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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

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GREAT ARTESIAN BASIN, AEROMAGNETIC RECONNAISSANCE SURVEY 1958

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ABSTRACT.

An aeromagnetic reconnaissance survey, consisting of a series of widely spaced traverses, was made of the south-western part of the Great Artesian Basin, extending from Cloncurry in the north to Tibooburra in the south and from Charleville in the east to the Curralulla in the west.

The results of the survey show good agreement with the known general structure of the Basin. From a qualitative interpretation of the data, it has been possible to distinguish the shallow from the deeper parts of the Basin and to trace several basement ridges extending into the Basin.

Depths to "magnetic basement" have been calculated from individual magnetic anomalies where possible. Errors in the depth determinations may occur due to non-validity of certain simplifying assumptions about deep-seated causes of magnetic anomalies, but the estimated basement depths appear to be in broad agreement with depths based on seismic results and depths known from bore holes. The maximum estimated depth to basement is of the order of 8,000 to 9,000 feet.

I. INTRODUCTION.

During the period 18th to 29th May, 1958, the Commonwealth Bureau of Mineral Resources carried out a reconnaissance survey of the south-western portion of the Great Artesian Basins. The survey consisted of a series of widely spaced traverses giving a broad coverage of the greater part of the Thomson sub-basin, which, according to Whitehouse (1954), constitutes one of the three main structural divisions of the Basin. The area surveyed, lying mainly in Queensland, but including also adjoining parts of South Australia, New South Wales and the Northern Territory, is shown on Plate I.

The personnel engaged on the survey were W.A.L. Forsyth (Party Leader), Miss C. Leary, F. Clements, N. Hamilton and H. Herzog. The D.C.3 aircraft, VH-MIN, was piloted by Captain N. Pascoe and First Officer D. Wright of Trans Australia Airlines.

Additional traverses connecting the Curralulla with Dajarra and Oodnadatta and Alice Springs with Adelaide were flown in 1958 by D.C.3 aircraft VH-BUR, piloted by Captain P. Noriss and First Officer J. Bartlett. The survey party on this occasion consisted of R.M. Carter (Party Leader), R. Wells, J. Pollard, J. Croger and R. Jones.

The traverses, Tennant Creek to Mackay and Broken Hill to Alice Springs, were flown in 1956 by aircraft VH-BUR, piloted by Captain L. Evans and First Officer K. Purnell. The Bureau personnel on the aircraft were P.E. Goodeve and A. Spence.

II. GEOLOGY.

The following geological information is taken mainly from Whitehouse (1954). The Great Artesian Basin is an approximately pear-shaped syncline in Mesozoic and later sediments widening southwards from the Gulf of Carpentaria. The northern boundary is unknown and may lie in New Guinea. The eastern and western margins are regarded as being defined by pre-Mesozoic outcrops ranging in age from Pre-Cambrian to Permian, although the sand-dunes of the Simpson Desert conceal the western margin south of the visible outcrops which define a boundary roughly through Cloncurry and Glenormiston. The eastern margin lies to the east of the survey data.

Two main ridges of basement of pre-Mesozoic rock, over which the Mesozoic sediments settled, divide the Basin into three component sub-basins, the Thallon (south-east), Thomson (central) and Carpentaria (north). The Nebine Ridge dividing the Thomson and Thallon basins, runs roughly north-south on and about the 147 degrees east meridian. The Euroka Shelf, dividing the Thomson and Carpentaria basins, is an area of shallow basement lying to the north of the Selwyn Range. It is continuous to the south-west with the Boulia Shelf, also an area of shallow basement which lies within the north-western margin of the Thomson basin. The three basins are expressed quite well by the surface topography. Thus the Thallon basin corresponds with the basin of the Balonne River, the Thomson basin with the drainage pattern of the

Lake Eyre system, and the Carpentaria basin with the depression forming the Gulf of Carpentaria. Outcrops of Pre-Cambrian granite in the vicinity of the Peake Creek and of metamorphic rocks at Tibooburra set a limit to the southerly extension of the Thomson basin. In the south-east an area of shallow basement, the Eulo Shelf, west of the Nebine Ridge, gives rise to granite outcrops in the neighbourhood of Eulo.

