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16. Summary of geophysical work, Gladstone area.

D.E. Leaman

The Gladstone area, as considered in this report, is the region north and west of Gladstone bounded by Ringarooma Bay. The Ringarooma River flows across the area and its former courses are worked for tin deposits. The alluvial cassiterite-bearing deposits are commonly found at shallow depth, and are derived from nearby granites.

As information from workings, drilling and previous investigations was generally sketchy and it was decided to try a range of geophysical methods in order to determine which method would:

(1) yield the greatest information in this geologically complex area,

(2) provide information on the overall structure, and

(3) determine whether the tin-bearing material could be directly located.

The initial field work, a refraction seismic traverse survey, was undertaken in 1967 by M.J. Longman on line 14 (fig. 25). The details and interpretation of that survey are given briefly by Longman (1969). No further geophysical work was done until late 1968 when gravity and magnetic surveys of the area were made along all available access routes. The station spacing was of the order of 300 m. All field work was by M.J. Longman with station elevations surveyed and levelled by B. Knox.

The magnetic survey was corrected for instrumental drift and diurnal variations by M.J. Longman and the profile of part of line 14 appears in Longman (1969).

The reduction and correction of the gravity survey was undertaken during 1970 by D.E. Leaman. More recent field work (during 1971) has been directed to establishing the value of the tie stations in the survey with reference to State datum.

During the period of survey and reduction a generalised geological map became available of the entire north-east of Tasmania. Although primarily concerned with the distribution of the granitic rocks the map provides general information on other rock types (see Groves, 1974).

GEOLOGY

The geology of the area is quite complex. Five main geological regimes may be noted. This summary is based on the map of Groves (1974) and discussions with A.J. Noldart and D.J. Jennings.

(1) East of Ringarooma Bay and west of the Portland road but several kilometres north of the plain of the Ringarooma River. Jurassic dolerite is widely exposed but there is evidence of much cross faulting (N-S, E-W; Groves, 1974). There is patchy but generally thin cover of windblown sand.

(2) East of the Portland road. Ordovician-Silurian slate and sandstone/quartzite with some sand cover. Between regimes 1 and 2 Permian mudstone unconformably overlies the slate. Dolerite intrudes the Permian rocks although the nature of the intrusion is not known.

(3) South of the Gladstone-Tomahawk road. A granitic area with variable cover of more recent sand, gravel and clay. This regime passes southward into the Mt Cameron massif.

(4) East Ringarooma River valley plain area. Exposures in this region are very limited. There is a variable amount of surface sand and gravel related to Recent activity of the river and this overlies Tertiary gravel, sand and clay in places. Elsewhere the Recent materials appear to overlie dolerite or slate. Drilling information is not particularly reliable as most drilling is terminated where 'basement' or 'bedrock' is encountered. This may be large boulders or gravel. Many holes have also terminated in blue clay, considered to be derived from weathered dolerite often assumed to be below tin-bearing or supposedly tin-bearing sediment.

(5) Similar to regime 4 but no pre-Tertiary rocks are exposed. Drilling has demonstrated gravel and clay, with a thickness of over 60 m.

Due to low relief and to the presence of Recent overburden it is often difficult to establish whether apparent rock exposures represent *in situ* material or large boulders. Little granite is observed in the boulder beds (D.J. Jennings, pers. comm.).

GEOPHYSICAL SURVEYS

Seismic survey

Line 14, the seismic traverse of Longman (1969) is indicated in Figure 25. The 'two deep leads' noted at the western end of the spread correspond to the region of the large gravity low; as discussed below this is not a lead system but is probably a filled fault block. The smaller lead near Holes 31 and 32 does appear to be an extension of the Scotia lead. Longman (1969) interprets the seismic velocities at depth between Holes 15 and 38 as indicating weathered dolerite (15-30) and quartzite and slate (30-38). Drilling between Holes 20 and 31 indicated dolerite or dolerite boulders at very shallow depth. It should be noted that there is a considerable overlap in velocities and only in the region of Holes 30 and 31 is the velocity sufficiently high to identify dolerite definitely.

