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RECONNAISSANCE AIRBORNE MAGNETIC SURVEY OF THE
EUCLA BASIN, SOUTHERN AUSTRALIA

by

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A B S T R A C T

During May, 1954, the Bureau of Mineral Resources carried out a reconnaissance airborne magnetic survey of the Eucla sedimentary basin in the states of South and Western Australia. The survey consisted of a series of traverses across the basin area, some of which were extended southward across the Great Australian Bight.

The magnetic results indicate that the greatest thickness of sediments is to be found in an area extending 100 miles south from the northern boundary of the basin. Basement rock is estimated to be more than 2,000 feet below the surface in this area, but the data do not permit an estimate of maximum depth. Elsewhere the basement is estimated to be 2,000 feet or less below the surface, with progressive shallowing toward the eastern and western margins and southward into the Great Australian Bight.

1. INTRODUCTION

In December 1953, the Department of National Development received an application from Frome-Broken Hill Company Pty.Ltd., through the South Australian Government, to carry out a reconnaissance airborne magnetic survey over certain areas of the Eucla Basin in which the company held permits to explore for petroleum.

The Eucla Basin covers an area of approximately 150,000 sq.miles in the western part of the state of South Australia and the south-eastern corner of the state of Western Australia. The existence of Tertiary, Mesozoic and possibly Palaeozoic sediments in a broad depression of the Pre-Cambrian basement rock has encouraged exploration companies to examine the potentialities of the basin as an oil-producing field.

The basin is very large and the thickness of sediments is known only at a few isolated places. A reconnaissance magnetometer survey could therefore be expected to give basic data which would allow ground investigations to proceed more expeditiously and to be directed to the most favourable parts of the basin. As these objectives would be an important aid to exploration and possible developments in this area, the Department agreed to undertake the survey.

The survey was carried out by the Bureau of Mineral Resources between the 11th and 24th May, 1954. The area surveyed extends from Oodnadatta in the east to Kalgoorlie in the west, and from the Northern Territory border in the north to the Great Australian Bight in the south. The positions of the survey flights are shown in Plate No.1.

Bureau personnel engaged in the survey were P.E. Goodeve (party leader), A. Pattison and F. van Hulssen. The DC3 survey aircraft was piloted by Captain D.K. Duffield and First Officer J. Conroy-Welby of Trans Australia Airlines.

2. GEOLOGY

The Eucla Basin embraces the whole of the treeless, karstland area of about 69,000 square miles, known as the Nullarbor Plain, at the head of the Great Australian Bight and the dry salt lake country extending 200 miles north of the Trans-Continental Railway Line.

The flat plain surface rises gradually from an elevation of 200 to 400 feet above sea level near the coast to an elevation of about 1,000 feet above sea level some 200 miles inland. In the south, the plain ends abruptly in sea cliffs, except between the South Australia/Western Australian border and Eyre (W.A.), where it is fronted by a lower coastal plain 20 miles wide carrying trees and grasses. The Hampton Range scarp bordering the Nullarbor Plain here may mark a fault of comparatively recent date or may represent an erosion feature.

According to David (1950; p.548-551), the component rocks of the sedimentary basin are mainly Tertiary. Beneath a thin cover of Pleistocene and Recent deposits, the Miocene bryozoal Eucla limestone rests upon a series of clays and shales, some yielding marine Cretaceous fossils, in the western part of the basin. In the east, according to David, the limestones are underlain by Tertiary sandy clays with marine fossils, and these rest on sand, gravel and lignitic clay, possibly Oligocene in age. In a few of the deepest bores in Western Australia, sands with granite boulders were penetrated just above bedrock, and these are surmised to be glacial beds of Cretaceous or Upper Palaeozoic age. Bedrock, in marginal outcrops and where

it has been penetrated in bores, is of Pre-Cambrian granite, gneiss and slate.

