COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1963/74

PERTH BASIN AEROMAGNETIC SURVEY, WESTERN AUSTRALIA 1957

by

J.H. QUILTY

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1963/74

PERTH BASIN AEROMAGNETIC SURVEY, WESTERN AUSTRALIA 1957

by

J.H. QUILTY

CONTENTS

ILLUSTRATIONS

SUMMARY

The Bureau of Mineral Resources made an aeromagnetic survey of the Perth Basin in 1957 to determine the basement rock structure and the seaward extent of the Basin.

The results indicate the existence of a deep, elongated basement-trough filled with sediments. The trough is narrow in the northern part of the Basin, widens considerably towards the south to latitude $32^{\circ}30'$, and then decreases rapidly in width towards Cape Naturaliste. It assumes a graben structure of moderate depth between Cape Naturaliste and Cape Leeuwin. Subsidiary basement ridges are developed within the trough, often close to, and parallel with, the boundaries of the Basin. Near-surface basalt is indicated in the southern region.

A contour map of estimated depth to magnetic basement rock and consequent thickness of overlying sediments in the Basin is included with this Record.

1. INTRODUCTION

For six months of the period February to October 1957 the Bureau of Mineral Resources made an aeromagnetic survey of the Perth Basin between Cape Leeuwin and Geraldton, Western Australia.

The survey extended from basement-rock outcrops east of the Darling Scarp seaward to longitude 115° east, and between latitudes 31°30' south and 33°30' south the seaward extent of the survey ranged between longitudes 114°10' east and 115° east. Flight-lines were flown in an east-west direction and were spaced one mile apart. The western limits were variable, the flight-lines in some areas being extended where significant data were recorded; additional exploratory lines were flown to longitude 114° east every 15 minutes of latitude. The flight altitude was 1500 feet above sea level except on the western ends of some flight-lines where it was increased to maintain control with Shoran radar control beacons.

The objects of the aeromagnetic survey were to delineate structural features of the Basin by means of the magnetic pattern, and to extend the investigations seaward to determine the extent of sedimentation off-shore.

The Bureau of Mineral Resources personnel engaged in the survey were: J.K. Newman (party leader), W.A.L. Forsyth, F.J. Merrick, C.L. Cookson, R. Wells, Miss C. Leary, W.A. Porta, P.G. Grimsley, R.O. Franklin, M.A. Hazelbrook, F.S. Clements, D.W. Walker, W.J. Bresser, J.P. Pigott, K.A. Mort, C.J. Braybrook, P.J. Muir, and E. Granville. Trans-Australia Airlines personnel were Capt. D.K. Duffield, J. Bartlett, A.H. Worley, M. Gatley, R. Luniss, and C. Renshaw.

The preliminary report of the survey (Newman, 1959) summarised the results and their possible significance.

Provisional maps of aeromagnetic contours, at a scale of 1 inch to 4 miles, were issued in March 1960. Final maps showing aeromagnetic and gravimetric data were printed and issued in 1961. Copies of these provisional maps are shown on Plates 2 to 7.

2. GEOLOGY

Geological investigations of the coastal area of Western Australia commenced as early as mid-nineteenth century. The petroleum prospects of the Perth Basin were seriously considered only in recent years, and a comprehensive review of all previous geological work, together with his own investigations, was made by Fairbridge (1949). He gave the first specific attention to the tectonic structure of the Basin. The results of a gravity reconnaissance survey by the Bureau of Mineral Resources (Thyer and Everingham, 1956) added further information on subsurface structure, and indicated a much greater depth of sediments than was previously considered likely. McWhae, Playford, Lindner, Glenister, and Balme (1958) have described the stratigraphy of the Perth Basin.

The Perth Basin lies partly beneath the coastal plain in the south-western corner of Western Australia. The Basin is marginal to the ancient Precambrian shield area, the 'West Australian Plateau' (Fairbridge, 1949) and is separated from it by the Darling Scarp. The coastal plain itself is subdivided into a series of plateaus bounded by scarps or contacts between sediments of different ages.

The basement rocks of the Basin are the older Precambrian crystalline rocks which crop out east of the Darling Scarp. They are also exposed within the Basin on the coast between Cape Naturaliste and Cape Leeuwin, and near the coast north of Geraldton.

The oldest sediments in the Basin are stratigraphic units of doubtful age, either Proterozoic or older Palaeozoic (McWhae et al, 1958, p.12). The more important of these are:

(a) Moora Group with an aggregate thickness of more than 4000 ft intruded by dolerite dykes,

(b) Yandanooka Group, a thick sequence of unfossiliferous clastic rocks with an aggregate thickness of 30,000 ft in outcrop, in the northern part of the Basin,

(c) Cardup Shale with an aggregate thickness of 3000 ft, intruded by dolerite dykes, in the southern part of the basin, and

(d) Tumblagooda Sandstone with an aggregate thickness of more than 6000 ft.

Permian sediments crop out over an area of about 500 square miles in the northern part of the Basin towards Geraldton and have been penetrated in boreholes east of Geraldton. They consist of glacial tillite, shale, sand, and limestone overlain by coal measures and continental sandstone. The known outcrop thickness of the Permian cross-section is over 6000 ft (McWhae et al, 1958, p. 53).

Mesozoic sediments crop out over large areas both in the northern and southern parts of the Basin, and have been penetrated in deep bores in the Perth Sunkland (Fairbridge, 1949, p.6). The total thickness of known Mesozoic cross-section is several thousand feet.

