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RECORD No. 1962/91

POOLE RANGE GRAVITY SURVEY, WESTERN AUSTRALIA 1953

by

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SUMMARY

The Fitzroy Basin lies south-east of Derby, Western Australia, and is considered to be an excellent oil-prospecting area. There are several large anticlines in the Basin and it has been the aim of the Bureau of Mineral Resources, as part of its broader policy of regional mapping, to investigate certain of these structures at depth using gravity, seismic, and magnetic methods. Seismic and gravity work on the first anticline tested (Nerrima Dome) indicated that the surface structure does not persist at depth.

The present Record describes a gravity survey made in 1953 of an area around the Poole Range structure. The Pinnacle Fault was traced for about 60 miles and the survey indicated that the faulting probably dies out about 25 miles south-south-east of Fitzroy Crossing. Estimates of the throw of the fault at various points range from 6600 ft to 12,000 ft, the maximum throw being near Pinnacle Yard.

The gravity survey does not clearly indicate whether the surface anticlinal structure at the Poole Range persists at depth.

FOREWORD

The report of this survey was written not long after the survey ended. West Australian Petroleum Pty Limited was advised of the findings, and the gravity results have been used in more recent maps issued by the Bureau. However, for various reasons the report has not been issued previously. Although the report is issued in the present form mainly to place the survey findings permanently on record, the interpretation has been brought up to date by the inclusion of information from later surveys.

1. INTRODUCTION

In the area south-east of Derby, known as the Fitzroy Basin, the search for oil has continued sporadically over the past thirty years. Geologists of the Bureau of Mineral Resources have been studying the area since 1948, and geophysical work was commenced in 1952. Acting on suggestions by Schneeberger (1952) for a geophysical exploration programme in the Fitzroy Basin, the Bureau sent gravity and seismic parties to investigate structures in the Poole Range-Prices Creek area in 1953. Results of the seismic work have been given by Smith (1955).

This Record describes the gravity survey of most of the region between longitudes 125°30'E and 126°00'E and latitudes 18°30'S and 19°00'S, held, under authority to prospect for oil, by West Australian Petroleum Pty Ltd (Plate 1).

Within this area are two major structural features, namely the Pinnacle Fault and the Poole Range structure (Plates 2 and 3). The latter is considered to be a prospective oil trap (Guppy, 1953). The nearest known outcrop of potential oil source rocks (about 20 miles north-east of the Poole Range) terminates at the Pinnacle Fault on the northern margin of the Fitzroy Basin, and it is not known whether these rocks exist farther south within the Basin and beneath the Poole Range. The main objects of the gravity survey were:

(a) To estimate the throw of the Pinnacle Fault and trace its possible continuation to the north-west, and

(b) To ascertain whether the anticlinal structure of the Poole Range persists at depth.

The survey lasted from 8th June to 18th October 1953. The party consisted of W.H. Oldham (party leader and geophysicist), I.B. Everingham (geophysicist), two surveyors from the Department of the Interior, four survey assistants, and a cook. Additional staff were available for a small part of the time.

2. GEOLOGY

The geology of the Fitzroy Basin has been described by Guppy et al. (1958) and McWhae et al. (1958).

Two major structural features in the Basin are the Pinnacle and Fenton Faults. The latter forms the south-western margin of the Basin, and the Pinnacle Fault forms part of the north-eastern margin (Plates 2 and 3). The Poole Range anticline is a culmination on one of the major east-west-trending anticlines of the Fitzroy Basin.

Stratigraphy

The Fitzroy Basin contains Ordovician, Devonian, Carboniferous, Permian, and Mesozoic sediments.

The highest-grade known source rocks for petroleum are of Ordovician age. These are exposed in a small area of about 12 square miles near Prices Creek (Plate 3), but it is not known whether they have regional significance throughout the Basin or whether they occur only as erosional remnants preserved in local basement depressions. The Prices Creek Group of Ordovician sediments includes fossiliferous limestone, shale, and dolomite, and is believed to attain a thickness of 2630 ft near Prices Creek.

Carboniferous sediments were not known in the region of the survey, but exist in an outcrop and in bores to the west and probably extend throughout the Basin proper.

The Devonian sediments crop out extensively along the north-eastern margin of the Basin and possibly extend over a large part of the Basin, under cover of Permian sediments. The Devonian sequence includes a high percentage of reef limestone and rests with angular unconformity on the Ordovician.

Permian rocks, consisting mainly of sandstone, siltstone, and tillite, extend without facies change over the greater part of the Basin and may attain a thickness of about 19,000 ft. Poole Range No. 3 Bore penetrated 3264 ft of the Grant Formation (of lower Permian age), indicating a minimum thickness of 3460 ft for the Formation near the centre of the Poole Range.

The Ordovician and Devonian sediments are considered most important formations in the oil exploration programme, as their equivalents within the Basin are likely to include source and reservoir rocks.

Structure (Plate 3)

Tectonic features in the area surveyed are:

(a) Pinnacle Fault

(b) Poole Range-Mount Hutton structure

(c) Talbot Syncline

(d) Virgin Fault

The Pinnacle Fault has been located by surface mapping from near Bohemia Homestead to a point about 6 miles north-east of Chestnut Bore. This fault separates an area of Ordovician and Devonian outcrops on the north- east from one of Permian outcrops within the Basin on the south-west.

The Poole Range-Mount Hutton structure is within the Fitzroy Basin and lies on the eastern extension of a large anticlinal axis which also includes the St George Range and Nerrima structures. Along this anticlinal axis there is a major culmination at the Poole Range and a minor culmination at Mount Hutton.

The Talbot Syncline is parallel to the Pinnacle Fault and approximately two miles south of it.

The Virgin Fault, which is about 12 miles north of the Pinnacle Fault, strikes north-west and has been mapped at the surface for a distance of about 10 miles. Here, Precambrian rocks are in juxtaposition with Devonian sediments.

3. FIELD PROCEDURE

Vehicles

The vehicles used were:

1 3-ton Commer supply truck

1 Landrover gravity meter carrier

3 Landrovers for use by surveyors

Topographical survey

The positions of the gravity stations were determined by compass and stadia traversing, with reference to trigonometrical stations at approximately five-mile intervals along the traverses. Traverses A, B, and Z were set out as seismic traverses; the stations on these traverses were located by theodolite and chain.

Elevations were determined by levelling and were referred to Mean Sea Level by a tie made by a topographical survey party in 1953. The elevation of tie station T45 (Chestnut Bore) was taken as 378.9 ft.

Some of the gravity stations in the area were levelled and located by the surveyors from the seismic party and the regional gravity party.

About half the traversing was along roads and tracks, which were followed wherever possible. The remainder was across virgin country which was easily accessible in four-wheel-drive vehicles.

An area of about 1500 square miles was surveyed by traverses on which six hundred gravity stations were established at 1-mile, $\frac{1}{2}$-mile, and $\frac{1}{4}$-mile intervals (average interval about $\frac{3}{4}$-mile). The station spacing was decreased in the Poole Range area, along seismic traverses, and across the Pinnacle Fault.

Each surveyor averaged approximately 14 miles per week for the four months spent in the field. Considerable time was lost because of frequent dust storms, high winds, and resignations of field assistants.

Gravity measurements

A temperature-controlled gravity meter (Western Type G4-A No. 29), with a sensitivity of 0.09665 mgal per scale division, was employed in the survey. The reading accuracy of the meter was approximately $\pm$ 0.01 mgal.

The method employed was to take readings at several consecutive stations along a traverse; then, before going farther, to repeat the readings at the first and last stations occupied. This procedure was then repeated along the traverse. Tie readings were made at traverse intersections. The time interval between repeat readings was usually less than $1\frac{1}{2}$ hours.

An overall average of 35 miles of gravity traverse per week was obtained for the four months of field work. The gravity meter was out of commission for about two weeks during this period.

The observed gravity values were tied to station T45; the observed gravity value adopted for that station was 978,533.2 mgal, determined by the 1953 regional gravity survey from a tie to the Derby pendulum station. The value used for Derby was the then accepted value of 978,516.7 mgal. Since that date the value has been revised and is now accepted as 978,520.3 mgal (Dooley, 1962). Thus, to conform with this datum, all gravity values given in this Record should be increased by 3.6 mgal.

Additional field work, 1954

Results of gravity observations at seismic shot-points which were laid out during 1954 have been included in the gravity maps with this Record. The gravity stations observed in 1954 are numbered SP 201 to SP 328. The meter used was a Worden (No. 61), with a sensitivity of 0.0758 mgal per scale division.

4. REDUCTION OF RESULTS

Determination of Bouguer anomalies

Gravity readings were first corrected for instrument drift. The loop misclosures were then eliminated by the method of least-squares.

To determine the value of Bouguer anomalies relative to the International Ellipsoid, absolute observed gravity values were corrected for elevation and latitude. The Bouguer anomaly contours are shown on Plate 4.

The elevation correction factor of 0.06 mgal/ft, corresponding to a density of 2.2 g/cm^3, was derived by a statistical method, in which the relation between elevation and gravity variations was determined. As elevation gradients were small throughout the area surveyed, a slightly inaccurate correction factor would have no appreciable effect on the Bouguer anomaly contours.

