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Record 1975/155

AEROMAGNETIC SURVEY OF PERENJORI, NINGHAN, BENCUBBIN AND MOORA 1:250 000 SHEET AREAS, W.A., 1972

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SUMMARY

An airborne magnetic survey of PERENJORI, NINGHAN, BENCUBBIN and part of MOORA 1:250 000 Sheet areas was flown by Aero Service in 1972 under contract to the Bureau of Mineral Resources. The objectives of the survey were to assist the systematic regional mapping of the Western Australian Precambrian Shield and the search for minerals.

Interpretation of the magnetic data is primarily qualitative, Geological strikes and major boundaries have been interpreted by delineating magnetic trends, by dividing the area into zones depending on magnetic character and by comparison of these zones with known geology. Faults and folds have been interpreted from a study of zones and trends.

The magnetic data have defined the major faults controlling the eastern edge of the Perth Basin and Irwin Sub-basin. Most of the Shield area is occupied by granite and gneiss. Banded iron formations give rise to large arcuate anomalies which indicate structure within greenstone belts. Several areas are interpreted as being most likely to contain basic or ultrabasic intrusives.

Most trends are north-northwest, parallel to the regional trend of the Yilgarn Block. Other trends oriented northeast and easterly are due to the doming effect of granite batholiths and the intrusion of basic dykes respectively. Most interpreted faults trend east to east-northeast, northeast or northwest. Interpreted fold axes trend between northwest and northeast.

Areas recommended for further work include the more anomalous parts of the greenstone belts and the interpreted basic or ultrabasic intrusives.

1. INTRODUCTION

In 1956 the Bureau of Mineral Resources (BMR) commenced an extensive program of airborne surveys in the Archaean Yilgarn Block of Western Australia at the request of the Western Australian Department of Mines. The prime objective was to delineate the boundaries of major rock units and to determine geological structure. By the end of 1970, twenty-six 1:250 000 Sheet areas had been surveyed within this region.

This program was continued during 1972 by Aero Service (Australia) Pty Ltd, under contract to BMR. Aero Service acquired and processed aeromagnetic data over ROBINSON RANGE, PEAK HILL, NABBERU, STANLEY, NINGHAN, BENCUBBIN, PERENJORI 1:250 000 Sheet areas and the eastern third of GLENBURGH* and two-thirds of MOORA. The data have been contoured by the BMR and released to the public.

This Record covers PERENJORI, NINGHAN, BENCUBBIN, and MOORA bounded by latitudes 29°S and 31°S and longitudes 115°30'E and 118°30'E. The Perth basin in these Sheet areas (minor parts of PERENJORI and MOORA west of the Darling Fault) was surveyed by the BMR in 1957 and was described by Quilty (1963). The area surveyed in 1972 covers part of the Archaean Yilgarn Block consisting of granites, metasediments, and metavolcanics.

2. PREVIOUS GEOPHYSICAL WORK

BMR has surveyed an extensive area surrounding the present area. Results of these previous airborne magnetic and radiometric surveys have been reported in the BMR Record Series (Parkinson, 1957; Spence, 1958; Carter, 1959; Mulder, 1960; Forsyth, 1960, 1961; Wells, 1962; Quilty, 1963; Young & Tipper, 1966; Shelley & Waller, 1967; Gerdes et al., 1970; Tipper & Gerdes, 1971; Waller & Beattie, 1971; Lambourn, 1972; Wyatt, in prep.). These surveys provided data for basement depth calculations within the Perth and Carnarvon Basins and outlined the geological structure of the Precambrian Shield.

The magnetic data from MENZIES and LEONORA (Young & Tipper, 1966) and from all shield areas subsequently surveyed by BMR (see list of authors above) have been interpreted by resolving and analyzing magnetic trends and by subdividing the area into zones of specified magnetic character in order to delineate aspects of the regional geological structure (Young, 1971). In these reports, numerous fold axes, and cross-fold axes have been interpreted by tracing anomalies caused by interbedded magnetite-rich rock units. Meridional anomalies of the order of 1000 nT are calculated to be due to susceptibility contrast in the range 0.002 to 0.003 cgs units and have been attributed by BMR authors

* Names of 1:250 000 Sheet areas are printed in capitals and '1:250 000 Sheet area' omitted.

to serpentinite bodies. Anomalies of larger amplitude, approaching 10 000 nT, are calculated to be due to susceptibility contrast in the range 0.025 to 0.40 cgs units and have been attributed to jaspilite. Areas having a relatively flat magnetic field have been ascribed to near-homogeneous acid igneous rocks or to non-magnetic sedimentary sequences. In several areas strongly magnetic ultrabasic intrusions are thought to be of economic significance and have been recommended for ground investigation.

Regional gravity surveys have been made over the area by BMR (Plate 1). The major feature is a deep gravity depression west of the Darling and Urella Faults. The Darling Fault appears to be a normal fault dipping steeply to the west with a maximum throw of at least 9 km in MOORA. In PERENJORI the maximum Bouguer gradient is associated with the Urella Fault (Fraser, 1973; Mathur, 1973; Hawkins et al., 1975). More specific references to the Bouguer Anomaly maps are made in the interpretation section of this record.

3. GEOLOGY

No systematic regional geological mapping has been carried out in the area. General references to the geology and structure of the survey area are found in Miles (1953), Wilson (1958), McWhae et al. (1958), Prider (1965), and O'Driscoll (1971). The only available geological maps are the Geological Map of Western Australia (Geological Survey of Western Australia; 1973), the Tectonic Map of Australia (Geological Society of Australia, 1971) and a 1:1 267 200 - scale map in Wilson (1958).

Most of the area is part of the Archaean Yilgarn Block. The western edge of the area is occupied by part of the Perth Basin. The major faults are the north to north-northwest-trending Urella and Darling Faults which are the western limits of the Yandanooka Inlier and Yilgarn Block respectively.

Archaean

The Yilgarn Block is made up of gneisses and lenticular areas of greenstone and metasediments which are elongated generally north-northwest. The greenstone and metasediments have been intruded by regionally concordant bodies of massive granite. Dips are generally greater than 70°. The belts of metamorphics may represent either original geosynclines or material which has slumped into the form of synclinoria between slowly rising granite massifs (Wilson, 1958). There are two main ages of granitic rocks. Those to the west of Koolanooka Hills give radiometric ages of 3100 to 2800 million years while those to the east are 2500 to 2200 m.y. old (Ariens, 1971; Muhling & Low, 1973).

Proterozoic sediments around Yandanooka rest unconformably on an Archaean metamorphic complex known as the Mullingarra Gneiss (McWhae et al., 1958).

McCall (1971) describes 'immense Archaean layered intrusives isolated as residual enclaves within granites' in NINGHAN and KIRKALOCKA to the north, and considers that these areas 'could prove of considerable economic significance in respect to nickel, platinoids and vanadium'. He describes the Mount Singleton enclave as a broad open syncline containing ultrabasics (sills?), pyroclastics, volcanic breccias, basalts, and cut by east-west dykes of gabbro and some small bodies of granophyre, residual to the tholeiitic magma.

Proterozoic

Sediments of probable Precambrian age (Moora and Yandanooka Groups, and Billeranga Beds) occur sporadically on the eastern margin of the Perth Basin and in the Yandanooka Inlier. They are unconformable on the Yilgarn basement and are composed of volcanic and arkosic detritus, orthoquartzite, chert, shale, stromatolitic dolomite and some acid volcanics. The thickness of the Moora Group and Billeranga Beds is about 1000 m, and the Yandanooka Group reaches 9000 m (Brown et al., 1968; Logan & Chase, 1961; Wall, 1968).

Dolerite dykes are common in the area but their age is uncertain. Logan (1958) has recorded dolerite dykes cutting rocks of the Moora Group.

Phanerozoic

The Perth Basin is a narrow trough of sediments extending north-south for about 1000 km. The eastern boundary is the great Darling Fault and the basin is strongly faulted throughout by north to north-northwest trending normal faults. The total thickness of the Silurian, Permian, Triassic, Jurassic and Tertiary sediments probably exceeds 7000 m in the southwest part of PERENJORI (Quilty, 1963). Much of the section is paralic to continental, the continental deposits being largely of fluvial origin and shed from the active faults (Playford, 1971). In PERENJORI, post-Permian movements have been taken up mainly along the Urella Fault. The Irwin Sub-basin occurs between the Darling Fault and the Urella Fault and contains a Permian succession at least 2000 m thick. This overlies the Proterozoic sediments of the Yandanooka Group (Playford, 1959; Muhling & Low, 1973).

Sand, laterite, grit, alluvium, colluvium, hardpan, calcrete, clay and gypsum beds, form a superficial cover over most of the survey area.

Economic Geology

Iron Ore (MacLeod, 1965; Pratt, 1973). Until early 1975, Western Mining Corporation Ltd were mining hematite-goethite ore at Koolanooka Hills in PERENJORI. The ore is approximately 60% Fe and annual production in 1970-71 was about 670 000 tonnes of ore. The banded iron formation is flanked to the west by other Archaean sedimentary rocks including chert, and to the east by a late Proterozoic dolerite dyke.

East of Koolanooka, there are numerous outcrops of coarsely granular magnetite quartzite, derived by recrystallization from banded iron formation. The magnetite quartzite constitutes a very large reserve of low-grade ore.

