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Interpretation of a Positive Bouguer Anomaly Feature near Cootamundra, New South Wales

by

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SUMMARY

A semi-detailed gravity survey to the east of Cootamundra, N.S.W., has given more precise definition of a major positive Bouguer anomaly feature originally observed on a reconnaissance helicopter gravity survey. Consideration of geological and geophysical evidence suggests that the main cause of the Cootamundra Gravity High is a north-trending belt of basic metamorphic rocks, with a steep contact on the west separating it from rhyolitic volcanics and Lower Palaeozoic sediments, and with a comparatively gently dipping contact on the east, where a Devonian granite is believed to overlie the metamorphics. A minor part of the Bouguer anomaly feature is attributed to a small, high-density body in the vicinity of the worked-out Cullinga gold mine.

An appendix describes in detail the use of iterative interpretational programmes which were used to produce various two-dimensional models.

1. INTRODUCTION

During a reconnaissance helicopter gravity survey of part of southern New South Wales in 1966 (Lodwick & Flavelle, 1968), an intense, positive Bouguer anomaly feature was indicated to the east of Cootamundra. After the completion of the helicopter survey, a semi-detailed gravity survey was planned to aid in the definition and interpretation of this Bouguer anomaly feature.

Gravity readings on the semi-detailed survey were made at 400-metre intervals along seven roughly east-west and two north-south spirit-levelled road traverses (Plate 2). Station location, marking, and levelling were carried out by the Survey Branch of the Department of the Interior. Field work for the survey took place between January and March 1967.

The computer gravity-data reduction system adopted by the Bureau of Mineral Resources (BMR) was used to process the results, and it computed a standard deviation of 0.09 milligals (mgal) for the errors of the Bouguer anomaly values. The quality of the gravity data was directly controlled by a network of sub-bases established by Cooke (1968), who demonstrated that excessive drift (greater than 0.14 mgal) had occurred on seven occasions. This error is well within acceptable limits, however.

2. GEOLOGY

There exists very little published information on the geology of the Cootamundra area. This account is based mainly on two unpublished sources: a reconnaissance 1:250,000 map by the NSW Mines Department; and a more detailed map by Exploration Holdings Pty Ltd (E.H.P.) of Sydney (Plate 1).

A north-trending belt of metamorphic rocks (Sub_1, Sub_2 in Plate 1) is bounded on the west by the Devonian Harvey Group (Duh) and Silurian rhyolitic volcanics (Suv), and on the east by the Devonian Young Granite (Dgy). A large body of porphyry (Sup) within the metamorphic belt is separated from the granite by a narrow zone of metamorphics.

It is probable that the metamorphics are the oldest rocks in the area. The Sub_1 unit is lightly metamorphosed and consists of slate, phyllite, and mudstone. However, the Sub_2 unit is distinctly basic and consists of basic hornfelds, schist, serpentine, and amphibolite.

The presence of a complexly folded conglomerate has been noted at the southern extremity of the survey area. Further south, in the WAGGA 1:250.000 Sheet area, the continuation of the metamorphic belt has been mapped as a sandstone-siltstone unit. This suggests that there is either a lateral change of metamorphic degree, or that the geological mapping is inadequate. On the data at present available, it appears that the Sub_1 and Sub_2 units have resulted from the metamorphism of a geosynclinal sequence which included a large proportion of basic volcanics.

Within the basic metamorphic zone, many narrow jaspilite ridges have been mapped (jaspilite is a rock in which iron oxide and red jasper alternate in bands), some with magnetite and manganese mineralization; these ridges form a useful structural indicator. Also within the basic metamorphic zone are many small serpentine bodies, part of a long discontinuous belt extending throughout the length of the Tasman Geosyncline. Evidence from New South Wales and other parts of the world shows that ultrabasic bodies of this (Alpine) type are typically ribbon-like, being intruded either up-dip if small, or up-faulted along near-vertical planes if large (Turner & Verhoogen, 1960, p. 307 et seq.; Joplin, 1967, p. 137.).

Near Gundagai (15 kilometres south of the survey area), the serpentinites have been studied by Dr Golding of the University of New South Wales. He states (pers. comm.) that the bulk of the serpentinites consists of serpentinized harzburgite (a peridotite), and that most bodies take the form of a large sheet, apparently dipping steeply to the east. Associated with the serpentinites throughout this region are very small chromite bodies, the largest being of the order of 100 cubic metres (Carne, 1898). These were worked sporadically until 1958; the maximum annual production in the Cootamundra Mining Division was 256 tons in 1918 (Kalix, Fraser & Rawson, 1966).

Partially within the metamorphic zone is a porphyry body marked 'Sup' in Plate 1. It is described by E.H.P. as "feldspar porphyry with minor metasediments", and is a dark-coloured rock which bears little resemblance to the Young Granite. It does not appear to be an offshoot of the granite, and the truncation of its outcrop by the granite suggests that it was emplaced before the granite. Along its western edge a number of small gold prospects were worked, the largest - the Cullinga - until 1950; gold occurred in small discrete bodies, the principal gangue minerals being sulphides of iron, copper, lead, and zinc (McLeod, 1965, p. 262).

West and southwest of Cootamundra, the metamorphic belt is bounded by a sequence of rhyolitic volcanic rocks; their age is possibly Upper Silurian. To the north of these, the Upper Devonian Harvey Group crops out; it consists of unmetamorphosed clastics - siltstone, sandstone, shale, and conglomerate. The relation between these two units is again uncertain.

To the east of the metamorphic belt, the Young granite crops out; it is dated as Middle Devonian by comparison with radiometrically-dated granites farther east. Near Gundagai the western edge of the Young Granite has been observed to dip steeply to the east, and limited mapping indicates that the contact also dips to the east within the survey area.

3. AEROMAGNETIC SURVEY

Shortly after completion of the detailed gravity survey, four short east-west aeromagnetic survey lines were flown at a height of 150 metres above ground level across the area. The following interpretation of the results was prepared for this Record by D.B. Tipper of BMR. Anomaly and zone numbers referred to are indicated in Figure 1.

(a) Qualitative. The Survey area has been broadly divided into a number of zones based primarily on anomaly amplitudes. Zones B and C represent the major magnetic disturbance in the area; zone C encloses the highest-amplitude anomalies and zone B represents the southerly attenuation of these major highs together with other anomalies of moderate amplitude to the west. The two zones together virtually coincide with the Bouguer anomaly feature and, according to the published geology, are confined to a belt of basic hornfels and schist, with interjacent serpentinite bands.

Zone E encloses a northerly trending anomaly to the east of the major disturbances. It correlates also with a region of basic hornfels and schist, and on the basis of the aeromagnetic results these rocks are postulated to extend about 1½ kilometres north of the mapped outcrop.

The remainder of the area is relatively undisturbed magnetically, and is represented by zones A and D to the west and east respectively of the major disturbance. The undisturbed nature of zone A is broken by a single anomaly only (7) in the extreme south. Similarly, zone D contains one anomaly (8), also in the extreme south. This latter zone clearly correlates with porphyry and granodiorite, which, from the scanty magnetic evidence, are magnetically indistinguishable.

A few trend lines have been delineated; most are only tentative owing to the large ratio of line-separation to anomaly width.

(b) Quantitative

Anomaly	Depth below detector	Width	Comments
1	300 metres max.	490 metres approx.	
2	210 metres approx.	this anomaly is due to at least four separate bodies of varying widths.	
3	300 metres max.	400 metres max.	$k=3.2 \times 10^{-3}$ c.g.s
4	210 metres approx.	460 metres max.	dipping steeply to east. $k=9.3 \times 10^{-3}$ c.g.s.
5.	350 metres max.	1050 metres	double body
6.	260 metres	1300 metres max.	double body
7.))assumed northerly strike	140 metres	270 metres	
8.)	150 metres	240 metres max.	dipping 60° easterly $k=2.6 \times 10^{-3}$ c.g.s

(c) Conclusions

The magnetic disturbance is due to a large number of separate bodies lying at shallow depths (between 0 and 200 metres below the surface) and wholly confined to regions described as being of basic hornfels, schist, and serpentinite. These bodies are probably prismatic, of limited length, with generally north trends and steep dips. Their susceptibility range of 2.0 to 10.0 ($\times 10^{-3}$), together with the shape characteristics and geological environment, strongly suggest subregular bands of ultrabasic intrusives as being the sources of the major disturbance.

4. DESCRIPTION OF BOUGUER ANOMALY FEATURE

The first comprehensive geophysical survey of the region was the BMR Helicopter Gravity Training Survey of 1966. Lodwick and Flavelle (1968) used the results of this to define the Cootamundra Gravity High, a two-part feature within the Hume Regional Gravity Complex (Fig. 2).

However, extensive usage has since restricted the term "Cootamundra Gravity High" to the high-amplitude feature discussed in this Record, and so the feature of Lodwick and Flavelle is here redefined as the Temora and Gundagai Gravity Highs.

The Temora and Gundagai Gravity Highs include both the intense anomaly feature investigated in this report, and less-prominent features in WAGGA and COOTAMUNDRA 1:250,000 Sheet areas. Since the most positive parts of the Bouguer anomaly feature correlate approximately with mapped areas of serpentinite, Lodwick and Flavelle suggested that the gravity high delineates subsurface basic intrusions.

The redefined Cootamundra Gravity High is further divided into two sub-units (A and B, Fig. 3); B is considered to be a minor feature superimposed on the main Bouguer anomaly feature. This is deduced not only from the shape of the Bouguer anomaly contours, but also from the gradient at the northeast end of B, which is anomalous in relation to the smooth and comparatively low gradient on the eastern flank of the main anomaly.

The main Bouguer anomaly feature has a slightly sinuous axis which is subparallel to the metamorphic strike indicated by the jaspilite ridges; the axis also parallels the western boundary of the porphyry body (Sup), from which it is offset by one kilometre. The western edge of the feature is marked by a steep gradient which coincides approximately with the inferred position of the boundary between the basic metamorphics (Sub_2) and the less-strongly metamorphosed phyllites and slates (Sub_1); no such gradient is present on the eastern side of the features, where the gradient is low but uniform.

A remarkable aspect of the feature is its simplicity. Although the effective resolution of the gravity survey should be comparatively high, the Bouguer anomaly pattern is smooth when compared with other surveys over metamorphic terrain where a similar station spacing has been used (Smith, 1966, for example). The northern and southern limits of the Cootamundra Gravity High have not been established by the semi-detailed survey; data from the Helicopter reconnaissance survey suggest that in these directions the feature merges with the adjacent Bouguer anomaly features.

