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SIR SAMUEL-DUKETON AIRBORNE MAGNETIC AND RADIOMETRIC SURVEY, WESTERN AUSTRALIA 1967

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SUMMARY

An airborne magnetic and radiometric survey of the SIR SAMUEL and DUKETON 1:250,000 map areas was flown by the Bureau of Mineral Resources in 1967. The objects of the survey were to assist the systematic regional mapping of the Western Australian Precambrian Shield and the search for metals.

Interpretation of the magnetic data is primarily qualitative. Geological strikes and the boundaries of major rock units have been interpreted by delineating magnetic trends, subdividing the area into zones of specified magnetic character, and assessing the significance of these zones with reference to mapped geology. Regional structure has been interpreted from a study of anomaly configuration.

Within the regions mapped as interbedded basic and sedimentary rocks, the correlation between the magnetic data and geology is generally good. However, these regions appear to be more extensive than originally thought. An additional region of 'greenstone' rocks has been interpreted in the north-east part of DUKETON.

Four cross-fold axes, one of which has several mines located along it, have been delineated. All four are recommended for further investigation.

The radiometric data reveal many high anomalies most of which can be correlated with granitic outcrops. Some regions of the granite masses have a significantly greater radioactive content than others. Sixty-two radiometric anomalies produced by localised sources were detected. Thirty-nine of these are recommended for ground investigation.

1. INTRODUCTION

In 1956 the Bureau of Mineral Resources, Geology and Geophysics (BMR) commenced an extensive programme of airborne magnetic and radiometric surveys in the goldfields region 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 which could serve as key horizons in the determination of geological structure. By the end of 1966 the 1:250,000 map areas of SOUTHERN CROSS, KALGOORLIE, BARLEE, JACKSON, KURNALPI, WIDGIEMOOLTHA, BOORABBIN, NORSEMAN, LAKE JOHNSTON, MENZIES, LEONORA, EDJUDINA, and LAVERTON had been surveyed.

Between May and mid-July 1967, the BMR continued this programme with the surveying of the SIR SAMUEL and DUKETON areas, situated within the East Murchison and Mount Margaret Goldfields.

The survey area, bounded by latitudes 27°00'S and 28°00'S and longitudes 120°00'E and 123°00'E, constitutes a small part of the Archaean Yilgarn Block, a subdivision of the Western Australia Shield (Plate 1). The block is essentially a vast mass of granite and gneiss, which encloses lenticular remnants of older rocks, folded about north-north-west axes. These remnants are composed of various interbedded lavas and sediments which were intruded by concordant basic and ultrabasic rocks prior to regional folding. The folding was accompanied by intrusion of the granite and by generally low-grade metamorphism. Mineralisation, of which gold has been the most extensively worked, is virtually confined to the folded older rocks.

The objectives of this survey were to aid a programme of systematic regional geological mapping of the shield and to assist in the search for metals. Regional mapping by the Geological Survey of Western Australia has been mainly directed towards the determination of the basic structure of the shield and with establishing a relation between such structure and mineralisation. A relation has also been sought between gold-mineralisation and rock-type, and the concept of 'favourable beds' and 'gold lines' is supported in much of the geological literature. Recent investigations by mining companies have been focused on a search for nickel deposits which could be associated with magnetically detectable ultrabasic rocks.

The co-operation of the Geological Survey of Western Australia, Anaconda Australia Inc., and Cominco Exploration Pty Ltd is gratefully acknowledged.

2. PREVIOUS GEOPHYSICAL INVESTIGATIONS

Geophysical investigations within the survey area have been conducted by mining companies in a search for base metals and gold. Cominco Exploration Pty Ltd has used induced polarisation techniques and ground magnetic surveys over parts of their reserve in the DUKETON area but the results have not yet been finalised.

Since Miles (1953) first advocated the use of the airborne magnetometer to determine aspects of geological structure by delineating banded iron formations (jaspilites), airborne magnetic and radiometric surveys have been flown by the BMR over the areas of KALGOORLIE, SOUTHERN CROSS, BARLEE, and JACKSON (Spence, 1958), KURNALPI and WIDGIEMOOLTHA (Carter, 1959), BOORABBIN and NORSEMAN (Forsyth, 1961), LAKE JOHNSTON (Wells, 1962), MENZIES and LEONORA (Young and Tipper, 1966), and LAVERTON and EDJUDINA (Tipper, 1967). The magnetic data obtained from these surveys, with the exception of the MENZIES, LEONORA, LAVERTON, and EDJUDINA areas, were interpreted by Quilty (in preparation), who found that significant geological structure could be outlined from contour maps of total magnetic intensity, the interbedded iron-rich rock units being traced as marker beds. A number of major folds and cross-folds were interpreted by Quilty from the arcuate form of the magnetic trends. This interpretation was based on the conclusions of Ellis (1939) who had shown that the jaspilite outcrop pattern in the SOUTHERN CROSS area could be produced by strong folding followed by cross-folding of less intensity prior to peneplanation such that an 'hour-glass' pattern would be developed at the intersection of an anticline and a syncline.

Quilty (op. cit.) also found that many cross-fold axes were outlined by a series of easterly trending anomalies, some of which extend over several hundred miles. Two types of cross-trending anomalies were recognised; intense negative anomalies attributed to remanently magnetised near-vertical sheets, and positive anomalies attributed to vertical sheets magnetised in a direction close to that of the earth's present field. These sheets were interpreted to represent two or more suites of basic intrusives which possibly occupy tension fissures.

Anomalies due to interbedded formations were stated by Quilty to be of a form consistent with induced magnetisation. This assumption led to the calculation of susceptibility values mainly in the range 0.01 to 0.05 c.g.s. with a few as high as 0.2 c.g.s. Dip angles of the interbedded formations were found to be in the range 80^{o} to 90^{o} in all cases.

The magnetic data presented in profile form from MENZIES and LEONORA were interpreted by Young and Tipper (1966). Some aspects of regional geological structure were delineated by resolving and analysing magnetic trends and by subdividing the area into zones of specified magnetic character. Seven east-west dykes were defined with widths of 1000 ft, near-vertical dips and depths of burial within 100 ft of the surface. Two of these dykes were interpreted to be remanently magnetised. North-south trending anomalies of the order of 1000 gammas were calculated to represent susceptibility contrasts in the range 0.002 to 0.003 c.g.s. and these were attributed to serpentinite bodies. Larger anomalies approaching the order of 10,000 gammas indicated susceptibility values between 0.025 and 0.040 c.g.s., and these were attributed to jaspilites. Areas showing a relatively flat magnetic field were ascribed to near-homogeneous acidic igneous rocks or to non-magnetic sedimentary sequences.

The magnetic data obtained in profile form from the LAVERTON and EDJUDINA areas were interpreted by Tipper (1967). Practically the entire magnetic pattern was attributed to differences in magnetic properties between rock units at or near ground level. Geological strikes and boundaries of major rock units were interpreted by delineating magnetic trends, by subdividing the area into zones of specified magnetic character, and by assessing the geological significance of these zones with reference to mapped geology.

The area was interpreted as consisting of heterogenous acid igneous masses with ill-defined more basic regions, which enclose elongated zones of interbedded sedimentary and basic rocks. Correlation with mapped geology was very good. Sixteen fold axes, one cross-fold axis, twelve major dykes (one remanently magnetised), and fourteen faults were delineated.

Ultrabasic intrusions, thought to be of economic importance, were not resolved with absolute certainty by the magnetic pattern, but eleven areas with a high probability of containing these rocks were recommended for ground investigation.

Interpretation of radiometric data from the goldfields region indicated that most of the anomalies detected may be correlated with granitic outcrops. However, in the Southern Cross - Kalgoorlie region eighty-four anomalies were recommended for ground investigation following a low-level airborne radiometric survey (Mulder, 1960). Sixty-four radiometric anomalies were detected in MENZIES and LEONORA and of these, forty-seven were considered to warrant ground investigation (Young and Tipper, 1966). The radiometric data obtained in LAVERTON and EDJUDINA revealed many high anomalies which were mainly correlated with granite outcrops (Tipper, 1967). Eighty-three radiometric anomalies satisfying the point source criteria were detected and, of these, fifty-one were recommended for ground investigation.

3. GEOLOGY

Introduction

The survey area forms part of the Archaean Yilgarn Block, a subdivision of the Western Australian Precambrian Shield. The broad regional geology of this shield has been given by Forman (1953), Wilson (1958), and Prider (1948; 1954; 1961; 1965). The general sequence of Precambrian history is as follows. Basalts and minor rhyolite flows were extruded onto an ancient basement surface. Pillow lavas indicate that there was considerable submarine vulcanism. Interbedded shales, greywackes, tuffs, agglomerates, and banded iron formations (jaspilites) show that sedimentation was active during periods of volcanic quiescence. The lavas and sediments were intruded concordantly by gabbros, dolerites, ultrabasic rocks, and some minor porphyries. All these rocks were then folded about north-north-west trending axes, contemporaneously with widespread granitic intrusion, pegmatitic and aplitic intrusion, granitisation and metamorphism of variable grade. The granitic rocks have been dated at 2700 million years (Wilson et al, 1960). Gold mineralisation is probably genetically related to the granite (Campbell, 1965) and in parts of the shield the age of mineralisation has been dated as 2300 to 2400 million years (Wilson et al, 1960). A system of subordinate folding about east-north-east to north-east axes was superimposed on the major folding, and, in at least some parts of the shield, was a significant factor in localising gold mineralisation (Ellis, 1939; McMath, 1953). This cross-folding could be broadly contemporaneous with the major folding. Intrusion of cross-trending dolerite dykes marked the end of Precambrian time.

In much of the geological literature (e.g. Forman, 1953; Low, 1960), sections of the Archaean succession predominantly basaltic have been referred to as the Greenstone Phase or the Older Greenstones, and more sedimentary sequences as the Whitestone Phase or the Whitestones. The pre-folding intrusives have been referred to as the Younger Greenstones. A number of writers (e.g. Prider, 1965) have divided the granites into an Older (synkinematic) Granite and a Younger (postkinematic) Granite. Horwitz (1966) stated that there are two granite facies but that they show contradictory age relationships. He considered that the granites are both broadly contemporaneous and in detail of several ages. Many of the granites are folded.

The banded iron formations have been described by Miles (1941; 1943a and b; 1946; 1953), Connolly (1959),and MacLeod (1965).

The geology of the survey area, given below, is based largely on the work of Honman (1917), Clarke (1925), and Hobson and Miles (1950). The geological maps produced by Clarke (1925), Talbot (1926), and Hobson and Miles (1950) have been incorporated in Plates 4 to 9 of this record. Plates 4, 6, and 8 also include geology taken from the Geological Map of Western Australia (Western Australia Department of Mines, 1966).

In this record, the term 'greenstones' is used to include rocks described in the above sources as derivatives of dolerites and gabbros, amphibolites, lavas, and basic and ultrabasic intrusives. The term 'greenstone belt' refers to regions of interbedded sedimentary and basic igneous rocks, usually elongated along strike.

Stratigraphy

The major rock units and their distribution are described in order of decreasing age. It should be remembered that sedimentation commenced well before the end of igneous extrusion and the sediments and lavas are generally interbedded.

Basement gneiss. The oldest rocks of the district are those of the ancient basement upon which the lavas were extruded. Honman (1917) believed that the basement was completely changed to granite and gneiss and suggested that some of the gneissic areas scattered throughout the granite might be relics of this basement. Although Clarke (1925) found variations within the main mass of granite, he could find no evidence that the gneissic patches are distinct from, and older than, the normal granite. Hobson (Hobson and Miles, 1950) found granitic pebbles in a conglomerate which is older than any known granite, and he stated that these point to an ancient granite which has not yet been found.

Lavas. The extrusives are basic (basalt or dolerite) and acidic (porphyrite) and many are associated with agglomerates and tuffs. Basic lavas have a wide distribution throughout both SIR SAMUEL and DUKETON. They range from fine-grained zoisitic epidiorites to coarse-grained amphibolites. Carbonate chlorite rocks and other sheared 'greenstones' also occur in bands one-eighth of a mile wide and in places pass gradually into one of the other two preceding types. All the coarser varieties appear to have undergone dynamic metamorphism and are thought to have been derived from rocks ranging from basaltic dolerite to coarse gabbro (Clarke, 1925).

Outcrops of foliated quartz porphyries (described by some authors as granite schists) occur between Mount Amy (122°19'E, 28°03'S in LAVERTON) and just north of Duketon, and in three other bands between Duketon and Mulga Queen (Plate 5). These are considered to be contemporaneous with the basic lavas with which they are interbedded.