Tertiary marine deposits, penetrated in bores in the Perth metropolitan area, are over 1000 ft thick. (McWhae et al., 1958, p. 120). Tertiary basalt flows 30 to 100 ft thick are also found in some areas (Fairbridge, 1949, p. 14).

Quaternary rocks are widespread on the coastal plain and also cover the entire area of the Perth Sunkland (Fairbridge, 1949, p. 15).

Geological Structure

The main Darling Scarp extends over a distance of more than 500 miles as a linear feature from near Cape D'Entrecasteaux to north of the Murchison River. This scarp is the surface indication of a normal fault with a large downthrow west. Its trend is roughly north-south with divergences west in the southern part of the Basin and more westerly still in the northern part. There is a break in continuity of the Fault near Mingenew, where there are parallel faults over a considerable distance.

Plateaus on the coastal plain appear to have been formed by normal faults (Fairbridge, 1949, p.3). Near Gingin the Hill River Fault diverges from the Darling Fault and extends over 100 miles with a north-west to north-north-west strike to the Hill River. Farther north the Irwin Fault, over 100 miles long and passing almost through Geraldton, is parallel to the Hill River Fault which is 40 miles distant. The Whicher Fault diverges from the Darling Fault near Brunswick Junction with a south-west to south-south-west trend and dies out near the Dunsborough Fault south-west of Busselton. The Dunsborough Fault, over 100 miles long, extends from eight miles south-east of Cape Naturaliste to beyond Augusta. Along this Fault sediments abut a granitic-basement horst structure.

Steep gravity gradients over the entire length of the main Darling Fault confirm the existence of a fault, andindicate that it is a normal fault with an unusually large downthrow west (Thyer and Everingham, 1956). Similar but less-steep gravity gradients coincide with the Dunsborough Fault, and eight miles east another fault is indicated. No gravity anomaly is recorded over the Whicher or Irwin Faults, and only slight indications are recorded on the Hill River Fault; it is concluded that these are minor structural features as far as vertical movement is concerned.

The most likely cause of the large negative gravity anomalywithin the Basin is believed to be a deep rift or graben filled with light sediments. The gravity evidence does not support the subdivision of the Basin into the Perth Sunkland, Donnybrook Block, and Dandaragan Block, but rather a subdivision into two main troughs, one centred west of Watheroo and the other near Bunbury. The estimated maximum thickness of sediments is between 25,000 and 35,000 ft, west of Watheroo.

In the northern part of the Basin, the break in continuity of the main Darling Fault near Mingenew and the development of two parallel faults for some distance is indicated in the gravity results. A gravity gradient passing through Dongara is interpreted as a fault striking approximately north with downthrow east. The gravity reconnaissance survey terminated at latitude 28° south, but widely-separated gravity readings northward indicate that the Perth Basin continues north to join the Carnarvon Basin.

3. INTERPRETATION

Magnetic rocks in the Perth Basin

Precambrian rocks, exposed on the 'West Australian Plateau', form the basement rocks of the Perth Basin. They are divided stratigraphically into older Precambrian (Archaean and Lower Proterozoic) igneous rocks and highly metamorphosed sediments and lavas, separated by pronounced erosion from overlying unmetamorphosed Upper Proterozoic rocks (McWhae et al., 1958, p.5). Archaean granite, granite gneiss, and allied rocks, with meta-sediments, meta-volcanics, and various basic and ultra-basic intrusives are widespread in Western Australia. These crystalline rocks are all magnetic to some degree, depending on the proportion of magnetite in their mineral composition. The more-basic members normally display strongly-magnetic properties, and banded iron formations within them give rise to intense anomalies; the magnetic effect of granitic rocks with varying concentrations of disseminated magnetite is usually moderate. The Upper Proterozoic sediments have negligible magnetic effect, but inclusions of lavas and basic dykes can be the sources of magnetic anomalies.

The overlying sediments in the Basin are assumed to be nonmagnetic. Anomalies in the magnetic pattern may therefore be ascribed to sources at basement level, i.e. either to boundaries of magnetic material within the basement or to significant changes in the level of the basement surface. Exceptions occur where near-surface basalt disturbs the magnetic field near the coast south of Bunbury and elsewhere in the southern part of the Basin.

Interpretation of survey results

The survey area covered some basement rock outcrops east of the Darling Scarp. Advantage was taken of this to study the magnetic anomalies overlying typical basement lithology. In four southern localities, viz. Busselton, Rockingham, Cookernup, and Gingin, seismic measurements were available for control on estimated depths to basement (Lodwick, 1962; Moss, 1962; Vale and Moss, 1962; Vale, 1956). Depth estimates were made by measurements of anomaly parameters, together with the information derived from anomalies over basement outcrops. The prime assumption made was that virtually all anomalies recorded in the Basin were due to near-vertical boundaries of strong magnetic contrast extending from the basement surface downward to considerable depths in the complex (Vacquier, Steeland, Henderson, and Zeitz, 1951). The possibility of topographic effects being associated with these boundaries was not disregarded. However, no individual anomalies were ascribed solely to effects of basement relief.

The parameter most frequently used was the horizontal extent of the maximum gradient of an anomaly; this is considered to be nearly equal to the depth to the surface of the prismatic magnetic body. The formula used was D (depth) = 1.25 H (horizontal extent of maximum gradient). A contour map of estimated depth to magnetic basement rock was made from these measurements (Plate 8).