The rocks immediately underlying the Mesozoic sediments in the survey area range in age from the Pre-Cambrian to Permian. On the western margin of the basin they are successively Pre-Cambrian metamorphics as far south as 22° latitude, Cambrian and Ordovician limestones to the Tropic of Capricorn, and Ordovician sandstones southward until hidden by the Simpson Desert sands. In addition, granites and undifferentiated palaeozoic rocks appear on the eastern side. For the purpose of the aeromagnetic survey however, only igneous and metamorphic rocks will be regarded as constituting what might be termed "magnetic basement", they being generally speaking the only types of rock which include magnetic constituents in their composition. The surface of the magnetic basement as suggested by the survey will not necessarily conform to that of the pre-Mesozoic basement discussed above as there may be an unknown thickness of Palaeozoic sediments overlying it.

The Mesozoic succession is made up of Lower Cretaceous, Jurassic and Triassic fresh-water beds with a maximum thickness of 3,800 feet. overlain by Lower Cretaceous marine sediments and Upper Cretaceous fresh-water sediments whose total thickness is approximately 4,500 feet (David, pp 518 - 539, 1950). Cainozoic formations filling surface depressions cover a large part of the area. Shales predominate in the marine beds whereas the fresh-water sediments alternate between shales and sandstones. The rocks of Jurassic age include coal seams (The Walloon Coal-Measures).

The general structure of the basin is modified by subsidiary folding and faulting which it was hoped the aeromagnetic traverses would help to elucidate. Of particular interest is the possibility of a southern extension of the Manfred Fault, a prominent feature striking south-east in the Julia Creek area.

In addition, it may be that the Burke River Structure line, an anticlinal axis associated with a string of inliers of Cambrian - Ordovician limestone running S.S.E. through Black Mountain on the Boulia Shelf, has an extension to the south. Evidence of anticlines in the Cordillo Downs area or elsewhere would be of interest from the point of view of oil accumulation, and, finally, data obtained over the Simpson Desert might give information on the unknown basement topography beneath.

III. GEOMAGNETIC METHOD.

The difference in magnetic susceptibilities 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 follow a regular and predictable pattern. The observed variations (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 in 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 haematite less so. Other minerals are virtually non-magnetic. Igneous and metamorphic rocks by reason of their magnetite content are generally more highly magnetised than sedimentary rocks. Thus, magnetic variations recorded, for instance over a sedimentary basin, normally derive from whatever magnetic igneous or metamorphic rocks underly the sediments. Analysis of the variations enables conclusions to be drawn concerning the depth and possibly the configuration of the surface of this "magnetic basement", hence providing indirect information on the sedimentary structure.

The magnetisation of minerals may be either that induced by the earth's present magnetic field, or it may consist of remanent magnetism from a previous magnetisation. Both types of magnetisation are sometimes found in the same rock.

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 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 that results are less affected by local extraneous disturbances. The airborne magnetometer is designed to give a continuous record of the variations in the earth's total magnetic field.

IV. EQUIPMENT.

The magnetic field intensity was measured by means of fluxgate magnetometer, in the detector element being mounted on a boom projecting from the rear of the aircraft. A Speedomax paperchart recorder installed in the aircraft, provided a continuous record of the magnetic field.

A strip camera furnished a continuous photographic record on 35 mm. film of the ground traversed.

V. SURVEY OPERATIONS.

The flight line diagram of the survey is shown on Plate I. The total length of traverse was 7,580 miles and the flying time 74 hours 24 minutes. Navigation was accomplished by reference to an I.C.A.O. aeronautical map of the area. scale 1:1,000,000. A barometric altimeter showing height above sea-level served as sufficient indication in keeping the flying height at 1,500 feet above the remarkably flat terrain.

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The aircraft's location was periodically noted on each flight-line at "check-points" where the true ground position could be recognised from land features. Correct correspondence between the Speedomax chart and the plotted course of the aircraft was assured by annotating the chart at the instant of passing over each check point.

VI. RESULTS.

The profiles of magnetic field intensity, recorded on the chart on a scale of 53 gammas per inch, have been corrected for regional gradient, which in this area has an average value of 9.0 gammas per mile in a direction south 2 degrees west. The profiles are shwon, reduced in scale, in conjunction with the flight lines in Plate I. The magnetic datum level has been chosen arbitarily but the profiles are mutually consistent.

VII. INTERPRETATION.

(a) Method

Interpretation requires the study of the recorded profiles along with all available geological and borehole data and the results of other geophysical methods which have been applied in the same area. Such data have been noted on Plate I.