The broad structure of the basin is essentially simple. Boreholes along the Trans-Continental Railway Line indicate that the sedimentary beds thicken from the margin of the basin towards the centre, the greatest thicknesses being in Western Australia. The dip of the sedimentary beds is everywhere gentle. The supposedly glacial beds are the main aquifers of the Eucla artesian basin. The basin is situated in a region where, in Mid-Tertiary time, there was a deep embayment of the southern coastline of the continent.

3. MAGNETIC METHOD

The difference in magnetic susceptibility of different minerals, i.e. the degree to which they become magnetised in a magnetic field, may be used to delineate some types of subsurface ore bodies and rock structures. If the earth's crust were composed of uniformly magnetised material or layers of material, the magnetic field measured on the surface of the earth would have a regular and predictable pattern. The observed variations (called anomalies) in this pattern are due to the non-uniform magnetisation of the sub-surface materials. Boundaries of strongly magnetised orebodies or rock structures enclosed by weakly magnetised rocks may be delineated by measurement and analysis of these anomalies.

The magnetic properties of a rock are naturally those of its mineral constituents. The iron mineral, magnetite, is highly magnetic; ilmenite, pyrrhotite and hematite are less so. Other minerals are virtually non-magnetic. Igneous and metamorphic rocks, by reason of their magnetic content, are generally more highly magnetised than sedimentary rocks. This fact is the basis of the applicability of the magnetic method of prospecting over sedimentary basins. In general, the rocks forming the basement of the basin are magnetic igneous and metamorphic rocks, and the sedimentary rocks within the basin are virtually non-magnetic. Magnetic anomalies recorded over a basin normally arise in the basement rocks only, and the analysis of the anomalies enables conclusions to be drawn concerning the depth and possibly the configuration of the basement surface, and hence the distribution of the overlying sediments.

With the development of the airborne magnetometer, which was first used as a geophysical instrument in 1943, it has become practicable to carry out magnetic surveys of large areas, such as sedimentary basins, in a relatively short time. Compared with the ground method of magnetic surveying, the airborne method has the advantages that large areas can be surveyed rapidly regardless of the type of terrain and the results are less affected by local extraneous magnetic disturbances. The airborne magnetometer is designed to give a continuous record of the variations in the earth's total magnetic field.

4. EQUIPMENT

The airborne magnetometer consists essentially of a detector element, self-oriented with respect to the earth's magnetic field, electronic oscillators and amplifiers required for its operation, and equipment used to measure and record its output. Dobrin (1952, p.156-176) and Landsberg (1952, p.313-349) have described the operation of airborne magnetometers.

In the survey of the Eucla Basin, the airborne magnetometer was mounted in the rear end of the main compartment of a DC3 aircraft. An Esterline-Angus recorder with a chart speed of 3 inches per minute was used to record continuously the changes in total magnetic field.

The aircraft was equipped with a Sperry C.L.2 gyro-syn compass, radio altimeter and drift-sight, in addition to the normal radio communications equipment.

5. SURVEY OPERATIONS

The survey consisted of six flights made at an altitude of 1,500 feet above ground level. The flights were:-

- | | |
|----------|--|
| Flight 1 | Kalgoorlie to Kalgoorlie along the Trans-Continental Railway Line. |
| Flight 2 | Kalgoorlie to Oodnadatta. |
| Flight 3 | Oodnadatta to Ceduna. |
| Flight 4 | Ceduna to Kalgoorlie mainly over the Great Australian Bight. |
| Flight 5 | Kalgoorlie to Mt. Talbot, south to the Bight, north to Forrest. |
| Flight 6 | Forrest to Mt. Harriet, thence to Cook and Ceduna. |

The positions of these flights are shown on Plate 1.

With the exception of Flight 1 along the Trans-Continental Railway Line, all flights were navigated by dead reckoning. Aircraft positioning control during each flight was made by a series of check points, each of which fixed accurately the position of the aircraft; between check points, the most probable path of the aircraft was determined from aircraft speed, wind velocity and course bearing. Between check points, departure of the true course of the aircraft from the plotted course may be as much as 20 miles. Where flight lines are shown by a dotted line, the error may be more than this.