A hematite deposit at Mount Gibson in NINGHAN has estimated reserves of 55 million tonnes. Here the grade at the surface is 65% Fe.

Talc (Kalix, 1973). Talc is being quarried 13 km east of Three Springs in PERENJORI. The lenticular orebody was formed by metamorphism of magnesium rich limestone near the top of the Moora Group. Annual production in 1970-71 was about 30 000 tonnes.

Other minerals and commodities which have been reported to occur in the area (Department of National Development, 1970) are: amphibole asbestos, near Bindi Bindi in MOORA; bauxite, at Wongan Hills in MOORA; fire clay and pottery clay at Three Springs in PERENJORI and at Marchagee in MOORA; gold in greenstone areas in northeastern PERENJORI and western NINGHAN; manganese in northeastern NINGHAN; salt and gypsum at Cowcowing Lakes in BENCUBBIN; selenium in tellurides at Rothsay in PERENJORI (Townsend, 1965); and tungsten to the east of Mongers Lake in PERENJORI.

4. MAGNETIC RESULTS AND GEOLOGICAL INTERPRETATION

The magnetic data are shown in Plates 2 to 5 as total magnetic intensity contours at a scale of 1:250 000. Interpreted faults, fold axes, and magnetic trends and zones are also shown in Plates 2 to 5 and in Plate 6, together with an interpretation of the regional geology, at a scale of 1:1 000 000.

The data have been qualitatively analyzed by delineating magnetic trends and zones. A magnetic trend is defined as the line joining the maxima or minima of those anomalies which are together attributed to one continuous magnetic body. Except in perfectly symmetrical anomalies, the trends do not coincide exactly with the apical axes of the magnetic bodies. The axis generally lies towards the negative side of the anomaly by an amount which is a function of the body's dip and strike angles.

Magnetic zones have been delineated by considering the character and direction of magnetic trends including the dominant amplitude range. The boundaries of such zones are often coincident with inferred rock type boundaries and/or faults.

The various types of magnetic zones that have been delineated are characterized in Table 1. The amplitude range quoted for each type includes most, but not necessarily all, of the anomalies in any zone of that type.

TABLE 1. CHARACTERISTICS OF MAGNETIC ZONE TYPES

Zone type	Amplitude range (nanoteslas)	Magnetic linearity
1	less than 50	poor
2	50 to 100	"
3	100 to 250	"
4	greater than 250	"
5	less than 100	good
6	100 to 250	"
7	250 to 500	"
8	500 to 4000	"
9	greater than 4000	"

The geological significance of these zone types has been discussed in detail in the previous survey records for the Yilgarn Block. In summary it may be stated that zones of Types 1, 2 and 3 generally indicate increasingly basic composition in acid igneous masses. Where elongate zones of this type occur adjacent to zones of Types 5, 6, 7, and 8, they may indicate sedimentary sequences.

Zones of Type 4 have been taken to indicate greenstone belts or basic intrusives. Single anomalies are generally interpreted as plugs, whereas some larger Type-4 zones have anomalies which appear to be caused by bodies whose depth is of limited extent. The interpretation of these sill-like intrusive bodies has been aided by a comparison of anomaly contours with those computed by Andreason & Zietz (1969). The remaining Type 4 zones are interpreted as greenstone belts of complex structure, having no recognizable linearity.

In granitic areas, zones of Type 7, 6 and 5 (in order of decreasingly basic composition) are generally interpreted as basic dykes where they are narrow and as areas where partial assimilation of greenstone belts has taken place where they are broad.

Zones of Type 8, and any elongate zones associated with them are attributed to greenstone belts. Zones of Type 9 generally indicate banded iron formations.

Structural features have been interpreted from the trends and zones. Faults are interpreted from the collinear terminations of magnetic trends and zones or by abrupt changes in trend direction. Folds have been interpreted from a symmetric or assymmetric repetition of zones or individual anomalies or both.

PERENJORI (Plate 2)

Phanerozoic (Perth Basin) and Proterozoic sediments are confined to the large zone of Type 1 in the west of the sheet. The eastern boundary of this zone, the Darling Fault, is indicated by a distinct change in magnetic character. Within the Perth Basin, a north-northwest-trending area contains zones of Types 2, 4, 6 and 7 corresponding to Archaean gneiss within the Yananooka Inlier. This area is bounded to the west by the Urella Fault, a structure clearly indicated by an intense Bouguer anomaly gradient. Depths to magnetic basement are interpreted to be about 500 m in the Irwin Sub-basin and greater than 5000 m fifteen to twenty kilometres west of the Urella Fault. These figures are in good agreement with depths obtained by Quilty (1963).

In the Archaean Yilgarn Block, zones of Types 1, 2 and 3 predominate over an extensive area of granite and gneiss. A few trends within these zones probably indicate relict structure within the gneisses.

Several zones of Type 4 delineate isolated anomalies which may be due to basic plugs. The area of Type 4 in the northeast of PERENJORI is the continuation of a greenstone belt mapped by Muhling & Low (1973) in YALGOO.

Part of a north-northwest-trending zone of Type 6 eighteen kilometres west of Morawa was mapped by Wilson (1958) as a greenstone belt within gneiss, and Horwitz & Daniels (1966) have identified thin lava flows in the area. The greenstone belt appears to extend farther south than mapped by Wilson and to join another mapped greenstone outcrop 15 km east-northeast of Three Springs.

The zone of Type 7 in the Moonagin Range is continuous with outcrops of amphibolite in YALGOO to the north (Muhling & Low, 1973).

The northeastern part of the sheet area is occupied by the southern quarter of a complex batholith mapped by Muhling & Low (1973) in YALGOO. The batholith is formed from curved sheets, cones and domes of granitic rock and its outline is defined by metamorphosed greenstone belts. The south-trending zone of Type 9 through Huts Well, on the northern margin of PERENJORI, corresponds to Association 1 in Muhling & Low's (1973) Figure 2, while the northeast-trending zones of Types 8 and 9 near 'Old Karara' homestead correspond to their Association 2. Association 1 contains basic volcanics and intrusives, ultrabasic intrusives and banded iron formations. Association 2 contains fine-grained sediments, banded iron formation, chert, and basic, ultrabasic and acid volcanics. The area enclosed by these two associations is mapped by Muhling & Low on YALGOO as porphyritic granite to adamellite. The batholith gives rise to a Bouguer anomaly low.

Southeast of the batholith, anomaly amplitudes in general range up to 5000 nT. One anomaly exceeds 25 000 nT near Windaning Hill. The arcuate form of Windaning Hill suggests that this large anomaly may be due to a thickening of banded iron formation in the crest of a fold structure. Nearby anomalies may have a similar source or may be related to basic intrusives.

The area around and southeast of the Koolanooka Hills and Bowgarder Hills contains north-northwest-trending zones of Types 8 and 9 which coincide with topographic features and indicate the presence of banded iron formation within a greenstone belt. The iron ore deposits at Koolanooka are associated with dominantly volcanic sequences (Crohn, 1971).

A large area in the central eastern part of PERENJORI has a fairly flat magnetic field with few trends. These magnetic characteristics coincide broadly with a Bouguer anomaly low and therefore indicate an extensive granite batholith.

Several folds are indicated by contorted anomalies within the greenstone belts. In the northeast corner the fold axes are parallel to the borders of the batholith. Elsewhere they parallel the regional strike. A number of faults have been interpreted from collinear features apparent in the contours. Most of these trend either at 135° or between 040° and 070°.

<u>NINGHAN</u> (Plate 3)

Much of NINGHAN is occupied by granite and gneiss especially the southern and eastern parts of the sheet. This is indicated by the broad Bouguer anomaly lows and the relatively flat magnetic field.

The greenstone belt in the northeast of PERENJORI extends into NINGHAN around Woodley's Find and Warriedar Mine.

Another greenstone belt occurs in the area around Bullajungadeah Hills, Pinyalling Hill, and Walagnumming Hill. Trends are north-northeast to northeast and there are several mines within this belt.

A further area of greenstone occurs around and to the north of Mount Harry, Warrdagga Hill, Mount Edon and Paynes Find.

Zones Types 4, 8 and 9 form an arcuate region through Retaliation Mine, Mumaloo-Wye-Bubba Hill, Peedhal Rocks and Pedan Rocks. This area contains many mines and is interpreted as a greenstone belt forming the eastern margin of a granite batholith.

The northeast corner of the sheet contains zones of Types 6, 7 and 8 trending north to northwest and a number of Type 4 zones containing isolated anomalies up to 800 nT. These are extensions of greenstone belts indicated by magnetic data on the KIRKALOCKA sheet (Waller & Beattie, 1971).

The northwest-trending range which includes Mount Singleton and Wylacoopin Hill contains Type 4 and Type 7 zones symmetrically arranged about a zone of Type 3. This area is described by McCall (1971) as a broad open syncline of Archaean basic and ultrabasic rocks.

A prominent Bouguer anomaly high coincides with the Mount Singleton enclave while less extensive highs are associated with most of the greenstone belts mentioned above.

