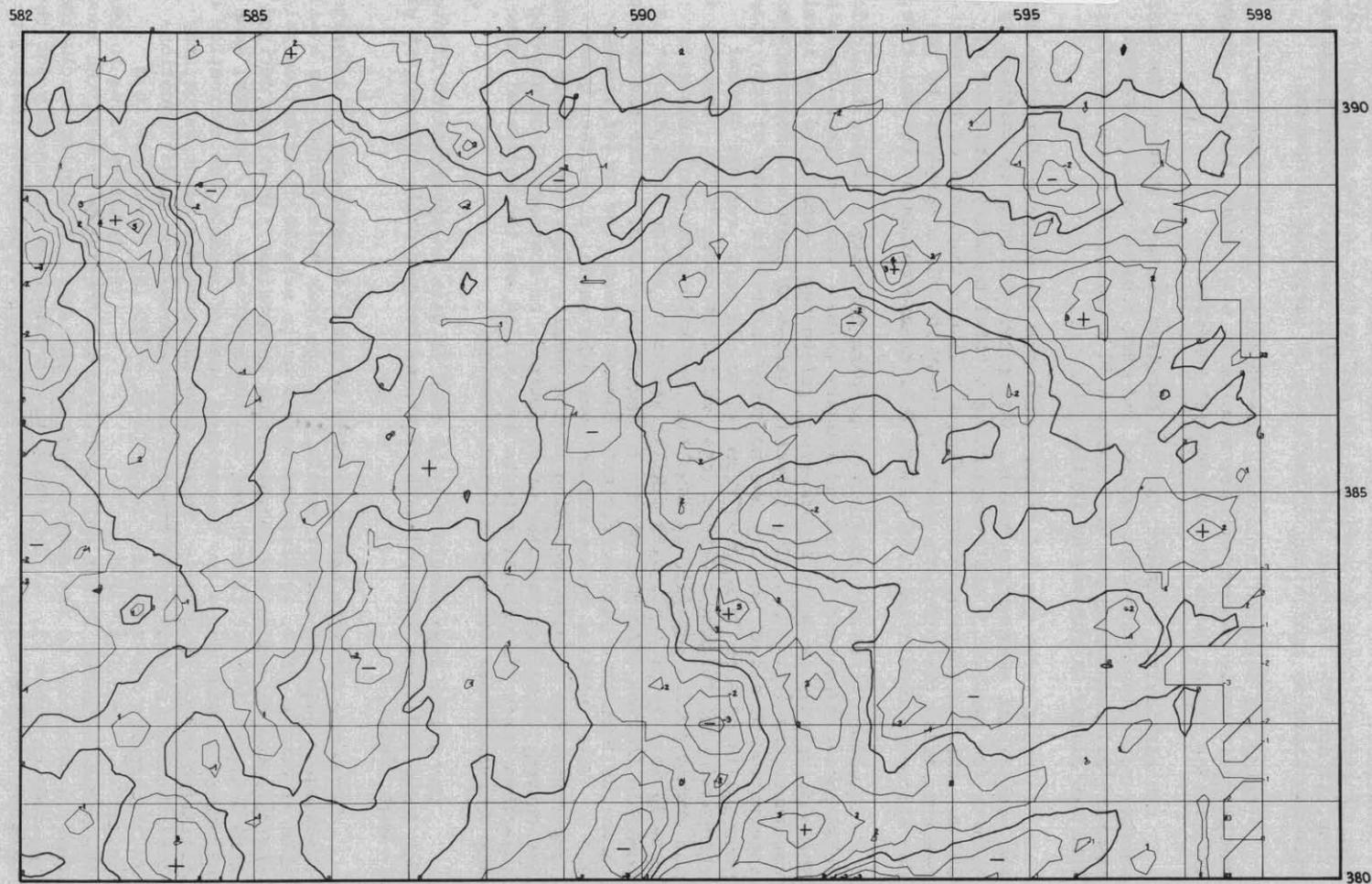
The filter maps should only be read to gain an appreciation of overall forms and allow interpolation of shapes between drill hole points within each region.

Even so, attempts have been made to quantify estimates of dolerite thicknesses based on contour levels. If the bore hole control, as available at June 1, 1980, is directly used a quite erratic distribution relating dolerite thickness and anomaly value is obtained for values derived from 3-0, 3-1 and 3-2 filters and 250 continuations. If, however, some allowance is made for a two dimensional span of anomaly, or correction of estimated end or 3D effects, rather than the specific point value, the distribution is found to be bimodal about *approximate* linear equations

$$\text{Jd thickness} = 5.0 \times \text{anomaly value (3-0)} + 310 \text{ (W)} \quad (\text{thickness in m})$$
$$\text{or } \text{Jd}_t = 5.0 \text{ A} + 200 \quad \text{(E)} \quad (\text{anomaly value in } \mu\text{m/s}^2)$$

The second equation is not well specified but does seem to meet the known control data best in the eastern part of the area. A similar conclusion was made on pages 29, 30, in regard to cap thickness and anomaly for the Dalmayne-Douglas Region. The dichotomy appears to be partly related to overall structural levels and bias in the regional averages. These

5 cm



56

Figure 31. Residual Bouguer anomaly, Fingal Tier detailed survey. Filtered residual (3-0; 3 km grid average and data)

equations should only be used as rule of thumb guides under the conditions specified or inferred. Thus an indicated  $-10 \mu\text{m/s}^2$  anomaly in the west of the area implies 260 m of cap or 150 m in the east. Note that an appropriate anomaly value may depend on the coverage of the survey and obvious refinements between the regional and detailed coverages described in this report reveal the extent of the improvement of definition.

Part of the difference is also due to the average elevation difference between the anomaly location calculation point and the surface distribution of stations. Consider DOM DDH 45 [EP897850] which was completed after derivation of the equations as this text was being prepared for printing.

local anomaly  $\sim -10 \mu\text{m/s}^2$  (1 mgal). However, the entire zone is narrow and surrounded by large positive values and some strong gradients. A more realistic value is at least  $-15 \mu\text{m/s}^2$

dolerite thickness implied  
 $T = 5 \times -15 + 310 = 235 \text{ m}$

average elevation of local gravity observations = 790-810 m

elevation of borehole = 710 m

thickness of dolerite to be excluded from calculation  $\sim 90 \text{ m}$

corrected thickness of dolerite at DOM DDH 45  $\sim 145 \text{ m}$

drilled thickness 126 m

This sample calculation exposes most of the assumptions implicit in use of the equations. Firstly, it is essential to make a sound estimate of the two dimensional value. Secondly, the relevant level of the Bouguer anomalies must be established. In this case if more stations had been observed at the level of the borehole, were this possible, the value of the field would have been substantially lower and the calculated thickness less. This excess must be estimated and deducted. Where the relief is less or the terrain more uniform this problem is less serious and possibly the second equation is more relevant.

The value of 5.0 for the slope of the line is rounded from the slope calculated for the lines of best fit. The nearness of the actual value to the theoretical value ( $50 \text{ m} = 10 \mu\text{m/s}^2$  or  $5 \text{ m}/\mu\text{m/s}^2$ ) indicates that any approximation should use the predicted value.

Most discrepancies fit either the alternate equation or relate to points on obvious three dimensional features not readily evaluated.

The principal value of the filtered maps lies in the ability to indicate critical areas. Thus contour values in excess of  $+10 \mu\text{m/s}^2$ , which imply cap thicknesses of 360 m or more, suggest that the coal measures have been intruded at relatively low levels with loss of coal. It appears from the drilling to hand that the  $+10 \mu\text{m/s}^2$  contour is, in general, the critical level. However, it must be considered in company with the shapes and variations apparent in the low level continuations since the 3 km filters have integrated many of the effects and therefore yield a slightly pessimistic indication.

Only one other anomaly warrants examination. It is the substantial, localised negative feature situated on the west side of the Duncan mine

operation [EP844888]. Its value is  $-30 \mu\text{m/s}^2$  (fig. 31) or  $-120 \mu\text{m/s}^2$  (fig. 30). It is clearly anomalous and these values probably do not accurately reflect the actual contrast due to the presence of the strong positive gradient in the immediate west. Such values could only result in four ways - spurious observations, local mass deficiency, increased sections, substantial surface deposits. While the first and third are possible, the second and fourth are not. This part of the mine has never been worked and surface deposits are absent. Indeed, the  $-70 \mu\text{m/s}^2$  contour approximates the location of faults at which mining has been terminated. It is inferred therefore that a downthrown block of coal measures is present; the throw may be as much as 50 m. The triangular area south of this feature, east of the Fingal Rivulet feeder and west of the interpreted fault (see fig. 30) appears to be comparable with the remainder of the Duncan mine.

#### *Summary*

Observation and interpretation of the detailed coverage on Fingal Tier has confirmed the conclusions based on the regional survey. The refinements made are directly related to the reduction in station spacing. Faults and feeder systems are better located and specified. Examination has shown that faulting is ubiquitous and the feeders are smaller and more numerous.

The interpretive treatment has yielded a high resolution, but it is apparent that the factors of resolution, coverage and cost of such a procedure interact to limit improvements. Even so, future exploration using these techniques should be made with spacings no greater than employed here and that similar processing is essential if a full yield is to be obtained from the survey. The level of yield can be assessed by contrasting the interpretation qualitatively based on Figure 5 with those derived by continuation (fig. 30) or filtering (fig. 31). All aspects are complementary but often exclusive.

## CONCLUSION

The results of the gravity surveys undertaken as part of the East Coast Coal Project are summarised in Figures 13 and 30. A number of promising areas are indicated, on both a regional and local scale, for exploration.

The surveys have clearly established:

- (1) the locations of more than twenty dolerite feeders. Quantitative analysis of the detailed coverage and part of the regional coverage has shown that the feeders are multiple structures composed of discrete pipes and dykes. Many of these bodies are not revealed directly by the Bouguer anomalies, and inference of location depends on complex data processing. This is especially so in the case of small pipes.
- (2) the general occurrence of the coal-bearing Triassic rocks. The succession is universal and, unless dislocated by intrusion or terminated by surface exposure, exceeds 250 m in thickness. Qualitative analysis reveals those areas in which thick dolerite sheets occur and consequently regions where coal horizons may be destroyed or displaced. Quantitative analysis has shown that the sedimentary succession may be continuous between the discrete pipes of a feeder system and that the volume lost at feeder centres is quite small. Only around the periphery of the area is the section variable.
- (3) that faulting is ubiquitous. The bulk of the coverage is inadequate to fully define likely fault zones or precisely locate the structures. However many large structures can be identified and many more smaller features inferred. It is likely that many more have not been recognised. The gravity method is inappropriate for complete resolution in the prevailing geological conditions.
- (4) prime target areas for coal exploration, i.e. those regions where the Triassic section is thickest. This is not to infer that such sections are automatically coal-bearing, rather that they offer the best chances of finding a range of seams. Examples are Mt Nicholas, Fingal Tier east, Douglas River, Llandaff north-west.
- (5) the sheet like character of the St Marys porphyry, the stock character of granite at Rossarden and Royal George and located a smaller stock west of Bicheno. A sheet-slab of granodiorite in the Gray - Dalmayne region is also indicated. Structures bounding the bulk of the area, especially along the coast, appear to include major faults.
- (6) that a regional survey based on a station spacing of 1 - 1.5 km can define all important gross features (large feeders, thick sections, basement relief) and reliably suggest areas for detailed coverage. Such an area on Fingal Tier east is partly covered by State Reserve 1964/167 and has been resurveyed with a 250 - 350 m spacing. This spacing provides the best compromise between cost, coverage and resolution. The two tiers of survey are essential for reliable interpretation, since the regional coverage provides the setting and the detailed coverage the resolution. Terrain corrections must be applied.

- (7) that the gravity method has a real place in coal exploration in Tasmania. Interpretive techniques are critical. While some guide estimates can be based on two dimensional assumptions, any complete or reliable interpretation must be three dimensional. Further, allowance must be made for above-geoid anomaly contributions. The filter-equivalent mass/continuation-3D approach utilised here is essential if features such as faults and feeders are to be resolved and scaled.
- (8) the necessity for adequate control information. The gravity field integrates the effects of many structures. Separation of the many contributions may be dependent on independent control, whether by drilling, mapping or other geophysical methods. Absence of such control in large tracts of this area has limited the ultimate interpretation. Fortunately, there is sufficient information available to confirm many deductions and allow moderate extensions to other areas. Unfortunately most data is restricted to the Triassic rocks or the capping dolerite/Triassic interface. The interpretation provided has benefited from the control currently available and is sufficiently advanced to stand as a qualified guide to exploration with avoidance of often risky and wasteful wildcat drilling. It should not be considered final.

Other methods should now be used to advance the exploration using the gravity surveys as indicator. Where drilling is commenced in virgin areas at least one hole should penetrate to the pre-Permian basement. Only the seismic reflection method offers the possibility of resolving details of mine planning, seam continuity and fault placement. The gravity interpretation merely indicates those zones or blocks worthy of closer examination and at the same time positively establishing those zones which should be excluded or treated with caution; its great asset is the areal assessment.

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## APPENDIX 1

## Gravity survey tie stations.

<i>Place &amp; number</i>	<i>Description</i>	<i>Observed gravity (m/s<sup>2</sup>)</i>	<i>Elevation (m)</i>
FALMOUTH 7551-9401	Foot signpost, Tasman Highway. Falmouth 3, junction.	9.8031916	61.0
ST MARYS 7551-9402	Esk Highway, St Marys 1 mile peg adjacent HEC 524.	9.8028160	255.0
ESK HIGHWAY 7551-9403	Concrete slab, foot of sign, Mt Nicholas Road.	9.8028097	238.4
FINGAL 7551-9404	Foot HEC 335, 400 m east of Duncan Colliery road.	9.8027822	250.3
AVOCA 7551-9405	Foot eastern leg, overpass sign between Esk Highway and rail bridges.	9.8027417	197.0
ROYAL GEORGE 7551-9406	Foot of HEC 65	9.8027788	223.0
LOCHABER 7551-9407	Foot of Lochaber signpost, Old Coaching Road.	9.8029221	252.0
CRANBROOK 7551-9408	Foot HEC pole, fence corner beside Old Coaching Road at Tasman Highway junction.	9.8036502	20.0
SWANSEA 7551-9409	Entrance gate "Belmont".	9.8037094	11.0
BICHENO 7551-9410	Foot signpost, Coles Bay, Freycinet, Tasman Highway (west side road)	9.8035173	20.0
7551-9411	Foot 60/70 kph post north side Bicheno	9.8035056	11.0
DOUGLAS RIVER 7551-9412	Upper gate, road termination, DMR camp, Douglas River.	9.8034738	17.0
CHAIN OF LAGOONS 7551-9413	Centre traffic island, road junction, Tasman Highway.	9.8034635	14.0
MATHINNA 7551-9414	HEC pole, bus shelter corner Beauty Flats & Mathinna Roads.	9.8026704	260.2
ROSSARDEN 7551-9415	Station/grid 04, SPM, slab, Rossarden/Storys Creek road junction.	9.8018495	626.6
COLES BAY 7551-9416	End concrete path, launch ramp, Coles Bay.	9.8038758	0.0
LAKE LEAKE 7551-9417	Foot signpost, concrete slab, junction entry road to Lake Leake on Swansea-Campbell Town (Lake Leake) Road.	9.8024145	565.0
LAKE LEAKE DIVIDE 7551-9418	Foot signpost, SE side inter- section Lake Leake Road and TPFH M Road.	9.8023130	640.0

## Appendix 1 (continued)

<i>Place &amp; number</i>	<i>Description</i>	<i>Observed gravity (m/s<sup>2</sup>)</i>	<i>Elevation (m)</i>
FINGAL TIER 7551-9419	Foot of wooden step, old storage shed, intersection of tracks [EP89448726]	9.8016461	841.0

## APPENDIX 2

The equivalent source technique for the vertical continuation of gravitational data.

### INTRODUCTION

Gravity data is commonly corrected to yield the Bouguer anomaly at the point of observation. This results in difficulty where much of the anomalous mass lies above the reference horizon, since the Bouguer correction cannot properly compensate. In addition interpretation procedures normally presume a mass distribution below a planar reference level.

The equivalent source technique (Dampney, 1966; 1969) may be used to project gravity data acquired at irregularly distributed observation points with differing elevations onto a regularly gridded horizontal plane. Such a plane may be positioned to allow for the local mass and terrain distributions and permit conventional interpretation. Computation time is long with the number of iterations in the approximation dependent on the distribution of observation points and on the anomaly wavelengths present.

Prior computation of the A coefficients reduces the computation time by an estimated 80% and the use of bulk storage for these coefficients keeps memory requirements to a minimum. Recovery from system or programme crashes is provided by intermediate dumps to output files.

A cartesian co-ordinate system is used for position specification in all the programmes. Elevation is positive upward. Units of measurement must be consistent throughout the programmes as all calculations are dimensionless. Input and output formats and array bounds should be specified for each project.

### PROGRAMMES

#### INITIAL/MASS

Control of this programme is from logical unit 5, which contains:-

N the number of observation points

H the depth of the plane of the point masses forming the equivalent source (negative below the datum). An applicable H value may be estimated from

$2.5\Delta X < (Z_I - H) < 6\Delta X$  where  $\Delta X$  is the average separation of observation points and  $Z_I$  is the station elevation.

EPS the error value at which the approximation is sufficiently good

$EPS = N\sigma^2$  where  $\sigma$  is the mean variance in the observed data.

CON sets the minimum rate of convergence at each iteration. If convergence is too slow and the number of iterations is greater than LOOPS then  $A = C*A$ .

Try CON = 0.1

LOOPS is used to decide when to increase A

Try LOOPS = 2

C the factor by which A will be increased if convergence is not sufficiently fast.

Try C = 1.5

LIMA the upper value allowed for A

Try LIMA = 2.8

The above variables are passed to GRAVTWO/A and GRAVTWO/B for later use. The exact values of the above variables for a particular project are found on a trial and error basis.

Observed values of X,Y,Z and G(X,Y,Z) for the N data points are read from logical unit 2 (data specification includes all co-ordinates, elevation and Bouguer anomaly for each observation point).

Output is disk files G2FA, G2FB and G2FC which are used as initial data files by GRAVTWO/A and then as dump files.

The A coefficients are stored on magnetic tape (logical unit 1) in blocks of N words using unformatted writes.

For N=1013, processor time on a B6700 was approximately 330 seconds.

#### GRAVTWO/A

To calculate the equivalent masses at depth H. This program uses as input the output from INITIAL/MASS or data dumped from a previous run. The tape file of A coefficients is copied to disk but where system restrictions are imposed the file could remain on tape with the random access calls being replaced by rewind statements.

Iterative adjustment of the point masses proceeds until the sum of the squares of the difference between the observed and approximate anomaly values at each point is less than EPS. The actual value is printed at each iteration. Provision is also made for dumping intermediate results and terminating the programme gracefully after a predetermined processor time.

For N = 1013 the processor time on a B6700 may be considerably in excess of 42 000 seconds. Input-output time could treble this.

#### GRAVTWO/B

To calculate the field, based on equivalent masses, at height Z. This program has a small control file (G2B/CONTROL) and reads

Z<sub>1</sub> the height at which the gravity values are to be calculated.

GSPACE the grid spacing at which the values are to be calculated.

The output from GRAVTWO/A constitutes the remaining input. The grid ranges are specified within GRAVTWO/B.

For 625 grid points the processor time on a B6700 is approximately 250 seconds.

#### CONCLUSIONS

The programmes discussed above are somewhat machine dependent but provide a general and easily adapted technique to assist in the interpretation of gravity data, particularly in areas of rough terrain.

#### Model computation

Three dimensional modelling techniques have been employed wherever possible. These have been based on the method of Talwani and Ewing (1960). As suggested by the configurations presented in Figures 18 and 20, there is little restriction on the conceived form of any part of the model required. However, the shape must be cut into a number of horizontal slices. The number of slices prepared, or calculated in a single run, will depend on the precision required, computing funds available, complexity of specification of any layer set and computer size or efficiency. In this study no more than eleven layers have been included in any model and thicknesses have been quite coarse (of the order of 100-150 m at least). Although this latter factor has introduced some uncertainty in the results, it is commensurate with the overall precision and the quality of the geological control currently available. Each layer perimeter is digitised for presentation to the processor and the results for each layer in a model are summed to yield a resultant.

Details, or copies, of the computer programmes used may be obtained by writing to the Director of Mines, GPO Box 124B, Hobart, Tasmania, 7001 stating preferred form of copies.

#### REFERENCES

- DAMPNEY, C.N.G. 1966. *Geophysical studies in Tasmania*. M.Sc. thesis, University of Tasmania : Hobart.
- DAMPNEY, C.N.G. 1969. The equivalent source technique. *Geophysics* 34:39-53.
- TALWANI, M.; EWING, M. 1960. Rapid computation of gravitational attraction of three-dimensional bodies of arbitrary shape. *Geophysics* 25:203-225.

#### ACKNOWLEDGMENT

The authors acknowledge the correspondence and encouragement of Dr C.N.G. Dampney of Macquarie University to develop the equivalent source technique and apply it to the large array of points observed, without modifying the observations by translating them to the advised gridded data arrangement for a faster algorithm.

The first part of the report is devoted to a description of the work done during the year. It is divided into two main sections, the first of which deals with the work done in the laboratory and the second with the work done in the field.

### LABORATORY WORK

The first part of the laboratory work is devoted to the study of the properties of the various types of soil. It is found that the properties of the soil vary with the amount of water and the amount of air. The amount of water in the soil is determined by the amount of rainfall and the amount of evaporation. The amount of air in the soil is determined by the amount of oxygen and the amount of carbon dioxide. The amount of oxygen in the soil is determined by the amount of photosynthesis and the amount of respiration. The amount of carbon dioxide in the soil is determined by the amount of fermentation and the amount of decomposition.

### FIELD WORK

The first part of the field work is devoted to the study of the distribution of the various types of soil. It is found that the distribution of the soil varies with the amount of rainfall and the amount of evaporation. The amount of rainfall is determined by the amount of clouds and the amount of wind. The amount of evaporation is determined by the amount of heat and the amount of wind.

### CONCLUSIONS

The first part of the conclusions is devoted to a summary of the work done during the year. It is found that the properties of the soil vary with the amount of water and the amount of air. The amount of water in the soil is determined by the amount of rainfall and the amount of evaporation. The amount of air in the soil is determined by the amount of oxygen and the amount of carbon dioxide.

### APPENDIX 3

#### Drilling records summary

The listing below is not exhaustive and only the most basic of logs is quoted. Further details, about coal seams especially, can be obtained from Hills *et al.* (1922), Threder (1968) and Departmental files. All sites are indicated on Figure 10.

#### *Department of Mines programme*

Hole 1	0 - 218 m	Coal measures. Hole completed near presumed base of Triassic succession.
Hole 2	0 - 184 m	Coal measures.
Hole 3	0 - 88 m	Dolerite scree.
	88 - 217 m	Coal measures.
Hole 4	0 - 12 m	Weathered dolerite.
	12 - 254 m	Coal measures.
	254 - 330 m	Permian mudstone, sandstone, limestone. Glauconite at 315 m.
Hole 5	0 - 6 m	Dolerite scree.
	6 - 270 m	Coal measures.
Hole 6	0 - 129 m	Dolerite.
	129 - 451 m	Coal measures.
	451 - 458 m	Permian mudstone with grit.
Hole 7	0 - 9 m	No core.
	9 - 52 m	Coal measures - hole abandoned.
Hole 7B	30 - 341 m	Coal measures.
	341 - 352 m	Permian siltstone.
Hole 8	0 - 6 m	No core.
	6 - 227 m	Coal measures.
	227 - 251 m	Permian mudstone, grit, limestone.
Hole 9	0 - 81 m	Coal measures.
	81 - 140 m	Permian mudstone, siltstone.
	140 - 180 m	Calcareous siltstone, limestone.
	180 - 232 m	Mudstone, siltstone, grit.
	232 - 234 m	Mathinna Beds.
Hole 10		Dolerite scree - abandoned.
Hole 11	0 - 42 m	Dolerite scree.
	42 - 139 m	Coal measures.
Hole 12	0 - 44 m	Dolerite scree.
	44 - 224 m	Coal measures.
Hole 13	0 - 228 m	Coal measures.
Hole 14		Abandoned.
Hole 15		Abandoned.
Hole 16	0 - 263 m	Dolerite.
	263 - 364 m	Coal measures.
Hole 17	0 - 323 m	Dolerite.
	323 - 505 m	Coal measures.
Hole 18	0 - 371 m	Dolerite.
	371 - 425 m	Coal measures.

Hole 19	0 - 247 m 247 - 455 m	Dolerite. Coal measures.
Hole 20	0 - 247 m 247 - 465 m	Dolerite. Coal measures.
Hole 21	0 - 282 m 282 - 492 m 492 - 502 m	Dolerite Coal measures. Permian mudstone, grit.
Hole 22	0 - 229 m	Coal measures.
Hole 23	0 - 341 m 341 - 546 m 546 - 554 m	Dolerite. Coal measures. Permian siltstone, grit.
Hole 24	0 - 386 m 386 - 523 m	Dolerite. Coal measures.
Hole 25	0 - 194 m 194 - 511 m 511 - 526 m	Dolerite. Coal measures. Permian siltstone.
Hole 26	0 - 241 m 241 - 459 m	Dolerite. Coal measures.
Hole 27	0 - 260 m 260 - 488 m	Dolerite. Coal measures.
Hole 28	0 - 151 m 151 - 160 m	Coal measures. Permian siltstone, grit.
Hole 29	0 - 346 m 346 - 424 m 424 - 431 m	Dolerite. Dip base 60°. Coal measures. Permian siltstone, grit.
Hole 30	0 - 27 m 27 - 242 m 242 - 255 m	Dolerite talus. Coal measures. Permian siltstone, grit.
Hole 31	0 - 302 m 302 - 566 m 566 - 576 m	Dolerite. Coal measures. Permian siltstone, grit.
Hole 32	0 - 40 m 40 - 256 m 256 - 274 m	Dolerite talus. Coal measures. Permian siltstone.
Hole 33	0 - 16 m 16 - 198 m 198 - 199 m	Dolerite talus. Coal measures. Permian siltstone?
Hole 34A	0 - 65 m	Coal measures.
Hole 34B	0 - 47 m	Coal measures.
Hole 35	0 - 94 m	Dolerite talus - abandoned.
Hole 36	0 - 11 m 11 - 124 m 124 - 133 m	Dolerite talus. Coal measures. Permian siltstone.
Hole 37	0 - 49 m 49 - 309 m 309 - 311 m	Dolerite talus. Coal measures. Permian siltstone.

Hole 38	0 - 340 m	Dolerite.
	340 - 552 m	Coal measures.
	552 - 558 m	Permian siltstone.
Hole 39	0 - 296 m	Dolerite.
	296 - 519 m	Coal measures.
	519 - 522 m	Permian siltstone.
Hole 40	0 - 236 m	Dolerite.
	236 - 461 m	Coal measures.
	461 - 465 m	Permian siltstone.
Hole 41	0 - 228 m	Dolerite.
	228 - 570 m	Coal measures.
	570 - 584 m	Permian siltstone.
Hole 42	0 - 340 m	Dolerite.
	340 - 571 m	Coal measures.
	571 - 576 m	Permian siltstone.
Hole 43	0 - 316 m	Dolerite.
	316 - 506 m	Coal measures (abandoned in quartzose sandstone).
Hole 44	0 - 178 m	Dolerite.
	178 - 401 m	Coal measures.
	401 - 407 m	Permian siltstone.
Hole 46A	0 - 37 m	Dolerite - abandoned.
Hole 46B	0 - 200 m	Dolerite.
	200 - 546 m	Coal measures.
	546 - 547 m	Permian siltstone.
Hole 49	0 - 165 m	Dolerite talus.
	165 - 409 m	Coal measures.
	409 - 415 m	(approx.) Permian siltstone.
Hole 54	0 - 392 m	Dolerite.
	392 - 524 m	Coal measures.
	524 - 530 m	Permian siltstone.
Hole 55	0 - 98 m	Dolerite.
	98 - 441 m	Coal measures.
	441 - 470 m	Permian siltstone.
Hole 56	0 - 198 m	Dolerite.
	198 - 405 m	Coal measures.
Hole 69	0 - 442 m	Dolerite.
	442 - 546 m	Coal measures.
Hole 70	0 - 349 m	Dolerite.
	349 - 406 m	Coal measures.
	406 - 416 m	Triassic basal quartz unit.
Hole 71	0 - 234 m	Dolerite.
	234 - 459 m	Coal measures.
	459 -	Triassic quartz unit.
Hole 72	0 - 340 m	Dolerite.
	340 - 385 m	Coal measures.
	385 - 391 m	Permian.
Hole 73	0 - 197 m	Dolerite.
	197 - 465 m	Coal measures.

