Section

DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
EXPLORATION SERVICES DIVISION

NOTES ON AEROMAGNETIC AND GRAVIMETRIC INTERPRETATION OF THE OTWAY BASIN

by

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SR.11/5/123

9th June, 1967

DEPARTMENT OF MINES
SOUTH AUSTRALIA

A GRAVITY INTERPRETATION OF THE WESTERN OTWAY BASIN WITH NOTES ON AEROMAGNETIC INTERPRETATION

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PLAN REFERENCES

Plan No.	Title	Scale
66-490?	Bouguer Anomaly Map	1:500,000
L66-54/6	Composite Regional Gravity Effect	1:500,000
L66-55/6	Residual Gravity Contour Plan	1:500,000
L66-56/6	Composite Gravity Interpretation Map	1:500,000
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	Isobath Contours of the Magnetic Basement and intermediate Horizon.	1:500,000

Rept.Bk.No.
G.S. No.
D.M. No. ? None.

19th December, 1968.

DEPARTMENT OF MINES
SOUTH AUSTRALIA

Rept.Bk.No.
G.S. No.
D.M. No. 9

A GRAVITY INTERPRETATION OF THE WESTERN OTWAY BASIN WITH NOTES ON AEROMAGNETIC INTERPRETATION

ABSTRACT

From Bouguer Anomaly Maps of the western onshore portion of the Otway Basin, a Residual Gravity Map has been constructed from which the subsurface Geological structure is interpreted to give good agreement with known Geology.

The area is one of complex gravity features in which a major increase of regional gravity towards the coast is interpreted as being from intra-basement, and in which several Bouguer anomalies are interpreted as intra-basement intrusions.

The correlation of anomalies of aeromagnetic and gravimetric onshore surveys in the Western Otway Basin and offshore aeromagnetic surveys of the Otway Basin generally, is discussed.

The two geophysical methods delineate the subsurface structure in the onshore Western Otway Basin, whereas, only the northern limits near Cape Jaffa and the eastern limits near King Island of the offshore portion of the basin are defined by the aeromagnetic method.

INTRODUCTION

The Gravity area interpreted is the western portion of the Otway Basin between Cape Jaffa in South Australia and Warrnambool in Victoria, covering an onshore area of approximately 9,000 square miles. The area consists essentially of

a broad peneplain gently rising to the northwest with the natural surface broken by a series of calcareous sand dunes and a few volcanic cones.

Four Bouguer Anomaly Maps, with Bouguer anomaly contour intervals of 2 milligals, are used for the interpretation. The one inch to four mile scale maps covering the area are PORTLAND, HAMILTON, PENOLA and part of NARACOORTE (i.e. A name in Upper Case, underlined, defines a 4 mile or 1:250,000 Military sheet area extending over 1^{o} of Latitude and $1\frac{1}{2}^{o}$ of Longitude). These maps are contoured from Gravity Stations established by S.A. Department of Mines (S.A.), Alliance Oil Development (S.A.), Beach Petroleum (S.A.), Frome Broken Hill (Vic.), and Planet Oil (Vic.). The density of the stations is 0.13 stations per square mile over the whole area. In the southwestern area of Victoria results from a gravity survey completed by the Bureau of Mineral Resources in late 1949 and 1950 are included as regional gravity contours. Gravity trends, in the Caroline area S.E. of Mount Gambier, are also included from part of a gravity survey by Alliance Oil Development Aust. N.L., carried out during the period 12th March, 1966 to 1st June, 1966. (Plan No. 66-190).

The Observed Gravity Datum is from the Bureau of Mineral Resources Pendulum Station at Mount Gambier of 979.99367 gals. from the B.M.R. Isogal Regional Gravity Survey. The Elevation Datum is Mean Sea Level and the Elevation Correction Factor derived from a density contrast of 2.43 gm/cm^3 is 0.063 milligals/foot. The density of the Tertiary in this report is interpreted as 2.2 gm/cm^3 which gives an Elevation Correction Factor of 0.066 milligals/foot. Due to the lack of major relief in the area the Elevation Correction Factor of 0.063 milligals/foot used to determine the Bouguer Anomaly does not affect the overall picture.

Aeromagnetic coverage of the offshore Otway Basin was completed as part of an airborne magnetometer survey which cov-

ered a large area off the coast, from Gippsland (Vic.) across Bass Strait in the east, to Encounter Bay and Kangaroo Island (S.A.) in the west (Plan No. L67-38/6). The survey was flown at 2,000 feet above sea level, by Aero Service Limited for Haematite Explorations Proprietary Limited, between September and December, 1961. This followed a reconnaissance survey flown in December, 1960.

The South Australian portion of the Otway Basin bounded to the north by the parallel 36°45'S and to the east by the South Australian-Victoria State boundary, was covered by an airborne magnetometer survey at 500 feet above ground level (Plan No. S5692/6). This survey was carried out by Adastra Hunting Geophysics Ltd. for the South Australian Department of Mines in 1957. The survey was re-interpreted by the Compagnie de Geophysique in 1965 for the Department of National Development.

No comprehensive airborne magnetometer survey has been completed over the Victorian onshore area of the Otway Basin.

More recently (1960-1966), reconnaissance and detailed seismic surveys have been completed in the area. Only in the eastern part of the area have reliable basement reflections been mapped. Intermediate horizons, though, have been mapped in detail. The seismic refraction method appears to be the only reliable method of mapping basement. Basement is mapped by the latter method near Kalangadoo and south of Lucindale by Alliance Oil Development Aust. N.L. and south of Kingston S.E. by the S.A. Department of Mines. Comprehensive offshore seismic reflection work has also been completed by Haematite Explorations Pty. Ltd.

Because of the restricted coverage by the geophysical surveys, the Otway Basin is divided into two areas for interpretation, the onshore Western Otway Basin in South Australia based on aeromagnetic and gravity surveys, and the offshore area, based on aeromagnetic surveys alone. The Victorian onshore

area is not discussed.

GEOLOGY

The Otway Basin extends from the Padthaway Ridge in South Australia to the Mornington (26 miles south of Melbourne) - King Island basement ridge in Victoria. The southern half of the basin lies offshore.

The stratigraphy of the Otway Basin can be considered in terms of three units, Tertiary, Upper Cretaceous and Lower Cretaceous, which are separated by regional angular unconformities. The extent of the Upper Jurassic, as located in Casterton No. 1 well, is at present unknown.

The onshore Tertiary sediments are well known and have been broken down into several correlatable formations. The Tertiary dips southwards towards the coast beyond which it extends down the continental slope in the form of successive foresets. The Tertiary sediments are absent at about 22 miles off-shore.

Only two wells in the area under consideration have so far drilled into basement. Pretty Hill No. 1 in the eastern part of the area went into ?Cambrian diabase at 7874 feet, probably on a local basement high, and Casterton No. 1 in the northern edge of the basin went into ?Ordovician slates at 8,000 feet after passing through nearly 2,000 feet of Upper Jurassic sands, gravels, mudstones and basaltic flows. Other wells of note in the area are:-

Beachport No. 1 which bottomed at 3,963 feet in Lower Cretaceous

Geltwood Beach No. 1 which bottomed at 12,301 feet in Lower Cretaceous.

Mt. Salt No. 1 which bottomed at 10,004 feet in Upper Cretaceous

Penola No. 1 which bottomed at 4,958 feet in Lower Cretaceous.

Kalangadoo No. 1 which bottomed at 9,049 feet in slightly metamorphosed sandstones and shales of unknown age.

Eumeralla No. 1 which bottomed at 10,308 feet in Lower Cretaceou

GRAVITY INTERPRETATION

Regional Effect

Interpretation of the area between Robe and Portland i complicated by anomalous high gravity readings in the deepest part of the basin as indicated by wells, seismic and aeromagneti results.

A basic regional gradient of plus 1 milligal per 8 miles is interpreted in a S62°E direction. This regional when subtracted from the Bouguer values north and northeast of the Penola gravity trough gives a residual map with gravity highs and lows sympathetic with basement highs and lows.

Correlating basement depths from seismic refraction results south of Kingston S.E., near Kalangadoo and from seismic reflection results north of Portland with the gravity profiles, it is noted that the basic regional gradient also persists south of the Penola Trough. Complications exist south of the Penola trough in that there is also a 1 milligal per 1.2 miles gradient increasing southward from an axis of flexure which passes through the gravity low north of Robe, the Penola gravity trough and near the Victorian towns of Branxholme and Myamyn. This gradient is added to the basic regional gravity gradient to form a composite effect which is shown on Plan No. L66-54/6, which also shows the axis and the direction of the gravity gradients.

Residual Gravity

The composite regional gravity effect is subtracted from the Bouguer anomaly map to form a residual contour plan (Plan No. L66-55/6) with the zero contour, north of Kalangadoo, being equivalent to 12,000 feet below sea level.

From this map the points to note are the Kalangadoo

high, the Beachport highs, the decrease of gravity values south of Mount Gambier, the 'Dartmoor Ridge' which is not as pronounced as previously thought and the two highs north of Dartmoor.

Interpretation of Anomalies

The 1 milligal per 1.2 miles gravity gradient increasing towards the coast was interpreted without reference to the off-shore seismic results. When the axes of flexure of this gravity gradient were extended seawards an agreement with the seismic results was noted as shown on Plan No. L66-56/6. The seismic survey lines completed by Haematite Explorations Pty. Ltd. shown on this plan are the only offshore survey lines which extend far enough from the coast and locate the reflection events, the depths of which are given on Plan No. L66-56/6. North of line SS23 only basement reflections at depths of about 10,000 feet are located. It is interpreted that the reflection event as mapped on plan No. L66-56/6 swings to the S.W. where it is parallel to the intra-basement line of flexure passing north of Robe. The 10,000 feet contour between SS23 and SS25 is nearly parallel to the intra-basement line of flexure through the Penola Trough. The correlation between the intersections of the lines of flexure and the change in direction of the 10,000 feet contour between SS25 and SS26 can be clearly seen. The 10,000 feet contour through SS26, SS27 and SS34 is nearly parallel to the intra-basement line of flexure north of Portland. Thus the 1 milligal per 1.2 miles gravity gradient is interpreted as expressing the dip of the offshore reflection event. Using the dip of the reflection event, the gravity gradient and the lines of flexures, the depths to this interface are contoured dipping northeastwards to a maximum depth of over 50,000 feet below sea level at the intra-basement line of flexure. A density of 0.10 gm/cm^3 contrast is calculated to

give the 1 milligal per 1.2 miles gradient or from a section of density 2.77 gm/cm^3. The density of the latter sections and all sections in the interpretation are based on the assumption that the density of the basement is 2.67 gm/cm^3.