5. INTERPRETATION

A two-fold approach to the interpretation of this Bouguer anomaly feature has been adopted. Firstly, all geological and geophysical data were considered, to derive a model qualitatively which would fit all pertinent facts; subsequently a gravity profile was computed from this model, using a two-dimensional line-integral programme (Talwani, Worzel & Landisman, 1959; R. Whitworth, pers. comm.), and adjusted empirically until a better fit was obtained between the observed and computer gravity profiles. The second approach was to use iterative interpretational programmes developed by R. Whitworth of BMR, to obtain geological models directly from the gravity data.

The standard density of 2.67 g/cm^3 has been assumed for the granitic rocks of the area, whilst limited surface samples indicate a density of 2.9 - 3.1 g/cm^3 for the basic metamorphic rocks. The very few density samples available (twenty, from six localities), suggest that a density contract of about 0.2 g/cm^3 is not unreasonable.

In the absence of satisfactory density data only one density contrast has been considered.

In addition, only two-dimensional models have been used: this is justified by the fairly high length/breadth ratio of the Bouguer anomaly feature - about 4.2 measured on the -10 mgal contour: two-dimensional models are acceptable if this ratio is greater than 2.5, according to Skeels (1963, p. 729). The use of a Bouguer anomaly profile across the centre of the feature minimizes end effects. All quantitative deductions have been based on a regionally-corrected Bouguer anomaly profile along latitude 34° 42.5'S. Profile values were determined from the Bouguer anomaly contours, which act as a high-frequency suppression filter, thereby removing noise caused by reading errors and near-surface effects.

Method 1: the empirical approach

The most significant factors of the Cootamundra Gravity High are its shape, amplitude, and gradients as has been brought out in Chapter 4.

The close correspondence between the areal extent of the Bouguer anomaly feature and the metamorphic belt (Plate 1) immediately suggests that the gravity feature is caused by the outcropping metamorphic belt. The steep gradient on the western flank of the feature implies that the main density interface on that side of the anomalous body is near-vertical; the zone of maximum gradient marks the position of the surface trace of the upper western edge of the anomalous body. The comparatively gentle gradient on the eastern side of the Bouguer anomaly feature precludes a rapid horizontal mass variation, and implies that there is either a gradational density change or that the density interface dips more gently to the east. This latter interpretation is supported by geological evidence showing the granite/metamorphics contact to dip to the east, and by the aeromagnetic interpretation, which suggest that two of the magnetically anomalous bodies near this contact dip to the east.

A semi-quantitative analysis of the Bouguer anomaly data was carried out, using parameters listed in Table 1. Application of the formula of Bott and Smith (1958), in its two-dimensional form, gives the maximum depth to the top of the anomalous body, irrespective of its size or density, and assumes only that the density distribution throughout the body is uniform. The expression used is

$$d_{max} = 0.65\ (\Delta g/\Delta g')$$

where d = depth

Δg = amplitude of anomaly in milligals

$\Delta g'$ = maximum horizontal gradient

TABLE 1

PARAMETERS OF COOTAMUNDRA GRAVITY HIGH

Amplitude	:	40 mgal
Half-width	:	14 km
Max. horizontal gradient (stations 228 to 230)	:	9.7 mgal/km
Length/breadth	:	4.2
Skewness (as defined by Grant & West, 1965)	:	about 2

These figures give a figure of d_{max} = 2.7 km

A more complex maximum depth estimator is given by Skeels (1963); again a two-dimensional body is assumed, but of rectangular cross-section. Relevant parameters and results are shown in Figure 4. Because of the asymmetry of the profile, each side was analysed separately. The results suggest that the anomalous body, if of tabular form, dips to the east, but also, that if this occurs, the lower eastern edge of the body may reach the improbably large depth of 25-30 km. This implies that the body thins towards the east. The results also show that the anomalous body is probably of large size. As current petrological theory does not favour the possibility of an ultrabasic body of this size occurring at shallow depths (e.g. Turner & Verhoogen, 1960), except in the case of an upwarp of the mantle (which is excluded by the maximum depth criteria already cited), the most likely origin of the gravity feature is within the metamorphic belt.

A qualitative picture of the anomalous body has thus been built up:

1. Its upper surface is at a maximum depth of 2.7 km, and probably less than 2.0 km.
2. The western boundary is near-vertical.
3. The eastern boundary probably dips to the east.
4. The maximum width of the upper surface of the body is about 10 km.
5. The density contrast between the anomalous body and the surrounding rock is within the range 0.2 - 0.6 g/cm^3.

Clearly, these data fit the known facts about the basic metamorphics fairly well, and so it is not unreasonable to base further interpretation on the assumption that the basic metamorphics are in fact the anomalous body. This implies that the models may be restricted to those that crop out - a necessary restriction to avoid an infinity of models. Consequently, the model shown in Figure 5 was devised, and the gravitational attraction of such a model was computed. However, the theoretical Bouguer anomaly profile thus obtained produced a gross misfit with the observed profile. The computed amplitude was too low, and so the thickness of the anomalous body was increased; the width of the anomaly was too great, requiring a decrease in the width of the model; the gradient on the western flank was too great, and so a sloping contact was adopted, whilst a more gently sloping contact on the east was required to increase the computed Bouguer anomaly in that area.

The final model and profile, produced after several further modifications, is shown in Figure 6. The validity of the assumption of a horizontal base is questionable. Nevertheless the results suggest that below about 6.5 km depth the crust in this region is uniformly dense. The easterly-dipping granite/metamorphic contact resulting from the interpretation is a highly probable feature, and suggests that thrust-faulting may have occurred during which the granite over-rode the metamorphics. Possible evidence for a wide occurrence of this type of thrusting is found on the WAGGA 250,000 Sheet area where a Bouguer anomaly high, probably related to Palaeozoic metasediments, partially overlies a granite to the east.

At the northern end of the main Cootamundra Gravity High, sub-unit 'B' occurs (Fig. 3). Application of Skeels' technique to the rather inadequate gravity data available suggests that the cause of the feature is a small, dense (ultrabasic?) body, with a density contrast of 0.4 - 0.6 g/cm^3 with respect to the granitic rocks; other quantitative estimates are summarized in Figure 7.

The lack of correspondence between this interpretation and the multi-body solution presented by Tipper in the aeromagnetic section (Chapter 3) is not considered serious. In general, the aeromagnetic anomalies reflect the proportion of magnetite present beneath the detector, and so it is not unreasonable to postulate that the magnetite-rich zones associated with jaspilites within the basic metamorphics do not have sufficient mass-excess to give rise to a Bouguer anomaly feature although they do cause a magnetic anomaly. The long-wavelength magnetic anomaly shown in Figure 2, corresponds closely (as Tipper mentioned) to the main Bouguer anomaly feature; also, the western edge of the magnetically disturbed zone nearly coincides with the western boundary of the anomalous mass deduced from gravity data and shown in Figure 3.

Method 2

Iterative interpretational programmes were used to generate two-dimensional geological basin, pluton, and density-contrast models automatically from the Bouguer anomaly profile (see Appendix 1). Although the solutions are restricted, they allow a rapid assessment of a wide range of assumptions of depth to the body and density contrast.

The basin-fitting method is of marginal relevance considering the conclusions arrived at above. However, it does support the idea that the main anomalous mass is of restricted width, with a steep western boundary and a shallow dipping interface in the east (Figure 8).

A plutonic model is obviously of great relevance, and this was investigated in detail. The best fit of profile to model was obtained with the base of the model at about 6.5 km using a density contrast of 0.2 g/cm^3 (Figures 9 and 10). This implies that the crust has no horizontal density variations at depths greater than 6.5 km. The major features of the derived model are an almost vertical interface in the west, corresponding very closely with the western boundary of the basic metamorphic zone, and a more gently sloping eastern boundary, with a dip of about 30 to 45 degrees. The model differs only slightly from the empirically deduced body. The major differences is a minor lobe at depth in the computer-derived model, which may represent an upfaulted high-density block.

The gravity feature was also interpreted in terms of horizontal density changes between two parallel planes, one at the surface and the other at 10 km (Fig. 11). The main conclusion suggested by the resulting density profile is that two high-density bodies may be present; one with a contrast of +0.15 g/cm^3 corresponding to the Sub_1 unit, the other with a contrast of +0.20 g/cm^3 corresponding to the more basic Sub_2 unit.

The computational procedure and conclusions are dealt with in more detail in Appendix 1.

6. CONCLUSIONS

The main Cootamundra Gravity High, redefined in this Record, is believed to be caused by a zone of basic metamorphic rocks with a density contrast of about +0.2 g/cm^3 with respect to the country rock. The metamorphics are in the form of a narrow north-trending belt 5 km wide at the surface but widening rapidly with depth; they are bounded on the west by a near-vertical surface, possibly a fault, but on the west by a gently dipping contact. It seems probable that the Devonian Young Granite has been thrust westward over the metamorphic belt. The deduced geological profile is given in Figure 12.

Near the worked-out Cullinga Gold Mine, the presence of a comparatively small, high-density body has been inferred from a minor lobe of the main Bouguer anomaly feature.

There have been two significant results of this investigation: attention has been drawn to an old mining area, and further geophysical, geochemical, and geological surveys, culminating in a drilling programme, have been carried out (Exploration Holdings Pty Ltd, pers. comm.). Secondly, interpretational problems of the Bouguer anomaly feature have provided a stimulus for the production of the interpretational programmes FITPLUTN, FITBASIN, and FITRHO.

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APPENDIX 1

DATA ANALYSIS BY INTERPRETATIONAL COMPUTER PROGRAMMES

Three types of iterative interpretational programme have been devised by R. Whitworth; designated FITPLUTN, FITBASIN, and FITRHO, they vary the top, bottom, and density respectively of otherwise constant two-dimensional bodies, until a close fit is obtained between observed and computed gravity profiles. The computational process is described briefly below.

FITBASIN

As the name of this programme implies, its primary object is to generate two-dimensional models of a sedimentary basin from a Bouguer anomaly profile; its use in the case of the Cootamundra Gravity High is of only indirect value. From the input of Bouguer anomaly data and a given density contrast, a first approximation to the basin shape is made by using the plane parallel slab formula at each station. The exact gravity effect of the approximation is then determined by a line-integral method (Talwani et al., 1959); the difference between the actual Bouguer anomaly value at a station and the computed value is then used to derive an adjustment to the first basin-depth approximation, again by use of the plane parallel slab formula. This iterative process is carried out ten times, usually with convergence upon a stable solution. The programme assumes that the gravitational effect is generated entirely by the body in question; therefore the regional component present in the Bouguer anomaly profile has to be effectively removed. Because high-frequency components also imply shallow depth of origin, they also require elimination: failure to do so will cause oscillation and divergence of the solution.

