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EXPLANATORY NOTES ON THE KURNALPI 1:250,000 GEOLOGICAL SHEET

by I. R. Williams

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INTRODUCTION

The Kurnalpi 1:250,000 Sheet SH/51-10 lies between latitude $30^{\circ} 00' S$ and $31^{\circ} 00' S$ and longitude $121^{\circ} 30' E$ and $123^{\circ} 00' E$ in the Eastern Land Division of Western Australia. It is part of the region known as the Eastern Goldfields and is named after the abandoned gold mining centre of Kurnalpi, latitude $30^{\circ} 32' S$, longitude $112^{\circ} 14' E$.

The city of Kalgoorlie which now includes Boulder City, and most of the gold mines of the "Golden Mile" are just outside the western boundary of the Kurnalpi Sheet area. The Lake View and Star Mine is situated just inside the sheet area at the southeastern end of the "Golden Mile".

The scattered station homesteads are linked with Kalgoorlie by graded roads. These and numerous pastoral station tracks provide access to most parts of the area. It is also crossed in its southwest corner by a recently completed sealed road which runs from Kalgoorlie to the Kambalda nickel mines. A section of the standard gauge Trans-Australian railway line which extends from Parkeston to a point near Chifley Siding crosses the southern part of the sheet area.

There are no towns and the only populated centres are homesteads on pastoral holdings and railway maintenance settlements. A large number of abandoned mines and towns indicates that the region had a much greater population in the past. The better known of these towns include Kanowna, Bulong, Pinjin, Kurnalpi and Feysville.

The discovery of nickel in the Eastern Goldfields has initiated renewed interest in the district and much of the sheet area has now been taken up as Temporary Reserves or Mineral Claims.

The climate is semi-arid and has an average annual precipitation of between 9 and 10 inches. The rainfall distribution varies from general light winter falls (March to August) in the southern part of the area to patchy heavier summer-autumn

falls (January to June) in the north. In general the rainfall is more reliable in the south and becomes less so travelling northwards. Occasional tropical cyclones which move in from the northwest bring more general, and sometimes flood rains to the region. An evaporation rate of between 90 to 100 inches per annum gradually increases northwards with latitude.

The summer is hot and dry and the maximum temperatures are often above 100⁰F. Scattered thunderstorms associated with easterly movements of low pressure troughs bring some relief from the summer heat. The winter is cool to mild with occasional frosts. The weather pattern is sometimes dominated by easterly moving cold fronts which bring strong winds, showers, and occasionally hail.

The amount of vegetation belies the semi-arid nature of the climate. North of Lake Yindarlgooda the region is covered with dense mulga scrub interspersed with tracts of more open bluebush (*Kochia*), saltbush (*Atriplex*), and eucalyptus country. The sandier areas, and particularly those over granitic rocks, are covered with mallee, spinifex (*Triodia*), and occasional native pine (*Callistris*).

Open eucalyptus woodlands which consist mainly of salmon gums, gimlet, and mallee, interspersed with saltbush and bluebush, cover the flat and undulating country of the south. Much of the timber in this region has regenerated since it was almost completely removed by former gold mining activities. The hilly regions are covered with low thick scrub. Vegetation density increases towards the southern margin of the sheet area.

The salt lakes or playas are bordered by saltbush and numerous varieties of samphire. Native pines are common on kopai dunes (gypsum) which border the salt lakes.

PREVIOUS INVESTIGATIONS

The earliest geological investigations were primarily concerned with gold mining. Geological reports date from 1894

when S. Göczel["] described mining activities at the White Feather (Kanowna) and I. O. U. (Bulong) centres.

Some of the more important references prior to 1920 include reports by Blatchford (1900), Blatchford and Jutson (1912) and Jutson (1914a) on Kanowna; Maitland (1900) and Feldtmann (1916, 1918, 1919) on the Bulong district; Jackson (1905) on Mulgabbie; Jutson (1914b) on Kurnalpi and Honman (1914) on Golden Ridge. A report by C. S. Honman (1916) was singular as it records one of the earliest attempts at regional mapping. The area mapped covered the region south of Kalgoorlie and included the Kurnalpi Sheet mining centres of Feysville, Boorara, and Golden Ridge.

There was very little published on the Kurnalpi Sheet area between 1920 and the late 1950's but a considerable amount of published material dealing with the Kalgoorlie district includes parts of the western boundary areas of the region. A list of the relevant references has been given by Kriewaldt (1967).

An airborne magnetometer and radiometric survey was carried out by the Bureau of Mineral Resources, Geology, and Geophysics in 1958 (Carter, 1959) and published map sheets of this work are available from the Bureau in Canberra at a scale of 1 inch to 2 miles.

The geological work on the Kurnalpi Sheet described in these notes was commenced in 1966 and completed in 1968.

PHYSIOGRAPHY

The sheet area is situated near the eastern margin of the salt lake or Salinaland physiographic division of Jutson (1950). In this division Jutson distinguishes an 'old' and 'new' plateau surface, both of which can be recognised in the Kurnalpi Sheet area. The 'new' plateau surface is represented by fresh bedrock and extensive tracts of superficial deposits derived

from the 'old' plateau surface by erosion. The 'old' plateau surface is characterised by laterite, sand, and gravel plains. It occurs in the form of isolated remnants and small areas which are confined mainly to the elevated country along divides that separate the major drainage basins.

The relief of the area ranges between 400 and 500 feet but individual hills rarely rise more than 200 to 300 feet above the surrounding countryside. The highest points are about 1,500 feet above sea level. Generally the topography is subdued and characterized by low rounded hills which grade gently into wide alluviated valleys. Many of these contain claypans and extensive salt lake systems, or playas.

The only prominent topographic features are low extensive scarps or "breakaways" that commonly mark an abrupt junction between the 'old' and 'new' plateau surfaces and only occur in deeply weathered or kaolinized rock. They form part of the present erosion cycle and are found either near or along the western margin of salt lakes, or close to the headwater divide regions between major drainage basins.

A rosette diagram of the direction of facing of the scarps is given in Figure 1. The predominance of the southerly facing scarps is thought to be related to regional migration of the salt lake systems to the west-northwest (Jutson, 1950).

Where there are no breakaways the 'old' plateau surface passes imperceptibly into the 'new' plateau surface and in alluviated valley areas commonly passes beneath it. Shallow drilling in the Hannans Lake area has shown that a ferruginous (laterite?) profile which probably corresponds to this 'old' surface is buried beneath more recently accumulated alluvial deposits (Urquhart, 1956).

All outcrops of fresh rock are a product of the present erosion cycle. The best exposures are found along the western and northern margins of the salt lake systems.

The present drainage of the sheet area is internal. The distribution of this drainage and the locations of the drainage basins are shown in Figure 2.

The lack of permanent streams and surface water is caused by the semi-arid climate. The claypans and salt lakes remain dry for long periods and contain water only after heavy or prolonged rains. The drainage lines are poorly defined and as many have no definite stream channels sheet flooding is common after heavy rain. However some erosion channels do exist in headwater regions where they are being actively eroded, or occur where water has eroded through alluvial and eolian deposits marginal to salt lakes. The present drainage is consequent on an older erosion surface which was formed by a river system that originally flowed easterly towards the Nullarbor Plain. No definite age can be given for the system but it is thought to have been active in late Mesozoic or early Tertiary times.

The drainage basins of the sheet area have been subdivided into primary and secondary basins (Table 1). The primary basins represent original drainage lines that existed before lateritization; possibly at the beginning of the Tertiary. The secondary basins were formed subsequent to lateritization and have been produced by damming of the primary basins by later alluvium and wind-blown sand which has mainly been derived from the sandy surface overlying the laterite.

TABLE 1 - DRAINAGE BASINS

PRIMARY	SECONDARY
RAESIDE	Goddard
REBECCA	Emu, Marmion, Rebecca
YINDARLGOODA	Kanowna, Yindarlgooda, Roe, Yindana
LEFROY	Hannan?

After heavy rain sheets of water collect on the salt lake surfaces where a considerable lateral movement is generated by prevailing winds. Some of the water sinks underground but the remainder evaporates and leaves salt encrustations. An exception to this is the Goddard basin which briefly flows southeasterly after heavy rain. It is suggested tentatively that the direction of underground water movement in the secondary basins coincides with that of the original surface drainage of the primary basins.

Little is known about the depth of alluvium beneath the present lake surfaces although boreholes have indicated depths of unconsolidated material in excess of 250 feet. The material intersected in the boreholes indicates that the filling may be old stream or colluvial deposits rather than salt lake deposits. This suggests that the salt lakes are probably a recent physiographic feature.

STRATIGRAPHY

There is sufficient geochronological evidence to assign the layered succession of the Kurnalpi Sheet to the Archaean (Wilson and others, 1960; Turek, 1966). The layered succession is intruded by granites dated at ca. 2615^{m.y.} and both acid extrusive and basic intrusive rocks have been assigned ages of between^{ca.} 2700 and 2615 m.y. by using the rubidium-strontium method. By the same method the age of several prominent basic dykes belonging to the Widgiemooltha Dyke Suite have been determined to be ca. 2410 m.y. (Turek, 1966). Horwitz and Sofoulis (1965) suggest that the suite belongs to the Lower Proterozoic.

Earlier papers about the Archaean on the Eastern Goldfields region have variously referred to the Yilgarn-Kalgoorlie system (McMath and others, 1953), the Kalgoorlie system (Wilson, 1958), or the Kalgoorlie-Yilgarn succession (Prider, 1965). The succession to which these refer consists of a greenstone phase overlain by a whitestone phase. Both phases were believed to be intruded by a younger greenstone phase. Subsequently the entire

succession has been described as having been folded, faulted, regionally metamorphosed, metasomatised, and finally subjected to widespread granitic intrusions and possibly granitisation processes. Sofoulis (1966) described equivalent rocks in the Widgiemooltha and Boorabbin 1:250,000 Sheet areas and called them the Coolgardie-Kalgoorlie Metamorphics.

The genesis of the Archaean rocks in the Eastern Goldfields, and particularly in the Kalgoorlie district, was first postulated by Maclaren and Thompson (1913). Later Gustafson and Miller (1937) gave a good description of the same rocks and commented on their origin. Recently Woodall (1965) also presented a lucid description of the rocks and discussed their origin. In all cases the observations were derived from detailed studies of a restricted area, that is, the Kalgoorlie mining district.

The geological concepts that were formulated from regional mapping and used on the Kurnalpi 1:250,000 Sheet do not contradict earlier syntheses of the Eastern Goldfields geology and represent an extension of many accepted ideas. The concepts can be summarised as follows:

1. A stratigraphic succession could be established which would apply to the whole of a 1:250,000 scale sheet area.
2. Lithological associations could be defined as groupings of lithological units that are either genetically related or show constant spatial relationships as a result of the geological environment. (The use of these associations proved invaluable as a mapping tool in the poorly exposed Archaean).
3. The associations could be divided into two types:
 - (a) basic volcanic
 - (b) acid volcanic-clastic
4. It was possible to establish five associations, numbered from I to V, which were alternately basic and acid-volcanic clastic, the lowest exposed association on the Kurnalpi Sheet area being basic volcanic.

5. A transitional boundary could be established between associations I and II and between associations III and IV. In contrast a disconformable or unconformable relationship exists between associations II and III and between IV and V.

In this concept the natural pairing of associations I and II, and associations III and IV as demonstrated by a progressive change from a basic to an acid clastic environment, is considered to be a major volcanic cycle. Three cycles, numbered 1, 2, and 3 were recognised and these numbers have been incorporated in the rock symbols, e.g. A3B, A2S, and A1D.

A generalised map showing the regional distribution of the associations and volcanic cycles has been presented in an earlier paper (Williams, 1969). In these Notes the associations have been given formation status (Table 2).

TABLE 2

FORMATION	ASSOCIATION	
Morelands	I	(basic association)
Gindalbie	II	(acid volcanic-clastic association)
Mulgabbie	III	(basic association)
Gundockerta	IV	(acid volcanic-clastic association)
Kalpini	V	(basic association)

Some preliminary work on dating the units of the sheet area has been carried out by Dr. W. Compston of the Australian National University. His results are given in Table 3 along with additional dates from Turek (1966).