Correct correspondence between the record on the Esterline-Angus chart and the flight diagram was assured by annotating the chart during flight with the same check points as those on the flight diagram.

6. RESULTS

The magnetic profiles, recorded on the Esterline-Angus chart on curvilinear co-ordinates, were replotted on rectangular co-ordinates and are shown on Plate 1.

The profiles remain uncorrected for the earth's regional magnetic field. In this area, the correction is approximately 7.5 gammas per mile in a direction 3° west of south (183°).

The profiles also remain uncorrected for diurnal variation of the earth's magnetic field and instrumental drift, which are inherent in the measurement of magnetic field with the airborne magnetometer. The arrangement of the flights did not permit corrections for these sources of error.

7. INTERPRETATION

(a) Methods of Interpretation.

In the interpretation of the results of aeromagnetic surveys of sedimentary basins, it is assumed that all magnetic anomalies have their origin in structures of igneous rocks and metamorphosed sediments forming the basement rocks of the basin. The anomalies may be due to lithological changes in the basement complex or to topographic changes in the basement surface.

The chief difficulty in the interpretation of results is that there is no uniqueness of solution of a problem involving magnetic potential. Different sources at different depths can produce the same anomaly. However, by the use of some external control supplied by geological and borehole data or the results of some method of geophysical prospecting not involving measurements of potential fields, some limits of depth or shape of source can be applied to the interpretation.

A common method of interpreting an anomaly is to compare its shape with that of an idealised source for which the magnetic effect has been computed, and estimate its depth within the limits set by control data. Full use of this method would require more detailed data than that obtained in the Eucla Basin survey where the flight lines were widely spaced and the extent of individual anomalies is not clearly defined.

Another method involves a useful qualitative relationship which can be established between sharpness of anomalies on a profile and depth to basement. On the assumption that all anomalies have their origin in the basement rock, the sharpness of the anomalies will decrease with increase in distance from the height of observation, i.e. increase in depth to basement rock. In a survey area, the applicability of this method can be determined by a study of profiles obtained over known basement outcrops. The qualitative relationship can be extended to a quantitative one if sufficient information is available to allow direct correlation of magnetic profile characteristics with known depths to basement. This method was used in the interpretation of the Eucla Basin survey.

In the following interpretation estimations of depth are based on comparison of features of the profiles such as "roughness" or "smoothness" of the profile line and degree of sharpness of the more clearly defined individual anomalies, with the features of profiles recorded where depth control is available from basement rock outcrops, records of boreholes which penetrated basement rock, and in one area from seismic measurements of depth to basement rock.

(b) Interpretation of Survey Results.

In the following interpretation, the magnetic profiles in areas where depth control exists are discussed. Each of the six flight profiles is then discussed, and estimates are made of the order of the depth to basement rock. These estimates are shown on the profiles on Plate 1.

Areas where depth control exists.

Profiles recorded over known basement rock outcrops or very shallow basement are shown on:-

1. The northern sections of Flight No.6 in the Warburton-Musgrave Ranges.

5.

2. The eastern sections of Flights Nos. 1 and 6.
3. The western sections of Flights Nos. 1, 2, 4 and 5.
4. The southern section of Flight No. 3.

In these areas the shallowness of basement rock is evident from the number of mapped basement rock outcrops adjacent to the flight lines.

The irregular form of the magnetic profiles recorded over these sections represents the summed effect of a series of individual anomalies which are relatively sharp (large height-width ratio), in addition to several more clearly defined sharp anomalies of greater intensity.

Such profiles indicate shallow, magnetically disturbed basement rock. On geological grounds, it is probable that the depth of the basement ranges from zero to a maximum of 500 feet below the surface along these sections.

It may be concluded therefore that the degree of irregularity of the profile, together with the sharpness of the more outstanding anomalies exhibited in these sections characterize a profile recorded over basement which is at a depth of the order of 0 to 500 feet below the surface.