Use of the FITBASIN programme on the Cootamundra gravity data achieves two objects: it gives an indication of the size of the anomalous body (if outcropping), in particular its width, and also shows whether a regional component has been left in the Bouguer anomaly profile input. Profiles computed on three different density contrasts are shown in Figure 8; all give approximately the same width to the main anomalous body, but they also contain wide, shallow 'shoulders', probably indicating that an extraneous long-wavelength component still remains in the Bouguer anomaly input.

FITPLUTN

This programme has the greatest potential use to the Cootamundra gravity data, but suffers from mathematical limitations which restrict the solutions.

From a specified subsurface datum plane, a two-dimensional profile is built upwards. The first approximation is computed by means of the plane parallel slab formula, subsequent adjustments and the exact computations being carried out as in FITBASIN. The regional component has to be carefully removed from the Bouguer anomaly profile input; the density contrast and the subsurface datum plane also require careful consideration. If these points are neglected, the later iterations may tend to oscillate; convergence at the ends of the profile is very much slower than with FITBASIN, because with large depth of burial, adjustment of a small body-thickness produces negligible change in the gravity profile at the surface. An example of FITPLUTN print-out is given in Appendix 2. Profiles computed for different datum planes are shown in Figure 10; the standard deviation of the misfit is plotted against datum-plane depth in Figure 9, and shows that once the upper surface of the model reaches the surface, misfit increases, because the central blocks cannot then be adjusted further.

It will be noted that the general form of FITPLUTN models is similar to that produced by empirical reasoning; however, each model took about 20 seconds of computer time to prepare - obviously a rapid process compared with that of human iteration.

The FITPLUTN profile for a density contrast of 0.2 differs from the empirically-deduced body only in detail. The most notable difference is a minor lobe at the western end of the FITPLUTN profile, which may represent an upfaulted high-density block.

FITRHO

This programme can be used to generate a body with lateral density variations, provided the upper and lower surfaces of the body are defined. A two-dimensional prism is considered to exist beneath each gravity station in a profile, and since the size of the prism is known, a density can be rapidly worked out by an adjustment technique similar to those already described. The programme is very rapid and converges easily to a stable form, but its geological significance is clearly limited.

In Figure 11 a profile across the northern part of the Bouguer anomaly feature is shown; the anomalous body was defined as being wholly between two parallel planes ten kilometres apart, the upper one being the ground surface. Apparent density variations were computed for a gravity station separation of one km, that is, each block used in the calculation was 1 x 10 x 100 km.

The density profile suggests that two high-density bodies may be present: one with a contrast of + 0.15 g/cm^3 corresponding to the Sub_1 unit, the other with a contrast of + 0.20 g/cm^3 corresponding to the more basic Sub_2 unit.

COMPUTER FIT OF TWO-DIMENSIONAL PLUTON MODEL TO BOUGUER ANOMALY PROFILE BY ITERATION

APPENDIX 2

COOTAMUNDRA SEMI-DETAILED GRAVITY SURVEY-PROFILES　　　REGIONAL BACKGROUND ANOMALY = -0.00 MGALS

MISFIT BETWEEN COMPUTED AND B.A. PROFILE

ITERATION	AVGE DIFF	SD OF DIFF
1	-3.219	6.172
2	-0.044	2.528
3	0.542	1.408
4	0.599	1.145
5	0.577	1.025
6	0.565	0.967
7	0.544	0.936
8	0.530	0.911
9	0.516	0.893

GRAVITY ANOMALY AT EACH ITERATION

	1	2	3	4	5	6	7	8	9	BA
0	5.54	5.87	5.61	5.46	5.33	5.27	5.22	5.19	5.15	2.00
1000	6.26	6.68	6.40	6.22	6.08	6.01	5.95	5.90	5.84	2.80
2000	7.05	7.62	7.32	7.12	6.96	6.88	6.81	6.75	6.71	4.00
3000	7.84	8.71	8.41	8.19	8.01	7.91	7.83	7.77	7.72	5.40
4000	8.93	9.96	9.67	9.44	9.24	9.14	9.05	8.97	8.91	7.50
5000	10.01	11.39	11.14	10.90	10.70	10.58	10.48	10.41	10.33	10.00
6000	11.19	13.02	12.85	12.61	12.41	12.29	12.18	12.09	12.02	12.30
7000	12.47	14.98	14.83	14.64	14.45	14.33	14.22	14.14	14.06	14.00
8000	13.86	17.03	17.17	17.05	16.90	16.80	16.71	16.63	16.56	15.80
9000	15.34	19.52	19.98	19.98	19.92	19.87	19.82	19.77	19.72	19.10
10000	15.90	22.45	23.41	23.64	23.72	23.78	23.81	23.83	23.85	23.70
11000	15.44	25.56	27.66	28.30	28.65	28.90	29.06	29.23	29.39	30.20
12000	19.84	29.65	32.93	34.34	35.17	35.01	35.74	35.79	35.77	35.60
13000	20.90	33.19	38.50	39.35	39.07	38.91	38.79	38.73	38.69	38.70
14000	21.47	34.76	40.55	40.44	40.15	40.04	39.96	39.97	39.97	40.00
15000	21.49	33.17	36.72	37.52	37.72	37.78	37.78	37.77	37.76	37.80
16000	21.05	30.74	33.10	33.71	33.92	34.01	34.03	34.03	34.02	33.90
17000	20.32	28.43	30.75	30.80	31.04	31.16	31.22	31.25	31.25	31.40
18000	19.42	26.31	27.78	28.28	28.52	28.66	28.73	28.79	28.80	28.90
19000	18.43	24.32	25.93	25.96	26.10	26.32	26.40	26.45	26.49	26.30
20000	17.40	22.45	23.43	23.79	23.99	24.12	24.21	24.27	24.31	24.40
21000	16.39	20.68	21.45	21.74	21.90	22.02	22.10	22.15	22.21	22.60
22000	15.31	19.00	19.58	19.78	19.90	19.99	20.05	20.12	20.14	20.70
23000	14.29	17.40	17.80	17.91	17.98	18.03	18.06	18.09	18.17	18.10
24000	13.30	15.89	16.13	16.16	16.17	16.18	16.19	16.23	16.20	15.90
25000	12.35	14.49	14.58	14.54	14.51	14.49	14.47	14.46	14.45	14.10
26000	11.44	13.20	13.16	13.07	13.00	12.95	12.91	12.89	12.87	12.70
27000	10.59	12.30	11.87	11.73	11.63	11.56	11.52	11.49	11.46	11.40
28000	9.78	10.90	10.69	10.51	10.40	10.32	10.26	10.23	10.20	10.20
29000	9.02	9.58	9.61	9.41	9.28	9.20	9.14	9.10	9.08	9.20
30000	8.30	8.94	8.62	8.40	8.27	8.18	8.13	8.09	8.06	8.10
31000	7.63	8.08	7.72	7.50	7.36	7.27	7.22	7.19	7.16	7.10
32000	7.00	7.29	6.90	6.67	6.54	6.46	6.40	6.37	6.35	6.20
33000	6.41	6.56	6.16	5.94	5.81	5.73	5.66	5.65	5.63	5.20
34000	5.86	5.99	5.50	5.28	5.17	5.09	5.04	5.02	5.00	4.40
35000	5.35	5.29	4.90	4.71	4.60	4.53	4.49	4.46	4.45	3.70
36000	4.88	4.75	4.30	4.20	4.10	4.04	4.00	3.95	3.97	3.10
37000	4.44	4.27	3.92	3.76	3.67	3.62	3.58	3.57	3.55	2.60
38000	4.03	3.93	3.52	3.38	3.30	3.29	3.29	3.21	3.19	2.20
39000	3.66	3.45	3.17	3.05	2.98	2.94	2.91	2.90	2.88	1.80
40000	3.32	3.18	2.87	2.76	2.70	2.66	2.64	2.63	2.62	1.40
41000	3.01	2.82	2.60	2.51	2.46	2.42	2.40	2.39	2.38	1.10

015775

ESTIMATE OF DEPTH OF TOP AT EACH ITERATION　　BOTTOM AT 7500 M　　DENSITY 0.20 GMS/CC

	1	2	3	4	5	6	7	8	9	10
0	7261	7500	7500	7500	7500	7500	7500	7500	7500	7500
1000	7166	7500	7500	7500	7500	7500	7500	7500	7500	7500
2000	7023	7387	7500	7500	7500	7500	7500	7500	7500	7500
3000	6856	7159	7500	7500	7500	7500	7500	7500	7500	7500
4000	6605	6779	7069	7398	7500	7500	7500	7500	7500	7500
5000	6307	6337	6473	6610	6717	6800	6870	6927	6974	7014
6000	6032	5899	5985	6050	6088	6101	6100	6385	6067	6020
7000	5879	5647	5752	5851	5927	5980	6020	6344	6063	6070
8000	5619	5383	5529	5693	5842	5973	6093	6202	6101	6302
9000	5221	4773	4873	4928	5034	5131	5223	5307	5180	5462
10000	4672	3860	3711	3677	3669	3672	3682	3695	3710	3726
11000	3896	2493	1976	1673	1447	1262	1107	971	857	759
12000	3252	1371	661	343	192	141	147	160	181	201
13000	2892	758	101	77	155	200	225	234	239	234
14000	2727	516	0	66	118	130	140	137	135	137
15000	2980	1043	491	361	397	318	316	314	310	306
16000	3459	1822	1544	1449	1426	1429	1444	1454	1473	1487
17000	3753	2431	2076	1939	1868	1825	1798	1774	1756	1730
18000	4091	2970	2611	2477	2403	2358	2329	2309	2294	2283
19000	4362	3423	3186	3094	3094	3040	3042	3054	3072	3064
20000	4588	3795	3521	3405	3333	3284	3250	3227	3211	3200
21000	4803	4398	3829	3692	3590	3507	3438	3379	3326	3280
22000	5030	4387	4184	4090	3940	3844	3750	3681	3610	3543
23000	5340	4886	4802	4766	4743	4728	4720	4715	4715	4717
24000	5603	5292	5292	5319	5350	5382	5416	5451	5487	5523
25000	5817	5678	5655	5713	5766	5815	5861	5905	5948	5989
26000	5985	5834	5894	5949	5993	6028	6058	6084	6106	6126
27000	6140	6143	6114	6170	6209	6236	6256	6273	6280	6287
28000	6283	6233	6310	6374	6411	6434	6448	6456	6460	6460
29000	6402	6391	6462	6510	6535	6544	6544	6537	6525	6510
30000	6533	6598	6698	6720	6757	6777	6787	6790	6789	6789
31000	6653	6716	6833	6907	6934	6985	7006	7020	7030	7037
32000	6760	6956	6985	7069	7126	7167	7197	7221	7242	7250
33000	6879	7024	7186	7301	7389	7462	7500	7500	7500	7500
34000	6975	7150	7328	7459	7500	7500	7500	7500	7500	7500
35000	7058	7256	7446	7500	7500	7500	7500	7500	7500	7500
36000	7130	7342	7500	7500	7500	7500	7500	7500	7500	7500
37000	7190	7409	7500	7500	7500	7500	7500	7500	7500	7500
38000	7237	7456	7500	7500	7500	7500	7500	7500	7500	7500
39000	7289	7500	7500	7500	7500	7500	7500	7500	7500	7500
40000	7333	7500	7500	7500	7500	7500	7500	7500	7500	7500
41000	7369	7500	7500	7500	7500	7500	7500	7500	7500	7500