Sediments (SIR SAMUEL). Sediments similar to those occurring in 'greenstone' belts in neighbouring LEONORA and LAVERTON probably exist within the 'greenstone' areas in the vicinity of Sir Samuel, Bates Range, Darlot, and in the south-west and north-east of the area. No specific reference to the older sediments is made in the early geological texts and the regional geology of this area is at present not well known. Jaspilites which are known to produce intense magnetic anomalies, have not been mapped in this area to date.

Sediments (DUKETON). It is probable that extensive areas of country in the vicinity of Erlistoun and Duketon consist of sediments. They are more limited in distribution elsewhere, usually occurring as narrow bands in 'greenstone'. They vary in type from argillaceous through arenaceous to conglomerates with quite large pebbles. A feature of these rocks is their low grade of metamorphism.

Jaspilites and related rocks crop out generally as conspicuous ridges and, being of sedimentary origin, are used extensively for determining the broad structure of the area. They are divided into two main types - the ferruginous type and the siliceous type. The ferruginous type includes the typical red and black banded jaspilite consisting of alternating bands of chert and iron oxide (haematite and martite). Below the zone of oxidation these rocks consist essentially of fine-grained quartz and granular magnetite. The siliceous types are white to grey banded cherts.

In the vicinity of Pinje - Eda Hill there are extensive outcrops of a very weathered rock consisting of rounded grains of quartz in a white sericitic groundmass. These are probably metamorphosed sediments rather than foliated prophyries as described in early geological reports on the area.

Ultrabasic intrusives. Small outcrops of ultrabasic rocks have been mapped about eight miles south of Mount Mabel in DUKETON. They were probably intruded as sills in pre-folding times. Ultrabasics have also been recorded near Erlistoun. In both cases they appear as sheared serpentines, which are regarded as the ultrabasic segregations of a dolerite magma (Clarke, 1925).

Basic intrusives. No outcrops of these rocks have been mapped so far in the survey area but they are known to intrude the 'greenstones' near Eulaminna and Murrin Murrin in the LAVERTON area to the south.

Acid intrusives. Extensive areas of granite have been mapped in both SIR SAMUEL and DUKETON, although in many places outcrops are poor and boundaries are difficult to establish completely. Besides the three main belts of granite, small patches surrounded by 'greenstone' occur in various places. The granite can be subdivided into massive and gneissic types. The commonest varieties of the massive type are potassic or sodic biotite granites.

The granite is variable in composition and near the contact with 'greenstone' is often more basic. In other places, for example south-west of Darlot, granite has been mapped which should be more correctly described as a hornblende porphyrite (Clarke, 1925).

Gneisses do not form extensive areas of outcrop and are generally confined to localities near the junction of granite and the older rocks. They include cataclastic gneisses granulated by pressure and injection gneisses caused by penetration and replacement of basic schists by granitic magma.

Acid dykes intrude the 'greenstones' in many places near contacts between granite and greenstone. These are mainly sheared and massive porphyries and their is almost a complete absence of pegmatites.

Basic intrusives (post-folding). A basaltic olivine dolerite has been mapped as intruding the granite near Point Sheila in DUKETON. No other instances of basic intrusion have been reported elsewhere in the survey area although occurrences of these rocks have been reported in several places in LAVERTON to the south.

Later sediments. A small portion of the survey area in the north-east of DUKETON is mapped as Nullagine Series sediments. These rocks are probably Lower Cambrian or Upper Precambrian in age, and range from coarse conglomerates to shales, with limestones developed in some localities.

Recent deposits. Alluvium and aeolian deposits cover more of the country, and their thickness could exceed 100 ft in places. Glacial boulders have also been recorded in a number of localities.

Structure

Folding. The older Archaean rocks are folded into a series of anticlines and synclines, which plunge generally south-south-east. Five folds of this type occur in LAVERTON but only one, the Erlistoun Anticline, extends into the survey area. The western limb of this anticline is known to be overturned and in LAVERTON the structure lines have a slight convexity to the east. Also east of the axis the structure lines have a general north-north-west trend. From Erlistoun to a point east of Duketon, east of the axis, the trend is north, while beyond this the trend is again north-north-west.

Thus from Erlistoun northwards the rate of divergence of the structure lines increases and then tends to decrease near Duketon. This was interpreted by Hobson and Miles (1950) to mean that near Erlistoun the pitch of the fold increases, whereas near Duketon the pitch decreases.

Mapping in the remainder of the survey area has not been very detailed. No other major folding features have been reported. No faults have been mapped in the area from Erlistoun to Duketon, which has been studies in comparative detail by Hobson and Miles (1950) and in their opinion there was no evidence for suspecting major faults in the area.

All members of the older igneous rocks have been subjected to dynamic strain with consequent development of shearing planes with a general north-north-west strike. Shears and quartz veins striking approximately at right angles to these main shears have been noted in several places.

Mineralisation

Gold and silver. The mineral most extensively worked in the survey area was gold, which in some places had associated silver. Most of the gold in DUKETON has come from numerous small mines in the 'greenstone' belt between Erlistoun and Mulga Queen. The principal production has been from quartz reefs in schists usually occurring near the contact of the 'greenstones' and granite. Quartz reefs occur in both classes of rock and generally are of fair size, but are irregular and lenticular and mainly of low grade.

The other main mining centres in the survey area are Sir Samuel and Darlot. In these areas the gold has been won from quartz reefs in 'greenstones' or near the contact of the granite and the 'greenstone'.

Clarke (1925) has stated that a most important feature of the area as regards gold mineralisation has been the general shearing of the 'greenstone' country in a north-north-westerly direction and that gold deposits were most likely to be found in zones of pronounced shearing.

Nickel. Prospecting for nickel is currently taking place in the survey area but no finds have been reported to date.

4. MAGNETIC RESULTS AND INTERPRETATION

The magnetic data are shown in Plates 2, 3, 4, and 5. Plates 2 and 3 show all profiles of total magnetic intensity reduced to an east-west scale of 1:250,000 and related to a series of east-west lines which approximate the flight paths. A north-south scale of 1:62,500 has been used to improve data presentation. The profiles are accurately positioned with respect to longitude near longitudes 120°22', 121°30', and 122°38'. For the reduction of the original profiles by pantography, the aircraft's ground speed was considered along any one traverse. Departures from this constant speed introduce a positional error in the presentation of the data, which is manifested by a herringbone pattern in the magnetic trends and zonal boundaries. The probable positional error, of $\pm \frac{1}{2}$ mile, is a function of distance from the control longitudes.

Plates 4 and 5 show every fourth magnetic profile together with the geological mapping to facilitate correlation.

The interpretation of the magnetic data is given in Plates 6 and 7. Virtually the entire magnetic pattern reflects near-surface lithological variations. The qualitative analysis of the data involved the delineation of magnetic trends and the subdivision of the area into magnetic zones. The magnetic parameters used to determine the zone-type are the anomaly continuity from line to line (linearity) and the dominant amplitude range representative of each zone. The limitations of this classification are discussed in Appendix 1 together with the techniques employed in the quantitative interpretation of the magnetic data.

Analysis of magnetic trends

Plates 6 and 7 show a large number of magnetic trends, most of which extend for several miles with some over 30 miles long. These trends are concentrated in, though by no means confined to, the 'greenstone' belts and the direction of the trends show good agreement with mapped geological strikes. These observations confirm that much of the 'greenstone' belts consist of regular, alternate bands of at least two very dissimilar rock types which can be traced along strike for many miles.

A random selection of anomalies of simple form has been analysed. The analysis indicated that the magnetic bodies have apices within 300 ft of the surface, and dip more steeply than 55°. Width calculations ranged from 500 to 3000 ft.

In the north-western quadrant of SIR SAMUEL and the region east and west of Lake Miranda, the dominant trend is north-north-west. These trends diverge south of Lake Miranda. The trends in the eastern half of SIR SAMUEL are generally north to north-north-west, except for those south of Lake Darlot and east of Stirling Peaks, which strike north-west.

In the Erlistoun region the trends are dominantly north to north-north-west and diverge northwards towards Duketon. To the west of Duketon they strike north-west and then converge to north-north-west again west of Mulga Queen. East of Duketon they strike north and then swing to north-north-west again north-east of Duketon. In the north of DUKETON the magnetic trends are predominantly to the north, whereas elsewhere in the area they are north-north-west.

Magnetic zones and their significance

Listed below are the zone types and a brief description of their geological significance. The anomaly range quoted for each type includes most, but not necessarily all, of the anomalies in any zone of that type.

Zone type	Anomaly range	Magnetic linearity
1	less than 50 gammas	poor
2	50 to 100 gammas	poor
3	100 to 250 gammas	poor
4	greater than 250 gammas	poor
5	less than 100 gammas	good
6	100 to 250 gammas	good
7	250 to 500 gammas	good
8	greater than 500 gammas	good

Zone types 1 and 2 are interpreted as relatively homogeneous acid igneous masses or non-magnetic sedimentary rocks. Zones of type 1 surrounded by zones of type 2 or 3 are almost certainly due to the igneous masses, whereas elongate zones of type 1 flanked by zones containing magnetic trends are probably due to sedimentary sequences between more magnetic strata. Zones of type 2 probably represent rocks of slightly more basic composition than those of type 1.

Zones of type 3 occurring in regions mapped as granite are probably caused by igneous rocks of intermediate to basic composition such as granodiorite or syenite. These could either be caused by regional metamorphism or result from assimilation of pre-existing basic rocks by the granitic magma. These zones may also represent gneissic parts of the granite bodies.

Where zones of type 3 occur in the 'greenstone' belts they usually occur along strike from zones of types 1, 2, or 5 and so represent iron-rich sedimentary units or minor intrusives in the sediments.

Zones of type 4 are rather variable in size and have irregular shapes. Where they occur in granite masses they may be attributed to basic and ultrabasic intrusions. Those delineated in the areas mapped as 'greenstones' possibly represent structurally complex basic rocks with no recognisable linearity.

Zone types 5 and 6 cannot be attributed to any specific rock types but probably represent stratigraphic sequences of alternating lavas and sedimentary rocks. The transition between the two zones is not definite, but it is probably due to an increase in basicity from zone type 5 to zone type 6 or perhaps an increase in the width of the magnetic strata. Where narrow zones of these types occur in granites, they may be caused by basic pegmatites and dykes. Wide zones of types 5 and 6 in granite regions probably represent areas of partially assimilated 'greenstone' material.

Bedded basic lavas and sediments are interpreted as the source of zones of type 7. The proportion of lavas is greater in these zones than in the zones of types 5 or 6. Some of the lineations may be due to banded iron formations and possibly tabular basic or ultrabasic intrusives.

The maximum anomaly amplitude recorded is 7000 gammas in the north-west of the DUKETON area. It is not possible to subdivide zone type 8 as was done in the MENZIES and LEONORA areas (Young and Tipper, 1966) as zones of this type include anomalies representative of each part of the range 500 to 7000 gammas. The extremely high anomalies are almost certainly due to banded iron formations. However, anomalies recorded over mapped banded iron formations in the DUKETON area vary considerably in amplitude along strike, decreasing in places to only a few gammas. This indicates that the width and lithology of these formations are quite variable and this is in agreement with accepted geological concepts.

Anomalies in type-8 zones are also known to occur over basic lavas in SIR SAMUEL. Long and narrow type-8 zones containing only one or two trend lines are probably due to banded iron formations, whereas wide zones with many trend lines are more likely to represent a variety of rock types including banded iron formations, basic lavas, and basic and ultrabasic intrusives.

Comparison of geophysical interpretation with mapped geology

Based on the zone-type/rock-type correlation discussed above, it is possible to assess the agreement between mapped and interpreted geology and to note the areas where conflicting geological and magnetic data indicate that further geological mapping is desirable.

SIR SAMUEL area (Plate 6). The south-western corner of the area, which according to the geological mapping lies in a belt of sedimentary and basic igneous rocks, is characterised by zones of types 1 and 2. The presence of basic igneous rocks is not supported by the magnetic data. It appears more probable that this region either contains sedimentary material only or is an extension of the western granite. The former interpretation is more likely as strong photogeological trends have been mapped in the continuation of this belt in the neighbouring SANDSTONE area.

The western granite can be divided into two parts. The south-eastern part is represented by zones of types 5 and 6 with numerous lineations up to 15 miles long. This may be the result of partial assimilation of 'greenstone' material by the granite. The structure of the 'greenstones' has been well preserved as evidenced by the length of some of the lineations and the presence of two short interpreted fold axes. On the other hand, this region may actually be part of the neighbouring 'greenstone' belt.