Two east-west trends are prominent across most of NINGHAN at latitudes 29°07'S and 29°32'S. The northernmost trend is due to a reversely magnetized source and continues only a short distance into BARLEE. The other extends from near Copperdie Hill and can be traced east through BARLEE, MENZIES and EDJUDINA. It is offset by northeast-trending faults around Copperdie Hill. A third prominent linear feature trends approximately east-northeast through Mount Churchman and can be traced for some distance into BENCUBBIN and BARLEE. The trend is marked by a line of positive anomalies and by a gradient. These three linear features are all interpreted as being due to dipping dykes which were intruded along fault lines. In the third case down-faulting to the south is inferred.

Several other faults have been interpreted from the collinear termination of zones and anomalies. These generally trend northeast or northwest.

Two fold axes have been interpreted from symmetry of anomalies and zones. One of these trends northwest through Mount Singleton, the other northeast from Mt Edon to Pullagaroo. Other possible fold axes occur near 29°38'S on the eastern margin of the sheet and south of Pedan Rocks in the southwest.

Most magnetic trends within the greenstone area are northwest except for the area around Bullajungadeah Hill and Pinyalling Hill where trends are northeast. Elsewhere the trends reflect the northeast, northwest or east-trending faults.

Twenty-one mines are indicated on the NINGHAN topographic map within the greenstone belts. Most are collinear along north-northeast or east-northeast-trending lines indicating the probable importance of structure in relation to mineralization.

MOORA (Plate 4)

The western edge of the survey boundary in MOORA approximates the edge of the Yilgarn Block. The Perth Basin strip is of Zone Type 1, whereas zones of Types 2 and 3 predominate on the shield.

Wilson (1958) mapped most of the shield area as granite or gneiss accept for isolated areas of greenstone around Wongan Hills and east of Moora. The greenstone around Wongan Hills corresponds to zones of Types 4 and 8. This area is connected to another mapped greenstone area near Wubin (Wilson, 1958) by a series of Type 4 zones which are also tentatively interpreted as greenstone but could be basic plugs. Similar isolated anomalies of Type 4 to the east of Moora may be due to basic intrusives or to greenstone areas.

Two extensive Type-4 zones around and to the east of Watheroo contain anomalies of up to 1000 nT. These are interpreted as basic sill-like intrusives.

In the northern part of MOORA, Zones of Type 6, 7 and 8 indicate extensions of greenstone areas from PERENJORI.

In the southwest corner of the area flown, zones of Type 4, 6 and 7 are common over an area mapped as schist and metasediments (Wilson, 1958). This area coincides with part of a Bouguer anomaly high which appears to be related to rocks of the Wheat Belt granulite terrain farther to the south (Wilson, 1969).

A few interpreted faults trend between northwest and north-northwest but most are easterly.

BENCUBBIN (Plate 5)

Wilson's geological map (1958) indicates granite over most of BENCUBBIN except for some gneiss and isolated greenstone outcrops in a belt which trends northwest through Bencubbin township. The granite accounts for the large areas of Zone Types 1, 2 and 3 and for the absence of easily recognizable trends.

Several zones of Type 4 occur in the southern half of the sheet. Those around Bencubbin and Waddouring Hill are due to greenstone (Wilson, 1958). The area in the southeast corner of the sheet may represent an extension of the greenstone belt through Westonia in SOUTHERN CROSS. Two other prominent zones of Type 4 occur west of Koorda and between Burakin and Kokardine. These contain anomalies in excess of a few thousand nT with little evidence of trends. They are interpreted as being due to sill-like basic intrusives.

A few other zones of Type 4 occur in the centre and west of the sheet. These contain anomalies of several hundred nT and may also be due to basic sills though of a lower susceptibility or lesser thickness than those mentioned above.

A number of linear features evident in the contour pattern have been interpreted as faults. Most of these trend between north and east.

5. CONCLUSIONS

The eastern part of the Perth Basin is downfaulted against the Yilgarn Block along the Darling and Urella Faults (Plate 6). Within the Irwin sub-basin 500 m of Permian sediments overlies Proterozoic rocks of the Yandanooka Inlier. The thickness of sediments in the southwest corner of PERENJORI is in excess of 5000 m. The positions of the faults are clearly indicated by the magnetic and the Bouguer anomaly contours.

Within the Yilgarn Block different general rock types have been interpreted from their magnetic response. Greenstone belts are indicated by linear anomalies of Zone Types 7 and 8 and any associated elongate zones or anomalous areas. These are generally aligned north-northwest or parallel to the margins of granite batholiths. Banded iron formations within the greenstone belts are characterized by Type-9 and some Type-8 zones. Basic intrusives are indicated by anomalies or anomalous zones of more than a few hundred nT amplitude but with no recognizable linearity. The single anomalies are probably due to plugs, whereas the larger zones have anomalies which appear to be caused by bodies of limited vertical extent. Bouguer anomaly highs generally correlate with the interpreted areas of greenstone and basic intrusives. A gravity ridge which trends northeast through part of MOORA and most of NINGHAN has no counterpart in the aeromagnetic results, and its significance is unknown.

The remainder of the shield area is occupied presumably by granite and gneiss. These have not been differentiated in Plate 6 because of the uncertainty involved. As a general guideline it can bet stated that the magnetically flat areas with no trends indicate granite, whereas the areas of gneiss and metasediments contain some anomalies due to susceptibility differences between adjoining metasediments. These anomalies show some ill-defined trends and amplitudes are limited to a few hundred nT.

Areas containing small amplitude Bouguer anomaly lows generally correspond to granite masses. This is most obvious in north-eastern and eastern PERENJORI and in the large expanse east of Lake Moore in NINGHAN and BENCUBBIN.

Several fold axes have been interpreted from the symmetric distribution of anomalies and zones. Those within the greenstone belts parallel the general trend of that belt.

Many linear features are evident within the contour pattern. In general they are delineated by strings of either positive or negative anomalies or by the truncation of magnetic trends and zones. Because of their pronounced linearity, these features have been interpreted as faults, some of which appear to have been intruded by basic dykes. Most of the major faults trend between east and east-northeast. Of the remainder, nearly all trend either northeast or northwest. These trends are similar to those of the numerous dolerite dykes indicated on the Geological Map of Western Australia (1973).

Mineralization appears to have a strong lithological and structural control. Known deposits are confined to greenstone belts and are generally related to folding or faulting or both.

6. RECOMMENDATIONS

Most mineralization occurs in northeast PERENJORI and west NINGHAN within the interpreted greenstone belts. Most of the mines occur along lines parallel to magnetic trends or interpreted faults. The interpreted structure presented in this Record requires ground checking and might prove useful in the search for iron ore, gold and base metal mineralization. Zones of Type 9 and some of Type 8 are almost certainly due to banded iron formation and should be investigated as possible sources of iron ore.

Several zones of Type 4 have been interpreted as being due to basic intrusives. The largest of these zones may indicate layered basic or ultrabasic complexes and as such could prove interesting as possible areas of base metal mineralization. Ground investigation of these is recommended both to check their interpretation as layered bodies and to investigate mineralization potential.

The sources of several large anomalies are either uncertain or unknown in terms of mapped geology or interpreted structure and such anomalies therefore warrent investigation in detail. The coordinates, peak values and amplitudes of these are given in Table 2.

TABLE 2. LARGE ANOMALIES OF UNCERTAIN SOURCE

Coordinates		Peak Value (nanoteslas)	Anomaly Amplitude (nanoteslas)
29°07'S	116°53'E	23 980	25 500
29°39'S	116°51'E	7 282	3 500
29°02'S	117°01'E	10 351	7 000
29°22'S	117°17'E	8 666	7 500(Cashens Find)
29°22'S	117°30'E	10 369	6 500
29°25'S	117°09'E	16 626	13 000
29°40'S	117°13'E	10 708	7 000
30°20'S	116°47'E	8 105	4 000
30°57'S	116°22'E	9 121	5 000

7. REFERENCES

ARRIENS, P.A., 1971 - The Archaean geochronology of Australia. Spec. Publ. Geol. Soc. Aust. No. 3, 11-23.

ANDREASON, G.E., & ZIETZ, I., 1969 - Magnetic fields for a 4 x 6 prismatic model. U.S. geol. Surv. prof. Pap. 666.

BROWN, D.A., CAMPBELL, K.S.W., & CROOK, K.A.W., 1968 - THE GEOLOGICAL EVOLUTION OF AUSTRALIA AND NEW ZEALAND. Oxford, Pergamon Press.

CARTER, R.M., 1959 - Airborne magnetic and radiometric survey of Kurnalpi and Widgiemooltha areas, W.A., 1959. Bur. Miner. Resour. Aust. Rec. 1957/137 (unpubl.).

CROHN, P.W., 1971 - Some features of the Precambrian geology and mineral deposits of Australia and Canada. (Abstract only). Spec. Publ. Geol. Soc. Aust. No. 3, 254.

DEPARTMENT OF NATIONAL DEVELOPMENT, 1970 - Atlas of Australian Resources, 2nd Series; Mineral Deposits, 2nd Edn, Canberra.

FORSYTH, W.A.L., 1960 - Carnarvon Basin airborne magnetic and radiometric survey, W.A., 1957. Bur. Miner. Resour. Aust. Rec. 1960/132 (unpubl.).

FORSYTH, W.A.L., 1961 - Boorabbin and Norseman airborne magnetic and radiometric surveys, W.A., 1959. Ibid. 1961/55 (unpubl.).

FRASER, A.R., 1973 - A discussion on the gravity anomalies of the Precambrian shield of Western Australia. Ibid. 1973/105 (unpubl.).