The second area where depth control is available is on Flight No. 1 at points 1.5, Loongana, 1.6, and at Maralinga 40 miles north of point 1.1 (Plate 1).

<u>Point</u>	<u>Depth of basement Rock</u>	<u>Recorded by</u>
1.5	1,000 feet	Borehole
Loongana	1,300 feet	"
1.6	1,200 "	"
Maralinga	1,600 " (approx).	Seismic

The profiles recorded over these sections of Flight No. 1 are generally smoother than those recorded over outcrops of basement rock, and the more clearly defined anomalies are less sharp. Such features may be said to characterize a profile recorded over basement which is at a depth of the order of 1,500 feet. An upper limit of about 2,000 feet has been set for this type of profile for reasons explained in the next paragraph.

A third area in which some measure of depth control is available is on the southern section of Flight No. 5 on the Hampton Scarp. A borehole at the site of the Madura caves, five miles south of the Hampton Scarp, had not penetrated basement rock at 2041 feet below the surface. However, it did penetrate artesian water at 1,980 feet and 2,041 feet, and is reported by T. Edgeworth David to be the only bore in the Eucla Basin yielding pressure water. It was found from boreholes in other parts of the basin that the main aquifers of the artesian basin are the sands containing boulders immediately overlying basement rock. It seems probable that in the Madura bore, the basement rock surface is not far below the bottom of the borehole, i.e. at a depth of the order of 2,000 feet below the surface.

The degree of profile smoothness and sharpness of the individual anomalies of the profile in this section are therefore concluded to characterize a profile recorded over basement rock which is at a depth of the order of 2,000 feet below the surface.

From the above controls, four depth ranges are used in the interpretation of the Eucla Basin magnetic profiles.

- Range 1. 0-500 feet below the surface.
- Range 2. Greater than 500 feet but less than 2,000 feet below the surface.
- Range 3. Of the order of 2,000 feet below the surface.
- Range 4. Greater than 2,000 feet below the surface.

Flight No.1 Kingoonya to Kalgoorlie along the Trans-Continental Railway Line.

The profile indicates that the basement rock attains a maximum depth of the order of 2,000 feet below the surface between points 1.1 and 1.3 on this flight line. East and west of this part of the profile, to the mapped outcrops of basement rock, the profile indicates that the basement rock depth is less than 2,000 feet below the surface.

The broad anomaly forty miles east of Rawlinna is interpreted as being due to a band of basic metamorphic rocks (parts of Greenstones and Whitestones Complex of Western Australia) with higher magnetic susceptibility than the surrounding granitic rocks. The width of the band is estimated to be about 10 miles. Broad anomalies west of point 1.7 are similarly interpreted as being due to large-scale changes in lithology of shallow basement rock.

This interpretation is supported by the fact that the positions of these magnetic anomalies coincide with those of positive gravity anomalies recorded during a gravimeter survey made by the Bureau of Mineral Resources along the Trans-Continental Railway Line. The density of the basic metamorphic rocks is approx. 3.0 gm/cc, whereas the density of the acid rocks is approx. 2.6 to 2.7. gm/cc. (Gunson and Van der Linden, 1956).

Flight No.2 Kalgoorlie to Oodnadatta.

Several sharp anomalies and generally irregular profiles were recorded over basement rock outcrops from Kalgoorlie to the western margin of the basin at approximately point 2.1. The profile indicates that the basement gradually deepens east of this point, being of the order of 2,000 feet to point 2.2. East of point 2.2, the smoothness of the profile indicates that the depth of the basement rock exceeds 2,000 feet south of the marginal outcrops in the Warburton-Musgrave Ranges. Eastward from the Ranges to Oodnadatta, the estimated basement depth is greater than 2,000 feet. The basement shallows near point 2.3, and between this point and Oodnadatta, is estimated to be less than 2,000 feet deep.

Flight No.3 Oodnadatta to Ceduna.