The rest of the western granite consists of zones of types 1, 2, and 3, which represent granites of various compositions. The elongated zones of type 5 within the granite are probably due to basic dykes.

The 'greenstone' belt trending approximately north-south through Sir Samuel is characterised by zones of types 1, 2, 3, 6, 7, and 8. Some small zones of types 4 and 5 are also present. The margin of the south-western part of this 'greenstone' belt, as indicated by the geological mapping, is well marked by zones of types 6 and 7. The south-eastern margin is not so well marked and it is thought that south of Mount Sir Samuel the 'greenstone' extends further east and joins up with the next 'greenstone' belt. This proposition will be discussed later.

In the south of this belt a zone of type 8 corresponds to a ridge trending south-south-east from Leinster Downs Homestead and is probably due to a banded iron formation. To the west of this and also in the Lake Miranda area, zones of types 1, 2, and 3 represent sedimentary units and probably minor granite bodies. The zones of types 6 and 8 between Lake Miranda and Mount Sir Samuel and the zone of type 7 surrounding Mount Goode are probably due to basic and ultrabasic lavas and intrusives.

The narrow type-8 zone which extends for 55 miles north-north-west from Mount Mann to the northern survey boundary probably represents a basic or ultrabasic member of the 'greenstone' sequence. It is probably not a banded iron formation as these are rarely as continuous as this zone. The north-western boundary of the 'greenstone' belt with the granite is not apparent in the magnetic results and the north-eastern margin is probably some 8 miles east of the position shown by the geology. This would put the zone of type 6, 13 miles east of Mount Keith, within the 'greenstone' belt. In fact, the mapped 'greenstone' belt would be better shown by the magnetic data between latitudes 27°00' and 27°45' if moved east by several miles.

The magnetic data indicate that the central granite is not as extensive as shown on the geological map. Its western margin is probably east of the mapped position as mentioned previously and the eastern margin may be four or five miles further west. The granite probably occupies the regions represented by the zones of types 1, 2, 3, and 5, and so would extend only as far as latitude 27°53'S. South of this, zones of types 6 and 7, with lineations up to 15 miles long, suggest the presence of series of alternating sedimentary and basic rocks. An interpreted fold axis in this region strengthens this argument. These zones are continuous with zones of types 5 and 6 previously interpreted in the LEONORA area to the south (Young and Tipper, 1966).

The magnetic results indicate that rocks of the 'greenstone' series are more widespread than originally thought in the rest of the SIR SAMUEL area. Large zones of types 6, 7, and 8 in the mapped area of the eastern granite are interpreted as sequences of alternating basic and sedimentary rocks. In general the anomalies are too large and persistent for these zones to be regions of poor assimilation of pre-existing 'greenstone'. Some of the zones of type 6 may represent partially assimilated basic material, but not those of types 7 and 8.

The magnetic data in the Darlot and Stirling Peaks to Wonganoo Homestead regions indicate that 'greenstones' are more widespread than shown on the geological map.

The elongated 'greenstone' inlier three miles north-east of Yandal Lagoon is represented by a zone of type 7. The 'greenstone' area six miles north-east of Mount Hilder corresponds to a zone of type 6 which is part of an elongated zone comprising types 6 and 7. The difference of two miles between the positions of the zone and the 'greenstone' is probably due to mapping and/or positional errors. The 'greenstone' belt trending north-south through Bates Range appears to be wider at its northern end than shown on the geological map and extends to east of Lake Maitland. The narrow zone of type 8 with a single lineation located seven miles north-east of Stirling Peaks coincides with a prominent ridge and is probably due to a banded iron formation.

DUKETON area (Plate 7). The 'greenstone' mapped in the Mount Step - Mount Carnegie region is represented in the magnetic results as zones of types 5, 6, and 7. Two zones of types 5 and 6 which trend south-south-east through Mount Martin may represent an area of partially assimilated 'greenstone' material although the presence of strong lineations suggests that the mapped 'greenstone' region extends a further five miles to the north-east.

The major 'greenstone' belt which occupies the central part of the southern half of the area is represented by zones of types 1, 2, 5, 6, 7, and 8. Both the eastern and western boundaries of this belt are well defined by the magnetic data. The zones in the western half of the 'greenstone' belt trend approximately north-west while those in the eastern half trend north. These trends are divergent about the Erlinstoun Anticline, which is defined by the symmetrical disposition of the magnetic zones.

Good correlation is apparent between the magnetic data and the mapped banded iron formations, although anomaly amplitudes vary considerably. The banded iron formation which trends north-west through Mount Mabel is represented by a type-5 zone, whereas those three miles east of Erlistoun are included in a zone of type 8.

The zone of type 6 which strikes north-north-west through Erlistoun includes a region of banded iron formations and ultrabasics noted by Clarke (1925). The zones of types 6 and 7 south-east of Pinje-Eda Hill are also probably due to similar rocks.

The large region of zones of types 1 and 2 which extends north and south of Duketon is interpreted as sedimentary units of the 'greenstone' sequence. It also includes acid igneous rocks as rocks of this type were recorded by Clarke (1925).

The zone of type 5 near The Patch can be correlated with dolerite and amphibolite (Honman, 1917). The other four zones of type 5 east, north, and west of Duketon are probably due to similar rock types. The zones of types 5 and 7 west of Mulga Queen represent basic and ultrabasic rocks (Hobson and Miles, 1950; Clarke, 1925). The type-2 zone south-east of Mount Mabel occurs in an area of sediments and quartz-porphyry rocks (Clarke, 1925).

The 'greenstone' belt may be more extensive than indicated by the geology. Zones of types 5, 6, and 7, located 15 miles north of Duketon, are interpreted as 'greenstones'. The large zone of type 5, 14 miles north-east of Duketon, may represent a region of partially assimilated 'greenstones' although an interpreted fold axis in the neighbouring type-1 zone would favour a repetition of the 'greenstone' sequence.

In the central northern part of DUKETON, zones of types 5, 6, 7, and 8 occur in a region shown as granite and porphyry on the geology of Clarke (1925) which is incorporated in Plate 7. The more recent geological map (Western Australia Department of Mines, 1966) shows a small 'greenstone' belt in this region, which is confirmed by the magnetic results. This belt probably extends eastwards to the north-east corner of the DUKETON area into a region which was mapped as sediments of Lower Cambrian or Upper Precambrian age (Talbot, 1926). Zones of types 6, 7, and 8 suggest, however, the presence of alternating sedimentary and basic and ultrabasic rocks. The type-8 zone, located seven miles north-north-west of Mount Gerard, includes the strongest anomalies detected during the survey: up to 7000 gammas. These are probably due to a banded iron formation or serpentinite.

In the south-east corner of the area, zones of types 5, 6, and 7 are probably due to 'greenstone' material which may be an extension of the small 'greenstone' belt near Cosmo Newbery Hill.

The remainder of the DUKETON area has been mapped as granite, gneiss, and minor acid igneous rocks. Large regions of zones of types 2, 3, and 4 in the western half suggest that the granite is slightly more basic there than in the eastern half where zones of types 1 and 2 predominate.

The zones of types 2 and 3, and perhaps 4, may represent gneissic parts of the granite mass or the more basic varieties as granite, described by Honman (1917) and Hobson and Miles (1950) as granodiorite and syenite. They could also be due to regions in which the granite has become more basic by assimilation of 'greenstone' material.

Some zones, such as the type-6 zone, 15 miles south-west of Mount Gerard, and the type-5 zone, eight miles west of Mount Mabel, may represent regions where the 'greenstones' have only been partially assimilated by the granite. These zones exhibit well-preserved lineations.

South of Point Sheila there is a large zone of type 3, which is probably due to an intermediate or basic intrusive. The displacement around it of the lineations and the narrow zones of types3, 5, and 6 suggest that it is later than the main mass of granite.

The large zones of type 4 in the north-west of DUKETON probably represent ultrabasic intrusions or ultrabasic differentiates of the granite.

The numerous narrow zones of types 5 and 6 containing a single trend line are probably due to basic dykes and pegmatites intruding the granite.

Structure

Plates 6 and 7 show the interpreted folding and faulting. Many of the fold axes may be longer than indicated but they have only been shown where the evidence has warranted it.

SIR SAMUEL area (Plate 6). Fourteen strike-fold axes and two cross-fold axes have been delineated. Because of the complexity of anomalies and the possibility of overturning it is not possible to determine the sense of the folds. The southerly convergence of the trend lines in the region ten miles east of Mount Roberts indicates a southerly plunging anticline or northerly plunging syncline. The opposite is indicated for the fold axis which strikes north-north-west through Mount Roberts.

Several fold axes have been delineated in areas mapped as granite. Where these axes are of short length it is possible that they represent preserved structure in partially assimilated 'greenstone'. However, those of considerable length, especially the one ten miles east of Mount Keith, are probably located in 'greenstones' and support the idea that these belts are more extensive than originally thought.

A cross-fold has been interpreted four miles north of Leinster Downs Homestead. This is based on the convergence and divergence of the regional strike trends in this region.

No east-west dykes or faults were interpreted in the area. Current geological opinion is that the major transverse dykes of the type located by Young and Tipper (1966) and Tipper (1967) are confined to a NNW-trending zone which passes to the west of the SIR SAMUEL area.

DUKETON area (Plate 7). The large 'greenstone' belt in the Erlistoun - Duketon region appears to have been strongly folded. Of the thirteen fold axes interpreted in DUKETON, eleven are located within this region of 'greenstone' rocks.

The regional southerly plunge of the fold system is manifested by the general southerly convergence of magnetic lineations and zones in the 'greenstone' belt.

The longest NNW-trending axis, extending from west of Duketon to east of Erlistoun, has been correlated with the Erlistoun Anticline. Its interpreted position is up to three miles east of the position shown on the geological map but at least part of this discrepancy may be caused by positional error. In any case, the actual position of the axis is doubtful between Erlistoun and Duketon although it is well defined south of Erlistoun (Hobson and Miles, 1950).

The trends of the magnetic lineations and zones east of the Erlistoun Anticline are parallel to the structure lines described by Hobson and Miles (1950). From Erlistoun to Duketon the trend is north, becoming north-north-west north-east of Duketon. This variation in the trend of the structure lines was attributed to a change in the pitch of the folds and the magnetic results suggest that cross-folding is the cause of this change.

As the major fold azis in the area is known to be anticlinal, the sense of some of the other interpreted folds may be determined. The folds north-west and south-west of Bandya Homestead, north-west of Baneygo mine and east of Pinje-Eda Hill are thought to be synclinal and those ten miles north-east of Erlistoun and ten miles north-east of Duketon are thought to be anticlinal. The fold axis just west of Mount Joanna may be a northerly extension of the Erlistoun Anticline, perhaps faulted to the west.

The fold north-east of Mount Carnegie was interpreted from the repetition of magnetic zones. Another fold may possibly be located in the north-eastern corner of the area trending approximately north through the zone of type 7 in that region.

Two cross-folds were interpreted after consideration of the variations in strike of the lineations. The northern one is interesting as it has four old mining areas located along it. These are Mulga Queen, Famous Blue, Mourillian, and Parrammatta. Ellis (1939) and McMath (1953) suggested that the system of cross-folds was a significant factor in localising gold mineralisation.

No transverse dykes were located in the area, but an east-west fault was interpreted just north of Erlistoun. This fault may be significant as the Baneygo, Mistake, and Midas mines are located near it.

5. RADIOMETRIC RESULTS AND INTERPRETATION

Radiometric data were recorded by two scintillometers, each adjusted for a specific purpose. The inboard scintillometer, set with a 10-second time constant, was used to record broad fluctuations of radiometric intensity across the area to assist geological mapping. The outboard scintillometer, set with a 1-second time constant, was used to detect localised sources of radioactivity.

Inboard scintillometer

A contour presentation of the radiometric data, superimposed on mapped geology, is shown in Plates 8 (SIR SAMUEL) and 9 (DUKETON). Some smoothing of the contours was necessary to minimise contour distortions introduced by a combination of errors. These include: parallax error due to delay in instrument response resulting from the 10-second time constant; temperature affected instrumental drift; variation in instrument sensitivity; positional error identical to that of the magnetic data; and errors due to variations in aircraft ground clearance.

In the LAVERTON - EDJUDINA survey (Tipper, 1967), a correlation was observed between the radiometric contours and the drainage pattern. This correlation is not entirely applicable in this survey as heavy rain had fallen in the area and most of the salt lakes and salt pans were filled. Anomalies are apparent over Lake Maitland and the two lakes ESE and SE of Yeelirrie Homestead but none was recorded over the large Lake Miranda and Lake Darlot systems.