015776

To accompany Record Nº 1971/34　　G65-225

APPENDIX 3

SURVEY STATISTICS

Date of gravity survey: 9/1/67 - 16/1/67
27/2/67 - 1/3/67

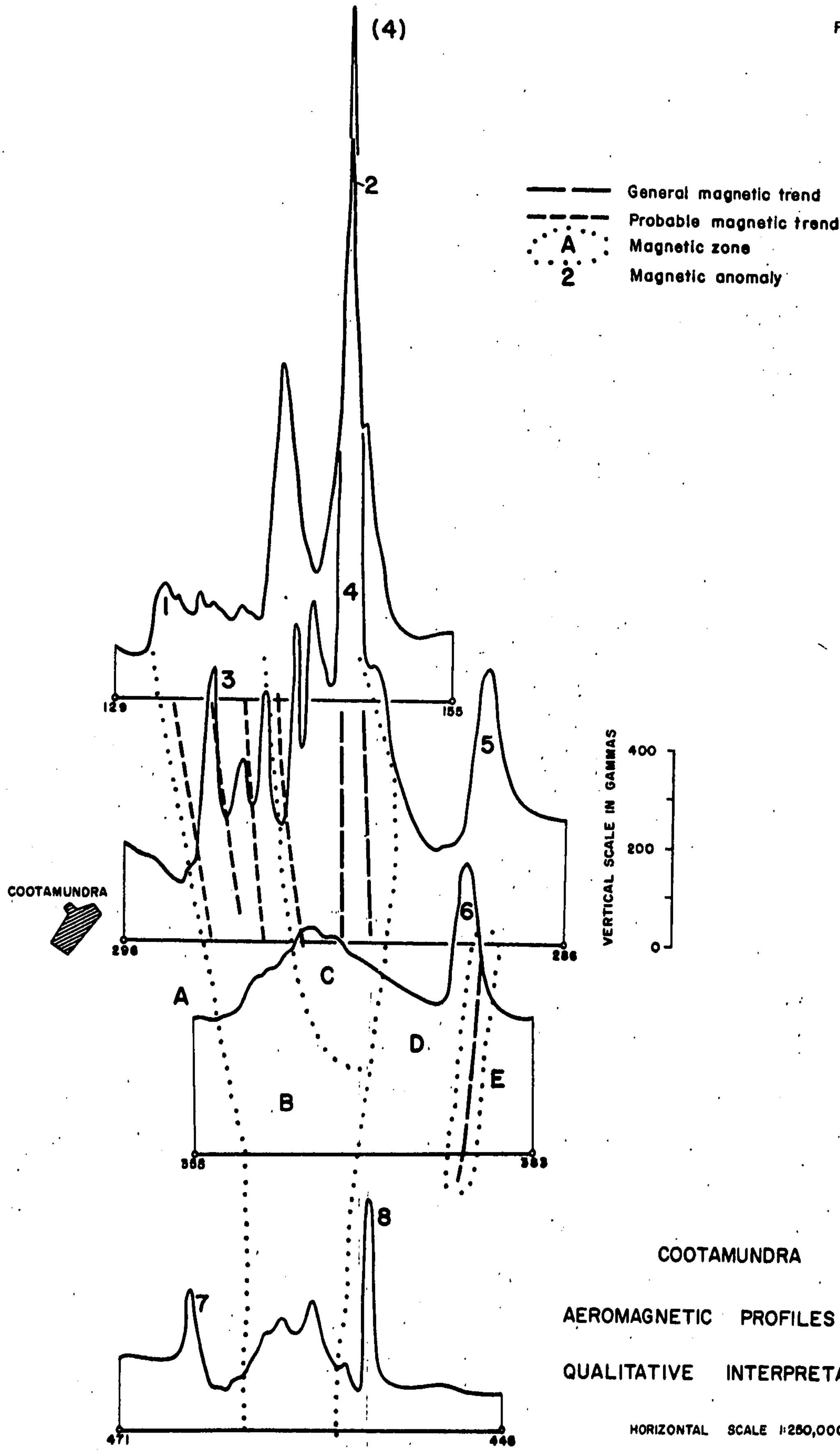
Personnel:

M.D. Watts (Party Leader)
M.J. Smith)
J. Weissel) University vacation students.
P. Sparggon)

Vehicles: 1 x LWB Landrover
1 x Falcon station waggon

Gravity meter: Worden 61
Calibration factor: 0.0906 mgal/scale division
Calibrated at Canberra on 12/12/66 and 13/2/67.