The information usually sought from aeromagnetic surveys is the depth of the basement, the term basement referring to the magnetic igneous or metamorphic rocks which immediately underly the non-magnetic sediments. Anomalies, i.e. significant variations magnetic intensity, are presumed to be due to lateral changes in the magnetite content of the basement as so defined. Such anomalies are narrower the smaller is the depth to the causative lateral change i.e. to the basement surface. The actual change in magnetic intensity is also greater the shallower is the basement. These two facts give rise to the following criteria used in determining depth :-

(i) The "smoothness" of the magnetic data.

A magnetic profile over an area where the basement lies at great depth usually appears in consequence smoother than one taken where the basement is shallow.

(ii) The shape, and in particular the width of individual magnetic anomalies. Difficulties in interpretation arise in that magnetic variations of great lateral extent may equally well be due to gradual changes in magnetic properties at shallow depths as to sudden changes at a deeper horizon.

Magnetic anomalies may also be due to changes in the basement topography caused for example by faulting. Such anomalies are in general smaller than those caused by changes in basement composition. Thus, they might be of the order of tens of gammas as against hundreds of gammas.

The coverage on this survey was not considered sufficient to warrant elaborate methods of depth estimation. A procedure due to L.J. Peters (1949) involving a simple geometrical construction has been applied to some of the individual anomalies. Depth determinations made from anomalies on single profiles are however, subject to large errors if the assumptions on which they are based are not valid. The method due to Peters gives acceptable results only under the following conditions :-

1. The anomalies are caused by sharp discontinuities in the magnetite content of the basement.

2. The contacts between the rock masses of differing magnetite content are vertical.

3. The contacts are at right angles to the direction of the profile and have considerable length.

4. The direction of magnetisation is predominantly vertical.

Interpretation of Survey Results.

Some of the anomalies used for depth determinations are too small to be seen on the profiles in Plate I, because of the small scale of this map.

The appearance of the profiles of magnetic intensity bears out quite well the known structure of that part of the basin covered by the survey. The large fluctuations of intensity recorded in the north of the area mark this region as one where the basement lies at shallow depth, as is known from the existance of the Boulia shelf. The profiles are similarly rough in the south-west where, judging from the granite outcrops of the Denison Range and the Everard Range, which lies off the survey area, south-west of the Curralulla, the basement is again shallow.

It appears that the smoothness of the profiles in the central part of the basin, i.e., the Betoota, Innaminka, Quilpie, Ruthven area, can be taken as indicative of greater depth, as witnessed by the occasional boreholes in this region which have failed to reach basement even after several thousand feet of drilling. However, the fairly smooth character of those profiles taken above the Eulo Shelf, where depths are comparable with those on the Boulia Shelf, is evidence that the "smoothness" criterion is the roughest only of guides to depth. Where the magnetite content of the basement is high, as in basic rocks, the lateral changes in magnetite content are likely also to be high and to give rise to large anomalies. Conversely, where the magnetite content is lower, as in acid rocks, the anomalies will be small, despite similarity in basement depth.

The estimated basement depths marked on the map have been computed from individual anomalies. They are not dependent on the size of the anomalies but are never the less subject to errors as explained in "method". Depths marked along a single profile however should give a reasonable indication of the rise and fall of the basement, which term refers, as explained previously, only to igneous or metamorphic rocks.

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Northern Area (Boulia Shelf)

Positive anomalies at Springvale and at a point 12 miles west of Hamilton appear to be in line with the Burke River Structure. An anticlinal axis running S.S.E. through Black Mountain, Minmaroo and Mt. Datson. A similar axis through Monedah, running roughly parallel to the first, also appears to extend further south, producing the anomaly in the vicinity of Hamilton and that at a point 17 miles east of Springvale. There is no evidence of any further extension southward, but to the north of Monedah, the axis appears to turn northward passing through Cloncurry.

The broad anomaly extending about 20 miles east from Marion Downs may correlate with the anomaly located 20 miles west of Boulia and the disturbed part of the Dajarra - the Curralulla profile extending 33 miles S.W. of Dajarra. This line of amonalies may indicate another structural high, trending S.S.E. analogous to the Burke River structure.

It is noteworthy that both the Glenormiston-Muttaburra and the Glenormiston-Longreach profiles become smoother towards the east. The transition from the disturbed part of the trace occurs quite abruptly at points 20 miles east of Brighton Downs and 110 miles east of Hamilton. It is probable that the Boulia Shelf extends this far east, the basement dipping more rapidly thereafter.