Most of the radiometric 'highs' occur in areas mapped as granite, gneiss, and porphyry. The highest anomalies in SIR SAMUEL were detected in the eastern half near Mount Blackburn and east of Yandal Homestead and in the western half north of Kaluwiri Homestead. Granitic rocks are present in these regions, corresponding to magnetic zones of types 1 and 2.

Several anomalies greater than 150 c.p.s. occur over mapped 'greenstones'. They correspond to magnetic zones of types 1, 2, and 5 and so are probably due to small regions of granite or pegmatites.

In DUKETON, the highest anomalies were recorded over granite in the western part of the area. They correspond to magnetic zones of types 1, 2, and 3. A line of radiometric 'highs' extends from Point Sheila north to Mount Mabel and thence north-west to the boundary of the area. This coincides with the granite ridges of the Neckersgat and Sholl Ranges.

The granite in the northern and eastern parts of the area does not give rise to radiometric anomalies except for a few which coincide with hills in the de la Poer Range and ten miles north-west of Gibson Hill.

The major 'greenstone' belt is well defined by the radiometric contours and only in a few places does its radioactivity exceed 100 c.p.s. The same applies to the interpreted 'greenstone' region in the north and north-east of the area.

<u>Outboard scintillometer</u>

Sixty-two anomalies from restricted sources were located. These are listed in Tables 1 and 2 of Appendix 2 and the criteria used in selecting them is discussed in Appendix 1. The anomalies have been classified into four categories: A, B, C, and D, examples of which are illustrated in Figure 1. Only those of types A and B are recommended for ground investigation. Anomalies of types C and D may prove quite difficult to detect by ground work and their significance is marginal.

Anomalies 19 (type B) and 20 (type A) occur over Lake Miranda and probably do not warrant investigation. Of the remaining thirty-nine anomalies of types A and B, thirty-two are situated in magnetic zones of types 1, 2, and 3, which are attributed to granite and gneiss. Anomalies 21, 23, and 24 occur in a group in a magnetic zone of type 5. This zone apparently contains some acid igneous material. Anomaly 1 is situated in a magnetic zone of type 7, Anomalies 31 and 32 in zones of type 8, and Anomaly 62 in a zone of type 4. The significance of these four anomalies is not apparent.

6. CONCLUSIONS AND RECOMMENDATIONS

A good agreement exists between the magnetic data and the mapped geology within the 'greenstone' belts. However, the boundaries of the 'greenstone' belts as shown in Plates 4 to 9 can only be correlated with the magnetic results in a few cases. In both SIR SAMUEL and DUKETON the magnetic results suggest that the 'greenstone' regions are more extensive than originally thought. This interpretation is in agreement with current geological opinion.

In SIR SAMUEL, the magnetic data indicate that the two major 'greenstone' belts are joined south of latitude 27°46'S. A region of 'greenstone' rocks has also been interpreted in the central-north and north-east parts of DUKETON. Lower Cambrian or Upper Precambrian sedimentary rocks were originally thought to exist in these regions.

The interpreted structure should prove valuable when combined with current concepts of ore-genesis with respect to locating gold mineralisation. The cross-fold near the centre of DUKETON has several old gold mines and prospects located along it and so this region is recommended for detailed prospecting. The other three cross-fold areas should also be investigated.

Zones of types 4 and 8 in the 'greenstone' belts are likely to contain ultrabasic rocks and so are recommended for further prospecting in the search for nickel.

The radiometric data recorded by the inboard scintillometer may be of assistance in mapping granite outcrops but the anomalies associated with topographic features and salt lakes will have to be ignored.

Sixty-two radiometric anomalies from 'point-sources' were detected. Only thirty-nine of these are considered to warrant ground investigation.

The results of this survey should be of great value in satisfying the basic survey objectives, namely to assist current geological mapping and mineral prospecting. The importance of the continued application of airborne prospecting over the Precambrian Shield of Western Australia may now be enhanced if this survey assists in the search for economic nickel and other base metal deposits.

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APPENDIX 1

INTERPRETATION PROCEDURE

Qualitative magnetic interpretation

The magnetic data have been qualitatively analysed by delineating magnetic trends and zones. A magnetic trend is defined as the line joining the peak positions of anomalies which are attributed to one continuous magnetic body. Except for perfectly symmetrical anomalies, however, a trend will not be coincident with the apical axis of the body. This axis will generally be situated towards the negative part of the anomaly by an amount which is a function of the body's dip and strike angles.

Magnetic zones are based on the criteria of the degree of magnetic linearity and dominant anomaly amplitude range. Although these criteria are generally satisfactory for distinguishing between contrasting rock types, they do introduce limitations to zonal significance when the zones are derived from profile data only. A series of interbedded lavas and sediments, for example, can produce anomalies with amplitudes equal to those produced by irregular masses of ultrabasic rock contained in granite. The magnetic trend criterion would generally differentiate between the two cases. Recognition of anomaly trends, however, requires a reasonably large angle between the flight-path direction and the geological strike; thus a type-3 zone could in fact represent a regular interbedded sequence striking near-parallel to the flight paths. Magnetic trends are also difficult to delineate when two or more strike directions are represented in the one region.

Significance of the amplitude criterion should be assessed with the knowledge that amplitude is a function not only of magnetic susceptibility contrasts but also of width, depth, and strike of the body. To be able more accurately to equate zones and lithology, the zones would need to be based on susceptibility values calculated for each anomaly.

Certain structural features have been qualitatively interpreted from the magnetic results. Faults were interpreted from the colinear termination of magnetic zones and trends or by abrupt changes in trend direction. Where a folded sequence contains one or more magnetic horizon, the fold has been interpreted from a repetition of zones and/or individual anomalies.

Quantitative magnetic interpretation

Quantitative interpretation involved the determination of depths, widths, and dip angles of selected anomalies. Depths of magnetic bodies were obtained by several methods. With anomalies of simple form, depths were rapidly calculated using the half-maximum-slope method devised by Peters (1949) and extended by Moo (1965). With anomalies not of simple form, the curve-matching technique of Gay (1963) was used.

Widths were obtained by measuring the horizontal distance between the two inflexion points on the limbs of an anomaly. This method is quite accurate except where the actual width is less than twice the detector-to-body distance (i.e. less than 1000 ft). In such cases, the calculated width represents the maximum possible. Dip angles were determined using the technique of Gay (1963).

Interpretation of outboard radiometric data

For an anomaly to be resolved from the normal gamma-ray background noise, its amplitude must be statistically significant. The acceptance level is three times the standard deviation (S.D.) of the background noise. Two distinct types of gamma-ray background noise are recognised.

'Statistical noise' is a statistical variation of the recorded gamma-ray intensity from a homogeneous source. The standard deviation of the count rate is given by:

$$S.D. = \sqrt{N/2T}$$

where N is the count rate and T is the time constant of the counter.

'Geological noise' is a variation of the gamma-ray intensity from a heterogeneous source which is often simulated by variations in overburden above a homogeneous source. The envelopes containing each form of background noise have a height of four times the standard deviation of that noise.

Examples of anomalies of different categories are shown in Figure 1.

Anomaly shape is a function of source configuration and location relative to the detector. The width of an anomaly at half-peak amplitude (W) is related to these factors, and the acceptance limits set are:

$$3 \text{ seconds} \geqslant W \geqslant 4 \text{ seconds.}$$

This width criterion results in the acceptance of a continuous series of sources, limited by those of 300-ft radius centred on the flight path, and point sources located 300 ft from the flight path.

APPENDIX 2

OUTBOARD RADIOMETRIC ANOMALIES

TABLE 1. SIR SAMUEL area

Anomaly No.	Line No.	Fiducial No.	Half-peak width (secs)	Amplitude x S.D.	Classification
1	3 W	0750.0	3.5	8	B
2	4 E	0161.0	3.5	5	B
3	6 E	1143.0	4.0	7	A
4	10 E	0988.5	3.5	8	A
5	11 W	0782.0	3.0	7	D
6	12 E	0176.0	3.0	6	D
7	13 W	1807.0	3.5	8	A
8	14 E	1092.0	3.0	4	B
9	14 E	1125.5	3.5	7	D
10	14 E	1217.0	3.5	4	D
11	17 W	1686.0	3.0	8	D
12	24 E	0144.5	3.0	11	B
13	24 E	0205.5	3.0	8	C
14	31 W	0762.5	3.5	6	D
15	33 W	1795.0	4.0	7	A
16	35 W	0863.5	4.0	10	B
17	37 W	1676.5	3.5	4	C
18	46 W	1877.5	3.5	7	D
19	51 W	1784.5	3.0	6	B
20	54 E	0102.0	3.5	4	A
21	56 E	1153.5	3.0	7	B
22	57 W	0927.5	3.0	6	A
23	57 W	0843.5	3.0	4	A
24	57 W	0842.0	3.0	5	A
25	59 E	0049.0	3.0	5	D
26	62 W	0870.0	3.0	3	C
27	62 W	0755.0	4.0	10	D
28	64 W	0967.0	3.0	4	A
29	65 E	0131.0	3.5	3	C
30	66 W	1021.5	4.0	6	A
31	69 E	0100.5	4.0	7	B

TABLE 2. DUKETON area

Anomaly No.	Line No.	Fiducial No.	Half-peak width (secs)	Amplitude x S.D.	Classi-fication
32	3 W	0500.5	3.5	15	A
33	4 E	0430.0	3.5	23	D
34	5 W	1567.0	3.5	10	B
35	5 W	1382.0	3.5	8	C
36	7 W	0476.0	3.5	10	B
37	8 E	0288.0	3.0	5	B
38	8 E	0437.0	4.0	13	A
39	10 E	1405.5	3.5	12	A
40	17 W	1652.0	4.0	8	D
41	21 W	1675.0	3.0	7	B
42	23 W	0599.0	3.5	6	B
43	27 W	0522.0	4.0	5	B
44	28 E	0389.5	4.0	5	B
45	30 E	1337.5	3.5	13	A
46	33 W	1480.5	3.0	8	D
47	36 E	0459.0	3.5	3	A
48	37 W	1450.0	4.0	6	A
49	48 W	0544.5	3.5	7	A
50	49 E	0366.0	4.0	6	C
51	51 W	1532.0	3.0	6	A
52	53 W	0578.0	4.0	11	A
53	56 E	1323.0	4.0	12	A
54	60 W	1580.5	4.0	5	A
55	60 W	1579.5	3.0	4	A
56	61 E	1228.5	4.0	7	D
57	64 W	0728.5	4.0	7	A
58	65 E	0344.0	3.5	6	A
59	67 E	0357.0	4.0	4	C
60	69 E	0299.5	3.5	4	D
61	69 E	0326.0	3.0	4	A
62	69 E	0468.0	3.0	3	A

APPENDIX 3

OPERATIONAL DETAILS

Staff

Party Leader	:	E. P. Shelley
Geophysicist	:	D. R. Waller
Senior Radio Technician	:	G. R. Swords
Drafting Officer	:	P. Kersulis
Geophysical Assistants	:	K. A. Mort D. Park
Pilots	:	Captain L. T. Giddens First Officer J. Smith First Officer J. R. Lindsay
Aircraft Maintenance	:	E. S. Routley G. W. Ferguson N. I. Woolmer

T.A.A.