Since there is a lack of subsurface control in the area from drilling, the gravity effects of certain generalized geometric forms are used in the interpretation. A sphere, a vertical cylinder in which the bottom of the cylinder is at an infinite depth, and the gravity effect of a fault, are used in the interpretations.

The Beachport gravity highs are interpreted on Plan No. 66-508. The anomalies are interpreted individually from profiles C-C' and D-D' (see L66-55/6) and then as one from the profile X-X'. From profile X-X' the Beachport Highs are interpreted as being from three masses. An intrusive mass of density 3.00 gm/cm^3, possibly basalt, in the form of a cylinder, with the top of the cylinder at 31,700 feet below sea level, is interpreted east of Beachport. Just north of Beachport the large gravity values are interpreted as being from a mass in the form of a vertical cylinder with a hemisphere on top. This form is split into two units, a sphere of density 2.90 gm/cm^3, and the remainder, a vertical cylinder with a hemisphere removed from the top. The latter unit is interpreted as a vertical cylinder with equivalent volume, that is, with the top of the cylinder two thirds of the radius of the sphere below the centre of the sphere. The density of the cylinder is 3.00 gm/cm^3. The composite gravity effect of the three masses gives a gravity profile in good agreement with the residual gravity profile. There are only a few gravity stations actually on the line of section, the profile being interpreted from stations near the line of section.

The two anomalies north of Dartmoor which are in line with the Beachport anomalies are also interpreted as intra-basement intrusives in the form of spheres of density 2.90gm/cm^3

centred about a depth of 31,700 feet and rising to about 10,000 feet below sea level.

All the previous anomalies are regarded as intra-basement anomalies, with a density contrast of 0.23 gm/cm^3, the remaining anomalies being regarded as basement anomalies with a density contrast of 0.24 gm/cm^3.

The structural boundary of the basin is interpreted to vary from steep faults to stepped faults and monoclines depending upon the closeness of the gravity contours. The Mesozoic sediments overlap the structural boundary so that in most cases the structural boundary is not indicated on the surface.

The gravity high south of Lucindale agrees quite well with the seismic results, the seismic giving 3,100 feet and the gravity 3,200 feet below sea level for depth to basement.

Between Lucindale and Naracoorte the gravity low is interpreted as being due to a local reduction in basement density causing an anomalous low where aeromagnetic results and seismic reflection results indicate a rise in basement.

The broad gravity high NW of Penola is interpreted as being a basement high. Seismic reflection lines and refraction 'depth probes', although not actually over the high, indicate the basement high which is calculated from gravity values to be at about 4,000 feet below sea level.

Between the latter high and the high south of Lucindal the basement is calculated to reach 10,000 feet below sea level.

The gravity trough north of Robe and the NW-SE trending Penola trough are interpreted as being basement lows with a maximum depth below sea level of 14,000 feet.

The gravity high ESE of Robe has poor gravity control but appears to be of the same order as, and in line with, the gravity high south of Lucindale which gives a basement high of 3,200 feet below sea level. An aeromagnetic anomaly is also centred over the anomaly with the form of a basement high as

shown in plan No. 66-507. The aeromagnetic anomaly is interpreted as equivalent to a sphere with its centre at 9,300 feet below flight level or approximately 8,700 feet below sea level. Using the Lucindale gravity high, with basement depth of 3,200 feet below sea level, as correlation the radius of the sphere is 5,500 feet. This equates to a magnetic susceptibility contrast of 52×10^{-5} c.g.s., which is a reasonable value for basement structures in the area.

In the onshore area between Portland and Port Fairy seismic reflection results indicate basement dipping southward from the northern boundary of the basin, and do not appear to locate the gravity high east of Myamyn as a basement high. The gravity residual map indicates that basement depth is actually deeper than the reflections indicate in the northern part of the area. This could be due to the seismic reflections not being from the basement, as shown from the gravity, or that the density contrasts of sediments and basement are such as to give the anomalous deeper gravity basement.

A definite interpretation of this area cannot be completed until more subsurface, especially basement, geology is known in the area. The myamyn gravity high is left as a basement high, although this could also be interpreted as being due to an intra-basement intrusion, until more definite subsurface evidence is forthcoming. Pretty Hill Well No. 1 in this area reached basement at 7,874 feet where gravity indicates basement at just over 12,000 feet below sea level. This anomaly is interpreted as a local basement high which, possibly because of the small number of gravity stations in the area, is not located on the Bouguer Anomaly map. Eumeralla No. 1 bottomed in Lower Cretaceous at 10,308 feet where basement is calculated at just over 12,000 feet below sea level.

The area described above and the area north of the Penola and Robe gravity troughs are all outside a regional basement high. This basement high sweeps round through Beachport, Kalangadoo, to a point just north of Dartmoor and then southwards

around Dartmoor, and appears, to some extent, to be in sympathy with the line of flexure of the intra-basement feature. Two faults interpreted on the northern flank of the basement high, north of Kalangadoo, are also parallel to the intra-basement line of flexure. Calculation of depths to basement along the basement high, from gravity values, are complicated near Beachport and north of Dartmoor, by gravity effects from intra-basement features which hide the basement gravity effects.

On the south flank of the Beachport, Kalangadoo, Dartmoor basement high there is a hingeline. South of this hingeline the Lower Cretaceous dips more steeply and the thickness of theUpper Cretaceous section increases markedly. North of the hingeline the thin Upper Cretaceous section wedges out seven miles north of Kalangadoo. The hingeline is interpreted as passing about three miles north of Geltwood Beagh No. 1 well and about seven miles SW of Kalangadoo and then extending towards Dartmoor.

The hingeline also divides the area into two different areas for gravity interpretation. On the northern side of the hingeline there is a Tertiary section of 2.20 gm/cm^3 and a lower Cretaceous section of 2.43 gm/cm^3. On the southern side of the hingeline there is an increasing Tertiary section of density 2.20 gm/cm^3 plus an increasing thickness of Upper Cretaceous of density 2.34 gm/cm^3 and an approximately constant thickness of Lower Cretaceous sediments of density 2.43 gm/cm^3. The basement underlying the sediments has an assumed density of 2.67 gm/cm^3 from which all the above section densities are calculated.

To determine the approximate depth contours of the basement on the southern side of the hingeline, the gravity effect of the Upper Cretaceous is removed, resulting in basement depths of over 19,000 feet below sea level as shown in Plans No. L66-56/6 and 66-509. No definite depth of the basement in this area can be calculated until basement is actually pinpointed by a deep well. Wells in this area are Kalangadoo No. 1 which, on the above interpretation, would have reached basement at about

10,000 feet below sea level, Geltwood Beach No. 1 which would have reached basement at about 12,700 feet below sea level and Mt. Salt which would have reached basement at about 19,000 feet below sea level.

GRAVITY AND AEROMAGNETIC INTERPRETATION

Western Otway Basin

The northern limits of the deep section of the basin are clearly defined by the contrast of many local, narrow aeromagnetic anomalies over shallow basement outside the basin, and the relatively few broad changes over deep basement to the south see Plan No. S.5692/6. The depth contrast between these two zones is approximately 10,000 feet. The basin margin is also clearly defined on the Bouguer Anomaly Map (Plan No. 66-190) by steep gravity gradients. The gravity values outside the basin are more than 30 milligals greater than the values near the edge of the basin. Concordance of the interpreted position of the basin margin based on the two methods is very good. In addition, both methods define the structural boundary of the basin as grading from monoclines, to stepped faults, to steep faults, depending upon the increase in steepness of the basin margin.

The gravity low known as the Penola Gravity Trough (Plan No. 67-85/6) and situated immediately south of the basin margin can be interpreted as a sedimentary trough with a depth of section of over 14,000 feet. The aeromagnetic interpretation similarly indicates a trough configuration (Plan No. S 5693/6).

On the other hand, the E-W gravity trough just north of Robe with over 10,000 feet of section is not specifically defined by the aeromagnetic interpretation.

South of the Robe and Penola gravity lows, in which basement and gravity lows are simply related, the relationship between basement and gravity aeromagnetic results is complicated by:

(a) increasing gravity values towards the south,

(b) local high gravity values i.e. in the Beachport area,

(c) intermediate magnetic markers, and

(d) monotonous magnetic contours of the broadest type.

The increasing gravity values towards the south may be explained by a gravity gradient arising from the transition zone between continental and oceanic type rock masses. The gradient in the gravity interpretation is correlated with a northeast dipping layer which is located by a Exploration Pty. Ltd. seismic reflection survey, about 28 miles offshore.

The Haematite offshore seismic reflection survey located, as the survey was extended towards the southwest, first a reflection horizon at a depth of about 10,000 feet, then a zone of discordance where seismic reflection correlation is difficult. West of the zone of discordance the northeasterly dipping layer was located dipping from near sea bottom to 15,000 feet below sea level.

The control on this gravity correlation is sparse and the gravity gradient could easily have originated from another horizon or gravity effect than the one interpreted. On the residual Bouguer Anomaly plan the area around Beachport contains local high gravity values while on the aeromagnetic interpretation plan (Plan No. S.5693/6), intermediate magnetic markers are identified and described later in the report.

South of the magnetic high near Beachport, broad magnetic contours of equal separation extending offshore, make depth determinations to basement very difficult. Consequently, for interpretation purposes the area south of the Robe and Penol Troughs may be divided on the basis of aeromagnetic and gravity characteristics into:

i) the Beachport-Kalangadoo-Dartmoor basement high,

ii) the Beachport area, and

iii) the deep basement section south of Mount Gambier.

The Beachport-Kalangadoo-Dartmoor basement high is a

term derived from the gravity interpretation. It is a basement high separating the Penola Trough from the deeper section south of Mount Gambier. Seismic refraction shooting by Alliance Oil Devel. Aust. N.L. has delineated this basement high in the Kalangadoo area. The aeromagnetic interpretation shows a similar structure, but at a greater depth, near Kalangadoo. The southeast trend of the basement high changes just east of Dartmoor to a southerly trend, to form the Dartmoor High which has its top at 11,000 - 12,000 feet below sea level.