Terrain corrections were not applied, as they were considered to be negligible.

Probable error of Bouguer anomalies

The accuracy of the Bouguer anomaly at a station depends on the accuracy of the observed gravity value and of the elevation and position of the station.

Probable error of the observed gravity values was calculated to be 0.01 mgal per square root mile, the following expression being employed to obtain this figure :

Probable error = 0.67 x standard deviation

$$= 0.67 \sqrt{\frac{\sum(E^2/N)}{n}} \text{ per square root mile}$$

where E = closure error for a loop of length N miles

n = number of loops (37 in this survey).

On all interconnected traverses, after adjustment between resected points, the true position of any station relative to the local trigonometrical system is within a circle of 150-ft radius. Most stations were located more accurately than this, and the relative positions of adjoining stations were more accurate.

Semi-regional traverses, such as that from Virgin Mill to Big Dam Bore, were within the accuracy of plotting at 2 miles to the inch, the relative positions of adjoining stations being correct to within ± 150 ft.

Latitudes, computed from Transverse Mercator co-ordinates, were reliable to within 2 sec, corresponding to 0.03 mgal in the gravity reductions.

An accuracy of elevation of 0.3 ft per square root mile was aimed at, and in most cases was improved upon. This corresponds to approximately 0.02 mgal in the gravity reductions. When the accuracy of gravity observations, latitudes, and elevations is considered, the probable error of the Bouguer values is about 0.04 mgal per square root mile.

Residual maps (Plates 5 and 6)

The values of gravity residuals were determined by a method described by Swartz (1954).

Two different residual maps were derived from the Bouguer anomaly map. To obtain the residuals on Plate 5, the mean value of gravity at eight points, equally spaced around the circumference of a circle of radius 6 miles, was subtracted from the mean value at points around a concentric circle of radius 2 miles. This gave a gravity residual value for the station at the centre of the circles. Gravity anomalies with widths between 20,000 ft and 60,000 ft were emphasised by this residual map. Such anomalies could be expected from pronounced structures with a density discontinuity at depth between about 8000 and 15,000 ft. Very broad features at shallower depths could also be shown.

To extract less extensive gravity anomalies with widths up to 20,000 ft, another set of residuals was determined (Plate 6). The mean value of gravity of eight points equally spaced around the circumference of a circle of radius 2 miles was subtracted from the value of gravity for the station at the centre of the circle, to obtain the gravity residual for that station. Anomalies due to structure deeper than about 5000 ft were suppressed by this process. However, inadequate station density prevented the use of this map for anything but broad interpretation.

5. CONTROL INFORMATION

As no gravity anomaly has a unique solution, information that controls the choice of a physical cause of an anomaly is most important. At the time this Record was written the control information comprised data from geological, aeromagnetic, and seismic surveys, rock density measurements in the area, and previous gravity and seismic surveys in a geologically similar area.

Geological information

The surface geology of the area has been mapped, (Guppy et al. 1958) and a stratigraphic bore (Henderson, 1956) penetrated the outcropping Ordovician rocks at Prices Creek. In the vicinity of the Poole Range, however, little is known of the subsurface geology. The deepest bore, Poole Range No. 3 (3264 ft), penetrated only Permian sediments, and it is not known whether there are Ordovician and Devonian sediments beneath the Permian sequence in the deeper part of the Basin, south of the Pinnacle Fault.

Seismic information

In 1953 a Bureau seismic party worked in the area between Prices Creek and Poole Range. Unfortunately, no reflections were recorded near the axis of the Poole Range structure, and subsurface information there will be difficult to obtain. The following conclusions were made on the basis of the seismic results (Smith, 1955):

(a) North of the Pinnacle Fault the sedimentary sequence is probably comparatively thin. This is indicated by lack of reflections in this region, and also by the presence of a refractor with a high velocity of 19,950 ft/sec at a depth of 1700 ft beneath Traverse Z in the Ordovician outcrop. It is estimated that 800 ft of the known section of Ordovician rocks is present here. If the high-velocity refractor represents Precambrian rocks, there is thus a further 900 ft of Ordovician sediments below the known sequence.

(b) South-west of the Pinnacle Fault the reflections obtained suggest a sedimentary sequence of approximately 20,000 ft.

(c) On the northern flank of the Poole Range structure, between Christmas Creek and the Pinnacle Fault, there is general conformity between near-surface beds and deeper beds down to a depth of about 8000 ft.

(d) North-east of station A 9.5 within the Talbot Syncline, the beds are conformable in cross-section below Traverse A to 13,000 ft. Closer to the Poole Range structure, however, near the junction of Traverses A and T there is an unconformity between the beds above 8000 ft and those below. At Station A 11.0 the true dip can be calculated from known components along Traverses A and T, giving 3½ degrees east-south-east at 5000 ft and 10½ degrees east at 10,000 ft.

Williams (1956) continued seismic work in the area south-west, south, and east of the Poole Range and concluded that:

> 'The results obtained confirm the surface information and show the existence of an anticlinal structure, the axis of which plunges to the east and whose axial plane probably dips to the south. A total thickness of sediments of the order of 20,000 ft is shown'.
>
> 'Some slight evidence of deep faulting down to 10,000 ft was recorded but is not conclusive'.

Williams found no evidence for the unconformity at 8000 ft, found by Smith, but he did note a sudden reduction in the number of reflections beneath this depth and assumed a facies change.

Smith (1957) later did a seismic refraction survey in the Christmas Creek area. The most relevant conclusion affecting the gravity interpretation was that a definite unconformity located at 7100 ft beneath the Talbot Syncline was assumed to be at the base of the Permian formations.

Aeromagnetic traverse

Quilty (1960) described results of a reconnaissance aeromagnetic survey of the Canning Basin. Traverse 11R of the survey passed approximately over Mt Hutton and between cross-sections BB' and CC' (see Plate 4). A clear magnetic anomaly is associated with the Pinnacle Fault zone and it was calculated that basement depth north of this zone is less than 3500 ft; south of the zone it is less than 20,000 ft.

Density determinations

Density data are listed in Table 1. Probably the greatest uncertainty lies in the selection of 'basement' density for use in gravity interpretation. The Precambrian Lamboo Complex, which crops out in the Virgin Hills, consists of a variety of rock types whose density could range between 2.65 and 3.05 g/cm^3, e.g. acid intrusives to basic volcanics (see Stott and Lngron, 1959). An average basement density of 2.73 g/cm^3 was assumed, as this value has been found to be typical for large Precambrian area. The density contrasts adopted between the Precambrian and younger, less dense rocks, and used for the interpretations which follow, are:

Permian	0.24	g/cm^3
Carboniferous	0.11	"
Devonian	0.14	"
Ordovician	0.13	"

Previous gravity surveys

A gravity survey was made in the Nerrima area (Wiebenga and van der Linden, 1953) during 1952. Conclusions from the result of that survey were that the surface structure of the Nerrima Dome is not similar to the deeper sub-surface structure and that there is possibly 'skin folding' of Permian sediments in the area.

Results of the regional survey and a semi-detailed survey at Grant Range were unpublished when this Record was written.

6. RESULTS AND INTERPRETATION

In gravity interpretations the word 'basement' is commonly employed. In the present report the term is used to mean 'higher-density formation'; it implies only a change in density at the surface of a formation whose age is not necessarily known. In this area the basement is probably Cambrian or Precambrian. However, there is no certainty that within the Basin at great depth Ordovician or younger rocks are less dense than these supposed basement rocks.

Bouguer anomaly map

The following features are prominent on the map showing the Bouguer anomalies (Plate 4):

(a) The Virgin Fault anomaly. The anomaly caused by this fault is clearly seen on the Plate in the north-eastern area of the survey, south of the Virgin Hills. The trend of the anomaly is parallel to the surface indication of the fault (Plate 3) but is displaced slightly south. This displacement is possibly due to the inaccuracy of the geological mapping, to the presence of dense reef limestones which abut the Precambrian inlier, to a southerly fault dip, or to multiple faulting.

The gravity anomaly indicates that the Devonian sediments are thrown down about 7000 ft by the fault (with a down-to-the-south movement) north of Virgin Mill.

(b) The Pinnacle Fault anomaly. This anomaly is the most conspicuous feature of the Bouguer anomaly map. The surface trace of the Pinnacle Fault, where mapped, coincides with the zone of maximum gradient of the anomaly. This suggests vertical dip of the fault plane. The anomaly strikes about 30 degrees north of west and extends from Bohemia Downs Homestead to about six miles east of Cherabun Homestead. To the north-west the throw diminishes, and east of Cherabun the fault either swings north or discontinues. A preliminary regional gravity map which includes the area north-east of Cherabun did not show an extension of the anomaly, but this may have been because the anomaly was diminished and the regional survey did not show sufficient detail. It is difficult to form an opinion on the nature of the Pinnacle Fault to the south-east near Bohemia Downs Homestead, because of the lack of gravity stations in that area. However, the fault anomaly apparently diminishes to the south-east.