TABLE 3 - TENTATIVE ISOTOPIC AGE DETERMINATIONS

UNIT	DATED MATERIAL	AGE
Basic dykes (clearly younger)	Gabbro	ca 2410 m.y.
(Granite	Biotite granite	
(Porphyritic granite	ca 2615 m.y.
(
(Association V	---	---
(
(Association IV	Conglomerate-clast of acid volcanic. Acid extrusive- rhyolite	ca 2615 m.y.
** (
(Association III	Basic intrusive - Golden Mile Dolerite. Basic extrusive - Paringa Basalt	ca 2660 m.y.*
(
(
(Association II	Acid extrusive, rhyolite breccia	ca 2660 m.y.
(
Association I (clearly older)	Acid intrusive	ca 2700 m.y.*

* Age determined outside of sheet area, inferred by correlation.

** Separable only by assuming particular interpretations of data

The Archaean stratigraphy is summarised in Table 4.

The age of superficial deposits is thought to range from early Tertiary or late Mesozoic to Recent. The deposits cover about 65 per cent of the sheet area and in many cases give some indication of the nature of the underlying rock type, e.g. sand plain and gravel plain units on granite; magnesite, opaline, silica, on ultramafic rocks.

Archaean

The Archaean layered succession and related intrusive rocks are discussed below within the framework of each formation or lithological association.

Morelands Formation (Association I). The Morelands Formation (Association I) contains the oldest exposed rocks on the sheet area. It is a basic volcanic association made up mainly of basic lavas, some intermediate lavas, and minor fine-grained clastic rocks with a high pyroclastic content. The

formation is intruded by basic, ultramafic, and some acid rocks. Although the base is not exposed the formation is at least 17,000 feet thick.

The formation crops out mainly in the western half of the area where it is exposed in a complex anticlinal structure. Small outcrops of the formation also occur in the core of an anticlinal structure in the Pinjin area. The type area lies 6 miles north of Kanowna on the old Kanowna-Gordon Road, latitude $30^{\circ} 31' S$, longitude $121^{\circ} 35' E$. At this locality southeasterly facing pillow lavas crop out on a small rocky islet in a salt lake. About 100 yards to the west an abrupt hill contains a sequence of variolitic basic lavas with pillow structures and zones of pillow breccias. These have been intruded by sills of basic, ultramafic, and acid rocks.

Most of the sedimentary rocks are now schistose but originally they were black carbonaceous shale (containing pyrite), siliceous and dolomitic shales, minor greywacke, and thin bedded cherts. They are probably mainly of chemical or tuffaceous origin and only a small percentage appear to be of clastic derivation.

Acid igneous rocks, including those described as porphyry, intrude the Morelands Formation. Extrusive rocks of rhyolitic and dacitic composition are rare and these are mainly found in the transition zone with the overlying Gindalbie Formation (Association II).

The Morelands Formation (Association I) was laid down in a stable basin environment with an extrusion of basic rocks under aqueous conditions concomitantly intruded by basic rocks of similar genesis. There is a distinct lack of coarse clastic material and although this could be interpreted as indicating a remoteness from continental sources and a probable deepwater environment, there is insufficient evidence to fully support this probability.

Gindalbie Formation (Association II). The Gindalbie Formation consists of acid volcanic complexes and clastic sequences which are contemporaneous but spatially separate. The term acid volcanic complex is used here to include minor, related acid intrusive rocks.

The acid volcanic rocks make up approximately 66 per cent of the total area of the formation. The maximum thickness of the formation, about 25,000 feet, is attained in areas of acid volcanic rocks. The thickness is about 15,000 feet in areas of clastic deposition.

Where there has been acid volcanic activity the rocks are conformable and transitional on the underlying basic rocks of the Morelands Formation (Association I). Elsewhere in areas of clastic deposition the relationship may be disconformable.

Major centres of acid volcanic and related rocks have been found in the Kanowna-Gordon area, Lindsays-Gindalbie area, Whitehead-Wild Dog Dam area, Rocky Dam-Lake Yindarlgooda area, Majestic-Mount Monger area, and in two zones, one 4 miles northwest of Pinjin Homestead and the other 13 miles east of Yindi Homestead.

The type area selected for the acid volcanic rocks is the Four Mile Hill region northeast of Kanowna, latitude $30^{\circ} 35'$ S, longitude $121^{\circ} 39'$ E. Here prominent hills of acid lavas interbedded with tuffs and agglomerates crop out beside a series of salt lakes. Four miles south of these hills and $3\frac{1}{2}$ miles southeast of Kanowna there is a rhyolite breccia containing

This area is regarded as a possible volcanic centre fragments of flow-banded and perlitic rhyolite and felsite. / The region has been discussed in detail by O'Bierne (1968). Two other probable volcanic centres are located half a mile south of Wild Dog Dam (Gindalbie Station) and 3 miles southeast of Taurus Dam (Hampton Hill Station).

Welded tuffs and tuff lavas have been found in the complexes. Some good examples of these rocks may be seen $4\frac{1}{2}$ miles south of the Gindalbie Mining Centre and 2 miles southwest of Perkolilli Homestead. Many schistose rocks of doubtful origin

are also associated with these complexes. They include quartz-muscovite, quartz-muscovite-chlorite-dolomite, and chloritoid-muscovite assemblages. Since they are interbedded with recognisable acid and intermediate extrusive rocks they are probably of pyroclastic origin.

Amygdaloidal and vesicular intermediate rocks crop out $2\frac{1}{2}$ miles west of Lake Emu on Gindalbie Station. Intermediate lavas with a considerable carbonate content are also widespread in the Rocky Dam - Lake Yindarlgooda area.

Thick widespread deposits of oligomictic conglomerates (Horwitz and others, 1967) frequently lie marginal to the acid complexes. The origin of these rocks is conjectural but field observations indicate a close relationship between them and acid volcanicity. The conglomerates have clasts of rounded and sub-rounded acid and intermediate material whose sizes vary from individual mineral grains to boulders 10 feet across. The matrix is derived from the same material. Interbedded with these coarse-grained rocks are chlorite-rich fine-grained rocks of probable pyroclastic origin. The oligomictic conglomerates are bedded and exhibit graded-bedded and cross-bedded structures. They are thought to be the product of direct deposition of pyroclastic material in water admixed with erosion products derived from the upbuilding acid igneous pile.

Trendall (1964) discusses the origin of similar rocks and came to the conclusion "that such porphyry conglomerates are breakdown products of lavas and sills in which the rounding of the cobbles took place internally during bulk flow, possibly soon after emplacement". The widespread distribution of the rocks in the Lake Yindarlgooda-Bulong district has been recorded in earlier literature where they are called the Yindarlgooda Series (Forman, 1937). The type area is half a mile east of Bennet Dam (Hampton Hill Station) on a rocky islet in Lake Yindarlgooda, latitude $30^{\circ} 43' S$, longitude $121^{\circ} 52' E$.

The remainder of the clastic sequence of the Gindalbie Formation (Association II) consists of interbedded siltstone, sandstone, and thin bedded conglomerates. It is suspected that much of the material is also of volcanic origin as most of the pebbles in the conglomerates are acid volcanics and intrusive types. The type area for these rocks is located 200 yards south of the Kanowna Town Dam, 2 miles southeast of Kanowna, at latitude $30^{\circ} 38' S$, longitude $121^{\circ} 36' E$. Graded bedding and other sedimentary structures indicate facing to the southeast.

Coarse-grained polymictic conglomerates are present in minor amounts at Kurramia, 7 miles northeast of Kalgoorlie. These lie near the top of the sequence and although they have a mixture of clasts the majority are still acid volcanic and intrusive rocks.

In the Rocky Dam area, 38 miles east-northeast of Kalgoorlie, several thick banded cherts interbedded with acid pyroclastic material and magnesite-rich black shales are prominent. They lie unconformably on acid and intermediate volcanic rocks belonging to the Rocky Dam-Lake Yindarlgooda area. This region has been described in detail by Sofoulis and others (1969). The cherts are thought to be genetically related to the underlying acid igneous rocks; structurally however they are part of the overlying Mulgabbie Formation (Association III). The ~~masses~~ formed the platform in this region upon which the basic lavas of the Mulgabbie Formation were laid down.

Similarly, in the northeast quadrant of the sheet area banded iron formation and jaspilite that are equivalents of the banded chert horizons disconformably overlie acid volcanic material.

Initially the Gindalbie Formation was formed during a period of increasing tectonism and explosive acid volcanic activity. Later this declined and erosion became the main geological process. The volcanic activity was concentrated in a series of centres and the subsequent build-up of volcanic piles represents the thickest part of the formation.

The similarity of clastic material to that in the acid igneous piles and the general decreased thickness of the formation in areas of clastic rocks suggests that the bulk of the clastic material is derived contemporaneously by erosion from the upbuilding volcanic piles.

The presence of banded chert, jaspilite, and banded iron formation at the top of the formation is thought to indicate a period of quiescence between volcanic cycle 1, represented by the Moreland (basic) and Gindalbie Formations (acid volcanic-clastic), and the beginning of volcanic cycle 2, that is, the basic rocks of the Mulgabbie Formation.

Mulgabbie Formation (Association III). The Mulgabbie Formation is the most widespread in the sheet area. The succession is lithologically similar to the stratigraphically lower Moreland Formation. However, the Mulgabbie Formation contains a higher proportion of fine grained clastic rocks, which originally were mainly carbonaceous shales and siliceous mudstones, and fewer layered basic bodies. The composition of the extrusive rocks is mainly basaltic and often thick sequences of these rocks contain few or no intrusive rocks. Elsewhere, thin basic coarse-grained rocks commonly intrude along sedimentary horizons within the basic extrusive piles. The succession is also intruded by acid porphyry, some albite-rich, and ultramafic rocks. The formation has a maximum thickness of about 14,000 feet and has a remarkably uniform thickness throughout its strike length.

The well described basic sequence at Kalgoorlie (Woodall, 1965) which extends into the southwestern corner of the sheet area is part of the Mulgabbie Formation. Mount Hunt which lies on the western margin of the sheet area 4 miles south of the "Golden Mile" is a type area for the formation (latitude $30^{\circ} 51' S$, longitude $121^{\circ} 30' E$). Here a sequence of pillowed basic lavas and carbonaceous shales have been intruded by ultramafic and layered basic rocks.

Kurnalpi, 48 miles east-northeast of Kalgoorlie, is a type area for variolitic basaltic rocks. A particularly good exposure lies just south of the Scottish Lass Well.

The basic succession at Mount Hunt can be structurally correlated with a belt of similar rocks to the east which passes through the Corsair, Golden Ridge, and Duplex Hill districts. Further structural correlations link these rocks with extensive tracts of basic rocks in the Kurnalpi, Mount Charnleigh, and Karonie districts and the Yindi, Mulgabbie, and Pinjin districts.

The clastic content of the formation ranges from 1 or 2 per cent to nearly 50 per cent of the lithology. At Corsair, 7 miles east of Kalgoorlie, thin basic lavas occur in thick sequence of metamorphosed carbonaceous and siliceous shales. Fuchsite-bearing schists and quartzites are located 2 miles southeast of Golden Ridge and 1 mile southeast of Mulgabbie Trig. In both cases these rocks overlies ultramafic rocks although they are not in contact with them.

About a mile northeast of Rocky Dam on Hampton Hill Station the Mulgabbie Formation is unconformably overlain by coarse polymictic conglomerates of the Gundockerta Formation (Association IV). The formation reappears about 8 miles north-northwest of Rocky Dam and half a mile north of Lake Penny.

The basal units of the Mulgabbie Formation in this area are prominent banded cherts. Their unique relationship to the Mulgabbie Formation has been discussed in the paragraph on the underlying Gindalbie Formation (page 11). In the Pinjin and Yindi districts the Mulgabbie Formation contains in an equivalent stratigraphic position a prominent banded iron formation which can be traced almost continuously for 40 miles.

Although the formation is uniform in thickness when followed from the western to the eastern side of the sheet area some lithological changes are apparent. Firstly the sill-like serpentinitised peridotitic bodies in the formation are confined to the western half and increase in number and size towards the western margin of the sheet area. Secondly, there is a facies

change in the basal units of the Mulgabbie Formation from west to east. On the western side the basal units are metamorphosed siliceous shales and minor pebble conglomerates and there is an angular unconformity in the Kurramia and Corsair districts. Near Rocky Dam in the centre of the sheet area prominent banded cherts appear at the base of the formation and the angle of unconformity is no more than 4 to 5 degrees. On the eastern side of the area the banded cherts are replaced by banded iron formations and jaspilites which disconformably overlies the Gindalbie Formation. However the bulk of the formation is similar to the Morelands Formation and it is thought that they were produced under similar environmental conditions.