The profile from Cloncurry towards Mackay gives depth estimates which indicate deepening of the basement towards the east. The deepening may be associated with a southern continuation of the Manfred Fault, but it is not possible to definitely correlate the Fault with any particular feature on the profile. The eastern portions of the Glenormiston-Muttaburra and Glenormiston-Longreach profiles are relatively free of anomalies and give no evidence of an extension of the Manfred Fault into this part of the survey area.

Central Area (Betoota, Cordillo Downs).

There is no positive evidence of structure in this region, the basement lying so deep that quite large changes in basement topography are unlikely to cause significant variations on the magnetic profile. A line of broad anomalies running S.W. through Betoota, Cadelga and a point 20 miles N.W. of Cordillo Downs may conceivable correspond to a basement ridge. The depth estimates made on these profiles are consistent with such a structure but they may be in error for the reasons mentioned previously. The general basement depth seems to be in the neighbourhood of 8,000 to 9,000 feet, however, compared with the 8,000 to 16,000 feet estimated from seismic work in this area (Smith and Lodwick, 1959).

South-eastern Area (Eulo Shelf, Quilpie).

The Innaminka-Cunnamulla profile, as would be expected, becomes more disturbed towards Eulo and Cunnamulla as the basement rises. The Quilpie-Charleville profile is quite smooth but the broad anomaly roughly 65 miles west of Charleville suggests that the Eulo Shelf extends as far north as this, though at the same time deepening . Depth estimates are insufficient,

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owing to the absence of anomalies in this area, to outline accurately the extent of the Eulo Shelf.

South-western Area.

The disturbed profile in the vicinity of Peake Creek is presumably an effect of the anticlinal axis corresponding to the Denison Range. According to computed depth estimates, the basement is shallow here, deepening to the east beneath lake Eyre and rising again east of Etadunna to a depth of the order of 2,600 feet. From Etadunna the basement deepens to the north-east towards Innaminka, and also to the south-east.

North-west of Peake Creek the basement appears to deepen although it must rise again to the north of the Currallulla where boreholes have discovered bedrock at a depth of roughly 1,000 feet. The profile Oodnadatta-Adelaide shows a gradual deepening of the basement south of Peake Creek.

Simpson Desert Area.

The traverses connecting Dajarra to Alice Springs and the Curralulla extend over shallow bedrock at either end. The profiles are disturbed over their whole length, indicating that the basement never reaches great depth. Estimates put the maximum basement depth attained as about 3,300 feet.

VIII. SUMMARY.

The aeromagnetic survey confirms the classic picture of this part of the Great Artesian Basin as an area possessing great thickness of sediments, thinning out gradually from the central portion, i.e. roughly the region including Betoota, Cordillo Downs, Quilpie and Ruthven. The maximum computed thickness of sediments is 9,000 feet.

The well-known Burke River structure appears to be marked by a magnetic anomaly, evidence that the anticlinal axis is associated with a structural high in the underlying pre-Cambrian rocks. The structure probably persists as far south as Springvale and is paralleled by a similar structure about 12 miles to the east. There may be a basement high trending S.S.E. along a line running 20 miles west of Boulia and 20 miles east of Marion Downs.

A continuation of the Denison Range produces anomalies in the vicinity of Peake Creek but not further north than this.

The basement is shown to lie at farily shallow depth beneath the eastern edge of the Simpson Desert.

There is the possibility of a buried ridge running roughly through Betoota and Cadelga. It is probable however, that many sedimentary domes are not an expression of basement topography and consequently do not produce anomalous magnetic indications.

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Appendix G.