Figures 1 to 4 (Plate 7) illustrate the profiles along Traverse A and cross-section lines AA', BB', and CC'. Figure 5 (Plate 7) shows likely basement depths north and south of the Pinnacle Fault and indicates the throw of the fault at the above cross-sections.

The method of Bancroft (1960) was used to calculate the depths to basement adjacent to the fault on the up-thrown side. This method assumes a vertical fault plane. The requirements are a knowledge of maximum horizontal gravity gradient (U_{xz}), the total change in gravity anomaly (Δg), and an idea of the density contrast. In the case of a step-like body due to faulting, the following equations are employed:

$$d_o = 0.315\Delta g/U_{xz}$$

$$D = \frac{t}{\exp(t/d_o)-1}$$

$$t = \Delta g/12.78\Delta d$$

d_o is the maximum possible depth to the top of the anomaly-producing body

D is the depth to the top of the step-like body

Δd = density contrast

t = fault throw (in kilofeet)

The throw of the fault was calculated on the assumption that the density contrast at the fault plane was 0.24 g/cm^3 (the Permian - Precambrian contrast), as seismic and geological evidence show that a large part of the sequence is probably Permian south of the Fault. The actual contrast could be lower than this (and the calculated fault throw greater) due to the slightly higher density of pre-Permian formations which may exist at the foot of the Pinnacle Fault and to the south.

To check these calculations of throw and depth to basement on the up-thrown area, curves were drawn of gravity anomalies due to density contrast over vertical fault planes which nearly crop out at the surface. These were derived from the curves of Nettleton (1940) for a thin slab approximating a fault. The effects of several successively thinner and shallower slabs were added to obtain the desired anomaly. Gravity profiles for faults in which the up-thrown basement nearly crops out were also drawn using dot charts, and these profiles were similar to those using the extension of Nettleton's method. From these curves the relation between 'quarter-wdith' (i.e. the distance between the point where the gravity anomaly is 0.5Δg and the point where it is 0.25Δg or 0.75 Δg) and depth to centre of the fault plane was established and used to check the values which are shown in Plate 7.

The Pinnacle Fault parameters used for plotting Fig. 5 of Plate 7 are as follows:

Cross-section	Δg (mgal)	U_{xz} (mgal/ mile)	Mean $\frac{1}{4}$ width (mile)	Δd (g/cm^3)	t (ft)	D (ft)
AA'	36	18	1.0	0.24	12,000	350
Trav. A	32*	15½*	0.8	0.24	10,000	1100
BB'	26	10	0.8	0.24	8500	1400
CC'	20	8	1.0	0.24	6600	1700

* Corrected for effect of localised 'basement' density increase

Thus it may be seen that the Fault has it maximum throw (12,000 ft) near Pinnacle Yard, but the basement is very shallow (350 ft) north of the fault. To the west-north-west the down-thrown basement shallows slightly or may be fairly level, depending on the density distribution assumed. In this direction, however, the basement north of the fault gradually deepens to 1700 ft at cross-section CC'. The estimate of basement depth in this region, on the basis of the aeromagnetic profile, was less than 3500 ft; thus the gravity and magnetic interpretations do not conflict. The structure south-east of Pinnacle Yard is not known except that the fault there probably has a smaller throw.

(c) Other anomalies. Apart from the Pinnacle Fault and Virgin Fault anomalies, others of interest are the extensive negative anomaly south of the Poole Range, the positive anomaly passing through stations A3.0 and Z4.0, and a minor anomaly caused by the Cadjebut Fault at the southern margin of the Ordovician outcrop.

The lowest Bouguer values of the area surveyed are south-west of Middle Bore, and it is likely that the deepest part of the Basin is situated there. If this zone of negative anomalies is caused by relatively light sediments within a syncline, their thickness is about 20,000 ft. There is no obvious anomaly caused by the Poole Range structure. Similarly, the gravity survey of the Nerrima Dome (Wiebenga and Van der Linden, 1953) indicated that the surface anticlinal structure there does not cause a distinct anomaly. That survey also showed that there is am extensive gravity 'low' associated with the major syncline north-west of the Nerrima Dome, but south of the Poole Range the geology has not been mapped in sufficient detail to ascertain whether the syncline suggested by the gravity 'low' is evident at the surface.

The long, narrow, positive anomaly centred along the southern edge of the Ordovician outcrop has a maximum Bouguer value about 8 mgal higher than that at the nearest Precambrian outcrop at the Virgin Hills. Because of the near-coincidence of the anomaly with the Ordovician outcrop, the Ordovician formations may appear to be a possible cause of the anomaly. However, if the full sedimentary sequence is about 3000 ft thick as suggested by seismic and subsequent drilling evidence, an average density of 3.1 g/cm^3 would be required to cause the gravity anomaly. There is no evidence to suggest such a high density for Ordovician rocks. The maximum of the anomaly would also be situated farther north if the anomaly were due to a maximum thickness of these sediments.

It is most likely therefore that the anomaly is caused either by a dense Cambrian or Precambrian residual or by a basic intrusive body. The actual anomaly is difficult to isolate because of the very high gravity gradients to the north and south, and mathematical analysis was not used as an aid to interpretation.

On the profiles of Traverse A and cross-sections BB' and CC' of the Pinnacle Fault anomaly, a small fairly sharp change in gravity gradient is evident on the northern side of the Pinnacle Fault. This minor anomaly is apparent on Plate 7 (Figures 1, 2, and 3). A similar anomaly is also present near station R6-12 (north of No. 1 Outcamp). On Traverse A this small anomaly coincides with the Cadjebut Fault, which runs along the southern boundary of the Ordovician outcrop. By removing the regional effect a local anomaly of magnitude approximately 4 mgal was derived, and therefore a fault with a down-throw of about 1000 ft on the southern side could be expected if the density contrast was 0.3 g/cm^3. Indications are that the basement density is high in this region, so that the density contrast would be higher than normal.

Should the anomalies seen at each cross-section be due to a common fault zone then the trace of the zone would be from between R1/39 and R1/40 (north-east of Pinnacle Yard) and A3.25, J16, and R6/12 (see Plate 3). The postulated extension of the Pinnacle Fault near No. 1 Outcamp and to the north-west, as shown by Guppy et al. (1958), may be in fact an extension of the Cadjebut Fault.

Residual maps

The residual anomalies are shown for the area lying mainly south of the main Fitzroy Crossing-Halls Creek road. Farther north the residual pattern would be dominated by the effects of the Pinnacle Fault anomaly.

The residual map of most interest is that on Plate 5, as the anomalies shown there are due to extensive, possibly deep-seated, structures. The effects of minor surface structures are eliminated in this map. Three large negative anomalies are centred near stations R5/1, C21 and R2/14, which lie close to the axis of the Poole Range-Mount Hutton Structure. An elongated, positive anomaly extends from Station G12, near Surprise Bore, to Station H4 and then north through Mount Hutton to Station R3/5. A second elongated positive anomaly is centred near Station C5 and trends north-north-west.

On the assumption that sedimentary rock density increases with depth there is no simple correlation between the residual pattern and the anticlinal structures mapped at the surface. The positive anomalies coincide with the anticlinal crests, but their trend is north-north-west across the anticlines and parallel to the fracture pattern at the surface. Thus the residual anomalies could be due to faulting, with up-thrown blocks crossing the anticlinal structure and forming the anticlinal crests of the Poole Range-Mount Hutton structure. Such faults would have a throw of about 1000 ft with assumed density contrast of 0.2 g/cm^3. As there is no surface evidence of faults with throws of this magnitude, the gravity evidence indicates either an increase of throw with depth of faults visible at the surface or the existence of buried faults. Williams (1956) also suspected buried faults, on seismic grounds.

Another possibility is that the anomalies are caused by undulations of the surface of a formation having a relatively high density. For example, seismic results showed unconformities at depths of approximately 8000 ft and 13,000 ft, and the residual map possibly represents the shape of one of these surfaces of unconformity.

Although a density increase with depth is to be normally expected of sedimentary rocks, there is evidence of density decreases with depth in the Fitzroy Basin. The Grant Range No. 1 Bore density log showed a zone of low densities within the Permian sequence, and the presence of rock salt in the western Kimberley region Frome Rocks bores showed that relatively light concentrations of rock salt could exist elsewhere in the Basin. Should either type of low-density zone occur beneath the Poole Range region, the interpretation of the residual map (Plate 5) is somewhat attractive.

The large, almost circular negative residual anomaly centred on the anticline axis at Station C21 could represent the structural centre of the Poole Range-Mount Hutton area. This negative anomaly is one of the dominant features of the residual map and, as it also coincides with the centre of the outcrop area of the Permian Grant Formation, it seems possible that the Poole Range and Mount Hutton structures are two subsidiary parts of a larger structure centred midway between the two. The negative anomaly is almost surrounded by positive anomalies, which is also indicative of a relatively low-density sequence. Should the negative anomaly centred at Station C21 represent the structural centre, the surrounding positive and negative anomalies would be caused by the changes in gravity gradient on the flanks of the structure.