The formation forms the basic portion of volcanic cycle 2.

Gundockerta Formation (Association IV). The acid volcanic-clastic rocks of the Gundockerta Formation are similar in most respects to those described in the Gindalbie Formation. However the percentage of acid volcanic material is markedly less. It constitutes only about 13 per cent by area of the formation. The decrease of acid volcanism in this formation is reflected in the smaller size of the acid complexes. Consequently the main feature of this formation is the high percentage of clastic rocks.

The Gundockerta Formation is confined to four major synclinal structures. The largest occupies the centre of the Kurnalpi Sheet and extends from the southern boundary through Gundockerta north to Cane Grass Swamp on Gindalbie Station. In most cases the formation lies conformably on the underlying basic rocks of the Mulgabbie Formation and is transitional with them. However in regions away from acid igneous activity the contact between the Mulgabbie and Gundockerta Formations can be disconformable or even unconformable.

An unconformity is present in the Rocky Dam district of Hampton Hill Station. Coarse polymictic conglomerates of the Gundockerta Formation rest on fine-grained clastic and pyroclastic rocks of the Gindalbie Formation. The basic rocks of the Mulgabbie Formation are completely missing. However the majority of clasts in the conglomerate are basic rocks similar in composition and appearance to the missing Mulgabbie Formation.

There is only one acid volcanic complex comparable in size to those found in the Gindalbie Formation. This is situated in the Steeple Hill and Gooragooggine Lake regions. A thick pile of rhyo-dacitic lavas and interbedded tuffaceous rocks are present in this complex. Basic and intermediate amygdaloidal lavas also occur in minor amounts and oligomictic conglomerates are marginal to the area.

Commonly the acid volcanic complexes are overlain by banded cherts, some of which carry a considerable amount of pyrite which has been largely reduced to goethite and limonite by weathering. An example occurs half a mile west of Old Plough Dam on Pinjin Station. The cherts are generally thinner and less continuous than those at the base of Mulgabbie Formation. However the proximity of both to acid volcanic rocks suggests an affinity with these rocks.

The cherts of the Gundockerta Formation are different from those of the Mulgabbie Formation as they are overlain by thick beds of coarse-grained clastic material and not basic volcanic rocks.

Polymictic conglomerates (Horwitz and others, 1967) are prominent in the Gundockerta Formation. One broad zone extends from Gundockerta Hill, on the southern side of Lake Yindarlgooda, northwestwards to the Penny's Find area, a distance of 25 miles. A second zone extends from south of Painted Rocks on Pinjin Station northwards for 15 miles to the northern boundary of the sheet area and beyond. The conglomerates contain clasts of acid volcanic rocks, porphyry, chert, jasper, shaley sediment, quartz pebbles, basic rock types, and granite porphyry. The type area

is half a mile northwest of Telephone Dam on Hampton Hill Station, latitude $30^{\circ} 33' S$, longitude $121^{\circ} 59' E$.

The thick conglomerate beds pass laterally and vertically into well bedded shales, siltstone, sandstone, and minor thin conglomerate beds which commonly exhibit slumping and graded bedding structures. The type area for the rocks is at the southern end of Tabletop Hill on Hampton Hill Station, latitude $30^{\circ} 35' S$, longitude $121^{\circ} 58' E$.

A thick turbidite sequence which lies 4 miles south of Randalls and 48 miles east-southeast of Kalgoorlie consists of metamorphosed interbedded greywacke, siltstone, and shale. Rhythmic sedimentation is present and sedimentary structures are common in the sequence. The sequence is thought to represent a deeper water facies of the shallow water deposits found in the Gundockerta Formation further north.

Although the lithological associations of the Gundockerta and Gindalbie Formations are similar, acid igneous activity is less intense and erosion plays a greater role in the genesis of the former than in the latter formation. The Gundockerta Formation is part of volcanic cycle 2.

Kalpini Formation (Association V). The youngest Archaean rocks of the Kurnalpi Sheet area belong to the Kalpini Formation which is confined to two narrow synclinal structures. One syncline stretches from Kalpini Mines south to the Sawmill Dam area on Avoca Downs Station, a distance of 40 miles, and the other lies south of Cowarna Rocks.

The association consists of a suite of pillowed carbonated basic lavas and pillow breccia intercalated with fine-grained mudstones and shales. It has been intruded by basic and ultramafic rocks. The type area for this assemblage is on an island near the eastern edge of Lake Yindarlgooda (latitude $30^{\circ} 41' S$, longitude $122^{\circ} 30' E$). Coarse-grained basic rocks are mainly confined to the western margin of the syncline, particularly near Nodule Dam on Hampton Hill Station and Kalpini.

The ultramafic rocks are mainly serpentinitised peridotites with some minor pyroxenites. They are all found near the base of the Kalpini Formation and are nearly all confined to two zones; the Nodule Dam - Lake Yindarlgooda area and the Jubilee area.

Prominent banded cherts occur near the base of the formation. These can be traced for long distances and are useful for delineating the regional structure.

In contrast with the other basic associations, such as the Morelands and Mulgabbie Formations, the Kalpini Formation is distinguished by its less altered character, lack of regional metamorphism, and paucity of acid intrusives.

The formation has been formed under similar environmental conditions to the Moreland and Mulgabbie Formations and represents the beginning of volcanic cycle 3.

The Archaean succession of the Kurnalpi Sheet totals at least 91,000 feet of volcanic and sedimentary material. It is thought that the buildup of this material was an almost continuous process of volcanic activity and sedimentation. The bulk of the sedimentary material was probably produced by contemporaneous erosion of the rising volcanic piles.

Bulong Complex. The formally named Bulong Complex is situated 19 miles east of Kalgoorlie. The complex measures approximately 23 miles long and is up to 15,000 feet thick. However, the maximum continuous thickness of intrusive rock is about 10,000 feet. It has a northerly strike and crops out almost continuously from a point 4 miles northwest of Mount Monger Homestead northwards to near the Unknown Mine on Hampton Hill Station. North of Gumbulgera Hill the complex bifurcates and the eastern limb strikes east-northeast for $2\frac{1}{2}$ miles to the Taurus Dam area on Hampton Hill Station. South of Gumbulgera Hill and east of Bulong the complex splits into two gently curving limbs. The western limb crops out discontinuously whilst the eastern limb crops out strongly southwards.

The Bulong complex intrudes rocks of the Moreland and Gindalbie Formations. The shape of the intrusion was probably controlled by the regional foliation of the host rocks in the north and the Mount Monger fault in the south. Shearing along the eastern side of the complex suggests a post-emplacement movement along the fault zone. Subsequent faulting is also present in the Gumbulgera Hill area and a post-intrusive fault offsets the complex, with a sinistral movement, near Magnesite Creek.

The complex is possibly a multiple intrusion with a boat-shaped form and consists of a number of sills which were intruded either simultaneously or consecutively. The composition of the bodies range from serpentinitised peridotite, dunite, and pyroxenite, through to gabbro and diorite. There is a pronounced layering within individual intrusions and cumulus textures are present. Colour banding (alternate mafic-rich and felsic-rich bands) in a pyroxene gabbro show "cross-bedded" structures that give a west facing for the eastern limb of the complex.

The type area of the complex is at Canyon Dam on Hampton Hill Station where there is a good creek section through the eastern limb of the complex (latitude $30^{\circ} 47' S$, longitude $121^{\circ} 50' E$).

The age of the intrusion is unknown. The only pertinent fact available from field evidence is that it intrudes a fault zone which displaces rocks of the Mulgabbie Formation. This formation belongs to volcanic cycle 2. Until a definite age can be established for the complex it is tentatively considered to be intermediate in age between volcanic cycles 2 and 3, and may possibly be related to cycle 3.

A second ultramafic body, informally named the Hampton Complex, lies $2\frac{1}{2}$ miles west of the Bulong Complex. It is about 2,000 to 3,000 feet thick, can be traced discontinuously for a distance of 26 miles, and follows a pronounced north-trending lineament. This complex differs from the Bulong Complex in that it is largely serpentinitised peridotite and dunite. However, like

the Bulong Complex there is a strong magnetic anomaly over the body and it is suggested that the two bodies are genetically related.

Granite and related rocks. The Archaean layered succession is intruded by a suite of plutonic igneous rocks ranging in composition from quartz diorite to granite. They occupy about 33 per cent of the sheet area but are confined mainly to the northern and eastern portions. The commonest rock type is a medium to fine-grained biotite granite consisting of microcline, plagioclase, quartz, and biotite.

The granitic rocks are grouped according to their field relationships and mineralogical characteristics. The main variant is a porphyritic granite. The phenocrysts are microcline and the groundmass is similar to the biotite granite. The intrusions are smaller and tend to be confined to a zone trending north-northwesterly across the sheet area from Dingo Rocks to Galvalley Rocks.

Some of the porphyritic granites on field data appear to be younger than the larger biotite granite masses. However a similar age of 2615 m.y. for both types has been reported (Table 3). In some cases the porphyritic granite appears as a marginal phase of the biotite granite.

A third category consists of a fine-grained leucocratic granite which contains little or no mafic material except for a pale green chlorite. Some of these intrusions are alaskitic as at Cardonia Rocks. They are generally subsequent plutons.

An unusual rock type, a unakite, has been described from Gilgarnah Rocks by Larcombe (1926). It is a coarse-grained rock with a granitic texture and consists of potash feldspar, epidote, chlorite, and a little quartz.

The margins of the biotite granite and porphyritic granite are strongly foliated roughly parallel to the regional foliation. A coarse fracture cleavage or shearing is also common and suggests that there was possibly some later diapiric movement

of the granitic masses.

Gneissic granite and migmatites are present east of Pinjin Station Homestead. The granitic rocks have contact relationships which vary from sharp and discordant with medium grade contact metamorphism to gradational and concordant with narrow margins of migmatite. They show a preference for anticlinal areas but commonly cross the regional structure. The rocks have reached a higher structural level in the eastern half than in the western half of the sheet area.

Widgiemooltha Dyke Suite. Five large basic dykes belonging to the Widgiemooltha Dyke Suite occur in the sheet area. Their general trend is 070 degrees but one dyke in Lake Rebecca near Old Pinjin Homestead strikes 330 degrees.

The largest dyke, informally named the Celebration, has been dated at 2410 m.y. (Turek, 1966). The other informally named dykes, the Randalls, Pinjin, and Ballona are thought to be of a similar age. All have a positive magnetic anomaly. The fifth dyke, the Kalpini dyke, differs in that it has a negative magnetic anomaly. This suggests a possible difference in the age of intrusion.

The composition of all the dykes can vary from pyroxenite to granophyre but the bulk of the material is quartz gabbro. Some layering has been observed in the Ballona dyke south of Stoney Dam (on Gindalbie Station). Scattered iron and copper sulphides have been seen at this locality.

Cainozoic

The superficial deposits of the Kurnalpi Sheet are grouped according to their relative ages. Within each group the contained units are contemporaneous or nearly so. The detailed stratigraphy is given in Table 4.

The subdivisions of the Cainozoic are morphological and because of the complete lack of palaeontological and palynological material no absolute age can be given to the units.

However on the Kalgoorlie 1:250,000 Sheet area some material from near Coolgardie has been dated as Upper Eocene by Balme and Churchill (1959). This material is similar to the thick colluvial and riverine deposits which are present on the Kurnalpi Sheet and are adjacent to, and underlie the present salt lake systems at Lake Rebecca and Hannan's Lake. The main subdivisions of the Cainozoic are summarised in Table 5.

TABLE 5 CAINOZOIC STRATIGRAPHY

AGE	TYPE	Prefix to Map Symbol
Recent	Fluvial and eolian deposits	Qr
Pleistocene?	Fluvial and eolian deposits	Qp
Late Tertiary or Pleistocene?	Fluvial and some eolian deposits	Qq
Tertiary	Laterite, fluvial deposits, deeply weathered rocks	T

A diagrammatic representation of the Cainozoic units is given in Figure 3.

The oldest deposits (Tu) are iron cemented silts, sands, grits, and clays of riverine origin. They are exposed along the shores of the salt lakes or in breakaways. They are pre-laterite and are grouped with the thick old valley fills which lie adjacent to, or underlie in places the present salt lake systems. The deep leads of Kurnalpi, Kanowna, and Bulong probably belong to this period. These deposits may be later Mesozoic.

The original widespread laterite horizon (Ti) now represented by isolated eroded remnants, is thought to be middle to late Tertiary age. Prider (1966) regarded the surface as Pliocene.