The quantitative interpretation of the prominent aeromagnetic and gravimetric anomalies situated immediately to the north of Beachport indicates the occurrence of a magnetic contrast at a depth of about 5,000 feet, and an intrusive plug culminating at a depth of about 5,500 feet. The average of the surrounding depth estimates from the aeromagnetic interpretation is about 13,500 feet, also, the gravity interpretation gives a depth of 15,000 feet above which the interpreted hemispherical top of the intrusion plug is centered. This tends to indicate a deep horizon which is not evident from geological and seismological results. This could be basement with possible volcanic intrusives above this basement forming a pseudo-basement high.

Northwest of Beachport a magnetic intermediate horizon is interpreted at depths between 3,500 feet and 8,000 feet below sea level, but this horizon is not indicated on the Bouguer Anomaly Map nor on seismic reflection cross-sections. It is noted that in the aeromagnetic interpretation (C.G.G. 1965) it is considered that long, wide anomalies near Beachport represent the integration of the individual magnetic effects of several parallel and highly magnetised bodies. Similar bodies are situated at depths between 1,000 and 2,000 feet outside the basin near Kingston and as such are located individually on the aeromagnetic map outside of the basin. It is suggested, therefore, that the variations of these anomalies within the basin, in particular the one N.W. of Beachport, is due, not to an inter-

mediate horizon, but to the variable alignment of the individual magnetised bodies causing the total anomaly effect. An exception is located north of Beachport and east of Robe where a local variation on the large magnetic anomaly is coincident with a gravity anomaly interpreted as a basement high.

The zone to the south of Beachport is in direct contrast in that it is one of broad magnetic contours with a lack of anomalies. Gravity and magnetic calculations indicate that this is a deep basement area at least 19,000 feet deep. The maximum depth of the basement appears to be onshore just north of Port MacDonnell and southeast of Dartmoor near the coast.

Offshore Area

The offshore area of the Otway Basin has been covered partly by flight lines 2-3 miles apart and partly by flight lines about 16 miles apart flown on behalf of Haematite Exploration Proprietary Ltd. (Plan No. L67-38/6). The northern limit of the basin offshore is again indicated by the contrast of the magnetic anomalies. The westerly trend of the basin margin, which is defined onshore is located and extended offshore. It is noted that at about 22 miles west of Robe along the basin margin the continental shelf has a marked change of strike to run parallel with the basin margin.

South of the basin margin there is a large N-S magnetic trend along the coast. This maximum trend near Beachport is interpreted as arising from a body of basic rocks, which becomes shallower just north of Beachport as perviously mentioned. The major part of the anomaly is explained in the offshore interpretation as a dyke at a depth of 16,000 feet. This confirms the concept of a large, deep body with parts protruding above its general level. An attempt has been made to construct depth contours away from the shallower areas, but the drop off is thought to be much more rapid than the contours imply. Away

from the coastal areas depth estimates across the area are unreliable because the magnetic relief is too small. Regional trends offshore from South Australia and Victoria reflect changes in composition of the basement rocks.

Along the Victorian coast near Bridgewater, Port Fairy and Warrnambool, numerous sharp anomalies are located and are re-lated to basalt flows known along the coast. Local areas offshore where sharp anomalies are found are also thought to be caused by minor volcanic bodies. The flight pattern across the area from Bridgewater to Cape Otway leaves large gaps, although, again because of the broad magnetic field with only minor variations, extra flight lines would not add much more useful information. No reliable depth estimates are calculated for this area. In the Cape Otway area near-surface effects again occur, varying in strength, and are thought to be related to volcanic rocks at different depths. Along the coast near ground surface effects are related to basalt and ferruginous tertiary sands. These ground effects obscure the magnetic effects of the basement and therefore basement depths are difficult to determine in these zones. East of Cape Otway shallow basement runs northeast from King Island to the mainland, as indicated by many sharp magnetic anomalies.

CONCLUSIONS

North of the Beachport-Kalangadoo-Dartmoor basement high, gravity highs and lows are generally in sympathy with basement highs and lows. Basement structure on the basement high itself is partly obscured by intra-basement features.

Gravity anomalies south of the hingeline on the southern flank of the basement high are the result of different combinations of increase in thickness of Tertiary, Upper Cretaceous, Lower Cretaceous sediments, or variations in the basement profile.

One area which is still open to different structural interpretations is the Beachport area, which would appear to be only definitely solvable by drilling techniques.

The offshore structural formation of the basin is not defined by the aeromagnetic surveys, and offshore gravimetric surveys have not been completed. Offshore reflection seismic surveys, not discussed here, help to solve the offshore problem.

It is considered that the aeromagnetic and gravimetric interpretations agree very well, considering the limitations of both methods.

GWK:CC
19.12.1968

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GEOLOGICAL SURVEYS OF SOUTH AUSTRALIA AND VICTORIA

OTWAY BASIN PROJECT

LEGEND

Gravity Station:

- S.A. Department of Mines (S.A.) .... •
- Alliance Oil Development (S.A.) .... ∘
- Beach Petroleum (S.A.) .... -∘
- Frome Broken Hill (Vic.) .... •
- Planet Oil (Vic.) .... ×

NOTE

OBSERVED GRAVITY DATUM: *B.M.R. Pendulum Station, Mt. Gambier. Observed Gravity = 979.99367 gals (from the 1964 B.M.R. Isogal Regional Gravity Survey).*

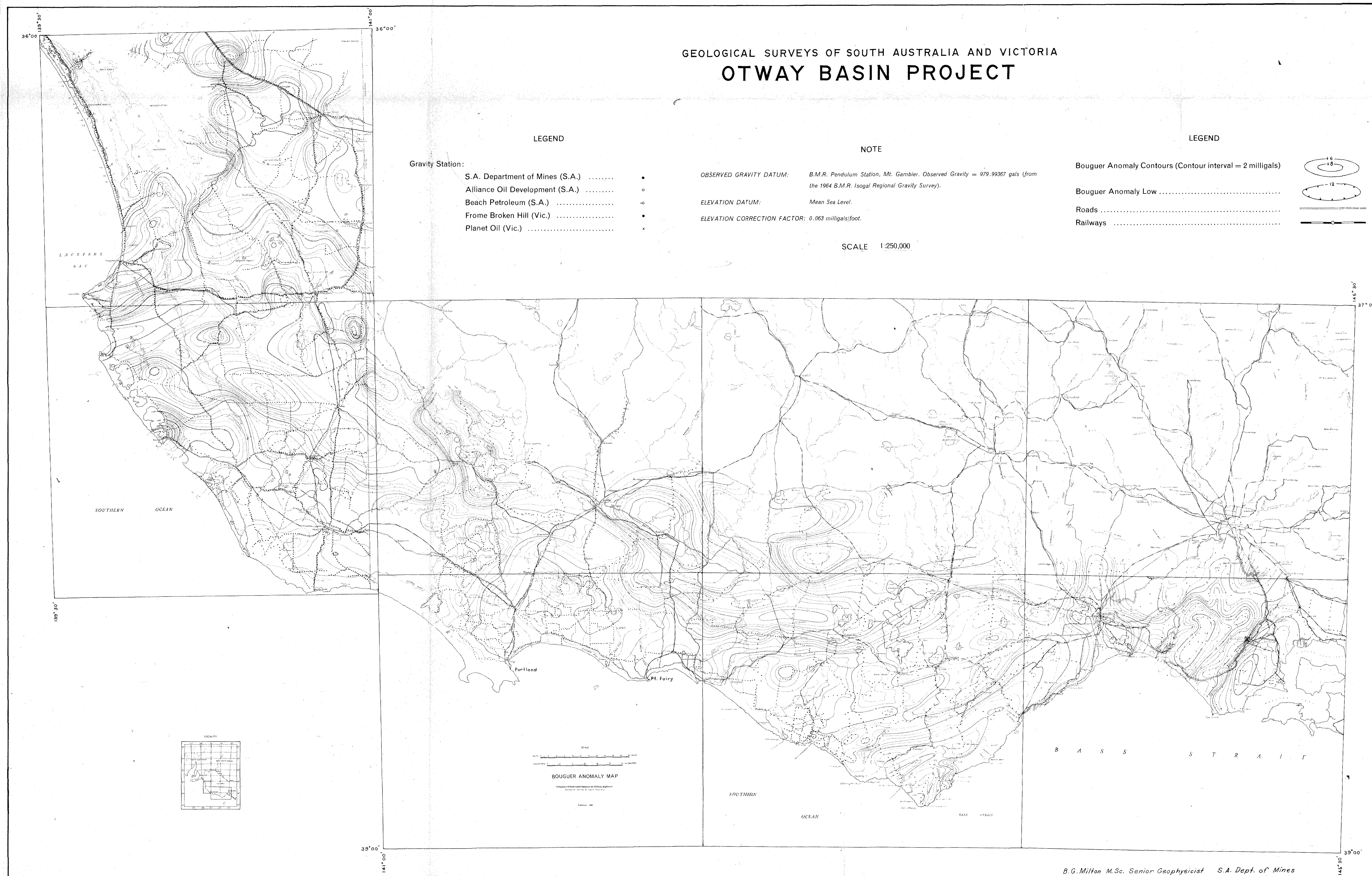
ELEVATION DATUM: *Mean Sea Level.*

ELEVATION CORRECTION FACTOR: 0.063 milligals/foot.

SCALE 1:250,000

LEGEND

- Bouguer Anomaly Contours (Contour interval = 2 milligals)
- Bouguer Anomaly Low ....
- Roads ....
- Railways ....



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66-190/6
994-2+5

S.A. DEPT. OF MINES
WESTERN OTWAY BASIN
COMPOSITE REGIONAL GRAVITY EFFECT
N
KINGSTON S.E.
CAPE JAFFA
LUCINDALE
NARACOORTE
ROBE
PENOLA
BEACHPORT
KALANGADOO
MILLICENT
CASTERTON
HAMILTON
MOUNT GAMBIER
BRANXHOLME
DARTMOOR
MYAMYN
PORT MACDONNELL
PORTLAND
PORT FAIRY
WARRNAMBOOL
SOUTH AUSTRALIA
VICTORIA
AXIS
SCALE IN MILES
SCALE IN KILOMETRES
SCALE
Gravity contours in milligals
Interpretation by G.W. Kendall
L66-54/6

20

S.A. DEPT. OF MINES

WESTERN OTWAY BASIN
RESIDUAL GRAVITY CONTOUR PLAN

N

LEGEND

C ——— C' Line of gravity profile.