GEOLOGICAL SOCIETY OF AUSTRALIA, 1971 - Tectonic map of Australia and New Guinea, 1:5 000 000, Sydney.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 1973 - Geological map of Western Australia, 1:2 500 000, Perth.

GERDES, R.A., YOUNG, G.A., CAMERON, B.F., & BEATTIE, R.D., 1970 - Sandstone and Youanmi airborne magnetic and radiometric survey, W.A., 1968. Bur. Miner. Resour. Aust. Rec. 1970/2 (unpubl.).

HAWKINS, L.V., HENNION, J.F., NAFE, J.E., & THYER, R.F., 1965 - Geophysical investigations in the area of the Perth Basin, Western Australia. Geophysics, 30 (6), 1026-1052.

HORWITZ, R.C., & DANIELS, J.L., 1966 - A late Precambrian belt of vulcanicity in Central Australia. Geol. Surv. W. Aust. Ann. Rep., 50-53.

KALIX, Z., 1973 - Talc, in AUSTRALIAN MINERAL INDUSTRY 1971 REVIEW. Canberra, Bureau of Mineral Resources.

LAMBOURN, S.S., 1972 - Aeromagnetic survey of the Glengarry, Wiluna and Kingston 1:250 000 Sheet areas, W.A., 1970. Bur. Miner. Resour. Aust. Rec. 1972/100 (unpubl.).

LOGAN, B.W., 1958 - Clastic dykes from Watheroo, Western Australia. J. Roy. Soc. W. Aust., 41(1), 27-28.

LOGAN, B.W., & CHASE, R.L., 1961 - The Stratigraphy of the Moora Group, Western Australia. Ibid., 44, 14-31.

MATHUR, S.P., 1973 - Crustal structure in southwestern Australia from seismic and gravity data. Bur. Miner. Resour. Aust. Rec. 1973/63 (unpubl.).

McCALL, G.J.H., 1971 - Some ultrabasic and basic igneous rock occurrences in the Archaean of Western Australia. Spec. Publ. Geol. Soc. Aust. No. 3, 429-42.

MacLEOD, W.N., 1965 - Banded iron formations of Western Australia, in GEOLOGY OF AUSTRALIAN ORE DEPOSITS, 2nd Edn. Melbourne, Australas. Inst. Min. Metall., 113-117.

McWHAE, J.R.H., PLAYFORD, P.E., LINDNER, A.W., GLENISTER, B.F., & BALME, B.E., 1958 - The stratigraphy of Western Australia. J. Geol. Soc. Aust. 4, 1-161.

MILES, K.R., 1953 - Banded iron formations in Western Australia, in GEOLOGY OF AUSTRALIAN ORE DEPOSITS, 1st Edn. Melbourne, Australas. Inst. Min. Metall., 159-71.

MUHLING, P.C., & LOW, G.H., 1973 - Explanatory notes on the Yalgoo 1:250 000 geological sheet, Western Australia. W. Aust. Geol. Surv. Rec. 1973/6 (unpubl.).

MULDER, J.M., 1960 - Southern Cross and Kalgoorlie regions airborne radiometric survey, W.A., 1958. Bur. Miner. Resour. Aust. Rec. 1960/120 (unpubl.).

O'DRISCOLL, E.S.T., 1971 - Deformational concepts in relation to some ultramafic rocks in Western Australia. Spec. Publ. Geol. Soc. Aust. No. 3, 351-66.

PARKINSON, W.D., 1957 - Preliminary report on airborne surveys (scintillograph and magnetometer) of Geraldton-Onslow region, W.A., 1956. Bur. Miner. Resour. Aust. Rec. 1957/9 (unpubl.).

PLAYFORD, G., 1959 - Permian stratigraphy of the Woolaga Creek area, Mingenew district, Western Australia. J. Roy. Soc. W. Aust., 42(1), 7-32.

PLAYFORD, P.E., 1971 - Petroleum exploration in Western Australia, past, present and future. Ibid. 54(1), 1-13.

PRATT, R., 1973 - Iron Ore, in AUSTRALIAN MINERAL INDUSTRY 1971 REVIEW. Canberra, Bureau of Mineral Resources.

PRIDER, R.T., 1965 - Geology and mineralization of the Western Australian shield, in GEOLOGY OF AUSTRALIAN ORE DEPOSITS, 2nd Edn. Melbourne, Australas. Inst. Min. Metall. 56-65.

QUILTY, J.H., 1963 - Perth Basin aeromagnetic survey, W.A., 1957. Bur. Miner. Resour. Aust. Rec. 1963/74 (unpubl.).

SHELLEY, E.P., & WALLER, D.R., 1967 - Sir Samuel-Duketown airborne magnetic and radiometric survey, W.A., 1967. Ibid. 1967/136 (unpubl.).

SPENCE, A.G., 1958 - Preliminary report on airborne magnetic and radiometric surveys in Kalgoorlie-Southern Cross region, W.A., 1956-1957. Ibid. 1958/45 (unpubl.).

TIPPER, D.B., & GERDES, R.A., 1971 - Laverton-Edjudina airborne magnetic and radiometric survey, W.A., 1966. Bur. Miner. Resour. Aust. Bull. 118.

TOWNSEND, F., 1965 - Non-ferrous minor metal ore deposits of Australia, in GEOLOGY OF AUSTRALIAN ORE DEPOSITS, 2nd Edn, Melbourne. Australas. Inst. Min. Metall., 49-50.

WALL, L.N., 1968 - Preliminary hydrologic report on the Moora Group. W.A. Geol. Surv. Rec. 1968/5 (unpubl.).

WALLER, D.R., & BEATTIE, R.D., 1971 - Airborne magnetic and radiometric survey of Belele, Cue, Kirkalocka and eastern parts of Byro, Murgoo and Yalgoo 1:250 000 Sheet areas, W.A., 1969. Bur. Miner. Resour. Aust. Rec. 1971/28 (unpubl.).

WELLS, R., 1962 - Lake Johnson area airborne magnetic and radiometric survey, W.A., 1960. Ibid. 1962/100 (unpubl.).

WILSON, A.F., 1958 - Advances in the knowledge of the structure and petrology of the Precambrian rocks of southwestern Australia. J. Roy. Soc. W. Aust., 41, 57-83.

WILSON, A.F., 1969 - Granulite terrains and their tectonic setting and relationship to associated metamorphic rocks in Australia. Spec. Publ. Geol. Soc. Aust. No. 2, 243-58.

WYATT, B.W., in prep. - Aeromagnetic survey of Glenburgh, Robinson Range, Peak Hill, Nabberu and Stanley 1:250 000 Sheet areas, W.A., 1972. Bur. Miner. Resour. Aust. Rec. (unpubl.).

YOUNG, G.A., 1971 - Applications of regional airborne geophysical data to metals search in Western Australia. Ibid. 1971/78 (unpubl.).

YOUNG, G.A., & TIPPER, D.B., 1966 - Menzies and Leonora airborne magnetic and radiometric survey, W.A., 1964. Ibid. 1966/15 (unpubl.).

APPENDIX 1

OPERATIONAL DETAILS

Contractor

Aero Service (Australia) Pty Ltd

Data processing subcontractor

Engineering Computer Services Pty Ltd

Equipment

Magnetometers...Gulf Research and Development Mark III fluxgate couples to a 25-cm recorder and digital recorder.
Gulf fluxgate (Magnetic Storm Monitor).

Cameras.........Aeropath 35 mm strip camera synchronized with Doppler.

Altimeters......Honeywell Radar Altimeter

Digital Systems.Lancer digital logging system

Dopplers........Bendix Doppler Navigator system coupled to digital recorder.