FIGURE 1



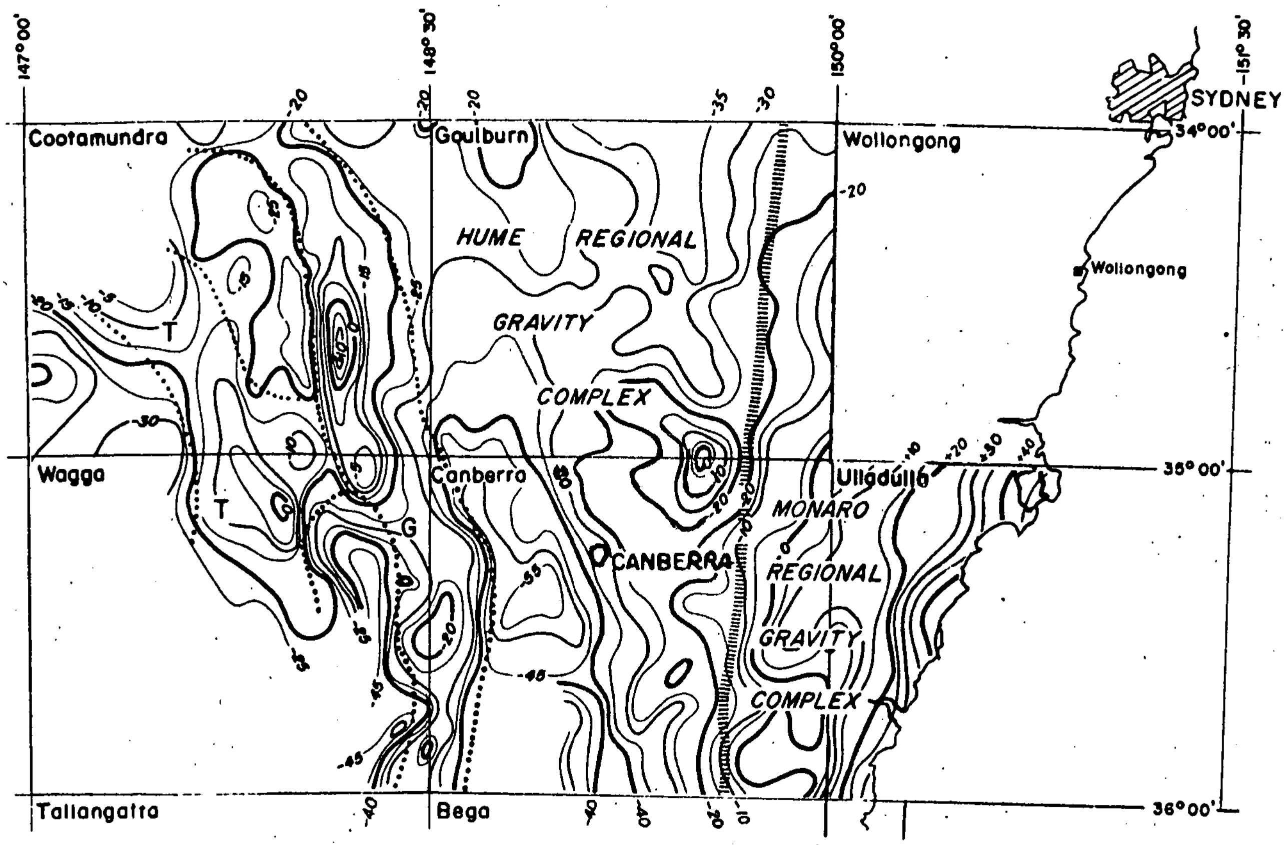
COOTAMUNDRA

AEROMAGNETIC PROFILES AND

QUALITATIVE INTERPRETATION

HORIZONTAL SCALE 1:250,000

FIGURE 2



SCALE
1:2,534,400

40 0 40 MILES

25 0 25 50 75 100 KILOMETRES

LEGEND

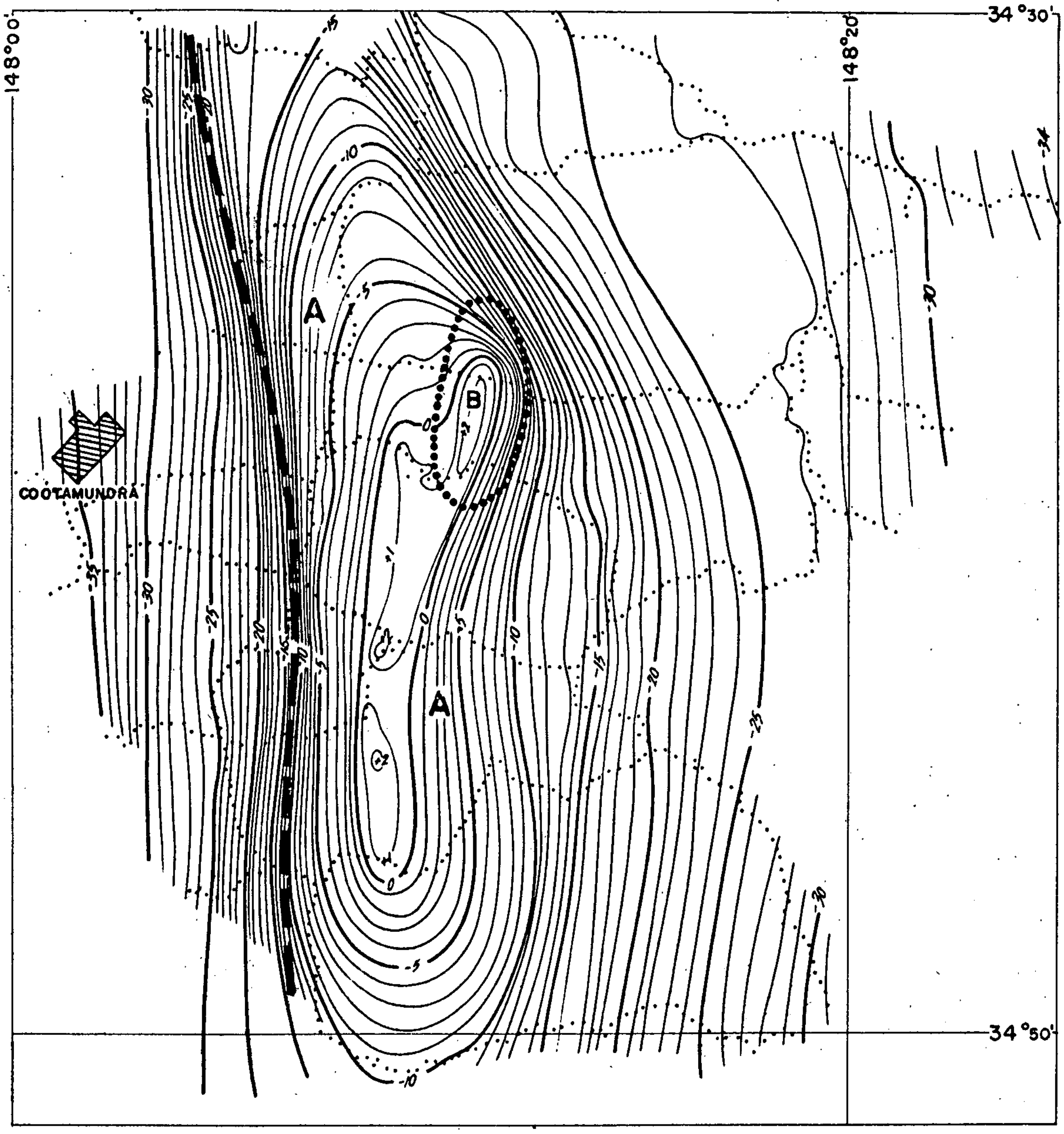
T = Temora Gravity High

G = Gundagai Gravity High

T+G = Cootamundra Gravity High of Lodwick & Flavelle (1968)

REGIONAL BOUGUER ANOMALIES

FIGURE 3



SCALES

5 0 5 MILES

5 0 5 10 KILOMETRES

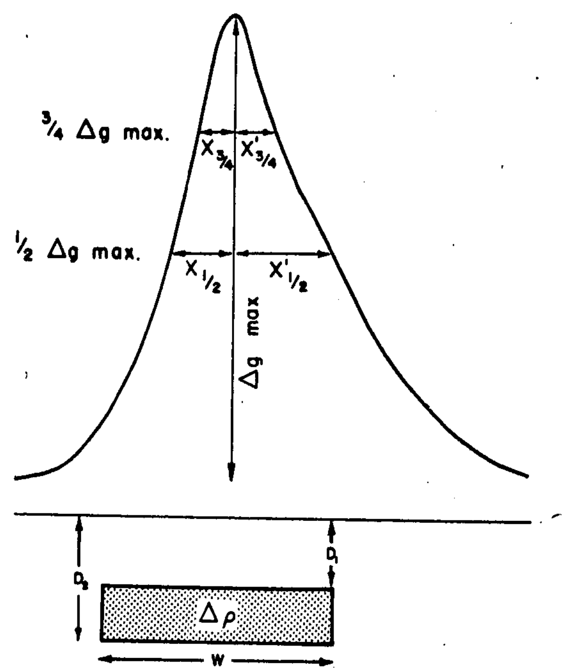
LEGEND

A, B Sub-divisions of Bouguer anomaly feature referred to in text

Probable western boundary of outcropping anomalous mass

COOTAMUNDRA GRAVITY HIGH

FIGURE 4



(a) Western side of profile

$X_{3/4} = 4{\cdot}0$ km

$X_{1/2} = 5{\cdot}8$ km

$\Delta\rho$ g/cm³	D_1 km	D_2 km	W km
0·2	0·5	10·4	9·4
0·4	1·6	6·0	10·8
0·6	2·2	4·5	9·9

(b) Eastern side of profile

$X'_{3/4} = 3{\cdot}5$ km

$X'_{1/2} = 8{\cdot}2$ km

$\Delta\rho$ g/cm³	D_1 km	D_2 km	W km
0·2	1·2	24·6	2·7
0·4	1·8	30·0	2·4
0·6	1·9	31·4	1·9

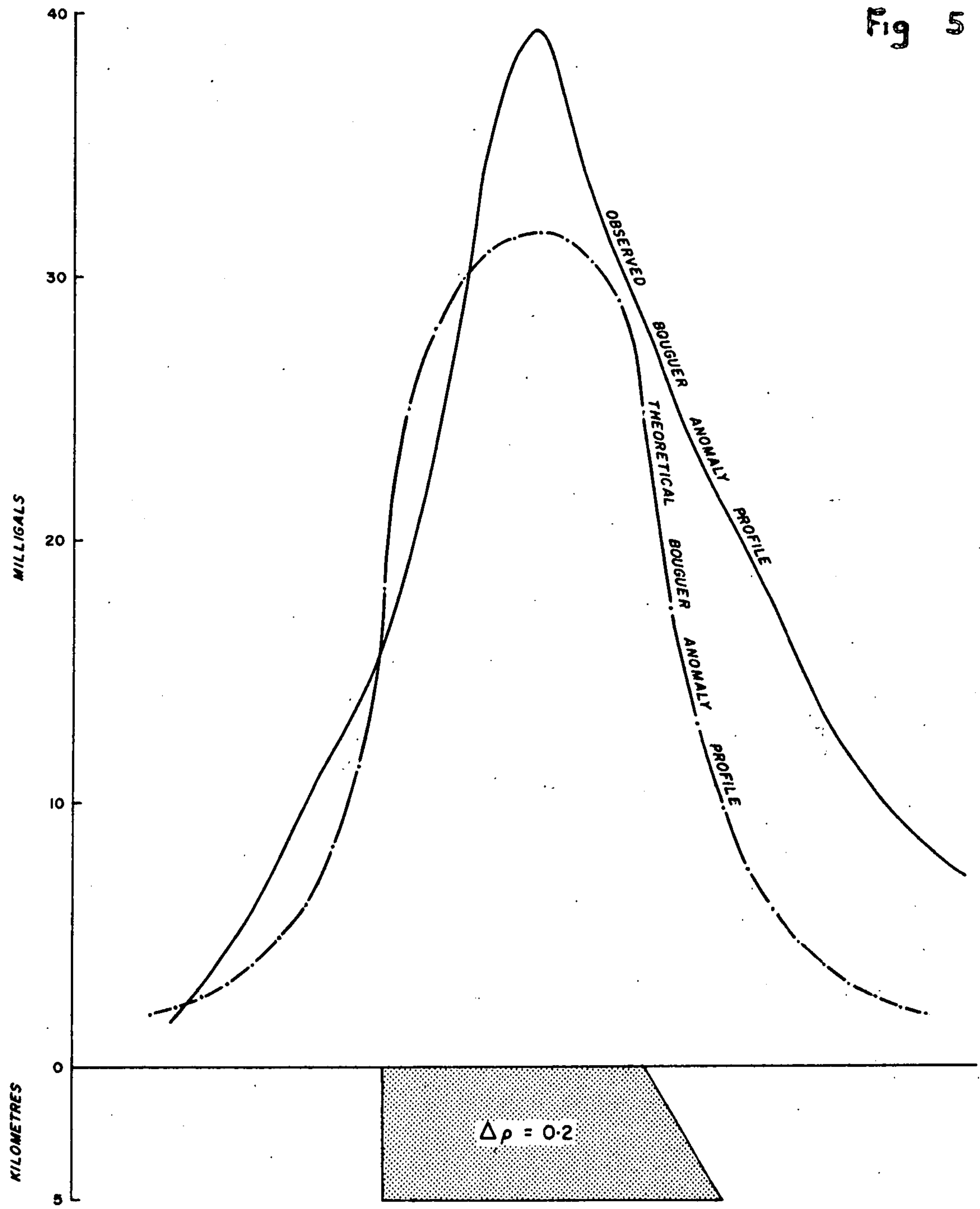
Note: due to method of construction of Skeels' reference charts, only the values for D_1 are considered reliable