Magnetic contour plans. The most clearly marked features in the magnetic pattern are the abrupt change in the degree of magnetic disturbance along the length of the main Darling Fault on the eastern boundary of the Basin, and a similar change along the Dunsborough Fault forming the western boundary in the most southerly part of the Basin. The pattern also shows a significant change in direction of the western boundary north of Cape Naturaliste. From a north-south trend along the exposed basement, the boundary chnages first to a direction 30° west of north, then to a direction 45° west of north. The edge of the Cape Naturaliste horst structu undoubtedly follows the trend of the anomaly pattern, and does not continue in a direction due north of the Cape. Increasing depth of this structure below sea level is indicated in a north-west direction.

The depth to basement is shown to be not uniform west of the main Darling Fault; considerable shallowing of depth to basement is shown by the magnetic pattern along the coast between latitudes 29°30' and 30°30' south, particularly at latitude 29°50' south; also at latitude 31° south a short distance off the coast, and in an area about ninety miles west of Perth, South of Bunbury, moderate depths to basement are evident from the more intense pattern over that part of the Basin.

The magnetic character of the basement rock underlying the sediments in the Basin is shown by the anomalies recorded over the basement outcrops east of the Darling Fault. Individual anomaly forms are distinguishable, commonly extending over many miles in length, narrow in width, and with intensities of several hundred gammas. The sources of these anomalies are correspondingly narrow, elongate bands of strongly magnetic material with near-vertical boundaries extending to considerable depths below the basement surface. Basic dyke structures, banded iron formations (jaspilites) characteristic of the Precambrian rocks, or other discrete bands of magnetite concentration could account for such anomalies. Many of them show trends in a northerly direction, indicating that tectonic movements have been directed generally along northerly axes.

7

6

Outcrops of basalt have been found on the coast near Bunbury and in other places in the southern part of the Basin. This basalt produces magnetic anomalies, as evidenced in the aeromagnetic map. In an area west of Leschenault Inlet where the regularity of the regional magnetic pattern indicates reasonably deep basement, a line of magnetic disturbance extends west possibly to longitude 115° east. The disturbance can also be traced south from Bunbury across the sediments, passing west of Quilergup and swinging towards Nannup. Another line of magnetic disturbance extends south through Darradup; south-west of Darradup a line of disturbance runs north of White Point.

It is probable that these distinctive lines of magnetic anomalies, many of which exhibit reverse polarisation, trace the pattern of an old stream system filled with basalt. The western arm evidently extended from Bunbury well out on to the continental shelf, and the southern arm can be followed as far as the present southern coast. The basalt filling the old stream valleys off the present shoreline is possibly the source of some of the heavy minerals (ilmenite, rutile, and zircon) found in beach deposits at Minninup, 11 miles south of Bunbury and at Wonnerup, 4½ miles east of Busselton (BMR, 1951). There is no indication of basalt in the northern part of the Basin.

Basement depth contours A contour map of depths to magnetic basement is shown in Plate 8. The individual figures shown are representative depth estimates. Although the depths can only be obtained approximately because of uncertainties inherent in depth estimation from aeromagnetic data, the contours give a reliable indication of relative depths and hence of the main features of the magnetic basement surface. In most parts of the Basin the magnetic basement surface probably corresponds with the surface of the Archaean rocks; in some places it may correspond with the surface of the Proterozoic rocks where they have been intruded by basic dykes.

The depth contours show a deep elongate trough abutting the Darling Fault in the central part of the Basin, but diverging from the Fault in the north and south. In the northern part of the Basin the trough is narrow and heads in a north-north-west direction towards the coast, presumably passing into the Carnarvon Basin. Between latitudes 29° 00' and 30° 00', the trough is bounded on the eastern side by near-surface basement rocks lying west of the Darling Fault and on the western side by basement rocks at depths of a few thousand feet along the coast between latitudes 29°30' and 31°15'. This has been confirmed by drilling at Beagle Ridge (BMR 10A), where basement rock was struck at 4794 ft (McTavish, 1960). Basement relief inland from the coast between latitudes 30°15' and 30°45' further narrows the trough.

The trough widens progressively southward from latitude 31°. The trend and position of shallow basement rock on the western boundary appear to follow the continental slope with a projecting ridge west of Rottnest Island (latitude 32°). Maximum westward extension of the trough is shown at latitude 32°30'; southward the trough width decreases rapidly towards Cape Naturaliste (latitude 33°30'). A basement spur is shown on the eastern side of the trough at latitude 32°45'.

South of latitude 33°30' the contours show a graben structure with localised basement relief in the structure. It is evident that the basement rock is not deeply buried west of the coast in this region and that the basement rock outcrop of the Cape Naturaliste horst is part of a much larger area of shallow basement rock extending west at least as far as longitude 114° east.

4. CONCLUSIONS

The aeromagnetic results over the Perth Basin indicate the existence of a deep elongate trough of possible Upper Proterozoic, Palaeozoic, and Mesozoic sediments overlying a basement complex of older Precambrian age.

In the northern part of the Basin the trough, which is narrow, is bounded on the eastern side by shallow basement rocks extending beyond the main fault line, and on the western side by shallow basement rock along the coast.

South of latitude 31° south, the trough widens considerably, reaching maximum westward extension at latitude 32°30' south. Its width then decreases rapidly towards Cape Naturaliste, and assumes a graben structure of moderate depth towards Cape Leeuwin. The eastern boundary is the Darling Fault.

Subsidiary basement ridges are developed within the trough, often close to, and parallel with, the boundaries of the Basin.