The residual map presented on Plate 6 is included in this Record only to give an idea of how useful a similar map would be if the network of gravity stations were more detailed. Some minor structures seen at the surface seem to be represented on the map. The Poole Range structure is crossed by a system of small northerly-trending faults. These faults could possibly be traced by a detailed gravity survey, but by semi-detailed work this is impossible. However, remembering that the effect of a fault is to give positive and negative residual anomalies parallel to the fault, correlation between the trend of the residual gravity anomalies and the trend of surface faulting may be seen. It is interesting to note that the small residual anomaly near Station 10.0 on Traverse A coincides with a small anticlinal structure found by the seismic survey but not noted on the geological map.

7. CONCLUSIONS

Wherever possible the conclusions are illustrated on Plate 3. The information of most consequence gained from the survey is that regarding the trace to the north-west of the Pinnacle Fault, which probably dies out east or north-east of Cherabun Homestead. The fault zone strikes south-east to Bohemia Downs Homestead as indicated by geological mapping.

In the area of maximum throw of the Pinnacle Fault, i.e. near Pinnacle Yard, it is estimated that there is at least 12,500 ft of sediments immediately south of the fault. These may include Permian, Carboniferous, Devonian, and Ordovician sediments. On the up-thrown side of the Fault, indications are that a pre-Ordovician high-density formation is near the surface (350 ft) in the region of Pinnacle Yard, but to the north-west along the Fault the higher-density formation apparently deepens slightly and the fault throw decreases. The basement depth of the foot of the fault appears to be reasonably uniform at about 12,000 ft, but may become shallower west-north-west of Pinnacle Yard.

Within the Basin, south-west of the Pinnacle Fault, sediments may thicken to the south with a maximum thickness of about 20,000 ft south of the Poole Range. The Poole Range structure is not associated with a pronounced gravity anomaly.

The residual pattern on Plate 5 may represent the structure of a pre-Permian formation having a north-north-westerly structural trend. Faults or folds parallel to the faults mapped at the Poole Range may be present in this formation. Faulting of Permian formations with increased throw at depth is also a possibility. On the other hand, should a density decrease occur beneath the Poole Range-Mount Hutton area, the gravity residuals indicate that there is a structure centred between Mount Hutton and the Poole Range (Station C21). This interpretation should be checked by other methods, as negative gravity anomalies could be associated with many anticlinal structures in the Fitzroy Basin.

The residual map on Plate 6 indicates that if a detailed gravity survey were made, a similar map may be of use in the determination of shallow structural trends in the Permian formations.

The throw of the Virgin Fault was found to be approximately 7000 ft. This may not be a simple fault.

The Cadjebut Fault along the southern margin of the Ordovician outcrop has a throw of about 1000 ft at Traverse A. This fault probably extends from one mile north of No. 1 Bore to about 3 mile north-east of Pinnacle Yard, a distance of 30 miles.

The positive gravity anomaly in the Prices Creek region (near the junction of Traverses Z and A) is probably due not to a structural 'high', but to a very dense body within the 'basement'.

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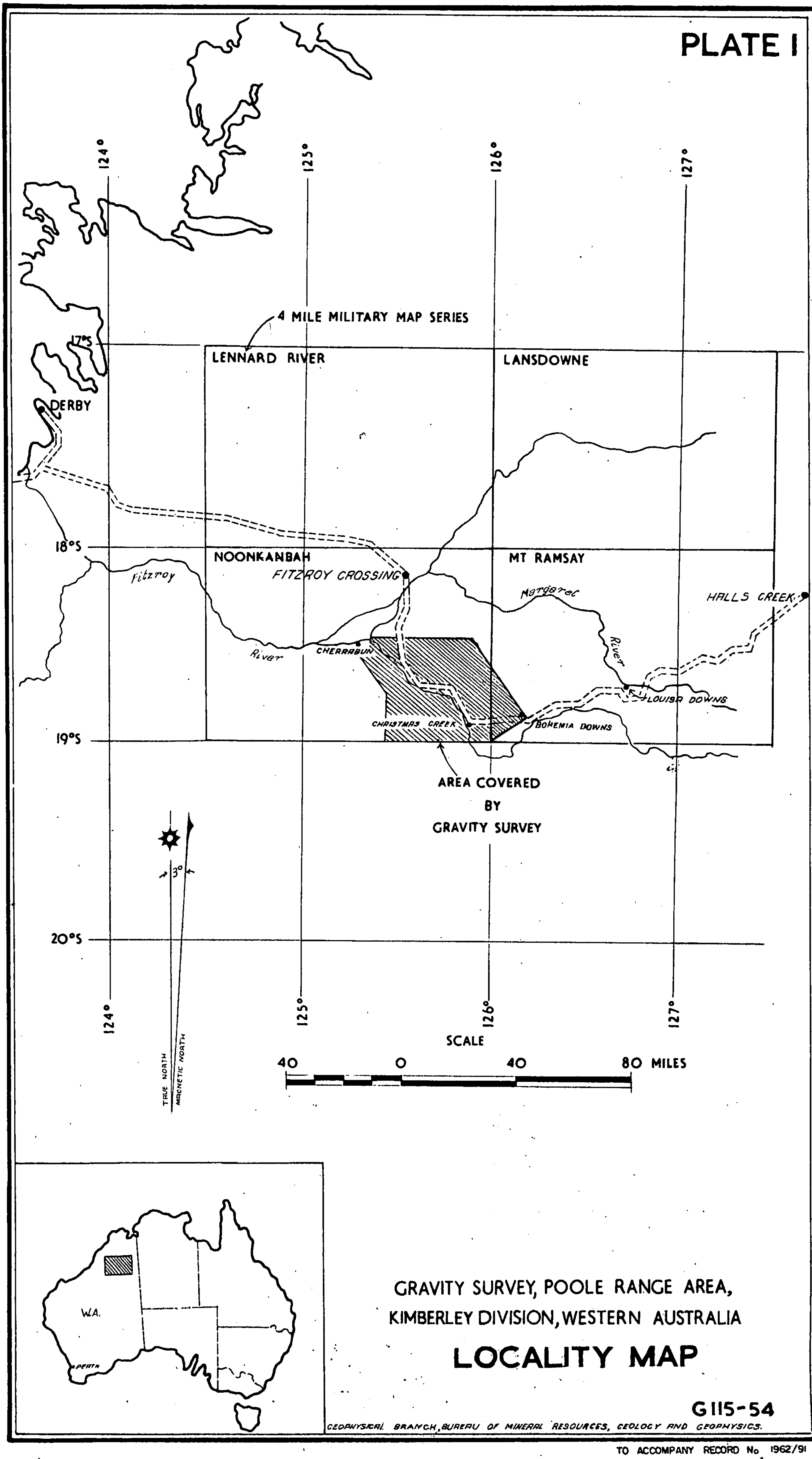
TABLE 1

ROCK DENSITY MEASUREMENTS OF FITZROY BASIN REGION, WESTERN AUSTRALIA.

Interval (ft)	Formation	Density dry g/cm^3	Number of Samples	Estimated wet density g/cm^3
BMR No. 2 Bore				
30 - 178	Permian (Grant)	2.28	2	2.38
178 - 1420	Lower Carboniferous	2.55	13	2.60
1420 - 4000	Upper Devonian	2.51	25	2.56
BMR No. 3 Bore				
0 - 593	Ordovician	2.38	6	2.48
593 - 694	Hart basalt or Mornington Volcanics and Lamboo Complex	2.74	4	2.74
Selected outcrop samples from Poole Range area				
	Permian (post-Grant)	2.20	10	2.30
	Upper Devonian	2.60	11	2.65
	Ordovician	2.61	10	2.65
Nerrima No. 1 Bore				
0 - 2200	Permian (post-Grant)	2.30	15	2.40
2200 - 4271	Permian (Grant)	2.53	14	2.58
Grant Range No. 1 Bore				Measured wet density
0 - 1000	No measurements of density			
1000 - 2000	Permian (Grant)	2.55	4	2.55
2000 - 3000	" "		4	2.50
3000 - 4000	" "		2	2.38
4000 - 5000	" "		4	2.43
5000 - 6000	" "		4	2.55
6000 - 7000	?		19	2.55
7000 - 8000	?		9	2.60
8000 - 9000	Upper Carboniferous		7	2.64
9000 - 10,000	" "		10	2.67
10,000 - 11,000	" "		3	2.55
11,000 - 12,000	" "		4	2.59
12,000 - 13,000	" "		10	2.66