Hole 74	0 - 177 m	Dolerite.
	177 - 459 m	Coal measures.
	459 - 477 m	Triassic basal quartz unit.
	477 - 481 m	Permian siltstone.
Hole 894/497	0 - 8.2 m	Alluvium and boulders.
	8.2 - 49.4 m	Coal measures.
	49.4 - 51.9 m	Dolerite.
	51.9 - 116.4 m	Coal measures.
	116.4 - 136.1 m	Dolerite.
Hole 963/546	0 - 21 m	Coal measures?
	21 - 31 m	Permian.
	31 - 47 m	Granite.
Hole 986/620	0 - 30 m	Dolerite.
	30 - 321 m	Coal measures.
	321 m	Permian siltstone.
Hole 992/637	0 - 3 m	Coal measures.
	3 - 118 m	Permian shale, limestone, grit.
	118 - 128 m	Granite.
Hole 040/675	0 - 217 m	Coal measures.
	217 - 441 m	Permian siltstone, limestone, grit, conglomerate.
	441 - 450 m	Metamorphosed Mathinna Beds.
Hole 045/732	0 - 70 m	Coal measures.
	70 - 335 m	Permian siltstone, limestone, grit and conglomerate.
	335 - 336 m	Mathinna Beds.
Friendly Beaches 1	0 - 54 m	Permian limestone, calcareous mudstone.
	54 - 228 m	Permian siltstone, conglomerate, arkose.
	228 m	Granite.
Friendly Beaches 2	0 - 85 m	Permian limestone, siltstone.
Killymoon	0 - 153 m	Permian siltstone, limestone, grit.
	153 - 154 m	Mathinna Beds.
Harefield	0 - 110 m	Coal measures.
	110 - 216 m	Permian succession.
	216 - 221 m	Mathinna Beds.
Llandaff 1	0 - 142 m	Coal measures.
	142 - 145 m	Granite.
Llandaff 2	0 - 171 m	Coal measures.
	171 - 218 m	Permian siltstone, limestone, grit, conglomerate.
Llandaff 3	0 - 17 m	Dolerite talus.
	17 - 221 m	Coal measures.
	221 - 228 m	Granite.
Seymour 1	0 - 52 m	Coal measures.
Seymour 2	0 - 94 m	Coal measures.
Seymour 3	0 - 73 m	Coal measures.
	73 - 75 m	Dolerite.
Seymour 4	0 - 103 m	Coal measures.
	103 - 271 m	Permian shale, limestone, conglomerate.

Seymour 5            0 - 197 m        Coal measures.

*Drilling by the Hydro-electric Commission, Fingal area*

C1	0 - 116 m	Dolerite (talus).
	116 - 266 m	Coal measures.
C2	0 - 245 m	Coal measures.
	245 - 250 m	Permian.
C3	0 - 3 m	Talus.
	3 - 159 m	Coal measures.
	159 - 163 m	Permian.
C4	0 - 16 m	Talus.
	16 - 104 m	Coal measures.
	104 - 105 m	Permian.
C5	0 - 12 m	Talus.
	12 - 97 m	Coal measures.
	97 - 101 m	Permian.
C6	0 - 101 m	Coal measures.
	101 - 104 m	Permian.
C7	0 - 112 m	Coal measures.
	112 - 118 m	Permian.
C8	0 - 82 m	Talus.
	82 - 156 m	Coal measures.
	156 - 159 m	Permian.
C9	0 - 38 m	Talus.
	38 - 112 m	Coal measures.
	112 - 118 m	Permian.

*Drilling by Investigator Coal Exploration Pty Ltd (EL 16/77)*

*Details: refer open file 55/8*

78RG1	0 - 17 m	Dolerite scree.
	17 - 200 m	Coal measures.
78RG2	0 - 12 m	Dolerite scree.
	12 - 203 m	Coal measures including very small dolerite intrusions.
78RG3	0 - 11 m	Dolerite scree.
	11 - 43 m	Dolerite.
	43 - 185 m	Coal measures (including minor intrusions)
78 RG4	0 - 24 m	Dolerite scree.
	24 - 113 m	Coal measures.

*Drilling by Shell Co. (Aust.) Ltd (EL 18/77)*

*Details: refer open file 62/1*

AV8	0 - 300 m	Dolerite.
AV9	0 - 299 m	Dolerite.

Note: Coal measures term includes lithic, quartz sandstone, shale, mudstone, coal, carbonaceous beds, some limestone, grit.

Existing in one or more of the following classes

20	10 - 1500	Police (Police)
21	10 - 1500	Police (Police)
22	10 - 1500	Police (Police)
23	10 - 1500	Police (Police)
24	10 - 1500	Police (Police)
25	10 - 1500	Police (Police)
26	10 - 1500	Police (Police)
27	10 - 1500	Police (Police)
28	10 - 1500	Police (Police)
29	10 - 1500	Police (Police)
30	10 - 1500	Police (Police)
31	10 - 1500	Police (Police)
32	10 - 1500	Police (Police)
33	10 - 1500	Police (Police)
34	10 - 1500	Police (Police)
35	10 - 1500	Police (Police)
36	10 - 1500	Police (Police)
37	10 - 1500	Police (Police)
38	10 - 1500	Police (Police)
39	10 - 1500	Police (Police)
40	10 - 1500	Police (Police)

Existing in one or more of the following classes

41	10 - 1500	Police (Police)
42	10 - 1500	Police (Police)
43	10 - 1500	Police (Police)
44	10 - 1500	Police (Police)
45	10 - 1500	Police (Police)
46	10 - 1500	Police (Police)
47	10 - 1500	Police (Police)
48	10 - 1500	Police (Police)
49	10 - 1500	Police (Police)
50	10 - 1500	Police (Police)
51	10 - 1500	Police (Police)
52	10 - 1500	Police (Police)
53	10 - 1500	Police (Police)
54	10 - 1500	Police (Police)
55	10 - 1500	Police (Police)
56	10 - 1500	Police (Police)
57	10 - 1500	Police (Police)
58	10 - 1500	Police (Police)
59	10 - 1500	Police (Police)
60	10 - 1500	Police (Police)

Existing in one or more of the following classes

61	10 - 1500	Police (Police)
62	10 - 1500	Police (Police)

Section 5 of the 1917 Act

## APPENDIX 4

### Processing and interpretation sequence

#### INTRODUCTION

The problems related to the interpretation of the survey data, when observations are distributed on a high relief terrain, have been referred to in the body of the text. A solution to the problems of terrain, topographic relief, absence of a meaningful reference surface for classical interpretation procedures, and anomaly sources within the terrain above sea level, was crucial to a sound evaluation of the survey. In such situations the Bouguer correction, requiring a density assumption and reduction to sea level, clearly leads to difficulties if a quantitative interpretation is to follow.

The following procedure was adopted to produce data appropriate for modelling. The main text presents the results at various stages and demonstrates the value of the extended processing. The quality of interpretation and extraction of all possible information from a survey is important to any project, but the cost of extended processing may not be easily justified. This is especially true where the survey is directed at research or structural problems lacking any obvious economic significance. In this case the survey was intended to guide a large scale and expensive drilling programme, and funds were made available to extend the evaluation of the work beyond a comprehensive qualitative interpretation. Even though severe constraints were imposed by the extent of funding and the cost of commercial data processing of large arrays, the effort has proven worthwhile.

Consider the costs expressed in terms of drill holes, each comprising about 600 m of diamond drilling (N size) at commercial rates prevailing at the time. Field work, associated expenses and reduction to qualitative interpretation stage cost the equivalent of one hole and the quantitative expansion, another. Since the results of the survey (and drilling) have shown that one hole in nine or ten would fail to yield useful results if drilled on any randomly located but regular grid, any programme in excess of 18 holes is advantaged by the survey. The advantage is enhanced when it is also appreciated that the information is not restricted to points and also offers feature shape information.

#### PROCESSING SEQUENCE

- (1) All observations were tabulated by station number, co-ordinates, elevation terrain correction and sorted by regions - as specified for the core area of the regional survey or the Fingal Tier coverage. The processed form of the latter includes stations from both surveys.
- (2) The observations were Bouguer corrected using a density of  $2.67 \text{ t/m}^3$ . Although this density has no physical relevance to the area, it is a median value and provides a reference for contrast calculations. The resultant Bouguer anomalies may be compiled and contoured but with the understanding that the anomaly sources may be anywhere between the earth's surface (very irregular in this area) and the earth's centre. Since the bulk of the regional survey core area and Fingal Tier detailed area lie above 300 or 600 m respectively, most sources are above the geoid (sea level).

- (3) The Bouguer correction was then considered to be inverted. Note that the Bouguer anomaly is defined as the resultant determined after correcting the observed value ( $g_o$ ) for elevation, density and terrain (by reducing it to the geoid) and removing the 'normal' ( $g_n$ ) or predicted value based on the International Ellipsoid (1957 version). This may be expressed as

$$BA = g_n - (g_o + H - B + T)$$

where H is the height (free air) term

B is the material (Bouguer) term

T is the terrain correction

H always increases  $g_o$  since g increases toward the earth's centre. B reduces the increase by allowing something for any material present.

Thus  $g_o$  at the reference level (geoid) is always greater than  $g_o$  at the land surface.

However, consider the inverse of this process,

$$\Delta = (g_n - H + B - T) - g_o$$

where the comparison is made at the land surface or actual observation point. In this case  $g_n$  is reduced by the same amount but  $g_o$  is increased in the calculated Bouguer anomaly. Thus  $\Delta$  is the value of the Bouguer anomaly but is not the Bouguer anomaly as defined. Physically  $\Delta$  is the surface value; BA is the geoid reference value. The equivalence, arithmetically, of these functions allows a properly referenced continuation of the field - with respect to anomaly observations at the surface. Although values included in processing are termed Bouguer anomaly values they are not, *sensu stricto* Bouguer values.

- (4) The anomalies can be assessed by conventional qualitative means irrespective of distribution within the terrain. The absolute value is merely converted into some local estimate, usually based on two-dimensional assumptions, of the materials present. No reliable integration is possible between estimates. In the case of this survey, two-dimensional assumptions are clearly not justified for any intensive interpretation.
- (5) Quantitative interpretation depends on the specific treatments as outlined in Appendix 2.
- (a) Calculation of equivalent sources on some surface below the the level of specific interest. The actual level may be governed by processing factors (including cost).
  - (b) Continuation of the field to any level. Since the sources are referenced to "Bouguer" values at the land surface, an effective continuation component is included in their calculation. Thus partial above-terrain continuations can be derived until the field surface is free of the terrain. Any surface only partially clear of the terrain displays some upward and some downward continuation effects with respect to the actual observations. Thus the variation of effects between levels of continuation may yield much information on anomaly form and source.

Any simple continuation based on Bouguer values must include gross regional effects inherent in the data. These may be separated by continuing to a suitably high level and subtracting the extended continuation from a near-surface continuation. Appropriate choice of levels can yield residual anomalies relevant to the relatively shallow targets of the project.

- (c) The residual anomalies so produced are at the same level and so are amenable to modelling. Three-dimensional models are built up of any desired geology (basic layer contrast with respect to  $2.67 \text{ t/m}^3$ , all other layers as relative contrasts) with the uppermost layer shaped to match the topography. The geology is of course 'overlain' by a layer of air. For economy, each layer or material is overlaid as explained on page 39 and corrected by a process of contrast-partial modification rather than complete re-digitisation.

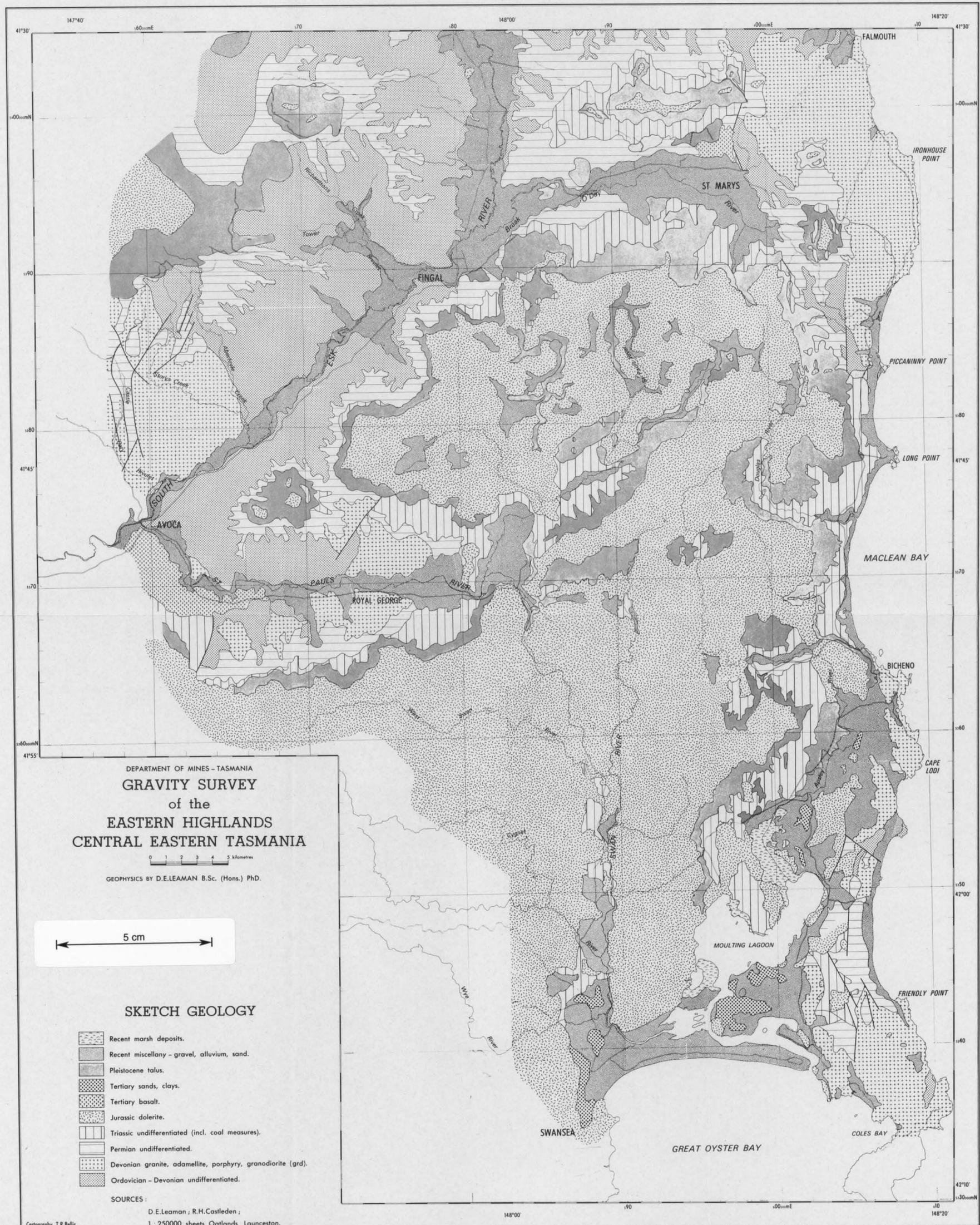
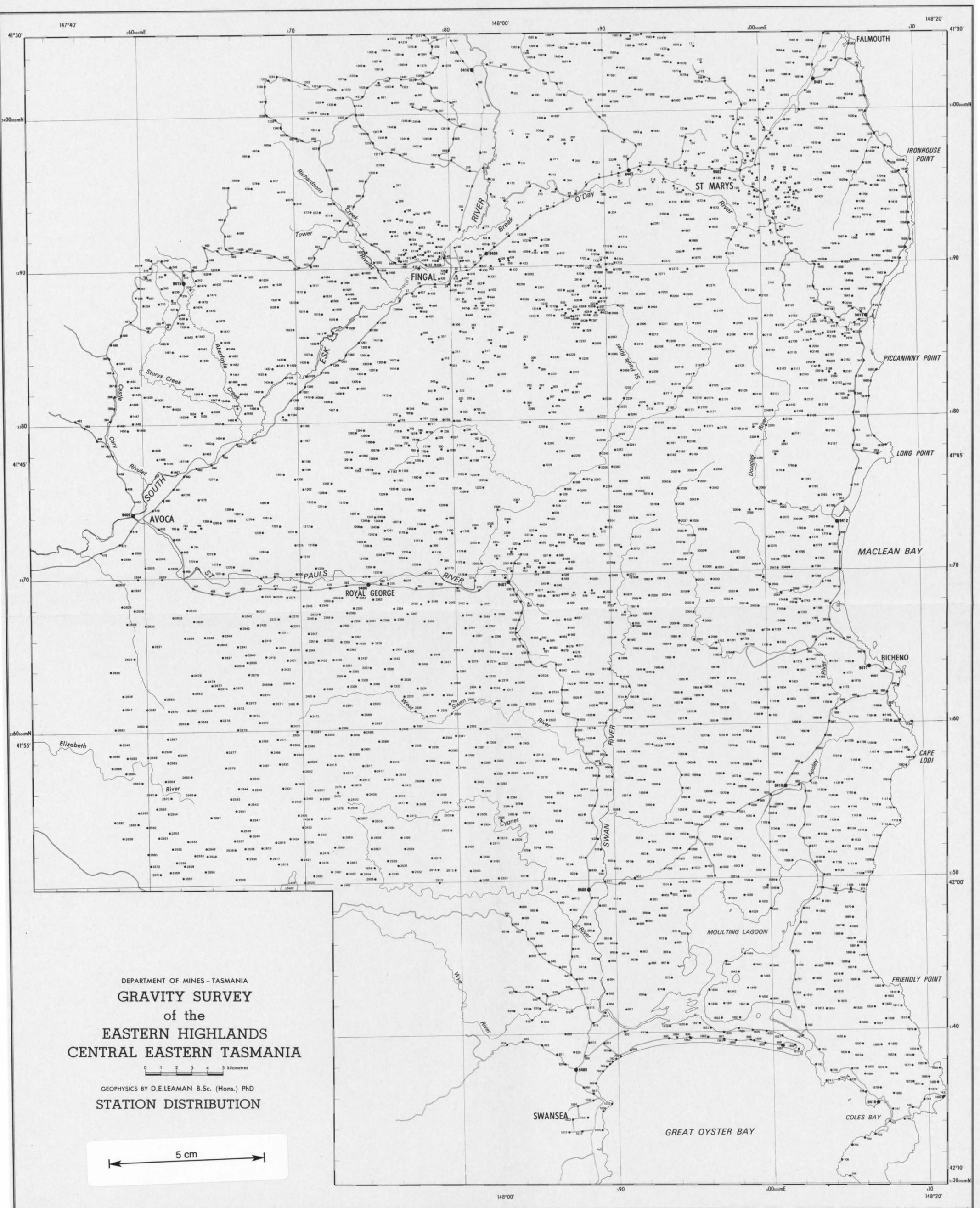


Figure 1

G5860



DEPARTMENT OF MINES - TASMANIA  
**GRAVITY SURVEY**  
of the  
**EASTERN HIGHLANDS**  
**CENTRAL EASTERN TASMANIA**

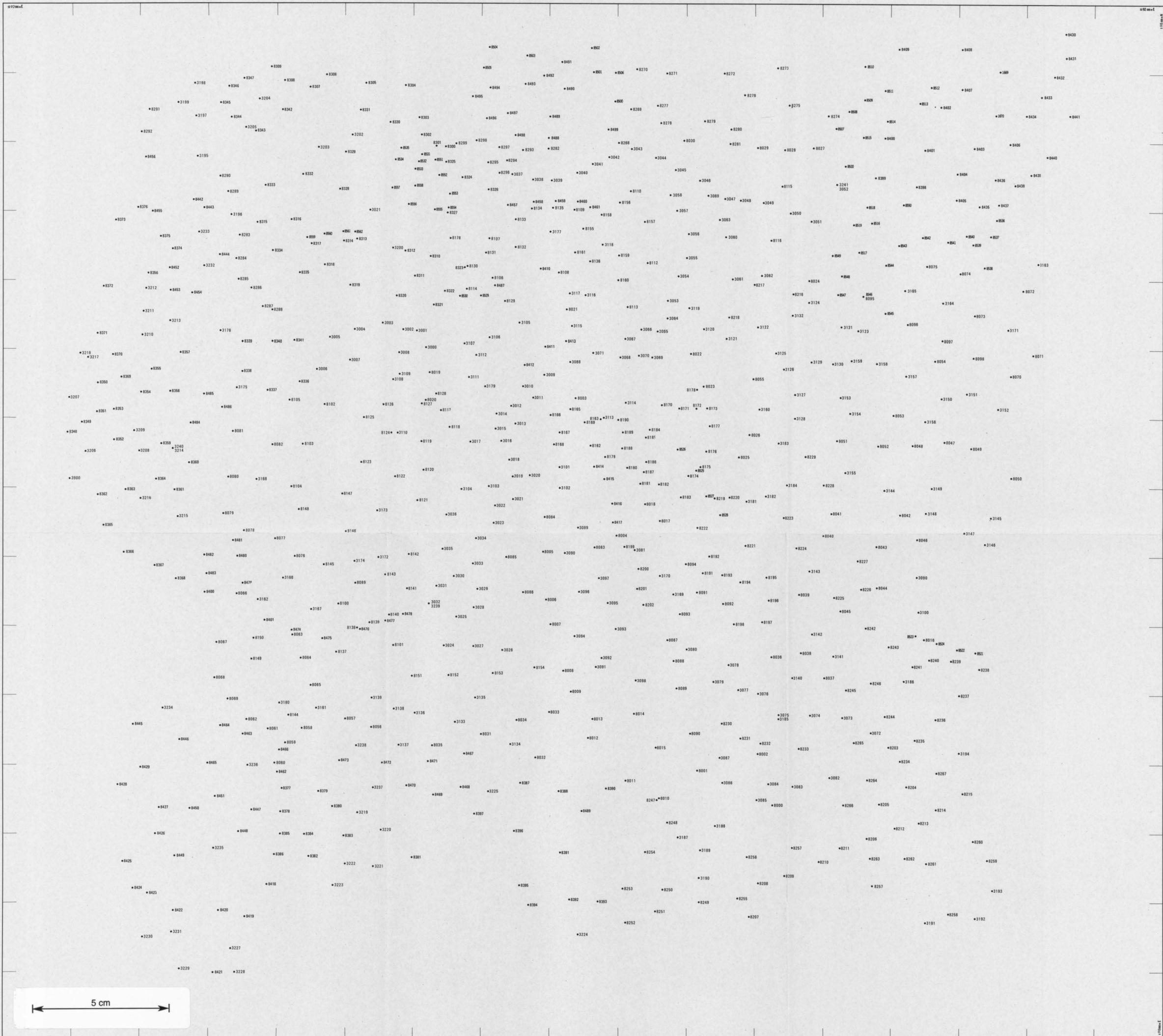
0 1 2 3 4 5 kilometres

GEOPHYSICS BY D.E. LEAMAN B.Sc. (Hons.) PhD  
**STATION DISTRIBUTION**

5 cm

Figure 2

G5B60



5 cm

Figure 3

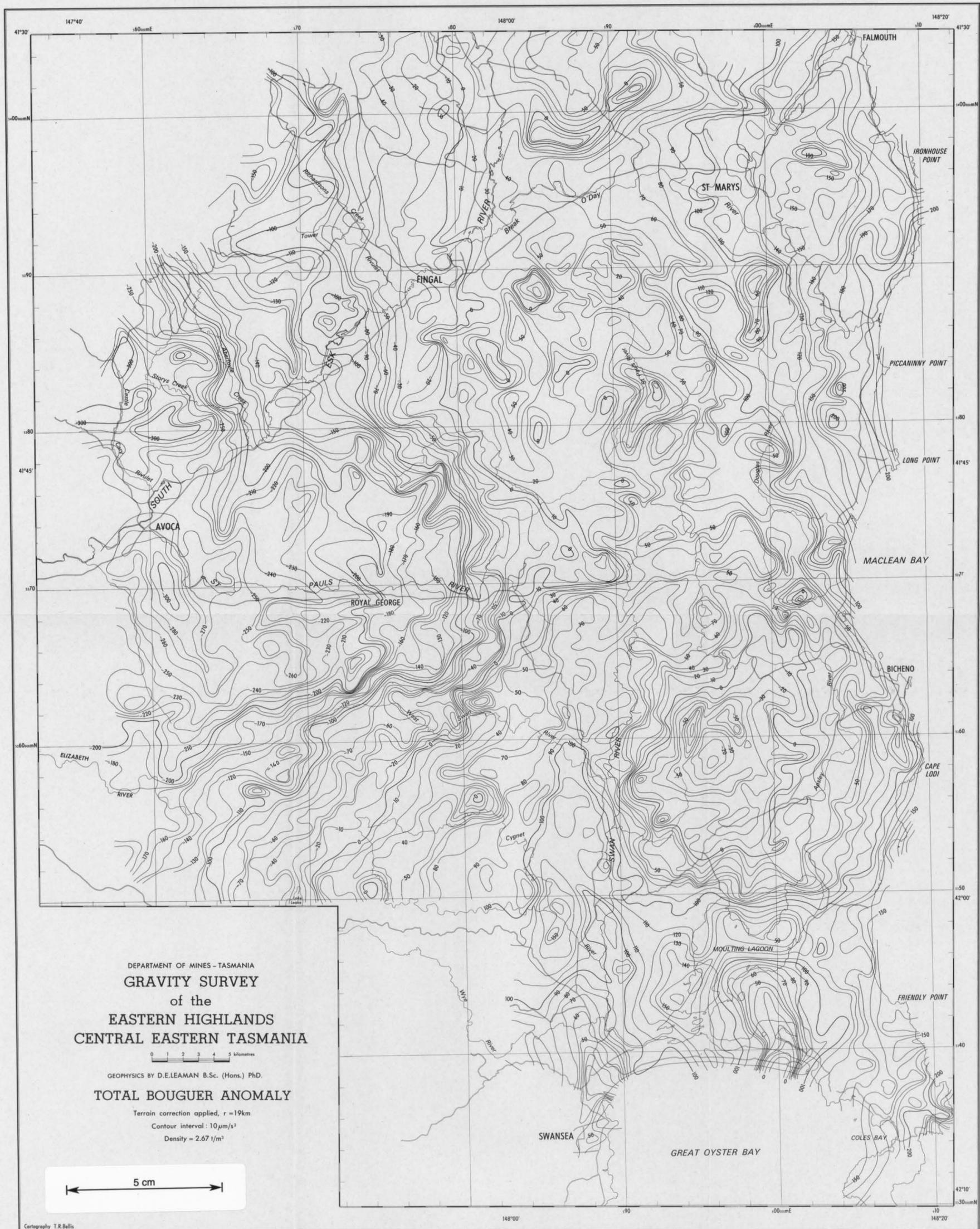


Figure 4

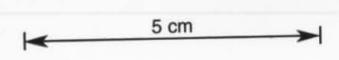
GSB60



Fig 5. GSB60

FINGAL TIER DETAILED GRAVITY COVERAGE BOUGUER ANOMALY  $\rho = 2.67 \text{ t/m}^3$

CONTOUR INTERVAL  $10 \mu\text{m/sec}^2$



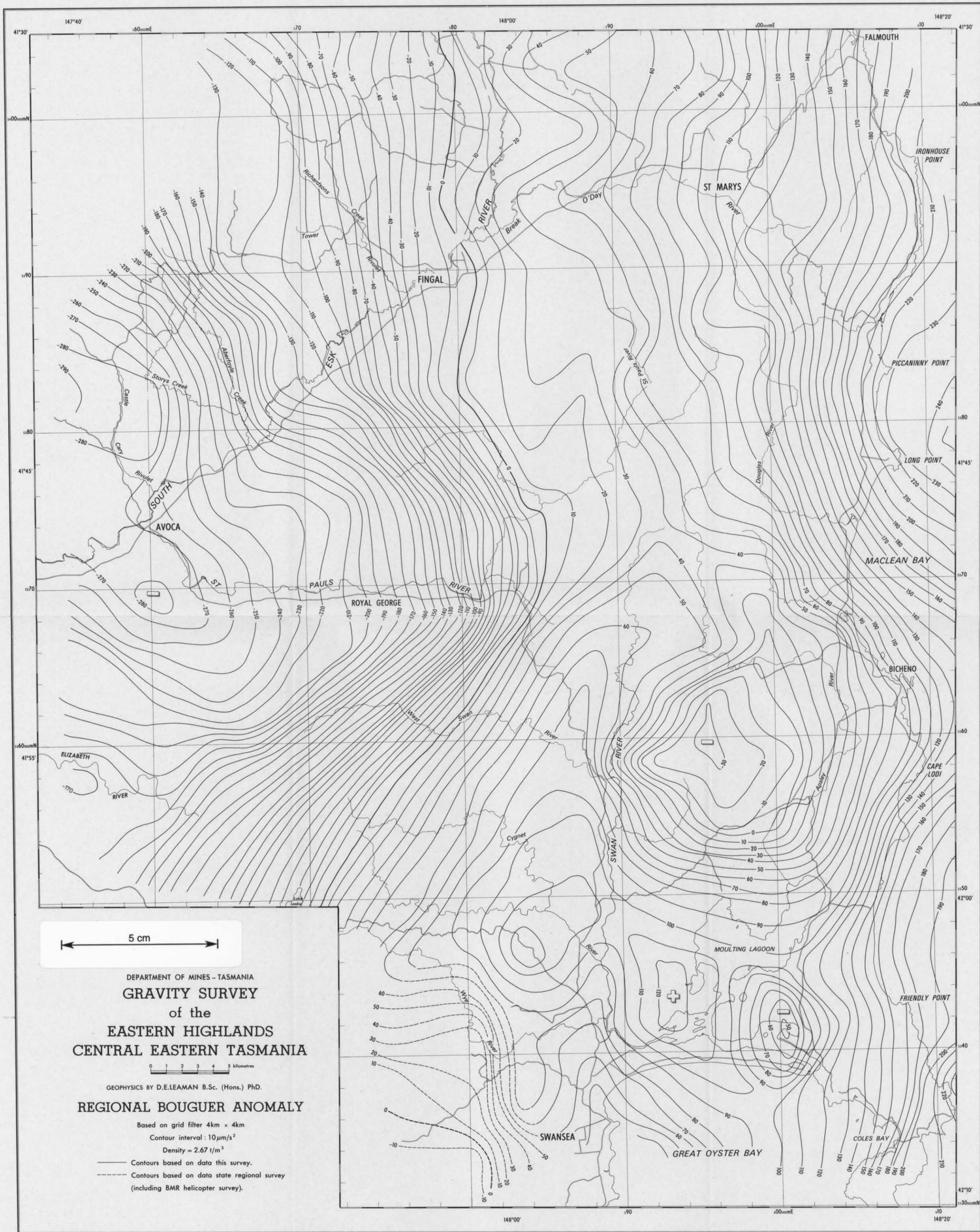
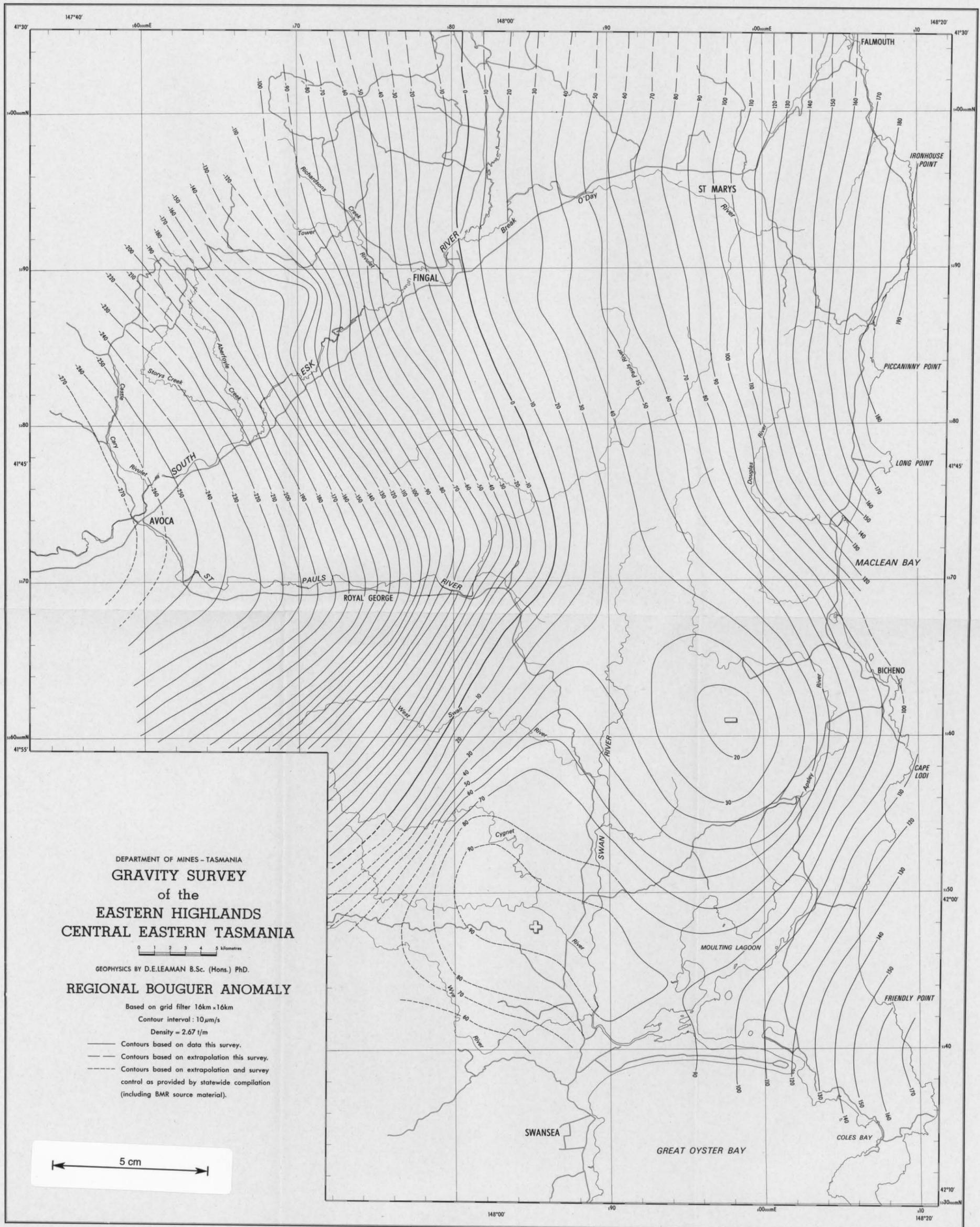


