COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1965/26

KALGOORLIE DETAILED AEROMAGNETIC SURVEY,

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SUMMARY

A detailed aeromagnetic survey was made at the request of New Consolidated Gold Fields (Aust) Pty Ltd over an area immediately north-north-west of the Golden Mile, the most important gold producing area in Australia. The surveyed area falls within the Precambrian Shield of Western Australia, all the rock types of which have been affected by metamorphic and metasomatic alteration. This alteration is particularly evident in the vicinity of orebodies, which tend to occur in meta-quartz-dolerites of the Younger Greenstone Series.

The magnetic field profiles were used to delineate the sub-alluvial contacts between beds of contrasting magnetic susceptibility. Based on their magnetic characteristics, these beds are grouped into zones and their geological identification is suggested.

No mineralisation was detected by the survey, but the possibility of a drag fold in the structure of one of the zones warrants further investigation, as such a structure might be favourable for mineralisation.

1. INTRODUCTION

During June and July 1964, a detailed aeromagnetic survey was made by the Bureau of Mineral Resources (BMR) over an area of 65 square miles immediately north-north-west of Kalgoorlie (Plate 1). The survey was made at the request of New Consolidated Gold Fields (Aust.) Pty Ltd, who held Temporary Reserves within the surveyed area, and was supported by the Geological Survey of Western Australia.

Kalgoorlie lies within the East Coolgardie Goldfield of Western Australia and is adjacent to the Golden Mile, the most important gold producing area in Australia. An important study of the Golden Mile and adjacent areas was undertaken by the Geological Survey of Western Australia and has been described by Simpson and Gibson (1912), Feldtmann and Farquharson (1913), Honman (1914), Feldtmann (1916), and Stillwell (1929). Since this study, all subsequent papers have tended to deal only with the interpretation of the structure of the Golden Mile. There is no recent description of the lithology of the rocks or of the metamorphic and metasomatic processes that have been impressed on them. There is no report dealing specifically with the geology of the area surveyed.

The only known previous geophysical work over the survey area was a regional aeromagnetic survey by the BMR in 1957 (BMR, 1965a).

The aim of the detailed aeromagnetic survey described in this Record was to aid geological mapping in the soil-covered portion of the survey area. The survey was made in conjunction with a drilling and mapping programme by geologists of New Consolidated Gold Fields Pty Ltd. The results of this programme and discussions with the geologists greatly assisted the interpretation of the results of the aeromagnetic survey, particularly the suggested identification of some of the beds delineated by the magnetic field profiles.

The Kalgoorlie 1:250,000 map area was being mapped by geologists of the Geological Survey of Western Australia while the aeromagnetic survey was in progress. Discussions with these geologists were also of assistance in carrying out the interpretation of the aeromagnetic results.

Further assistance was derived from discussions with W. Cleverly of the Western Australia School of Mines, Kalgoorlie, on the geology of the Kalgoorlie district.

2. GEOLOGY

The aeromagnetic survey was over an area for which there was negligible geological knowledge prior to the drilling and mapping that were done by geologists of New Consolidated Gold Fields (Aust.) Pty Ltd concurrently with the aeromagnetic survey. A few scattered outcrops were known in the area, but the major portion of it is covered by recent soil. Owing to this lack of geological knowledge, it was necessary to study the geology of the Precambrian Shield of Western Australia in order to have some idea of the possible developments within the survey area, which falls within this Precambrian Shield.

The Precambrian Shield forms the greater part of the Western Australian land mass, and is made up of Precambrian igneous rocks or rocks of metamorphic origin resulting from igneous activity and earth movements. These rocks are the source of the majority of metallic mineral deposits in the State and have been described by several authors. These descriptions have been studied and combined into one composite description by Prider (1948); this is summarised below.

Older Greenstone Series

The earliest record of Archaeozoic igneous activity is provided by the rocks of the Yilgarn-Kalgoorlie System, the basal system in Western Australia. The best known development of this system is in the Kalgoorlie and Murchison regions, where there is an extensive development of the greenstone phase, with which the most important gold-bearing areas in the State are associated.

The oldest rocks of volcanic origin form the Older Greenstone Series. They are rocks that are metamorphosed to some extent and, in many areas, they have suffered regional metasomatism, upon which has been impressed more intensive local metasomatism in the vicinity of orebodies. This has tended to reduce all varieties to a common end-product. From the relic structure, it can be seen that the rocks originated from basaltic lava flows (often pillow lavas) and associated fragmental volcanic rocks.

The least altered of these basic lavas are the fine-grained amphibolites in which the pyroxene of the original basalts has been replaced by pale-green fibrous amphibole. With further metasomatism (propylitisation), the fine-grained amphibolites become fine-grained greenstones in which the amphibole has been replaced by chlorite, and with progressive metasomatism there is noticeable replacement of all rock minerals by various carbonates, the final product being 'calc schists'. In areas of high-grade metamorphism the fine-grained amphibolites are represented by hornblende schists (schistose plagioclase amphibolites).

In some areas, there is a minor development of acid flows interbedded with basaltic lavas; for example, in the Yerilla District (North Coolgardie Goldfield) where there is a rhyolitic series contemporaneous and interbedded with basic lavas.

In most of the mining areas of the Central Goldfields, the basaltic lavas of the Older Greenstone Series contain intercalated bands of sediments, generally jaspilites.

Whitestone Phase

The latter part of the Yilgarn-Kalgoorlie period was characterised by various epochs of volcanicity. After the Older Greenstone Series came the Black Flag Series, composed of rhyolite, trachyte tuffs, tuff-agglomerates, tuff breccias, occasional thin bands of lava and flow breccias, and erosion sediments such as grits, quartzite, and mudstone; thus the record is one of explosive volcanism associated with acid extrusions. The rhyolite phase of the Older Greenstone Series may be related to the Black Flag Series. However, there is no information on the conformity or otherwise except that the Black Flag Series is higher in the succession.

The Black Flag Series is overlain unconformably by the Yindarlgoorda Series. This Series consists of andesitic and dacitic lavas, associated agglomerates and tuffs, and interbedded erosion sediments.

The Kundana Series lies unconformably on the Yindarlgoorda Series; it consists of erosion sediments without any evidence of igneous activity.

Younger Greenstone Series

The Younger Greenstone Series represents a hypabyssal phase of basic magma intrusion, which appears to be the final stage of igneous activity in the Yilgarn-Kalgoorlie times. Rocks of this group, intrusive into all pre-existing formations, form the country rock for nearly all the important auriferous lodes at Kalgoorlie.