Equipment

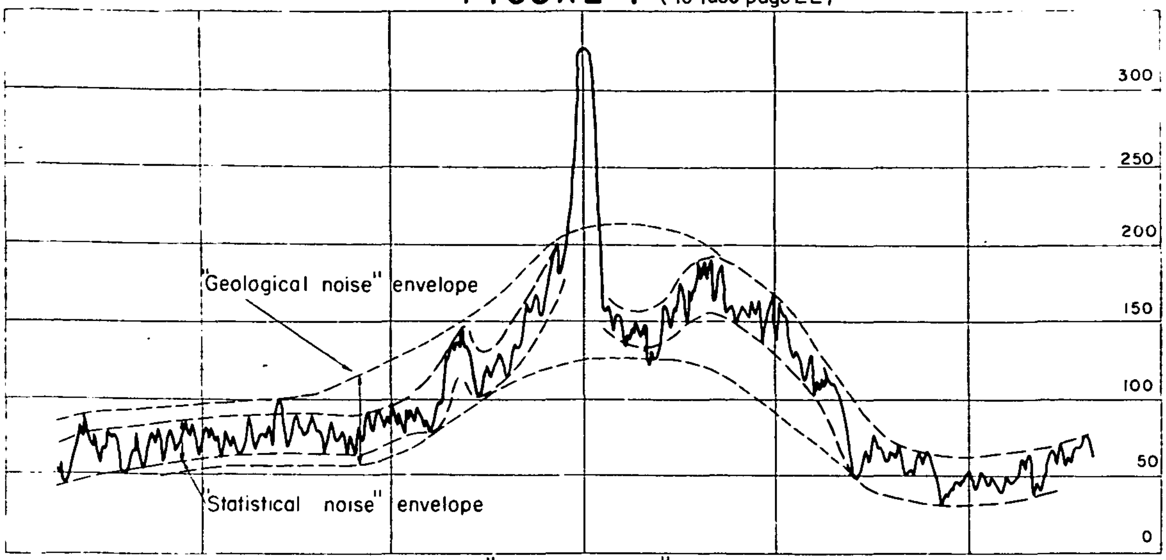
Aircraft	:	DC 3 - VH-MIN
Magnetometers	:	MFS-5 saturable core fluxgate, tail boom installation, coupled to Speedomax recorder. MFS-3 saturable core fluxgate magnetic storm monitor, ground installation, coupled to Esterline-Angus recorder
Scintillometers	:	Twin crystal MEL scintillation detector heads inboard. Single detector head outboard suspended by a cable 290 ft below the aircraft. Outputs to De Var recorder
Camera	:	35-mm strip camera of BMR design
Radio altimeter	:	STR 30B, frequency modulated type, output to De Var recorder
Air position indicator	:	Track recorded by integration of aircraft heading and airspeed, on De Var recorder

Survey specifications

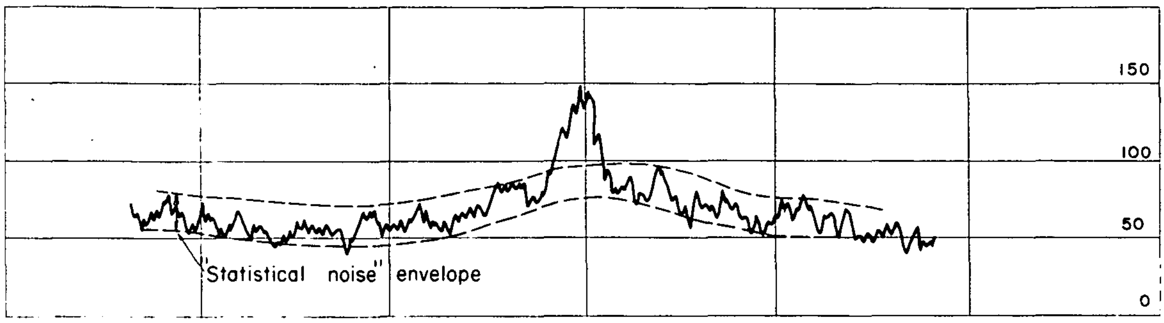
Altitude	:	500 ft above ground level
Line spacing	:	1 mile
Line orientation	:	East and west

Tie system	:	Single north-south ties spaced 15 miles apart Double ties near eastern and western boundaries of each 1:250,000 area
Navigation control	:	Aerial photographs
Recorder sensitivities	:	MFS-5 100 gammas/inch MFD-3 20 gammas/inch Scintillometers 50 c.p.s./cm Radio altimeter 100 ft/cm
Scintillometer time-constants	:	Inboard 10 seconds Outboard 1 second

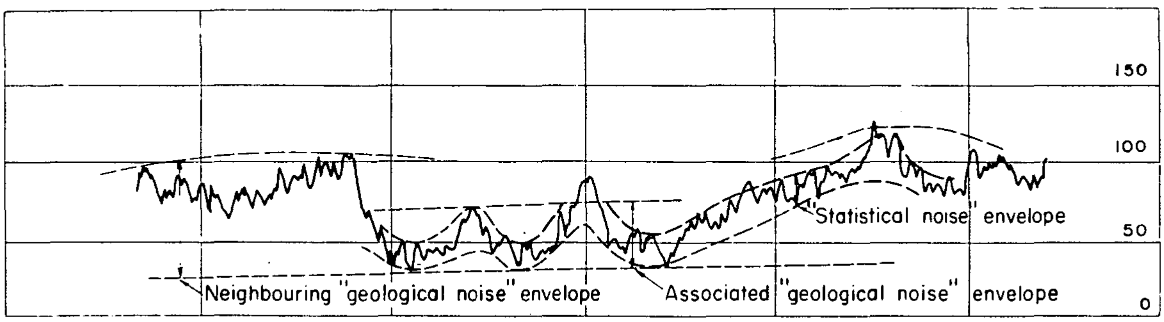
FIGURE 1 (To face page 22)



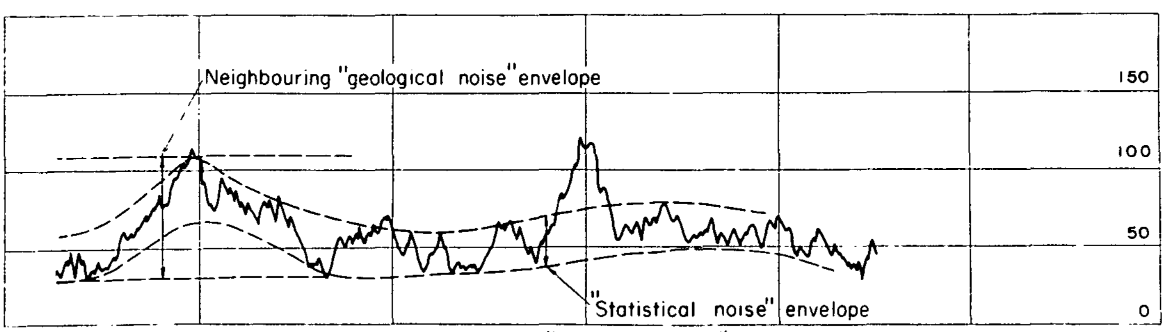
A Anomaly significant with respect to "geological noise" envelope.



B. Anomaly significant with respect to "statistical noise" envelope.



C. Anomaly significant with respect to associated "geological noise" envelope but insignificant with respect to neighbouring "geological noise" envelope.



D. Anomaly significant with respect to associated "statistical noise" envelope but insignificant with respect to neighbouring "geological noise" envelope.

COUNTS PER SECOND

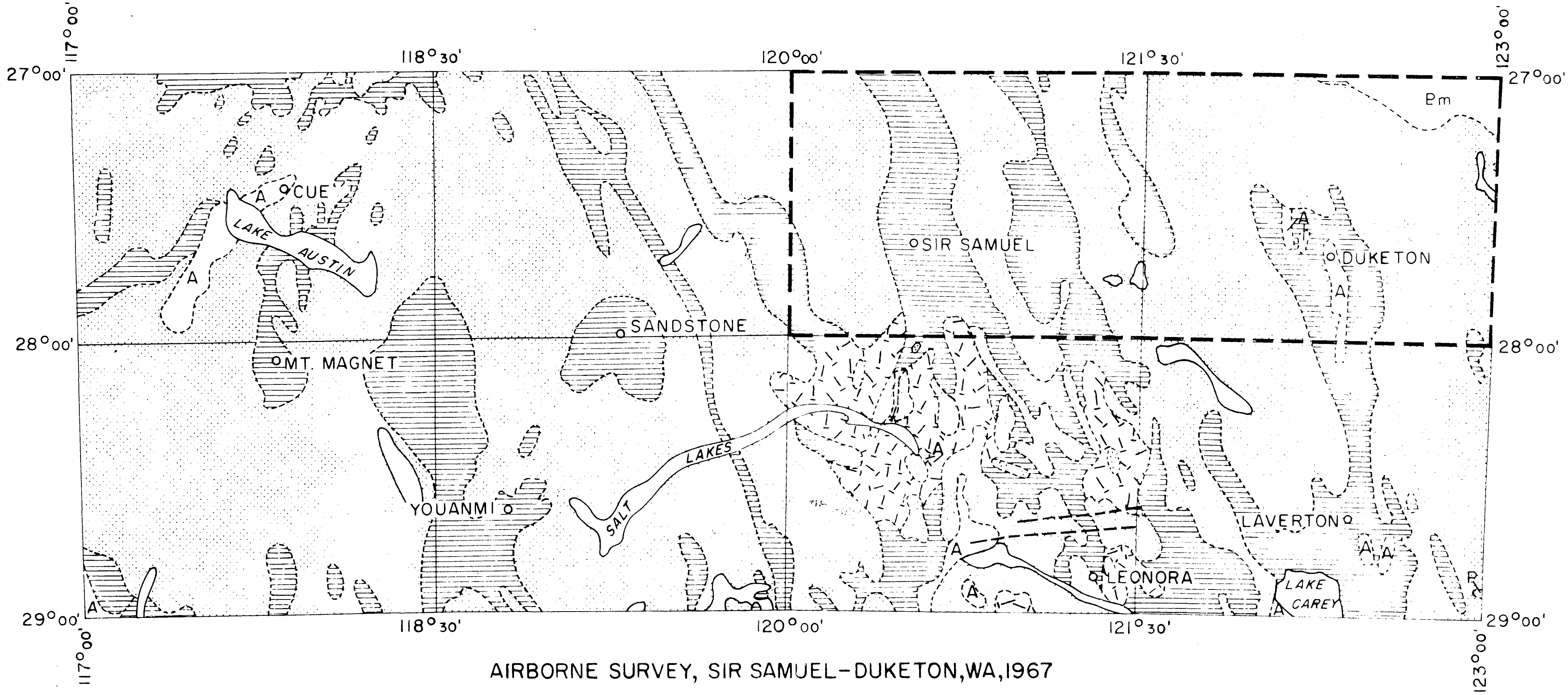
AIRBORNE SURVEY

TYPES OF RADIOMETRIC ANOMALIES

TO ACCOMPANY RECORD No. 1967/136

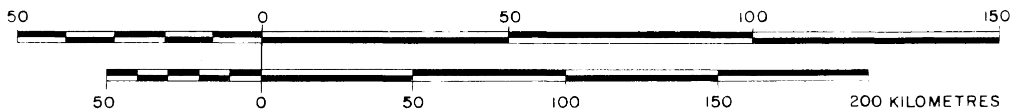
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics **H51/B1—74—1**

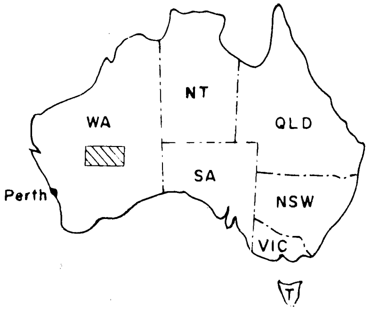
PLATE I



AIRBORNE SURVEY, SIR SAMUEL-DUKETON, WA, 1967

LOCALITY MAP





LEGEND

- Geological boundary
- Survey area boundary
- P — *Permian sedimentary rocks*
- Pm — *Middle Proterozoic sedimentary and volcanic rocks*
- A — *Archaean sedimentary rocks*
- *Basic dykes and sills of undetermined Precambrian age*
- *Archaean sedimentary rocks contains basic igneous rocks*
- *Archaean granite*
- *Zones of nigh grade metamorphism and zones of migmatite and gneiss*

GEOLOGY AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 1966

TO ACCOMPANY RECORD No. 1967/136

G51/B1-20

SIR SAMUEL

WESTERN AUSTRALIA

PLATE 2

LOCATION DIAGRAM

INDEX TO ADJOINING SHEETS

GLENGARRY	WILUNA	KINGSTON
SANDSTONE	SIR SAMUEL	DUKETON
YOUANMI	LEONORA	LAVERTON

AIRBORNE SURVEY, SIR SAMUEL–DUKETON WA, 1967

TOTAL MAGNETIC INTENSITY PROFILES

APPROX PROFILE SCALE

EXPLANATORY NOTES

THE SURVEY WAS MADE WITH A DC3 AIRCRAFT AT AN ALTITUDE OF 500 FEET ABOVE GROUND LEVEL ALONG LINES SPACED ONE MILE APART. THE FLIGHT-LINES ARE IDEALISED, AND SERVE AS BASELINES TO THE PROFILES. THEY APPROXIMATE THE ACTUAL FLIGHT PATH WITH A PROBABLE ERROR OF ± ½ MILE.

THE PROFILES HAVE BEEN CORRECTED FOR THE SOUTH COMPONENT OF A REGIONAL GRADIENT IN TOTAL MAGNETIC INTENSITY. THIS COMPONENT AMOUNTS TO 8.5 GAMMAS PER MILE.