From depths of less than 2,000 feet west of Oodnadatta, the basement becomes shallow to the south. The very sharp anomalies immediately south of point 3.1 indicate a very shallow basement, although geological maps show no outcrops in this area. For the remainder of the line to Ceduna, the irregularity of the

profile indicates a very shallow basement - this is confirmed by the adjacent outcrops.

Flight No.4 Ceduna to Kalgoorlie mainly over the Great Australian Bight.

This profile is interesting because the irregular features recorded indicate that the basement rock is relatively shallow in the Great Australian Bight.

Maximum depth, estimated to be of the order of 2,000 feet below the surface (sea level), is attained between points 4.1 and 4.2.

From Ceduna to point 4.1, the estimated depth is in the 0 to 500 feet range, and west of point 4.2 to point 4.3, the basement is considered to be less than 2,000 feet deep. From point 4.3 to Kalgoorlie, the flight line traverses basement rock outcrops.

Flight No.5 Kalgoorlie to Mt.Talbot south to the Bight, north to Forrest.

In a north-easterly direction from Kalgoorlie, the flight line traverses basement rock outcrops to point 5.1 approximately. Between points 5.1 and 5.2 the basement rock depth is estimated to be 2,000 feet, deepening north of 5.2. On the north-south section of this flight, the basement is deepest south of the basement rock outcrops to point 5.3, the smoothness of the profile indicating a depth of more than 2,000 feet. Basement appears to be shallower between points 5.3 and 5.4 (estimated order of 2,000 feet) and less than 2,000 feet deep from point 5.4 to the southern end of the line in the Great Australian Bight.

The section of Flight No.5 over the Hampton Scarp has already been discussed. The source of the anomaly at point 5.5 is interpreted as a contact between basic and acid rocks within the basement. There is no evidence in the magnetic profiles of a fault beneath the Hampton Scarp.

Between point 5.6 and Forrest, estimated depth of basement rock is less than 2,000 feet.

Flight No.6 Forrest to Mt.Harriet, thence to Cook and Ceduna.

Between Forrest and point 6.1, the basement rock is probably less than 2,000 feet deep, but north of point 6.1 the smoothness of the profile indicates that the basement rock is considerably deeper than 2,000 feet. Immediately south of Mt.Harriet, where the basement is known to crop out, the profiles are characteristic of very shallow basement. South of the outcrop boundary to point 6.2, depths greater than 2,000 feet are indicated, with some shallowing between 6.2 and the coast to depths of the order of 2,000 feet.

In the portions of the flight line south of the coastline and eastward to Ceduna, the profiles indicate that the depth of the basement rock throughout this area is less than 500 feet.

8. SUMMARY

The aeromagnetic data recorded on the Eucla Basin reconnaissance survey indicate that the sediments have their greatest thickness in an area extending 100 miles south from the northern boundary of the basin. Basement rock is estimated to be more than 2,000 feet below the surface in this area, but the data do not permit an estimate to be made of the maximum depth to basement.

In the central basin area, the basement rock is estimated to be less than 2,000 feet deep (most probably in the range 1,000 to 2,000 feet), except in the vicinity of Cook on the Trans-Continental Railway Line, where the depth is probably of the order of 2,000 feet.

In the south-eastern part of the basin, basement rock shallows southward into the Great Australian Bight where it is probably less than 500 feet below sea level.