The Younger Greenstone magma appears to have been extensively differentiated prior to intrusion, it being represented by earlier ultrabasic intrusions followed by a basic (dolerite) phase and later by an intermediate to acid phase. As with the Older Greenstone Series, there has been considerable alteration of the rocks by post-crystallisation earth movements together with regional and local metasomatism; however, the three main phases - ultrabasic, basic, and acid - can usually be recognised. For example, at Kalgoorlie these are :-

(a) Ultrabasic phase. Serpentines and various metasomatised types such as talc-chlorite-carbonate rocks and some fuchsite-carbonate-quartz rocks derived from pyroxenes.

(b) Basic phase. Various low-grade metamorphic products of dolerite and quartz dolerite. The least altered types are uralitised dolerites and uralitic quartz dolerites termed epidiorites. With increasing propylitisation (chloritisation, albitisation and carbonatisation), the original quartz dolerites are represented by quartz dolerite greenstone and their highly carbonatised equivalents, the bleached quartz dolerite greenstones.

(c) Intermediate to acid phase. Represented by chloritised hornblende porphyries and a more acid group of albite porphyries or keratophyres.

The Younger Greenstone period was therefore a period of hypabyssal igneous activity of a basic magma. The earlier, ultrabasic and basic phases appeared largely as sills or laccoliths (Kalgoorlie and Wiluna), whereas the later acid porphyry phase is represented by dyke intrusions.

Older and Younger Granite Period

The greater part of the southern half of Western Australia is made up of granitic rocks (granites and gneisses), which enclose comparatively narrow strips of Yilgarn-Kalgoorlie rocks that trend north-west. Extensive granitisation of a folded complex of Archaeozoic metamorphic rocks has yielded various gneisses, after which the area was intruded by granite stocks. Thus there are two periods of granite emplacements: the earlier period (the Older Granite Period) is now represented by granitic gneiss; the later period (the Younger Granite Period) was one of dyke and stock intrusions.

Gneisses of the Older Granite Period are largely of a migmatitic nature, and show considerable variation in character owing to assimilation of the older rocks, whose original presence is indicated by the incompletely absorbed xenoliths.

The Younger Granite intrusion was accompanied by end-phase quartz-felspar and granite-porphyries, aplites, pegmatites, and quartz veins. Many of these dykes and veins are important for their gold, mica, felspar, cassiterite, tantalite, and other minerals.

Metamorphism

The main period of orogenesis and constructive regional metamorphism appears to have been contemporaneous with the emplacement of the Older Granite, but in certain goldfields there is extensive regional and local metasomatism that appears to be associated with the emplacement of the Younger Granite. In the Central Goldfields areas, the grade of regional metamorphism is apparently high in the vicinity of granitic gneisses and low in places remote from granitic rocks. Kalgoorlie is in the centre of an area of about 8000 square miles of rocks of the Yilgarn-Kalgoorlie System and thus exhibits low grade metamorphism.

The structure of the Central Goldfields shows that the main (isoclinal) folding in the area was along north-west axes. Superimposed on this structure, there is cross-folding on an east-west axis. The pattern of this major folding and minor cross-folding may have controlled the location and grade of metamorphism and the degree of granitisation.

Regional metasomatism is a marked feature of some of the Western Australian mining districts, especially the belt extending from Kalgoorlie to Wiluna, and has been closely studied at Kalgoorlie, where practically all the greenstones of the Older and Younger Greenstone Series are regionally albitised and carbonatised. The process was essentially one of propylitisation due to the introduction of carbonic solutions or vapours, which were probably the late-stage products of the Younger Greenstone Series magma. This regional metasomatism has been followed by more-intense local alteration along zones of weakness by somewhat similar, but more siliceous, ore solutions. This local alteration yielded the auriferous lode formations, which are shear zones that have been intensely metasomatised by the introduction of carbon dioxide, sulphur, silica, and potash.

Mineralisation

With few exceptions, all the primary metalliferous deposits in Western Australia were formed in Precambrian times as an aftermath of igneous activity. Of these, the gold deposits have been by far the most important.

In recent years, considerable attention has been given to the study of the relation between structure and the gold-bearing ore deposition. Although the rock structure has undoubtedly been a very important factor controlling ore deposition, the over-emphasis on structure has tended to obscure the fact that there must have been a source for the mineralisation solutions.

There are two distinct types of ore deposit:

(a) Sulphide-bearing lode formations associated with extensive silica-carbonate metasomatism of the country rock, as exemplified by the lodes of the Golden Mile at Kalgoorlie.

(b) Auriferous quartz reefs, which are characterised by very slight potash-silica metasomatism of the country rocks. Closely allied to this type are porphyry dykes traversed by networks of contemporaneous quartz veinlets.

The more common view as to the source of the gold mineralisation is that all the gold was ultimately related to a granitic magma. However, another view is that the sulphide-bearing lode formations are genetically related to the Younger Greenstone Series magma, whereas the quartz reefs are most probably derived from some granitic magma.

Some metals, namely silver, copper, arsenic, and antimony, are produced as by-products in the treatment of auriferous ores. All other sources of minerals, except those for iron, copper, and lead, appear to be genetically related to the Younger Granites. Some copper and lead deposits occur in Archaeozoic rocks and appear to be related to acid pegmatites. The end-phase pegmatites of the Younger Granite magma contain important deposits of tin, tungsten, molybdenum, tantalum and niobium, beryllium, lithium, radioactive minerals, and such minerals as mica and felspar.

Proterozoic igneous activity

There are two phases of igneous activity in Proterozoic times:

(a) An early volcanic phase represented by various lavas and pyroclastics, interbedded with the sediments of the Nullagine Series, which is extensively developed in the northern half of the State.

(b) A later hypabyssal phase represented by quartz dolerite dykes and sill intrusions.

In the southern half of the State, dyke intrusions have been noted that do not appear to be related to the quartz dolerites. All that can be said of their age is that they are post-gold or post-granite. The most prominent of these are the quartz dolerite dykes that trend east-north-east in the Central Goldfields region. Where mapped, the dykes are vertical or steeply dipping and are classified as gabbro, norite, or pyroxenite dykes. As a result of their recent mapping, the Geological Survey of Western Australia has grouped these dykes together as the Dundas Dyke Suite and dated the intrusions as possibly Lower Proterozoic.

The metamorphism associated with the Proterozoic igneous activity has been of very low grade, being confined mainly to contact metamorphism.