KINGSTON S.E.
CAPE JAFFA
ROBE
BEACHPORT
MILLICENT
MOUNT GAMBIER
PORT MACDONNELL
LUCINDALE
NARACOORTE
PENOLA
KALANGADOO
CASTERTON
HAMILTON
BRANXHOLME
DARTMOOR
MYAMYN
PORTLAND
PORT FAIRY
WARRNAMBOOL

SOUTH AUSTRALIA
VICTORIA

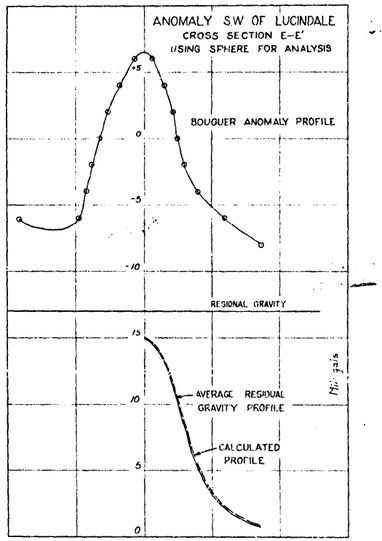
SCALE IN MILES
SCALE IN KILOMETRES
(20)

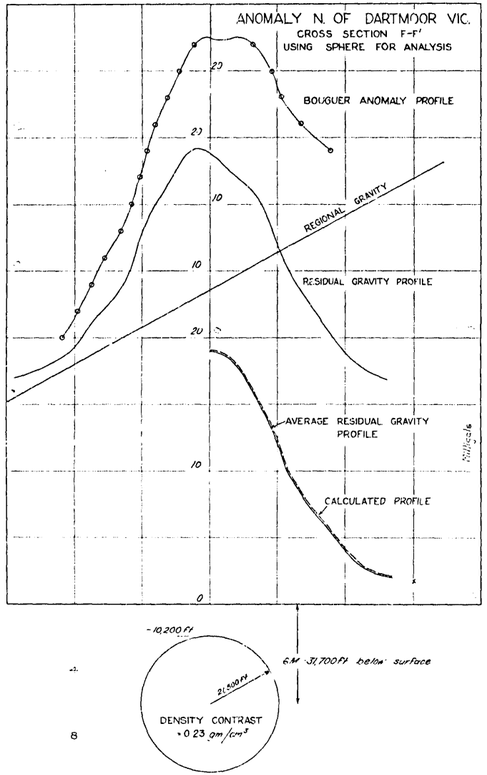
SCALE
MILES 4 2 0 4 8 12 16 20 MILES

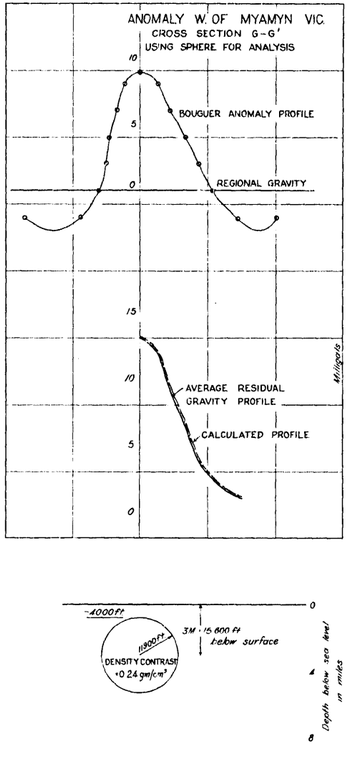
Gravity contours in milligals.
Interpretation by G.W. Kendall

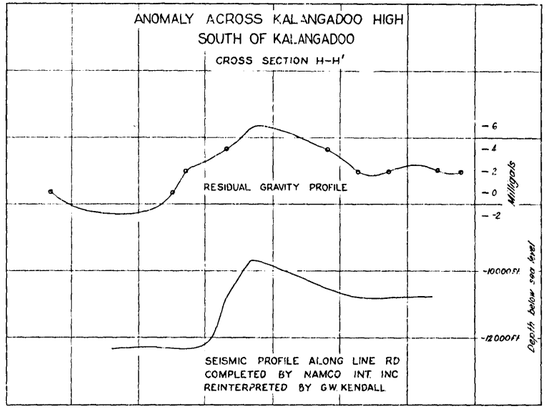
DRWG W.A.	SCALE: 4 mile = 1 inch
TCD T.R.S.	L66-55/6
CKD L.W.	994 245
E.I.D.	DATE 24-8-66.

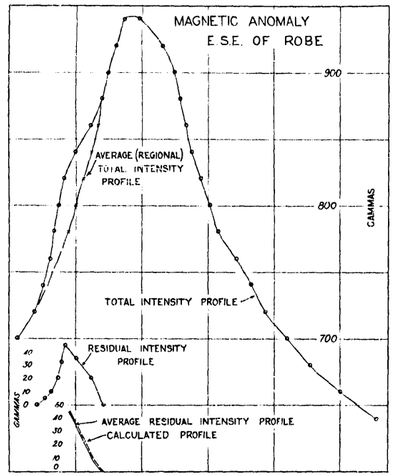

S.A. DEPT. OF MINES
WESTERN OTWAY BASIN
COMPOSITE GRAVITY INTERPRETATION MAP
LEGEND
Haematite Explorations Pty Ltd offshore seismic lines
Dry well, positive value well bottomed above basement, negative value well bottomed in basement
Contours of basement horizon (below 10,000 feet)
Contours of intra-basement horizon
Masses used for gravity interpretation
Depth in centre indicates depth to top of sphere or cylinder
Depth on circumference indicates depth to centre of sphere
SPHERE
CYLINDER
N
KINGSTON S.E.
PADTHAWAY RIDGE
APPROX. BOUNDARY OF MESOZOIC SEDIMENTS
LUCINDALE HINGE LINE
CAPE JAFFA
LUCINDALE
NARACOORTE
STRUCTURAL BOUNDARY OF BASIN
GRAVITY LOW DUE BASEMENT DENSITY CONTRAST ?
BASEMENT HIGH
ROBE
INTRA BASEMENT LINE OF FLEXURE
PENOLA TROUGH
PENOLA
PENOLA No1
BEACHPORT
BEACHPORT No1
INTRA-BASEMENT HIGH
KALANGADOO
KALANGADOO No1
BEACHPORT-KALANGADOO-DARTMOOR BASEMENT HIGH
HINGE LINE INDICATING SOUTHWARD INCREASE OF UPPER CRETACEOUS SEDIMENTS
MILLICENT
GELTWOOD BEACH No1
SOUTH AUSTRALIA
VICTORIA
CASTERTON
CASTERTON No1
HAMILTON
MOUNT GAMBIER
BRANXHOLME
DARTMOOR
MT. SALT No1
MYAMYN
PORT MACDONNELL
LINE OF FLEXURE
NO DEEP REFLECTIONS
DEPTH OF A SEISMIC REFLECTION EVENT
EUMERALLA No1
PRETTY HILL No1
PORTLAND
PORT FAIRY
WARRNAMBOOL
A
A'
B
B'
SCALE IN MILES
SCALE IN KILOMETRES
SCALE
Datum - Mean sea level
Interpretation by G.W. Kendall
SCALE: 4 mile = 1 inch
L66-56/6
DATE: 24-5-66











Interpreted as Basement High
Using sphere for analysis
Depth to centre of sphere - 9,300 Ft (Below flight line)
- 6,700 Ft (Below sea level)
Radius of sphere - 5,500 Ft
Magnetic Susceptibility - 52 · 10⁻⁶ c.g.s

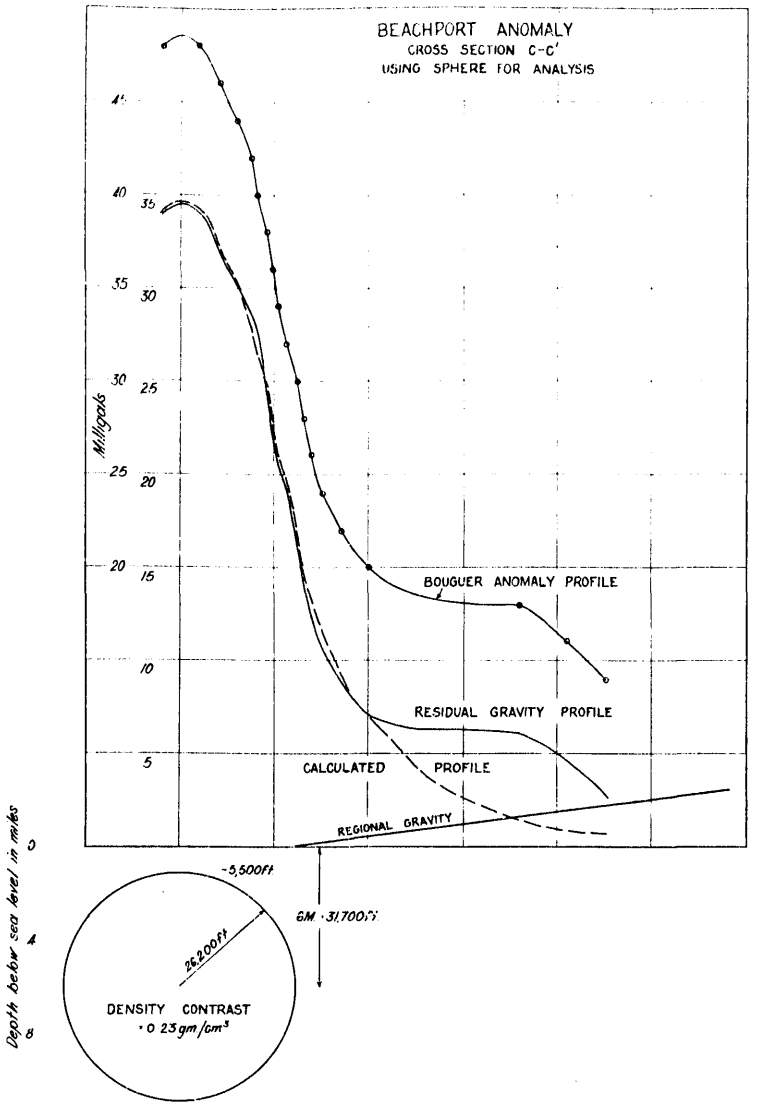
NOTE: This coincides with a Gravity Anomaly of the same dimensions as the Gravity Anomaly S.W. of Lucindale