The existence of near-surface basalt, probably filling the valleys of a former stream system, is clearly indicated in the southern part of the Basin.

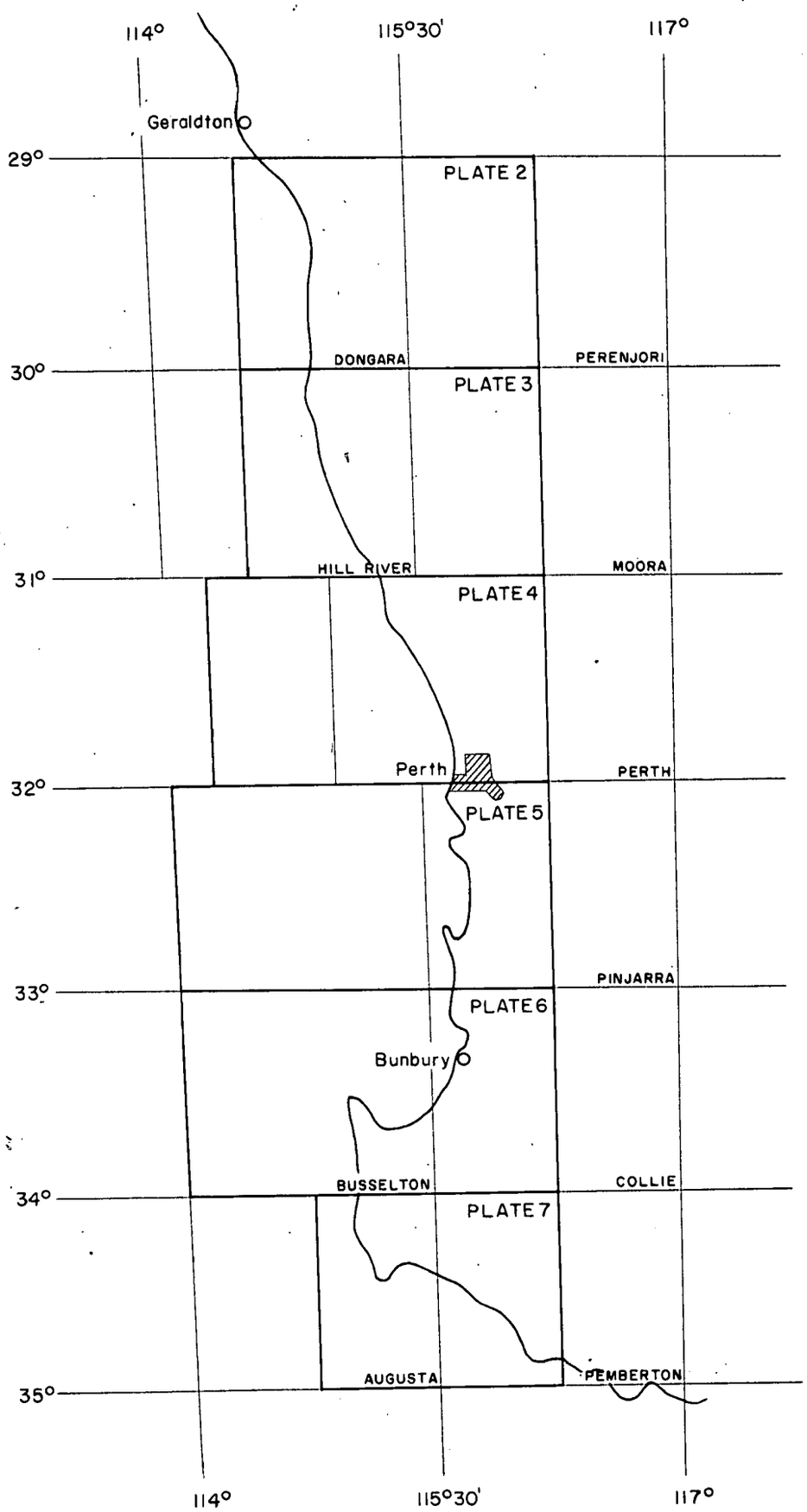
The depth contour map (Plate 8) shows the main structural features interpreted from the aeromagnetic survey data.

5. REFERENCES

BMR	1951	Titanium (rutile and ilmenite) Bur. Min. Resour. Aust. Summ. Rep. 2 (Revised 1951)
FAIRBRIDGE, R.W.	1949	Preliminary report on the geology of the coastal plain and other sedimentary areas between Busselton and Geraldton, Western Australia (unpubl.)
LODWICK, K.B.	1962	Busselton seismic reflection survey, WA 1956 Bur. Min. Resour. Aust. Rec. 1962/108. (unpubl.)
McWHAE, J.R.H., PLAYFORD, P.E., LINDNER, A.W., GLENISTER, B.F., and BALME, B.E.	1958	The stratigraphy of Western Australia. J. geol. Soc. Aust., 4 (2).
McTAVISH, R.A.	1960	Completion report on Bore BMR 10A, Beagle Ridge, Western Australia. Bur. Min. Resour. Aust. Rec. 1960/127 (unpubl.)