Longman also relates the tin-bearing areas to a lower velocity layer than non tin-bearing areas (<1,500 m/s compared with >1,700 m/s). This variation may reflect a compositional, textural or hydrologic difference but has not been proved to be definitely related to variation in tin content. He also experienced difficulties in relating the interpreted depths of layers to the drill results although the structural form appeared correct. Lack of detailed weathering or soil thickness spreads may seriously affect interpretation in unconsolidated materials. He does not record a seismic velocity of less than 550 m/s although dry, uncompacted sands would normally provide velocities of the order of 300 m/s. A thickness of only 2 m of such sand could allow appropriate correction of his interpretation.

Magnetic survey

Although both the gravity and magnetic surveys were made along available access routes, the traverse interval was 6-10 times more than the station spacing. As a result contouring at large scale produces little of value and the observations can only be realistically used in profiles. It was thus decided to present regional maps of the area by selecting one station in twenty and contouring the values selected. The result is a fairly even coverage which adequately conveys the field and structural properties.

The total magnetic field is shown in contour form in Figure 23. There is little coverage of regime 1, the dolerite. However, the field in this region is shown to be variable, but in excess of 62,000 gammas. The field is very uniform across regimes 2 and 3 and only in the northern part of regime 4 and the junction between regimes 1 and 2 is there any significant anomaly. The field intensity in this region is less than 61,800 gammas and appears unrelated to the geology being partly over dolerite, sand-covered slate, slate and Permian mudstone.

The field across regime 5 shows a slight positive bulge to nearly 62,200 gammas but is characterised by uniformity and smoothness as compared to the dolerite areas in regime 1 where the intensity may locally reach 63,000 gammas.

Gravity survey

Gravity observations have been corrected for instrumental drift and loop errors and are accurate to 0.02 mgal. The Bouguer anomaly is also reliable to 0.02 mgal as all elevations are accurate to about 1 mm. No terrain correction has been applied and in view of the scale of the anomalies and the low relief of the area surveyed it is possibly not necessary. The total Bouguer anomaly is presented in Figure 23. The regional gravity field is not precisely known in this part of Tasmania although it is believed to have a N-S gradient.

The major anomaly is directly related to regime 5. The strong marginal gradients imply a very steep escarpment, especially on the eastern side. There is a strong indent of the anomaly into regime 4 although in general it is clearly bounded by granite or dolerite outcrops. The +5 or +6 mgal contour closely frames the margin of regime 5.