Remnants of the old "sand plain" (Ts) overlying pisolitic-laterite and ferruginised and kaolinised granite are preserved along the major divides which separate the primary drainage basins. Elsewhere iron-rich laterite up to 100 feet thick, strongly coloured and weakly magnetic on the surface,

overlies deeply weathered basic rocks, Contemporaneously, acid volcanic rocks, granite, and certain sediments have weathered to silcrete, whilst weathered ultramafic rocks are overlain by banded jaspers, chalcedonic silica, magnesite, chrysoprase, and nickeliferous laterite.

The period of lateritisation was followed by the formation of semi-compacted colluvial, alluvial, and eluvial deposits (Qq). These are the most widespread of the Cainozoic units and contain extensive sheet kankar and kankar nodules within the profile. The sheet kankar gives way in places to a clay hardpan containing ironstone pebbles (Qqz). Generally the sheet kankar indicates a shallow depth to bedrock whereas kankar nodules and clay hardpan indicate greater depths of alluvium. Kankar nodules also form in some of the eolian deposits that overlie the granitic rocks. These deposits are possibly late Tertiary or early Quaternary. The presence of kankar is thought to reflect an arid or semi-arid climate.

The next group (Qp) is possibly early Quaternary and consists of alluvial, colluvial, and eolian deposits which overlie and are derived from the older units. They do not contain kankar except in an irregular nodular form that is confined to alluvium bordering the salt lake systems. The unit is largely confined to drainage systems as fill and sheet flood deposits. These include cavernous clay deposits also known as "crab-hole" or gilgai.

The group formed during the early stages of the development of the salt lake systems. Large sheet and dune kopai deposits contaminated with red clay are placed in this group. The kopai is being eroded by the present salt lake system.

The most recent deposits (Qr) are alluvial, colluvial, and eolian, and are mainly confined to the salt lake systems. Erosion is strongest along the western and northwestern margins of the salt lakes and in the headwater divide regions of the drainage basins. The present erosion surface is commonly bordered by active breakaways or scarps which may occur either in

older superficial deposits or deep-weathered Archaean rocks.

METAMORPHISM

The Archaean layered succession has been subjected to varying degrees of low grade regional metamorphism. The metamorphism has produced mineral assemblages which are stable in the greenschist facies but it has not completely destroyed the primary igneous or sedimentary textures of the rocks.

It is not uncommon to find in large homogeneous igneous bodies pre-metamorphic unmetamorphosed relicts.

In an attempt to avoid the ambiguity which has arisen in previous descriptions of these rocks the lithological units in these Explanatory Notes have been given their unmetamorphosed name in preference to a metamorphic term. Metamorphic terms are only used where both the mineral assemblage and texture are metamorphic. Therefore the term amphibolite is used in the restricted sense of a hornblende and plagioclase rock which has an obvious metamorphic texture (Williams, Turner and Gilbert, 1954). The term is not used to describe the altered basic rocks which are common in the Kurnalpi Sheet and contain tremolite-actinolite assemblages. The term is used to describe contact metamorphic rocks of medium grade.

The metamorphic grade is slightly less for each successive volcanic cycle with the Kalpini Formation of cycle 3 being largely unmetamorphosed. Volcanic cycle 2 rocks show a gradual increase in metamorphic grade to the southwest and in the Duplex Hill region the mineral assemblage is stable in the upper greenschist facies.

Metamorphic iron-poor chloritoid has been found in strongly cleaved rocks of the acid volcanic complexes of the Gindalbie and Gundockerta Formations.

The intrusive granitic masses are surrounded by a contact metamorphic aureole which may be up to 4 miles wide but is generally between 1,000 feet and 6,000 feet wide. The contact metamorphism is medium grade and belongs to the horn-

blende hornfels and rarely the pyroxene hornfels grade. The main assemblages are spotted and basic hornfels and amphibolite.

East of Pinjin Station in the northeast corner of the sheet area amphibolite and basic hornfels pass laterally into a zone of migmatite which is marginal to gneissic granite. The migmatites appear to be part of the contact metamorphic zone and are not a widespread regional feature.

STRUCTURE

The Archaean rocks of the Kurnalpi Sheet area are part of a broad tectonic unit, the Yilgarn Block (Prider, 1965).

The structural interpretation is derived from mesoscopic field observations and as yet no detailed structural analysis has been attempted on these Archaean rocks. An interpretation is given in Figure 4.

Folding

The dominant fold trend is north-northwest but the fold axes are sinuous and suggest interference of two fold systems. An apparent northeasterly trending en echelon fold pattern also suggests that more than one period of folding is involved. This relationship has been recognised and described elsewhere as cross-folding (McMath and others, 1953).

The regional fold style is largely similar folding of an almost isoclinal nature. Bedding dips are steep to vertical. Fold plunges are variable and range from shallow in the Kalgoorlie Anticline, to vertical and overturned in the Edjudina Anticline.

The fold pattern of volcanic cycle 1 is marked by many short axes which plunge mainly to the south and southeast but occasionally to the north and northeast. The fold axes commonly curve from a northerly trend to a northwesterly trend. The resultant structures are curved, elongated domes. Most of these fold axes plunge towards the boundary of the overlying volcanic

cycle 2 rocks. This folding however, is not reflected in the overlying rocks.

A slaty cleavage, mainly axial plane cleavage, is present in the pelitic and some acid volcanic rocks. Differential slip along cleavage planes, strain-slip cleavage, folded quartz veins, and pebbles stretched in the cleavage plane are commonly observed in the rocks of volcanic cycle 1.

However fresh basic rocks, particularly homogeneous intrusive bodies, do not show cleavage except where these rocks are deeply weathered.

The regional distribution of volcanic cycle 2 rocks is controlled by the dominant north-northwesterly fold axes. These long sinuous axes can be traced across the sheet area. They have a uniform plunge direction but a varying degree of dip. The major plunge direction of these folds in the sheet area is south-southeast. The large somewhat open folds of cycle 2 have been informally named.

The Bulong anticline contains in its core the main exposure of volcanic cycle 1 rocks. The structural sketch map (Figure 4) shows the distribution of the two cycles and the variations in fold directions. The Yindarlgooda syncline contains the basic volcanic rocks of cycle 3.

Although cleavage is evident throughout cycle 2 rocks, the original bedding is still well preserved and is often the dominant planar surface. The deep weathering of the rocks always emphasizes the cleavage. Bedding-cleavage intersections can be used to establish plunge directions of the major folds.

Volcanic cycle 3 rocks are steeply folded about a westerly dipping axial plane. Cleavage is not strongly evident.

Faulting

Major north-trending faults are present in the sheet area. However, minor faulting may trend in any direction although it tends to be closely related to the folding.

A later fracture system trending about 070 degrees has controlled the emplacement of the post-granite Widgiemooltha Dyke Suite (Sofoulis, 1966).

Three definite faults and one probable major fault have been found in the sheet area. They are the Boulder fault, Mount Monger fault, Claypans fault, and the Hampton fault. General information about these faults and the locations of others is limited by poor exposures. The established faults are mainly strike faults with vertical or near-vertical fault planes and probable movement in a vertical sense. The Mount Monger fault has a relative movement of west-block-south.

Large layered intrusions, the Bulong Complex and the informally named Hampton Complex, intrude the Mount Monger and Hampton faults respectively. All the major faults predate the emplacement of the granitic rocks.

Minor faulting with displacement from a few inches to tens of feet is common in all well exposed rocks. This faulting is generally oblique to the strike of the bedding. A complementary fault set has been described from the Rocky Dam area (Sofoulis and others, 1969). In this example the dip of these fault planes and sense of movement are both vertical.

Unconformities

Each volcanic cycle is thought to lie disconformably or unconformably on the preceding cycle. Two such discontinuities are present between volcanic cycles 1 and 2, and 2 and 3. The demonstrably different fold styles between cycles 1 and 2 supports this concept. The presence of an unconformity in the Rocky Dam district between the Gindalbie Formation of volcanic cycle 1 and the Mulgabbie Formation of volcanic cycle 2 has been confirmed by field mapping.

Local unconformities are also present within individual volcanic cycles. An example lies 2 miles north of Rocky Dam where the Gundockerta Formation of volcanic cycle 2 lies on the

eroded Gindalbie Formation of volcanic cycle 1. Disconformities are common in the acid volcanic-clastic associations of the Gindalbie and Gundockerta Formations and to a lesser degree in the remainder of the formations.

The discontinuity between the volcanic cycles represents no great span in time but rather a pause between the end of one tectonic event and the beginning of the next. The main process that has been at work between the periods of tectonism is erosion.

Palaeogeography

The distribution of the lithological units and related facies changes is fundamentally related to the paleogeography of the Archaean.

Earlier work by Horwitz and others (1967) suggested that there was a paleogeographic direction trending north-northeasterly. This is oblique to the dominant north-northwesterly tectonic trend. Further evidence to support this conclusion has been found in the present study.

The Archaean succession area can be divided into two sections by a line passing approximately through Randalls and Old Pinjin Homestead. This line trends approximately north-northeasterly. The western division contains the majority of ultramafic rocks, particularly serpentinitised peridotites, acid volcanic rocks, polymictic conglomerates, and the bulk of gold mineralisation. Unconformities are also common.

The eastern division contains a few ultramafic rocks, mainly altered pyroxenite, some acid volcanic rocks and polymictic conglomerates. However, it contains widespread areas of turbidite rocks and extensive banded iron formations. There are no obvious unconformities but disconformities are common. Mineralisation is rather poor.

The possibility of continuous tectonism with the deposition of the Archaean succession has been pointed out by

Horwitz and Sofoulis (1965). It is considered that the western division of the Kurnalpi Sheet area may have undergone continuous tectonism. On the other hand the eastern division has been subjected to a more intermittent tectonism with pauses between each successive volcanic cycle.

Further to the concept that tectonism is related to the volcanic cycles, it is thought that tectonism is a process which waxes and wanes with each successive volcanic cycle and reaches a maximum at the commencement of acid volcanic activity and a minimum at the end of the volcanic cycle.

It is possible that the older northerly tectonic trend of cycle 1 is closer to the original paleogeographic trend than the later dominant north-northwesterly tectonic trend of volcanic cycle 2.

ECONOMIC GEOLOGY

Mineral production in the Kurnalpi Sheet area has in the past been largely confined to gold mining. The area has produced nearly 1,000,000 fine ozs. of gold from ore averaging 12.6 dwt/ton. In addition over 3,000 ozs. of alluvial and 41,000 ozs. of dollied gold have been recorded. There has also been some minor production of copper, manganese, magnesite, vermiculite, gypsum, asbestos, alunite, and gemstones.

Mineralisation is confined to non-granitic rocks. Acid and basic extrusive and intrusive rocks are the main host rocks but all lithologies have been mineralised to some extent.

The current search for nickel has revived general interest in the region.

Gold

The gold mining centres with the total production of gold and silver are shown in Table 6. The figures do not include the "Golden Mile" at Kalgoorlie which overlaps the western boundary of the sheet area. Kriewaldt (1967) has described this

area in detail and gives a list of references.

The source of the gold and the geological association of the mining locality are summarised in Table 7.

The gold mineralisation of volcanic cycle 1 appears to be directly or indirectly related to acid igneous activity. Gold has been found in acid intrusive rocks at Red Hill near Kanowna, in oligomictic conglomerates marginal to the acid complexes at Taurus and Kanowna, and in fine-grained pyroclastic and clastic rocks in the Gindalbie area. The transition zone between the Morelands and Gindalbie Formations is also a favourable region for gold mineralisation.

The gold mineralisation of volcanic cycle 2 is mainly concentrated in the basic rocks of the Mulgabbie Formation. Gold-telluride mineralisation in basic intrusive rocks at Mulgabbie, 70 miles northeast of Kalgoorlie, and gold-quartz-tourmaline mineralisation in extrusive basic rocks at Kurnalpi have been recorded. The gold mineralisation in the Mulgabbie Formation is also related to acid intrusive rocks, as for example at the Golden Ridge and Celebration Mines.

Although little gold production has been obtained from rocks in the Gundockerta Formation of volcanic cycle 2 mineralisation is present near Jubilee, 39 miles east-northeast of Kalgoorlie, and Wellington, 6 miles north of Kalpini.

In volcanic cycle 3 the Kalpini Formation contains gold in basic extrusive rocks at Jubilee and in basic intrusive rocks at Kalpini.