Figure 6

GSB60



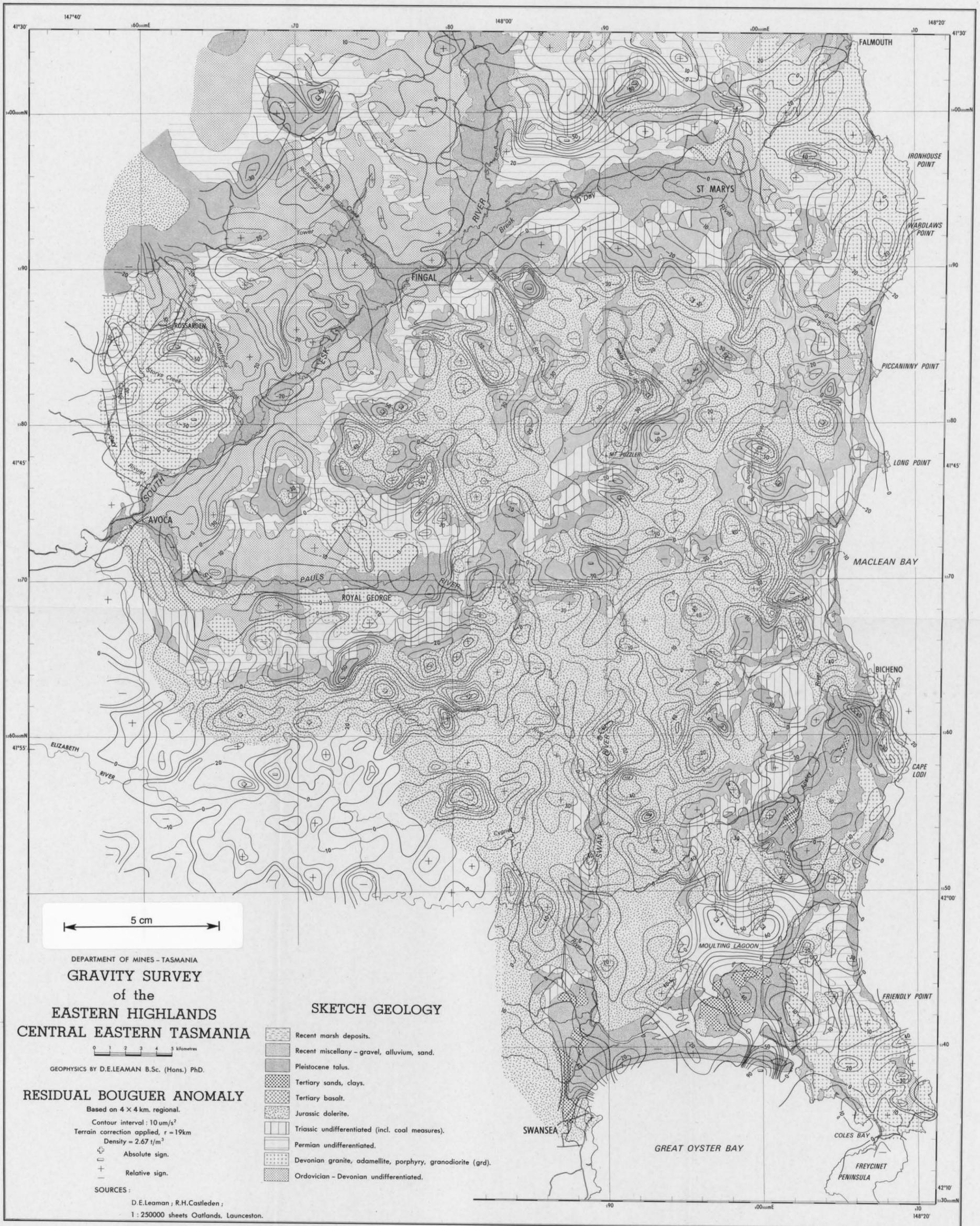
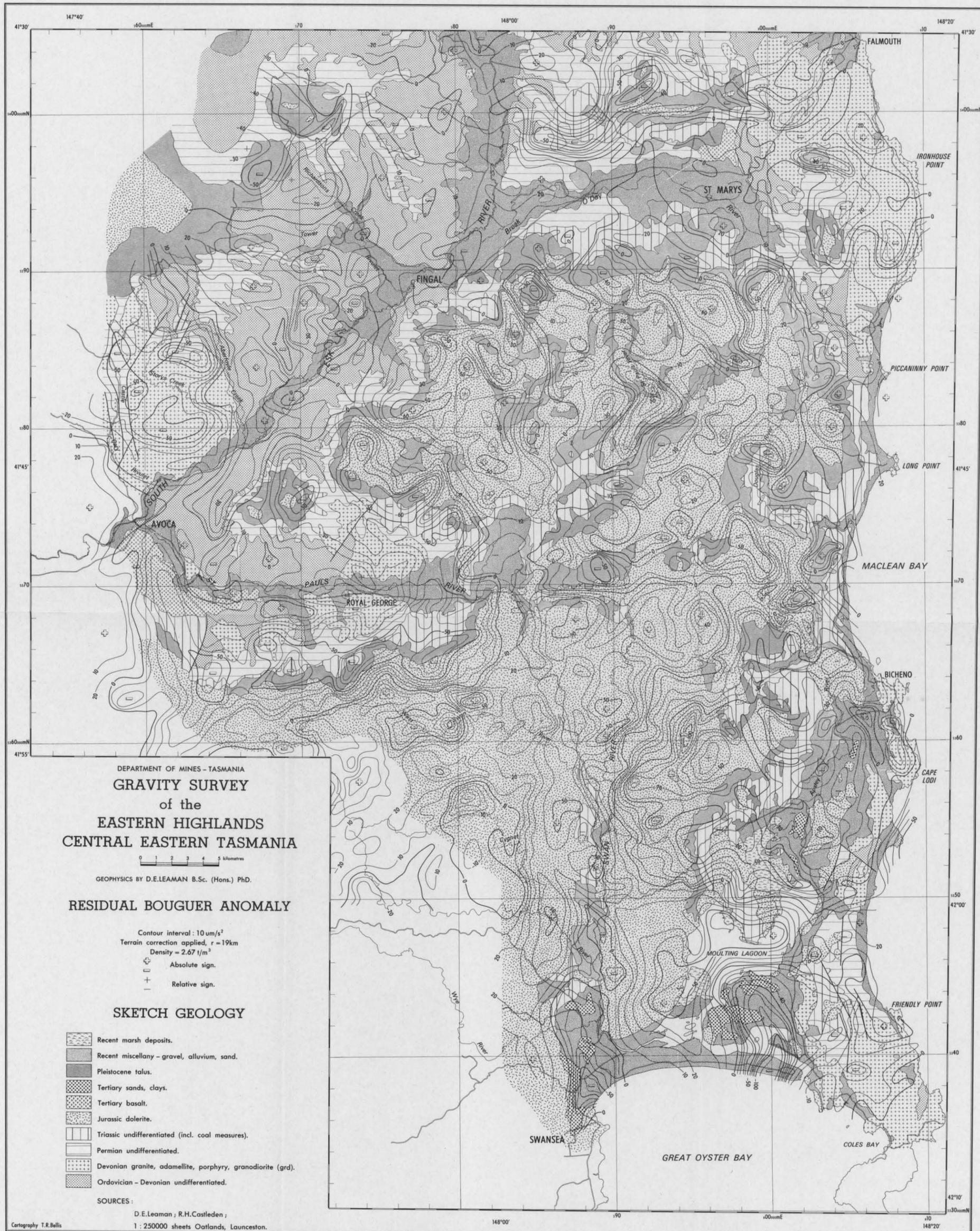
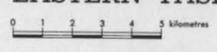


Figure 8

G5B60



DEPARTMENT OF MINES - TASMANIA  
**GRAVITY SURVEY**  
of the  
**EASTERN HIGHLANDS**  
**CENTRAL EASTERN TASMANIA**



GEOPHYSICS BY D.E. LEAMAN B.Sc. (Hons.) Ph.D.

**RESIDUAL BOUGUER ANOMALY**

Contour interval: 10  $\mu\text{m/s}^2$   
Terrain correction applied,  $r = 19\text{km}$   
Density = 2.67  $\text{t/m}^3$   
+ Absolute sign.  
- Relative sign.

**SKETCH GEOLOGY**

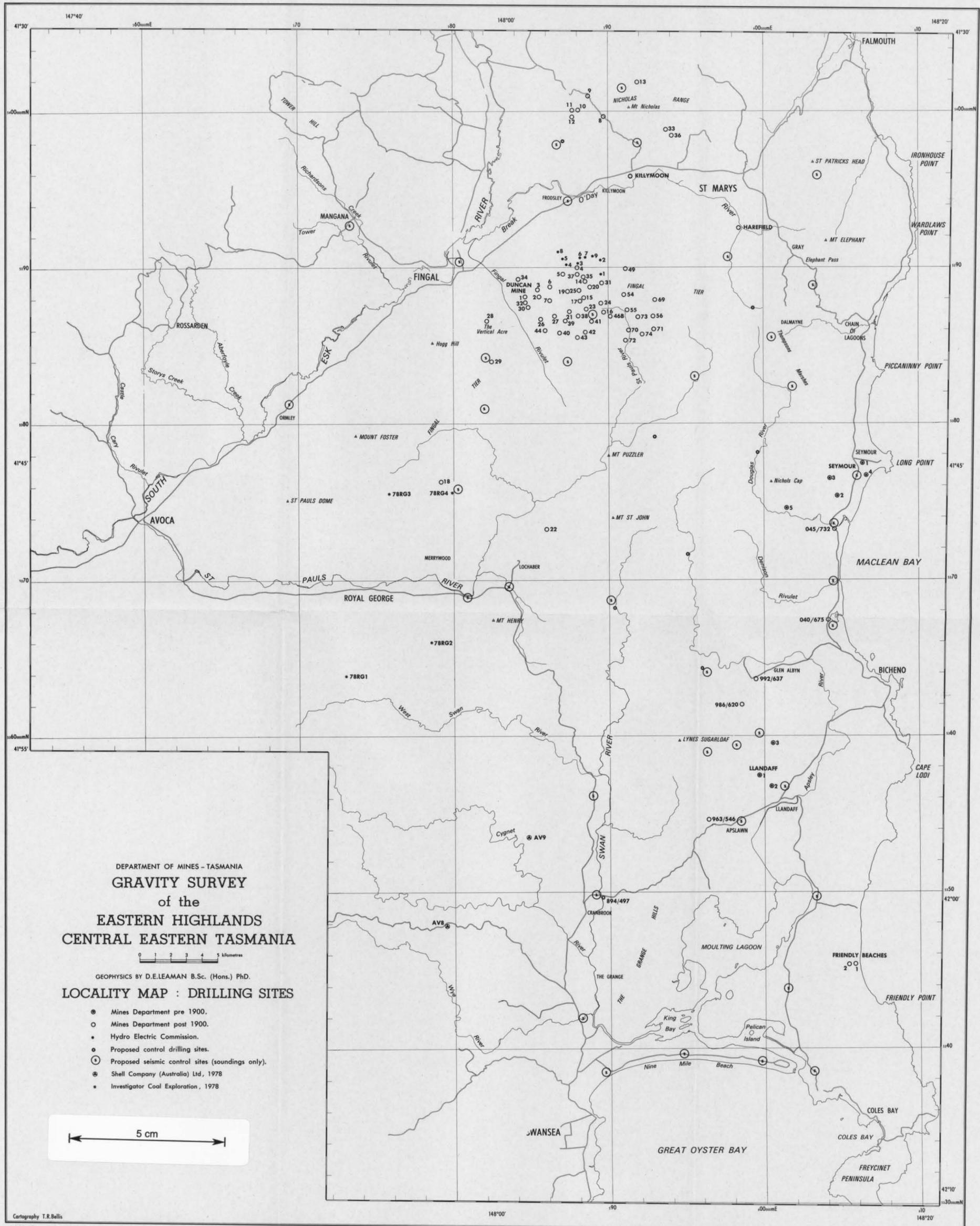
- Recent marsh deposits.
- Recent miscellany - gravel, alluvium, sand.
- Pleistocene talus.
- Tertiary sands, clays.
- Tertiary basalt.
- Jurassic dolerite.
- Triassic undifferentiated (incl. coal measures).
- Permian undifferentiated.
- Devonian granite, adamellite, porphyry, granodiorite (grd).
- Ordovician - Devonian undifferentiated.

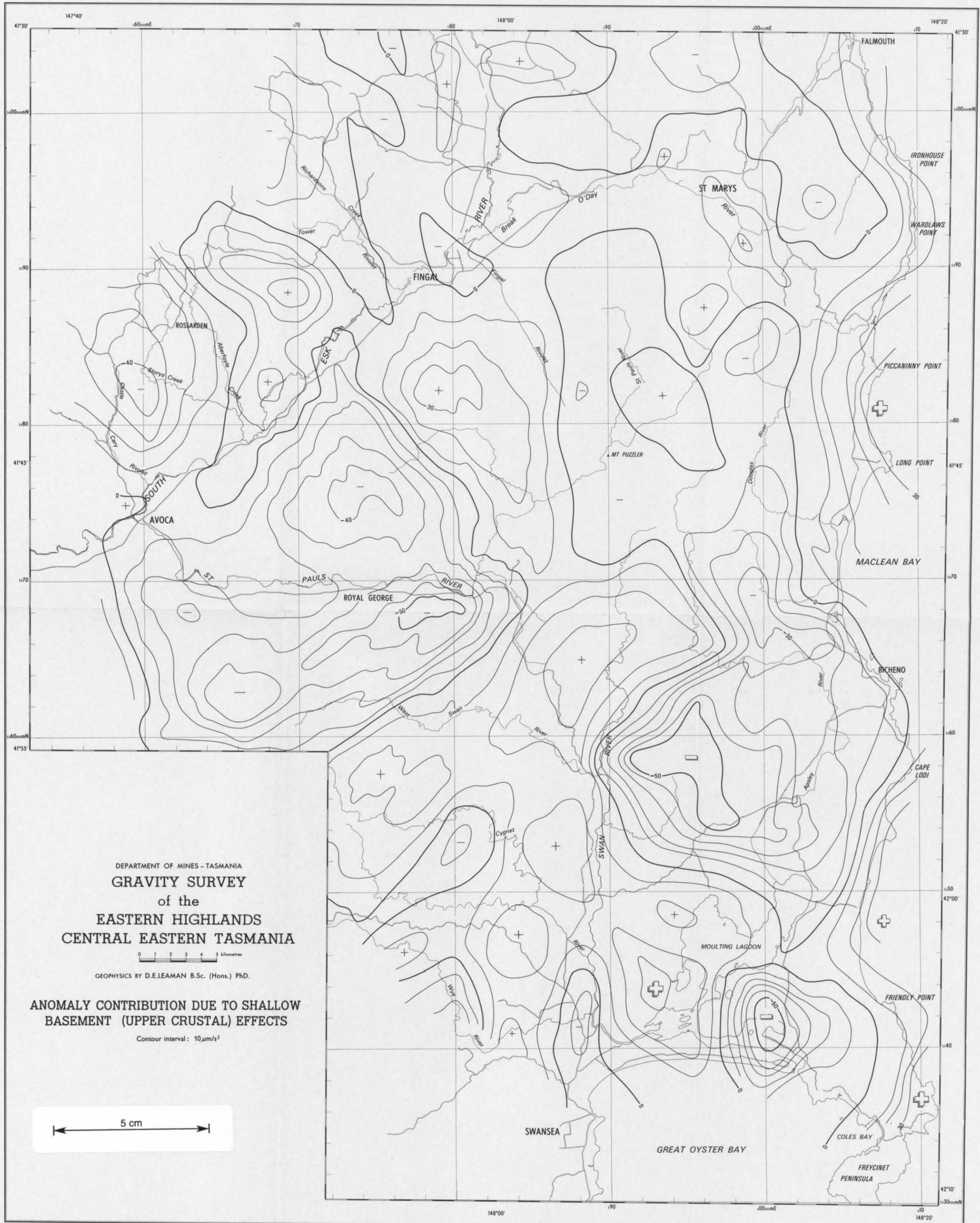
SOURCES:  
D.E. Leaman; R.H. Castleden;

Cartography T.R. Bellis  
1:250000 sheets Oatlands, Launceston.

GSB60







DEPARTMENT OF MINES - TASMANIA  
**GRAVITY SURVEY**  
of the  
**EASTERN HIGHLANDS**  
**CENTRAL EASTERN TASMANIA**

0 1 2 3 4 5 kilometres

GEOPHYSICS BY D.E. LEAMAN B.Sc. (Hons.) Ph.D.

**ANOMALY CONTRIBUTION DUE TO SHALLOW  
BASEMENT (UPPER CRUSTAL) EFFECTS**

Contour interval: 10 μm/s²

5 cm

Figure 11  
GSB60

Fig 13

5 cm

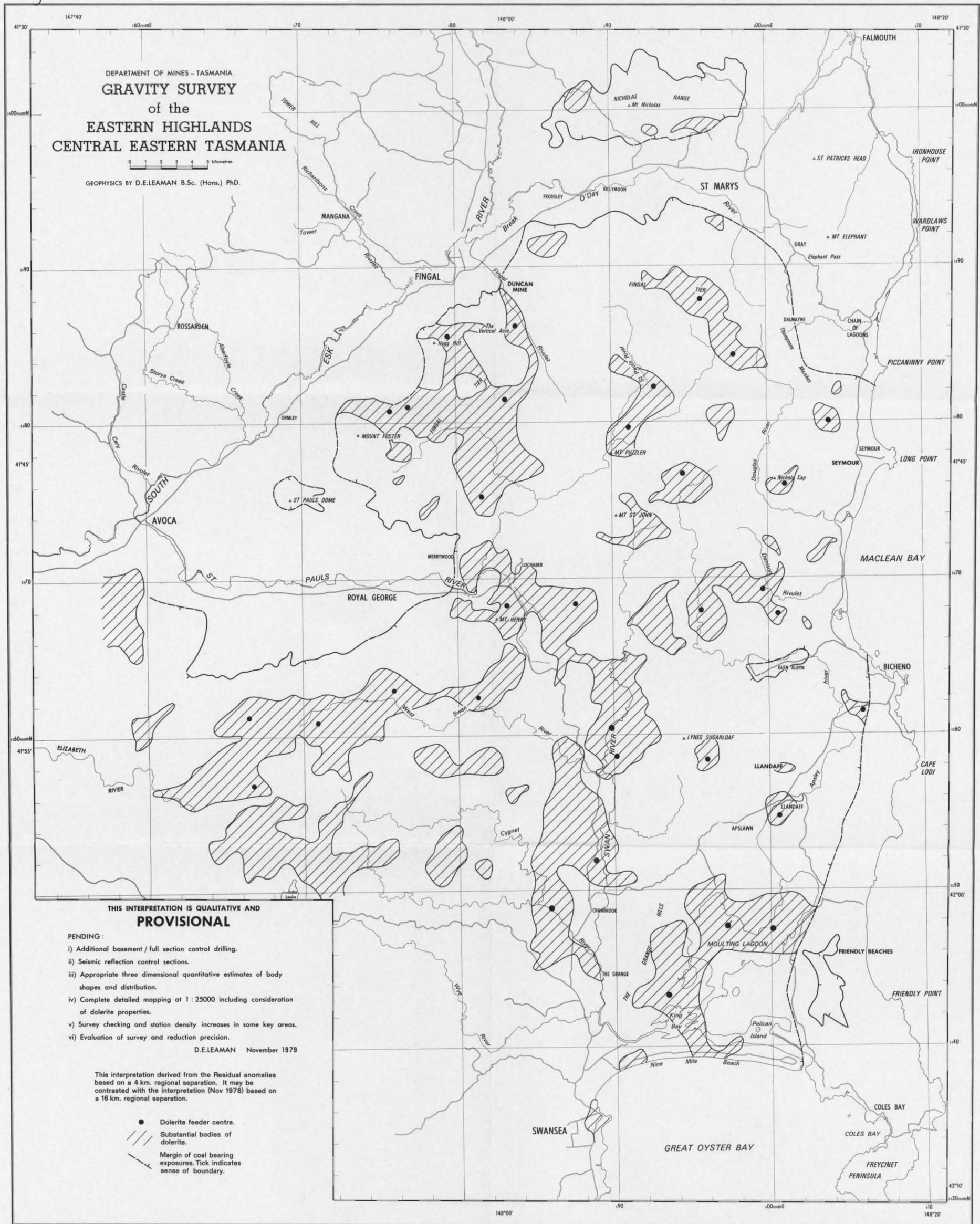
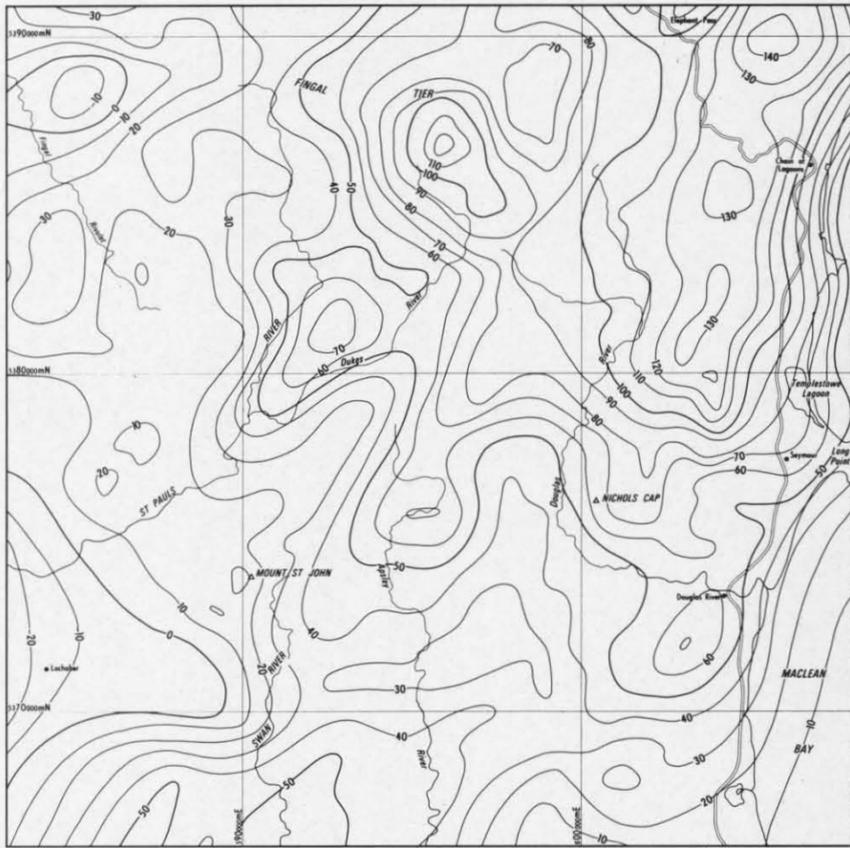