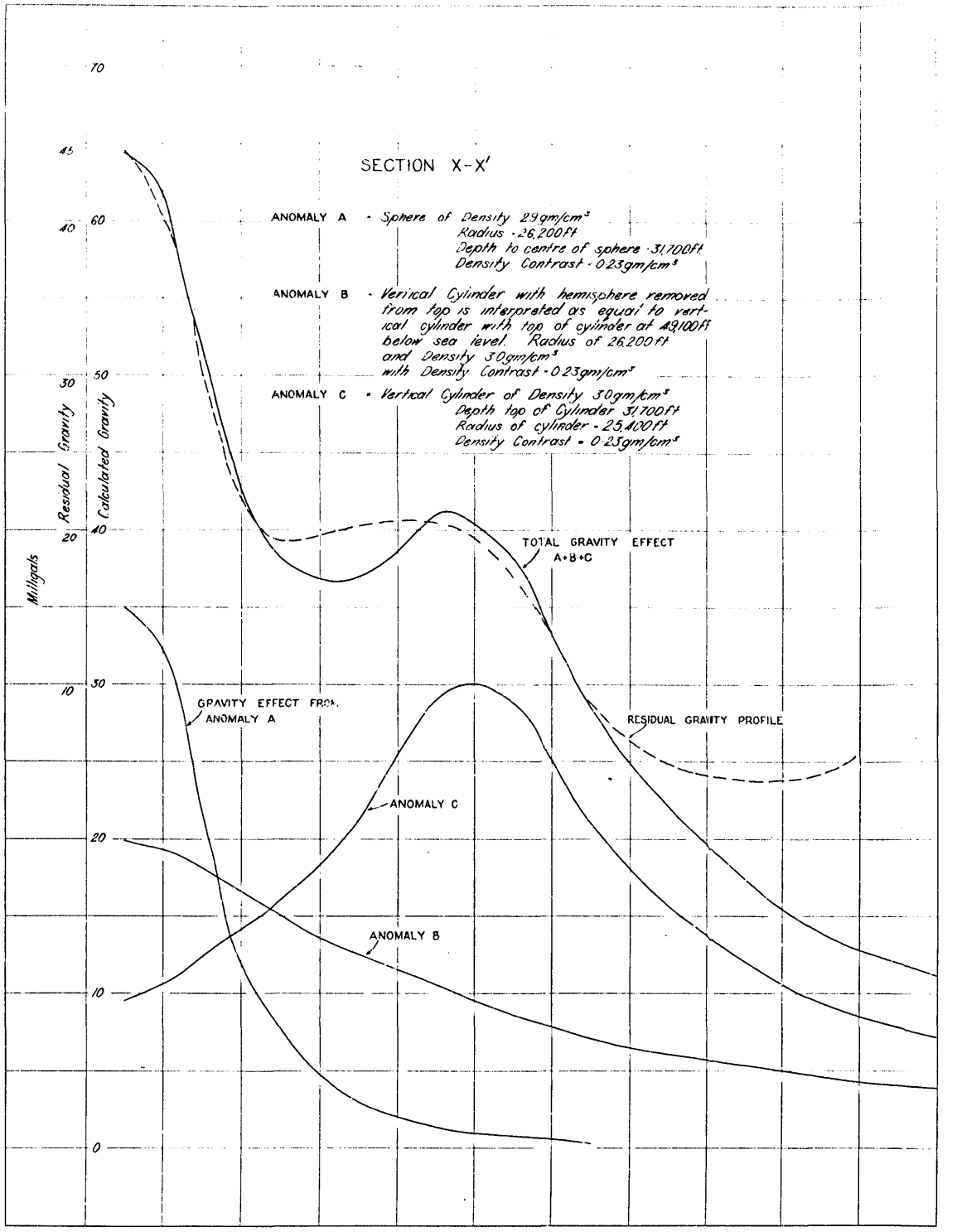
Interpretation by G.W. Kendall

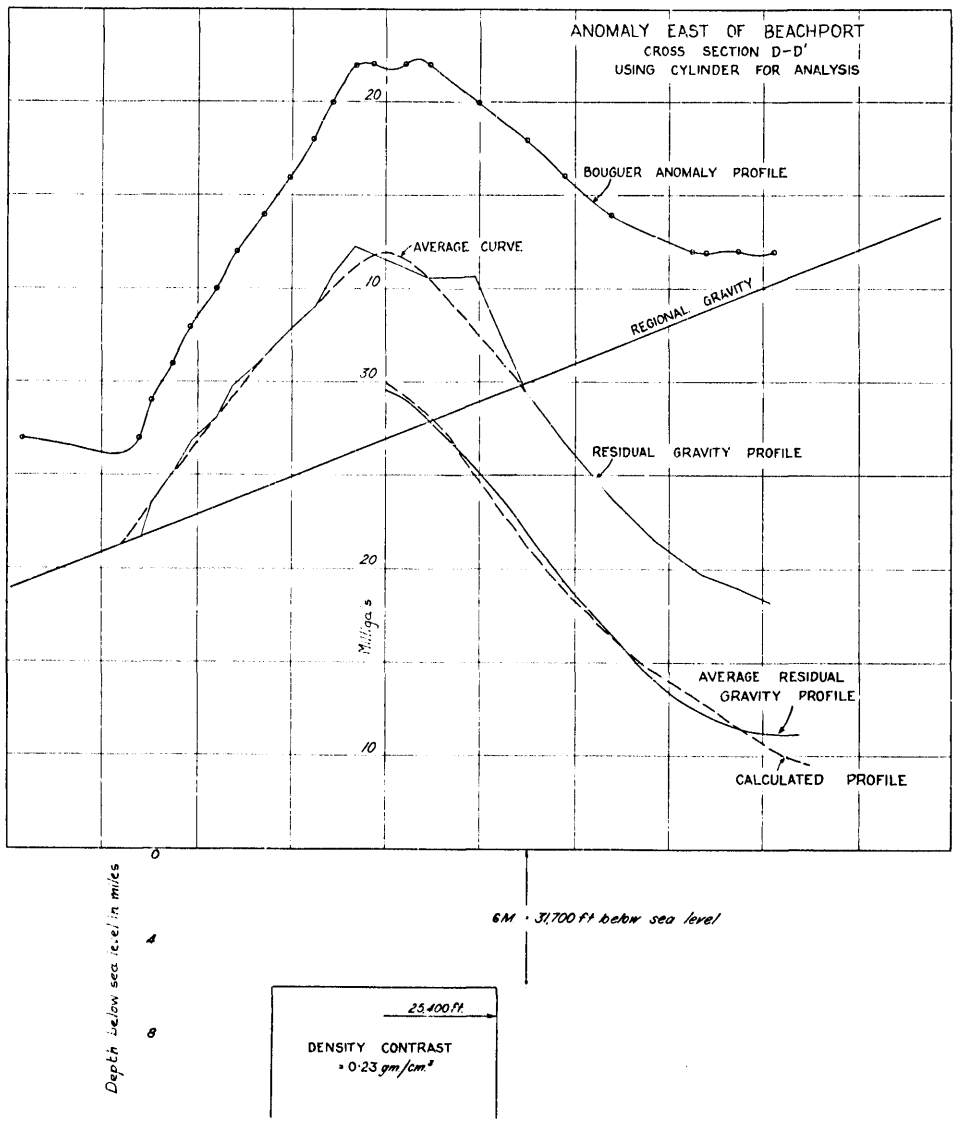
DEPARTMENT OF MINES — SOUTH AUSTRALIA

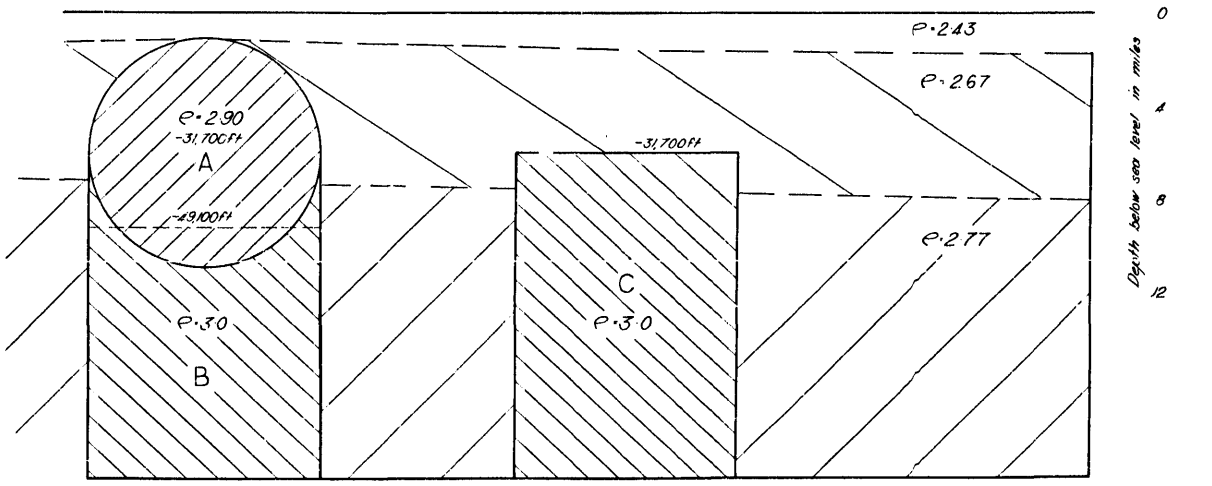
WESTERN OTWAY BASIN
BOUGUER ANOMALY PROFILES & INTERPRETATION

		Drn. G.W.K.	SCALES: VERT. AS SHOWN HORIZ. 1" - 4 MILES
		Tcd. R.H.	66-507 994 245
		Chd. L.V.W.	
Director of Mines		Exd.	DATE: APRIL 1966