Survey specifications

Altitude........150 m above ground level

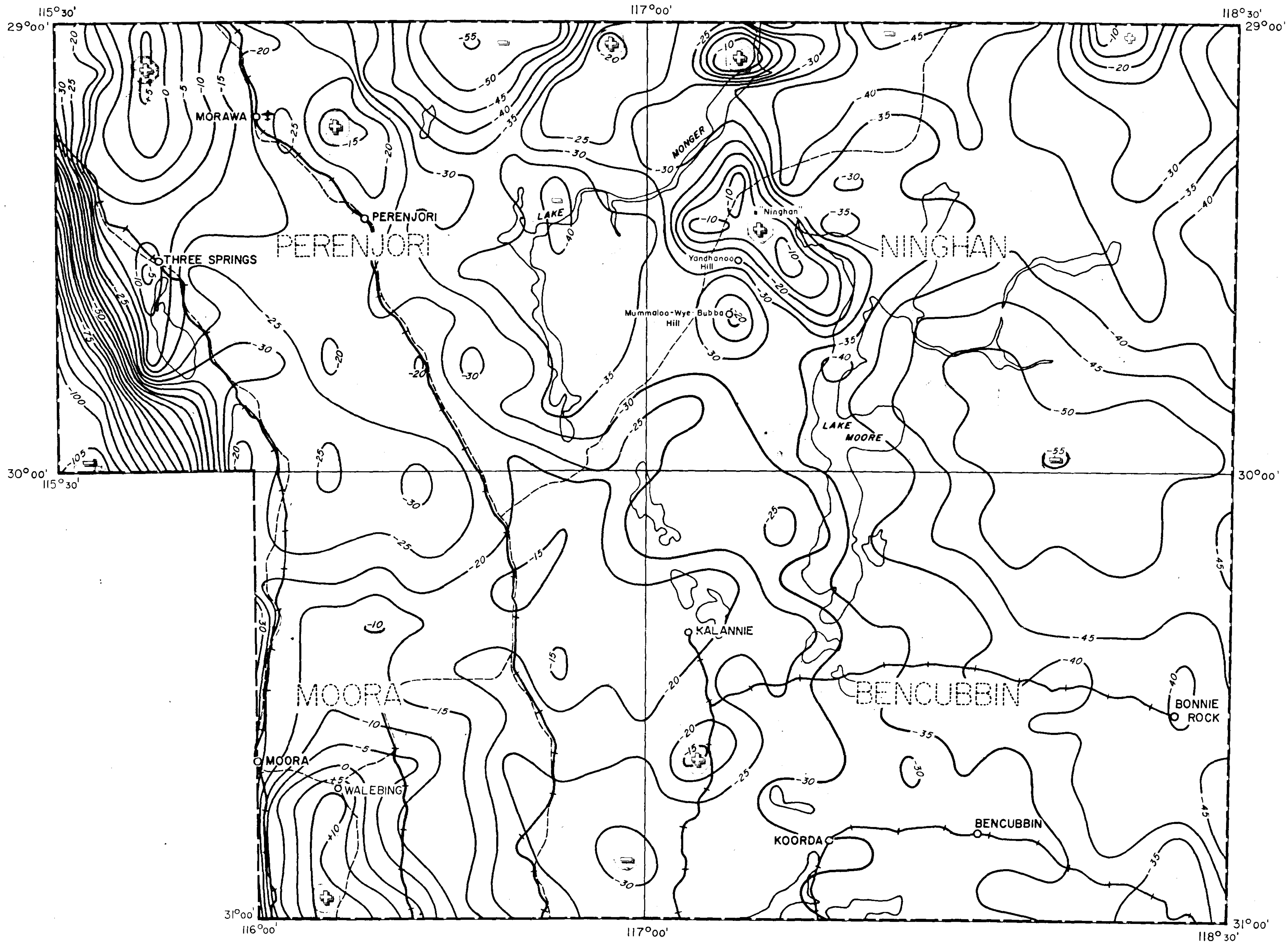
Line spacing....1.5 km

Line orientation.East and west

Tie system......Single north-south ties spaced 30 km apart

Navigation control...Pure doppler navigation grid flying

Recorder sensitivities...20 nT/cm (airborne)
9 nT/cm (ground)



AIRBORNE SURVEY, PERENJORI, NINGHAN, MOORA (PART),

AND BENCUBBIN 1:250 000 SHEET AREAS, WA, 1972

LOCALITY MAP

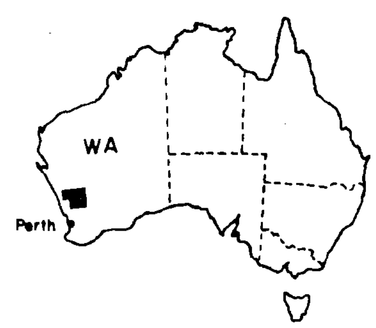
AND

BOUGUER ANOMALIES

SCALE 1:1000 000

KILOMETRES 10 0 10 20 30 40 50 60 70 80 90 KILOMETRES

LOCATION DIAGRAM



GRAVITY

—15— *Isogal*

'High' anomaly

'Low' anomaly

REFERENCE TO 1:250000 MAP SERIES

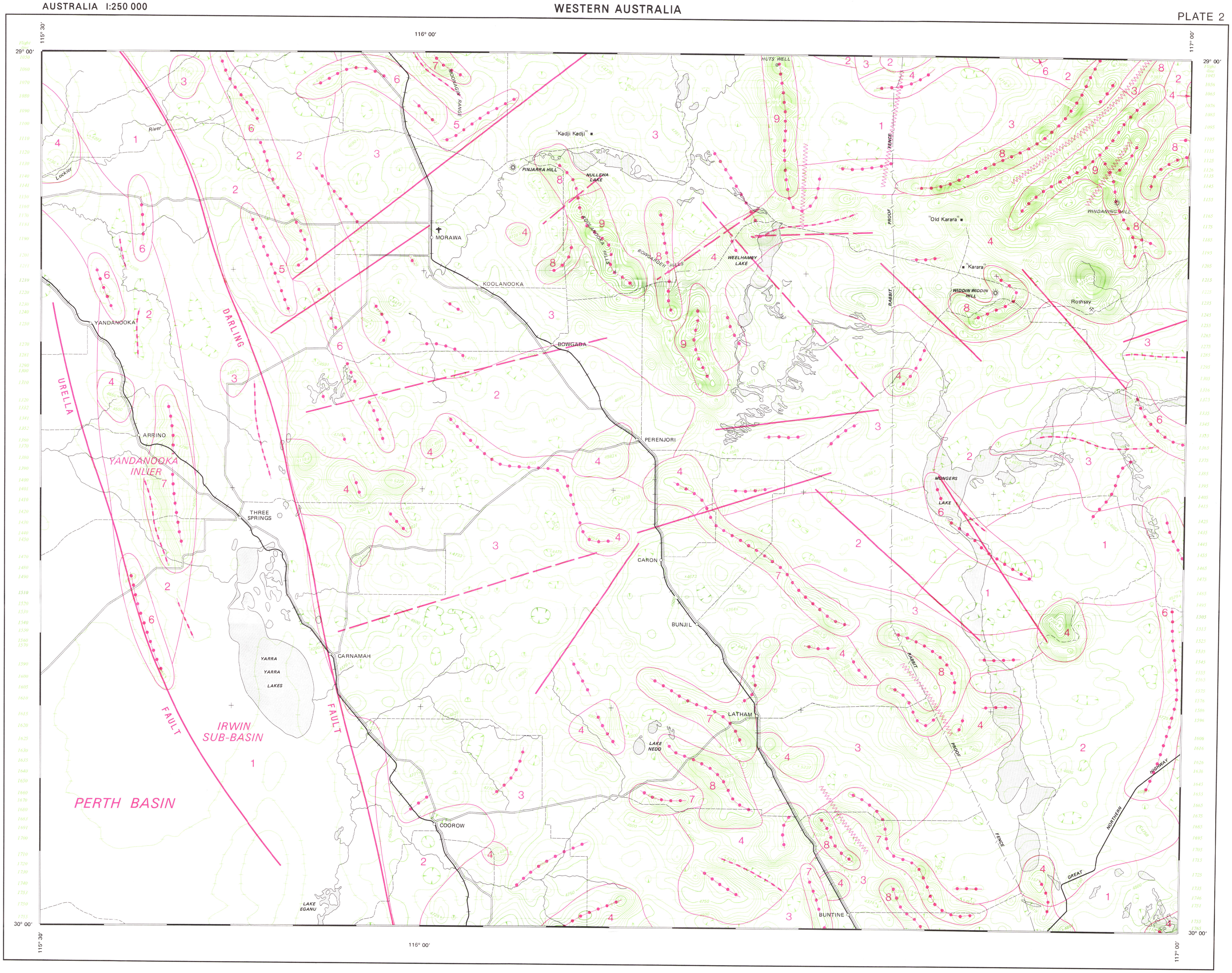
GERALDTON	YALGOO	KIRKALOCKA	YOUANMI
DONGARA	PERENJORI	NINGHAN	BARLEE
HILL RIVER	MOORA	BENCUBBIN	JACKSON
	PERTH	KELLER-BERRIN	SOUTHERN CROSS

—— *Survey Boundary*

AUSTRALIA 1:250 000

PERENJORI
WESTERN AUSTRALIA

PLATE 2



MAP DATA

PROJECTION : *Transverse Mercator*

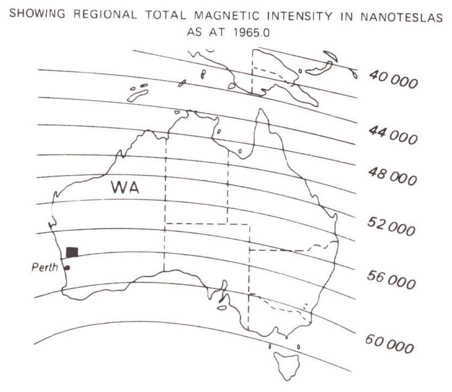
PLANIMETRY : *After Division of National Mapping 1:250 000 series SH50-6, First Edition planimetric map of the same area.*

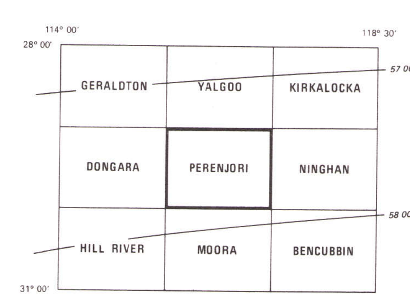
FLIGHT-LINES : *Error in position generally less than 300 metres.*

DEPARTMENT OF MINERALS AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS
DRAWN IN THE GEOPHYSICAL BRANCH

LOCATION DIAGRAM

SHOWING REGIONAL TOTAL MAGNETIC INTENSITY IN NANOTESLAS AS AT 1965.0





TOTAL MAGNETIC INTENSITY
AND
MAGNETIC INTERPRETATION

SCALE 1 : 250 000

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

MAGNETIC CONTOUR INTERVAL 50 NANOTESLAS: DATUM ARBITRARY

LEGEND

TOPOGRAPHIC

- Highway or main road
- Secondary road
- Road or track
- Railway with station
- Built-up area
- Named place
- Homestead
- Aerodrome or landing ground
- Mine
- Fence
- Telegraph line
- River or creek
- Lake
- Swamp
- Saltpan or claypan
- Floodout
- Hill feature
- Reef
- Post Office
- Well
- Rocks

MAGNETIC

- 750 / 650 Magnetic contours
- Magnetic "low"
- Contour/flight-line intersections
- x5562 Spot value

GEOPHYSICAL

- Positive magnetic trend
- Negative magnetic trend
- Fault interpreted from magnetic data
- Possible fault interpreted from magnetic data
- Interpreted fold axis
- 2 Zone boundary and number

Record No. 1975/155

EXPLANATORY NOTES

This map was compiled from an airborne survey flown in 1972 by Aero Service (Australia) under contract to the Bureau of Mineral Resources. The purpose of the survey was to obtain information on the depth, structure, and composition of rocks to aid oil and mineral exploration and geological mapping.