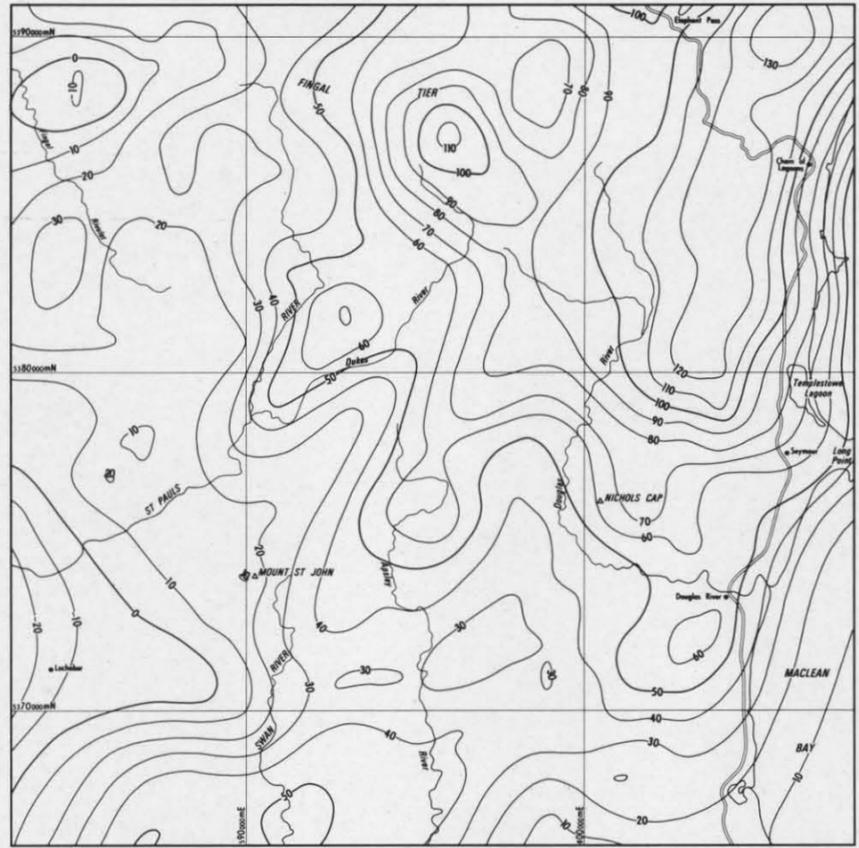
Figure 13

G5860

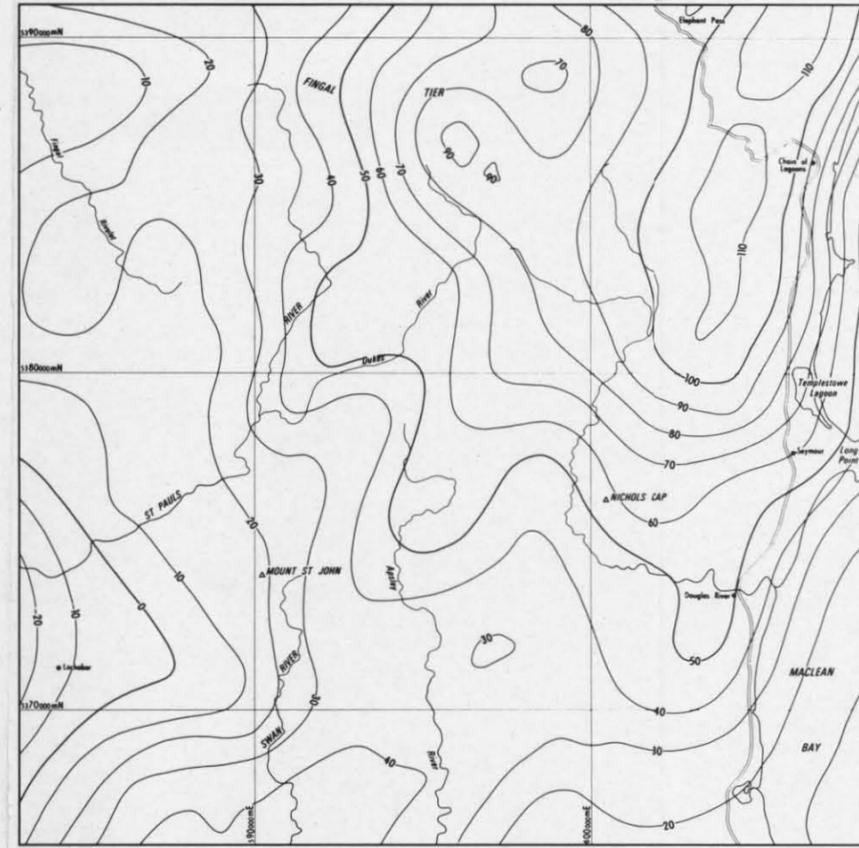
GSB60



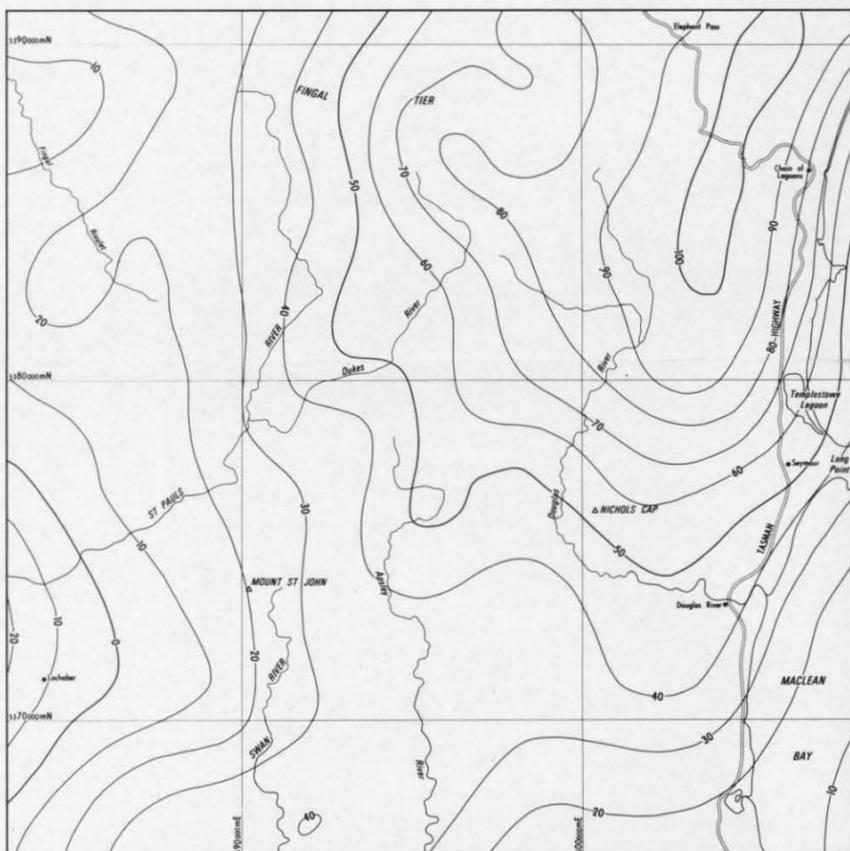
850m



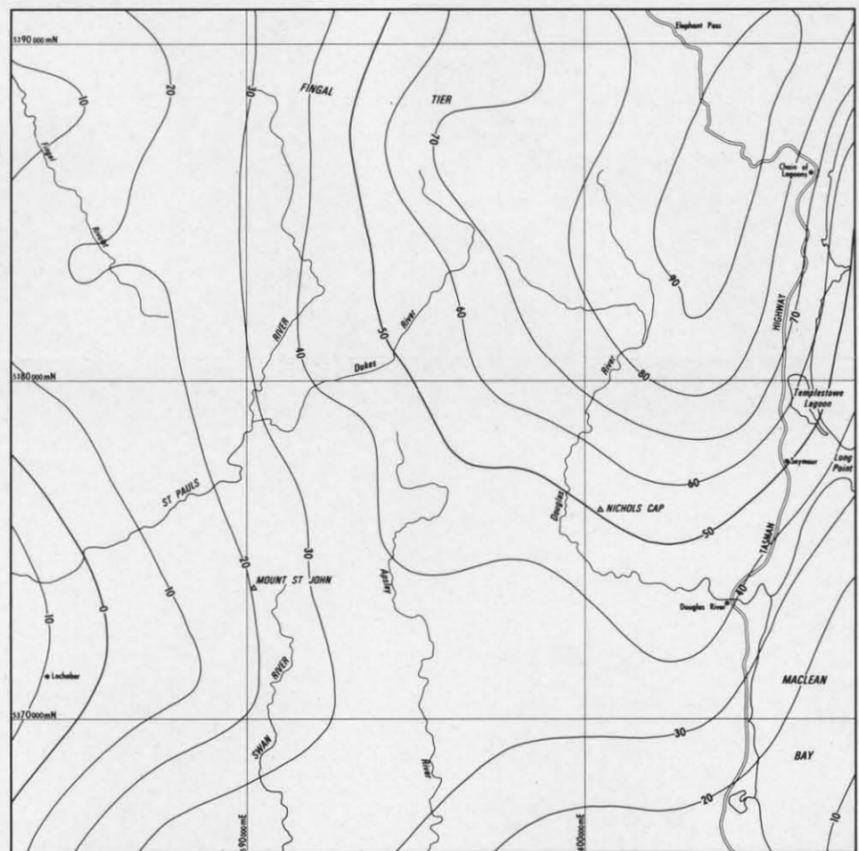
1000m



1500m



2000m

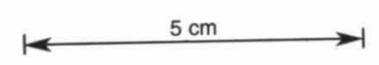


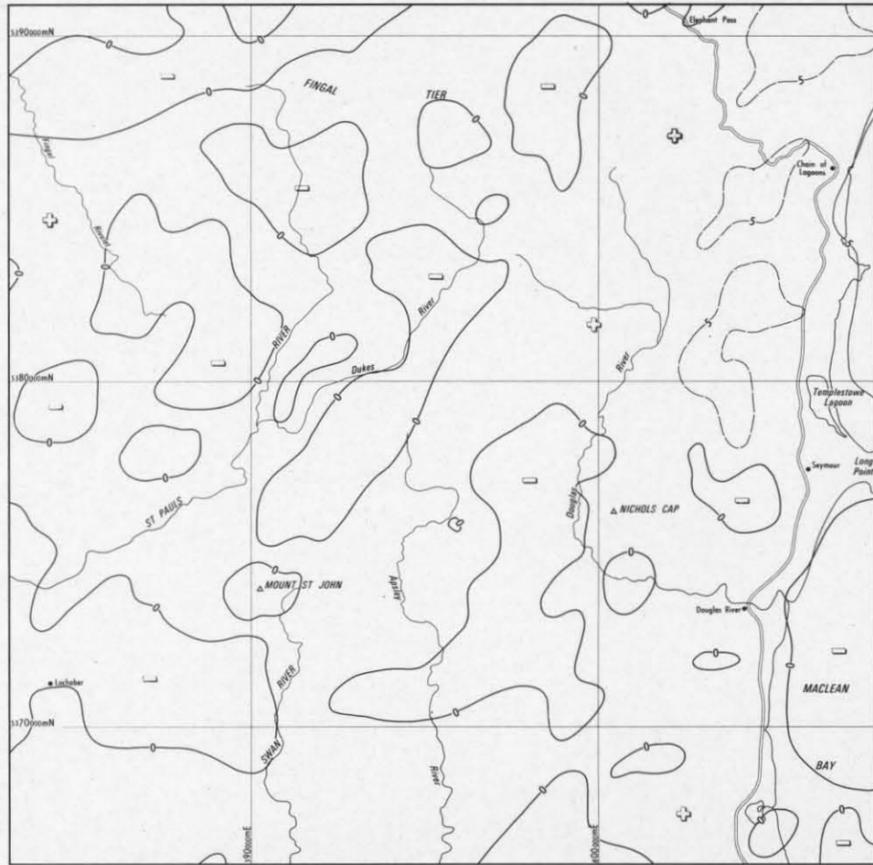
2500m

**EAST COAST GRAVITY SURVEY  
CORE AREA FROM REGIONAL COVERAGE**

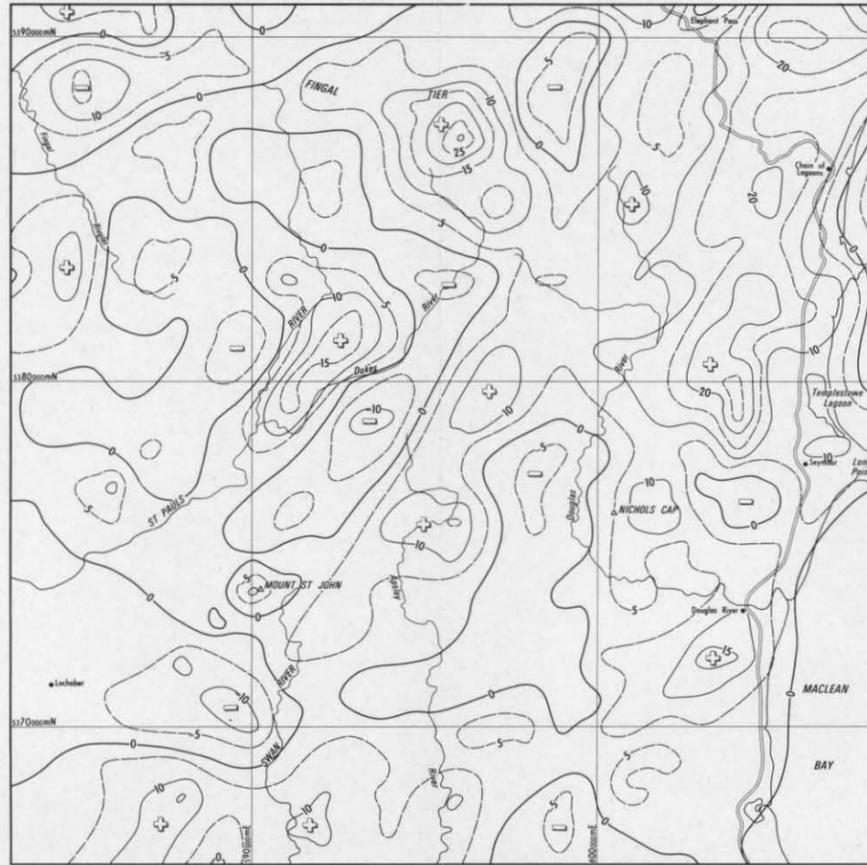
**UPWARD CONTINUATION  
BOUGUER ANOMALIES  
CONTOUR INTERVAL 10 $\mu$ m/sec<sup>2</sup>  
CONTINUATION HEIGHTS STATED  
EQUIVALENT MASSES AT -350m**

FIGURE 15

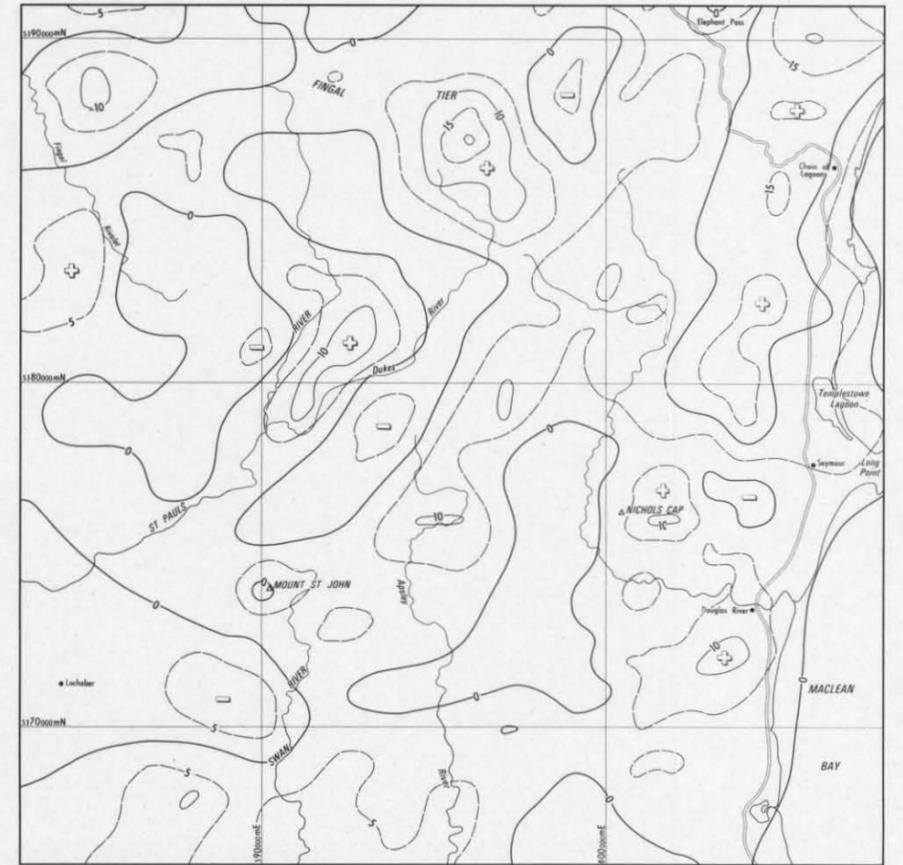




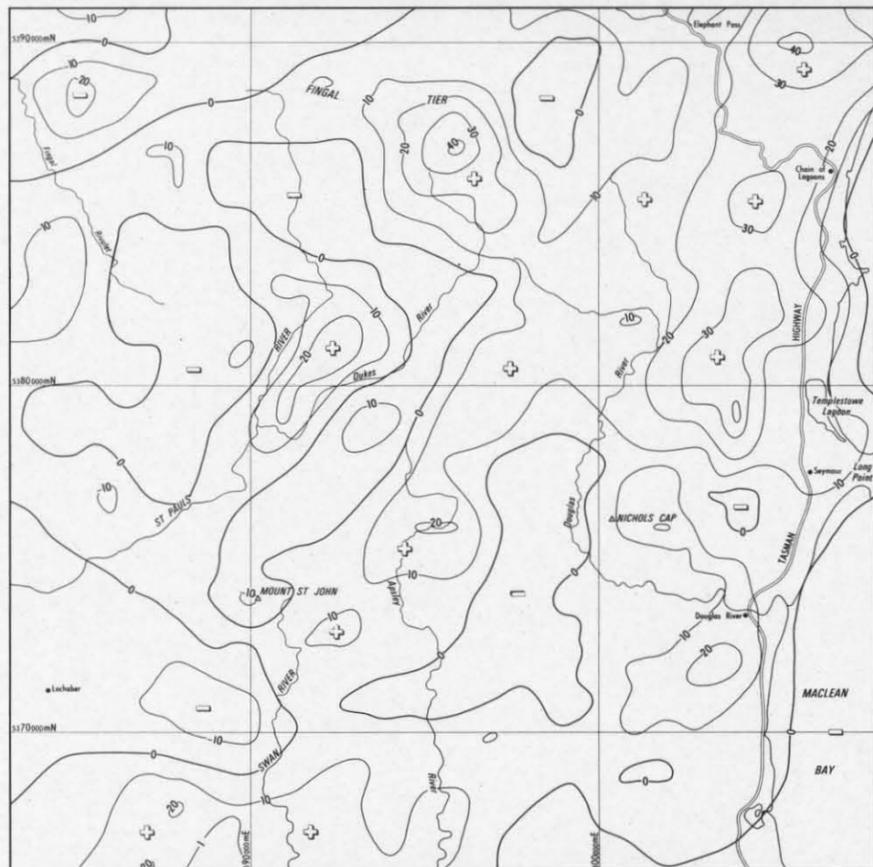
850/1000m



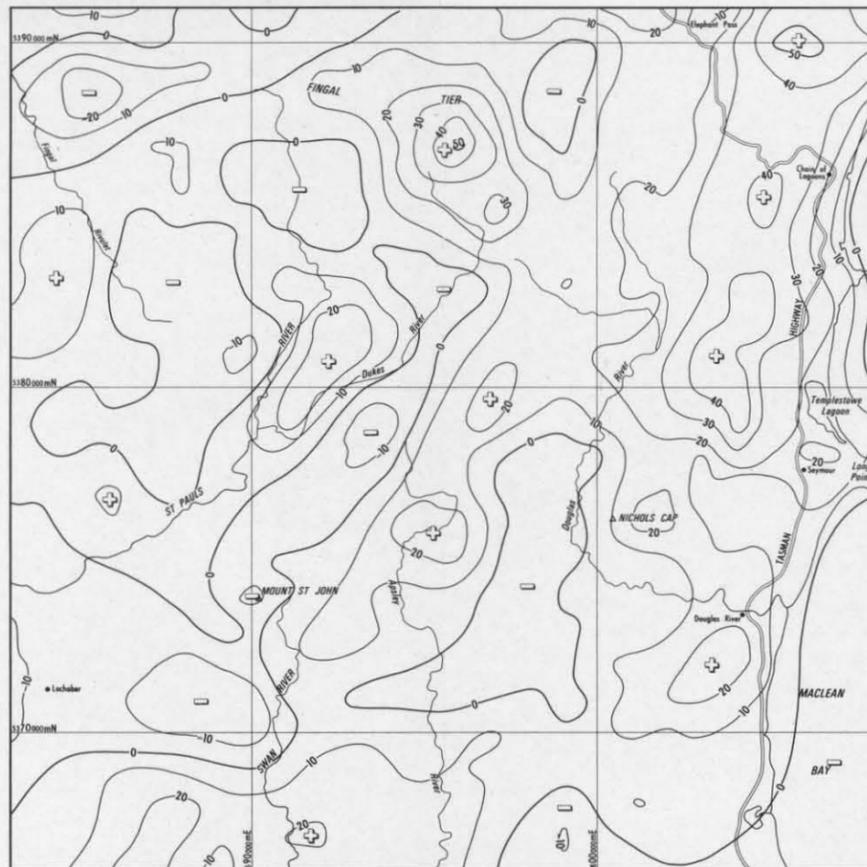
850/1500m



1000/1500m



850/2000m



850/2500m

**EAST COAST GRAVITY SURVEY  
CORE AREA FROM REGIONAL COVERAGE**

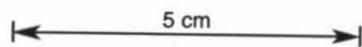
**CONTINUATION RESIDUALS**

**BOUGUER ANOMALIES**

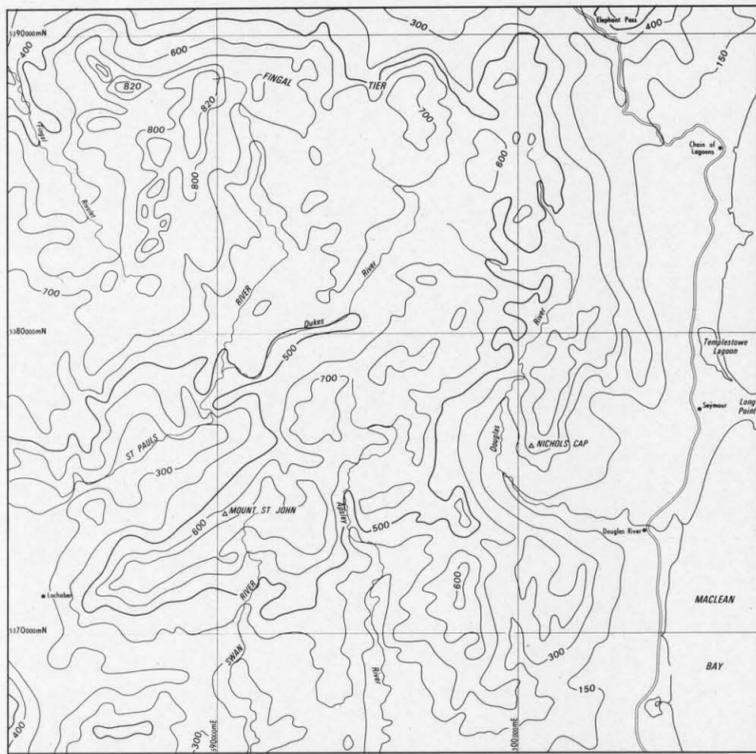
CONTOUR INTERVAL	$5\mu\text{m}/\text{sec}^2$	(850/1000)
		850/1500
		1000/1500
	$10\mu\text{m}/\text{sec}^2$	(850/2500)
		850/2500

**CONTINUATION HEIGHTS STATED  
EQUIVALENT MASSES AT -350m**

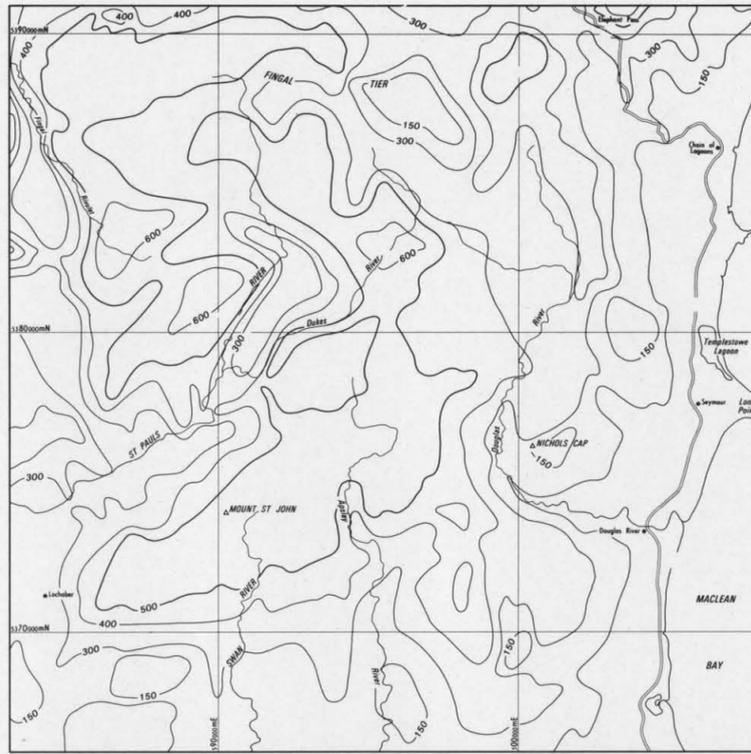
FIGURE 16



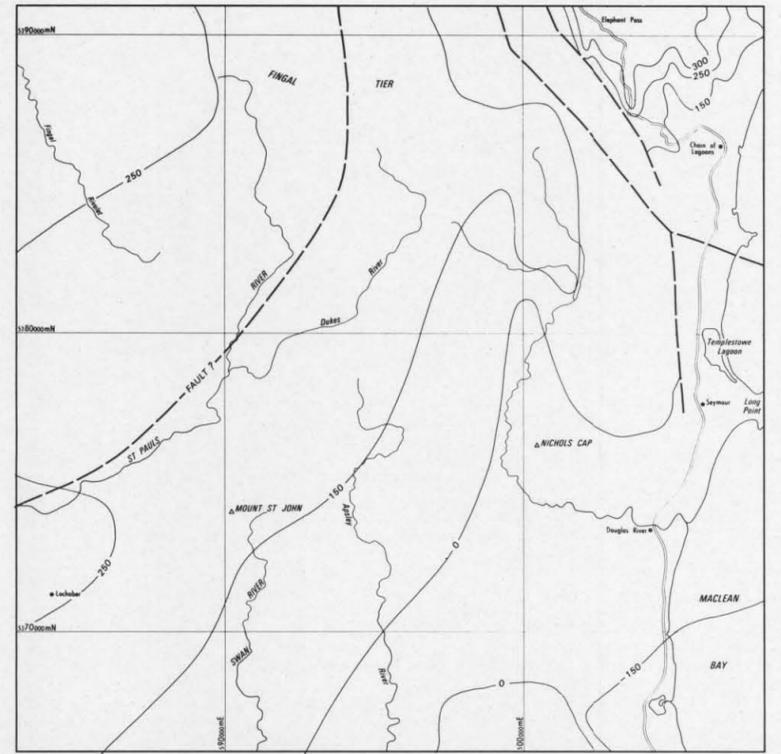
G5B60



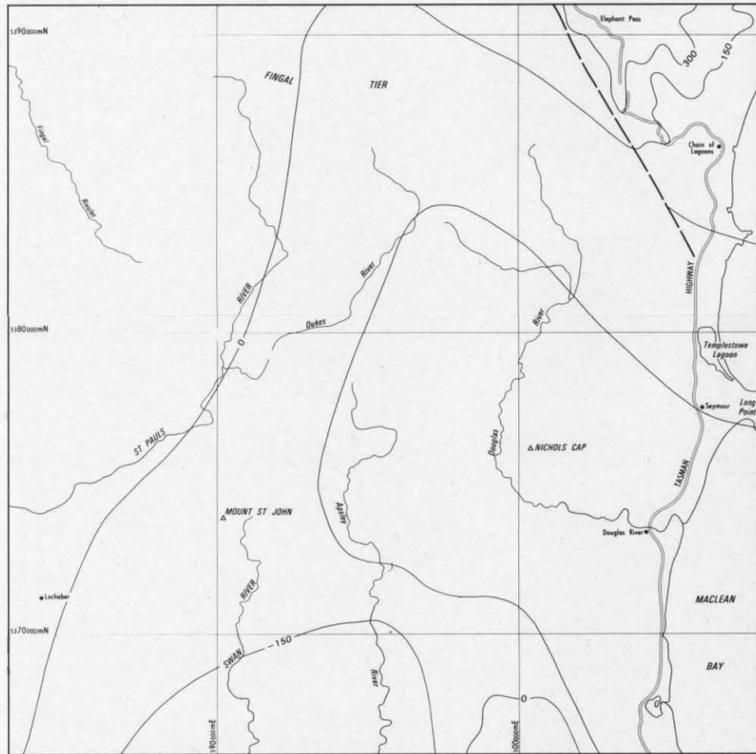
PART I TOP OF DOLERITE OR TOPOGRAPHY TO BASE LEVEL  $\Delta = + 0.16 \text{ t/m}^3$



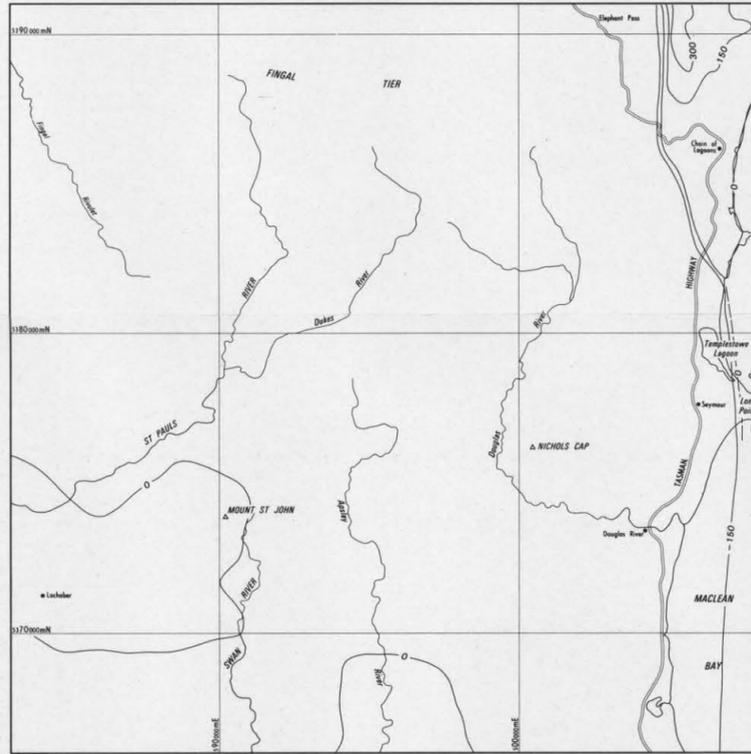
PART II TOP OF TRIASSIC COAL MEASURES OR TOPOGRAPHY TO BASE LEVEL  $\Delta = - 0.48 \text{ t/m}^3$



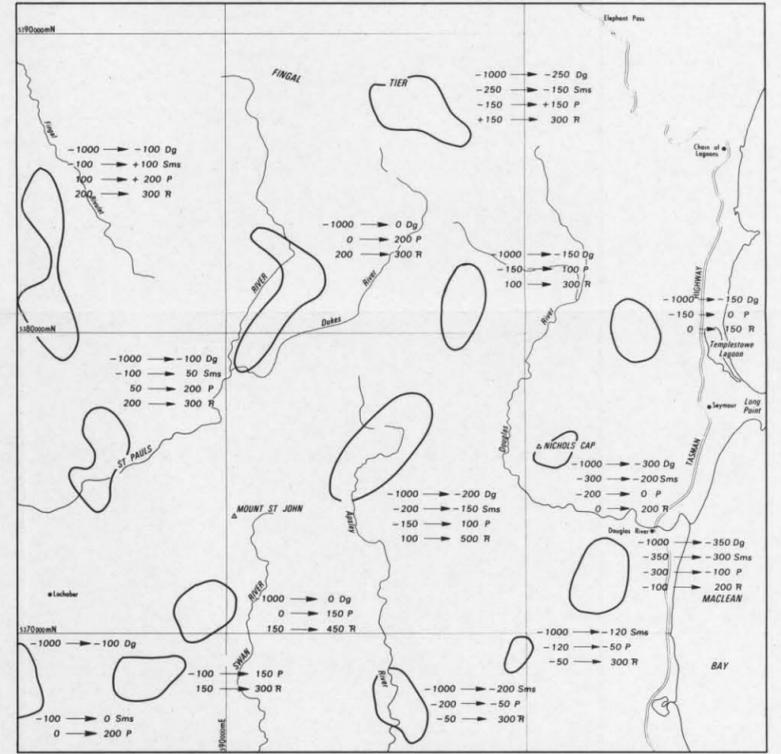
PART III TOP OF PERMIAN TO BASE LEVEL  $\Delta = + 0.10 \text{ t/m}^3$



PART IV TOP OF MATHINNA BEDS TO BASE LEVEL  $\Delta = + 0.22 \text{ t/m}^3$



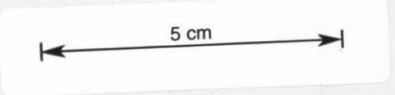
PART V TOP OF GRANITE TO BASE LEVEL  $\Delta = - 0.05 \text{ t/m}^3$



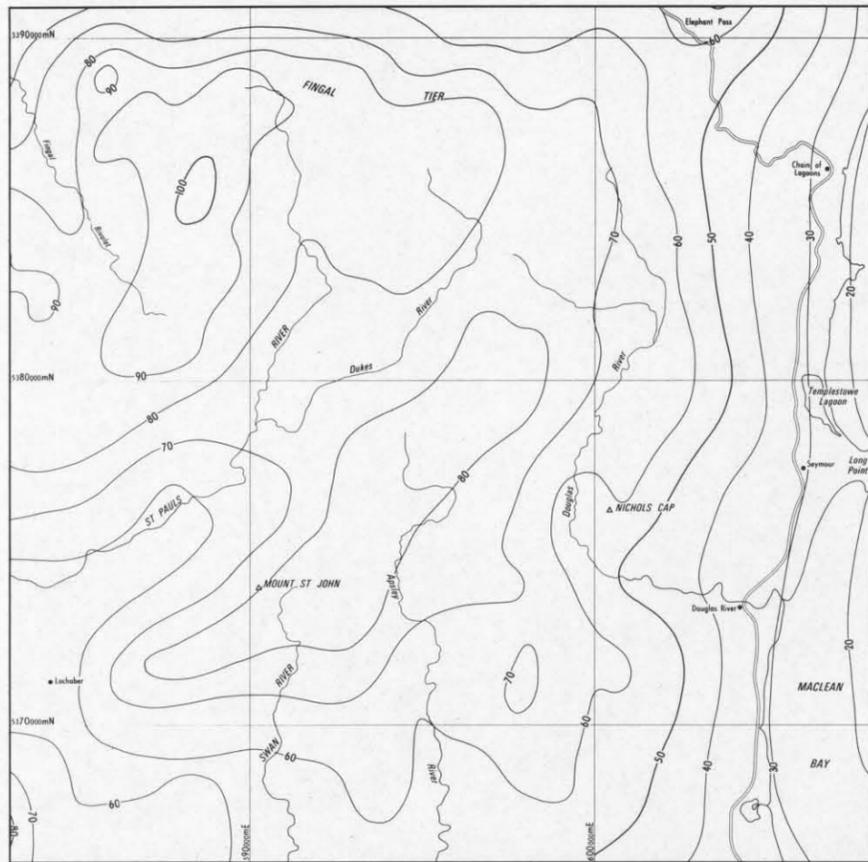
PART VI DOLERITE FEEDERS TO BASE DOLERITE AS DEFINED BY PART I LESS PART II CONTRASTS INDICATED.