Interpretation by G.W. Kendall

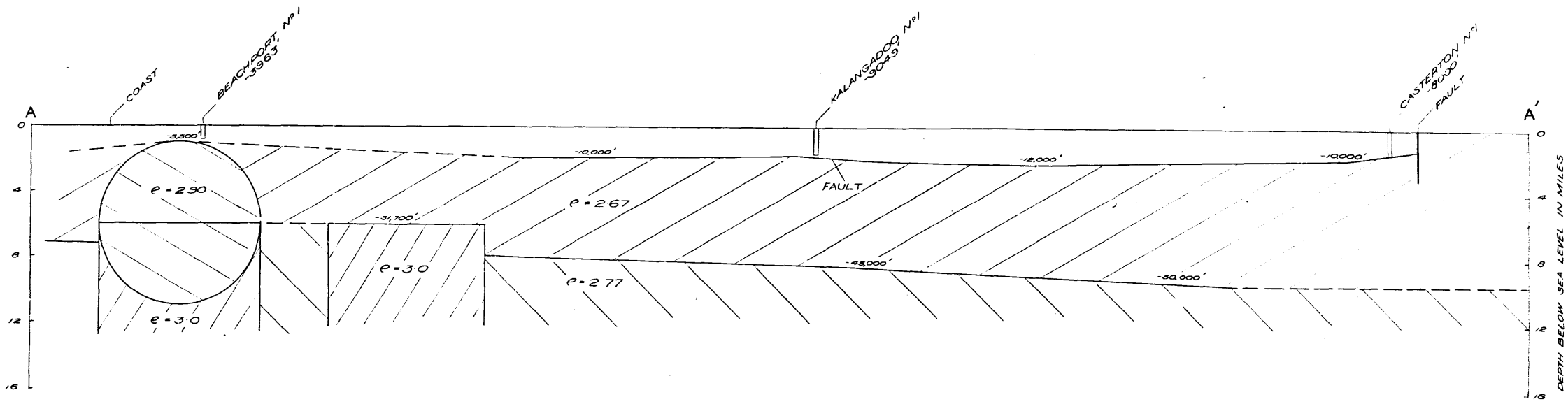
DEPARTMENT OF MINES — SOUTH AUSTRALIA

WESTERN OTWAY BASIN

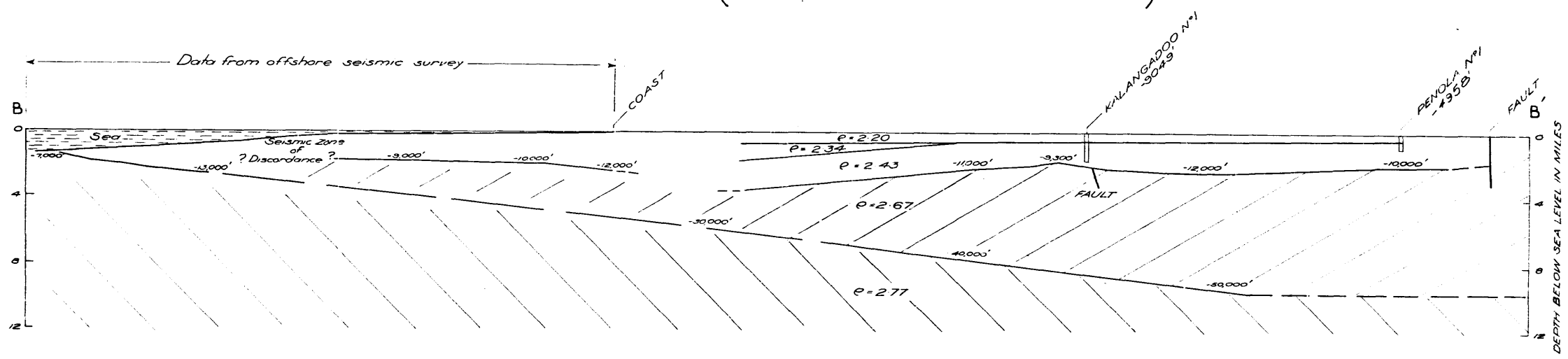
BEACHPORT GRAVITY ANOMALIES INTERPRETATION

		Drn. G.W.K	SCALES: VERT AS SHOWN HORIZ 1" = 4 MILES
		Tcd. R.H	66-508 994.2.5
Director of Mines		Ckd. L.V.W	
		Exd.	DATE: MAY 1966

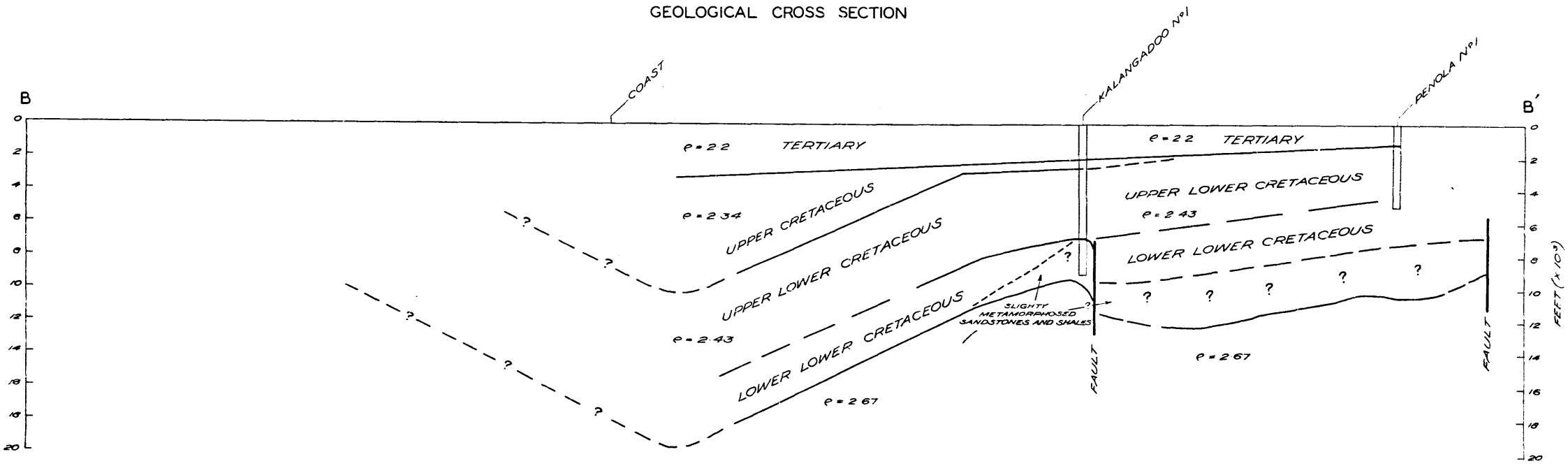
CROSS SECTION THROUGH A – A' (BEACHPORT Nº1 – KALANGADOO Nº1 – CASTERTON Nº1)



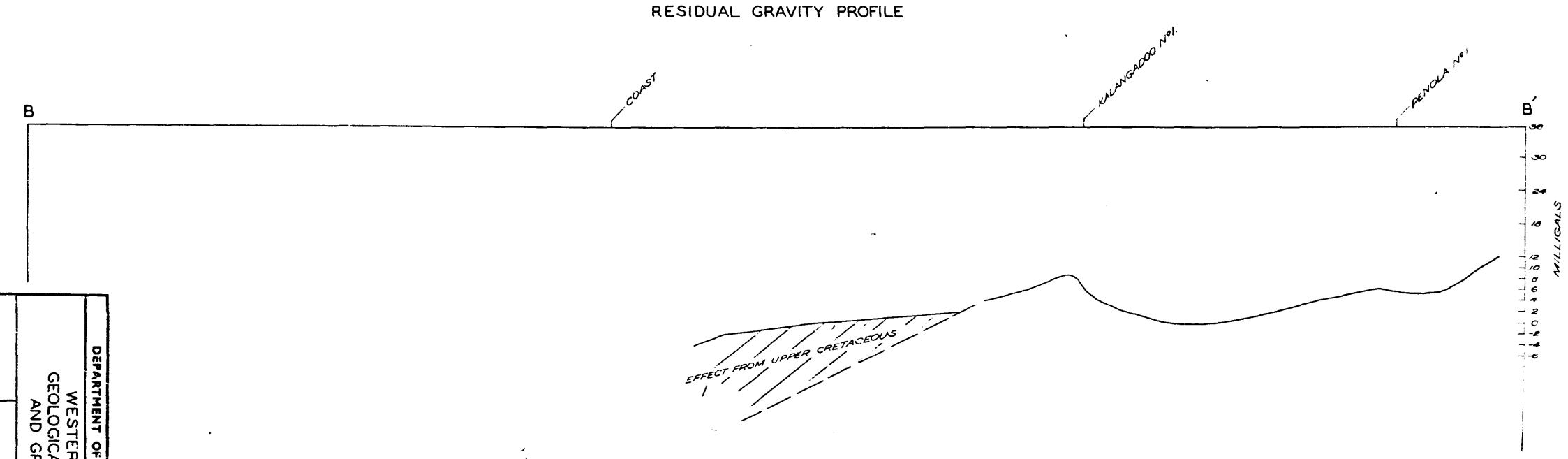
CROSS SECTION THROUGH B – B (OFFSHORE — KALANGADOO Nº1 — PENOLA Nº1)



GEOLOGICAL CROSS SECTION



RESIDUAL GRAVITY PROFILE



Scale – Horizontal : 1 inch = 4 miles.
Vertical : As shown.
Density of material ρ in gm/cm³
Interpretation by G.W. Kendall.

DEPARTMENT OF MINES — SOUTH AUSTRALIA

WESTERN OTWAY BASIN
GEOLOGICAL CROSS SECTIONS
AND GRAVITY PROFILES

Director of Mines

Drn. G.W.K. | Tcd. T.P.S. | Chd. L.V.W. | Enf.