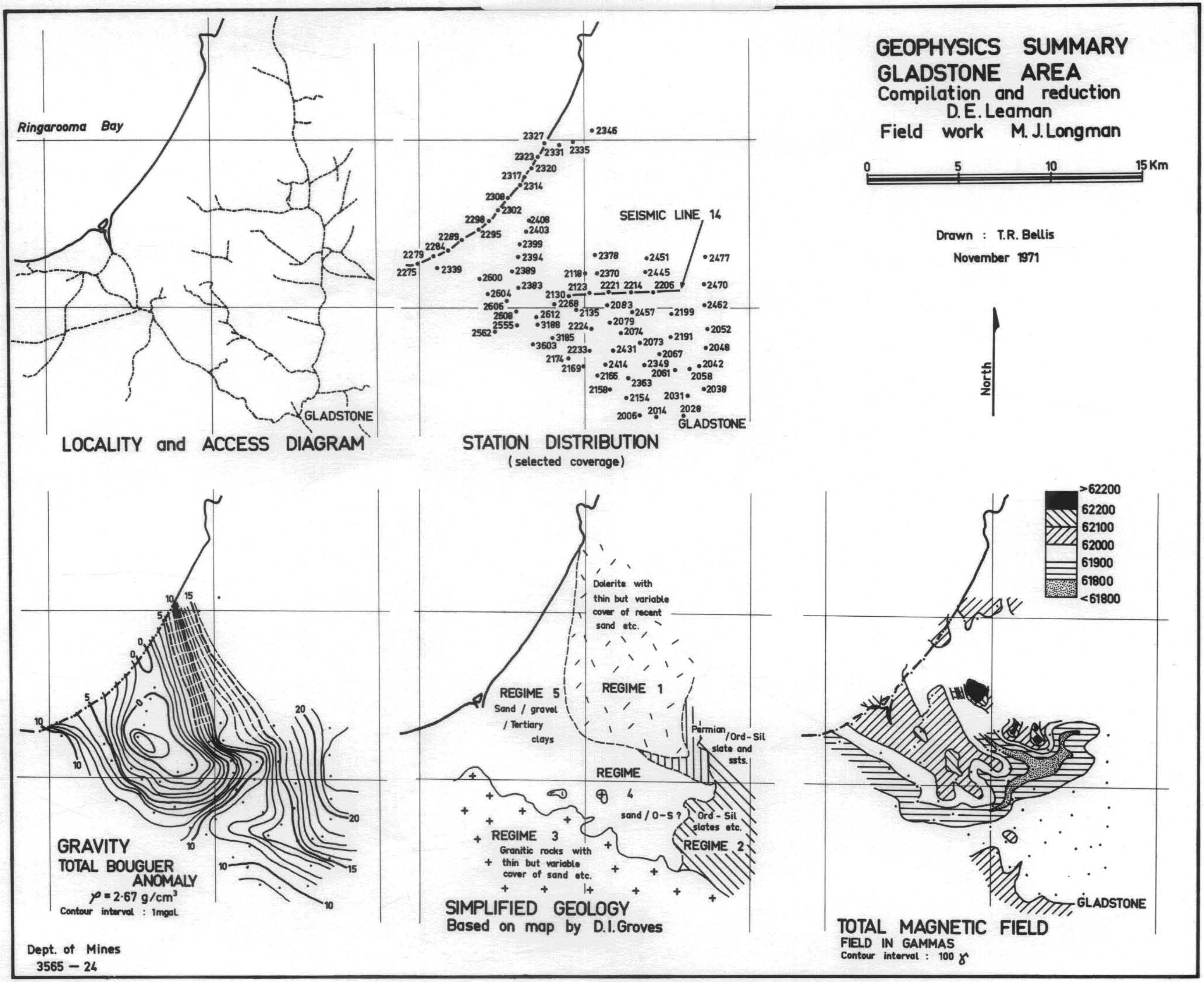
Very high anomaly values are recorded in regimes 1 and 2. In the case of regime 1 these are obviously related to dolerite, but the cause of the anomalies in regime 2 is unknown, since they are in an area of slate and quartzite overlain by a thin veneer of Permian mudstone. There is a significant gradient at the east edge of regime 4 rising onto regime 2 that is also shown in part in regime 1. A spur of anomaly extends along the junction of regimes 2 and 3 from Gladstone. South of this trend the anomaly is reduced implying that the Mt Cameron granitic complex is less dense than the intruded sedimentary rocks. This lowering of values is also reflected along the southern edge of the regime 5 anomaly. Anomalies across regime 4 suggest a platform between regimes 2 and 5.

It must be noted that in comparing anomaly values across the area valid profiles can only be obtained from E-W lines, as the regional trend would cause some tilting in a southerly direction.

INTERPRETATION

In order to control the interpretation of the three methods taken together it is necessary to consider the line 14 drilling results and implied geological distribution (fig. 23). Inspection of the profiles reveals a number of problems.

(1) *Magnetic field*. The magnetic profile correlates well with drilling and seismic results only in the eastern part of the area. The nature of basement implied from drilling results, seismic velocities and general geological considerations is also shown in Figure 23. A probable extension of the Scotia lead shows clearly, the implication being that the sediments



5 cm
GEOPHYSICS SUMMARY
GLADSTONE AREA
Compilation and reduction
D. E. Leaman
Field work M. J. Longman
0 5 10 15 Km
Drawn : T.R. Bellis
November 1971
North
Ringarooma Bay
GLADSTONE
LOCALITY and ACCESS DIAGRAM
SEISMIC LINE 14
GLADSTONE
STATION DISTRIBUTION
(selected coverage)
GRAVITY
TOTAL BOUGUER ANOMALY
ρ = 2·67 g/cm³
Contour interval : 1mgal.
Dolerite with thin but variable cover of recent sand etc.
REGIME 5
Sand / gravel / Tertiary clays
REGIME 1
Permian /Ord - Sil slate and ssts.
REGIME 4
sand / O-S ?
Ord - Sil slates etc.
REGIME 2
REGIME 3
Granitic rocks with thin but variable cover of sand etc.
SIMPLIFIED GEOLOGY
Based on map by D.I. Groves
>62200
62200
62100
62000
61900
61800
<61800
GLADSTONE
TOTAL MAGNETIC FIELD
FIELD IN GAMMAS
Contour interval : 100 γ
Dept. of Mines
3565 — 24

Figure 23.