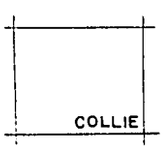
MOSS, F.J.	1962	Rockingham/Mundijong seismic survey, WA 1956. Bur. Min. Resour. Aust. Rec. 1962/107 (unpubl.)
NEWMAN, J.K.	1959	Preliminary report of an aeromagnetic survey of the Perth Basin 1957. Bur. Min. Resour. Aust. Rec. 1959/64 (unpubl.)
THYER, R.F. and EVERINGHAM, I.B.	1956	Gravity survey of the Perth Basin, Western Australia. Bur. Min. Resour. Aust. Bull. 33
VACQUIER, V., STEELAND N.C., HENDERSON, R.G., and ZEITZ, I.	1951	Interpretation of aeromagnetic maps. Mem. geol. Soc. Amer. 47
VALE, K.R. and MOSS, F.J.	1962	Cookernup seismic survey, WA 1955-56 Bur. Min. Resour. Aust. Rec. 1962/109 (unpubl.)
VALE, K.R.	1956	Preliminary report on a seismic reflection traverse across the Perth Basin at Gingin WA. Bur. Min. Resour. Aust. Rec. 1956/26 (unpubl.)

PLATE 1

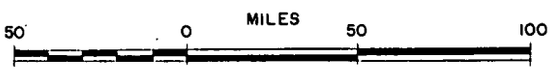


PERTH BASIN AEROMAGNETIC SURVEY, WA, 1957

LOCALITY MAP AND INDEX TO PLATES



REFERENCE TO AUSTRALIA
STANDARD MAP SERIES



PERTH BASIN AEROMAGNETIC SURVEY, WA, 1957

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

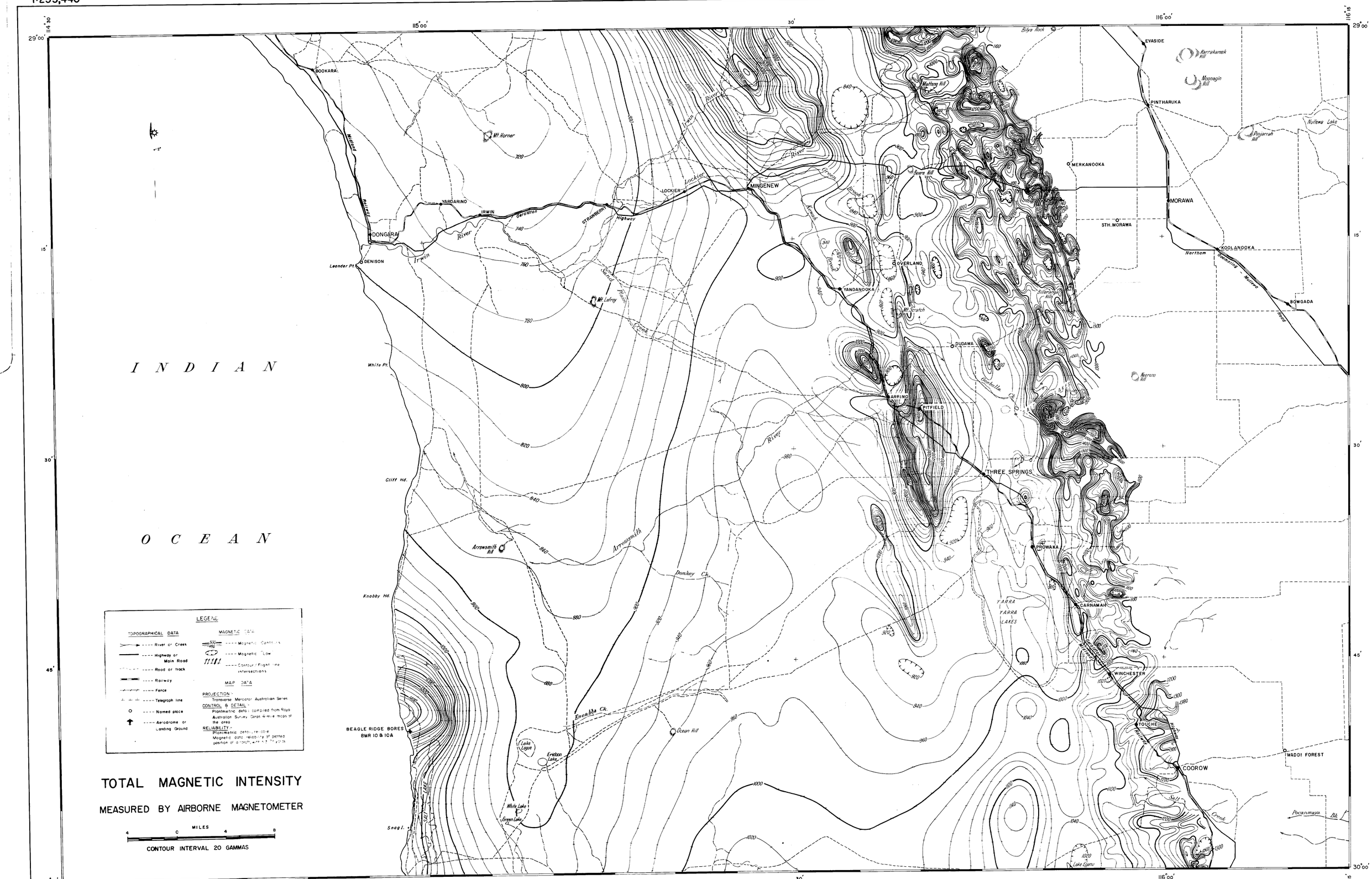
150/B1-5

TO ACCOMPANY RECORD No. 1963/74

DONGARA — PERENJORI
WESTERN AUSTRALIA

PLATE 2

1:253,440



LEGEND

TOPOGRAPHICAL DATA

- River or Creek
- Highway or Main Road
- Road or track
- Railway
- Fence
- Telegraph line
- Named place
- Aerodrome or Landing Ground