PLATE I



GRAVITY SURVEY, POOLE RANGE AREA,
KIMBERLEY DIVISION, WESTERN AUSTRALIA

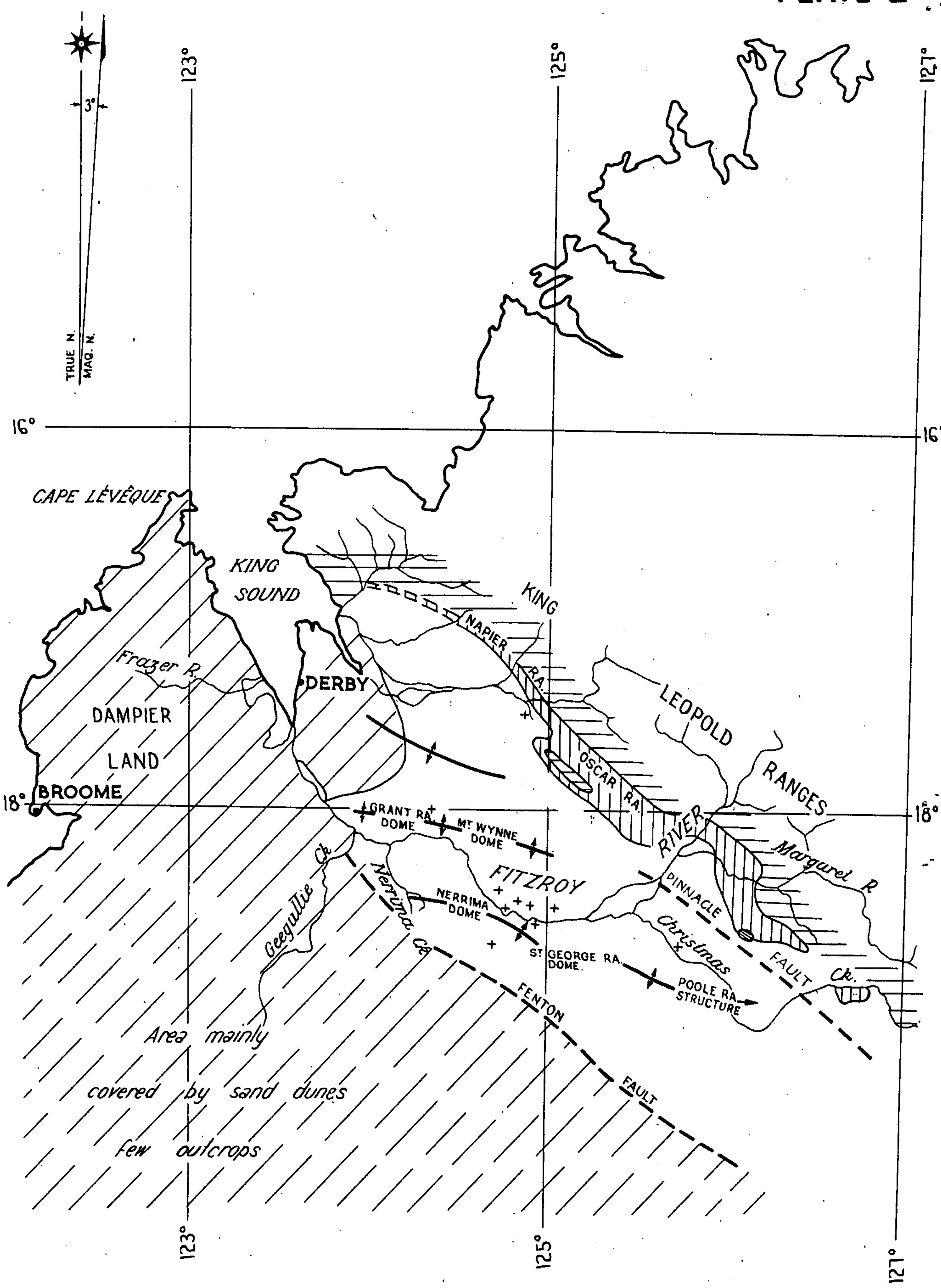
LOCALITY MAP

G115-54

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

TO ACCOMPANY RECORD No. 1962/91

PLATE 2



LEGEND

- MESOZOIC
- PERMIAN
- DEVONIAN
- ORDOVICIAN
- PRE-CAMBRIAN
- \+ TERTIARY LEUCITITES
- — — REGIONAL FAULTS
- MAJOR ANTICLINES

GRAVITY SURVEY, POOLE RANGE AREA,
KIMBERLEY DIVISION, WESTERN AUSTRALIA.

GEOLOGICAL SKETCH MAP

INFORMATION PROVIDED BY GEOLOGICAL BRANCH
BUREAU OF MINERAL RESOURCES

SCALE

0 20 40 60 80 100 MILES

G115-33

Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics

TO ACCOMPANY RECORD No 1962/91

TO ACCOMPANY RECORD Nº 1962/91

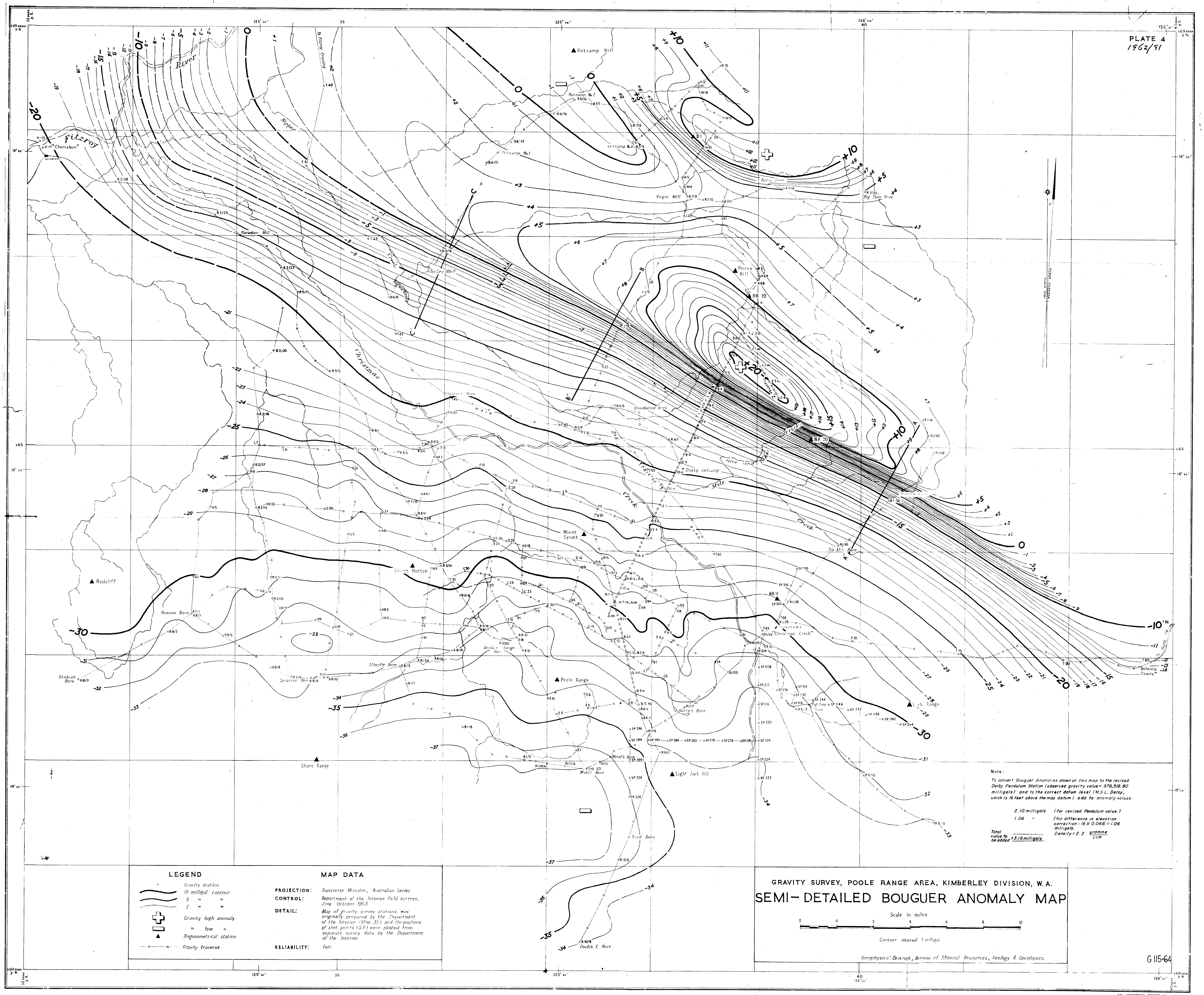


PLATE 4
1962/91
GRAVITY SURVEY, POOLE RANGE AREA, KIMBERLEY DIVISION, W.A.
SEMI-DETAILED BOUGUER ANOMALY MAP
Scale in miles
Contour interval 1 milligal
Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics.
G 115-64
LEGEND
Gravity station
10 milligal contour
5 " "
1 " "
Gravity high anomaly
" low "
Trigonometrical station
Gravity traverse
MAP DATA
PROJECTION: Transverse Mercator, Australian Series.
CONTROL: Department of the Interior field surveys, June - October 1953
DETAIL: Map of gravity survey stations was originally prepared by the Department of the Interior (Misc. 35) and the positions of shot points (S.P) were plotted from separate survey data by the Department of the Interior.
RELIABILITY: Fair.
Note:
To convert Bouguer Anomalies shown on this map to the revised Derby Pendulum Station (observed gravity value = 978,518.80 milligals) and to the correct datum level (M.S.L. Derby, which is 16 feet above the map datum) add to anomaly values:
2.10 milligals (for revised Pendulum value)
1.06 " (for difference in elevation correction: 16 X 0.066 = 1.06 milligals.
Density = 2.2 gramme/ccm
Total value to be added +3.16 milligals
Fitzroy
River
Christmas
Creek
Outcamp Hill
Pricks Hill
NK 19
NK 20
NK 11
Mount Synott
Mount Hutten
Redcliff
Poole Range
Light Jack Hill
Shore Range
Paradise Mill
Turkey Well
Virgin Mill
Dusty Outcamp
Six Mile Bore
Rexona Bore
Alberts Bore
Barry's Bore
Yard Bore
Double E Bore
Bohemia Downs
Big Dam Bore
Lark Range
TO ACCOMPANY RECORD No 1962/91