The Golden Mile

As the regional strike is north-west to north-north-west, the geology of the Golden Mile may have considerable bearing on that of the survey area. Part of the interpretation of the survey data has been made in terms of the geology of the Golden Mile as described by Woodall (1964). Relevant extracts from this paper appear below:

Stratigraphic Succession. The rock succession at Kalgoorlie is as follows:

Rock Unit	Thickness	Lithology
Black Flag Beds	Approx. 10,000 ft	tuff, acid to intermediate lavas and agglomerate, sandstone, shale, slate and quartzite.
Golden Mile Dolerite	1000 to 2000 ft	sill of meta-quartz-dolerite and meta-quartz-gabbro with minor more-basic sections.
Paringa Basalt	1000 to 3000 ft	meta-basaltic lavas (in part pillow lavas) and minor interbedded slates.
Williamstown Dolerite	500 to 1000 ft	sill of meta-dolerite and meta-gabbro, transitional to meta-quartz-dolerite near top and hornblendite near base.
Kapai Slate	10 ft	graphitic slate.
Devons Consols Basalt	200 to 500 ft	meta-basaltic lavas, typically pillow lavas.
Hannan's Lake Serpentinite	1000 to 3000 ft	massive, fine-grained serpentinite.

The basalts and doleritic rocks are equivalent to the Older Greenstones Series and Younger Greenstone Series described previously.

The doleritic rocks are broadly stratigraphic and probably are sills. The apparent differentiation in the Williamstown Dolerite into a more acidic upper section and a more basic lower section supports this view to some degree. The contacts of both dolerites are locally transgressive, notably the upper contact of the Williamstown Dolerite.

The most productive rock on the field has been the Golden Mile Dolerite but important gold mineralisation also occurs in the Paringa Basalt, especially in the vicinity of its upper contact.

<u>Metamorphism, metasomatism and mineralisation</u>. Where the basic igneous members of the rock succession have not been affected by subsequent metasomatism, they are composed of albite and pale green hornblende. Quartz, ilmenite, leucoxene, saussurite, epidote and ziosite are common in varying amounts. This mineralogy reflects albite-epidote-amphibolite facies regional metamorphism.

The basic and ultrabasic igneous rocks are extensively chloritised and carbonatised on a regional scale.

In the main productive area of the Golden Mile the Paringa Basalt is bleached. These bleached basalts are locally known as "calc schist".

The ore deposits of the Golden Mile are pyritic replacements along steeply dipping shears and fractures. They exhibit varying degrees of silicification and carry both free gold and gold tellurides. The pyrite contains finely disseminated gold.

A second type of gold mineralisation occurs at Kalgoorlie. In contrast with gold-telluride mineralisation, it is free of tellurides, and the associated pyrite is usually coarser in grain and contains negligible gold. Quartz is usually more abundant in this ore which is conveniently described as gold-quartz mineralisation. It is of minor importance in comparison with the gold-telluride mineralisation and has been exploited only at the north end of the field.

The gold-quartz type ore occurs either as replacement type lodes along shears (e.g. Hannan's North Mine) or as stockworks of quartz veins (e.g. Mount Charlotte mine).

Gold-telluride and gold-quartz mineralisation occur only in chloritised host rocks which are usually bleached adjacent to the lode or vein. The width of bleaching may vary from a few inches to many feet.

<u>Mount Charlotte/Hannans North area</u>

The Mount Charlotte/Hannans North area is described by Haycraft (1964). Extracts relevant to the interpretation of the survey results are given below:

> The Mount Charlotte-Hannans North Area lies north and east of the town of Kalgoorlie and is separated from the Golden Mile by the Golden Pike Fault. The orebodies provide a marked contrast to the pyrite-telluride lodes of the Golden Mile, although both groups of orebodies appear to be fundamentally related.
>
> The highly siliceous telluride free orebodies north of the Golden Mile are closely related to strong oblique faulting.
>
> The Mount Charlotte orebody occurs in a near vertical north-west-striking quartz-dolerite 240 feet thick conformable to its enclosing rocks; it forms part of a large dolerite sill.

The quartz-dolerite host rock is medium-grained, generally dark green and massive. Medium-grained ilmenite occurs throughout the quartz-dolerite and may be partially replaced by pyrite.

To the north-east of the orebody the rock is coarser in grain, approaching a gabbro. The ilmenite present is commonly very coarse-grained; skeletal ilmenite, partially replaced by leucoxene, has been observed with dimensions of up to 0.6 inches. To the west and south-west of the orebody the rocks are noticeably finer-grained and the ilmenite barely macroscopic.

The Hannans North Lode occurs in a medium-grained quartz-dolerite similar to the Mount Charlotte host rock, but with amphibolitic quartz-dolerite to the west and finer-grained quartz-dolerite to the east. The Hannans North Lode may thus be located in a medium-grained quartz dolerite west of the Mount Charlotte host rock.

3. RESULTS

The interpretation of the results of the survey was made within the framework of the geology presented in the preceding section. At the time of the aeromagnetic survey, the Geological Survey of Western Australia was carrying out mapping in the Australia 1:250,000 map area of Kalgoorlie. The results of this mapping may present a different geological picture, which would require a reinterpretation of the results of the aeromagnetic survey.

The results of the survey are shown in the form of a map (Plate 2) of total magnetic intensity contours. Three prominent features on this contour map are:

(a) A large-amplitude magnetic anomaly striking 20° west of north through the centre of the area,

(b) A large-amplitude magnetic anomaly striking 25° north of east across the northern boundary of the area, and

(c) A negative magnetic anomaly striking 37° west of north across the area.

These three features tend to obscure the less prominent magnetic features, and a study of the magnetic field profiles is necessary in order to obtain the maximum amount of information from the survey data. Plate 3 was derived from a study of the profiles; it shows the approximate boundaries of the formations that are the sources of the anomalies on the magnetic field profiles, and the suggested identification of these formations. The survey area has been divided into eight zones.

Zone 1, in the west of the survey area, contains a number of low-amplitude magnetic anomalies, which have a range of strikes from 20° to 45° west of north. The total intensity of the magnetic field gradually increases across this Zone towards the west.

This is due to beds of Kurrawang Conglomerate, which are delineated by the results of the regional aeromagnetic survey (BMR, 1965a) as a large-amplitude magnetic anomaly striking 45° west of north just to the west of the present survey area. The southern part of the anomaly corresponds with the position of the beds of Kurrawang Conglomerate that were mapped and described by Honman (1914). The Kurrawang Conglomerate would appear to belong to the Whitestone Phase and possibly is the local expression of the Kundana Series. However, this is only a suggestion and a more positive opinion is dependent on the results of the recent mapping by the Geological Survey of Western Australia.