MAGNETIC DATA

- Magnetic Contours
- Magnetic "Low"
- Contour / Flight line intersections

MAP DATA

PROJECTION :- Transverse Mercator Australian Series

CONTROL & DETAIL :- Planimetric data compiled from Royal Australian Survey Corps 4-mile maps of the area

RELIABILITY :- Planimetric data reliable. Magnetic data reliability of plotted position of all features with respect to others

TOTAL MAGNETIC INTENSITY

MEASURED BY AIRBORNE MAGNETOMETER

MILES 4 0 4 8

CONTOUR INTERVAL 20 GAMMAS

TO ACCOMPANY RECORD No. 1963/74 GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS H50/BI-7

HILL RIVER – MOORA
WESTERN AUSTRALIA

1:253,440

PLATE 3

PERTH
WESTERN AUSTRALIA

LEGEND

TOPOGRAPHICAL DATA

- River or Creek
- Highway or Main Road
- Road or track
- Railway
- Fence
- Telegraph line
- Named place
- Aerodrome or Landing Ground

MAGNETIC DATA

- Magnetic Contours
- Magnetic "Low"
- Contour / Flight line intersections

MAP DATA

PROJECTION - Transverse Mercator Australian Series

CONTROL & DETAIL - Planimetric detail compiled from Royal Australian Survey Corps 4-mile maps of the area

RELIABILITY - Planimetric detail, reliable. Magnetic data, reliability of plotted position of aircraft, within ± 75 yards

TOTAL MAGNETIC INTENSITY

MEASURED BY AIRBORNE MAGNETOMETER

4 0 4 8 MILES

CONTOUR INTERVAL 20 GAMMAS

T.N. M.N.

I N D I A N

O C E A N

Lancelin Island
LANCELIN
Edward Is.
Karakin Lakes
Ledge Pt.
Six Mile Swamp
Sun Gully Creek
MINDARRA ROAD
Bidaminna Lake
Nine Mile Swamp
Wannamal Lake
MOORE RIVER
MOUMBERING
WANNAMAL
Beermullah Lake
Boalina Swamp
Cape Leschenault
Moore River
MOORE RIVER ROAD
Gingin Brook
Lake Mackenburra
Burragoon Lake
MOOLIABEENEE
GINGIN
Lennard Brook
SOUTH BINDOON
Chittering Lake
Lake Nambung
CHITTERING
Lake Columbra
Loch Mc Ness
YANCHEP
MUCHEA
Lake Pinjar
Avon River
BULLSBROOK
PEARCE
Joondalup Lake
WANNERU
Lake Jandabup
Swan River
Gnangara Lake
GNANGARA OBSERVATORY
UPPER SWAN
WATERMANS BAY
SCARBOROUGH
MIDLAND JUNCTION
Great Eastern Highway
MT HELENA
ASHFIELD
DARLINGTON
PERTH
Swan R.
Mundaring Weir
KALAMUNDA
Rottnest Island

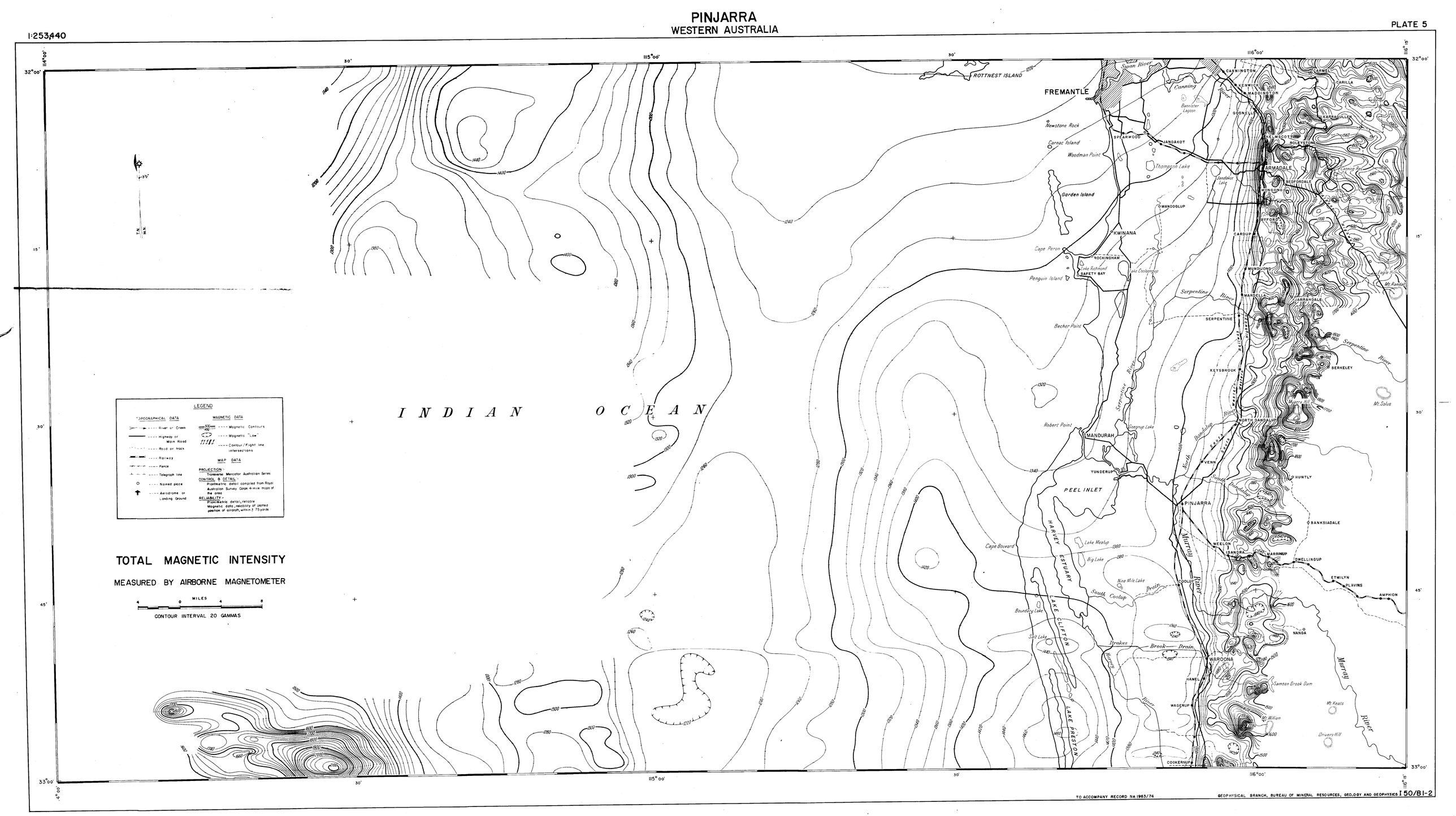
31°00' 30' 115°00' 30' 116°00' 30' 32°00'
114°15' 116°15'
15' 45'