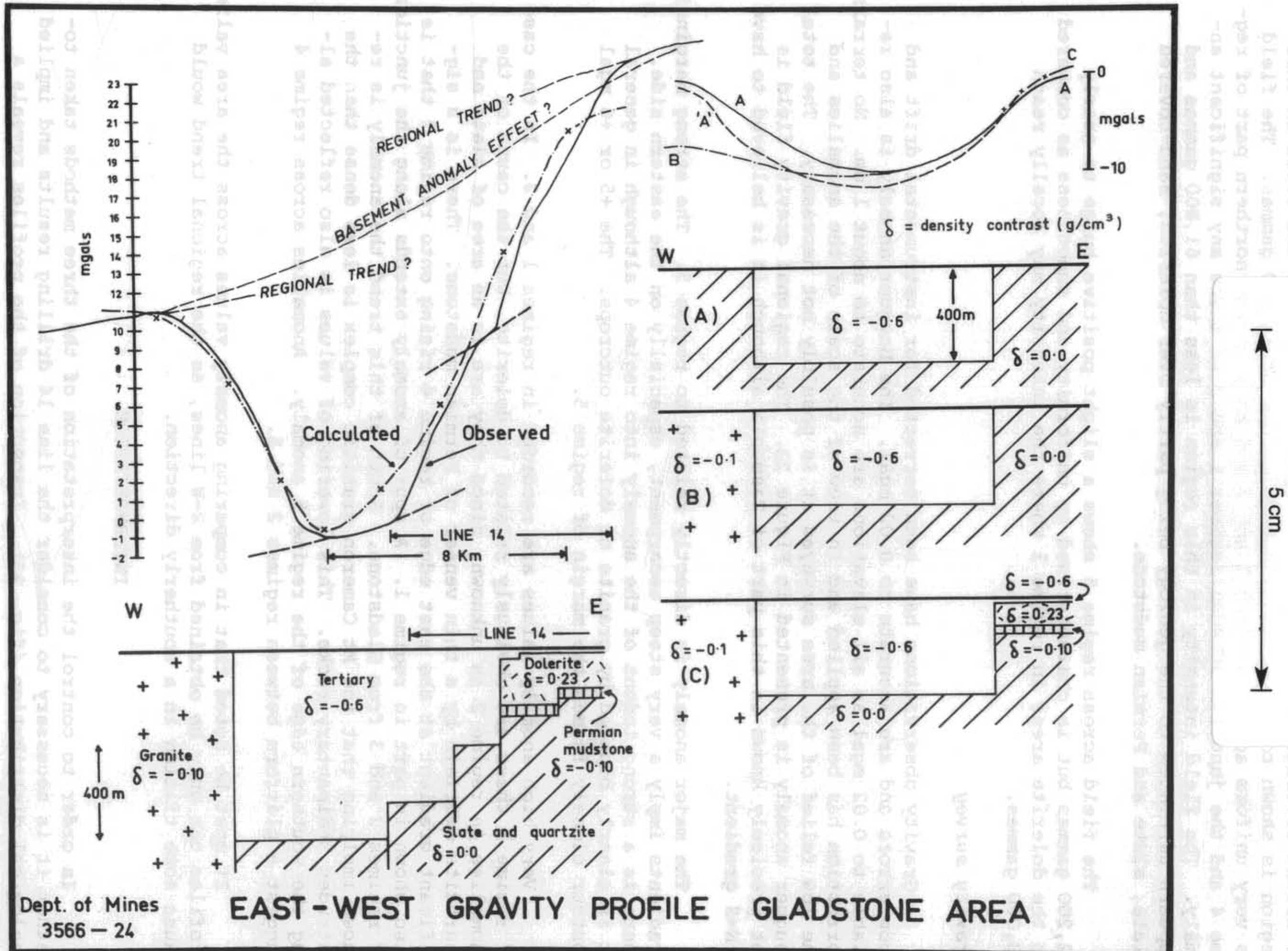

mgals
REGIONAL TREND ?
BASEMENT ANOMALY EFFECT ?
REGIONAL TREND ?
Calculated
Observed
LINE 14
8 Km
A
'A'
B
C
0
mgals
-10
δ = density contrast (g/cm³)
W
E
(A)
δ = -0·6
400m
δ = 0·0
δ = -0·1
(B)
δ = -0·6
δ = 0·0
δ = -0·6
δ = 0·23
δ = -0·10
δ = -0·1
(C)
δ = -0·6
δ = 0·0
5 cm
W
E
LINE 14
Tertiary
δ = -0·6
Dolerite
δ = 0·23
Granite
δ = -0·10
400 m
Permian
mudstone
δ = -0·10
Slate and quartzite
δ = 0·0
Dept. of Mines
3566 — 24
EAST-WEST GRAVITY PROFILE GLADSTONE AREA

Figure 24.