From a study of the magnetic field profiles of the regional aeromagnetic survey (BMR, 1965a), the low-amplitude anomalies in Zone 1 are most probably due to a northwardly continuation of the hornblende-bearing granitic porphyry rock that occurs at Binduli, five miles south-west of Kalgoorlie along the Kalgoorlie-Coolgardie road. This is because low-amplitude magnetic anomalies are present on these profiles over the formation mapped by Honman (1914) as porphyry with hornblende-bearing porphyry dyke intrusions, and because the dykes contain a ferromagnesian hornblende component. On magnetic characteristics alone these anomalies cannot be identified, as they are of the same order of magnitude as anomalies which occur in other Zones, and which have been attributed to Younger Greenstone Series.

Geologists of the Geological Survey of Western Australia described the so-called dykes as consisting of a hornblende-bearing granitic porphyry rock and expressed the opinion that they may be flows within a sedimentary sequence. The dykes of Honman (1914) could be the intermediate-to-acid phase of the Younger Greenstone Series intrusions or they may be acidic flows within the Yindarlgoorda Series. Again, a more positive identification must await the results of the mapping by the Geological Survey of Western Australia.

East of Zone 1, a belt of scattered magnetic anomalies with general strike of 20° west of north is marked as Zone 2. This Zone has been marked as consisting of beds of the Black Flag Series. Beds marked as greenstone are scattered throughout the Zone in a random manner that suggests minor basic flows of the Black Flag Series rather than the more extensive flows of the Older Greenstone Series. If Zone 2 represents the Black Flag Series, then that part of the Zone not marked as greenstone would consist of minor acid lava flows, agglomerates, tuff, and erosion sediments.

The amplitudes of the magnetic anomalies that occur over the beds marked as greenstone suggest that the beds consist of rock that has a greater magnetic susceptibility than that of the Younger or Older Greenstone Series further east. It is possible that these beds consisted originally of basic or intermediate rock, which in its present form has not undergone as much metasomatic alteration as the rocks to the east. Another possibility is that these are beds of intrusive Younger Greenstone Series, which again have not undergone as much metasomatic change as the Younger Greenstone Series of other Zones. This assumes that the metamorphism has been such that it has tended to reduce the magnetic mineral content of the rocks.

Zone 3 contains the source of the dominant feature on the contour map, the large-amplitude magnetic anomaly that strikes 20° west of north through the centre of the survey area. This Zone consists of a number of near-parallel beds whose general strike corresponds to that of the Zone. The central bed giving rise to the large-amplitude anomaly is tentatively identified as serpentinite, possibly the local equivalent of Hannan's Lake Serpentinite. In two places along the strike of this bed, the amplitude of the magnetic anomaly decreases and then increases over a short distance. This may represent short sections where the serpentinite has been carbonatised to a much greater extent than the rest of the bed. The serpentinite must represent an intrusion of the ultrabasic phase of the Younger Greenstone Series magma.

The northern extremity of the magnetic feature identified as a bed of Hannan's Lake Serpentinite is shown by inferred (dotted-line) boundaries, for, although the amplitude of the anomaly decreases rapidly to the north, as seen on the contour map (Plate 2), a study of the magnetic profiles indicates that the bed is still present between the two beds marked as Younger Greenstone. Either the bed is carbonatised over this northern section or it pitches to the north. To the south, the amplitude of the magnetic anomaly again decreases sharply and this would appear to mark the southern limit of the bed. The actual nature of the southern extremity of the bed is difficult to interpret from the contour map or the profiles and the form shown in Plate 3 is only one of a number of possibilities.

The other beds delineated within Zone 3 show up on the magnetic profiles as minor peaks on the sides of the main anomaly and are tentatively identified as meta-quartz dolerites of the Younger Greenstone Series. The remainder of the Zone is presumed to consist of meta-basalt beds of the Older Greenstone Series interbedded with minor erosion sediments, in conformity with the sequence at the Golden Mile. It has been assumed that the regional metamorphism has altered the basalt of the Older Greenstone Series to such an extent that little or no magnetic minerals remain and that the Younger Greenstone Series quartz-dolerites have retained sufficient magnetic minerals to contrast in susceptibility with the Older Greenstone Series.

For the sake of completeness, Zone 3 is shown as extending to the northern boundary of the survey area. Insufficient surveying was done north of Zone 4 to be certain of this extension. However, a study of the magnetic profiles of the regional survey (BMR, 1965a) indicated that an anomalous area does extend further north to a point where it is cut off by the northwards extension of Zone 7.

The possibility that the inferred bed of Hannan's Lake Serpentinite pitches to the north at its northern end, and the manner in which the beds of the Younger Greenstone Series bulge out around it, suggest that the bed may represent the core of a tight anticline that strikes 20° west of north. This anticline may have a cross-fold axis somewhere in the vicinity of the carbonatised sections of the Serpentinite so that the Serpentinite would pitch north at its northern end and very steeply south at its southern end. The apparently complex structure at the southern end of the Serpentinite may represent a drag fold in which the western bed of Younger Greenstone Series has been folded across to the eastern side of the

Serpentinite. Such a structure, a drag fold pitching south, in Younger Greenstone Series would be a particularly favourable place for the localisation of mineralising solutions.

A comparison of Plates 2 and 3 shows that there is a considerable variation in the magnetic susceptibility of the rock that occurrs within any one bed of Younger Greenstone Series. This is attributed to variation in the amount of metasomatic alteration impressed upon the rocks. Assuming that the metasomatism has tended to alter the magnetic minerals of the original quartz dolerite into various carbonates and silicates, then the smaller the amplitude of the magnetic anomaly is over a given bed the greater will be the amount of metasomatic alteration. As ore emplacement is usually associated with intense metasomatic alteration in the immediate locality of the orebody, this variation of anomaly amplitude along a bed may be a useful indicator for planning further geophysical or geochemical investigations.

Although Zone 4 is here treated as distinct from Zone 3, it may in fact be part of the sequence in Zone 3. The Zone corresponds to a region of low magnetic intensity over an outcrop of granitic porphyry rock, which would appear to be an intrusive plug. However, recent information from the Geological Survey of Western Australia, indicates that this outcrop and other granitic porphyry rocks in the area, are actually flows within the rock sequence. The interpretation as an intrusive plug is attractive in the light of the interpretations of Zone 3 and Zone 6 (discussed later), as the intrusion would then be on the major anticlinal axis of Zone 3 in a position where this axis is intersected by the minor cross-fold axis of Zone 6. This could then be a suitable area of weakness or fracture within which an intrusion could take place.