**SPECIFICATION OF INITIAL QUANTITATIVE MODEL ASSESSMENT — REGIONAL SURVEY CORE AREA**

Fig 18

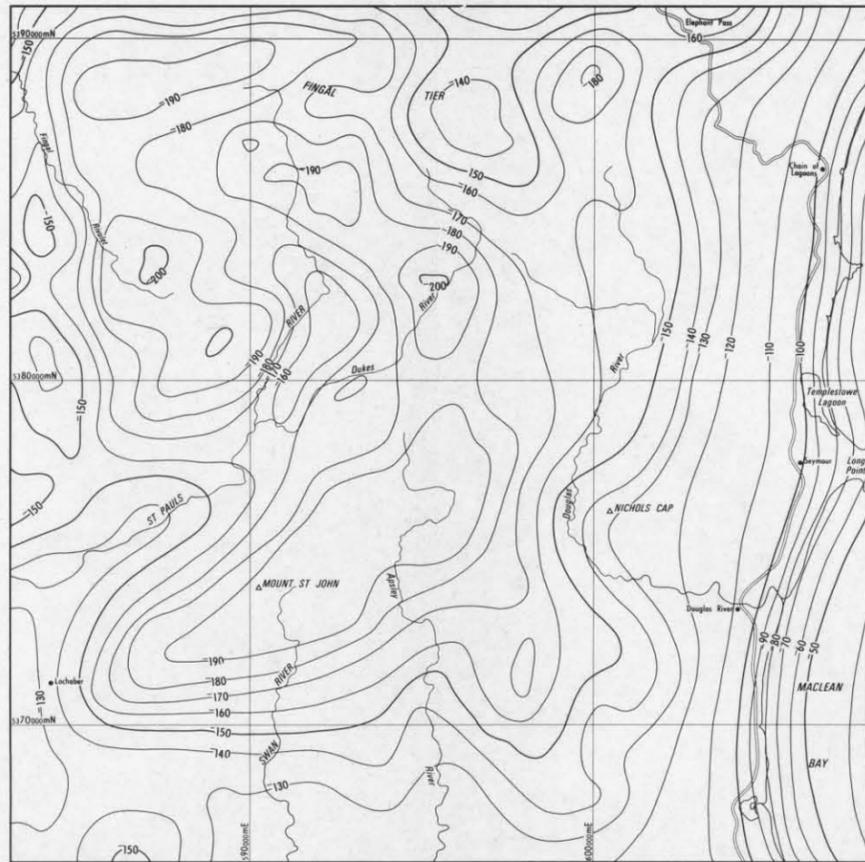


GSB60



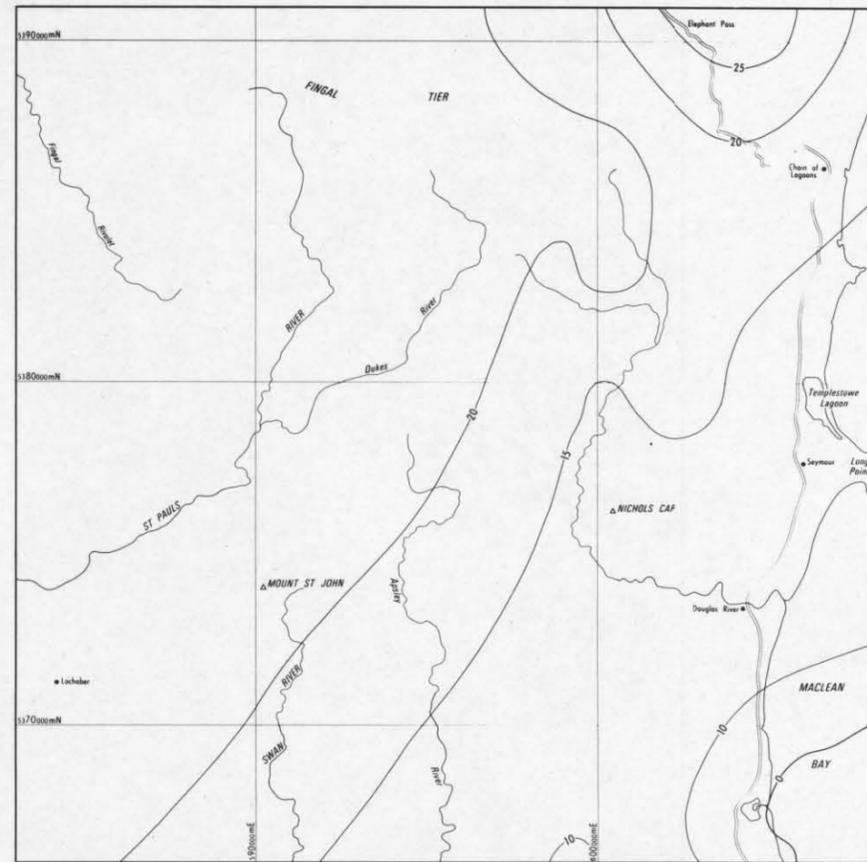
DOLERITE (LESS FEEDERS)

PART 1



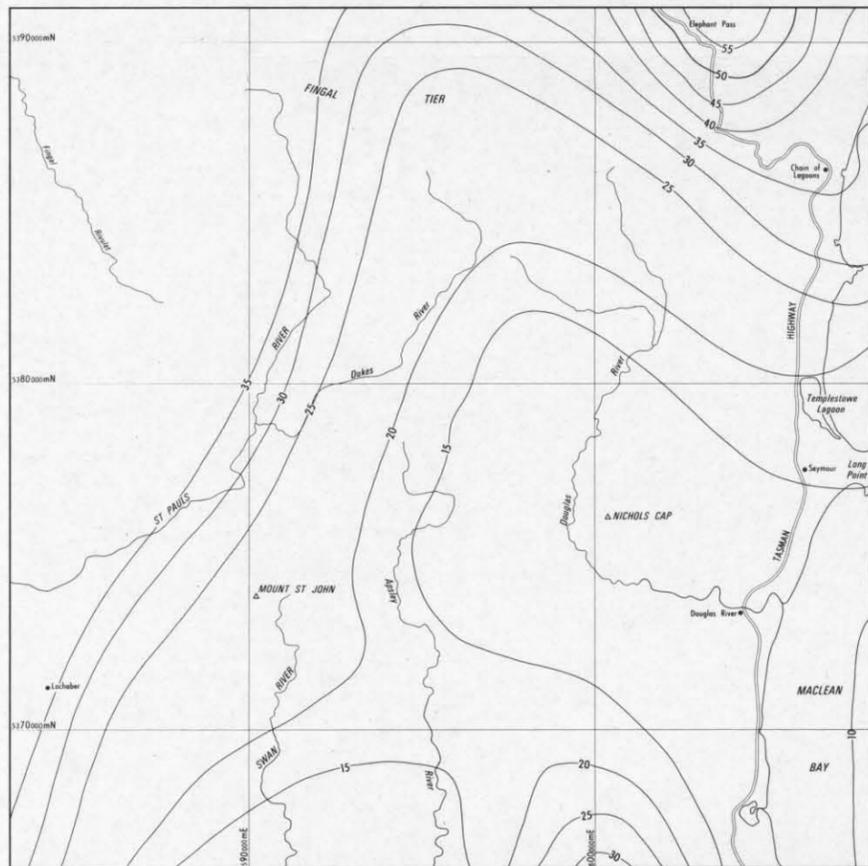
COAL MEASURES

PART 2



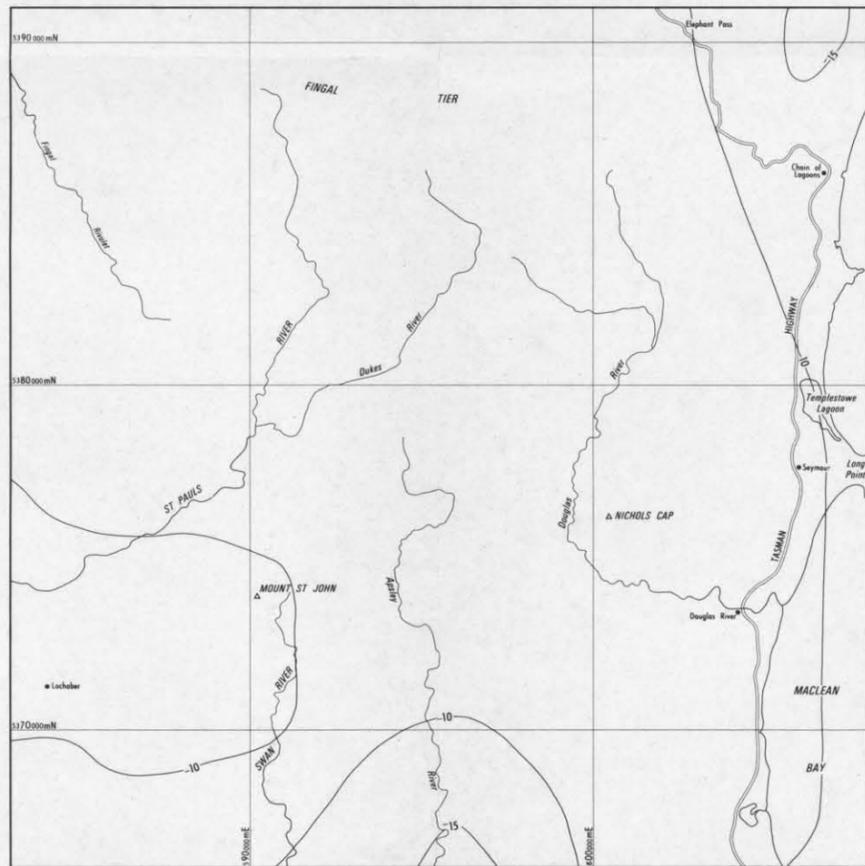
PERMIAN

PART 3



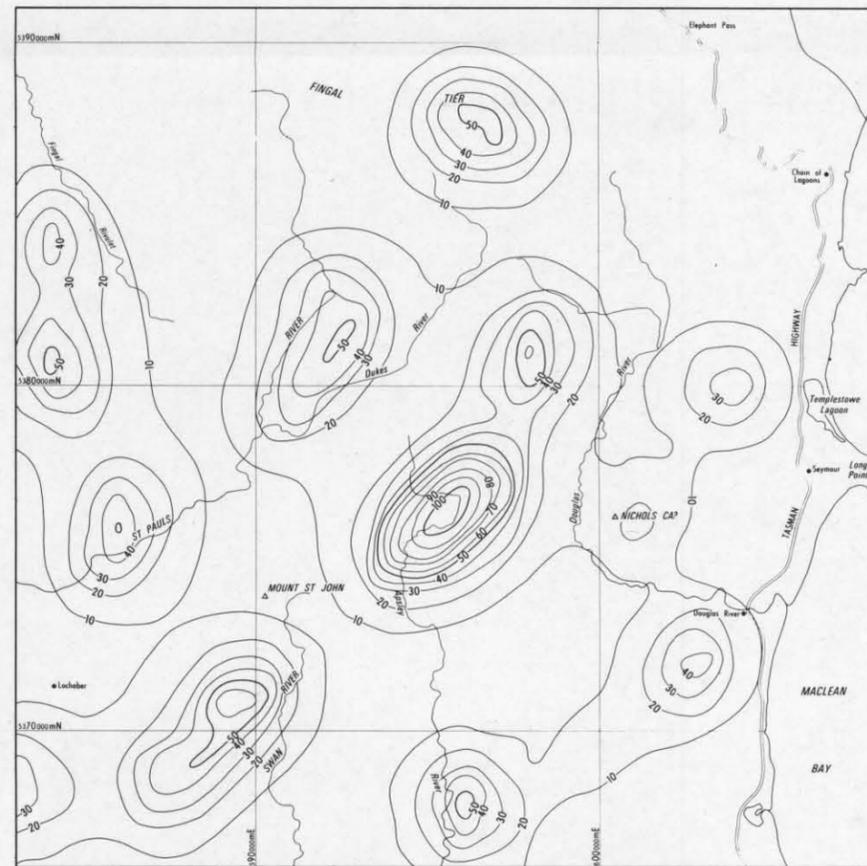
MATHINNA BEDS

PART 4



GRANITE

PART 5



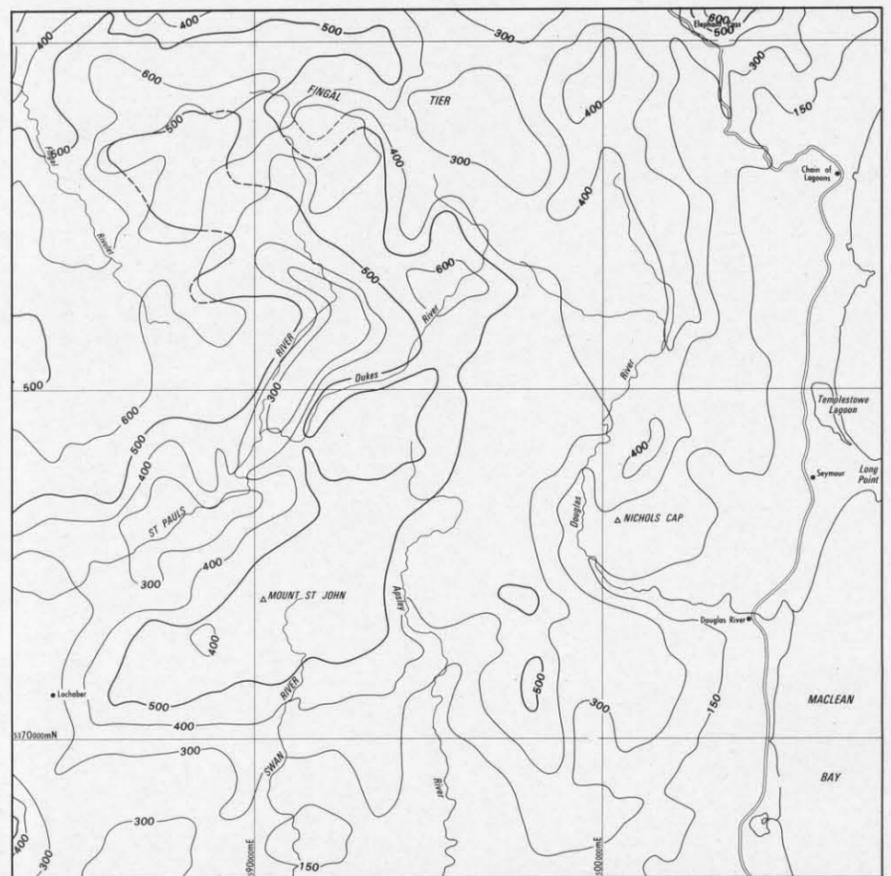
DOLERITE FEEDERS

PART 6

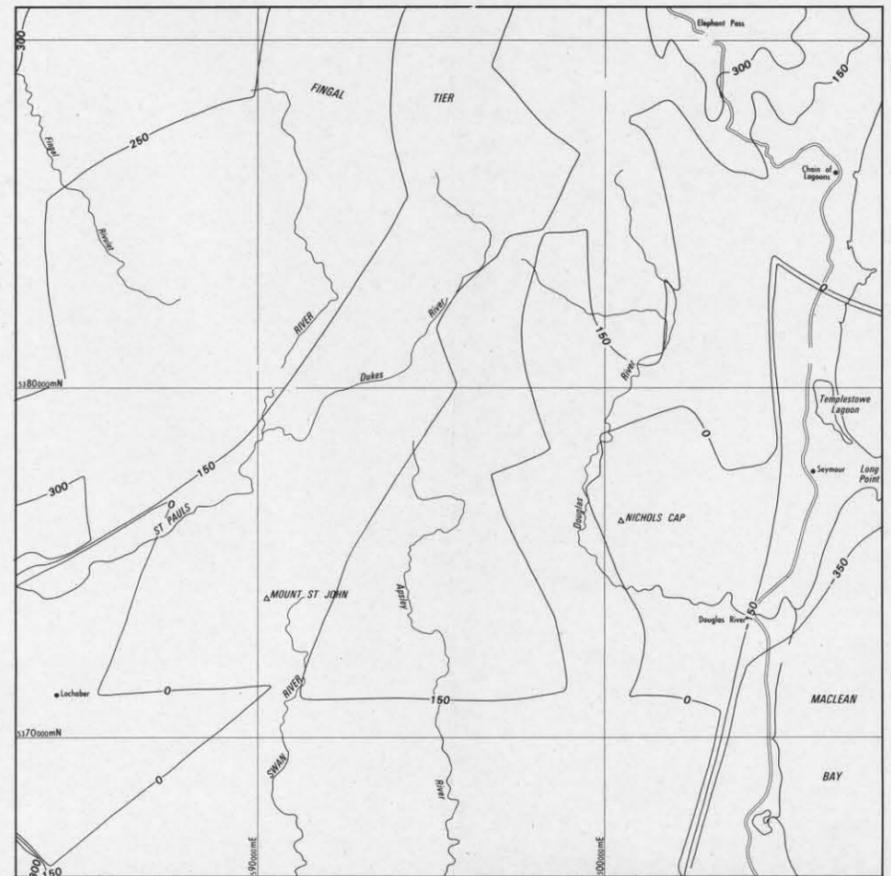
5 cm

CONTRIBUTION TO CALCULATED ANOMALY REGIONAL SURVEY MODEL 1  
 CONTOUR INTERVAL 5or10 $\mu$ m/sec<sup>2</sup>

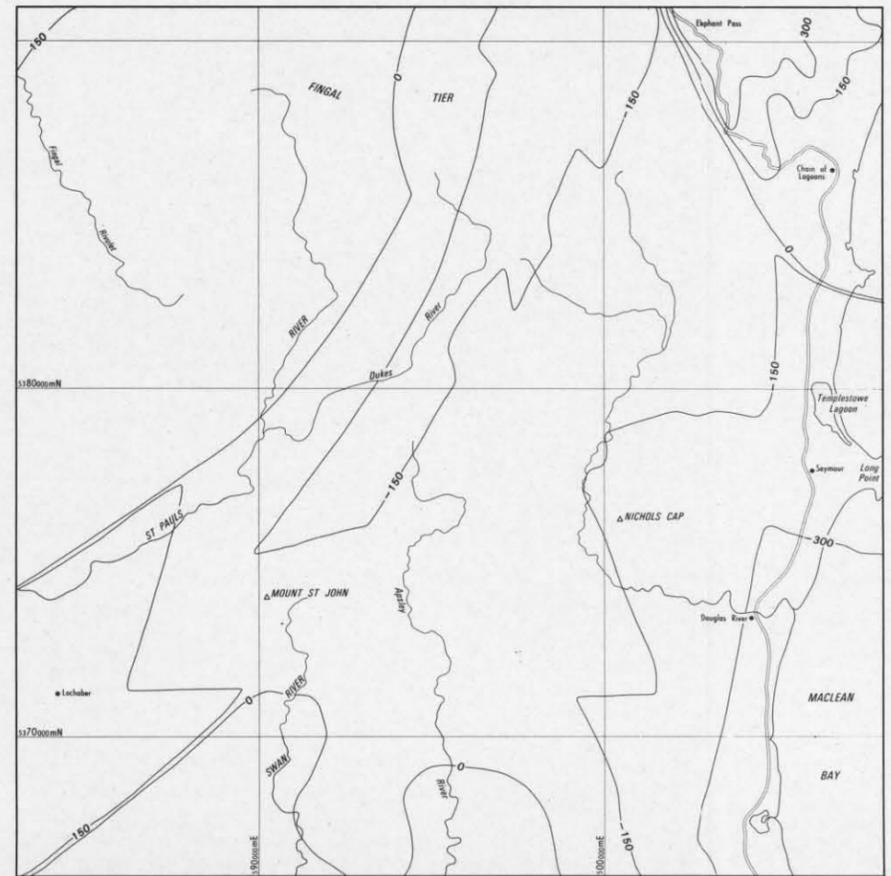
GSB60



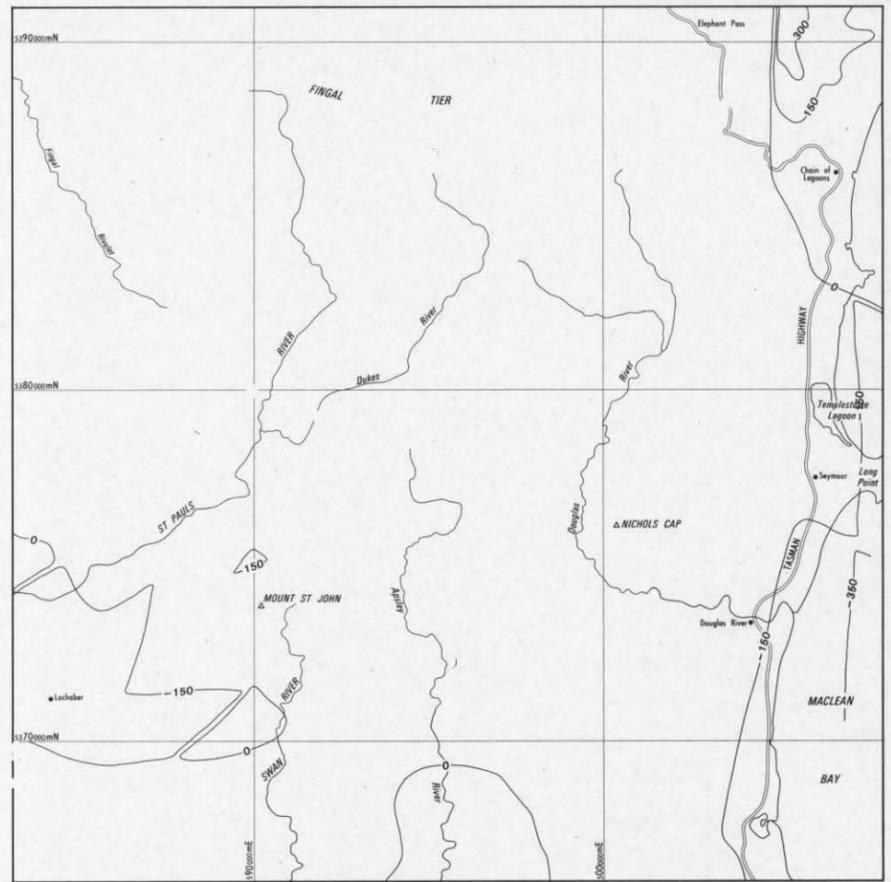
PART II BASE OF DOLERITE/TOPOGRAPHY TO BASE LEVEL (EXCLUDING FEEDERS)



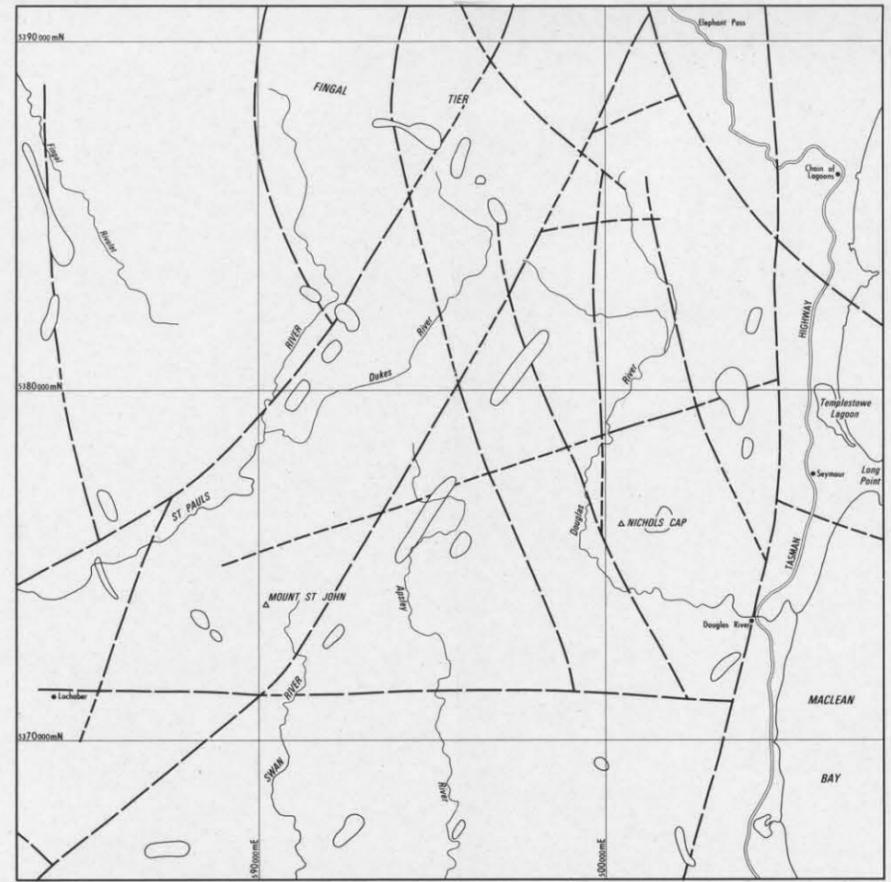
PART III BASE TRIASSIC COAL MEASURES/TOPOGRAPHY TO BASE LEVEL



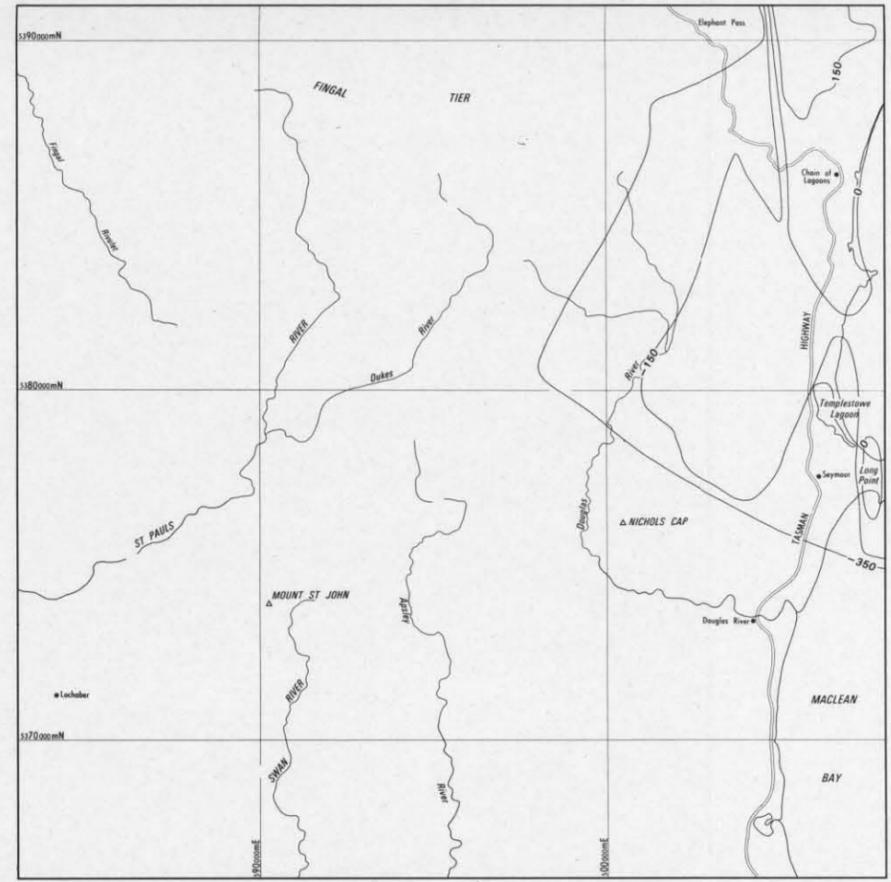
PART IV BASE PERMIAN/TOPOGRAPHY TO BASE LEVEL



PART V BASE MATHINNA BEDS TO BASE LEVEL



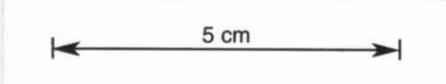
PART VI DOLERITE FEEDERS (ALSO SHOWING SUMMARY OF IMPLIED FAULTING).