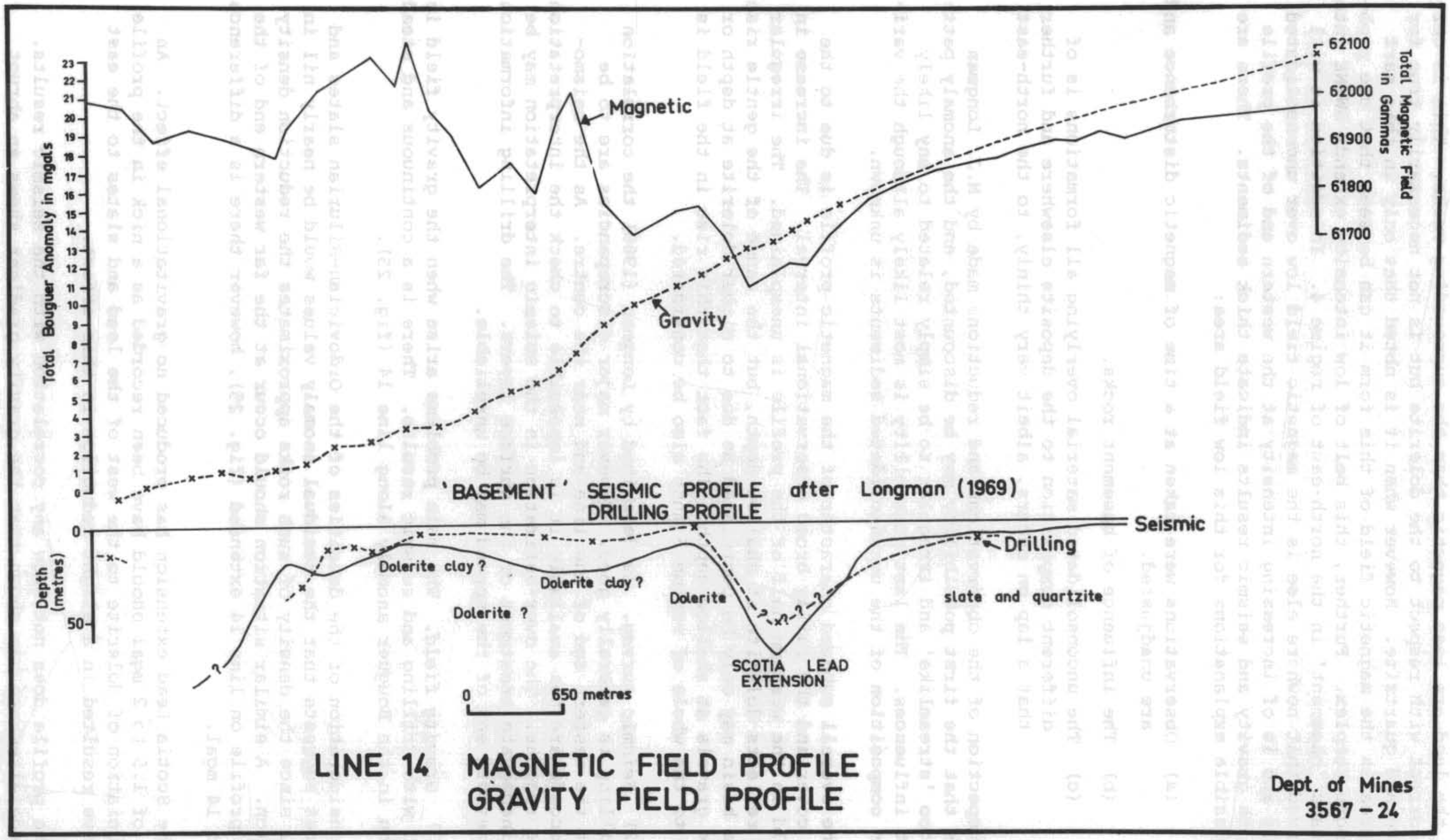


Figure 25.

5 cm

filling the lead are less magnetic than the surrounding rocks. This is certainly correct with respect to the dolerite but is not necessarily true for the slate and quartzite. However when it is noted that only in this part of the area is the magnetic field of this form it can be seen that the problem is more complex. Further, this belt of low intensity extends SW-NE into the exposed 'basement' in the north-east of regime 4. In addition it will be observed that nowhere else is the magnetic field low over unconsolidated materials and is of increasing intensity at the western end of the profile where both gravity and seismic results indicate thick sediments. There are three possible explanations for this low field area:

(a) Observations were taken at a time of magnetic disturbance and are unadjusted.

(b) The influence of basement rocks.

(c) The unconsolidated material overlying all formations is of different composition to the deposits elsewhere and further that a lap on occurs, albeit very thinly, to the north-east.

Inspection of the observations and reductions made by M.J. Longman suggests that the first possibility may be discounted, and the anomaly pattern is too 'streamlike' and irregular to be simply related to any likely basement influences. The last possibility is most likely although the variation in composition of the unconsolidated sediments is unknown.

The overall subdued character of the magnetic profile is due to the surface cover and the fairly broad observational interval. The increase in the field in the western half of the profile is unexplained. The irregular section reflects dolerite at shallow depth, but the cause of the gentle rise onto the basin may only be postulated as due to either dolerite at depth or dolerite gravels at shallow depth. The fact that this rise in the field is general to the whole of regime 5 must also be considered.