The survey was made at an altitude of 150 metres above ground level along lines spaced 1.5 km apart. The distance from aircraft to ground was measured by a continuously recording radio altimeter. Doppler navigation was used and the track of the aircraft was recorded by a 35-mm camera.

The total magnetic intensity was recorded by an airborne magnetometer and the data processed and contoured by computer. Regional gradient as shown in the location diagram has been removed from the data.

Printed by: Mercury—Walch Pty Ltd., Hobart, Australia

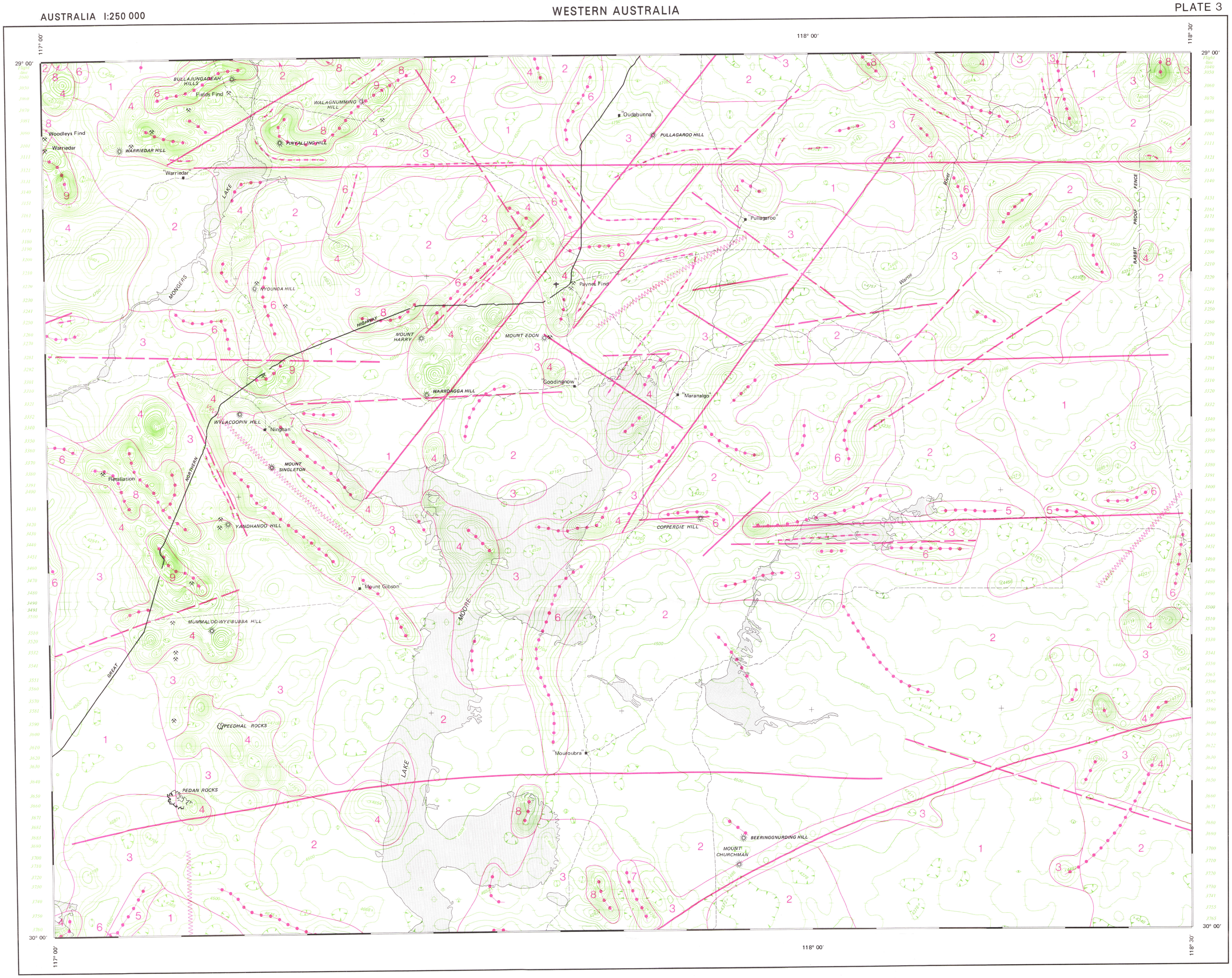
PERENJORI, WA
REFER TO THIS MAP AS: H50/B1-53-1
1975

AUSTRALIA 1:250 000

NINGHAN

WESTERN AUSTRALIA

PLATE 3



TOTAL MAGNETIC INTENSITY

AND

MAGNETIC INTERPRETATION

SCALE 1 : 250 000

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

MAGNETIC CONTOUR INTERVAL 50 NANOTESLAS: DATUM ARBITRARY

MAP DATA

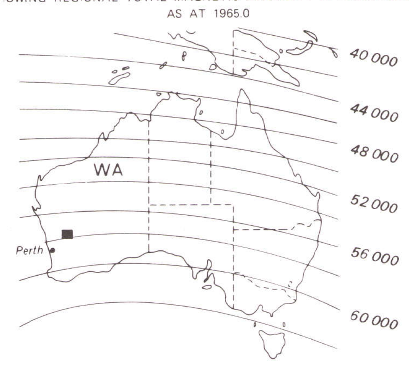
PROJECTION: *Transverse Mercator*

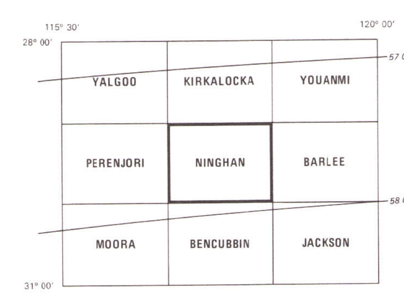
PLANIMETRY: *After Division of National Mapping 1:250 000 series SH50-7, First Edition planimetric map of the same area.*

FLIGHT-LINES: *Error in position generally less than 300 metres.*

LOCATION DIAGRAM

SHOWING REGIONAL TOTAL MAGNETIC INTENSITY IN NANOTESLAS AS AT 1965.0





DEPARTMENT OF MINERALS AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS
DRAWN IN THE GEOPHYSICAL BRANCH

LEGEND

TOPOGRAPHIC

- Highway or main road
- Secondary road
- Road or track
- Railway with station
- Built-up area
- Named place
- Homestead
- Aerodrome or landing ground
- Mine
- Fence
- Telegraph line
- River or creek
- Lake
- Swamp
- Saltpan or claypan
- Floodout
- Hill feature
- Reef
- Post Office
- Well
- Rocks

MAGNETIC

- 750 / 650 — Magnetic contours
- Magnetic "low"
- Contour/flight-line intersections
- ×5562 — Spot value

GEOPHYSICAL

- Positive magnetic trend
- Negative magnetic trend
- Fault interpreted from magnetic data
- Possible fault interpreted from magnetic data
- Interpreted fold axis
- 2 — Zone boundary and number

Record No. 1975/155

EXPLANATORY NOTES

This map was compiled from an airborne survey flown in 1972 by Aero Service (Australia) under contract to the Bureau of Mineral Resources. The purpose of the survey was to obtain information on the depth, structure, and composition of rocks to aid oil and mineral exploration and geological mapping.

The survey was made at an altitude of 150 metres above ground level along lines spaced 1.5 km apart. The distance from aircraft to ground was measured by a continuously recording radio altimeter. Doppler navigation was used and the track of the aircraft was recorded by a 35-mm camera.

The total magnetic intensity was recorded by an airborne magnetometer and the data processed and contoured by computer. Regional gradient as shown in the location diagram has been removed from the data.