In the magnetic results, the presence of this granitic porphyry rock is indicated only by the area of low intensity between two anomalies. The shapes of these anomalies define the boundaries of the basic rocks that cause the anomalies, but there is no indication from the magnetic profiles as to the exact boundaries of the granitic porphyry rock. The area of low intensity marked as Zone 4 may contain shale, tuff, or other sediments, as well as the granitic porphyry rock.

The region to the east of Zone 3 has been marked Zone 5. The magnetic anomalies in this Zone have been attributed to rocks of the Younger and Older Greenstone Series. The remainder of the Zone is probably composed of shale, tuff, or greywacke.

The northern part of Zone 5 consists simply of two northerly-trending beds that cause slight magnetic 'highs', amongst beds that have no magnetic effect. The containing rocks are possibly tuff, shale, or greywacke, as these types of rocks have been detected in the locality. The western bed, considered to be metabasalt of the Older Greenstone Series, showed up as a low-amplitude magnetic anomaly of about 8 to 10 gammas, at the limit of detectability of the magnetometer. Thus the boundary shown in Plate 3 can be taken only as an indication of the approximate position of this bed. The eastern bed, considered to be meta-quartz-dolerite of the Younger Greenstone Series, showed up as an anomaly of about 20 gammas amplitude.

It is apparently cut off at its northern limit by Zone 7; in the southerly direction the bed possibly branches into two discontinuous limbs, which branch again into minor limbs further south. At the southern boundary of the survey area, the minor limbs of Younger Greenstone Series prove to be offshoots of the source of a semicircular magnetic feature of large-amplitude. This semicircular feature occurs over what may be the northern extremity of the eastern limb of the Younger or Older Greenstone Series at Kalgoorlie, which contain the Hannan's North and Mount Charlotte mines. It is interpreted that these beds of Younger or Older Greenstone Series strike north as far as the southern boundary of the survey area, where they are folded through 180° and strike south into the town of Kalgoorlie. The Younger or Older Greenstone Series of the Hannan's North and Mount Charlotte mines contain an unusually large percentage of ilmenite. This ilmenite is possibly the major cause of the large-amplitude magnetic anomaly detected over these mines by the regional aeromagnetic survey (BMR, 1965a). The large-amplitude, semicircular magnetic anomaly in the south of Zone 5 may also be due to an abundance of ilmenite in the Younger or Older Greenstone Series that form this structure. However, the western limb of the semicircular structure must either suffer a sudden change in character as it strikes south or must be faulted away, as the magnetic profiles of the regional survey show only a low-amplitude magnetic anomaly over the town of Kalgoorlie in the position where this western limb should be.

From a study of the magnetic profiles of the regional survey and the aerial photographs, the greenstones in Zone 5 are part of the Younger or Older Greenstone Series to the east of Kalgoorlie, which contain the Golden Mile. They continue south of Kalgoorlie in a south-south-easterly direction for a distance of 44 miles past Hannan's Lake and on through Mount Shea, Feysville, Mount Goddard, and Red Hill. The western limb mentioned above shows no sign whatsoever of joining with the southern extension of the Younger Greenstone beds of Zone 3. The beds of Zone 3 are considered to be entirely separate from the beds that contain the Golden Mile. From Zone 3, they continue south on a south-south-easterly strike passing west of Kalgoorlie, where they are known locally as the 'Abbatoirs Greenstone', and on through Yilmia Hill, 32 miles to the south. They are roughly parallel to, and are three to eight miles west of, the beds that contain the Golden Mile. Although, on a small scale, they are considered to be two entirely separate beds, on a regional scale, they could possibly be two limbs of a major fold. Neither this survey nor the regional survey appears to have provided any information relevant to such a possibility.

Zone 5 contains a second large-amplitude magnetic anomaly about one mile north of the semicircular anomaly already discussed; at this stage it cannot be positively identified. It is a relatively small, roughly triangular block, whose long axis strikes east-north-east in contrast to the general north-north-west strike in the survey area. On the aerial photographs, its presence is indicated by a dark patch, which is presumably due to lateritic rubble, the normal weathered-surface expression of the greenstones. From the amplitude of the magnetic anomaly, this block could be either an intrusion of Hannan's Lake Serpentinite, as described in Zone 3, or a block faulted away from the semicircular structure that occurs immediately to the south.

Zone 6 has been attributed to dykes of the Dundas Dyke Suite. The Zone has a strike of 25° south of west and, along this strike to the west-south-west, there is a known area of outcrop of a dyke of the Dundas Dyke Suite. This occurs on the west side of White Flag Lake; the dyke is two-miles long, two-chains wide, and has chilled margins composed of an olivine-hypersthene-dolerite rock (Cleverly, 1964, pers. comm.). As mentioned below, the dyke of Zone 6 is cut by the reversely magnetised dyke of Zone 7, but cuts the other formations in the survey area. It appears likely that this dyke may mark the axis of a minor cross-fold. The regional strike at Kalgoorlie is north-north-west owing to the major folding taking place along axes in this direction. Superimposed on the major folding, there is minor cross-folding along axes striking east-north-east, and the dykes of the Dundas Dyke Suite may be intruded along some of these axes.

The eastern boundary of Zone 5 is formed by Zone 7, a prominent negative anomaly on the magnetic contour map. This feature is interpreted as a reversely magnetised dyke cutting across the survey area with a strike of 37° west of north. A study of the magnetic contours for the Kalgoorlie and Kurnalpi 1:250,000 map areas (BMR, 1965a & b) showed that this feature extends in a south-easterly direction for a distance of at least 40 miles, from a position midway between Grant's Patch and Paddington to the south of Golden Ridge. This dyke is considered to be possibly the youngest Precambrian feature in the survey area. It is not cut by any of the other beds in the survey area; in particular, it is not cut by Zone 6.