(2) *Seismic survey*. As described by Longman (1969) the correlation with drilling is generally good. However major discrepancies are to be noted at the western end of the line and near the centre. As the seismograph records are not available it is impossible to check the interpretation in these regions. The over-estimation in the seismic interpretation may be due to inadequate treatment of the surface layers. The drilling information at the western end of the spread may be unreliable.

(3) *Gravity field*. The main problems arise when the gravity field is compared with drilling and seismic results. There is a continuous and steady reduction in the Bouguer anomaly along line 14 (fig. 25).

Consideration of the densities of the Ordovician-Silurian slates and quartzites suggests that the residual anomaly values would be nearly nil in regime 2 since the density of such rocks approximates the reduction density assumption. A similar situation should occur at the far western end of the gravity profile on line 14 extended (fig. 25), however there is a difference of about 14 mgal.

The Scotia Lead extension has produced no gravitational effect. An anomaly of 1.5 to 2 mgal should have been recorded as a nick in the profile. The association of dolerite to the west of the lead and slates to the east would have resulted in a slight reduction in this effect.

The profile does not show any correlation with the seismic results. Experience elsewhere has shown that the gravity gradient shows an abrupt steepening across buried escarpments and that the field should be relatively flat across most of line 14. That this is not so suggests that:

(a) There is an E-W regional effect and, or

(b) The negative attraction of the basin is so great that it 'blankets' the whole area, or

(c) There is an additional mass of less dense rock present.

The various possibilities are indicated in Figure 24. The complete E-W profile, only a portion of which is shown in Figure 24, is seen to be quite asymmetrical. This profile has been constructed using the data from the present survey and some unpublished observations in areas to the east and west. There are sufficient stations outside the area to establish the E-W trend.