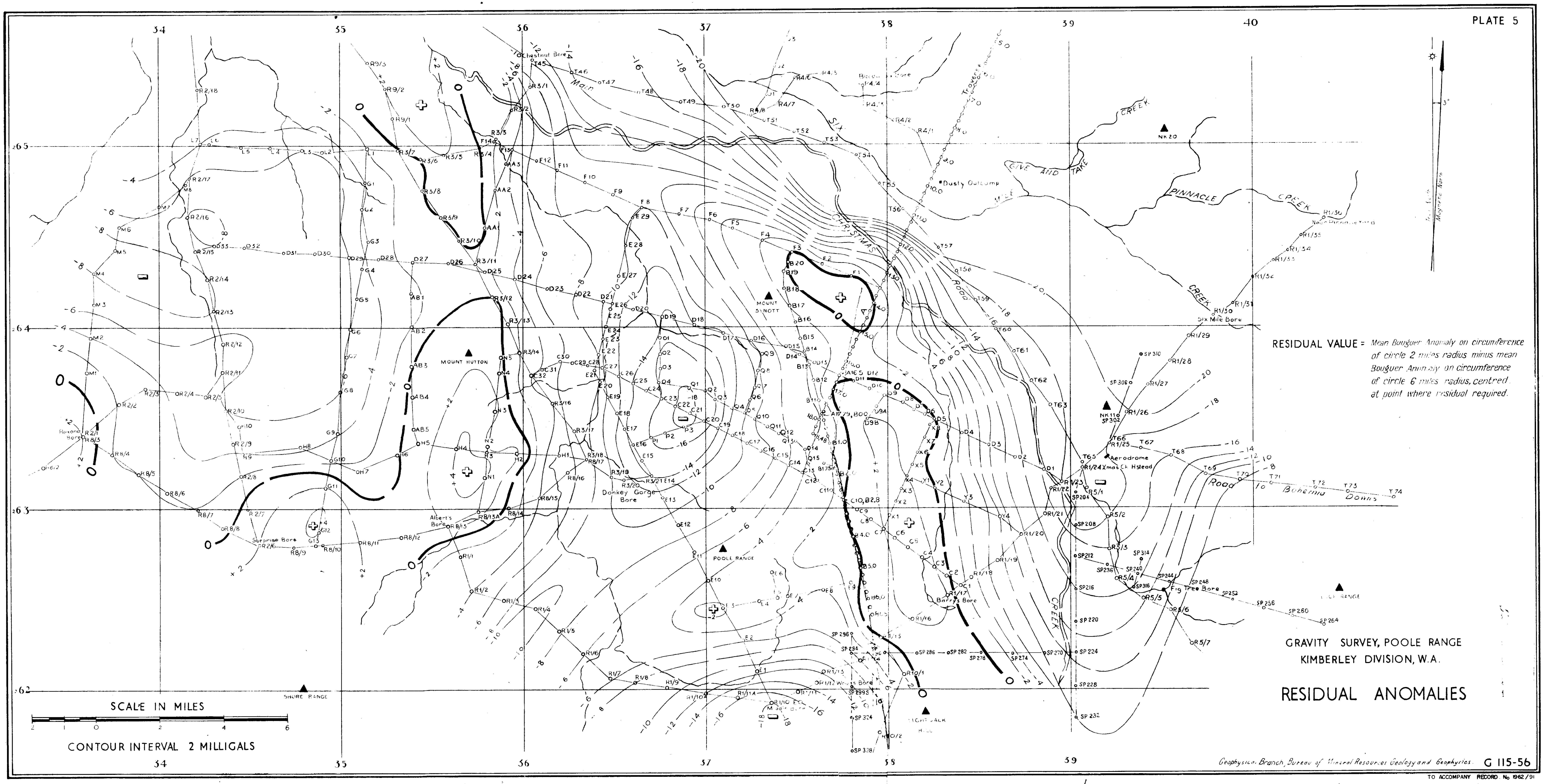
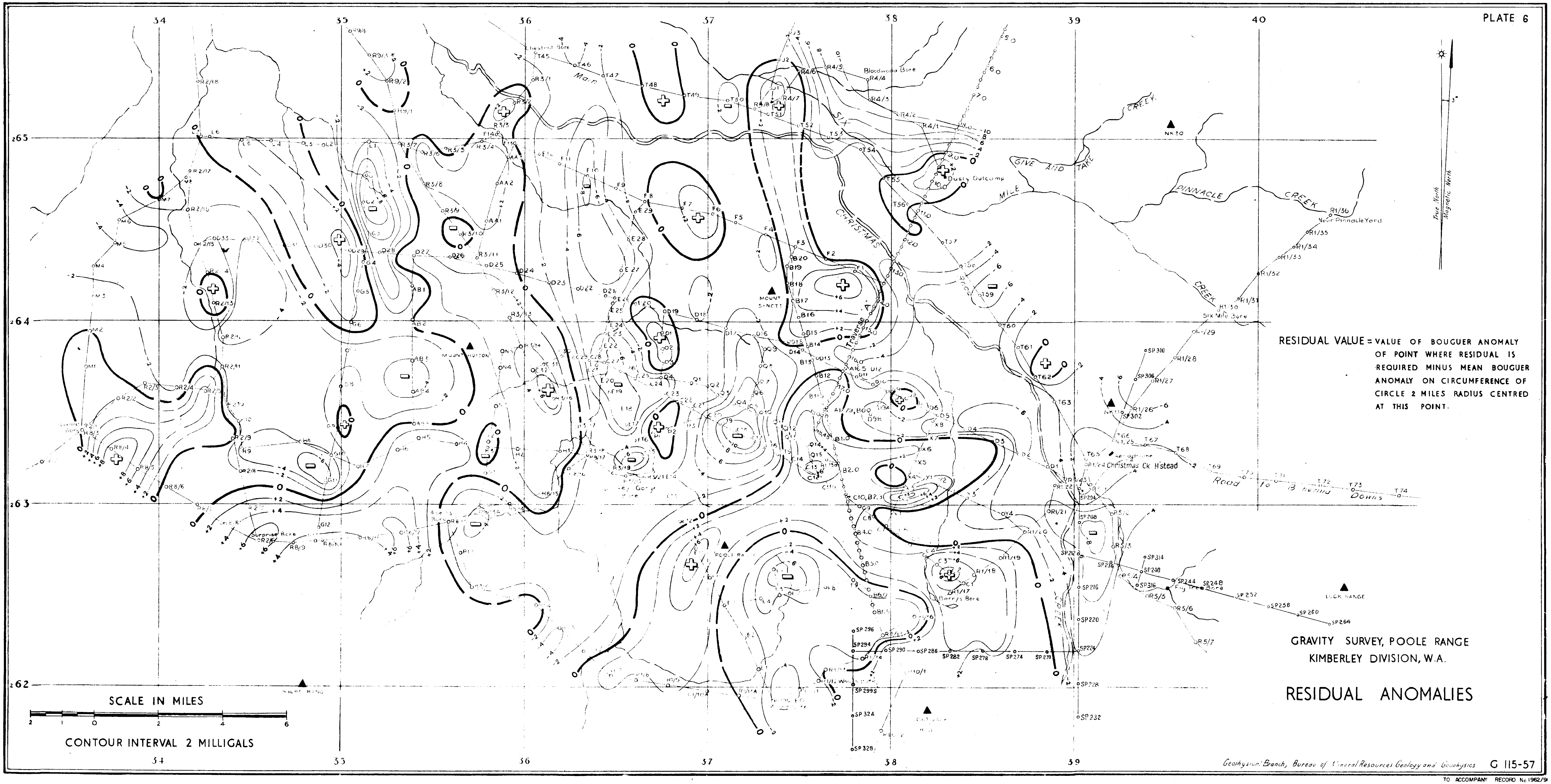