TO ACCOMPANY RECORD No 1967/136

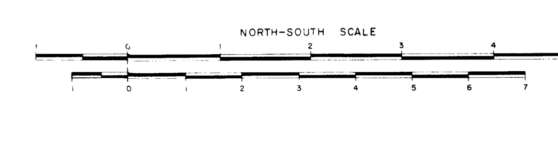
G51/B1-6

DUKETON

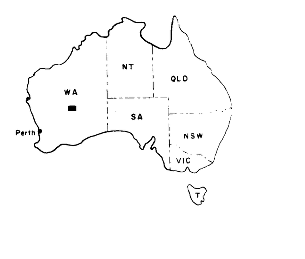
WESTERN AUSTRALIA

AIRBORNE SURVEY, SIR SAMUEL–DUKETON WA, 1967

TOTAL MAGNETIC INTENSITY PROFILES



LOCATION DIAGRAM



INDEX TO ADJOINING SHEETS

WILUNA	KINGSTON	ROBERT
SIR SAMUEL	DUKETON	THROSSELL
LEONORA	LAVERTON	RASON

APPROX PROFILE SCALE

EXPLANATORY NOTES

THE SURVEY WAS MADE WITH A DC3 AIRCRAFT AT AN ALTITUDE OF 500 FEET ABOVE GROUND LEVEL ALONG LINES SPACED ONE MILE APART. THE FLIGHT-LINES ARE IDEALISED, AND SERVE AS BASELINES TO THE PROFILES. THEY APPROXIMATE THE ACTUAL FLIGHT PATH WITH A PROBABLE ERROR OF ± ½ MILE.

THE PROFILES HAVE BEEN CORRECTED FOR THE SOUTH COMPONENT OF A REGIONAL GRADIENT IN TOTAL MAGNETIC INTENSITY. THIS COMPONENT AMOUNTS TO 8·5 GAMMAS PER MILE.

TO ACCOMPANY RECORD No. 1967/136

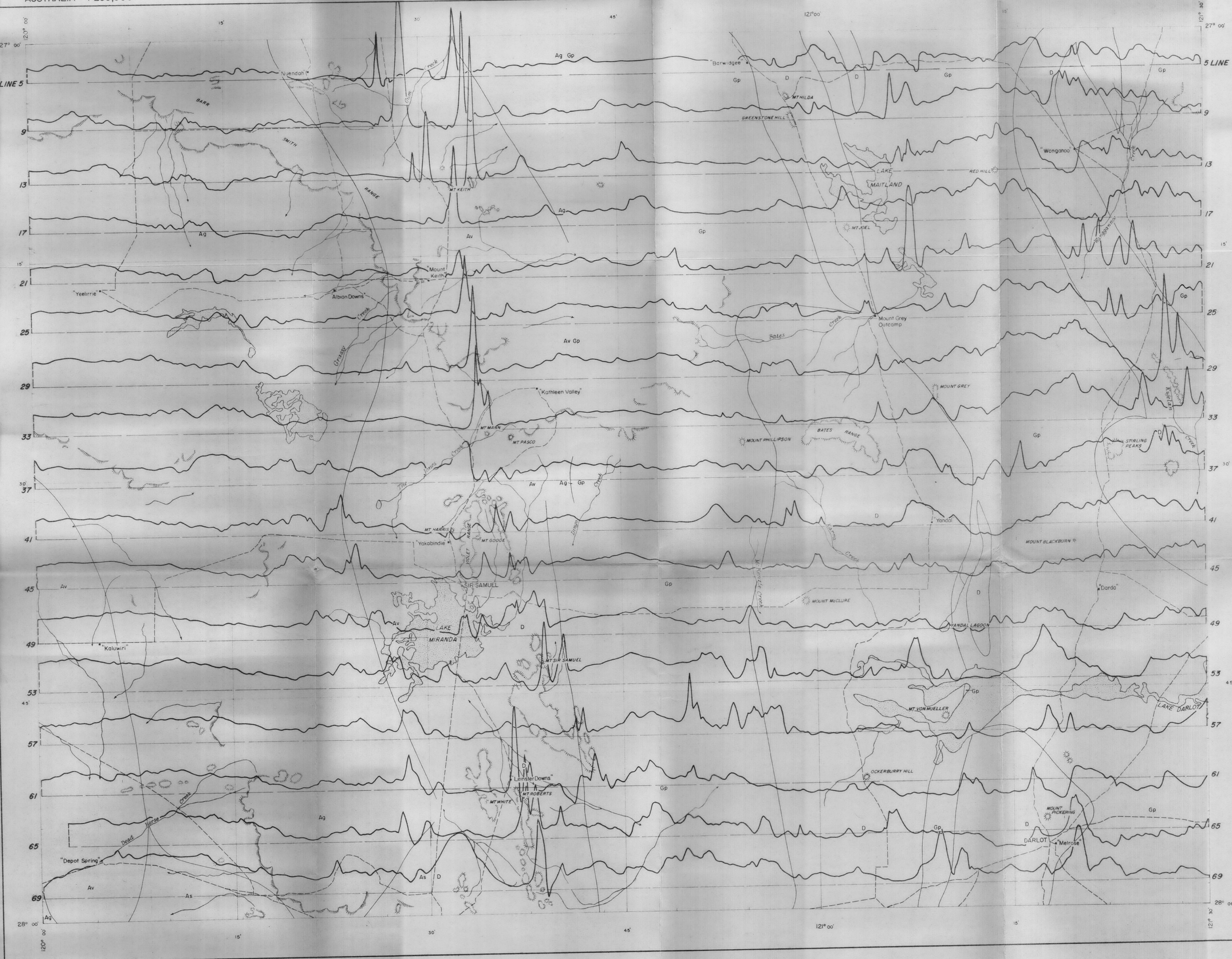
G51/B1–7

PLATE 4

SIR SAMUEL

WESTERN AUSTRALIA

AUSTRALIA 1:250,000

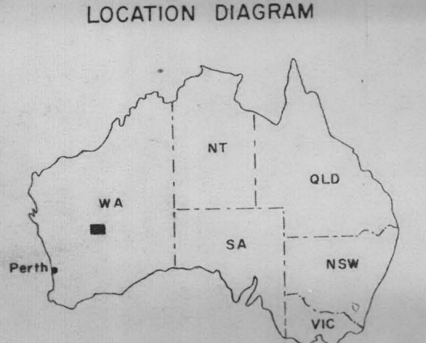


(BASED ON G51/B0-7)
(BASED ON G51/B1-8)

INDEX TO ADJOINING SHEETS

GLENGARRY	WILUNA	KINGSTON
SANDSTONE	SIR SAMUEL	DUKETON
YOUANMI	LEONORA	LAVERTON

LOCATION DIAGRAM



AIRBORNE SURVEY, SIR SAMUEL–DUKETON WA,1967

TOTAL MAGNETIC INTENSITY PROFILES AND GEOLOGY

MILES 5 0 5 10 15 20 MILES

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

APPROX. PROFILE SCALE

1000 gammas

500

0

EXPLANATORY NOTES

THE SURVEY WAS MADE WITH A DC3 AIRCRAFT AT AN ALTITUDE OF 500 FEET ABOVE GROUND LEVEL ALONG LINES SPACED ONE MILE APART. THE FLIGHT-LINES ARE IDEALISED AND SERVE AS BASELINES TO THE PROFILES. THEY APPROXIMATE THE ACTUAL FLIGHT PATH WITH A PROBABLE ERROR OF ±½ MILE.

PROFILES RECORDED AT INTERVALS OF FOUR MILES ARE SHOWN ON THE MAP.

THE PROFILES HAVE BEEN CORRECTED FOR THE SOUTH COMPONENT OF A REGIONAL GRADIENT IN TOTAL MAGNETIC INTENSITY. THIS COMPONENT AMOUNTS TO 8·5 GAMMAS PER MILE.

GEOLOGICAL LEGEND

AFTER GEOLOGICAL MAP OF WESTERN AUSTRALIA
(WA DEPT MINES, 1966)

Geological boundary

PRECAMBRIAN UNDIFFERENTIATED — ARCHAEAN

- Av — *Sedimentary rocks containing basic igneous rocks*
- Ag — *Granite*
- As — *Sedimentary rocks with zones of high grade metamorphism and zones of migmatite and gneiss*

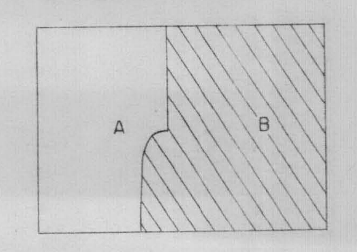
AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 84
(CLARKE, 1925)

Geological boundary

ARCHAEAN

- Gp — *Granite with some porphyry and porphyrite dykes*
- D — *Derivatives of dolerites and gabbros*

GEOLOGICAL REFERENCE



A. Geological Map of Western Australia 1966

B. Geological Survey of Western Australia Bulletin 84

TOPOGRAPHICAL LEGEND

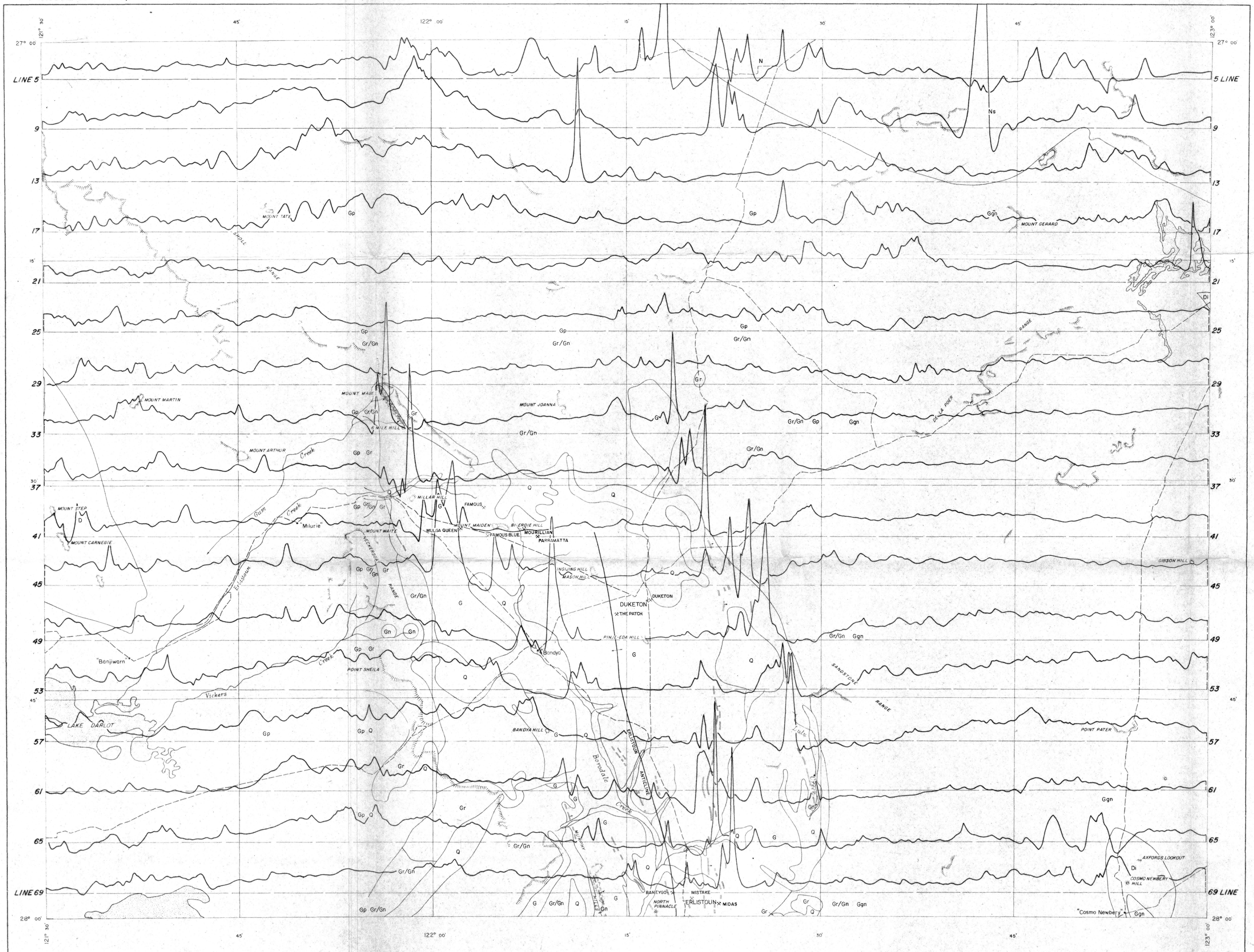
- *River or creek*
- *Road or track*
- *Homestead*
- *Hill feature*
- *Lake*
- *Mining group*
- *Named place*