The triangular area in the north-east of the survey area has been marked as Zone 8. The interpretation of this area is very indefinite, as the magnetic anomalies are not well-defined. The amplitudes of the anomalies were of a similar order of magnitude as the noise level recorded by the magnetometer, which makes the interpretation from either the contours or the profiles rather uncertain. Along the west side of Lake Gidgee, a magnetic feature has been interpreted as being due to conglomerate beds, which are known to outcrop along this side of the Lake. Further south, a magnetic feature has been tentatively interpreted as being due to highly altered serpentinite rock. However, although a small outcrop of this highly altered serpentinite is known to occur within the position marked for the magnetic feature, the rock has been described as a quartz-carbonate-fuchsite rock containing so much quartz and carbonate that a magnetic anomaly would not be expected over it.

Three north-trending, narrow dykes have been marked within Zone 8. They appear as low-amplitude, sharp anomalies on the magnetic profiles; hence the sources are presumably narrow, near-surface bodies. The manner in which these sources appear to cut across the general strike of the other features indicates that the sources may be north-striking dykes, although no such dykes have been mapped in the vicinity of the survey area.

Just south of the magnetic feature marked as highly altered serpentinite, there are other magnetic features having similar strike. However, there is no known outcrop in the vicinity of these features and no identification can be suggested.

In the southernmost part of Zone 8, there is a magnetic feature that has been marked as Younger Greenstone. This feature is coincident with an outcrop of similar shape on the aerial photographs, and inspection on the ground revealed the typical ironstone capping indicative of underlying greenstone. Further surveying would be necessary to the south-west of this feature to determine whether the greenstone is part of the Kalgoorlie structure or part of an entirely separate greenstone structure to the east of the dyke of Zone 7.

4. CONCLUSIONS

The detailed aeromagnetic survey has clearly delineated the positions of the sub-alluvial geological contacts between beds of contrasting magnetic susceptibility. The geological identification of these beds has been suggested. However, positive identification of the beds must eventually depend on the results of a drilling programme aimed at penetrating into the unweathered zone.

No mineralisation was detected by the survey, but the possibility of a drag fold in the structure of Zone 3 warrants further investigation, as such a structure might be very favourable for mineralisation.

A relation may exist between the amplitude of the magnetic anomaly detected over beds of Younger Greenstone Series and the amount of metasomatic alteration that has affected the bed and, hence, the possibility of mineralisation. Such a relation would be of great assistance in planning detailed geophysical and geochemical ground surveys in the area. However, a very detailed test survey would be necessary to prove this hypothesis before it could be used in planning and interpretation. This would involve a very close geochemical study of part of a bed of Younger Greenstone Series for which the magnetic data are already presented in this Record.

5. REFERENCES

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1965b Maps showing the results of an airborne magnetic and radiometric survey of the Kurnalpi 1:250,000 area, WA 1957. Bur. Min. Resour. Aust. Rec. 1965/34

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APPENDIX

Operational details

Survey specifications

Detector altitude	:	250 ft above ground level.
Line spacing	:	One-tenth of a mile between adjacent flight lines.
Line direction	:	The flight lines were flown on a heading of 64° and 244° for the southern three-quarters of the survey area and a heading of 75° for the northern quarter of the survey area.
Recorder Sensitivity	:	1st recorder - 20 gammas per inch, 2nd recorder - 2000 gammas per inch.
Diurnal correction	:	Applied correction rounded off to the nearest gamma.

Equipment

Aircraft	:	Cessna 180
Magnetometer	:	BMR proton precession type MNS1
Recorder	:	2 x Mosely Autograph 1 x Texas Instruments (two-channel)
Camera	:	Modified Vinten frame, 35-mm, 186° field of view
Radio altimeter	:	AN/APN-1

Method

A correction for diurnal variation was determined by flying a baseline at the beginning and end of each survey flight. The baseline for the survey was a section, approximately 9650 ft long, of a fence striking east-west and just south of Kurrawang Lake. The standard level for the mean of the magnetic field readings along this baseline was 58,300 gammas. The diurnal correction was applied on the assumption that the diurnal magnetic field varied in a linear manner during any one survey flight. No total magnetic field recorder was available to check this assumption.

Notification of magnetic storms was given by BMR Mundaring Observatory.

The airborne magnetometer records accepted for survey data showed a noise envelope of about 10 to 20 gammas.

The basis of the interpretation was that the position of the points of inflection on the magnetic profiles represented the contact between two formations of different magnetic susceptibilities. This premise implies that a point-source would be represented as having a finite width. Thus the width of narrow bodies will have been overestimated on the interpretation diagram (Plate 3).

No samples of rocks were collected during the survey because only highly weathered samples were available. Thus, no measurements were made of either the magnetic susceptibility or the remanent magnetisation of rocks occurring within the survey area.

Except in the case of Zone 7, the interpretation was carried out on the assumption that the rocks within the survey area had no remanent magnetisation.