SCALE: As shown

66-509

DATE:

DEPARTMENT OF MINES
SOUTH AUSTRALIA

RB 739

NOTES ON AEROMAGNETIC AND GRAVIMETRIC INTERPRETATIONS OF THE OTWAY BASIN

by

G.W. KENDALL
GEOPHYSICIST
EXPLORATION GEOPHYSICS SECTION

CONTENTS

PLAN REFERENCES

Plan	Title	Scale
S.5692/6	Aeromagnetic Map of Total Intensity.	1":1,000,000
S.5693/6	Isobath Contours of the Magnetic Basement and Intermediate Horizon.	"
67-85/6	Composite Gravity Interpretation Map.	"
66-190	Bouguer Anomaly Map	"
L67-38/6	Offshore Total Magnetic Intensity and Geophysical Interpretation.	"

Rept. Bk. No. 739
G.S. 3717
SR. 11/5/123

9th June, 1967

11

DEPARTMENT OF MINES
SOUTH AUSTRALIA

Rept. Bk. No. 739
G.S. 3717
SR. 11/5/123

NOTES ON AEROMAGNETIC AND GRAVIMETRIC INTERPRETATIONS OF THE OTWAY BASIN

ABSTRACT

The correlation of anomalies of aeromagnetic and gravimetric onshore surveys in the Western Otway Basin and offshore aeromagnetic surveys of the Otway Basin generally, is discussed.

The two geophysical methods delineate the subsurface structure in the onshore Western Otway Basin, whereas, only the northern limits near Cape Jaffa and the eastern limits near King Island of the offshore portion of the basin are defined by the aeromagnetic method.

INTRODUCTION

Aeromagnetic coverage of the offshore Otway Basin was completed as part of an airborne magnetometer survey which covered a large area off the coast, from Gippsland (Vic.) across Bass Strait in the east, to Encounter Bay and Kangaroo Island (S.A.) in the west (Plan No. L67-38/6). The survey was flown at 2,000 feet above sea level, by Aero Service Limited for Haematite Explorations Proprietary Limited, between September and December, 1961. This followed a reconnaissance survey flown in December, 1960.

The South Australian portion of the Otway Basin bounded to the north by the parallel 36°45'S and to the east by the South Australian-Victoria State boundary, was covered by an airborne magnetometer survey at 500 feet above ground level (Plan No. S5692/6). This survey was carried out by Adastra Hunting Geophysics Ltd. for the South Australian Department of Mines in 1957.

The survey was re-interpreted by the Compagnie de Geophysique in 1965 for the Department of National Development.

No comprehensive airborne magnetometer survey has been completed over the Victorian onshore area of the Otway Basin.

Gravity stations onshore have been established by S.A. Department of Mines (S.A.), Alliance Oil Development (S.A.), Beach Petroleum (S.A.), Frome Broken Hill (Vic.), Bureau of Mineral Resources (Vic.), and Planet Oil (Vic.). Bouguer Anomaly Maps of the whole area, with anomaly contour intervals at 2 milligals, have been produced by the Exploration Geophysics Section of the S.A. Department of Mines Plan No. 66-190.

An interpretation of the gravity on the onshore area between Cape Jaffa, S.A. and Warrnambool, Vic. has been completed by the author (Kendall 1966) Plan No. 67-85/6, the Composite Gravity Interpretation Map is taken from this report.

Because of the restricted coverage by the geophysical surveys, the Otway Basin is divided into two areas for interpretation, the onshore Western Otway Basin in South Australia based on aeromagnetic and gravity surveys, and the offshore area, based on aeromagnetic surveys alone. The Victorian onshore area is not discussed.

WESTERN OTWAY BASIN

The northern limits of the deep section of the basin are clearly defined by the contrast of many local, narrow aeromagnetic anomalies over shallow basement outside the basin, and the relatively few broad changes over deep basement to the south, see Plan No. S.5692/6. The depth contrast between these two zones is approximately 10,000 feet. The basin margin is also clearly

defined on the Bouguer Anomaly Map (Plan No. 66-190) by steep gravity gradients. The gravity values outside the basin are more than 30 milligals greater than the values near the edge of the basin. Concordance of the interpreted position of the basin margin based on the two methods is very good. In addition, both methods define the structural boundary of the basin as grading from monoclines, to stepped faults, to steep faults, depending upon the increase in steepness of the basin margin.

The gravity low known as the Penola Gravity Trough (Plan No. 67-85/6) and situated immediately south of the basin margin can be interpreted as a sedimentary trough with a depth of section of over 14,000 feet. The aeromagnetic interpretation similarly indicates a trough configuration (Plan No. S.5693/6).

On the other hand, the E-W gravity trough just north of Robe with over 10,000 feet of section is not specifically defined by the aeromagnetic interpretation.

South of the Robe and Penola gravity lows, in which basement and gravity lows are simply related, the relationship between basement and gravity and aeromagnetic results is complicated by:

(a) increasing gravity values towards the south,

(b) local high gravity values i.e. in the Beachport area,

(c) intermediate magnetic markers, and

(d) monotonous magnetic contours of the broadest type.

The increasing gravity values towards the south may be explained by a gravity gradient arising from the transition zone between continental and oceanic type rock masses. The gradient in the gravity interpretation is correlated with a northeast dipping layer which is located by a Haematite Exploration Pty. Ltd. seismic reflection survey, about 28 miles offshore.

The Haematite offshore seismic reflection survey located, as the survey was extended towards the southWest, first a reflection horizon at a depth of about 10,000 feet, then a zone of discordance where seismic reflection correlation is difficult. West of the zone of discordance the northeasterly dipping layer was located dipping from near sea bottom to 15,000 feet below sea level.

The control on this gravity correlation is sparse and the gravity gradient could easily have originated from another horizon or, gravity effect than the one interpreted. The gravity interpretation includes a residual Bouguer Anomaly plan with the above gravity effect removed (Plan No. 67-85/6). On this plan the area around Beachport contains local high gravity values while on the aeromagnetic interpretation plan (Plan No. S.5693/6), intermediate magnetic markers are identified and described later in the report.

South of the magnetic high near Beachport, broad magnetic contours of equal separation extending offshore, make depth determinations to basement very difficult. Consequently, for interpretation purposes the area south of the Robe and Penola Troughs may be divided on the basis of aeromagnetic and gravity characteristics into:

i) the Beachport-Kalangadoo-Dartmoor basement high,

ii) the Beachport area, and

iii) the deep basement section south of Mount Gambier.

The Beachport-Kalangadoo-Dartmoor basement high is a term derived from the gravity interpretation. It is a basement high separating the Penola Trough from the deeper section south of Mount Gambier. Seismic refraction shooting by Alliance Oil Devel. Aust. N.L. has delineated this basement high in the Kalangadoo area. The aeromagnetic interpretation shows a similar structure, but at a greater depth, near Kalangadoo. The

southeast trend of the basement high changes just east of Dartmoor to a southerly trend, to form the Dartmoor High which has it top at 11,000-12,000 feet below sea level.

The quantitative interpretation of the prominent aeromagnetic and gravimetric anomalies situated immediately to the north of Beachport indicates the occurrence of a magnetic contrast at a depth of about 5,000 feet, and an intrusive plug culminating at a depth of about 5,500 feet. The average of the surrounding depth estimates from the aeromagnetic interpretation is about 13,500 feet, also, the gravity interpretation gives a depth of 15,000 feet above which the interpreted hemispherical top of the intrusion plug is centered. This tends to indicate a deep horizon which is not evident from geological and seismological results. This could be basement with possible volcanic intrusives above this basement forming a pseudo-basement high.

Northwest of Beachport a magnetic intermediate horizon is interpreted at depths between 3,500 feet and 8,000 feet below sea level, but this horizon is not indicated on the Bouguer Anomaly Map nor on seismic reflection cross-sections. It is noted that in the aeromagnetic interpretation (C.G.G. 1965) it is considered that the long, wide anomalies near Beachport represent the integration of the individual magnetic effects of several parallel and highly magnetised bodies. Similar bodies are situated at depths between 1,000 and 2,000 feet outside the basin near Kingston and as such are located individually on the aeromagnetic map outside of the basin. It is suggested, therefore, that the variations of these anomalies within the basin, in particular the one N.W. of Beachport, is due, not to an intermediate horizon, but to the variable alignment of the individual magnetised bodies causing the total anomaly effect. An exception is located north of Beachport and east of Robe where a local

variation on the large magnetic anomaly is coincident with a gravity anomaly interpreted as a basement high.

The zone to the south of Beachport is in direct contrast in that it is one of broad magnetic contours with a lack of anomalies. Gravity and magnetic calculations indicate that this is a deep basement area at least 19,000 feet deep. The maximum depth of the basement appears to be onshore just north of Port MacDonnell and southeast of Dartmoor near the coast.

OFFSHORE AREA

The offshore area of the Otway Basin has been covered partly by flight lines 2-3 miles apart and partly by flight lines about 16 miles apart flown on behalf of Haematite Exploration Proprietary Ltd. (Plan No. L67-38/6). The northern limit of the basin offshore is again indicated by the contrast of the magnetic anomalies. The westerly trend of the basin margin, which is defined onshore is located and extended offshore. It is noted that at about 22 miles west of Robe along the basin margin the continental shelf has a marked change of strike to run parallel with the basin margin.

South of the basin margin there is a large N-S magnetic trend along the coast. This maximum trend near Beachport is interpreted as arising from a body of basic rocks, which becomes shallower just north of Beachport as previously mentioned. The major part of the anomaly is explained in the offshore interpretation as a dyke at a depth of 16,000 feet. This confirms the concept of a large, deep body with parts protruding above its general level. An attempt has been made to construct depth contours away from the shallower areas, but the drop off is thought to be much more rapid than the contours imply. Away

from the coastal areas depth estimates across the area are unreliable because the magnetic relief is too small. Regional trends offshore from South Australia and Victoria reflect changes in composition of the basement rocks.

Along the Victorian coast near Bridgewater, Port Fairy and Warrnambool, numerous sharp anomalies are located and are related to basalt flows known along the coast. Local areas offshore where sharp anomalies are found are also thought to be caused by minor volcanic bodies. The flight pattern across the area from Bridgewater to Cape Otway leaves large gaps, although, again because of the broad magnetic field with only minor variations, extra flight lines would not add much more useful information. No reliable depth estimates are calculated for this area. In the Cape Otway area near-surface effects again occur, varying in strength, and are thought to be related to volcanic rocks at different depths. Along the coast near ground surface effects are related to basalt and ferruginous tertiary sands. These ground effects obscure the magnetic effects of the basement and therefore basement depths are difficult to determine in these zones. East of Cape Otway shallow basement runs northeast from King Island to the mainland, as indicated by many sharp magnetic anomalies.