TO ACCOMPANY RECORD No.1967/136 — *Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics* G51/B1-9

AUSTRALIA 1:250,000

DUKETON

WESTERN AUSTRALIA



(BASED ON G51/80-8)
(BASED ON G51/81-10)

GEOLOGICAL LEGEND

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 103 (HOBSON & MILES, 1950)

RECENT
- Q — *Alluvium*

ARCHAEAN
- Gr — *Granite with some granodiorite and syenite*
- Gn — *Gneiss*
- Gr/Gn — *Mainly sandy soil which probably largely overlies granite and/or gneiss*
- G — *Mainly lavas, pyroclastics and sediments with some basic and ultrabasic intrusives. Variable grade of metamorphism*

Axis of major anticlinal fold

Banded iron formation, with dip

Geological boundary

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 84 (CLARKE, 1925)

LOWER CAMBRIAN OR UPPER PRECAMBRIAN
- N — *Conglomerates, quartzites, sandstones, shales and limestones*

ARCHAEAN
- Gp — *Granite with some porphyry and porphyrite dykes*
- D — *Derivatives of dolerites and gabbros*

Geological boundary

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 87 (TALBOT, 1926)

LOWER CAMBRIAN OR UPPER PRECAMBRIAN
- Ns — *Conglomerates, quartzites, sandstones, shales and limestones*

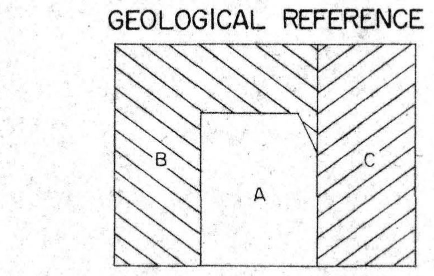
ARCHAEAN
- Di — *Amphibolite, uralitised dolerites etc*
- Ggn — *Granite (in places gneissic)*

Geological boundary

TOPOGRAPHICAL LEGEND

- *River or creek*
- *Road or track*
- *Hill feature*
- *Lake*
- *Named place*
- *Homestead*
- *Mining group*

GEOLOGICAL REFERENCE



A.... Geological Survey of Western Australia Bulletin 103

B.... Geological Survey of Western Australia Bulletin 84

C.... Geological Survey of Western Australia Bulletin 87

LOCATION DIAGRAM

INDEX TO ADJOINING SHEETS

WILUNA	KINGSTON	ROBERT
SIR SAMUEL	DUKETON	THROSSELL
LEONORA	LAVERTON	RASON

AIRBORNE SURVEY, SIR SAMUEL–DUKETON WA, 1967

TOTAL MAGNETIC INTENSITY PROFILES AND GEOLOGY

MILES 5 0 5 10 15 20 MILES

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

APPROX. PROFILE SCALE

1000 gammas

500

0

EXPLANATORY NOTES

THE SURVEY WAS MADE WITH A DC3 AIRCRAFT AT AN ALTITUDE OF 500 FEET ABOVE GROUND LEVEL ALONG LINES SPACED ONE MILE APART. THE FLIGHT-LINES ARE IDEALISED AND SERVE AS BASELINES TO THE PROFILES. THEY APPROXIMATE THE ACTUAL FLIGHT PATH WITH A PROBABLE ERROR OF ± ½ MILE.

PROFILES RECORDED AT INTERVALS OF FOUR MILES ARE SHOWN ON THE MAP.

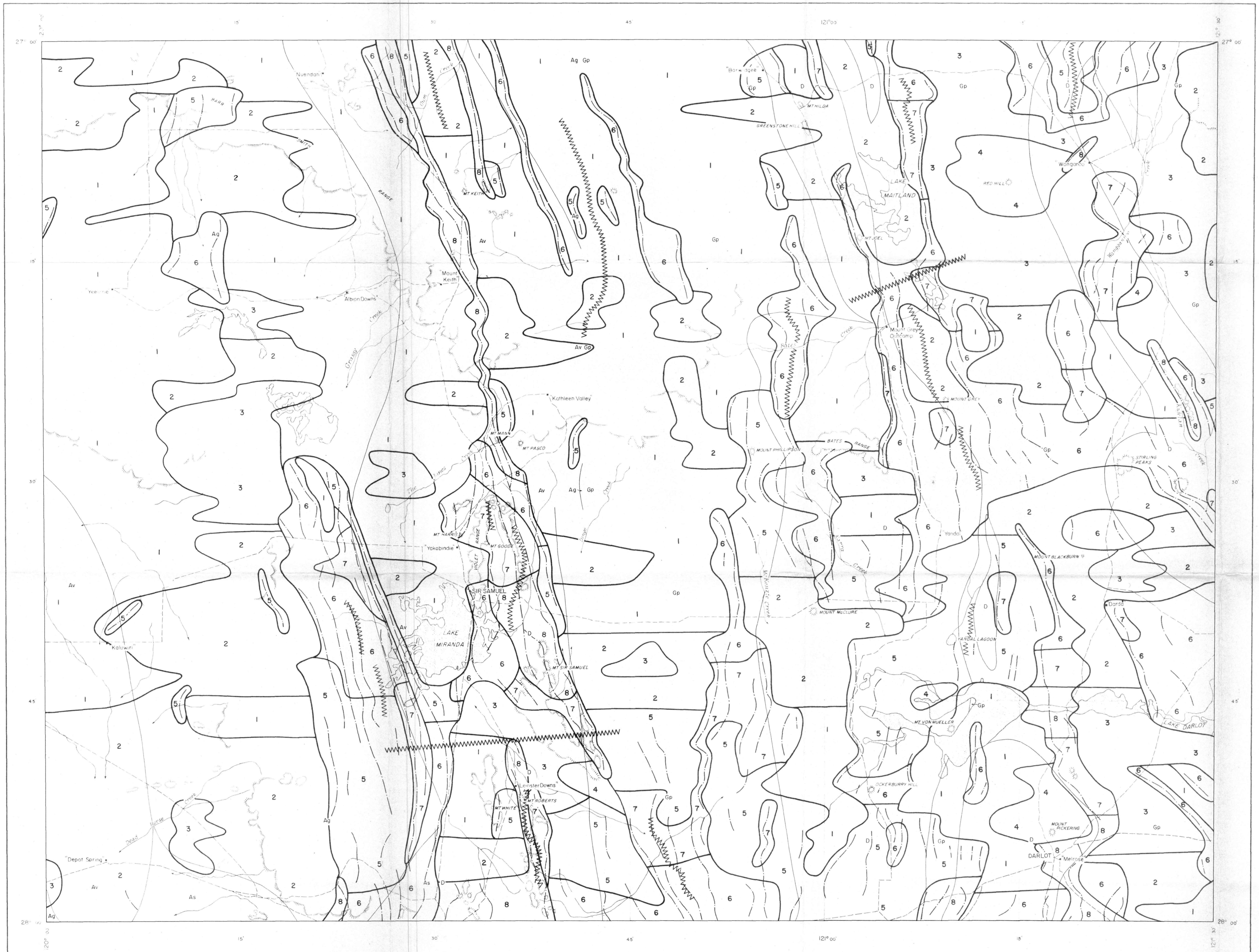
THE PROFILES HAVE BEEN CORRECTED FOR THE SOUTH COMPONENT OF A REGIONAL GRADIENT IN TOTAL MAGNETIC INTENSITY. THIS COMPONENT AMOUNTS TO 8·5 GAMMAS PER MILE.

TO ACCOMPANY RECORD No. 1967/136 *Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics* G51/B1-11

AUSTRALIA 1:250,000

SIR SAMUEL
WESTERN AUSTRALIA

PLATE 6



GEOLOGICAL LEGEND

AFTER GEOLOGICAL MAP OF WESTERN AUSTRALIA
(WA DEPT MINES, 1966)

Geological boundary

PRECAMBRIAN UNDIFFERENTIATED ARCHAEAN

Av	*Sedimentary rocks containing basic igneous rocks*
Ag	*Granite*
As	*Sedimentary rocks with zones of high grade metamorphism and zones of migmatite and gneiss*

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 84
(CLARKE, 1925)

Geological boundary

ARCHAEAN

Gp	*Granite with some porphyry and porphyrite dykes*
D	*Derivatives of dolerites and gabbros*

GEOLOGICAL REFERENCE

A B

A. Geological Map of Western Australia 1966
B. Geological Survey of Western Australia Bulletin 84

TOPOGRAPHICAL LEGEND

- River or creek
- Road or track
- Homestead
- Hill feature
- Lake
- Mining group
- Named place

(BASED ON G51/80-7)
(BASED ON G51/81-16)

LOCATION DIAGRAM

INDEX TO ADJOINING SHEETS

GLENGARRY	WILUNA	KINGSTON
SANDSTONE	SIR SAMUEL	DUKETON
YOUANMI	LEONORA	LAVERTON

AIRBORNE SURVEY, SIR SAMUEL – DUKETON WA, 1967

MAGNETIC INTERPRETATION
AND
GEOLOGY

MILES 5 0 5 10 15 20 MILES

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

GEOPHYSICAL LEGEND

- Magnetic trend
- 3 Magnetic zone
- Fold axis

AUSTRALIA 1:250,000

DUKETON

WESTERN AUSTRALIA

(BASED ON G51/80-8)
(BASED ON G51/81-18)

GEOLOGICAL LEGEND

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 103 (HOBSON & MILES, 1950)

RECENT	Q	*Alluvium*
ARCHAEAN	Gr	*Granite with some granodiorite and syenite*
	Gn	*Gneiss*
	Gr/Gn	*Mainly sandy soil which probably largely overlies granite and/or gneiss*
	G	*Mainly lavas, pyroclastics and sediments with some basic and ultrabasic intrusives. Variable grade of metamorphism*

Axis of major anticlinal fold

Banded iron formation, with dip

Geological boundary

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 84 (CLARKE, 1925)

LOWER CAMBRIAN OR UPPER PRECAMBRIAN	N	*Conglomerates, quartzites, sandstones, shales and limestones*
ARCHAEAN	Gp	*Granite with some porphyry and porphyrite dykes*
	D	*Derivatives of dolerites and gabbros*

Geological boundary

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 87 (TALBOT, 1926)

LOWER CAMBRIAN OR UPPER PRECAMBRIAN	Ns	*Conglomerates, quartzites, sandstones, shales and limestones*
ARCHAEAN	Di	*Amphibolite, uralitised dolerites etc*
	Ggn	*Granite (in places gneissic)*

Geological boundary

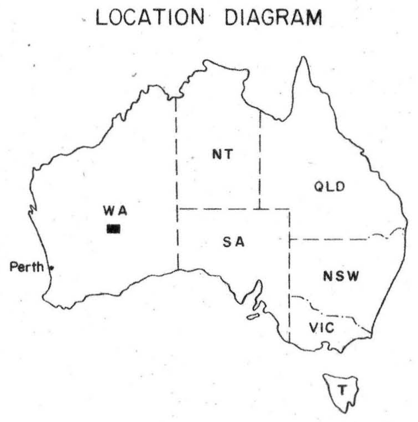
TOPOGRAPHICAL LEGEND

River or creek
Road or track
Hill feature
Lake
Named place
Homestead
Mining group

GEOLOGICAL REFERENCE

A ... Geological Survey of Western Australia Bulletin 103
B ... Geological Survey of Western Australia Bulletin 84
C ... Geological Survey of Western Australia Bulletin 87