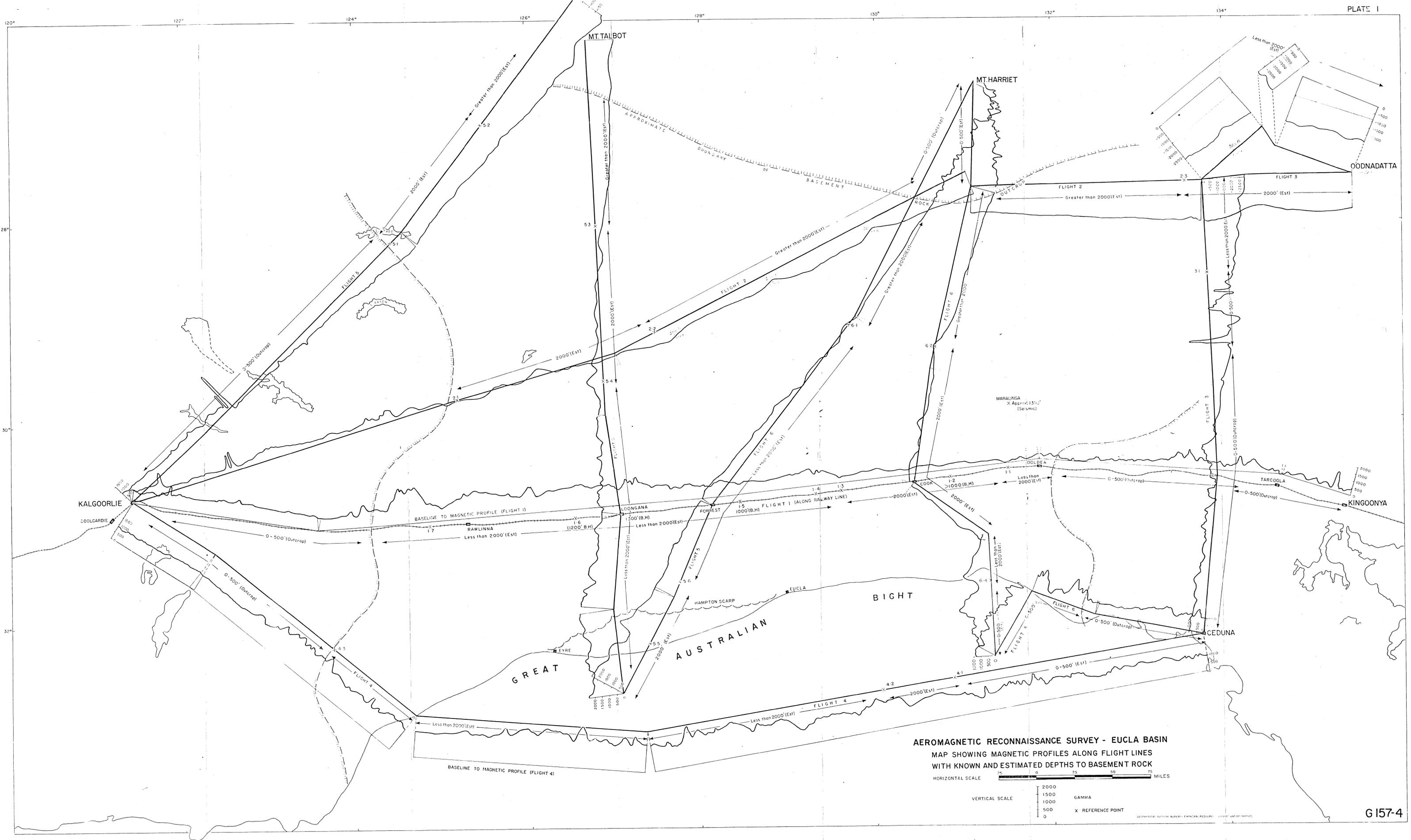
South of Forrest, the basement rock deepens gradually from 1,000 feet on the railway line to 2,000 feet at the Hampton Scarp and shallows to depths of less than 2,000 feet in the Bight.

In the south-western part of the basin the basement is estimated to be less than 2,000 feet deep from the railway line south into the Great Australian Bight.

The magnetic profiles across, and to the south of, the Hampton Scarp indicate there is probably no fault beneath the Hampton Scarp.

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AEROMAGNETIC RECONNAISSANCE SURVEY - EUCLA BASIN
 MAP SHOWING MAGNETIC PROFILES ALONG FLIGHT LINES
 WITH KNOWN AND ESTIMATED DEPTHS TO BASEMENT ROCK