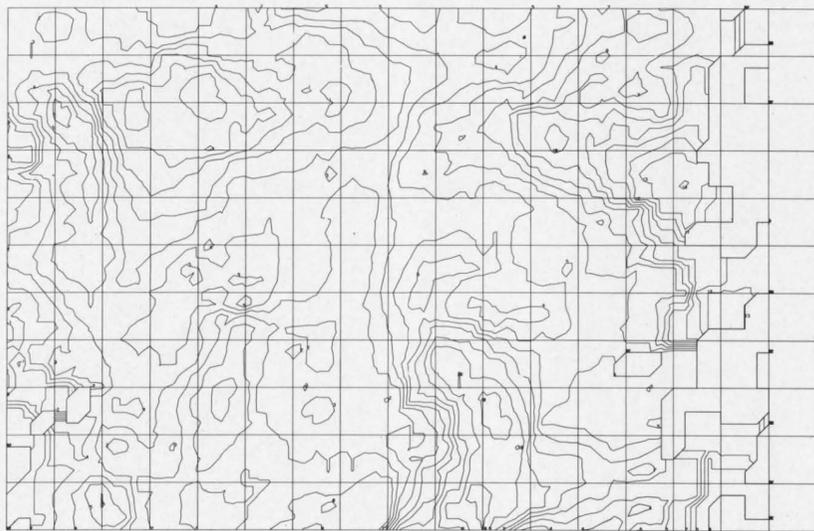
PART VII BASE GRANITE/TOP GRANODIORITE TO BASE LEVEL = + 0.08t/m<sup>3</sup>