LOCATION DIAGRAM



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SIR SAMUEL	DUKETON	THROSSELL
LEONORA	LAVERTON	RASON

AIRBORNE SURVEY, SIR SAMUEL – DUKETON WA, 1967

MAGNETIC INTERPRETATION
AND
GEOLOGY

MILES 5 0 5 10 15 20 MILES

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

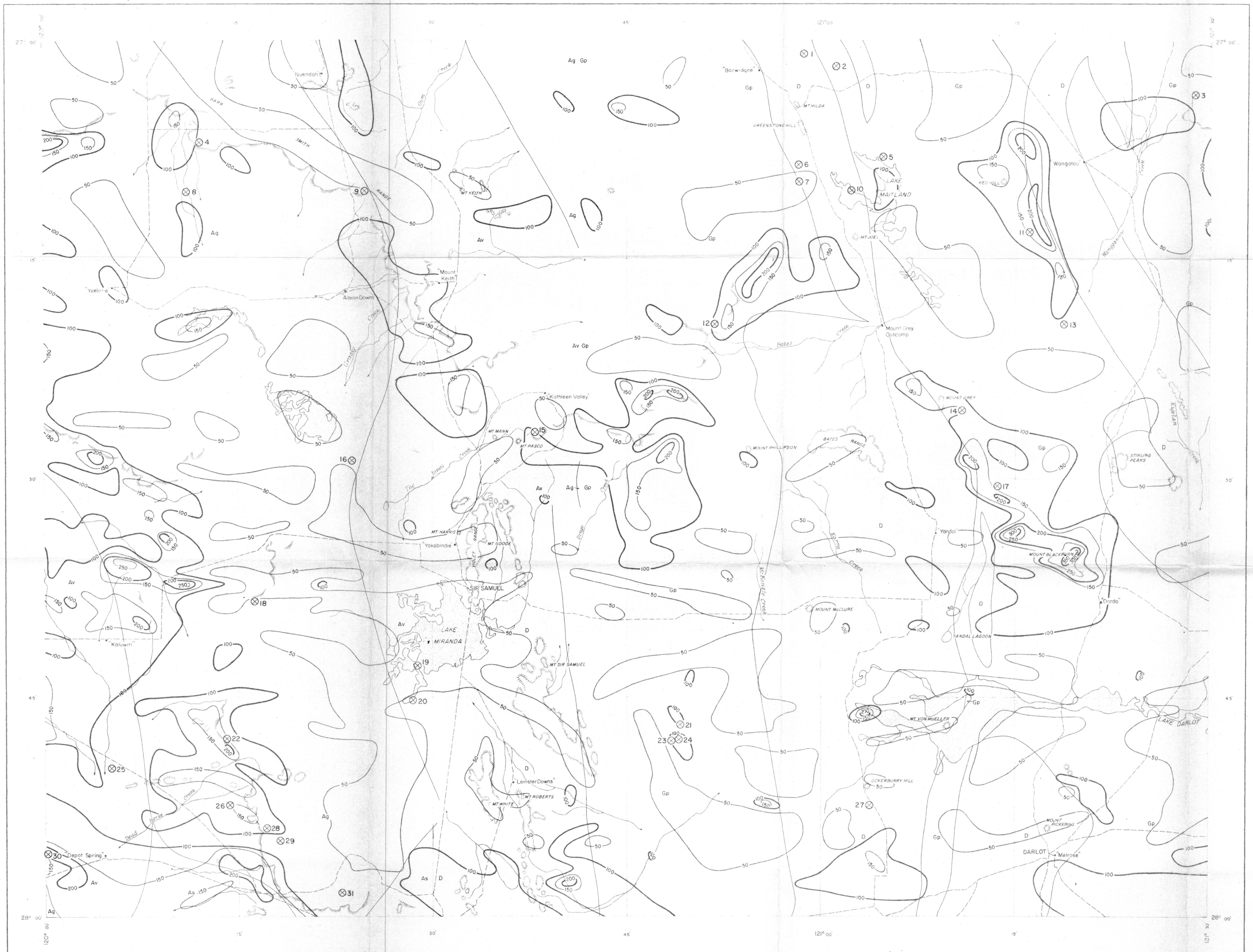
GEOPHYSICAL LEGEND

Magnetic trend
Magnetic zone
Fold axis
Interpreted fault

AUSTRALIA 1:250,000

SIR SAMUEL

WESTERN AUSTRALIA



(BASED ON G51/B0-7)
(BASED ON G51/B1-12)

GEOLOGICAL LEGEND

AFTER GEOLOGICAL MAP OF WESTERN AUSTRALIA
(WA DEPT MINES, 1966)

Geological boundary

PRECAMBRIAN UNDIFFERENTIATED ARCHAEAN

Av	*Sedimentary rocks containing basic igneous rocks*
Ag	*Granite*
As	*Sedimentary rocks with zones of high grade metamorphism and zones of migmatite and gneiss*

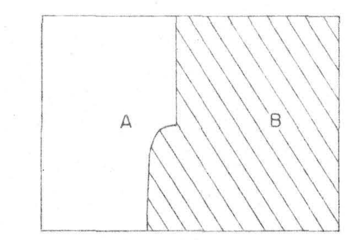
AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 84
(CLARKE, 1925)

Geological boundary

ARCHAEAN

Gp	*Granite with some porphyry and porphyrite dykes*
D	*Derivatives of dolerites and gabbros*

GEOLOGICAL REFERENCE



A. Geological Map of Western Australia 1966
B. Geological Survey of Western Australia Bulletin 84

TOPOGRAPHICAL LEGEND

River or creek
Road or track
Homestead
Hill feature
Lake
Mining group
Named place

LOCATION DIAGRAM

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GLENGARRY	WILUNA	KINGSTON
SANDSTONE	SIR SAMUEL	DUKETON
YOUANMI	LEONORA	LAVERTON

AIRBORNE SURVEY, SIR SAMUEL-DUKETON WA, 1967

RADIOMETRIC RESULTS AND GEOLOGY

MILES 5 0 5 10 15 20 MILES

KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

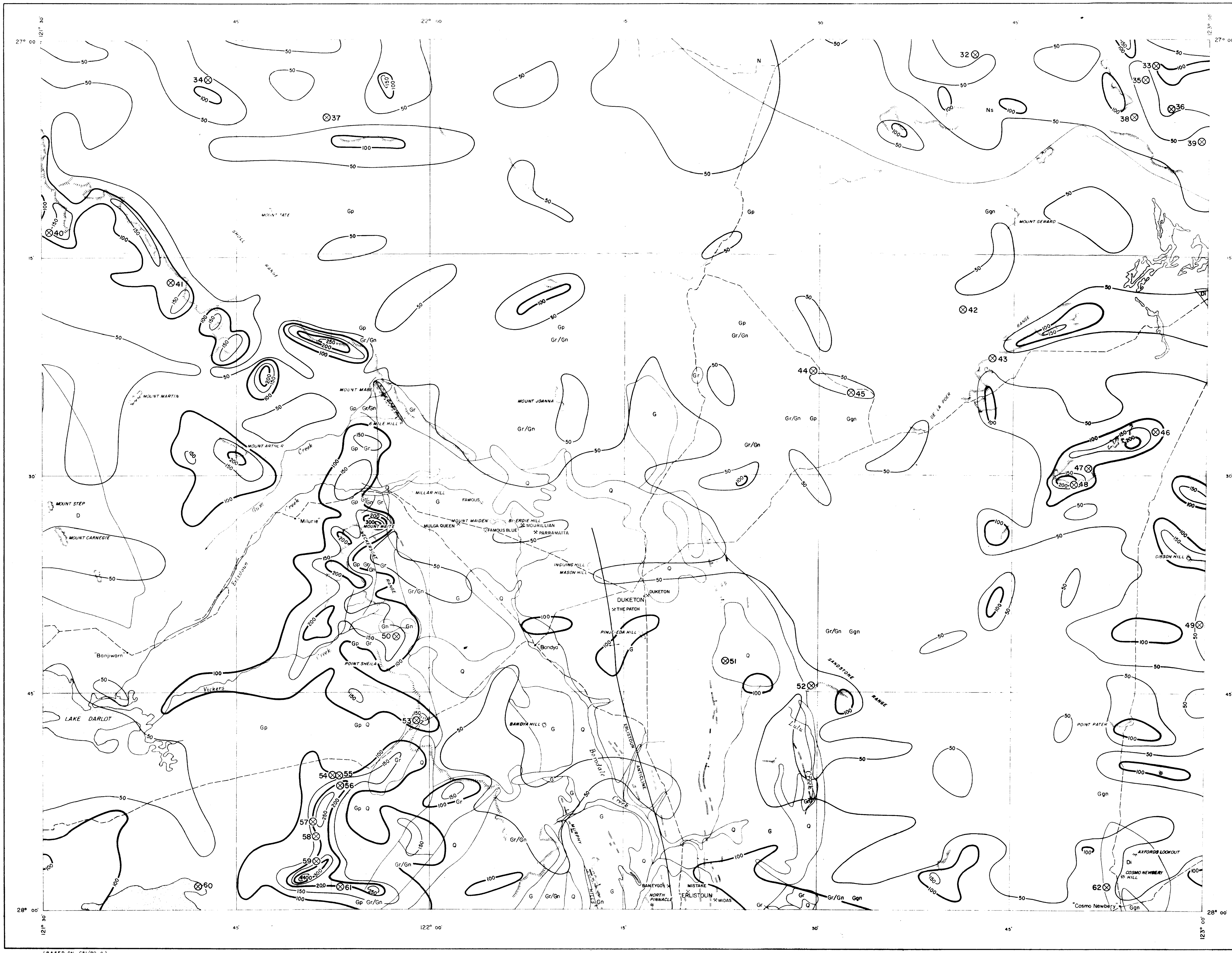
GEOPHYSICAL LEGEND

50 — 100 — 150 — 200 Radiometric contours, counts per second

10 ⊗ Radiometric anomaly restricted source
(Anomalies are numbered for reference only)

AUSTRALIA 1:250,000

DUKETON
WESTERN AUSTRALIA



(BASED ON G51/B0-8)
(BASED ON G51/BI-14)

GEOLOGICAL LEGEND

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 103 (HOBSON & MILES, 1950)

RECENT
- Q — *Alluvium*

ARCHAEAN
- Gr — *Granite with some granodiorite and syenite*
- Gn — *Gneiss*
- Gr/Gn — *Mainly sandy soil which probably largely overlies granite and/or gneiss*
- G — *Mainly lavas, pyroclastics and sediments with some basic and ultrabasic intrusives. Variable grade of metamorphism*

Axis of major anticlinal fold
Banded iron formation, with dip
Geological boundary

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 84 (CLARKE, 1925)

LOWER CAMBRIAN OR UPPER PRECAMBRIAN
- N — *Conglomerates, quartzites, sandstones, shales and limestones*

ARCHAEAN
- Gp — *Granite with some porphyry and porphyrite dykes*
- D — *Derivatives of dolerites and gabbros*

Geological boundary

AFTER GEOLOGICAL SURVEY OF WESTERN AUSTRALIA BULLETIN 87 (TALBOT, 1926)

LOWER CAMBRIAN OR UPPER PRECAMBRIAN
- Ns — *Conglomerates, quartzites, sandstones, shales and limestones*

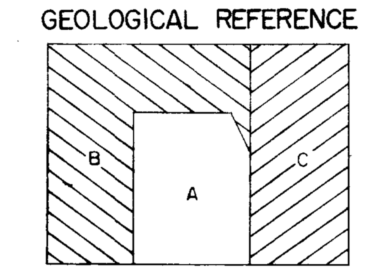
ARCHAEAN
- Di — *Amphibolite, uralitised dolerites etc*
- Ggn — *Granite (in places gneissic)*

Geological boundary

TOPOGRAPHICAL LEGEND

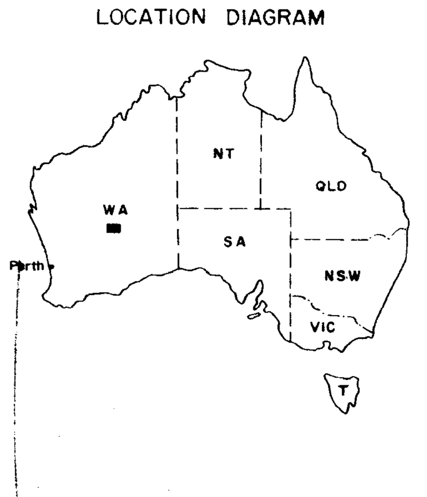
- *River or creek*
- *Road or track*
- *Hill feature*
- *Lake*
- *Named place*
- *Homestead*
- *Mining group*

GEOLOGICAL REFERENCE



A ... Geological Survey of Western Australia Bulletin 103
B ... Geological Survey of Western Australia Bulletin 84
C ... Geological Survey of Western Australia Bulletin 87

LOCATION DIAGRAM



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SIR SAMUEL	DUKETON	THROSSELL
LEONORA	LAVERTON	RASON

AIRBORNE SURVEY, SIR SAMUEL–DUKETON WA, 1967

RADIOMETRIC RESULTS
AND
GEOLOGY

MILES 5 0 5 10 15 20 MILES
KILOMETRES 5 0 5 10 15 20 25 30 KILOMETRES

GEOPHYSICAL LEGEND

- 50 / 100 / 150 / 200 — Radiometric contours, counts per second
- 10 ⊗ — Radiometric anomaly restricted source (Anomalies are numbered for reference only)

TO ACCOMPANY RECORD No. 1967/136

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics G51/B1-15