COOTAMUNDRA — INTERPRETATIVE PROFILES

AND PARAMETERS FOR SKEELS' TECHNIQUE

RECTANGULAR PRISM INFINITE LENGTH

Fig 5



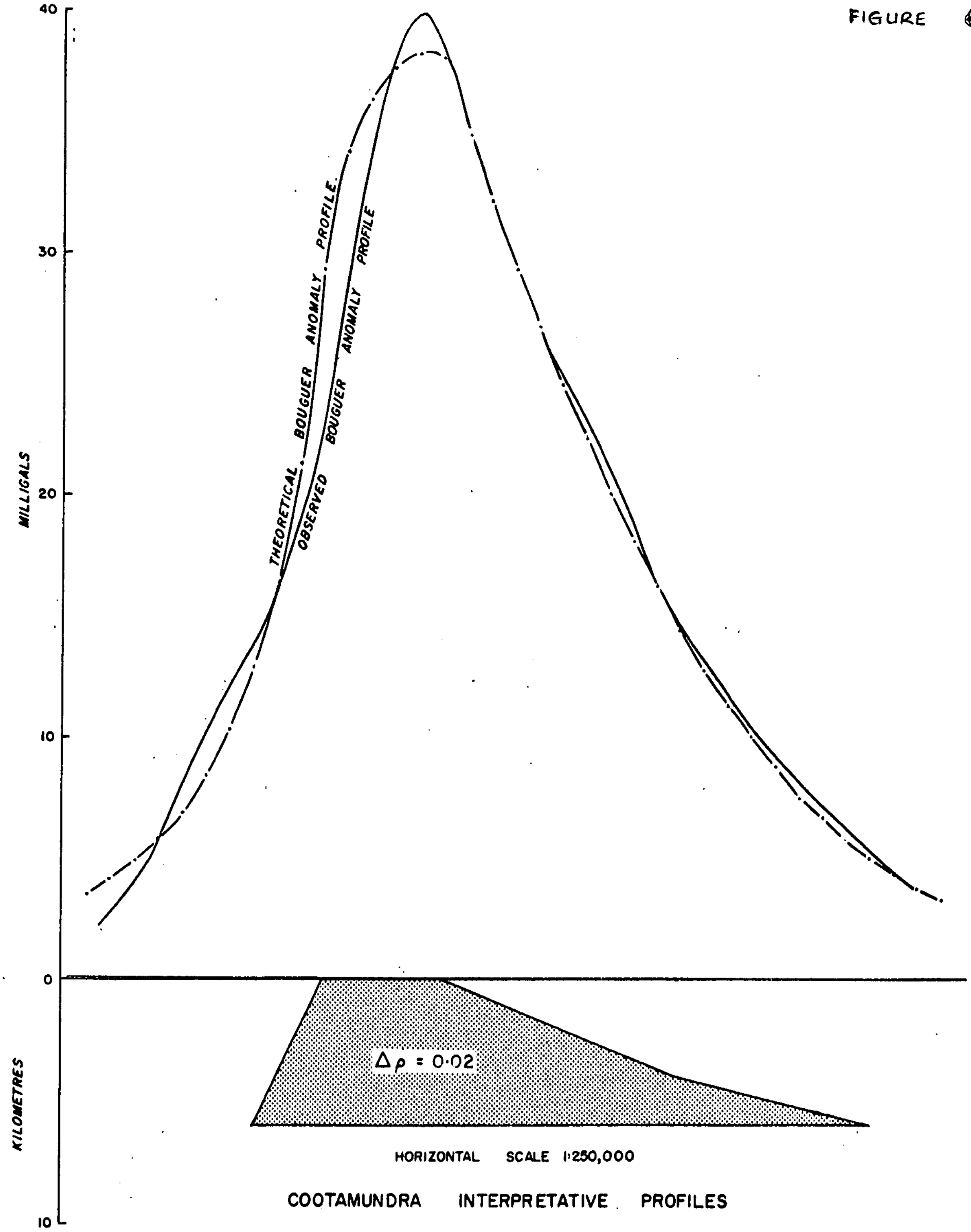
HORIZONTAL SCALE 1:250,000

COOTAMUNDRA INTERPRETATIVE PROFILES

EMPIRICAL MODEL N° 1

To accompany Record N° 1971/34 G65-213

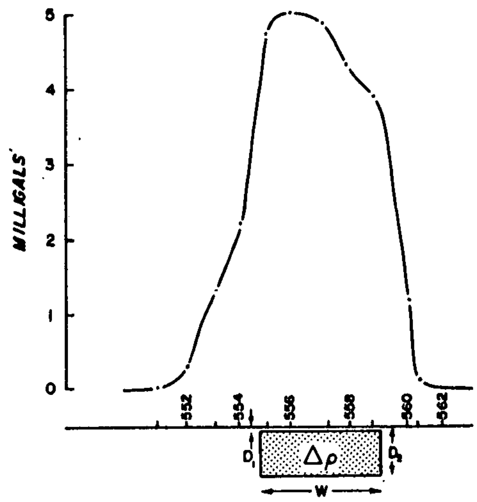
FIGURE 6



COOTAMUNDRA INTERPRETATIVE PROFILES

FINAL EMPIRICAL MODEL

FIGURE 7



ANOMALY PARAMETERS
$\Delta g = 5{\cdot}0$ mgal $\Delta g'_{max} = 7{\cdot}1$ mgal/km $X_{1/2} = 1{\cdot}0$ km $X_{3/4} = 0{\cdot}8$ km

Maximum depth : $0{\cdot}65 \left| \dfrac{\Delta g}{\Delta g'_{max}} \right| = 0{\cdot}92$ km

APPLICATION OF SKEELS' METHOD :

$\Delta\rho$	D_1 m	D_2 m	Wkm
0·2	60	750	1·65
0·4	150	540	2·05
0·6	180	450	1·98

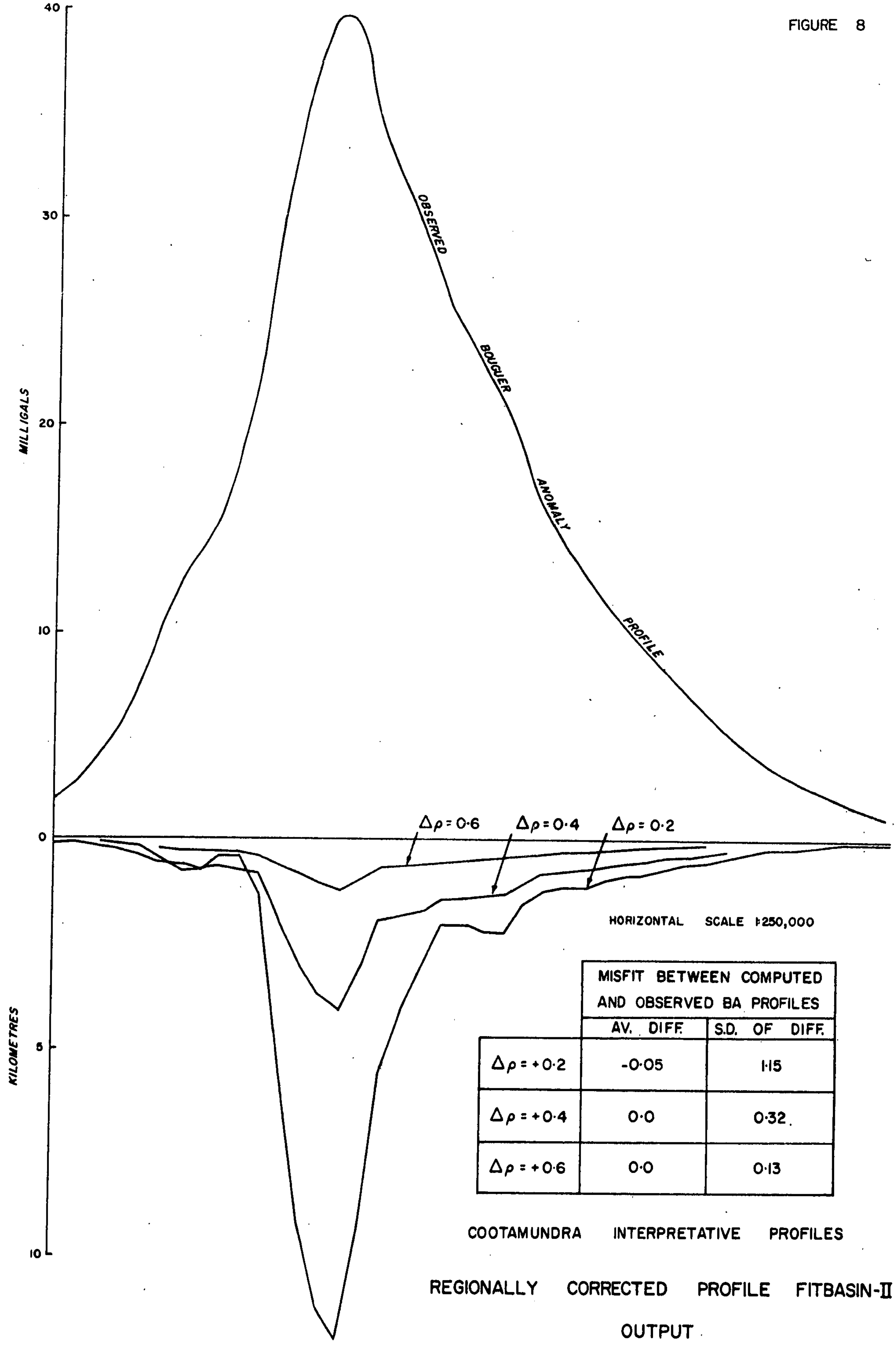
HORIZONTAL SCALE 1:100,000

COOTAMUNDRA INTERPRETATIVE PROFILES

INTERPRETATION OF ANOMALY FEATURE 'G' AFTER REMOVAL

OF REIONAL COMPONENT DUE TO MAIN GRAVITY ANOMALY

FIGURE 8

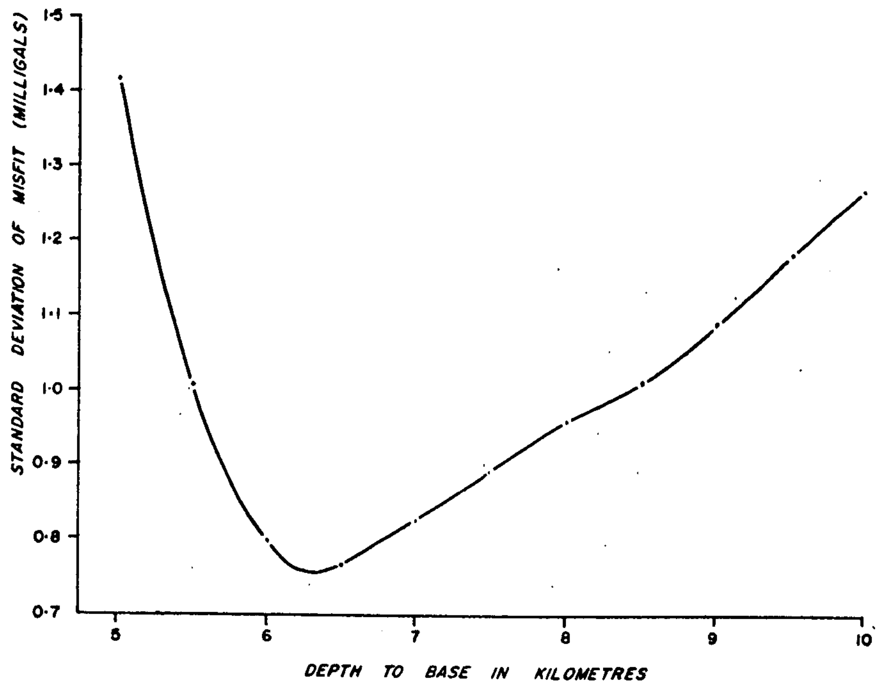


	MISFIT BETWEEN COMPUTED AND OBSERVED BA PROFILES	
	AV. DIFF.	S.D. OF DIFF.
$\Delta\rho = +0{\cdot}2$	-0·05	1·15
$\Delta\rho = +0{\cdot}4$	0·0	0·32
$\Delta\rho = +0{\cdot}6$	0·0	0·13