CONCLUSIONS

It is considered that the aeromagnetic and gravimetric interpretations agree very well, considering the limitations and [redacted] of both methods.

One area which is still open to different structural interpretations is the Beachport area, which would appear to be only definitely solvable by drilling techniques.

The offshore structural formation of the basin is not defined by the aeromagnetic surveys, and offshore gravimetric surveys have not been completed. Offshore reflection seismic surveys, not discussed here, help to solve the offshore problem.

G.W. KENDALL
GEOPHYSICIST
EXPLORATION GEOPHYSICS SECTION

GWK:SMA
9.6.1967

REFERENCES

COMPAGNIE GENERALE DE GEOPHYSIQUE, 1965 'Reinterpretation of the Airborne Magnetic Survey, Gambier - Otway Basin, S.A.'

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KENDALL, G.W. 1966 'A Gravity Interpretation of the Western Otway Basin between Cape Jaffa, S.A. and Warrnambool, Vic.' Geol. Surv. S. Aust. Rept. Bk. No. 728 (Unpub.)

S5692/6

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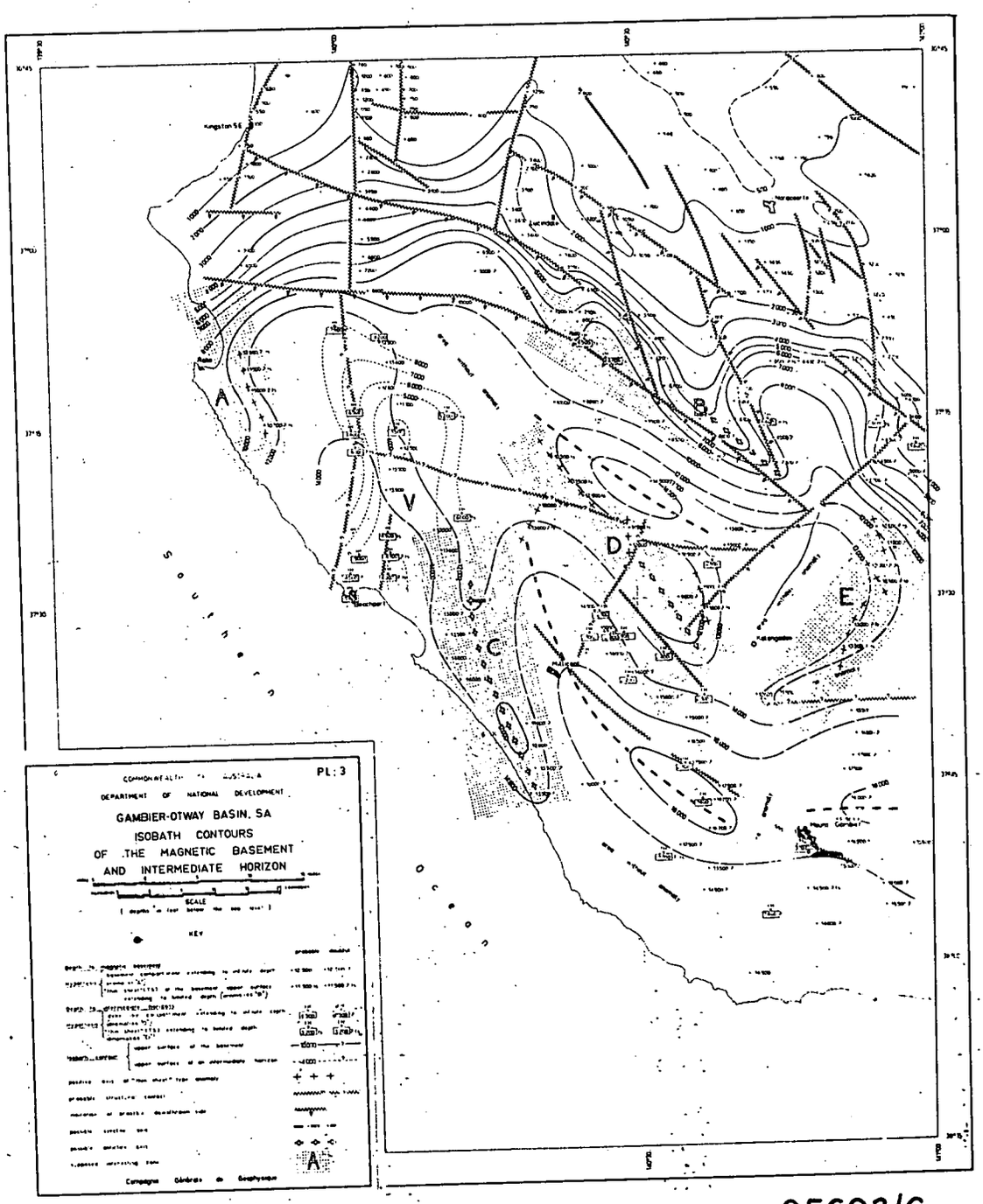

S5693/6

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S.A. DEPT. OF MINES

WESTERN OTWAY BASIN

COMPOSITE GRAVITY INTERPRETATION MAP

LEGEND

- Hematite Explorations Pty Ltd offshore seismic lines
- Dry well, positive value well bottomed above basement, negative value well bottomed in basement.
- Contours of basement horizon (below 10000 feet)
- Contours of intra-basement horizon
- Masses used for gravity interpretation. Depth in centre indicates depth to top of sphere or cylinder. Depth on circumference indicates depth to centre of sphere.

PADTHAWAY RIDGE

APPROX. BOUNDARY OF MESOZOIC SEDIMENTS

LUCINDALE HINGE LINE

STRUCTURAL BOUNDARY OF BASIN

PENOLA TROUGH

BEACHPORT-KALANGADOO-DARTMOOR BASEMENT HIGH

SOUTH AUSTRALIA / VICTORIA

KINGSTON S.E.

CAPE JAFFA

ROBE

LUCINDALE

NARACOORTE

PENOLA

BEACHPORT

KALANGADOO

MILLICENT

CASTERTON

MOUNT GAMBIER

DARTMOOR

PORT MACDONNELL

HAMILTON

BRATAHOLME

MYAMYN

PORTLAND

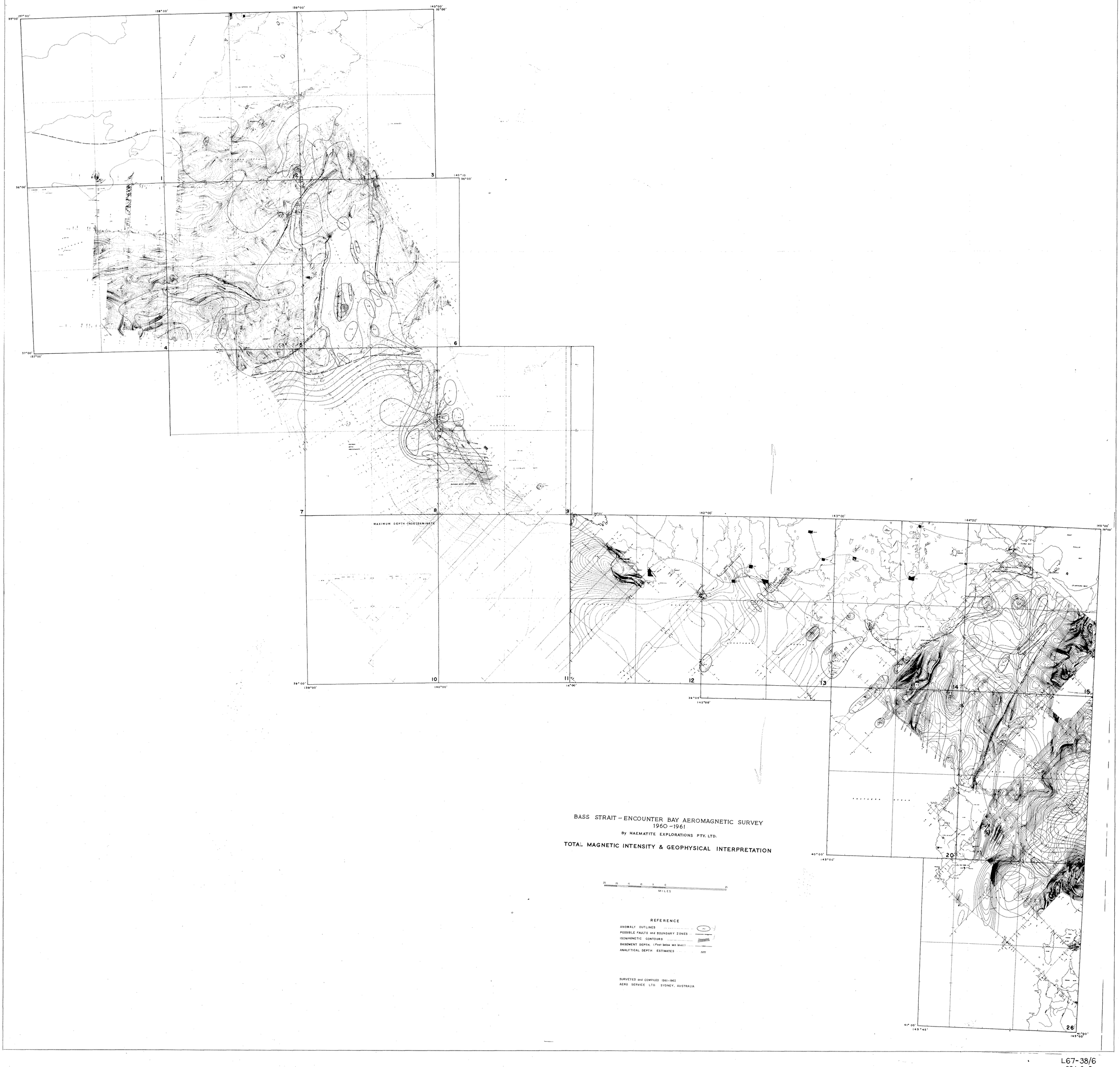
PORT FAIRY

WARRNAMBOOL

SCALE

Datum - Mean sea level

Interpretation by G.M. Kendall



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