TO ACCOMPANY RECORD No.1963/74 GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS H 50/BI-6

1:253,440

PINJARRA
WESTERN AUSTRALIA

PLATE 5



TO ACCOMPANY RECORD No.1963/74

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS I 50/B1-2


TOTAL MAGNETIC INTENSITY
MEASURED BY AIRBORNE MAGNETOMETER
MILES
4 0 4 8
CONTOUR INTERVAL 20 GAMMAS
LEGEND
TOPOGRAPHICAL DATA
River or Creek
Highway or Main Road
Road or track
Railway
Fence
Telegraph line
Named place
Aerodrome or Landing Ground
MAGNETIC DATA
Magnetic Contours
Magnetic "Low"
Contour / Flight line intersections
MAP DATA
PROJECTION:-
Transverse Mercator Australian Series
CONTROL & DETAIL:-
Planimetric detail compiled from Royal Australian Survey Corps 4-mile maps of the area
RELIABILITY:-
Planimetric detail; reliable
Magnetic data; reliability of plotted position of aircraft, within ± 75 yards
INDIAN OCEAN
BUNBURY
BUSSELTON
COLLIE
HARVEY
BRUNSWICK JUNCTION
DONNYBROOK
BALINGUP
BRIDGETOWN
NANNUP
CAPEL
YALLINGUP
DUNSBOROUGH
MARGARET RIVER
Cape Naturaliste
Cape Clairault
Cape Mentelle
Cowaramup Point
33°00'
34°00'
114°00'
115°00'
116°00'
116°15'