COOTAMUNDRA INTERPRETATIVE PROFILES

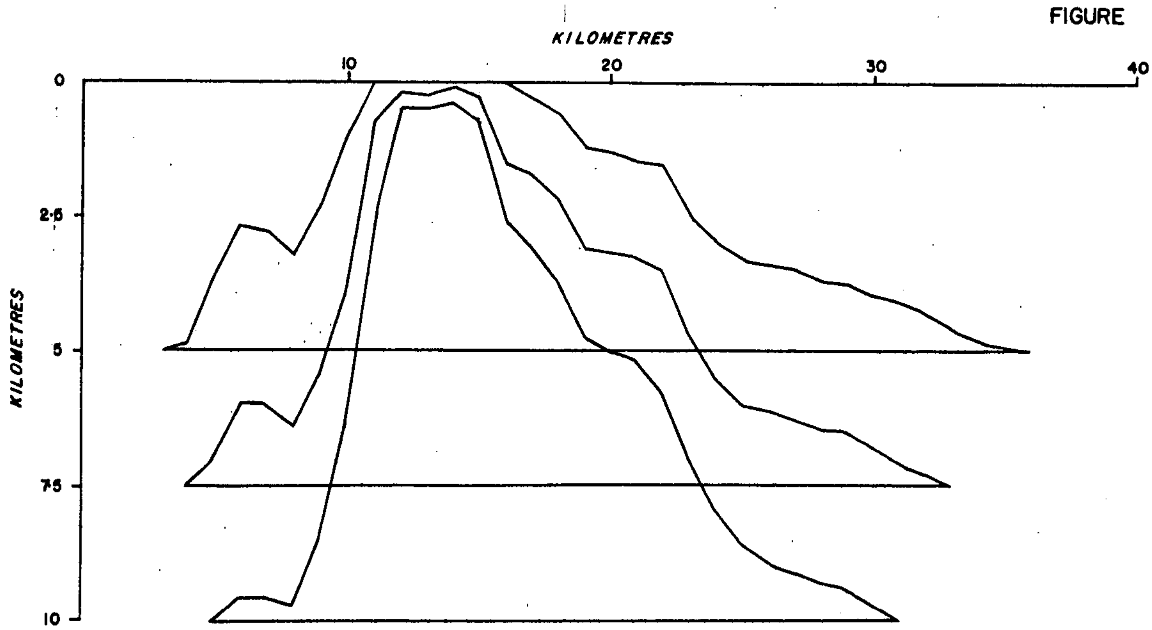
REGIONALLY CORRECTED PROFILE FITBASIN-II OUTPUT

FIGURE 9



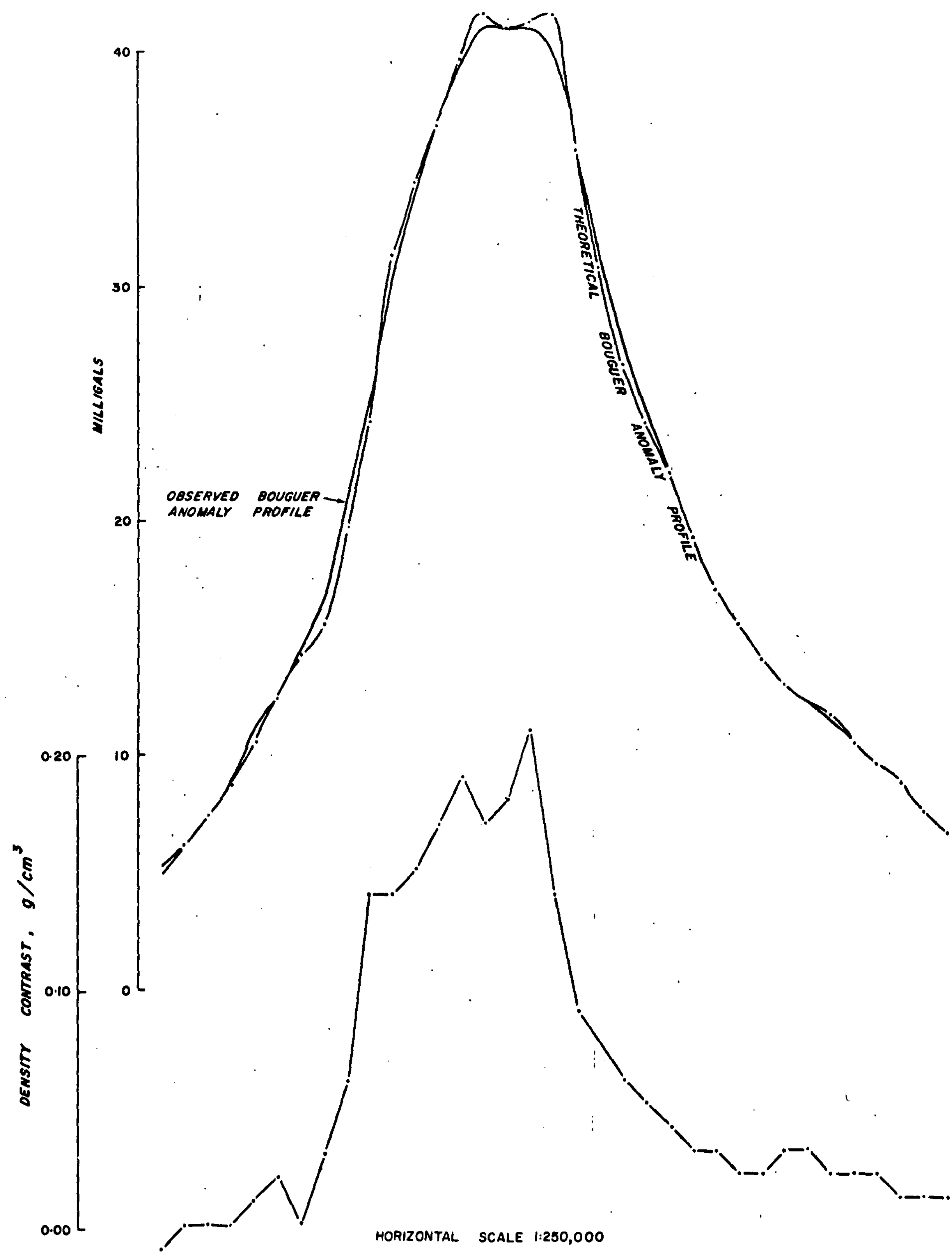
FITPLUTN-IV: Standard Deviation of difference between theoretical and observed Bouguer Anomaly profiles plotted against depth to base of model