Theories concerning the origin of gold in the Eastern Goldfields can be placed in two broad categories; those mainly concerned with ore control; Simpson (1902), Maclaren and Thompson (1913), Ward (1950), and Woodall (1965), and those mainly concerned with the source of mineralisation; Prider (1965) and Campbell (1965). The conclusion reached on the Kurnalpi Sheet area is that the gold mineralisation may have originally been derived from both basic and acid igneous activity. Subsequent

modification and reconstitution of the mineralisation has occurred during later tectonic and metamorphic events.

Nickel

The area has been intensely prospected for nickel mineralisation since early 1966. The extent and location of current holdings can be obtained from the Mines Department Lease Branch in Perth.

The most significant nickel discovery so far has been announced by Great Boulder Mines Limited at Carr Boyd Rocks, 12 miles northwest of Gindalbie Station Homestead. At the end of 1969 indicated ore reserves stood at 2,000,000 tons averaging 1.41 per cent Ni and 0.49 per cent Cu.

Nickel mineralisation is closely associated with magnesium-rich ultramafic rocks. The commonest types on the sheet area are serpentinitised peridotites and pyroxenites. The background nickel content of these rocks is about 0.2 per cent (2,000 ppm) Ni but the weathered surface outcrop may be considerably higher. Over 1 per cent Ni has been found in many localities including the Lake Rebecca Prospect and Carr Boyd Rocks area.

Ultramafic rocks are nearly always covered by magnetic anomalies and hence the total magnetic intensity maps published by the Bureau of Mineral Resources on a 1 inch to 2 mile scale are useful for prospecting. Surface weathering products are also useful in locating deeply weathered ultramafic rocks. These products include magnesite, opaline and chalcedonic silica, and chrysoprase.

Some observations on the distribution and location of ultramafic bodies are pertinent. Firstly, the concordant and nearly concordant ultramafic bodies are confined to the Moreland, Mulgabbie, and Kalpini Formations. Briefly they are part of the basic association or basic igneous environment. Consequently the remaining acid-clastic associations, the Gindalbie and Gundockerta Formations are regarded as zones of low potential

for nickel mineralisation. Secondly, the number of ultramafic bodies increases westwards across the sheet area. Thirdly, although the initial discoveries of nickel in the Eastern Gold-fields have been associated with serpentinitised peridotites, nickel mineralisation is also present in layered basic complexes, as for example at the Carr Boyd prospect. At this locality the nickel mineralisation occurs with an altered gabbro-pyroxenite complex.

Copper

Copper mineralisation has been reported from widely scattered localities. It was first recorded by Gocz["]el (1894) in the White Feather Gold Mine at Kanowna. Chalcopyrite with associated gold has been recorded at Feysville, Golden Valley, and Mulgabbie (Simpson, 1948). In each of these locations the mineralisation is present in basic igneous rocks. On the other hand the Kanowna mineralisation is in acid pyroclastic and intrusive rocks.

Some small gossans developed on a magnetite-rich dolerite, three-quarters of a mile east of Emu Dam on Hampton Hill Station, contain copper values. The mineralisation is located in small quartz veins within joints in the dolerite. Some minor prospecting has been carried out but little or no production is evident. Copper indications have recently been found in basic rocks, 6½ miles east of Yindi Station.

The only recorded production of copper ore is 79.67 tons from the Corsair Gold Mining Group which lies 3 miles north-west of Boorara and 7 miles east of Kalgoorlie. At this locality chalcopyrite was mined from quartz veins in fine-grained clastic rocks which were intercalated with basic and ultramafic rocks (Low, 1963).

A ministerial reserve (4538H) for copper, lead, zinc, nickel, cobalt and silver was declared in 1967 to cover the Rocky Dam area on Hampton Hill Station, 38 miles east-northeast

of Kalgoorlie. A full report of this project together with details of geophysical and geochemical results can be found elsewhere (Sofoulis and others, 1969).

Manganese

The only recorded production of manganese came from a small adit 300 yards north of the Corsair Copper Mine. The deposit is very small and has formed in the laterite profile over deeply weathered sedimentary rocks. Total production has amounted to 43.6 tons of manganese ore containing an average of 32 per cent manganese.

Iron

Iron ore deposits of economic potential are unknown but small patchy deposits of goethite, limonite, and hematite occur within the laterite profile, as for example at The Pinnacles, 10 miles northwest of Yindi Station Homestead. Banded iron formations crop out in the Pinjin district in the northeast quarter of the area. Simpson (1948) analysed similar rocks further north from the Edjudina Range, 36 miles north of Pinjin Station Homestead, and found that they contained between 32.6 per cent and 54.8 per cent Fe_2O_3 .

Bismuth

Bismuth in gold-quartz veins cutting dolerite has been recorded from a small mine 1½ miles north of Emu Dam on Hampton Hill Station on the edge of Lake Yindarlgooda.

Gypsum

Gypsum deposits are related to the playas or salt lake systems. The gypsum occurs mainly as kopai (flour gypsum) dunes and is admixed with variable amounts of red clay. The kopai dunes are almost always found along the eastern and southeastern margins of the salt lakes and most of them show some degree of erosion. Smaller deposits of seed gypsum and granular gypsum

(recrystallised kopai) are also present in, and marginal to, the salt lakes. Euhedral crystals and rosettes of gypsum have been found in silty-clay deposits of probable mixed alluvial and eolian origin in areas away from the salt lakes. Good crystals can be found at Christmas Dam, Pinjin Station.

A summary of gypsum deposits with analyses and potential tonnages is listed by de la Hunty and Low (1958).

The only recorded production is from the salt lakes north of Kanowna where kopai has been used for road surfacing. This deposit is located 5 miles northeast of Kanowna on the Kanowna-Kurnalpi road. Reserves have been estimated at 28,000 tons with an average grade of 90 per cent gypsum. The deposit is typical of the kopai dunes in the sheet area and similar deposits are located in Lakes Yindarlgooda, Roe, and Rebecca. However the average grade of the deposits may vary considerably and depends on the amount of admixed clay material.

Two thousand tons of crystalline gypsum which average 63 per cent CaSO_4 has been reported from a small claypan with a fringing kopai dune, $1\frac{1}{2}$ miles south of the abandoned Lakewood townsite.

Alunite

Alunite has been reported from several localities in the Kanowna district (Blatchford, 1919). The main locality is in "breakaway" country, 3 miles north-northeast of Kanowna. These deposits have been well described and analysed by Simpson (1948).

Small veins of alunite were found in "breakaways" near Lake Yindarlgooda, 2 miles east-southeast of Taurus Dam, during the present survey. The alunite occurs in horizontal and shallow dipping veins within deeply weathered fine-grained kaolinitic tuffaceous rocks which are interbedded with oligomictic conglomerates and acid extrusive rocks.

Vermiculite

Green vermiculite has been mined from the Bulong Complex, 3 miles southeast of the Bulong townsite. The deposit occurs in two veins contained within a talc-carbonate rock with accessory chlorite, calcite, and magnetite. Total production has amounted to 127.16 tons valued at \$1,760.60. Simpson (1951) gives analyses of the vermiculite.

Asbestos

Small deposits of asbestos occur with the ultramafic rocks. The main varieties are chrysotile (cross-fibre) and anthophyllite and tremolite-actinolite (slip-fibre and cross-fibre). The only recorded production comes from the Bulong district, 20 miles east of Kalgoorlie, where 8½ tons of anthophyllite valued at \$82 has been mined.

Magnesite

Shallow surface deposits of magnesite which cover about 350 acres occur 2½ miles east of Bulong townsite. Simpson (1952) regarded these deposits as the most important in the State. However the total production since mining commenced in 1913 has only amounted to 1548.96 tons valued at \$5,209.50. The low figure is partly due to competition from other sources and partly to the nature of the deposits which have to be selectively mined to maintain the grade of ore. The magnesite is obtained from flat-lying veins in the deeply weathered zone of the Bulong Complex.

The main deposit lies in a depression between hills of serpentinitised peridotite. Simpson (1952) considered the deposit to be a normal product of the weathering^{of}/serpentine-rich rocks by a surface carbonation of serpentine by meteoric carbonic acid.

Nodules and fragments of magnesite are always found on weathered ultramafic rocks. It has been used as an indicator of these rocks during field work.

Chalcedonic and opaline silica are common impurities in the magnesite. Nickeliferous magnesite with various shades

of green has been noted in several localities including Lake Rebecca and the Bulong Complex.

Gemstones

A great variety of chalcedonic and opaline silica is present in the deeply weathered cappings on the ultramafic rocks. This material is used in the Goldfields for gemstones and is slabbed, faceted, or tumbled. It is marketed under a variety of names (e.g., moss opal, lace opal).

Mixed siliceous material has been worked 4 miles north-east of Bulong townsite. The deposit is in weathered ultramafic rocks of the Bulong Complex.

Chrysoprase (chalcedony with traces of nickel) is also found with ultramafic rocks, where it generally occurs as veins within the weathered portions of the rock. Good quality chrysoprase has been worked $3\frac{1}{2}$ miles north of the Jubilee Mine 39 miles east-northeast from Kalgoorlie.

Some good banded jaspers suitable for tumbling have been found in the banded iron formations in the northeast quarter of the sheet area.

A little turquoise (hydrous copper aluminium phosphate) associated with quartz-filled joints in tuffaceous rocks has been found in the Ministerial Reserve (4538H) on the edge of Lake Yindarlgooda. It is not a commercial deposit.

Construction Materials

Suitable slabbing and facing material for building purposes may be found in areas of fresh granite outcrop. A potentially good rock for these purposes occurs at Gilgarna Rock, 20 miles northeast of Kurnalpi. The rock is described as a unakite by Larcombe (1926). It has a granitic texture and consists of pink, zoned feldspars set in dark green epidote and chlorite.

Sheet kankar, kankar nodules, pisolitic laterite

gravels, and kopai have all been used for road surfacing.

Ballast for the Trans Australian Railway has been quarried from Cardonia Rocks, 3 miles north of Koronie Siding. The quarry is linked by a spur line to the main line. The material is a fine-grained leucocratic granite. Quarrying operations have stopped but a considerable amount of material is stockpiled at the site.

Water Supply

The main source of fresh water is obtained from surface catchments and a total of 206 dams and earth tanks are used to catch some of this supply. The dams and tanks are constructed along the ephemeral drainage systems and rely mainly on thunderstorms or prolonged rain for replenishment.

Underground water prospects are poor; the main problems facing the finding of suitable underground water being the existence of high salinities and poor yields. A total of 35 bores and wells were inspected and of these 17 were in current use. Water samples from 22 accessible bores and wells were collected and a partial analysis was carried out of the contained salts. The results are recorded in Table 8.

A distribution study of well and bore sites show that the underground water is largely restricted to the northern half of the sheet area. Good quality water is rare and the prevailing high salinities of most of the water restricts its use to catering for stock.

Limited amounts of potable water have been obtained in the past from areas of fresh rock outcrop while large quantities of saline to very saline water can be obtained from the salt lake country. Slightly better quality water has been found close to the major divides. Arcoona Station bores fall into this category. Occasional shallow streams of fresh water have been found along major drainages e.g. Christmas Well on Yindi Station.

The apparent lack of potable water is probably due to a combination of several factors:

1. A deep weathering and kaolinisation of bedrock over large portions of the area. (Saline water is obtained from these rocks).

2. A low rainfall with an average of only 9 to 10 inches per annum.

3. Small drainage systems and catchment areas.

4. The presence of four salt lake systems; Lake Yindarlgooda, Rebecca, Hannan, and Goddard Creek, limit the areas where non-saline water may be obtained. It is the opinion of the non-saline water committee that the

Fresh water has been obtained from gnamma holes and soaks around fresh granite outcrops or from the eroded laterite surface. Many of the claypans bordering the salt lakes contain fresh water for short periods after rain.