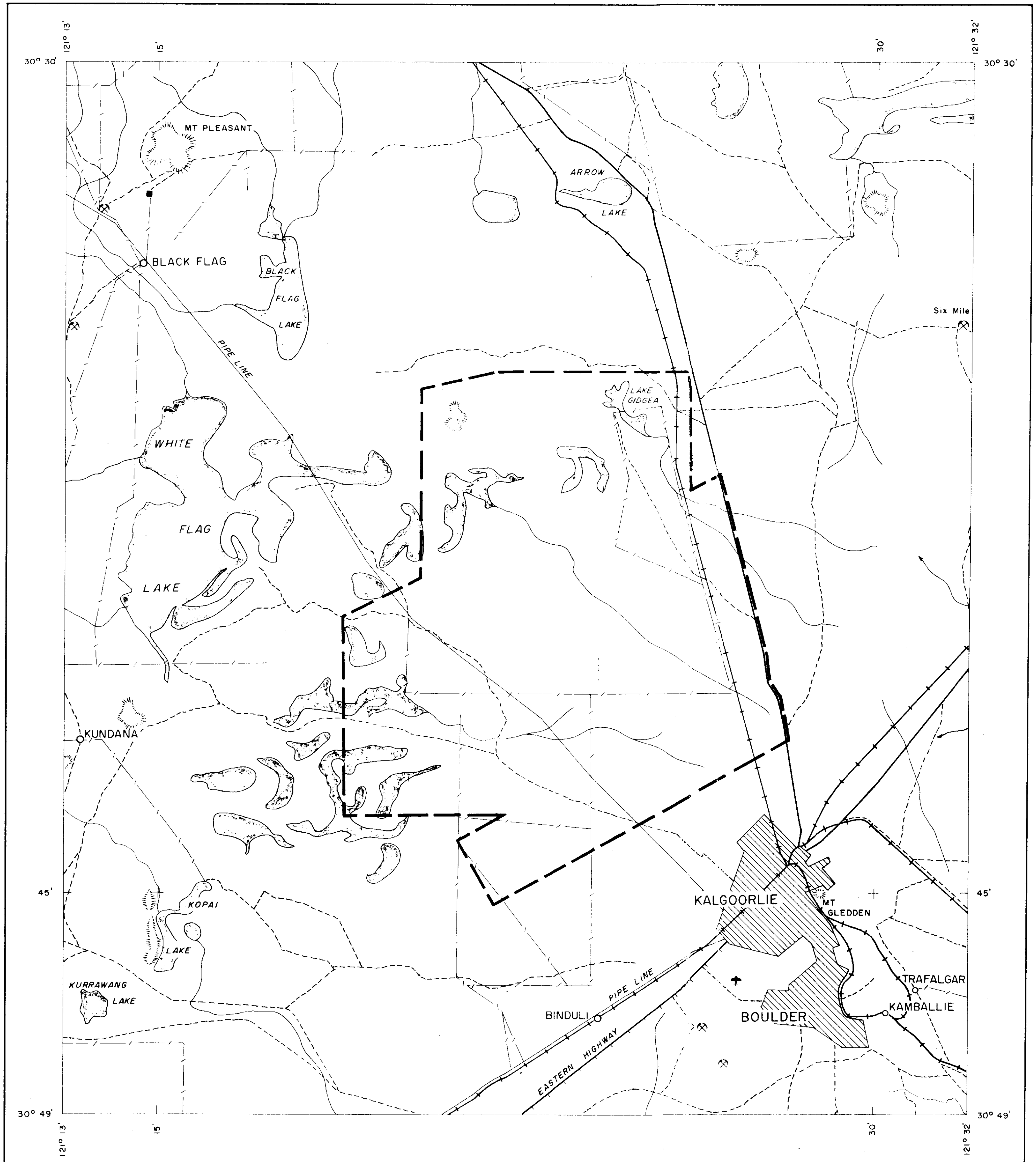
Personnel

Personnel engaged in the survey were :

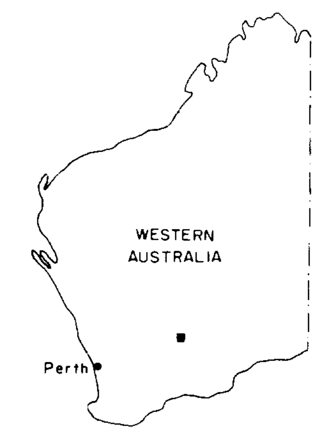
BMR: B.A. Dockery, W.A. Finney, A.S. Scherl, P. Zerial, C.J. Braybrook, B. Tregellas.

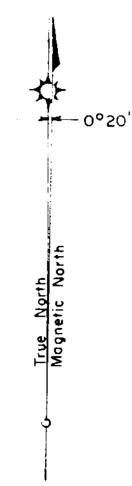
T.A.A.: First Officer G.B. Litchfield.

PLATE I



LOCATION DIAGRAM





LEGEND

River or creek
Highway or main road
Road or track
Railway
Fence
Telegraph line
Named place
Homestead
Hill feature
Aerodrome
Mine
Survey area boundary

DETAILED AEROMAGNETIC SURVEY 1964

KALGOORLIE

WESTERN AUSTRALIA

LOCALITY MAP

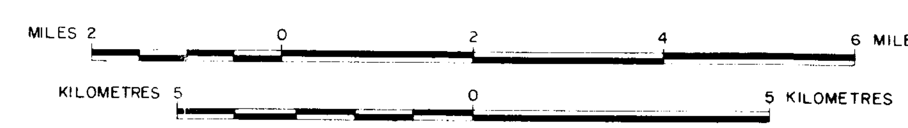


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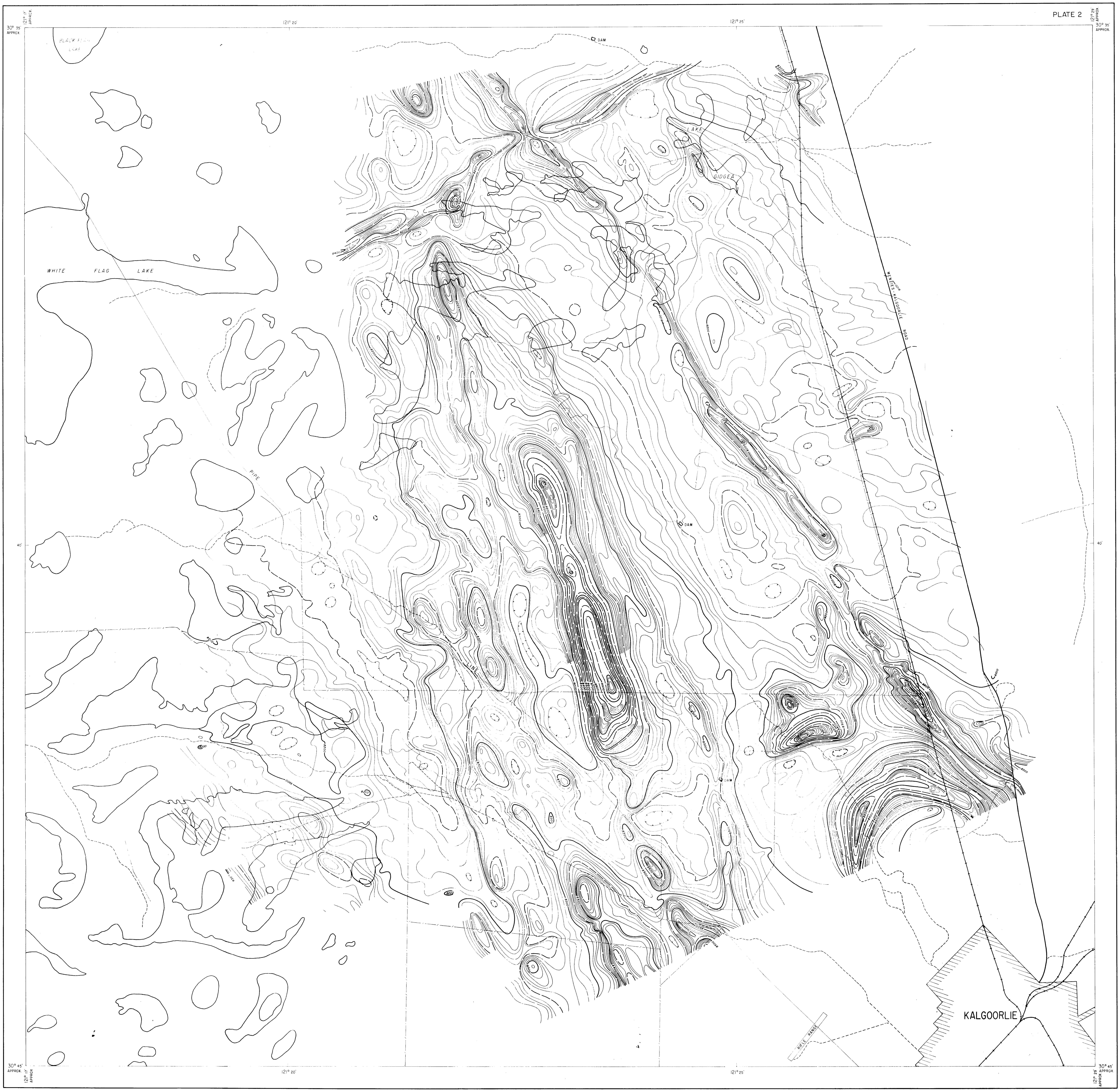
PLATE 2