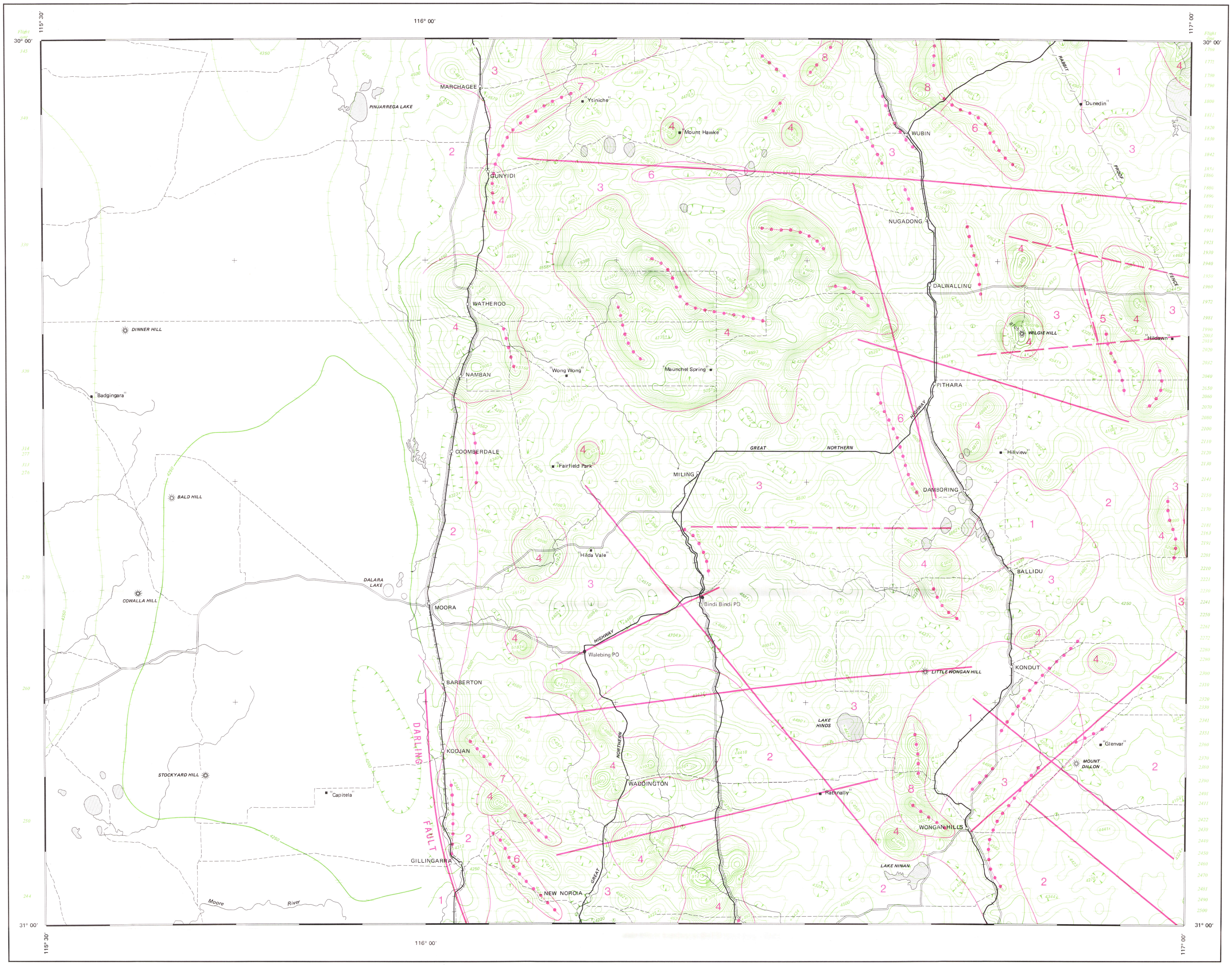
Printed by: Mercury—Walch Pty Ltd., Hobart, Australia

NINGHAN, WA
REFER TO THIS MAP AS: H50/B1-56-1
1975

MOORA
WESTERN AUSTRALIA

AUSTRALIA 1:250 000

PLATE 4



MAP DATA

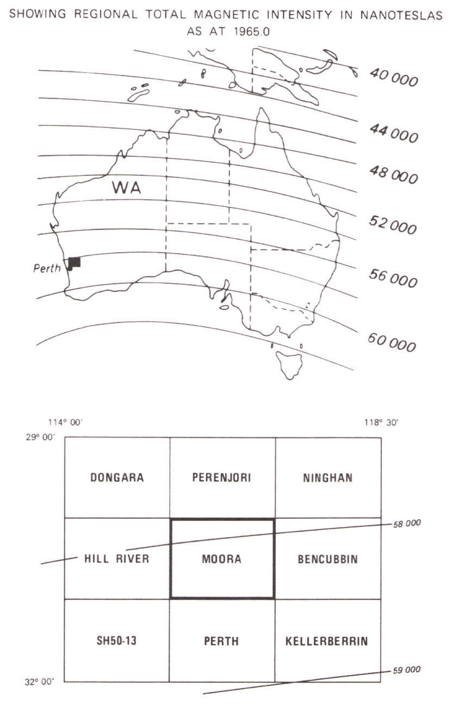
PROJECTION: *Transverse Mercator*

PLANIMETRY: *After Division of National Mapping 1:250 000 series SH50-10, First Edition planimetric map of the same area.*

FLIGHT-LINES: *Error in position generally less than 300 metres.*

LOCATION DIAGRAM

SHOWING REGIONAL TOTAL MAGNETIC INTENSITY IN NANOTESLAS AS AT 1965.0



TOTAL MAGNETIC INTENSITY

AND

MAGNETIC INTERPRETATION

SCALE 1 : 250 000

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

MAGNETIC CONTOUR INTERVAL 50 NANOTESLAS: DATUM ARBITRARY

LEGEND

TOPOGRAPHIC

- Highway or main road
- Secondary road
- Road or track
- Railway with station
- Built-up area
- Named place
- Homestead
- Aerodrome or landing ground
- Mine
- Fence
- Telegraph line
- River or creek
- Lake
- Swamp
- Saltpan or claypan
- Floodout
- Hill feature
- Reef
- Post Office
- Well
- Rocks

MAGNETIC

- 750 / 650 — Magnetic contours
- Magnetic "low"
- Contour/flight-line intersections
- x5562 — Spot value

GEOPHYSICAL

- Positive magnetic trend
- Negative magnetic trend
- Fault interpreted from magnetic data
- Possible fault interpreted from magnetic data
- Interpreted fold axis
- 2 — Zone boundary and number

Record No. 1975/155

EXPLANATORY NOTES

The western section of this map was compiled from an airborne survey flown by the Bureau of Mineral Resources in 1957. The eastern section of the map was compiled from an airborne survey flown in 1972 by Aero Service (Australia) under contract to the Bureau of Mineral Resources. The purpose of the surveys was to obtain information on the depth, structure, and composition of rocks to aid oil and mineral exploration and geological mapping.

The survey of the western section was made at an altitude of 450 metres above sea level, the eastern section at 150 metres above ground level, both along lines spaced 1.6 km apart. The distance from aircraft to ground was measured by a continuously recording radio altimeter. Navigation of the western section was mostly by a Shoran system and a Doppler navigation aid was used for the eastern section. The track of the aircraft was recorded by a 35-mm camera.

The total magnetic intensity was recorded by an airborne magnetometer and the eastern section data processed and contoured by computer. Regional gradient as shown in the location diagram has been removed from the data.

Printed by: Mercury—Walch Pty Ltd., Hobart, Australia

DEPARTMENT OF MINERALS AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS
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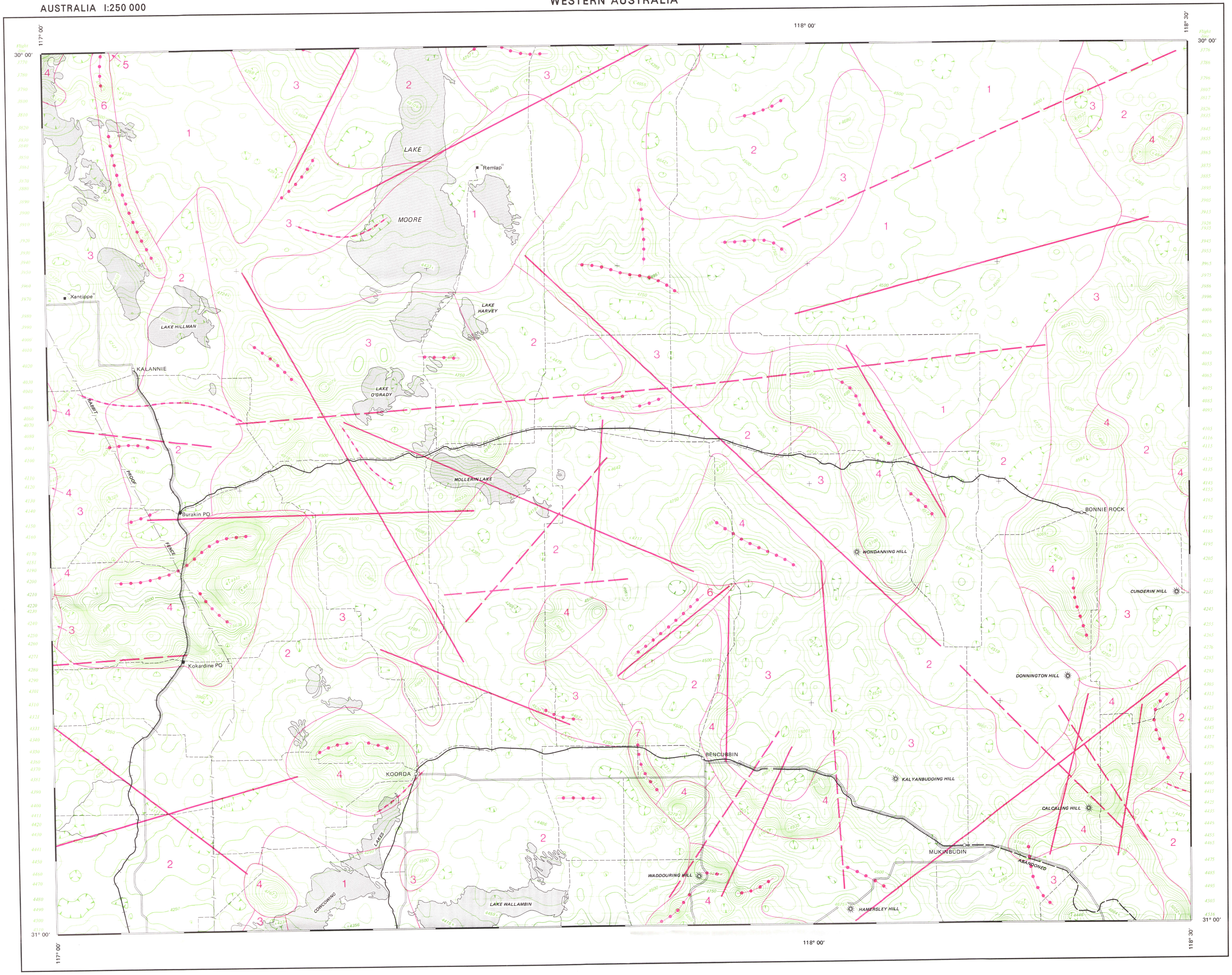
MOORA, WA
REFER TO THIS MAP AS: H50/B1-54-1
1975