AUGUSTA - PEMBERTON
WESTERN AUSTRALIA

1:253,440

PLATE 7

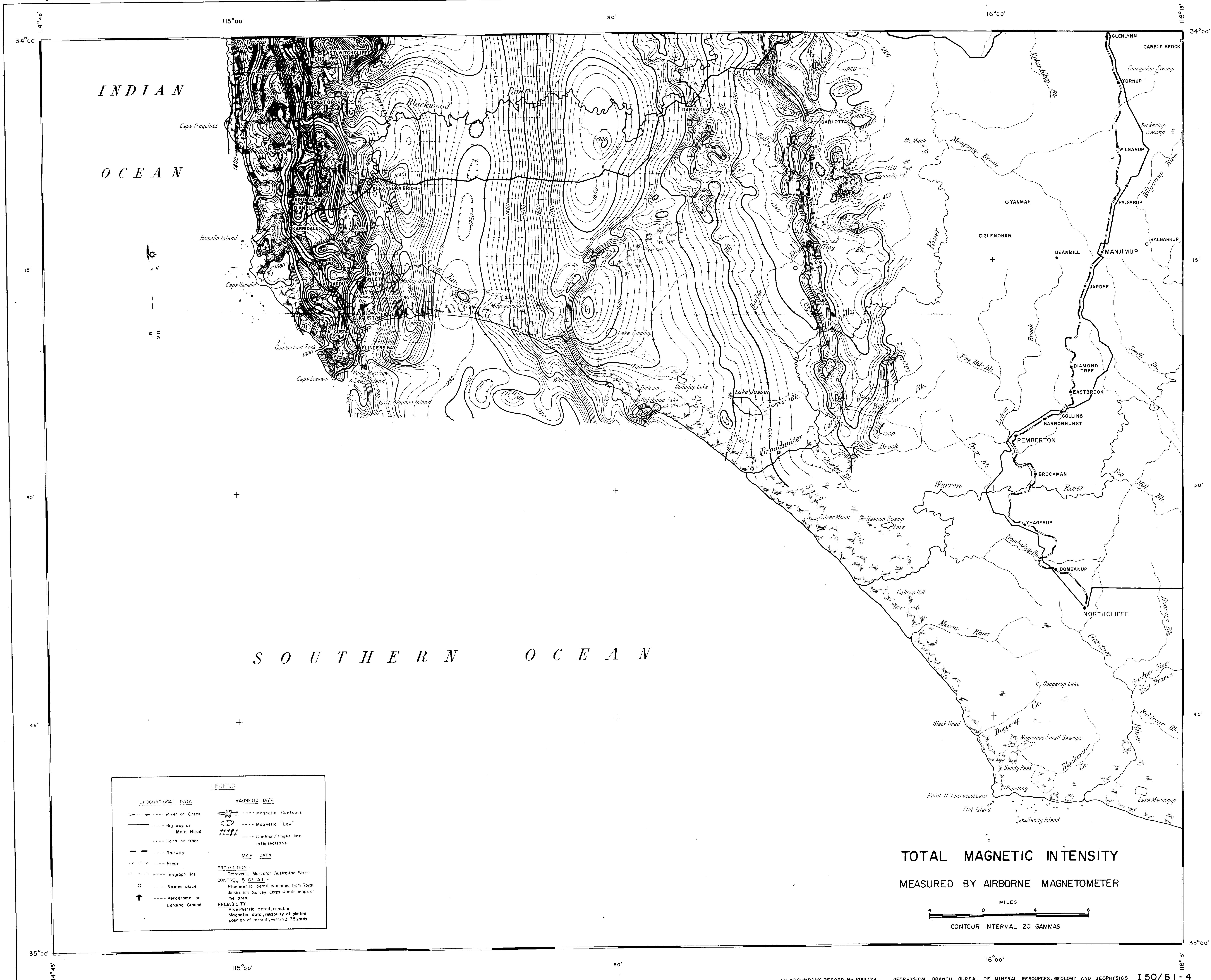
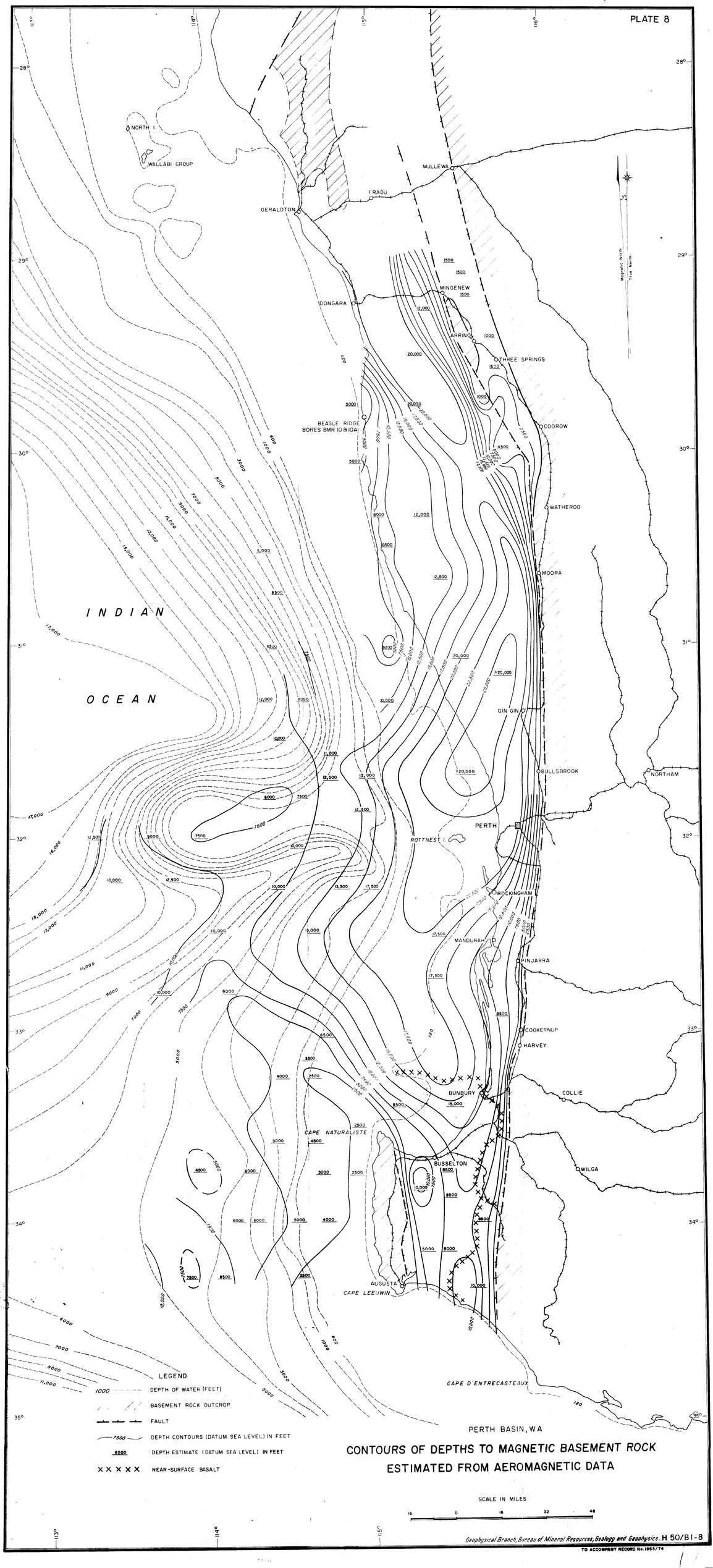


PLATE 8



PERTH BASIN, WA

CONTOURS OF DEPTHS TO MAGNETIC BASEMENT ROCK ESTIMATED FROM AEROMAGNETIC DATA

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. H 50/B1-8

TO ACCOMPANY RECORD No. 1963/74