FIGURE 10



Models produced by FITPLUTN-IV programme for a density contrast of + 0·20

COOTAMUNDRA INTERPRETATIVE PROFILES



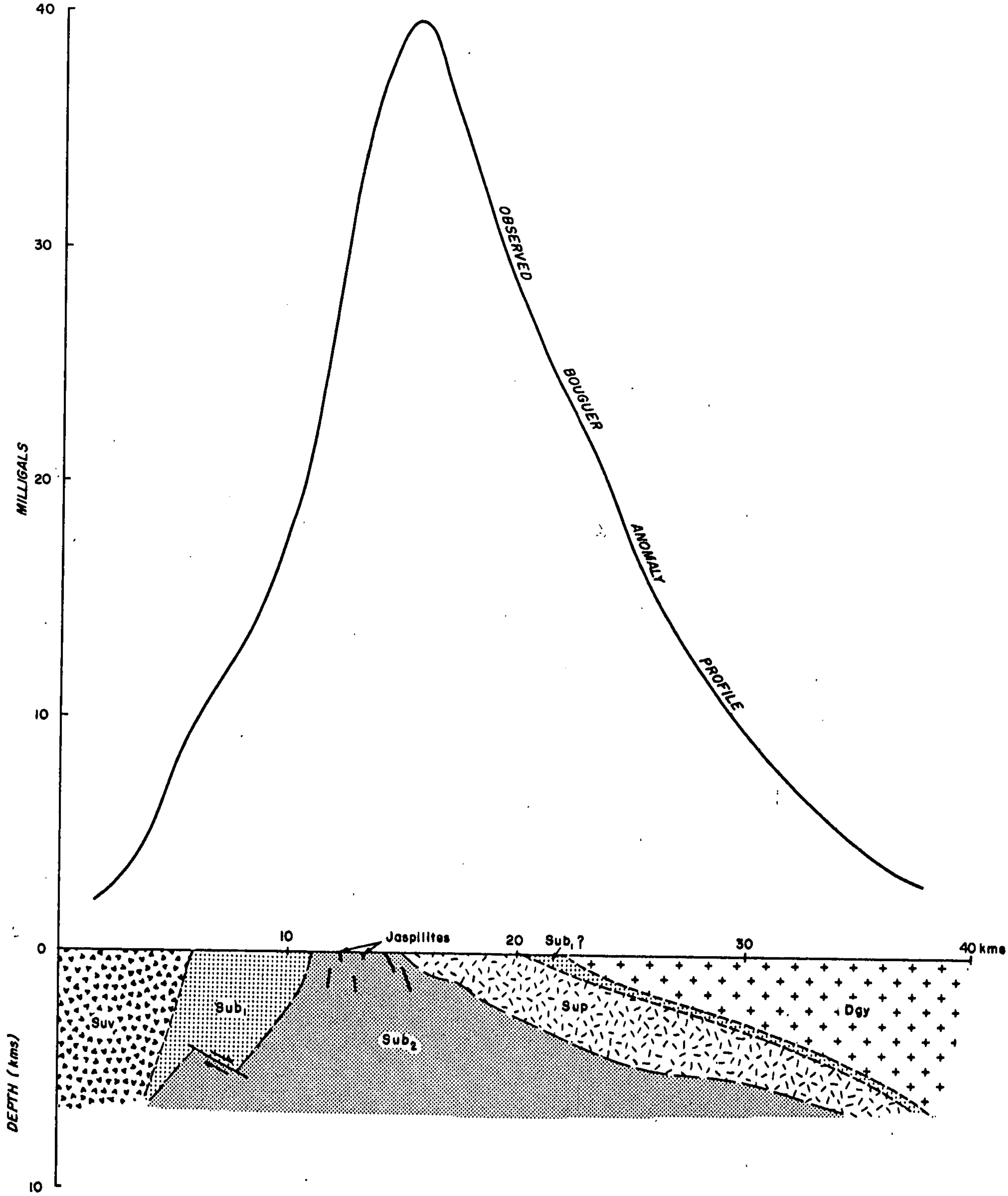
COOTAMUNDRA INTERPRETATIVE PROFILES

NORTH PROFILE FITRHO PROGRAMME OUTPUT SHOWING

CALCULATED DENSITY VARIATIONS FOR A 0-10 km SLAB

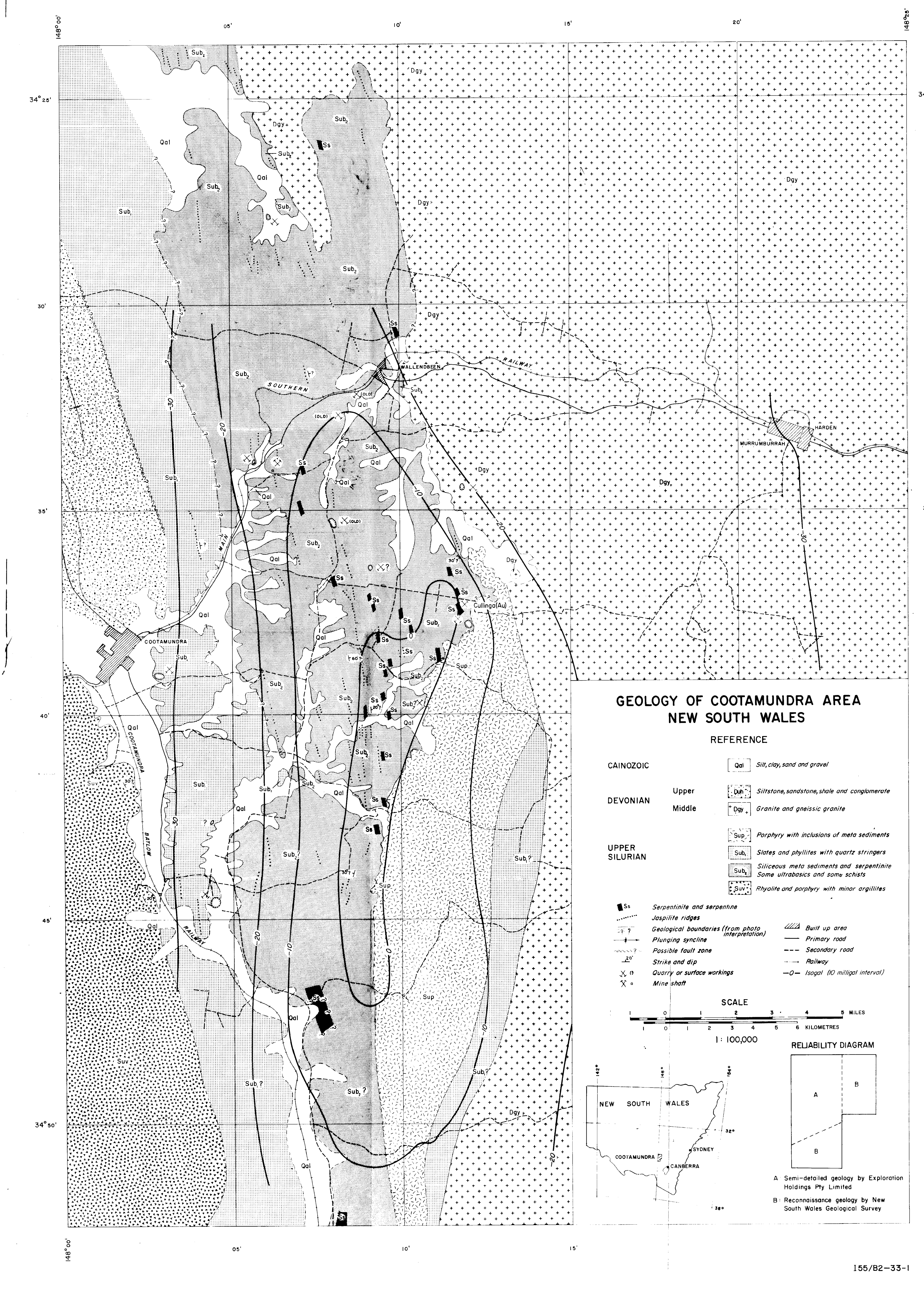
To accompany Record N° 1971/34

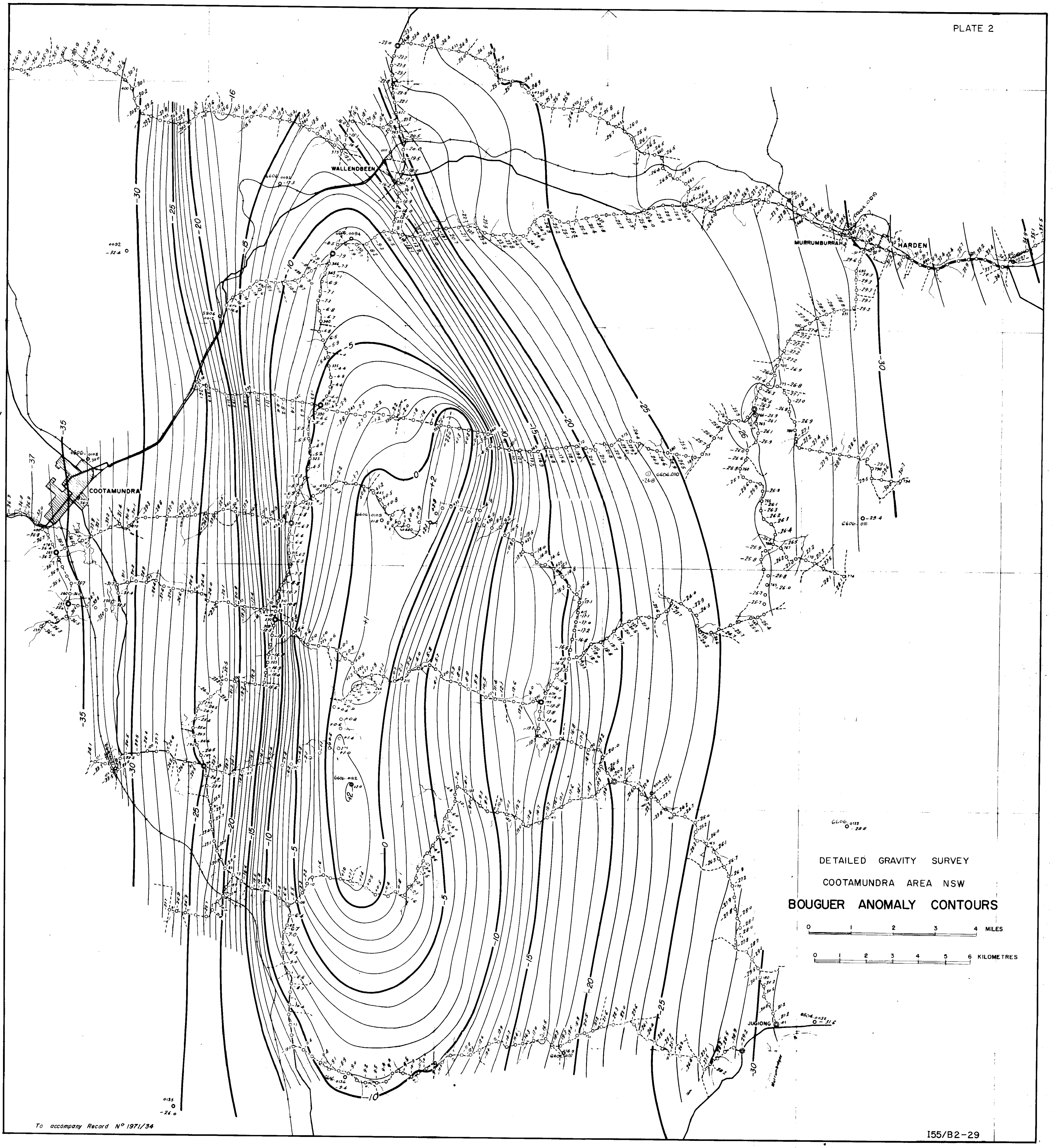
I55/B2-40



COOTAMUNDRA INTERPRETATIVE PROFILES

INTERPRETATIONAL PROFILE ALONG 34° 42·5' S BASED ON ALL GEOLOGICAL DATA


GEOLOGY OF COOTAMUNDRA AREA
NEW SOUTH WALES
REFERENCE
CAINOZOIC
Qal Silt, clay, sand and gravel
DEVONIAN
Upper
Duh Siltstone, sandstone, shale and conglomerate
Middle
Dgy Granite and gneissic granite
UPPER SILURIAN
Sup Porphyry with inclusions of meta sediments
Sub1 Slates and phyllites with quartz stringers
Sub2 Siliceous meta sediments and serpentinite Some ultrabasics and some schists
Suv Rhyolite and porphyry with minor argillites
Ss Serpentinite and serpentine
Jaspilite ridges
Geological boundaries (from photo interpretation)
Plunging syncline
Possible fault zone
Strike and dip
Quarry or surface workings
Mine shaft
Built up area
Primary road
Secondary road
Railway
Isogal (10 milligal interval)
SCALE
5 MILES
6 KILOMETRES
1: 100,000
RELIABILITY DIAGRAM
A Semi-detailed geology by Exploration Holdings Pty Limited
B Reconnaissance geology by New South Wales Geological Survey
NEW SOUTH WALES
COOTAMUNDRA
SYDNEY
CANBERRA
COOTAMUNDRA
WALLENDBEEN
HARDEN
MURRUMBURRAH
Cullinga(Au)
SOUTHERN
RAILWAY
MAIN
COOTAMUNDRA
BATLOW
148°00'
05'
10'
15'
20'
148°25'
34°25'
30'
35'
40'
45'
34°50'



To accompany Record N° 1971/34

I55/B2-29