BENCUBBIN
WESTERN AUSTRALIA

AUSTRALIA 1:250 000

PLATE 5



MAP DATA

PROJECTION: *Transverse Mercator*

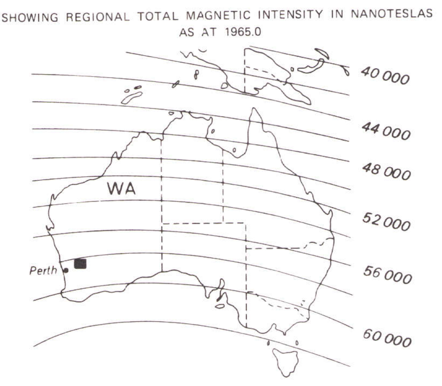
PLANIMETRY: *After Division of National Mapping 1:250 000 series SH50-11, First Edition planimetric map of the same area.*

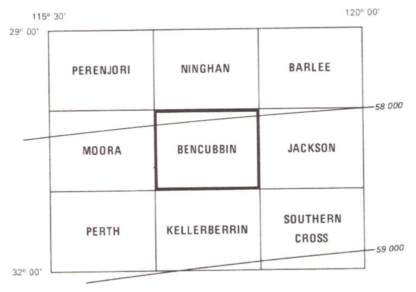
FLIGHT-LINES: *Error in position generally less than 300 metres.*

DEPARTMENT OF MINERALS AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS
DRAWN IN THE GEOPHYSICAL BRANCH

LOCATION DIAGRAM

SHOWING REGIONAL TOTAL MAGNETIC INTENSITY IN NANOTESLAS AS AT 1965.0





TOTAL MAGNETIC INTENSITY

AND

MAGNETIC INTERPRETATION

SCALE 1 : 250 000

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

MAGNETIC CONTOUR INTERVAL 50 NANOTESLAS: DATUM ARBITRARY

LEGEND

TOPOGRAPHIC

- Highway or main road
- Secondary road
- Road or track
- Railway with station
- Built-up area
- Named place
- Homestead
- Aerodrome or landing ground
- Mine
- Fence
- Telegraph line
- River or creek
- Lake
- Swamp
- Saltpan or claypan
- Floodout
- Hill feature
- Reef
- Post Office
- Well
- Rocks

MAGNETIC

- 750 / 650 — Magnetic contours
- Magnetic "low"
- Contour/flight-line intersections
- x5562 — Spot value

GEOPHYSICAL

- Positive magnetic trend
- Negative magnetic trend
- Fault interpreted from magnetic data
- Possible fault interpreted from magnetic data
- Interpreted fold axis
- 2 — Zone boundary and number

Record No. 1975/155

EXPLANATORY NOTES

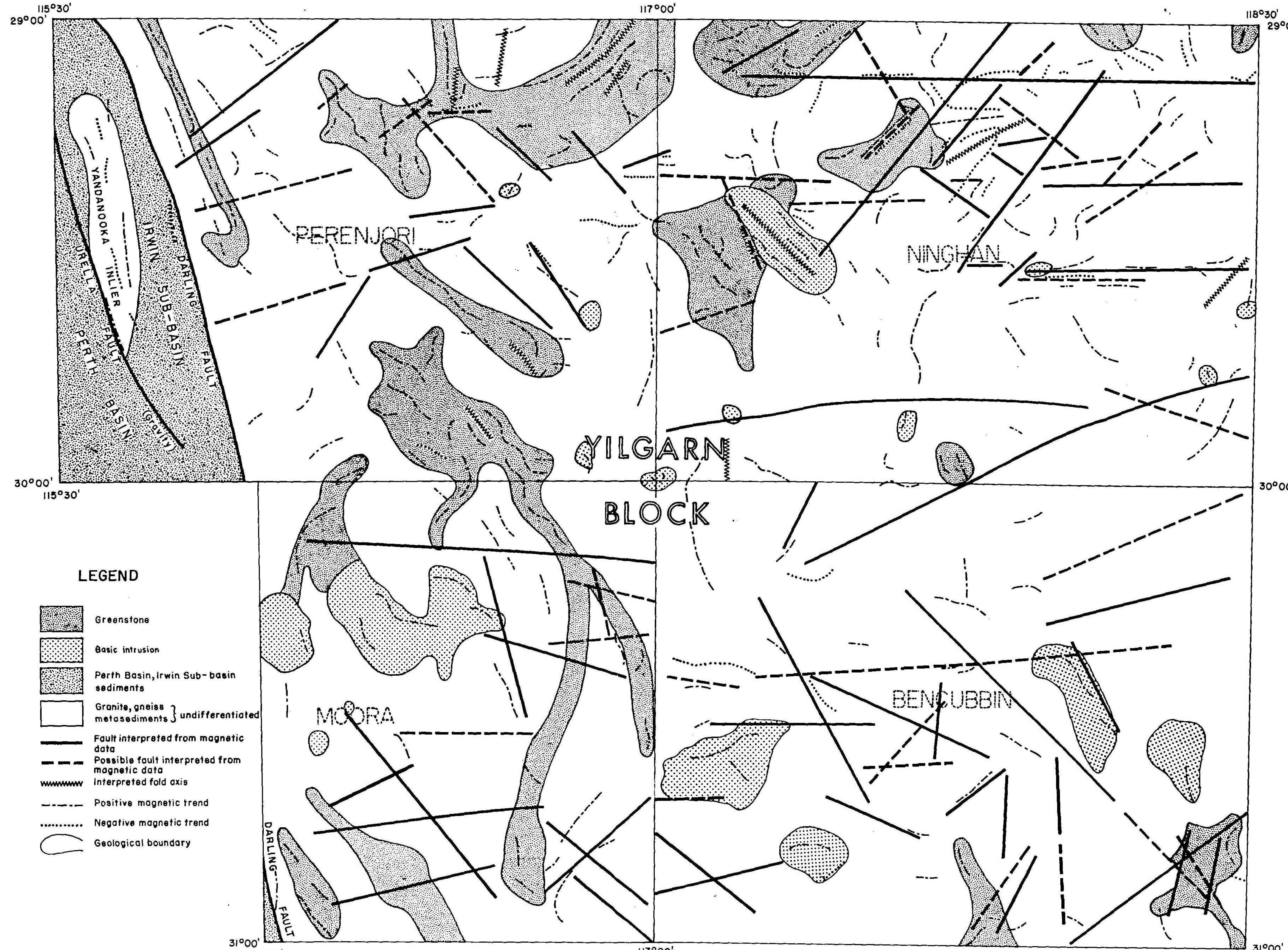
This map was compiled from an airborne survey flown in 1972 by Aero Service (Australia) under contract to the Bureau of Mineral Resources. The purpose of the survey was to obtain information on the depth, structure, and composition of rocks to aid oil and mineral exploration and geological mapping.

The survey was made at an altitude of 150 metres above ground level along lines spaced 1.5 km apart. The distance from aircraft to ground was measured by a continuously recording radio altimeter. Doppler navigation was used and the track of the aircraft was recorded by a 35-mm camera.

The total magnetic intensity was recorded by an airborne magnetometer and the data processed and contoured by computer. Regional gradient as shown in the location diagram has been removed from the data.

Printed by: Mercury—Walch Pty Ltd., Hobart, Australia

BENCUBBIN, WA
REFER TO THIS MAP AS: H50/B1-55-1
1975



MAGNETIC INTERPRETATION AND INFERRED REGIONAL GEOLOGY

1:1000 000

KILOMETRES 10 0 10 20 30 40 50 60 70 80 90 KILOMETRES

Record No. 1975/155

H50/B1-62