PLATE 5
RESIDUAL VALUE = Mean Bouguer Anomaly on circumference of circle 2 miles radius minus mean Bouguer Anomaly on circumference of circle 6 miles radius, centred at point where residual required.
GRAVITY SURVEY, POOLE RANGE
KIMBERLEY DIVISION, W.A.
RESIDUAL ANOMALIES
SCALE IN MILES
CONTOUR INTERVAL 2 MILLIGALS
MOUNT HUTTON
MOUNT SYNOTT
POOLE RANGE
SHORE RANGE
NK 20
Chestnut Bore
Dusty Outcrop
Six Mile Bore
Aerodrome
Xmas Ck Hstead
Donkey Gorge Bore
Albert's Bore
Surprise Bore
Barry's Bore
Fig Tree Bore
GIVE AND TAKE CREEK
PINNACLE CREEK
SIX MILE CREEK
CHRISTMAS CREEK
Bohemia Downs Road
Geophysical Branch, Bureau of Mineral Resources Geology and Geophysics.
G 115-56
TO ACCOMPANY RECORD No 1962/91



TO ACCOMPANY RECORD No 1962/91

FIG. 1
SECTION ALONG TRAVERSE A

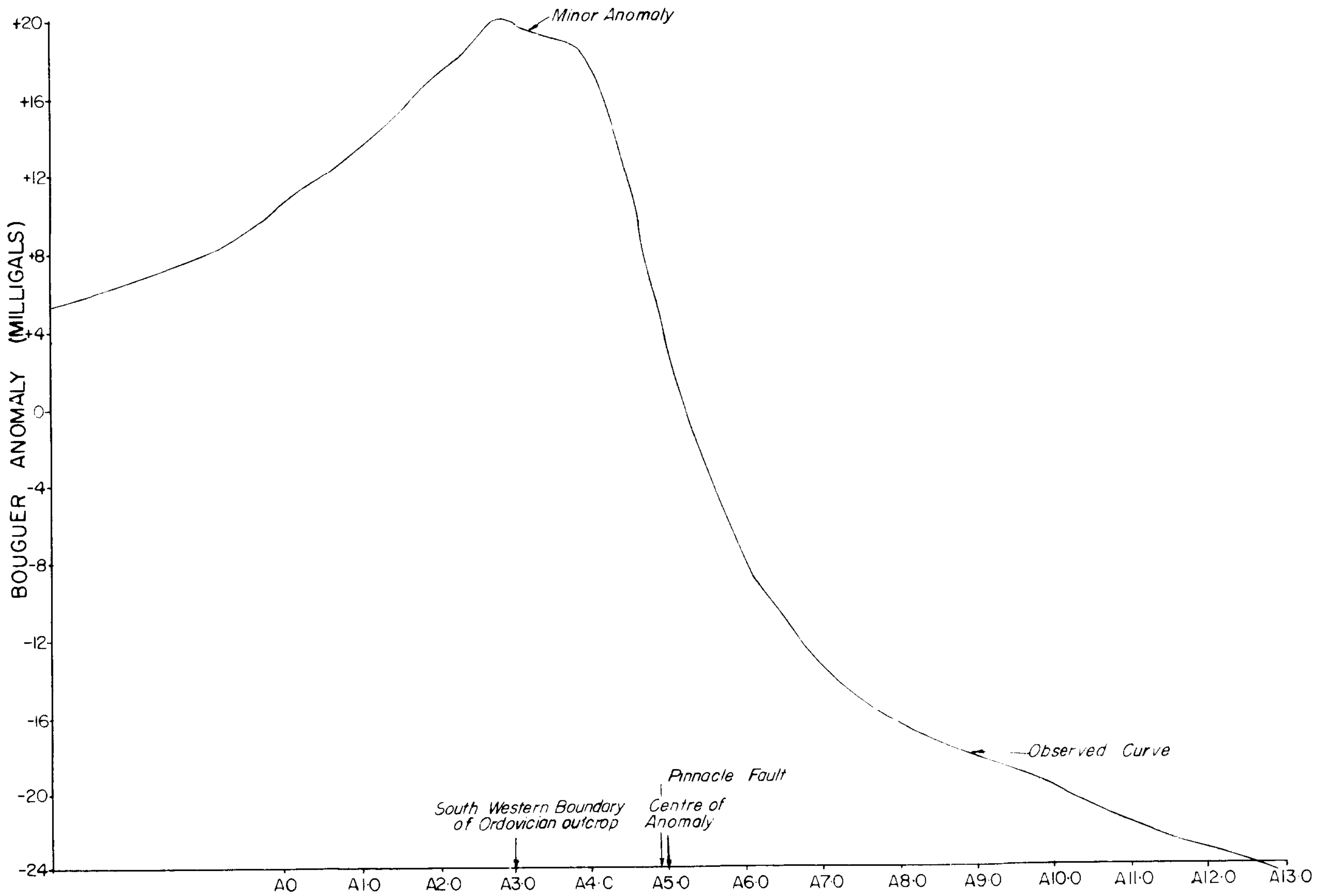


FIG. 2
SECTION ALONG AA'

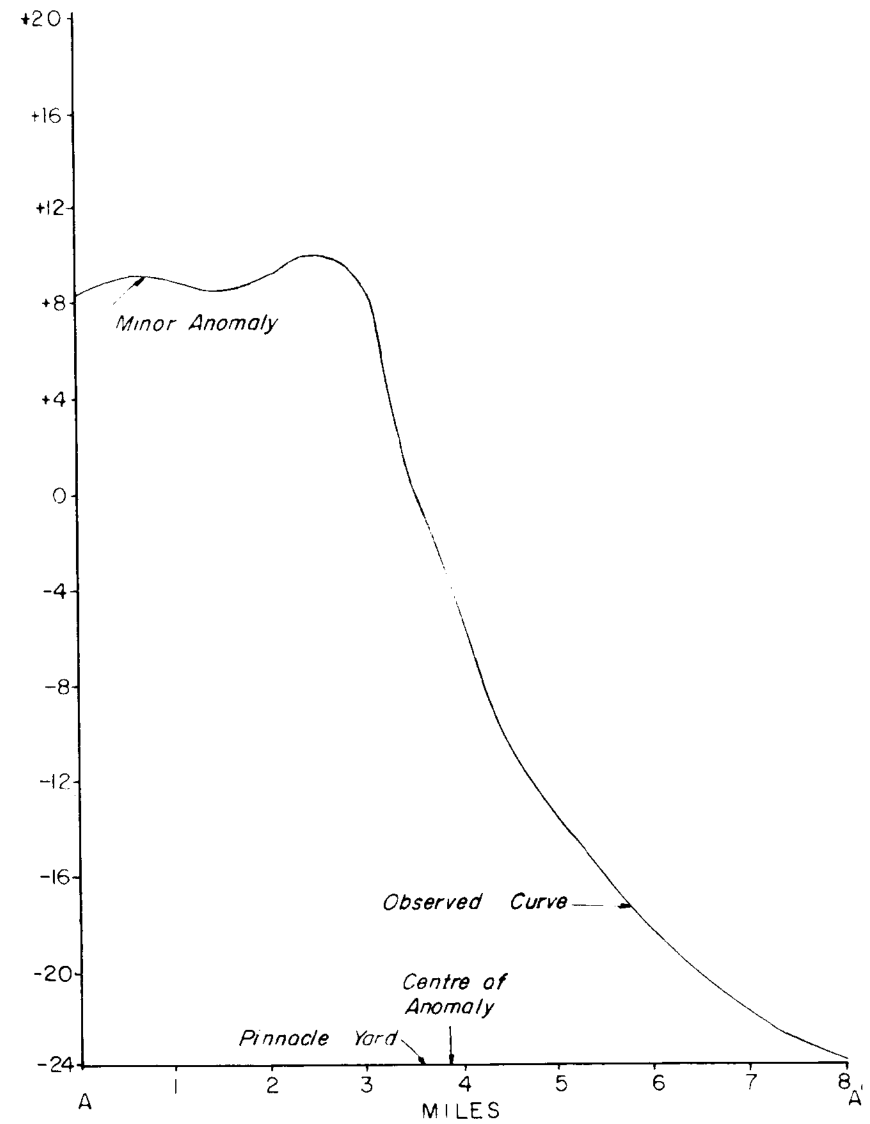


FIG. 3
SECTION ALONG BB'