**SPECIFICATION OF ACCEPTABLE MODEL**

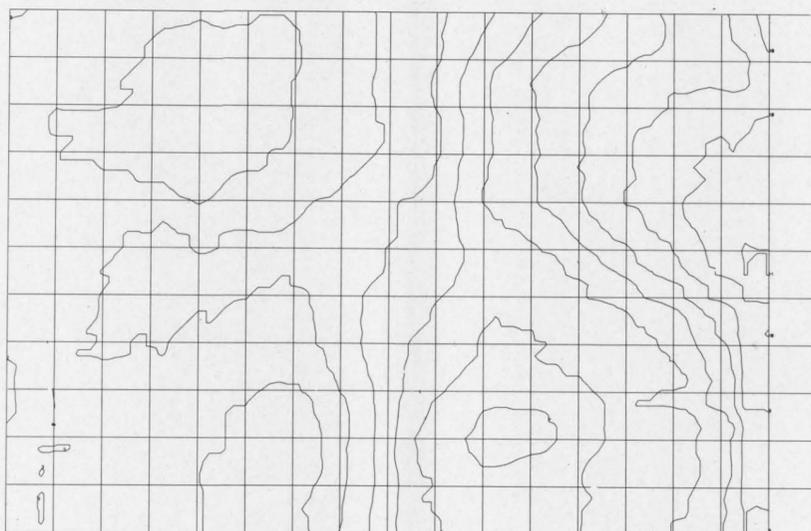
PARTS I, VIII NOT SHOWN PART I AS IN FIG. 18 PART VIII WATER



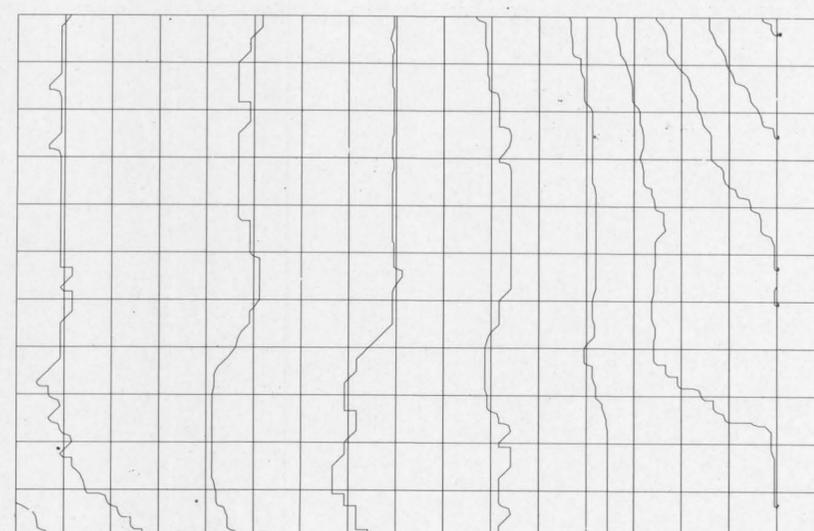
CSB60



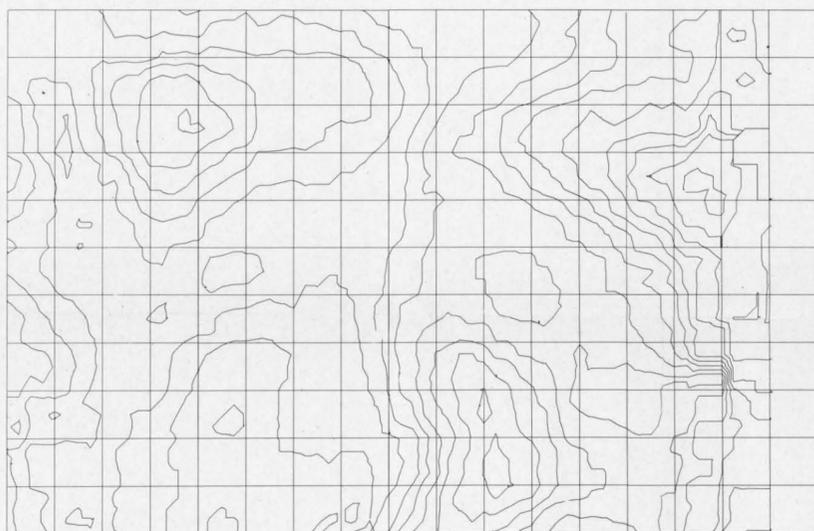
1



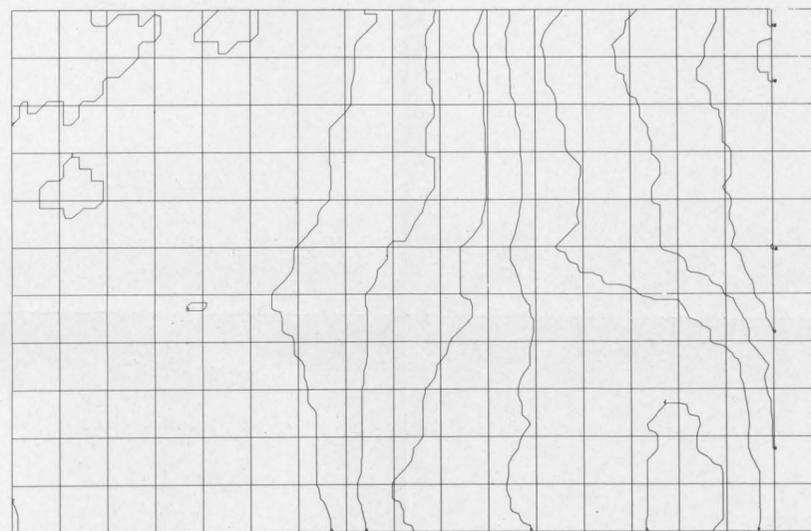
4



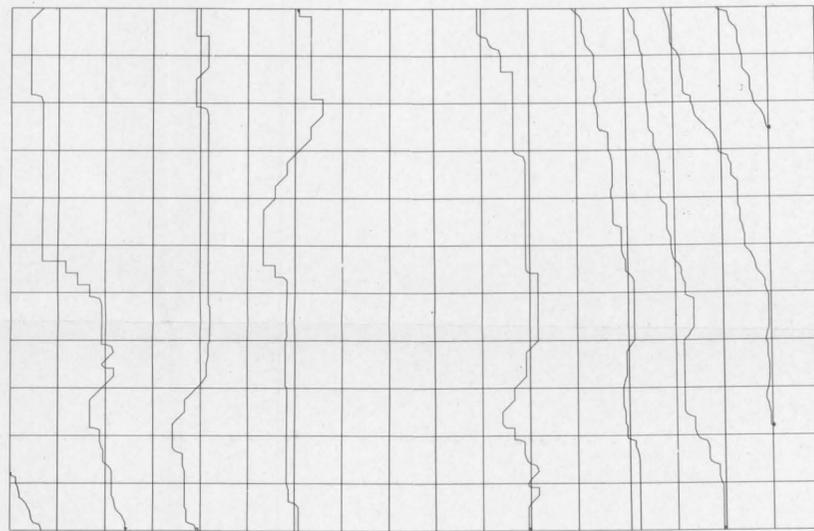
10



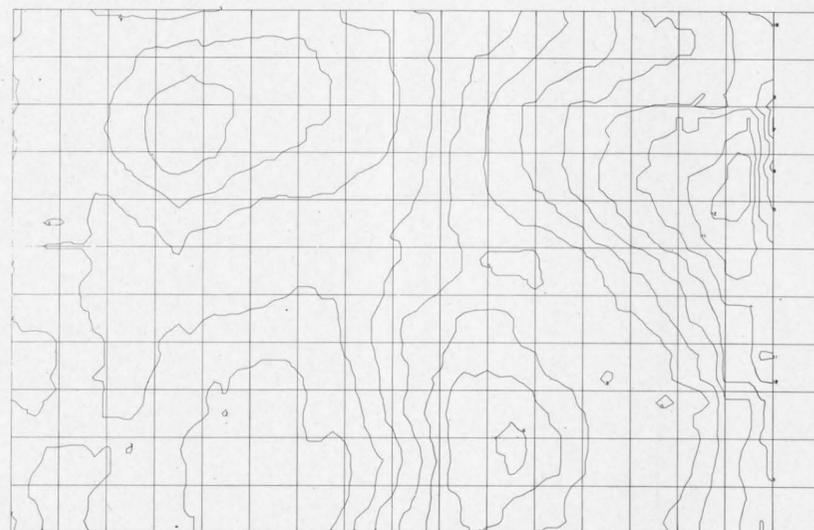
2



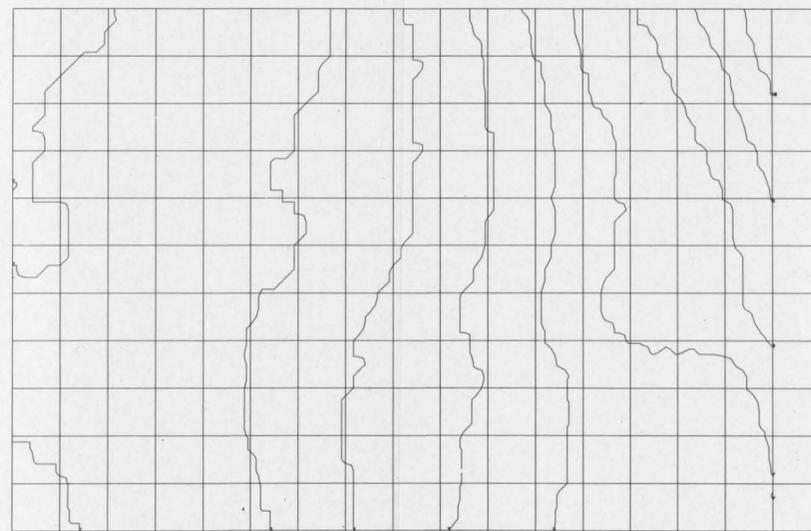
6



12



3



8

5 cm

Fig. 23 SET OF REGIONAL FILTERS FINGAL TIER SURVEY

1 mgal. interval

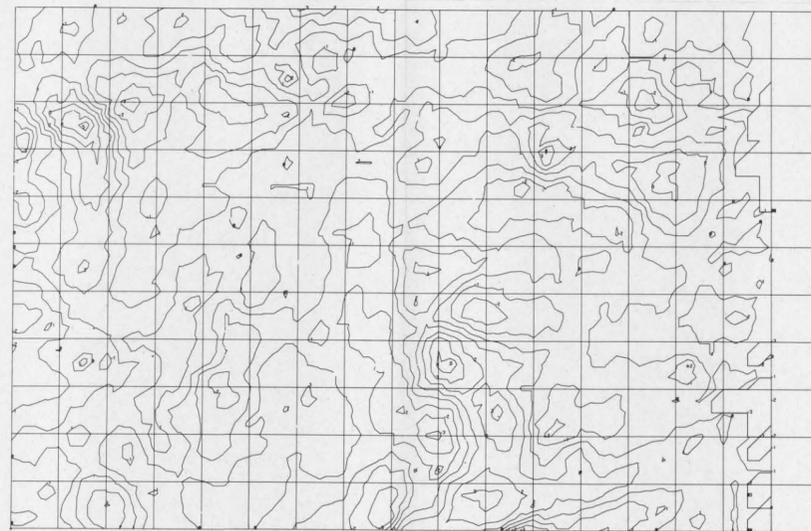
filter grid in km

Fig 23

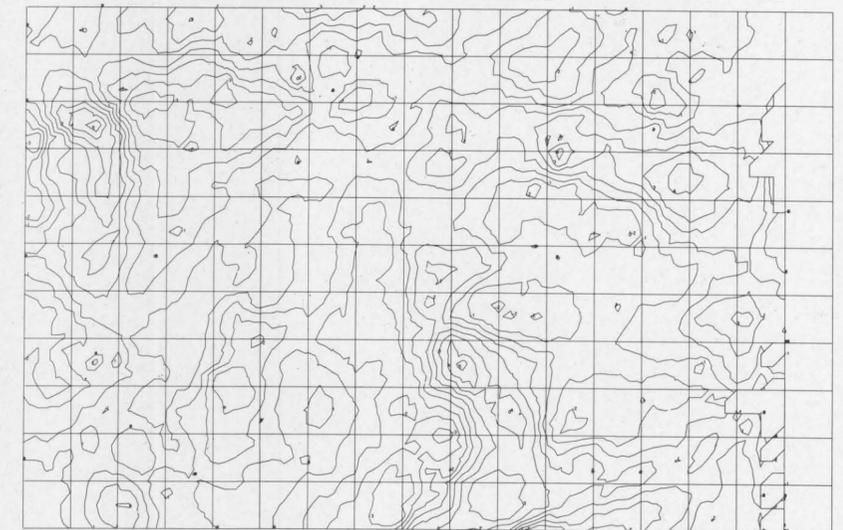
GSB60



1-0



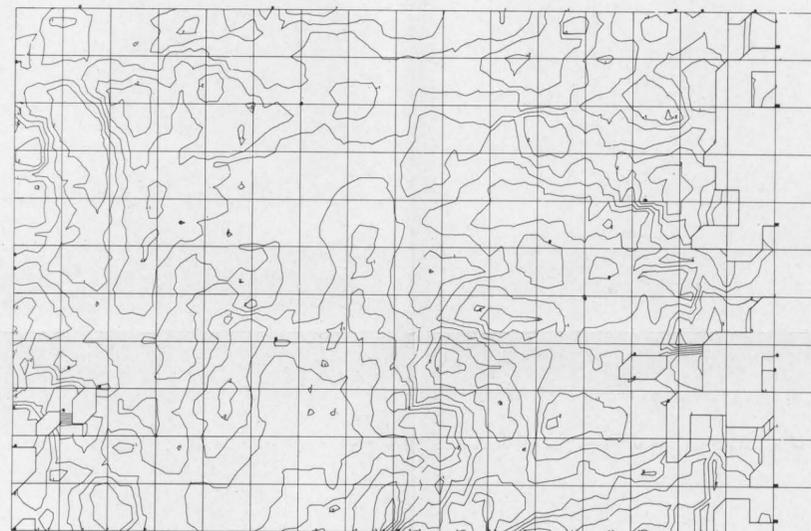
3-0



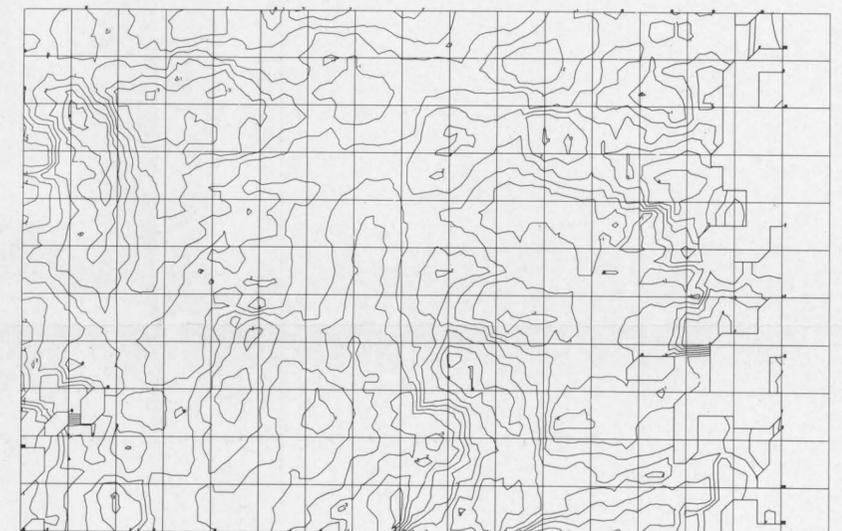
4-0



2-0



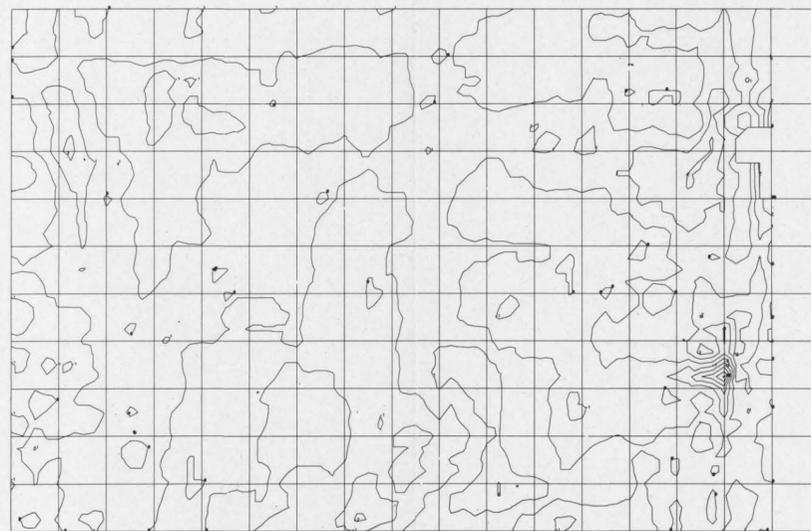
3-1



4-1



2-1



3-2

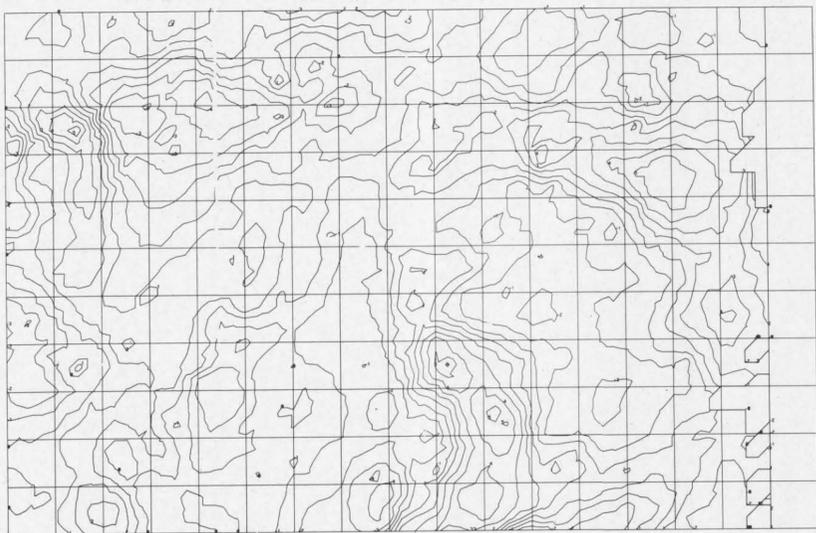


4-2

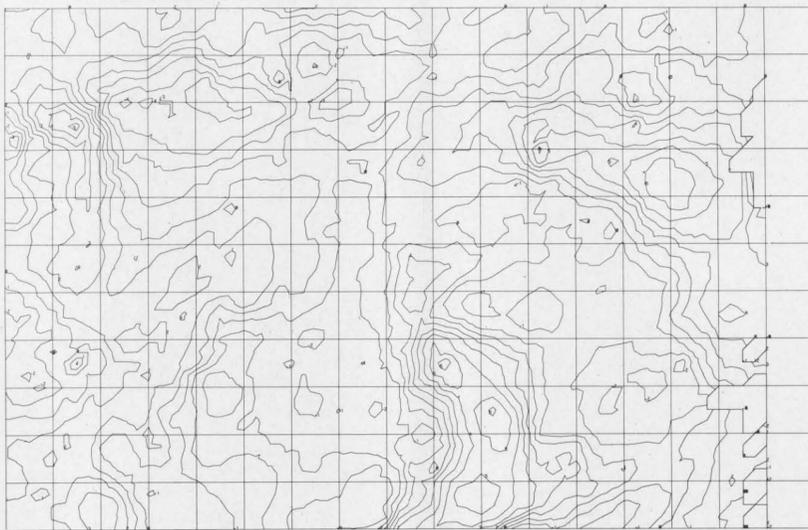
5 cm

Fig. 24 RESIDUAL ANOMALIES FOR REGIONAL FILTERS 0-4 kms FINGAL TIER SURVEY

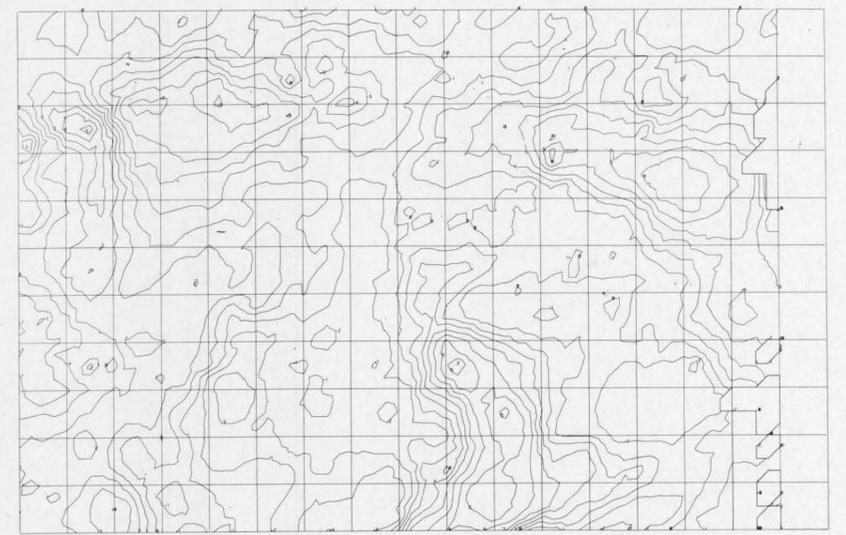
GSB60



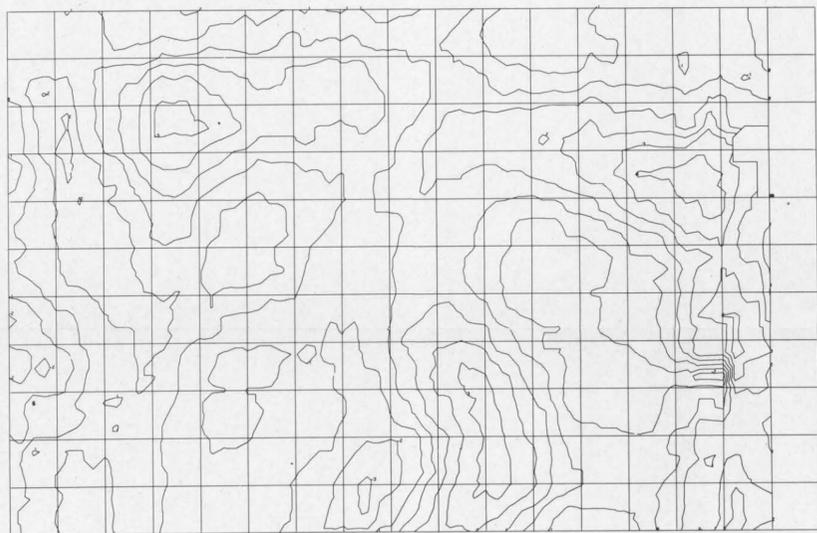
6-0



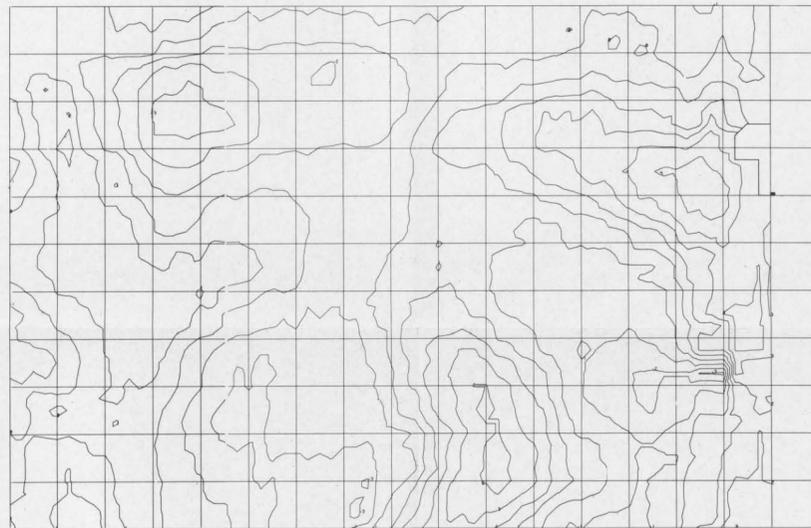
10-0



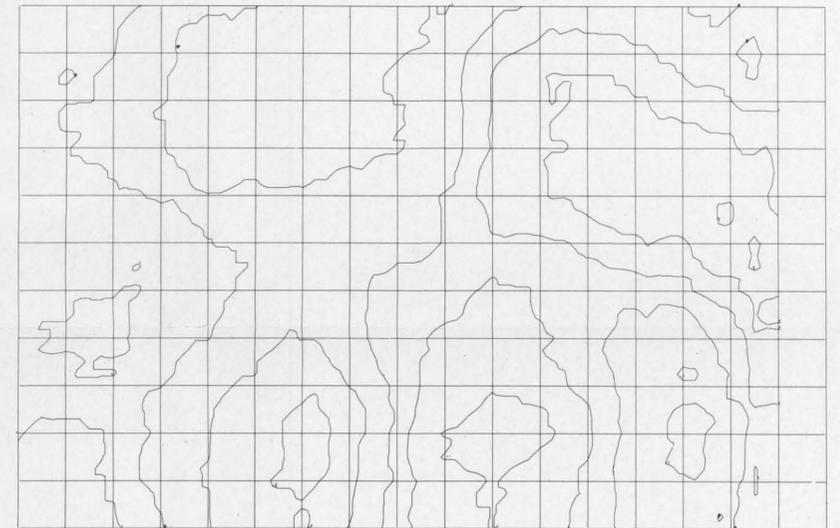
12-0



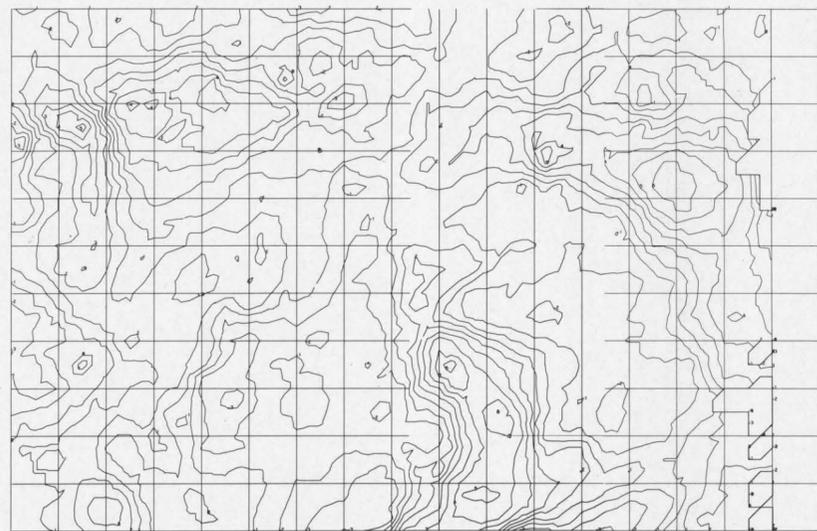
6-2



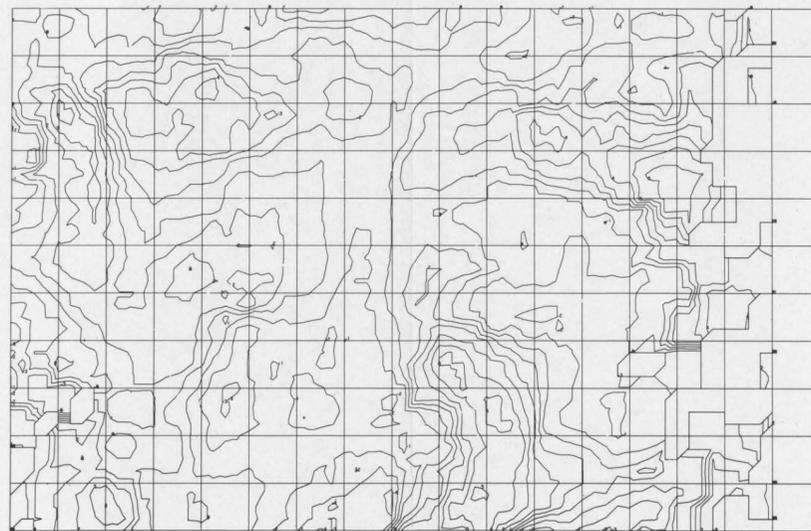
10-2



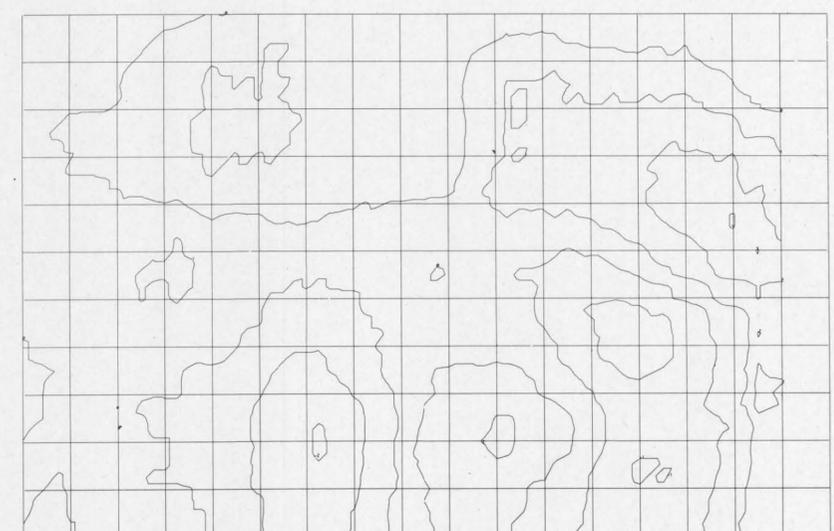
12-4



8-0



8-2



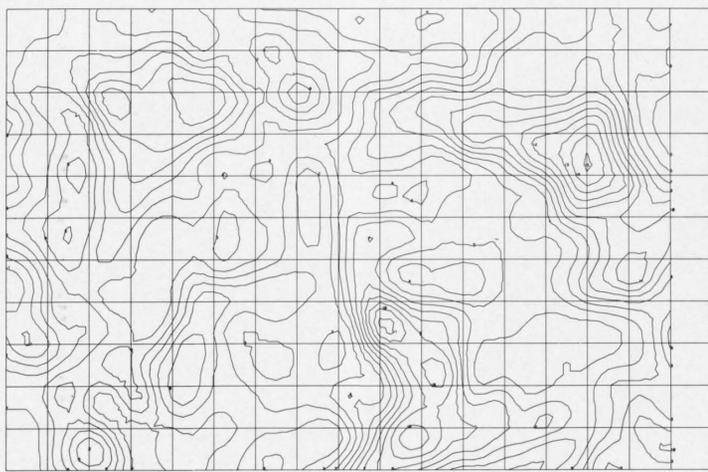
8-4

5 cm

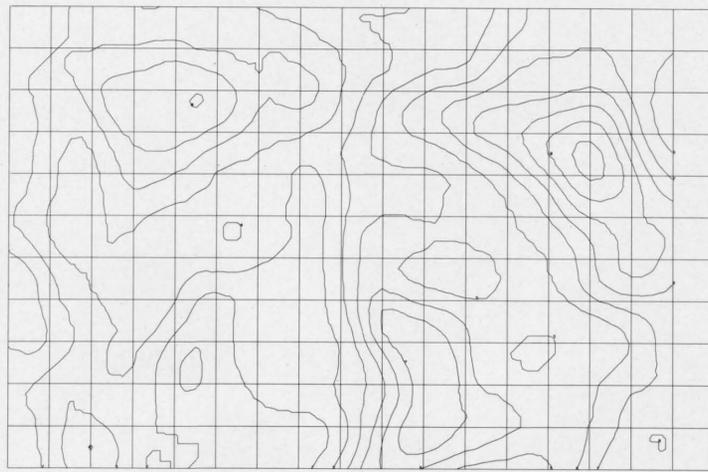
Fig. 25 RESIDUAL ANOMALIES FOR REGIONAL FILTERS 6-12 kms. FINGAL TIER SURVEY

1 mgal. interval

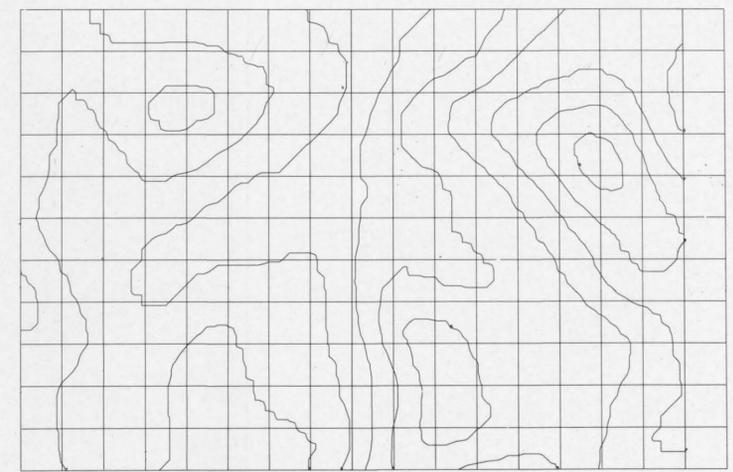
G5860



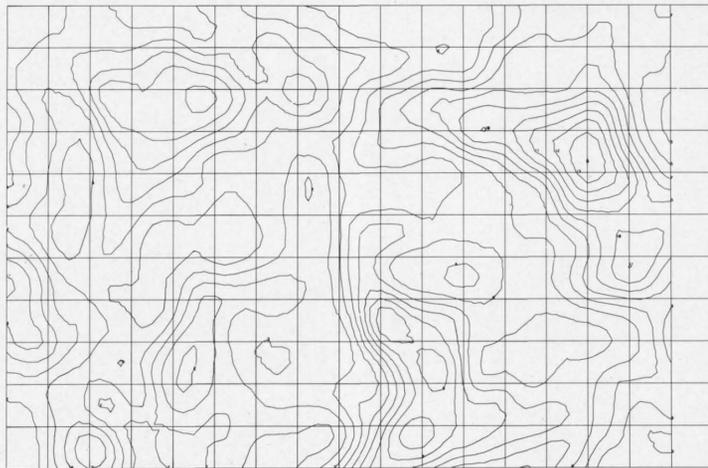
0.65



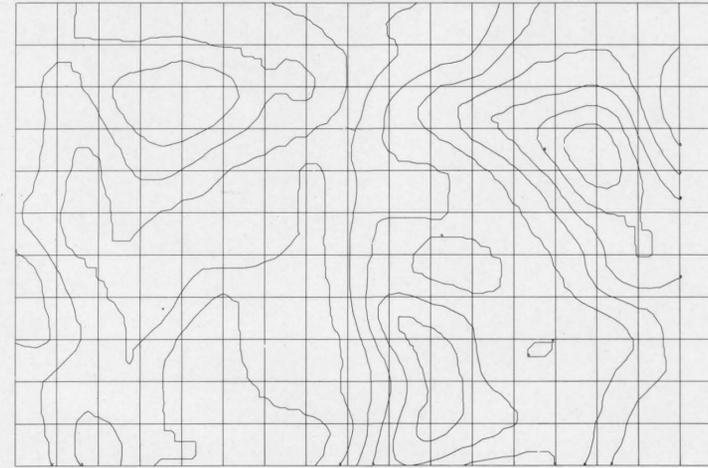
1.05



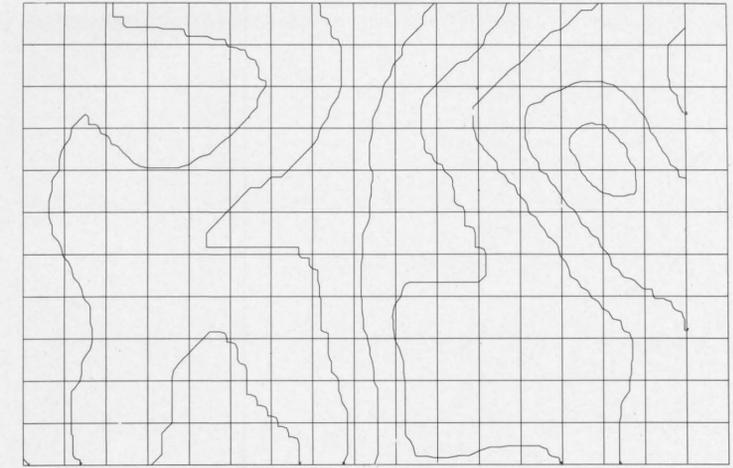
1.45



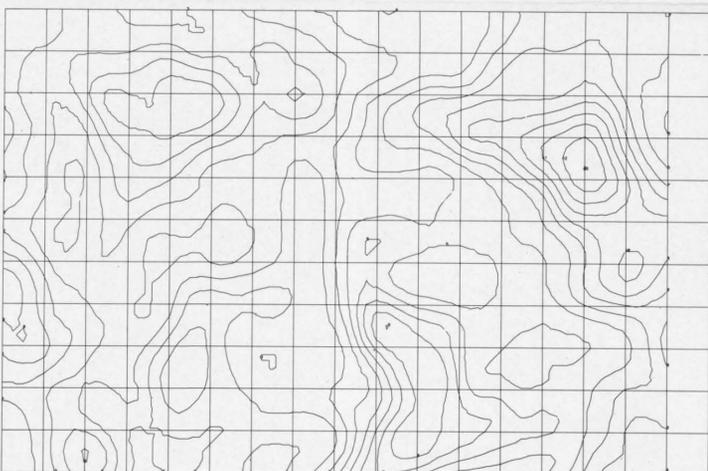
0.75



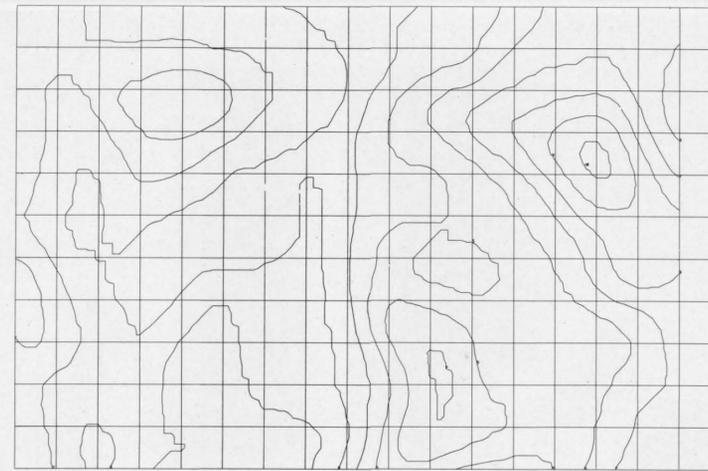
1.15



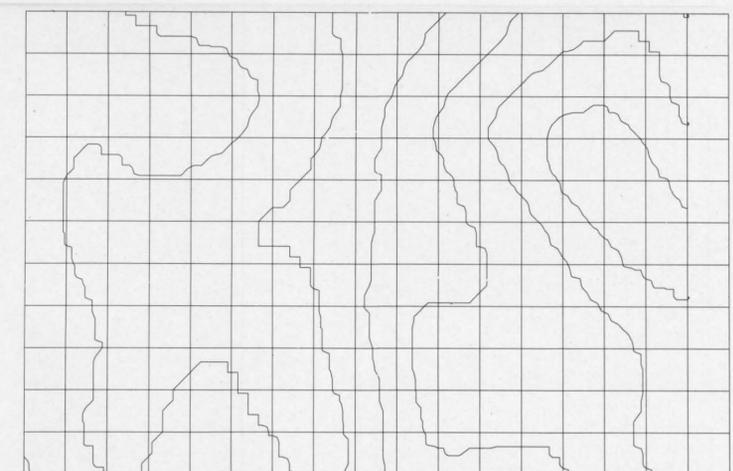
1.75



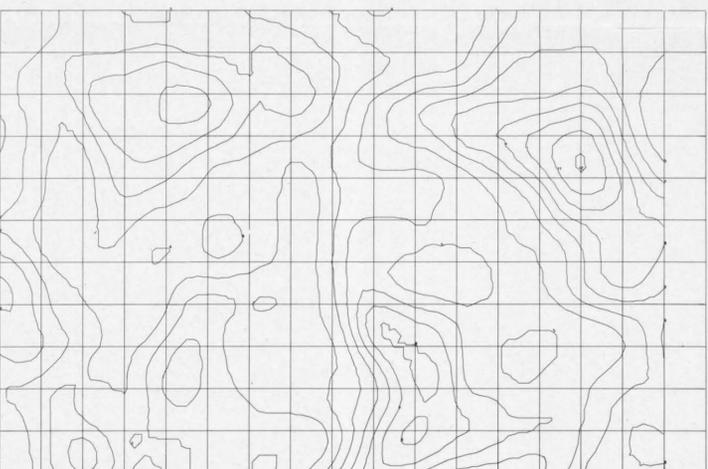
0.85



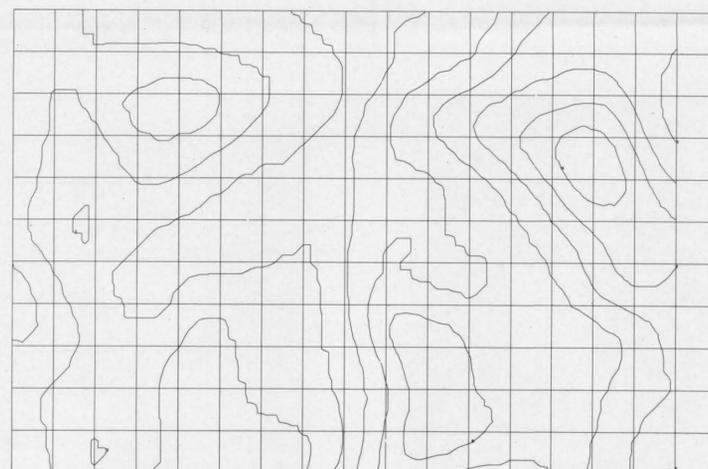
1.25



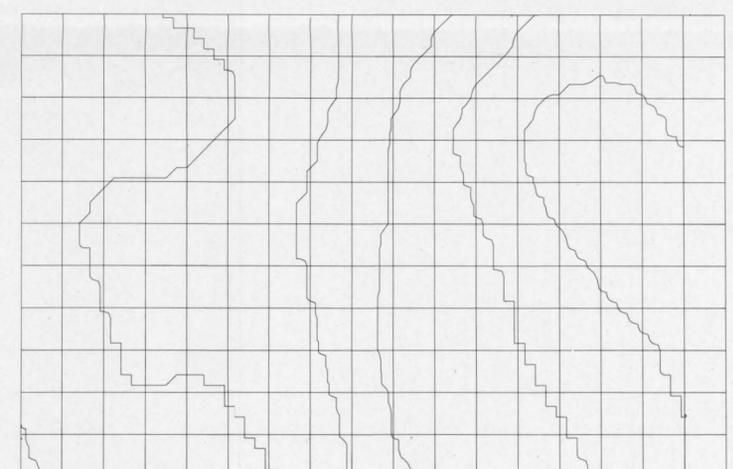
2.00



0.95



1.35



2.50

5 cm

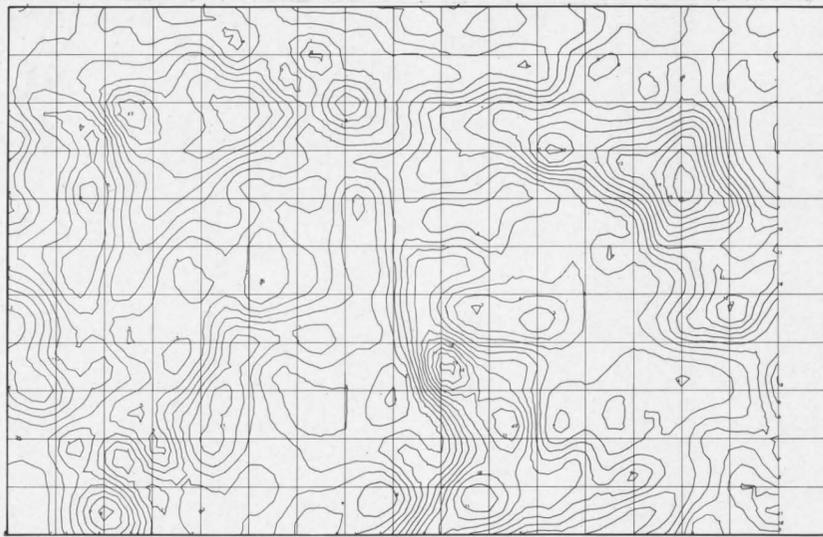
Fig. 26 CONTINUATIONS

FINGAL TIER SURVEY

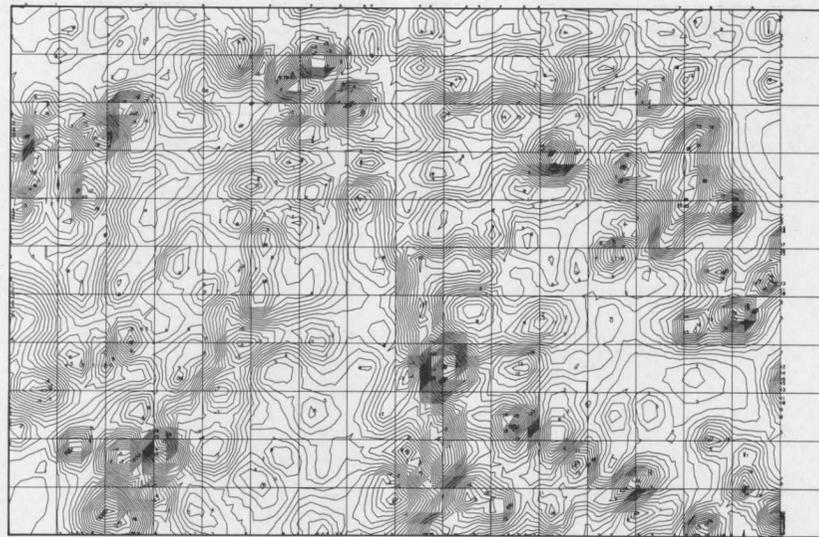
1 mgal interval

km. above sea level

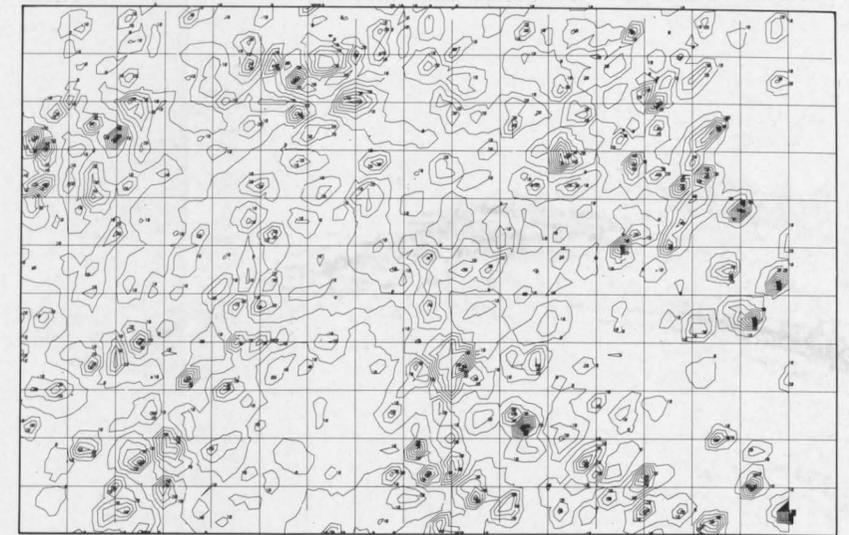
G5860



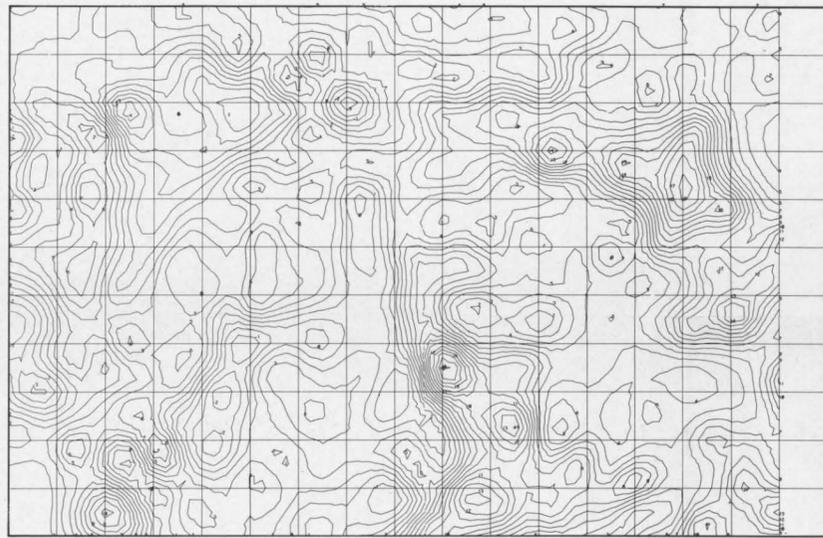
0.55



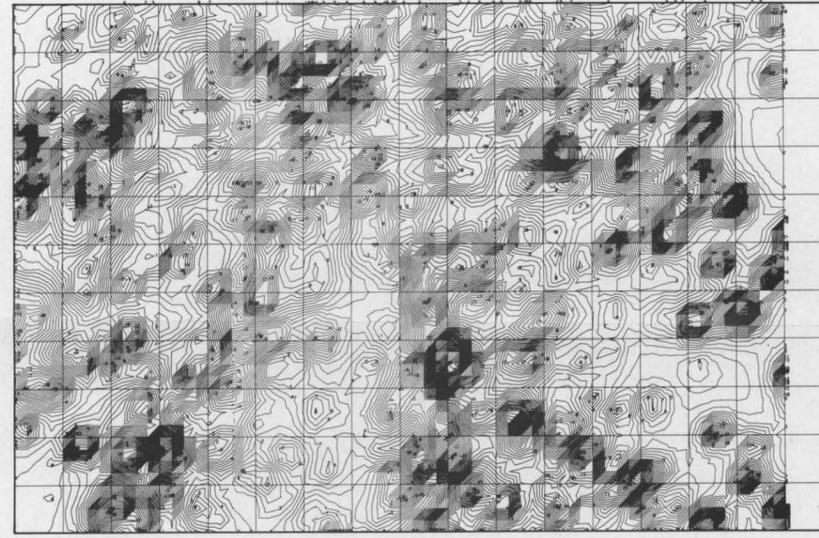
0.25



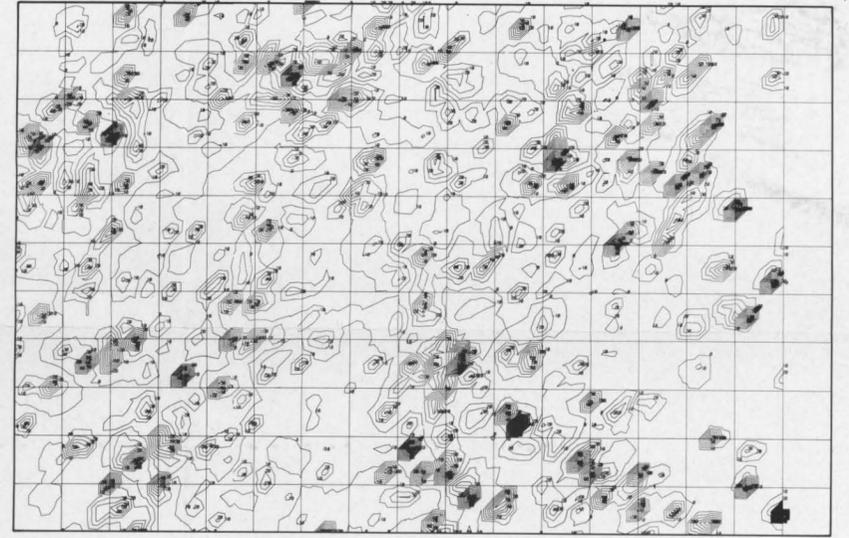
0.00



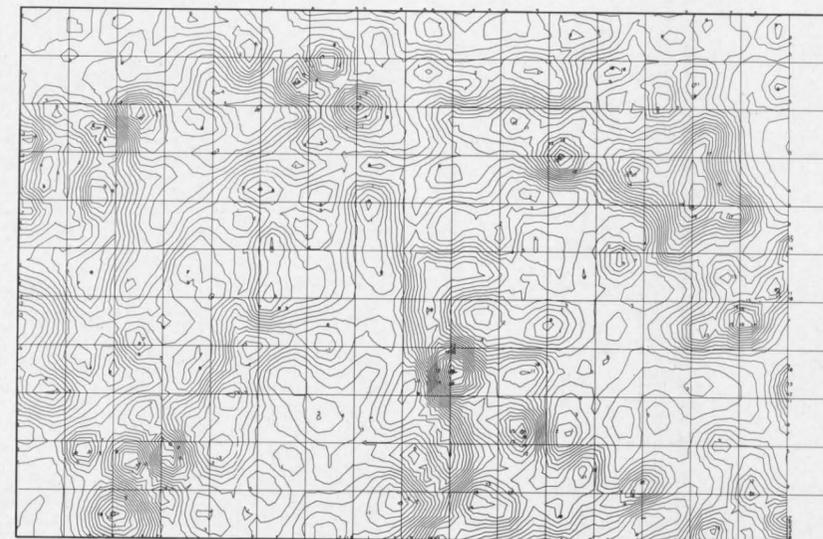
0.45



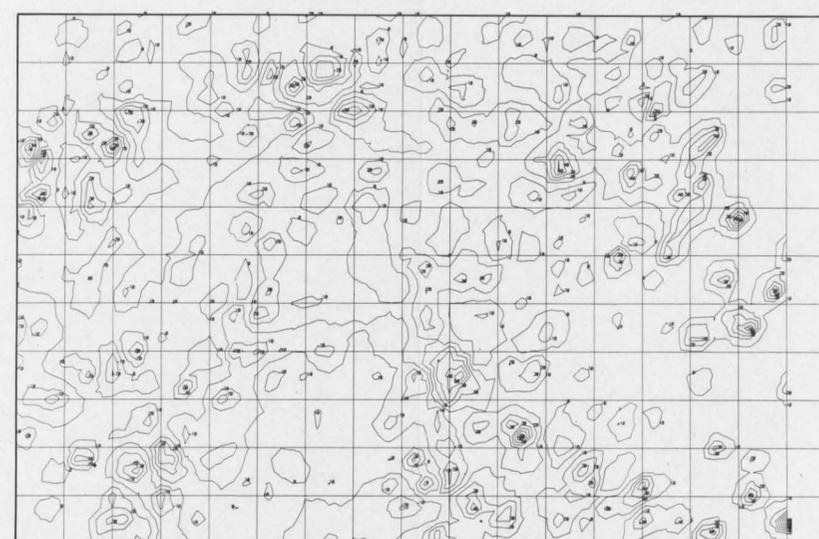
0.15



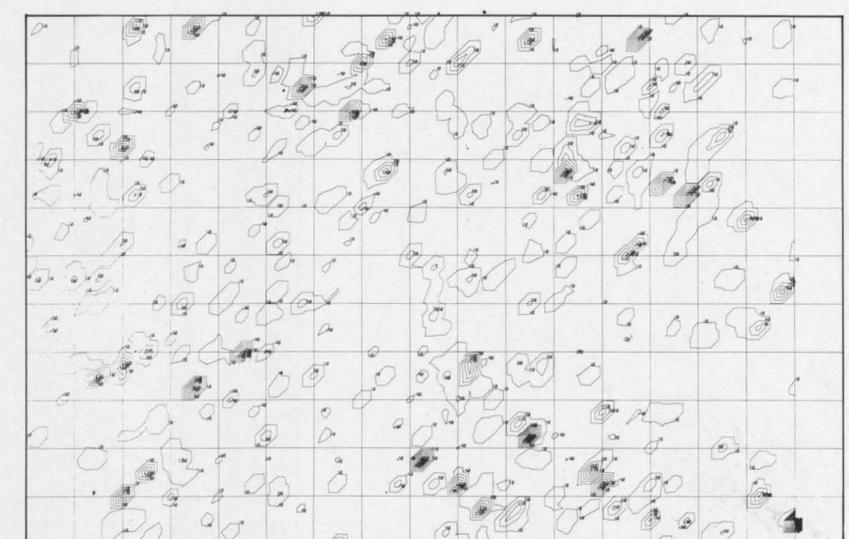
-0.05



0.35



0.05



-0.10

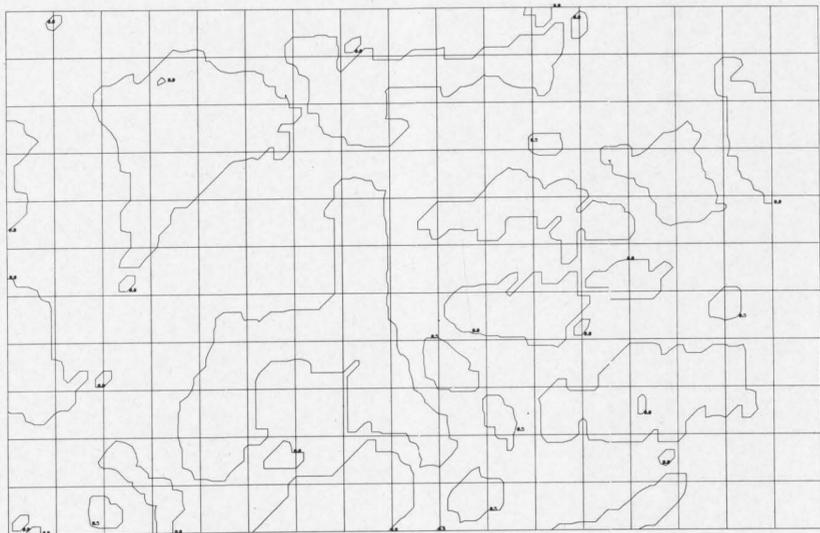
5 cm

Fig. 27 CONTINUATIONS

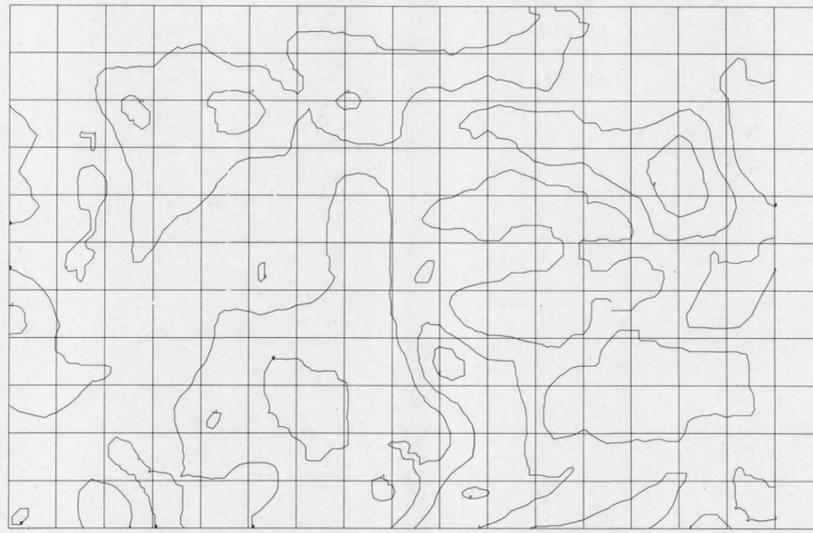
FINGAL TIER SURVEY

0.55 - 0.15 use 1 mgal. contour interval, others 10 mgal. interval km above sea level