Figure presents three type models for the overall structure of the basin assuming a standard thickness (400 m) of Tertiary sediments and a regional trend such that there is no component along the section line. Model A produces a symmetrical anomaly. It is noted that an inclined floor to the basin such that the western side is 50% deeper produces an asymmetry indicated by profile 'A', but which is not a regional asymmetry. If a large slab of light granitic material is inserted at the western end of the section (model B) an appropriate asymmetry can be produced. A semi-infinite slab of granite 2 km thick would produce a 7 mgal deficiency. However, while granitic rocks do outcrop along Ringarooma Bay west of the Gladstone area the exposure is only as a narrow disrupted belt (Groves, 1974). However a larger mass could be present at depth and this is certainly implied. The addition of detail to the eastern end of the section, (a 10 m thick cover of Tertiary sediments, an 80 m slab of dolerite and a thin slice of Permian rocks, $\delta = -0.10$ g/cm^3) adds only slightly to the asymmetry produced by model B. A very great thickness of dolerite is needed before any great effect is noted, a full sheet (400 m thick) raising the attraction by about 4 mgal.

Thus the combination of a thick dolerite sheet and a granit mass is probably responsible for the asymmetry of the anomaly profile, the two effects being sufficiently broad scale in association with the Tertiary anomaly to swamp any smaller effects. However there does appear to be a small crustal component in the profile. The gradient of this component in the section is far less than that produced by the near surface structure. A full interpretive model of the profile is also presented. As the eastern arm of the profile is stepped, step faulting is implied. Such faulting, if present, must be restricted to the part of the basin near line 14 where the total Bouguer anomaly shows much offset (fig. 23).

The model presented assumes no dolerite in the bottom of the basin. Each 3 m of dolerite added to the bottom of the section requires an increase in the thickness of sediment by 1 m. Allowance for a crustal trend would probably simply raise the profile at the eastern end of the section. A density contrast of -0.6 g/cm^3 has been used for the Tertiary sediments. This may be a little low and any increase in contrast would imply a shallower basin. The maximum contrast possible is -0.67 g/cm^3. Calculations made using two dimensional assumptions by the method of Longman and Leaman (1971) indicate a thickness of up to 800 m of Tertiary sediments. The amount of dolerite at the eastern end of the section is estimated to be generally more than 100 m although, due to faulting, the thickness varies. The eastern portion of the section containing the dolerite is not two dimensional but no allowance has been made for this.

SUMMARY

The Gladstone area contains a deep, fault-produced basin filled with Tertiary sediments. These sediments lap onto the upfaulted sides of the basin and near Gladstone overlie dolerite and slate. The Tertiary sediments are overlain by more recent alluvial deposits containing tin. The Tertiary or pre-Tertiary structure does not appear to control the known tin-bearing deposits significantly. An especially interesting feature is the nature of the sediments near the north end of the Scotia Lead which are magnetically distinctive.

When taken together the three methods employed reveal the nominal lead system (mainly seismic) the overall structure (gravity and seismic) and reliable indications as to 'bedrock' (seismic and magnetic).

The main fault directions appear to be slightly west of north and E-W. The gravity survey reveals a major E-W fault near line 14. To the south and west of the area the granitic complex is dominant and the belt of porphyritic granite mapped by Groves (1974) into the Ringarooma Bay-Tomahawk region is part of a very massive block.

The boundary of regime 5, the deep basin, appears to correspond to about the 15 mgal contour in the east of the area and the 7 mgal contour in the west.

RECOMMENDATIONS

(1) The anomalous sediment in the northern part of the Scotia lead should be re-examined geophysically and its composition determined. Further gravity work in the region of this lead should be undertaken in an attempt to establish why no effect was noted in this survey. It may be that a dolerite feeder is present and that the negative effect of the lead has been cancelled.

(2) The thickness of Tertiary sediment inferred in the basin should be confirmed by reflection seismic surveys. This would also confirm the presence or absence of dolerite at depth.

(3) Additional drilling should be undertaken to depths of at least 30-50 m within the deep basin in order to establish the origin of the increased magnetic field over that region. The information gleaned would also help establish the history and nature of active processes depositing material within such basins.

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