REFERENCES

- Blatchford, T., 1900, The geology of the "North Lead" Kanowna: West. Australia Geol. Survey Ann. Rept. 1899, p. 38.
- _____ 1919, Alunite deposits at Kanowna: West. Australia Geol. Survey Bull. 77, Appendix II, p. 38-44.
- Blatchford, T., and Jutson, J. T., 1912, The mining geology of the Kanowna main reef line, North-east Coolgardie Gold-field: West. Australia Geol. Survey Bull. 47.
- Balme, B. E., and Churchill, D. M., 1959, Tertiary sediments at Coolgardie, Western Australia: Royal Soc. West. Australia Jour. v. 42, p. 37-43.
- Campbell, J. D., 1965, Gold ore deposits of Australia in Geology of Australian ore deposits 2nd ed., (John McAndrew ed.), Commonwealth Mining Metall. Cong. 8th Australia 1965. Pubs. v. 1, p. 31-38; Melbourne, Australasian Inst. Mining Metall.
- Carter, R. M., 1959, Preliminary report of an airborne magnetic and radiometric survey of the Kurnalpi-Widgiemooltha areas,

- W. A.: Australia Bur, Mineral Resources Rec. 1959/137
(unpublished).
- de la Hunty, L. E., and Low, G. H., 1958, The gypsum deposits of
W. A.: West. Australia Geol. Survey Mineral Resources Bull.
6.
- Feldtmann, F. R., 1916, The magnesite deposit of Bulong, North-
east Coolgardie Goldfield: West. Australia Geol. Survey
Ann. Rept. 1915, p. 31-32.
- _____ 1918, The occurrence of asbestos at Bulong:
West. Australia Geol. Survey Ann. Rept. 1917, p. 14-15.
- _____ 1919, The magnesite deposits of Bulong, North-
East Coolgardie Goldfield: West. Australia Geol. Survey
Bull. 82.
- Forman, F. G., 1937, A contribution to our knowledge of the Pre-
cambrian succession in some parts of Western Australia:
Royal Soc. West. Australia Jour. v. 22.
- "Goczel, S., 1894, Report on the mines; Coolgardie District: Ad
interim report on the Dept. of Mines for half year ending
30th June. Appendix IV p. 20-21 By Authority. Perth.
- Gustafson, J. K., and Miller, F. S., 1937, Kalgoorlie geology
reinterpreted: Econ. Geology, v. 32, p. 285-317.
- Honman, C. S., 1914, The economic geology of the Golden Ridge
gold mine, East Coolgardie Goldfields: West. Australia
Geol. Survey Bull. 59, p. 176-185.
- _____ 1916, The geology of the country to the south of
Kalgoorlie including the mining centres of Golden Ridge
and Feysville: West. Australia Geol. Survey Bull. 66.
- Horwitz, R. C., and Sofoulis, J., 1965, Igneous activity and
sedimentation in the Precambrian between Kalgoorlie and
Norseman, Western Australia: Australasian Inst. Mining
Metall. Proc. 214, p. 45-59.
- Horwitz, R. C., Kriewaldt, M. J. B., Williams, K. R., and Doepel,
J. J. G., 1967, A zone of Archaean conglomerates in the
eastern goldfields of Western Australia: West. Australia
Geol. Survey Ann. Rept. 1966, p. 53-56.

- Jackson, C. F. V., 1905, Notes on the geology and ore deposits of Mulgabbie (North Coolgardie Goldfield): West. Australia Geol. Survey Bull. 18, pt. II.
- Jutson, J. T., 1914a, Further notes on the mining geology of Kanowna: West. Australia Geol. Survey Bull. 59, p. 215-227.
- _____ 1914b, Kurnalpi, North-East Coolgardie Goldfield: West. Australia Geol. Survey Bull. 59, p. 13-30.
- _____ 1950, The physiography of Western Australia: West. Australia Geol. Survey Bull. 95 (3rd ed.).
- Kriewaldt, M. J. B., 1967, Explanatory notes on the Kalgoorlie 1:250,000 Geological Sheet: West. Australia Geol. Survey Rec. 1967/10.
- Larcombe, C. O. G., 1926, Unakite from Gilgarna Rock, 20 miles northeast of Kurnalpi: West. Australia Dept. Mines Ann. Rept. 1925, p. 137.
- Low, G. H., 1963, Copper deposits of Western Australia: West. Australia Geol. Survey Mineral Resources Bull. 8.
- Maclaren, J. M., and Thompson, J. A., 1913, Geology of the Kalgoorlie Goldfield: Mining and Scientific Press.
- Maitland, A. G., 1900, The mineral wealth of Western Australia: West. Australia Geol. Survey Bull. 4.
- McMath, J. C., 1953, Regional geology in McMath, J. C., Grey, N. M., and Ward, H. J., 1953, The geology of the country about Coolgardie, Coolgardie Goldfield, W. A.: West. Australia Geol. Survey Bull. 107, p. 11-119.
- O'Bierne, W. R., 1968, The acid porphyries and porphyroid rocks of the Kalgoorlie area: University of West. Australia, Ph.D. thesis (unpublished).
- Prider, R. T., 1965, Geology and mineralisation of the Western Australian Shield; in Geology of Australian ore deposits, 2nd ed. (John McAndrew ed.) Commonwealth Mining Metall. Congr. 8th Australia 1965, pubs. v. 1, p. 56-65. Melbourne Australasian Inst. Mining Metall.

- Prider, R. T., 1966, The lateritized surface of Western Australia: Presidential Address, Aust. Jour. Science, Vol. 28, No. 12, pp. 443-451.
- Richard, T. W., 1898, Alluvial deposits of Western Australia: Trans. Am. Soc. Min. Eng., Buffalo.
- Simpson, E. S., 1902, Notes from the Departmental Laboratory - Rocks of Kalgoorlie: West. Australia Geol. Survey Bull. 6, p. 62-79.
- _____ 1948, Minerals of Western Australia, v. 1: Perth, Government Printer.
- _____ 1951, Minerals of Western Australia, v. 2: Perth, Government Printer.
- _____ 1952, Minerals of Western Australia, v. 3: Perth, Government Printer.
- Sofoulis, J., 1966, Widgiemooltha, W. A.: West. Australia Geol. Survey 1:250,000 Geol. Series Explan. Notes.
- Sofoulis, J., Williams, X. K., and Rowston, D. L., 1969, Investigation of Ministerial Reserve 4538H, Lake Yindarlgooda, Bulong District, W. A.: West. Australia Geol. Survey Ann. Rept., 1968, p. 42-46.
- Trendall, A. F., 1964, Notes on the nomenclature and significance of "porphyry" and "porphyrite" in Western Australia: West. Australia Geol. Survey Ann. Rept. 1963, p. 46-50.
- Turek, A., 1966, Rubidium-strontium isotopic studies in the Kalgoorlie-Norseman area, Western Australia: Australian National University Thesis (unpublished).
- Urquhart, D. F., 1956, The investigation of deep leads by the seismic refraction method: Australia Bur. Mineral Resources Bull. 35.
- Ward, H. J., 1950, Notes on the porphyry-porphyrite series of Coolgardie, Coolgardie Goldfield: West. Australia Geol. Survey Ann. Rept. 1948, p. 67-68.
- Williams, I. R., 1969, Structural layering in the Archaean of the Kurnalpi 1:250,000 sheet area, Kalgoorlie region: West. Australia Geol. Survey Ann. Rept. 1968, p. 40-41.

- Williams, H., Turner, F. J., and Gilbert, C. M., 1954, In Petrography: Publ. H. Freeman and Company. San Francisco, 1954, p. 240.
- Wilson, A. F., 1958, Advances in the knowledge of the structure and petrology of the Precambrian rocks of South Western Australia: Royal Soc. West. Australia Jour. v. 41, p. 57-83.
- Wilson, A. F., Compston, W., Jeffery, P. M., and Riley, G. H., 1960, Radioactive ages from the Precambrian rocks in Australia: Jour. Geol. Society Australia, vol. 6, part 2.
- Woodall, R. W., 1965, Structures of the Kalgoorlie goldfield, in Geology of Australian ore deposits, 2nd ed. (John McAndrew ed.) Commonwealth Mining Metall. Congr. 8th Australian 1965, pubs. v. 1, p. 71-74: Melbourne, Australasian Inst. Mining Metall.

TABLE 4 STRATIGRAPHY OF THE KURNALPI SHEET

A	G	E	MAP SYM- BOL	NAME OR SHORT DESCRIPTION	LITHOLOGY	THICK- NESS (app.)	REMARKS
C A I N O Z O I C	Q U A T E R N A R Y	P L E I S T O C E N E	Qra	Alluvium	Clay and silt	50'	In salt lakes or playas; saline
			Qrm	alluvium	Silt, sand and gravel	20'	In samphire flats and swamps adjacent to salt lakes; thin veneer on planed bedrock; saline.
			Qrp	Alluvium	Clay and silty clay	10'	In claypans and swamps; non-saline.
			Qrs	Eolian deposits	White to yellow quartz sand, red-brown silty sand	100'	In sheets and dunes; saline in part.
			Qrc	Colluvium	Pale red-brown to buff silt, sand and gravel	50'	Surface of unit commonly has thin veneer of quartz pebbles.
			Qpk	Eolian deposits	Kopai gypsum and clay	100'	In dunes and sheets; eroded by salt lake systems.
			Qpf	Alluvium	Dark red to red-brown silt and sand with hardpan	150'	Marginal to salt lakes; contains some non-saline swamps.
			Qpv	Alluvium	Poorly sorted dark red clay to pebble deposits	50'	Contains most present-day drainage, "gilgai" in places.
			Qpa	Alluvium	Yellow to buff silt and sand deposits	20'	Restricted to drainage lines over granitic rocks. Unit largely derived from Tg and Ts.
			Qpl	Colluvium	Dark red to red-brown, clay, loam and silt	20'	Thin veneer of ironstone pebble, quartz and weathered rock float, "gilgai"; low sloping deposits adjacent to Qpv.
			Qpm	Colluvium	Pale red silt and sand	10'	Sand consists of mixed quartz and feldspar grains; marginal to granitic rocks.
			Qps	Eolian deposits	Mixed red, brown & yellow sand	100'	In sheets and longitudinal dunes.
			Qqs	Alluvium	Buff to pink loam and silt	100'	Sand veneer; contains kankar nodules below surface of unit.
			Qqt	Colluvium	Dark red to red-brown clay, loam and sandy loam	50'	Contains clay hardpan or sheet kankar below surface of unit.
			Qqc	Colluvium	Mixed, angular to rounded rock fragments in loam	50'	Old scree, contains sheet kankar below surface of unit.
			Qqf	Eluvium	Ironstone pebble or gravel veneer	20'	Contains sheet kankar below surface of unit; commonly mantles low hills.

TABLE 4 Page 3.

A R C H A E A N	Ag	Gindalbie Formation (Association II)	1. Clastic sequence, Agc; fine to coarse-grained clastic rocks mainly derived from (2) 2. Acid volcanic complexes, Aga; acid to intermediate extrusive and intrusive rocks, some minor basic extrusive rocks, pyroclastic rocks	15,000 ft.	1. Contains map symbols A1v, A1g, A1c and A1w.
	Am	Morelands Formation (Association I)	Basic extrusive and intrusive rocks, ultramafic intrusive rocks, minor intermediate and acid extrusive and intrusive rocks, minor fine-grained clastic rocks	25,000 ft.	2. Contains map symbols A1p, A1l, A1x, A1o and A1z. The formation also has contact metamorphic unit A1a.
P R O T E R O - Z O I C O R A R C H A E A N			INTRUSIVE AND RELATED ROCKS	17,000 ft.	Contains map symbols A1d, A1j, A1u, A1e, A1r, A1b, A1i, A1n, A1s, and A1q. The formation also has contact metamorphic units A1h and A1m.
	Pd	Widgiemooltha Dyke Suite	Quartz dolerite, gabbro, norite granophyre and pyroxenite		Main trend 070
A R C H A E A N	Agf	Granitic rocks	Leucocratic granite		In stocks and small intrusions, subsequent
	Ag1		Porphyritic granite		Large intrusions, some late kinematic
	Agb		Biotite granite, granodiorite massive to weakly foliated, medium grained		Large intrusions, mainly synchronous
	Agg	Gneissic granite			Marginal to Agb
	Agm	Migmatite			Marginal to Agg and Agb.