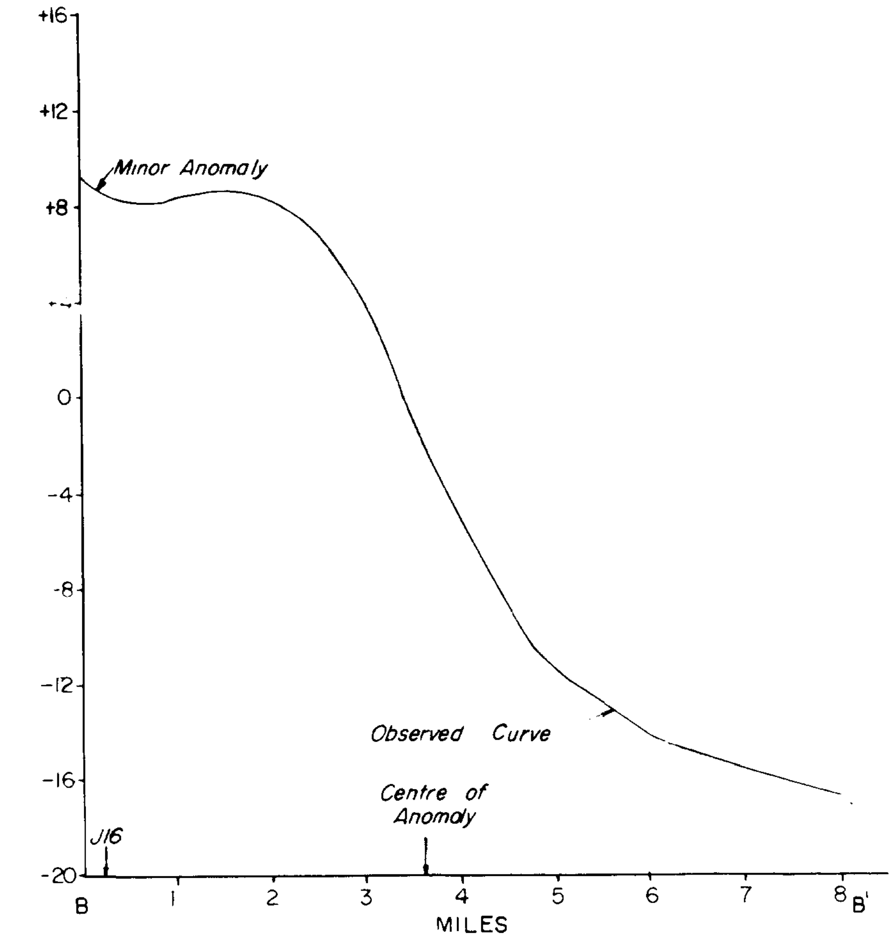


FIG 4
SECTION ALONG CC'

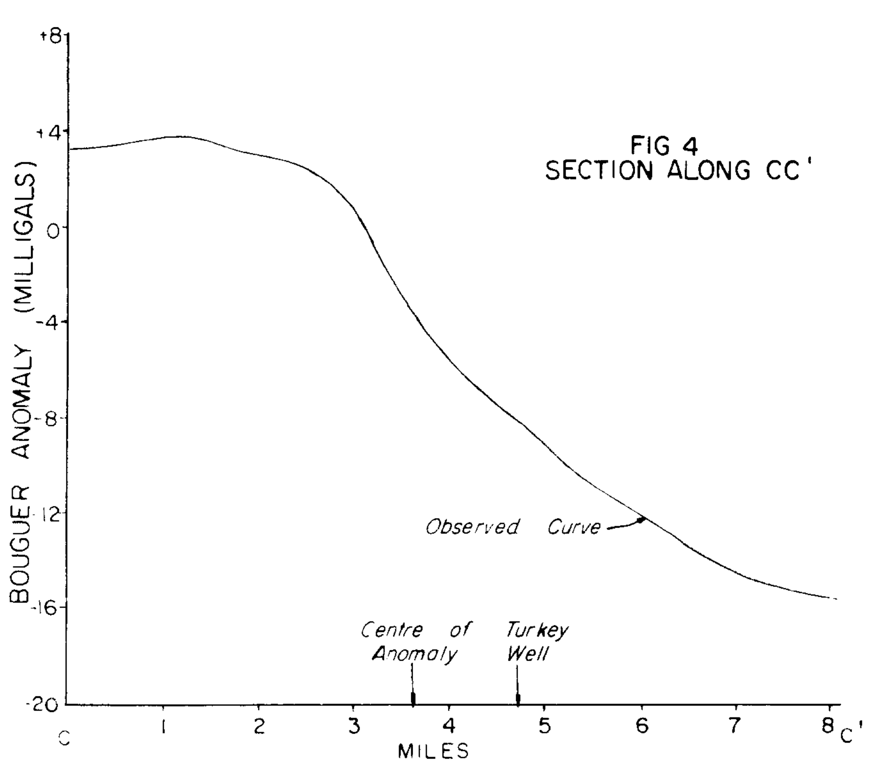


FIG. 5A

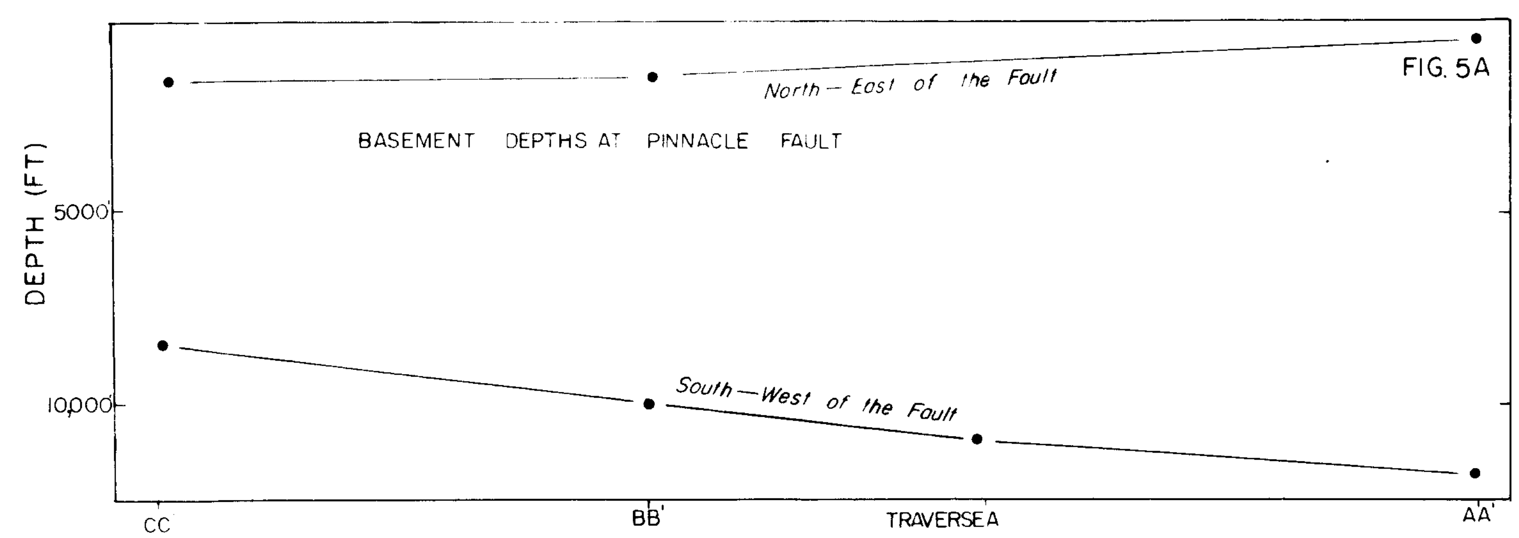
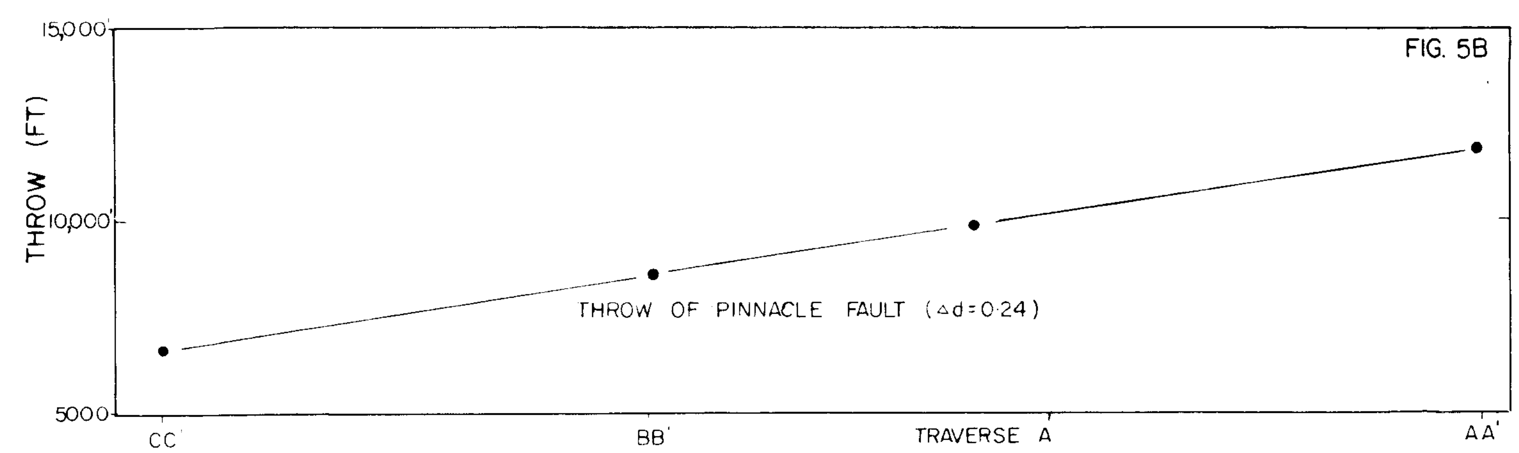


FIG. 5B



GRAVITY SURVEY, POOLE RANGE,
KIMBERLEL DIVISION, W.A.

PINNACLE FAULT GRAVITY ANOMALY