DETAILED AEROMAGNETIC SURVEY, 1964

KALGOORLIE

WESTERN AUSTRALIA

TOTAL MAGNETIC INTENSITY CONTOURS

MILES 1 — 0 — 1 MILES

KILOMETRES 1 — 0 — 1 KILOMETRES

MAGNETIC CONTOUR INTERVAL 10 GAMMAS

GEOPHYSICAL LEGEND

8200 / 8100 Magnetic contours

Magnetic "Low"

NOTE:- The magnetic data have not been corrected for the regional magnetic gradient.

TOPOGRAPHICAL LEGEND

River or creek

Highway or main road

Road or track

Railway

Fence

NOTE:- This map was compiled by direct plotting from uncontrolled aerial photographs.

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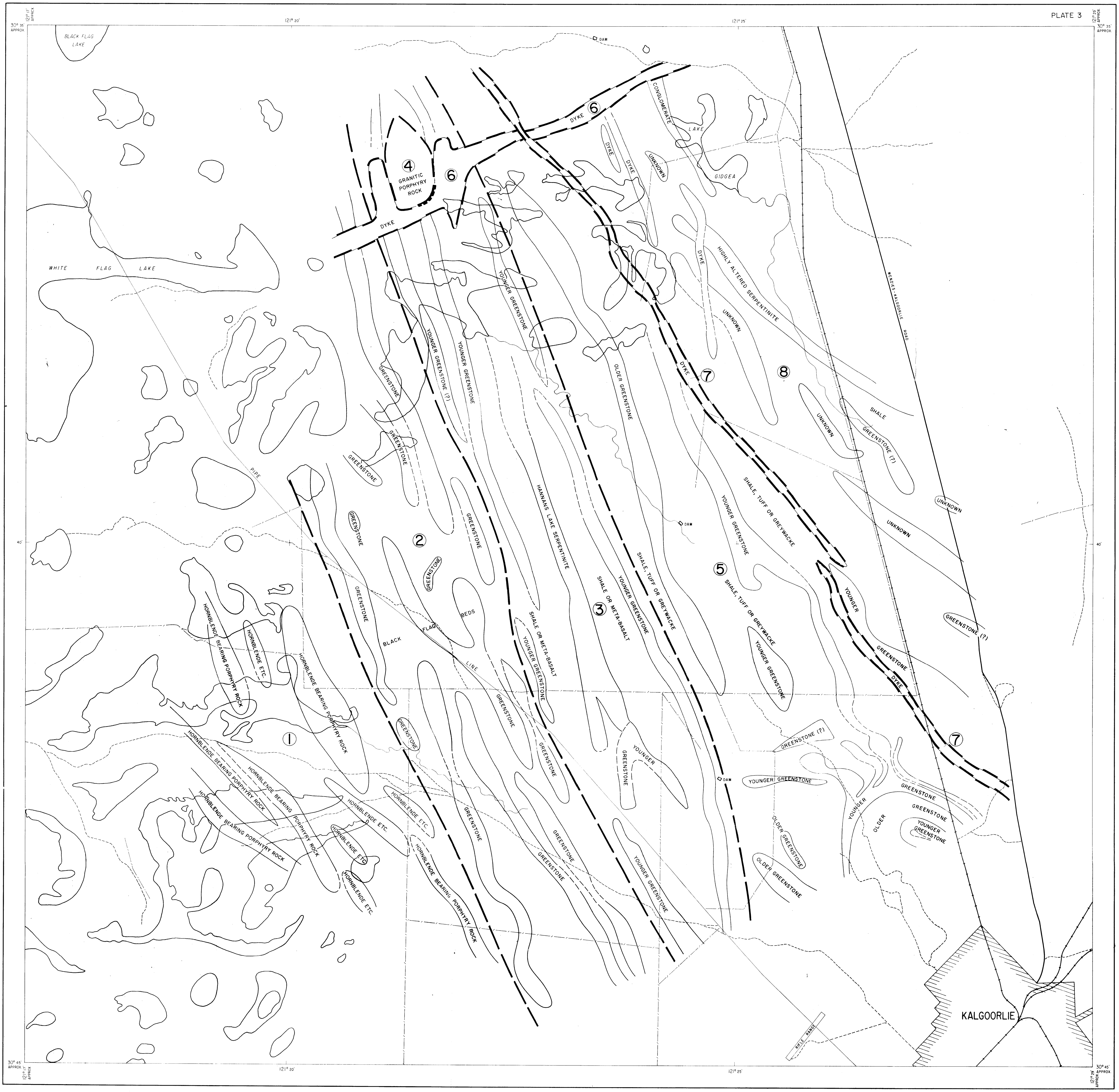
PLATE 3



DETAILED AEROMAGNETIC SURVEY, 1964

KALGOORLIE

WESTERN AUSTRALIA

GEOPHYSICAL INTERPRETATION

MILES 1 0 1 MILES

KILOMETRES 1 0 1 KILOMETRES

GEOPHYSICAL LEGEND

- Zone boundary
- ⑥ Zone number
- Boundary of magnetic feature
- Inferred boundary of magnetic feature

TOPOGRAPHICAL LEGEND

- River or creek
- Highway or main road
- Road or track
- Railway
- Fence

NOTE:- This map was compiled by direct plotting from uncontrolled aerial photographs.

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To Accompany Record No 1965/26