TABLE 6 KURNALPI SHEET SH/51-10

Summary of reported gold and silver production to 31st December 1967

Goldfield	District	Locality	Alluvial Fine ozs.	Dollied Fine ozs.	Ore Treated Tons	Gold Recover- ed Fine ozs.	Silver Recov- ered Fine ozs
North East Coolgardie	Kanowna	Gindalbie	-	1,868.51	52,321.05	45,240.85	38.42
		Gordon	-	859.92	56,166.53	32,302.38	517.61
		Kalpini	24.70	308.45	15,218.50	7,806.52	0.23
		Kanowna	150.26	6,797.15	719,097.97	394,876.16	2,493.02
		Mulgarrie	-	1,233.41	8,192.26	4,844.58	-
		Six Mile	-	1,660.23	1,330.75	1,000.38	-
	Kurnalpi	Jubilee	25.57	158.65	3,386.56	1,992.48	-
		Kurnalpi	695.30	3,894.19	8,755.62	6,405.39	6.27
		Mulgabbie	8.06	4,133.47	1,927.87	10,192.87	4.95
East Coolgardie	East Coolgardie	Boorara	0.49	604.63	313,929.91	174,537.25	413.29
		Feysville	-	309.93	2,382.30	1,101.65	-
		Wombala (incl. Sudden Jerk)	3.80	3,242.09	189,657.57	170,265.99	2,922.08
	Bulong	Balagundi	3.51	2,704.70	1,932.19	1,997.61	12.92
		Bulong	1,763.40	10,137.70	129,582.78	104,869.45	0.32
		Majestic	42.88	218.49	2,980.03	1,360.45	-
		Mt. Monger	215.60	2,771.39	1,816.90	1,564.58	-
		Taurus	114.75	55.58	4,459.95	1,970.70	-
		Trans Find	-	5.93	1,826.67	1,191.28	-
		Wood Line	-	-	792.75	610.57	-
North Coolgardie	Yerilla	Pinjin	-	48.34	17,462.59	10,742.79	-
	TOTALS:		3,048.32	41,012.75	1,533,220.52	974,873.93*	6,409.11

* Average grade 12.6 dwt/ton.

TABLE 7 SUMMARY OF GOLD MINERALISATION

LOCATION	MAIN SOURCE OF GOLD	GEOLOGICAL ASSOCIATION
Gindalbie	Underground mining (1)	Gindalbie Formation: fine-grained clastic and pyroclastic rocks.
Gordon	Underground mining	Transitional zone between Morelands and Gindalbie Formations. Acid intrusive, extrusive and fine-grained clastic rocks; basic intrusive and extrusive rocks.
Kalpini	Underground mining, some alluvial (2)	Kalpini Formation: basic intrusive rocks.
Kanowna	Underground mining, "deep leads" (3), alluvial	Morelands and Gindalbie Formations: Acid intrusive rocks, derived coarse to fine-grained clastic and pyroclastic rocks; basic and ultramafic rocks at Golden Valley 2 miles north of Kanowna.
Mulgarrie	Underground mining	Morelands Formation: Basic intrusive and extrusive rocks.
Six Mile	Underground mining, "deep leads"	Morelands Formation: Basic extrusive rocks.
Jubilee	Underground mining, some alluvial	Kalpini Formation: Basic extrusive rocks, ultramafic intrusive rocks, fine-grained clastic rocks belong to Gundockerta Formation.
Kurnalpi	"Deep leads" alluvial and underground mining	Mulgabbie Formation: Basic extrusive rocks.
Mulgabbie	Underground mining, some alluvial	Mulgabbie Formation: Basic extrusive and intrusive rocks.
Boorara	Underground mining	Mulgabbie Formation: Basic intrusive, extrusive and fine-grained clastic rocks.
Feysville	Underground mining	Mulgabbie Formation: Basic extrusive rocks; acid intrusive rocks.
Wombala (incl. Sudden Jerk)	Underground mining, some alluvial	Morelands Formation: Basic extrusive and intrusive rocks; fine-grained clastic rocks probably in Gindalbie Formation at Wombala.
Balagundi	Underground mining, some alluvial	Morelands Formation: Basic extrusive and fine-grained clastic rocks.
Bulong	Underground mining, "deep leads" and alluvial	Gindalbie Formation: Fine-grained clastic. Morelands Formation: Basic intrusive rocks.
Majestic	Underground mining, some alluvial	Gindalbie Formation: Acid intrusive, fine-grained clastic rocks.
Mount Monger	Underground mining, some alluvial	Morelands Formation: Basic and ultramafic rocks; coarse-grained clastic and pyroclastic rocks of Gindalbie Formation.
Taurus	Underground mining, "deep leads" and alluvial	Gindalbie Formation: Coarse-grained clastic and pyroclastic rocks.
Trans Find	Underground mining	Gindalbie Formation: Acid extrusive rocks, some fine-grained clastic rocks.
Woodline	Underground mining, some alluvial	Gindalbie Formation: Fine-grained clastic rocks.
Pinjin	Underground mining	Mulgabbie Formation: Basic extrusive rocks, fine-grained clastic rocks.

- †1) Underground mining includes free gold won from the oxidized zone at shallow depths (less than 300 feet) and gold obtained from deeper levels in the sulphide zone. Usually the gold mines ceased production when the sulphide zone was reached as it was not economic to mine the gold when it became intimately associated with pyrite, minor chalcopyrite and pyrrhotite. However there were some exceptions; Bulong (Queen Margaret), Kanowna (White Feather), Boorara, Feysville, and Gindalbie.
- (2) Most mining localities have produced some alluvial gold; however this is only mentioned where it contributed substantially to the total production.
- (3) The "deep leads" of the Eastern Goldfields are placer deposits formed under conditions of limited transport of material. They have been worked to depths of over 100 feet at Kanowna and Bulong. They pre-date the laterite and are probably part of a late Mesozoic to early Tertiary drainage system. Descriptions of the "deep leads" are given by Richard (1898) and Blatchford (1900).

TABLE 8 KURNALPI 1:250,000 GEOLOGICAL SERIES - ANALYSIS OF UNDERGROUND WATER

NAME	NO.*	EQUIPMENT	DEPTH OF HOLE	DEPTH OF WATER	QUALITY ppm	REMARKS
<u>GINDALBIE STATION</u>						
* Carr Boyd Well	G1	Windmill	140 feet	132 feet	10,600	Sunk in fresh granite with pegmatite dykes
* Binti Binti Bore	G2	Windmill	160 feet	100 feet	11,600	On drainage, alluvium over D.W. granite
* Comet Well	G3	Windmill	-	-	2,600	On drainage, alluvium over D.W. schist
* Lindsay Bore	G4	Windmill	186 feet	140 feet	7,320	On drainage, colluvium over basic hornfels
<u>YINDI STATION</u>						
X Four Corner Bore	Y1	N.I.U.	130 feet	-	12,000	Colluvium into schists?
* Milky Well	Y2	Windmill	70 feet	65 feet	2,280	On drainage, alluvium
X Borderline Bore	Y3	N.I.U.	150 feet	120 feet	11,010	Clay hardpan over granite
* Christmas Bore	Y4	Windmill	-	28 feet	540	On drainage, alluvium over basic rocks
<u>HAMPTON HILL STATION</u>						
* Hacketts Well	H1	Windmill	-	-	1,110	Basic lavas
* Cables Well	H2	Windmill	-	-	2,550	Basic lavas
* Christmas Well	H3	Windmill	-	-	2,230	Alluvium
* Wyo Well (also Yowie)	H4	Windmill	-	-	8,410	Alluvium, sheet wash over D.W. granite
<u>PINJIN STATION</u>						
X Kurrajong Well	P1	N.I.U.	60	-	11,440	D.W. gneissic granite, on drainage
* Oldfields Well	P2	Windmill	180	160	4,070	Chlorite schists (fresh)
X Ten Mile Well	P3	Windmill	-	-	7,080	Alluvial over D.W. basic rocks
X Bakers Well	P4	N.I.U.	90	73	775	In weathered basic rocks
X 43 Mile Well	P5	N.I.U.	59	42	1,440	Alluvium on D.W. basic rocks
* Gilgarna Well	P6	Windmill	80	-	1,060	Alluvium into siltstone/greywacke
<u>ARCOONA STATION</u>						
* Jocko Bore	A1	Windmill	-	-	2,880	Red sand over hardpan on granite
* Corner Bore	A2	Windmill	-	-	3,860	Yellow brown sand over granite
* Xmas Bore	A3	Windmill	240	-	9,100	Red brown sand over hard pan on granite
X Lords Lease Bore	L1	Windmill	-	-	5,000	Red sand over granite

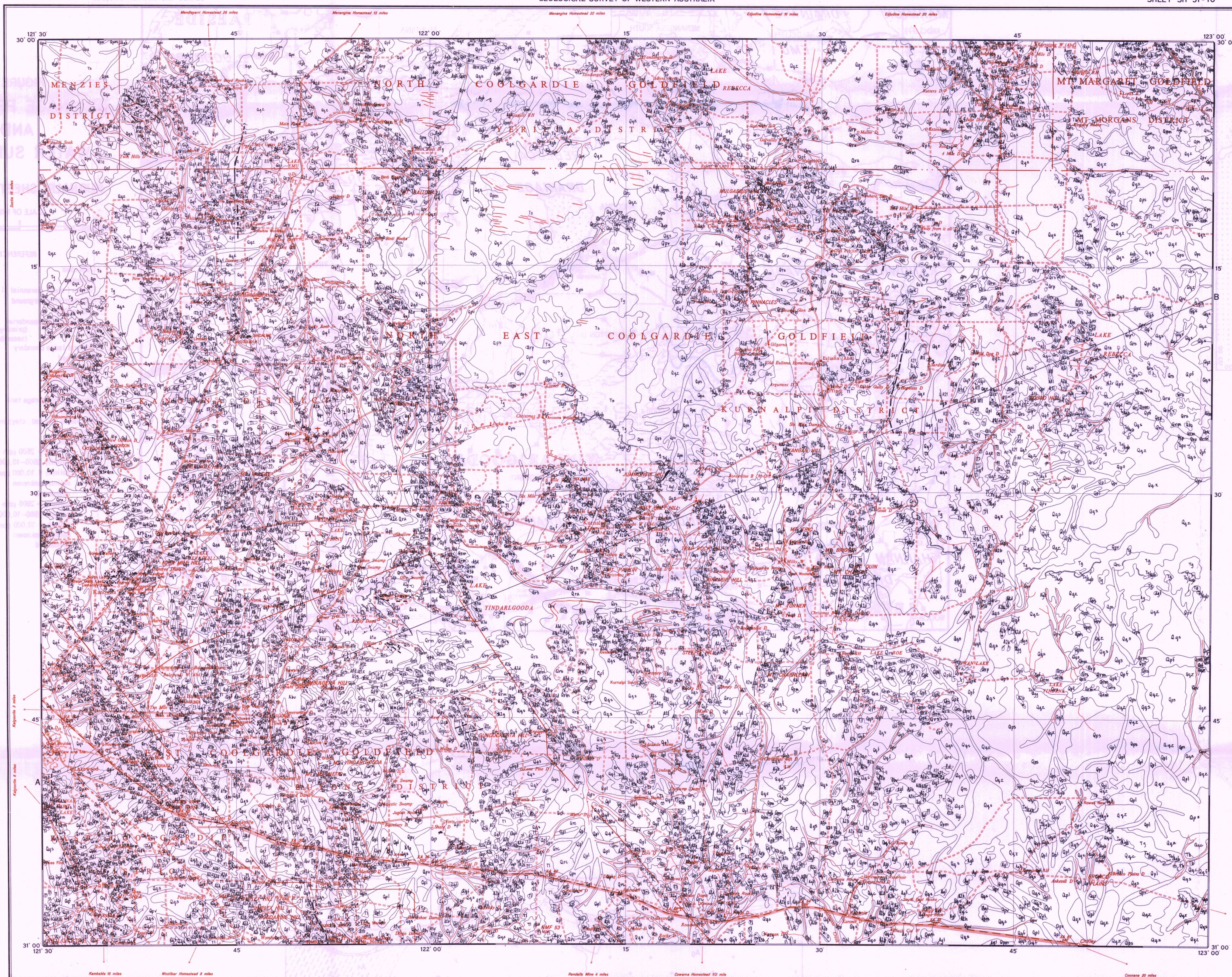
* Partial analysis, Government Chemical Laboratories

X Field determination.