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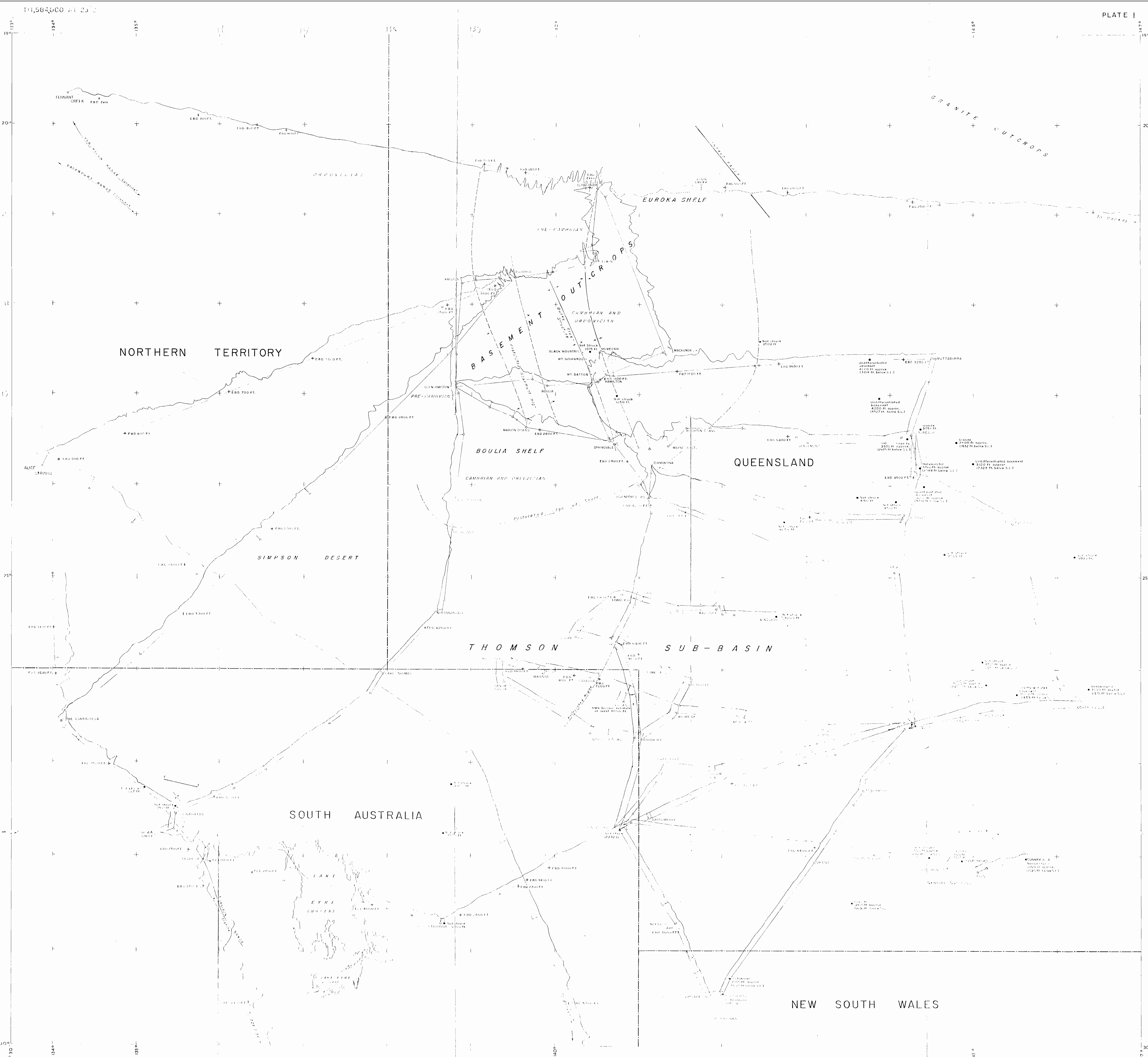
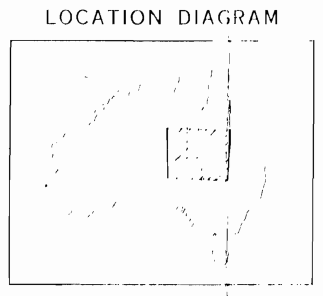
PLATE I



LOCATION DIAGRAM



MAP DATA

AEROMAGNETIC RECONNAISSANCE SURVEY

GREAT ARTESIAN BASIN

MAP SHOWING

MAGNETIC PROFILES

ALONG FLIGHT LINES

(WITH KNOWN AND ESTIMATED DEPTHS TO BASEMENT ROCK)

VERTICAL SCALE: 0, 250, 500, 750, 1000 GAMMAS

LEGEND

- FLIGHT LINE AND ARBITRARY MAGNETIC DATUM
- GROUND REFERENCE POINT
- SHADING INDICATES VALUES BELOW DATUM
- BORE HOLE STRUCK METAMORPHIC BASEMENT AT 3251 FT. BELOW GROUND LEVEL
- SEA LEVEL
- BOUNDARY OF REGION OF SHALLOW BASEMENT SUGGESTED BY MAGNETIC RESULTS
- STRUCTURAL LINE SUGGESTED BY MAGNETIC RESULTS
- ESTIMATED BASEMENT DEPTH BELOW GROUND LEVEL DETERMINED FROM MAGNETIC RESULTS
- KNOWN ANTICLINAL AXIS
- KNOWN SYNCLINAL AXIS

EXPLANATORY NOTES

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