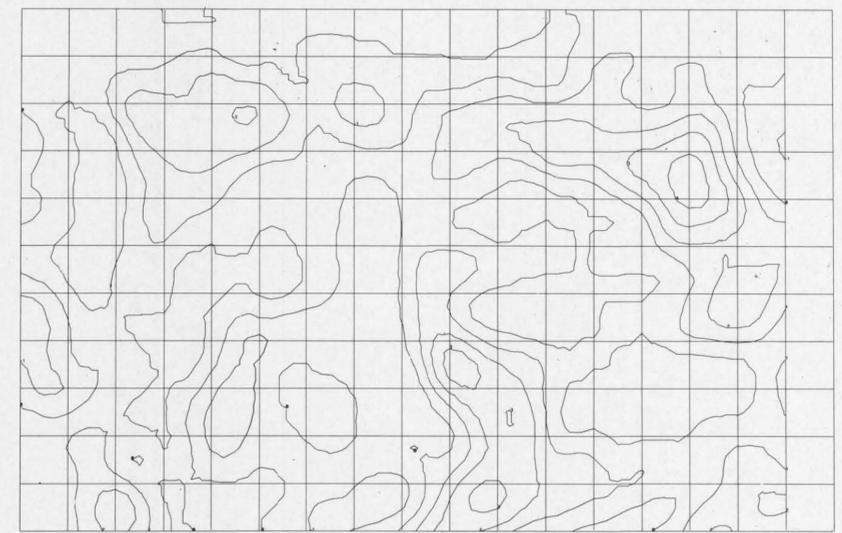
G5860



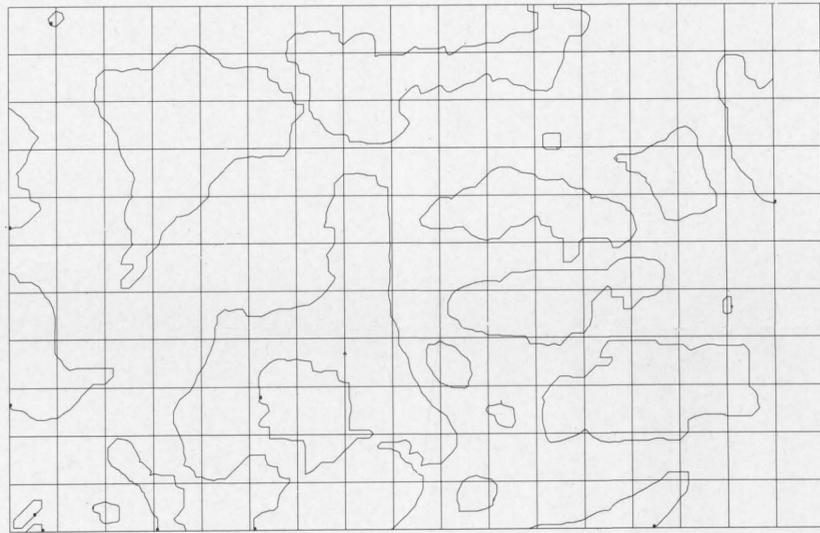
0.95/0.85



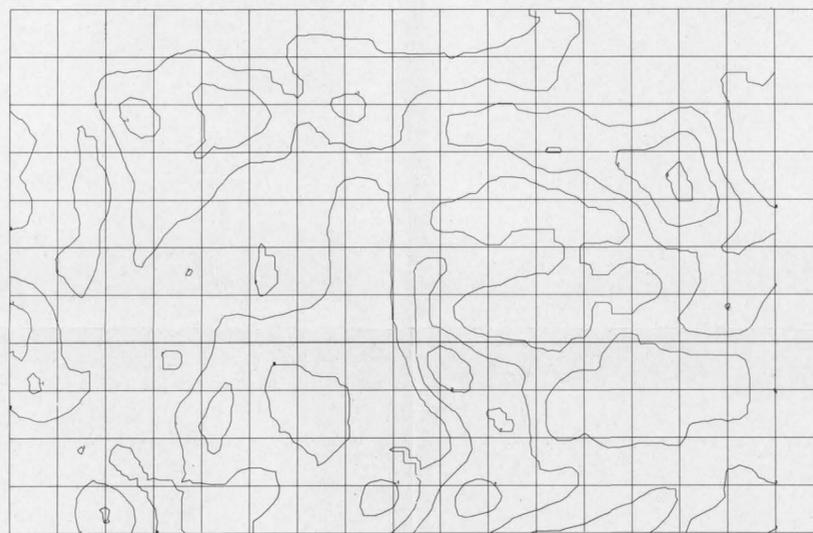
1.25/0.85



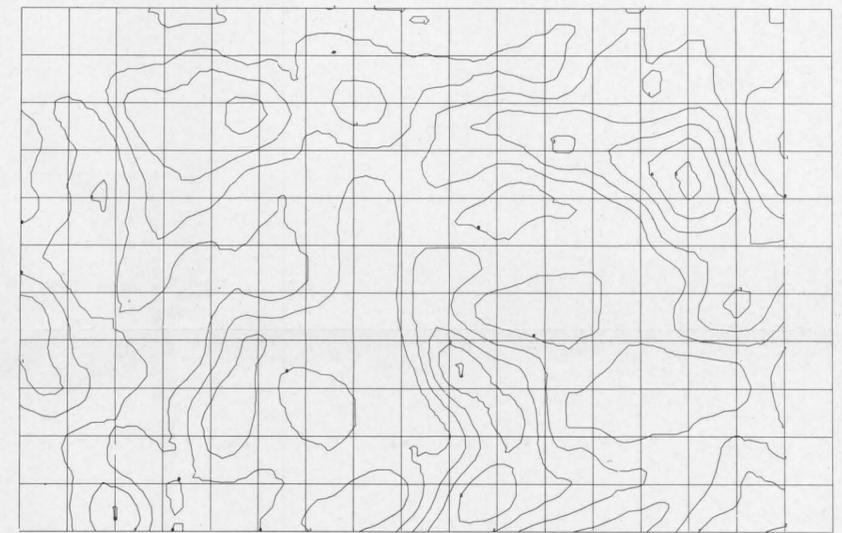
1.75/0.85



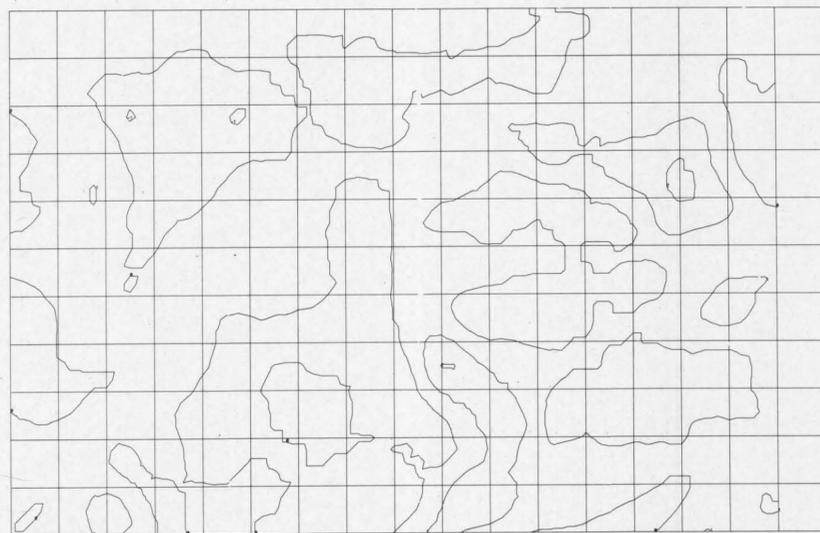
1.05/0.85



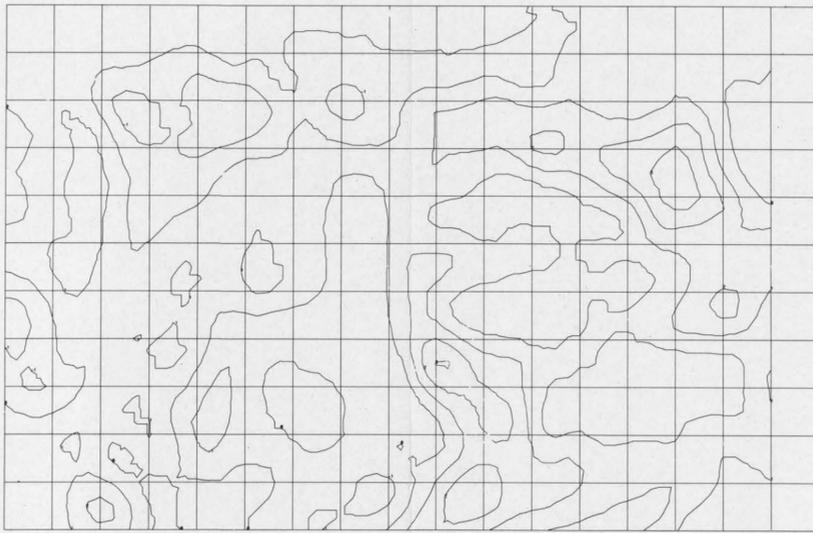
1.35/0.85



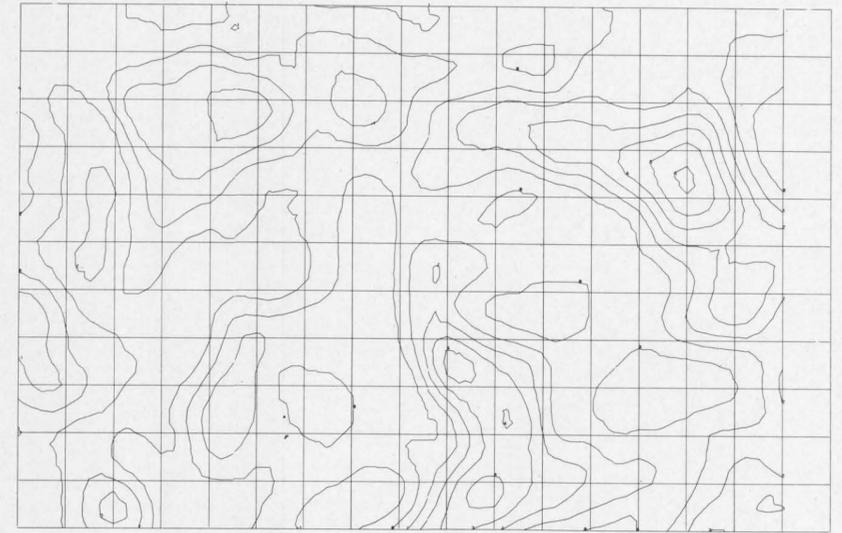
2.00/0.85



1.15/0.85



1.45/0.85



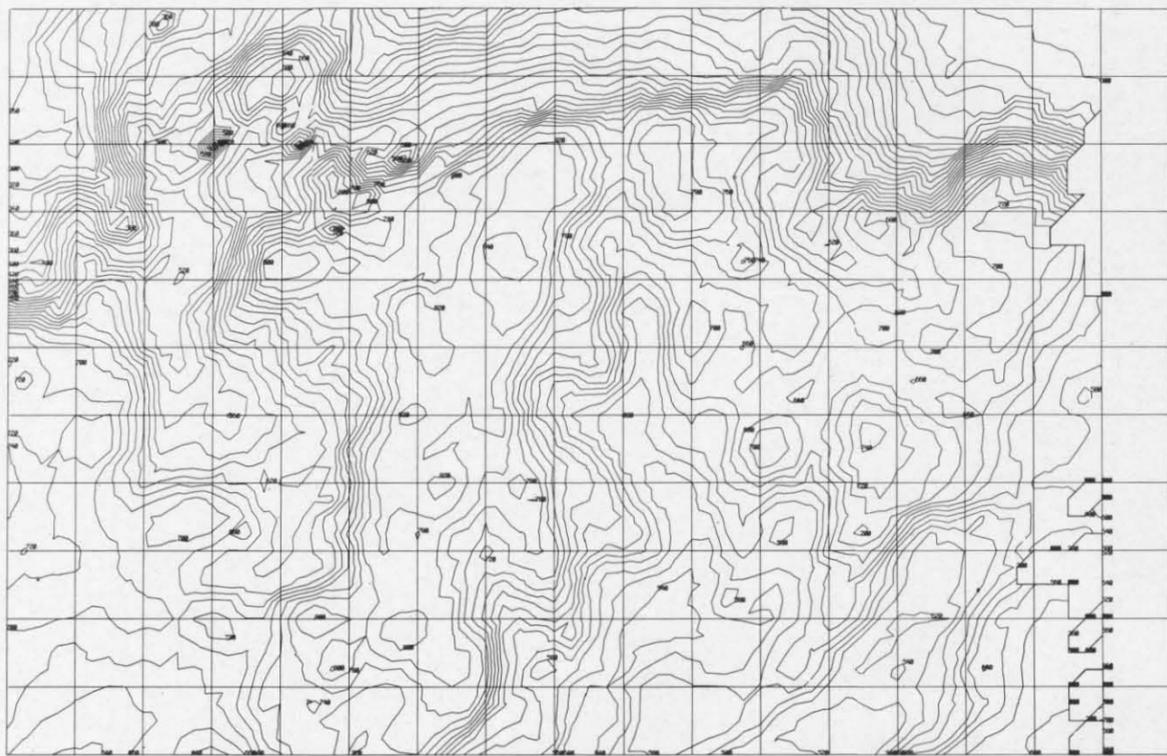
2.50/0.85

5 cm

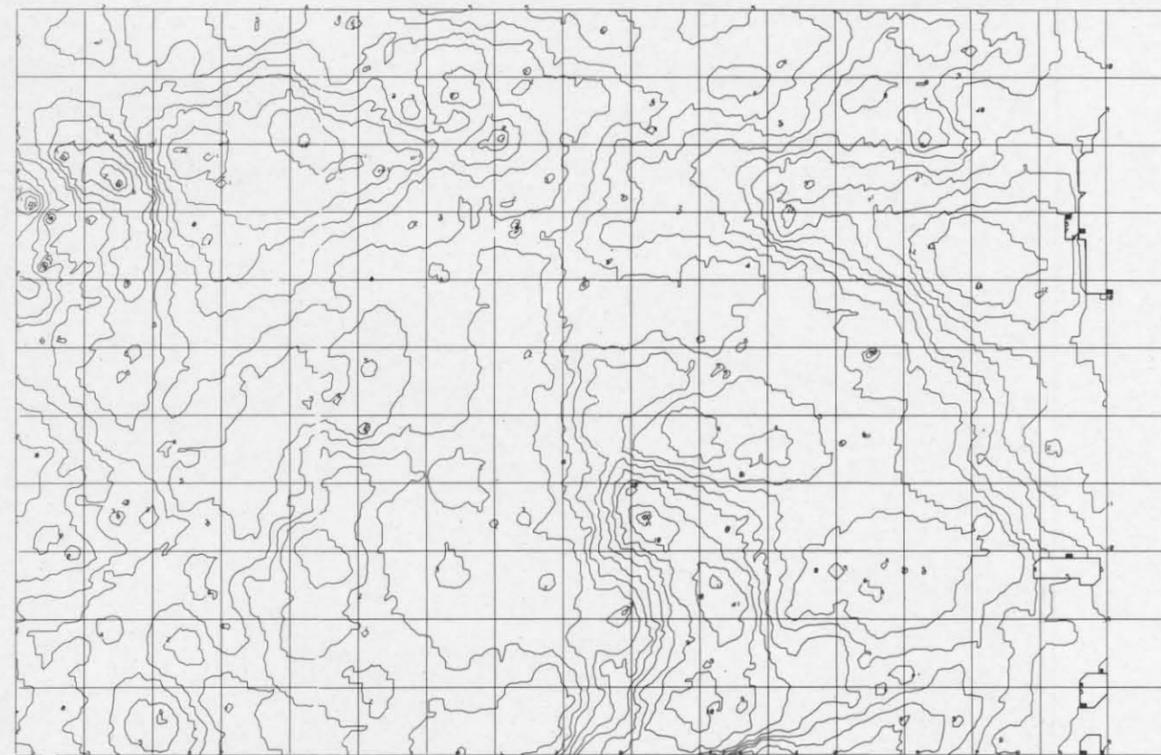
Fig. 28 CONTINUATION RESIDUALS AT 0.85 km. FINGAL TIER SURVEY

1 mgal. contour interval

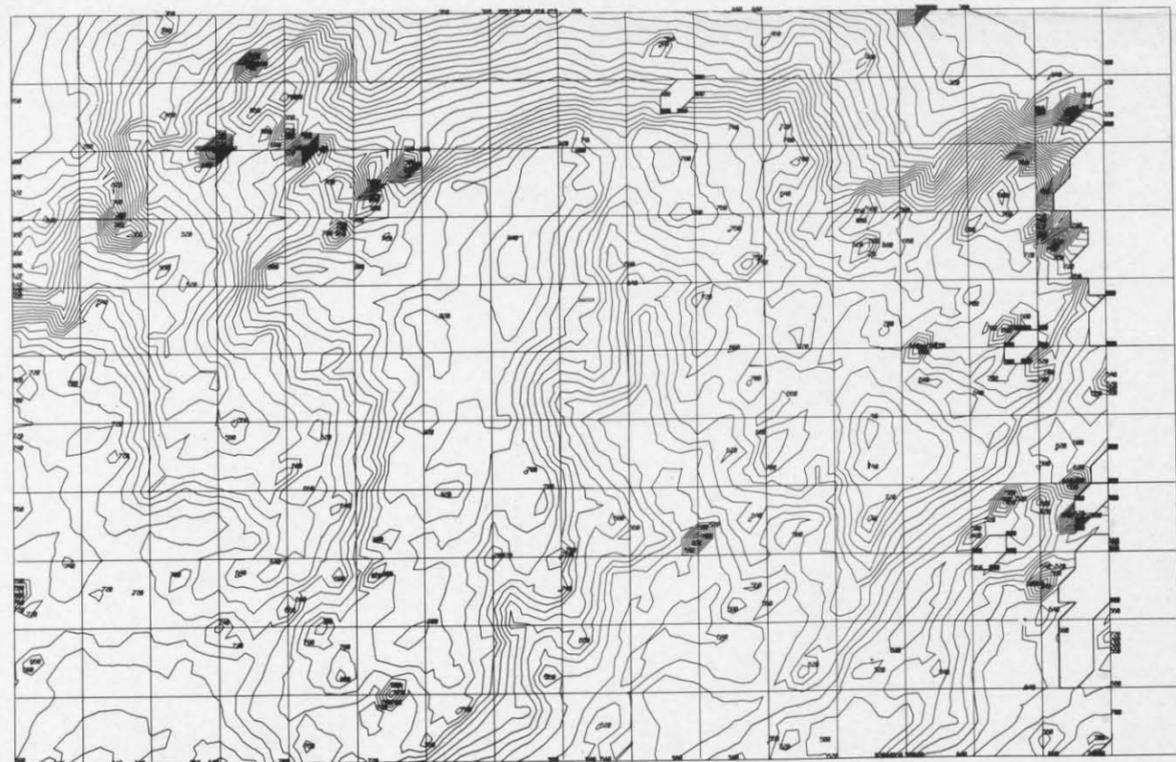
GSB60



ELEVATION — DAVIS



BOUGUER ANOMALIES — DAVIS



ELEVATION — KANSAS



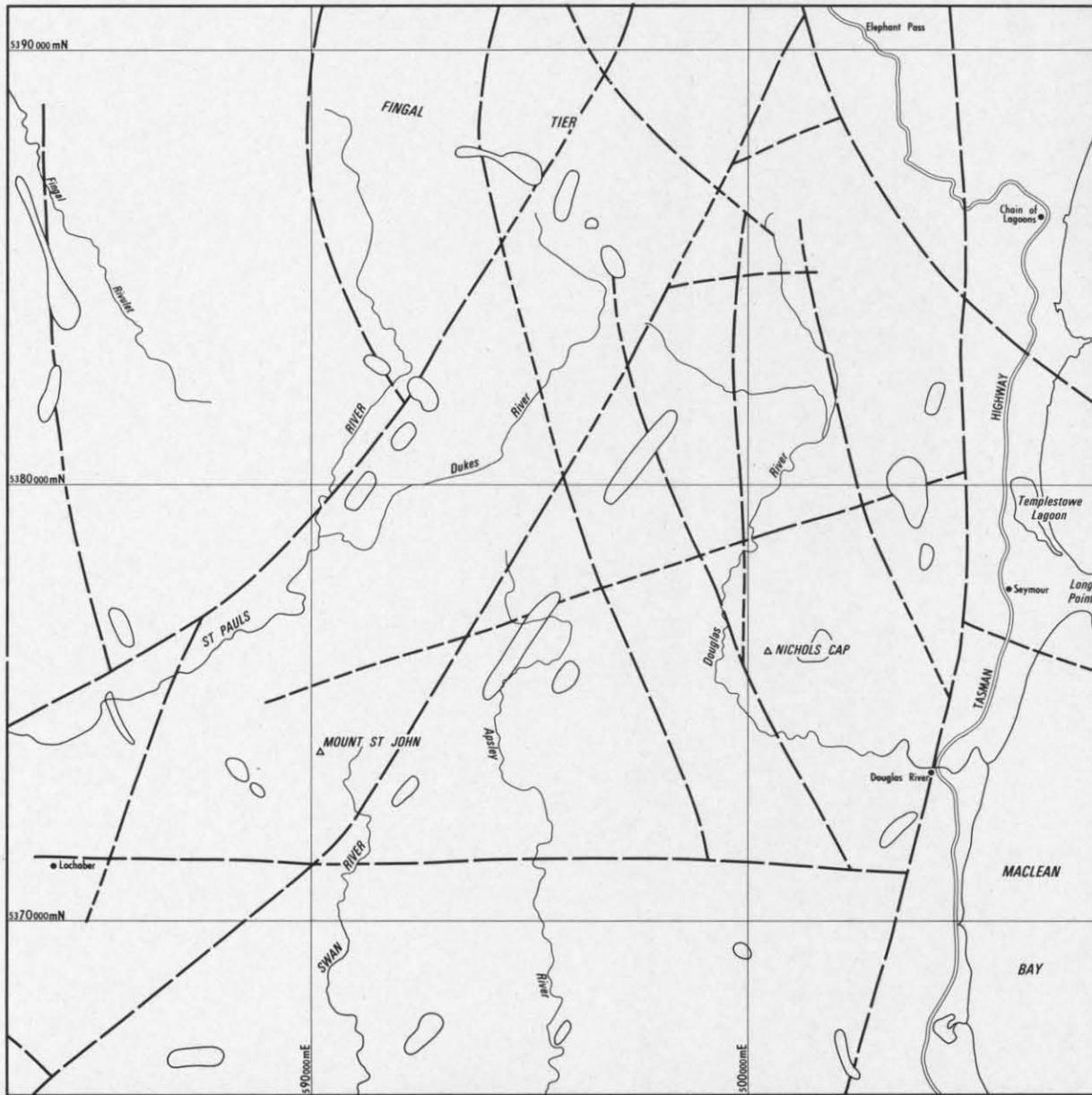
BOUGUER ANOMALIES — KANSAS

5 cm

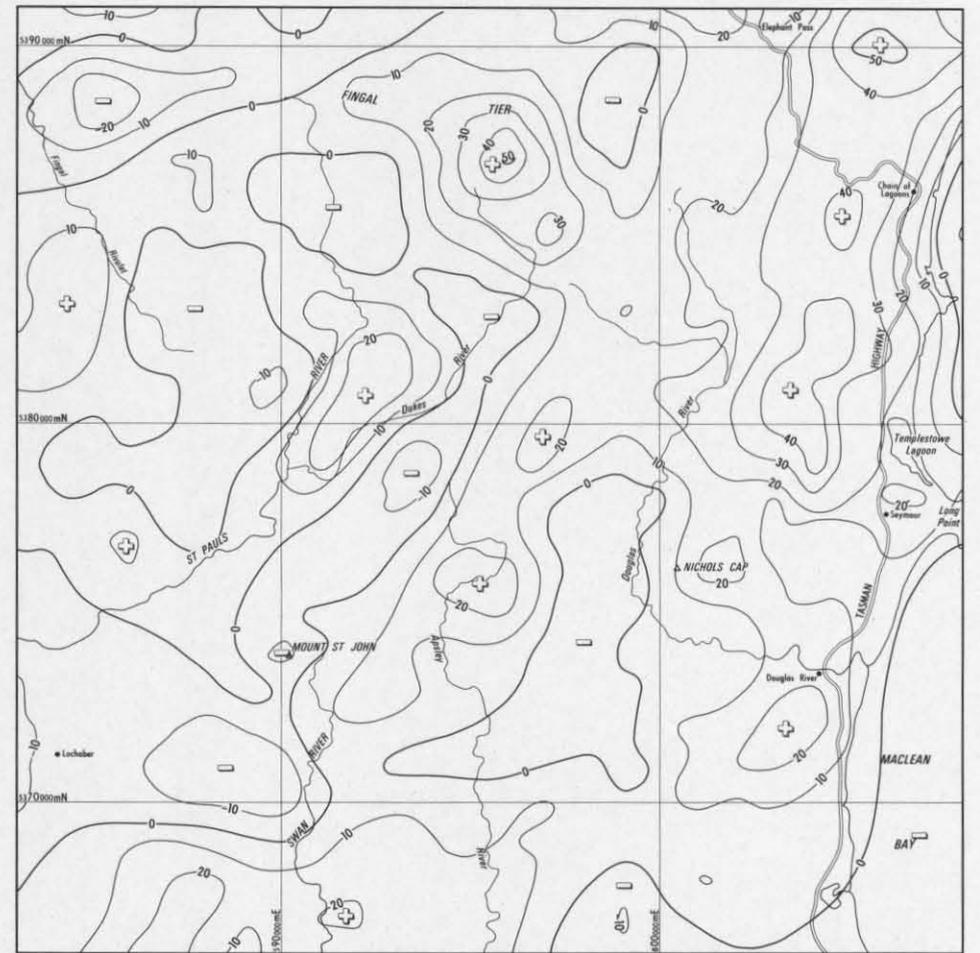
Fig. 29 REFERENCE DATA PLOTS

Bouguer anomalies 1mgal. interval  
Elevations 20m. interval

GSB60



PART VI DOLERITE FEEDERS (ALSO SHOWING SUMMARY OF IMPLIED FAULTING).



850/2500m

G5860

Fig 32.