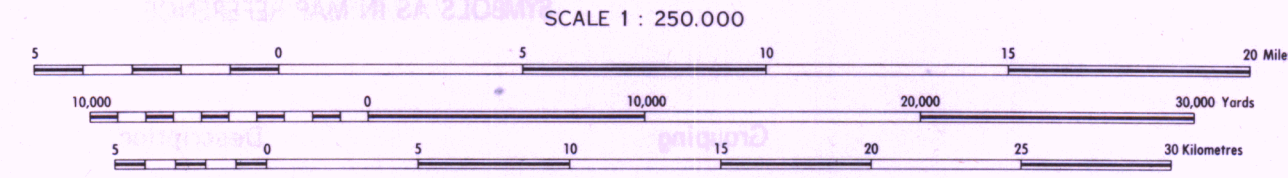
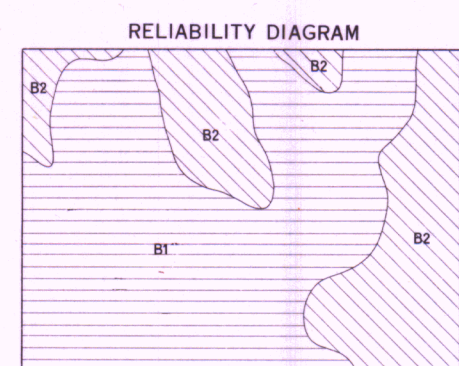
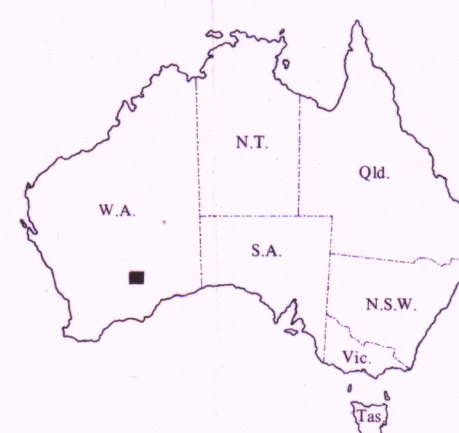
N.I.U. Not in Use

D. W. Deeply weathered

**, Refer to map number

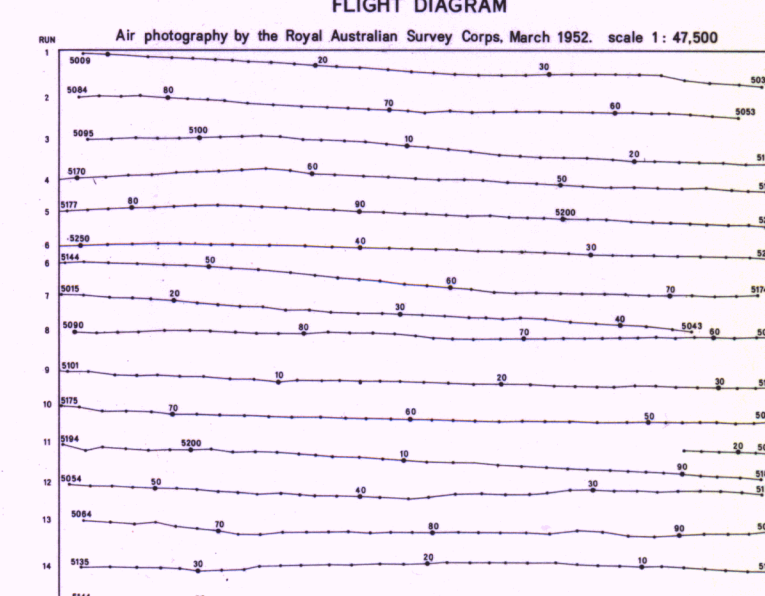
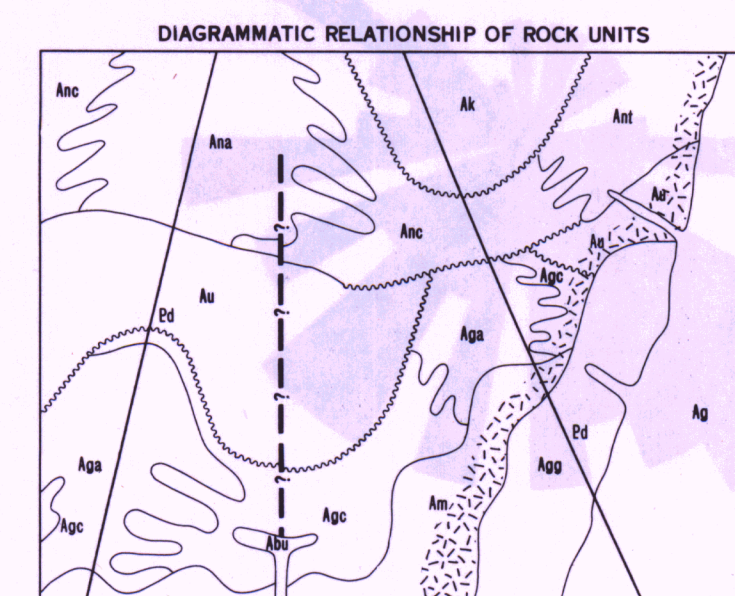
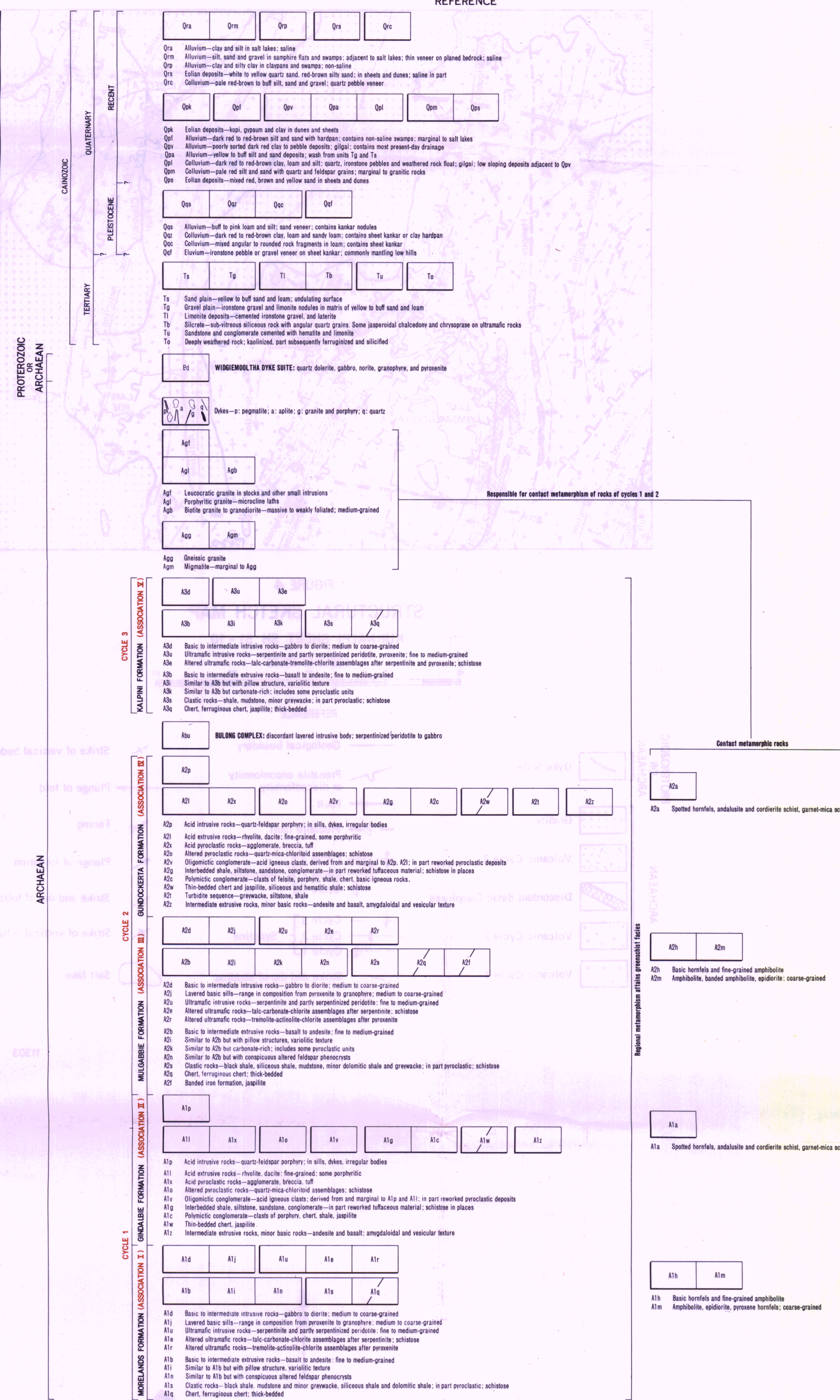
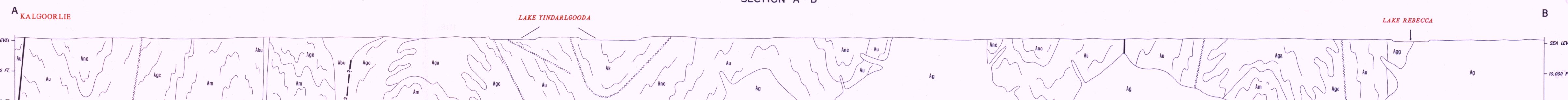


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DIAGRAMMATIC SECTION

SECTION A-B



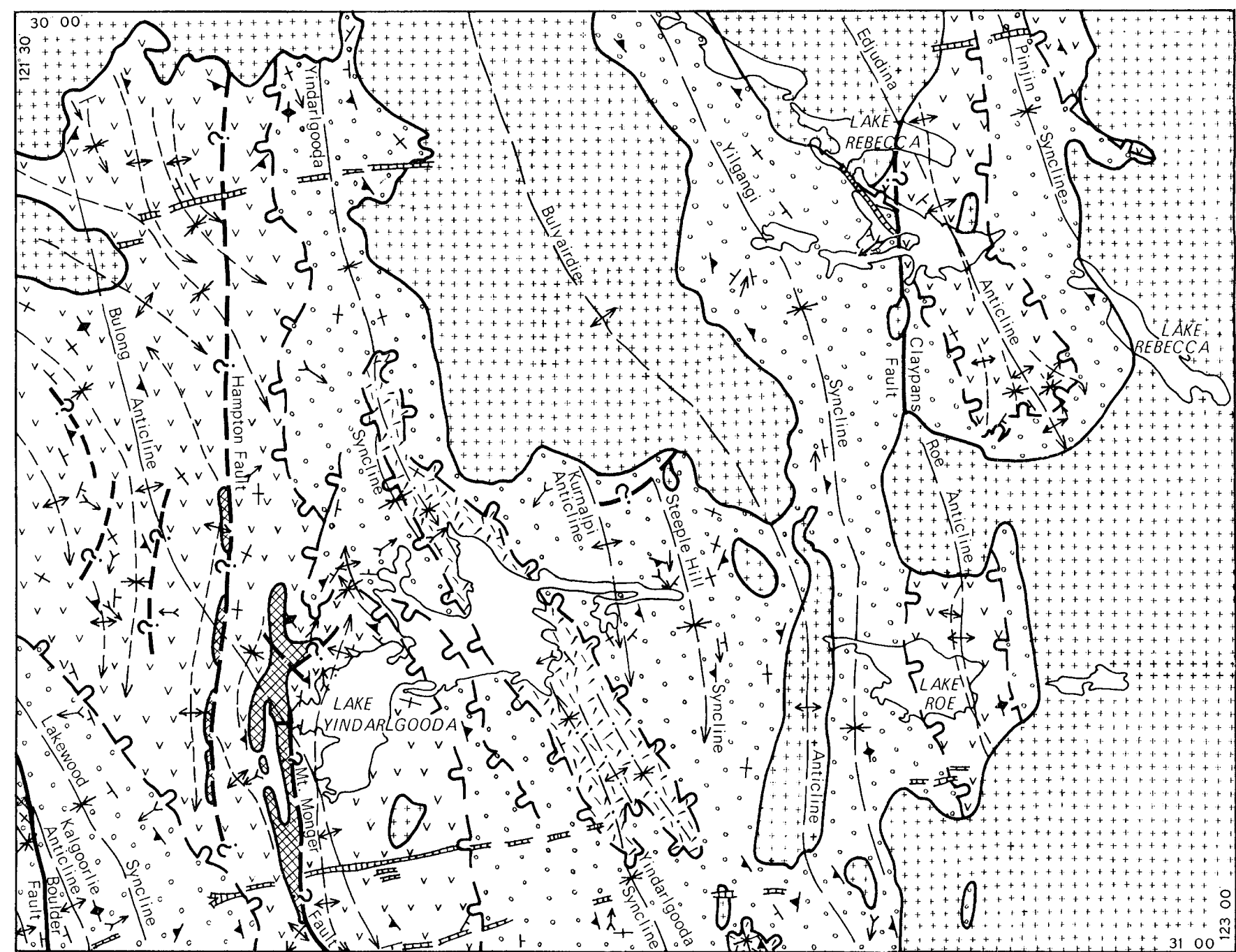
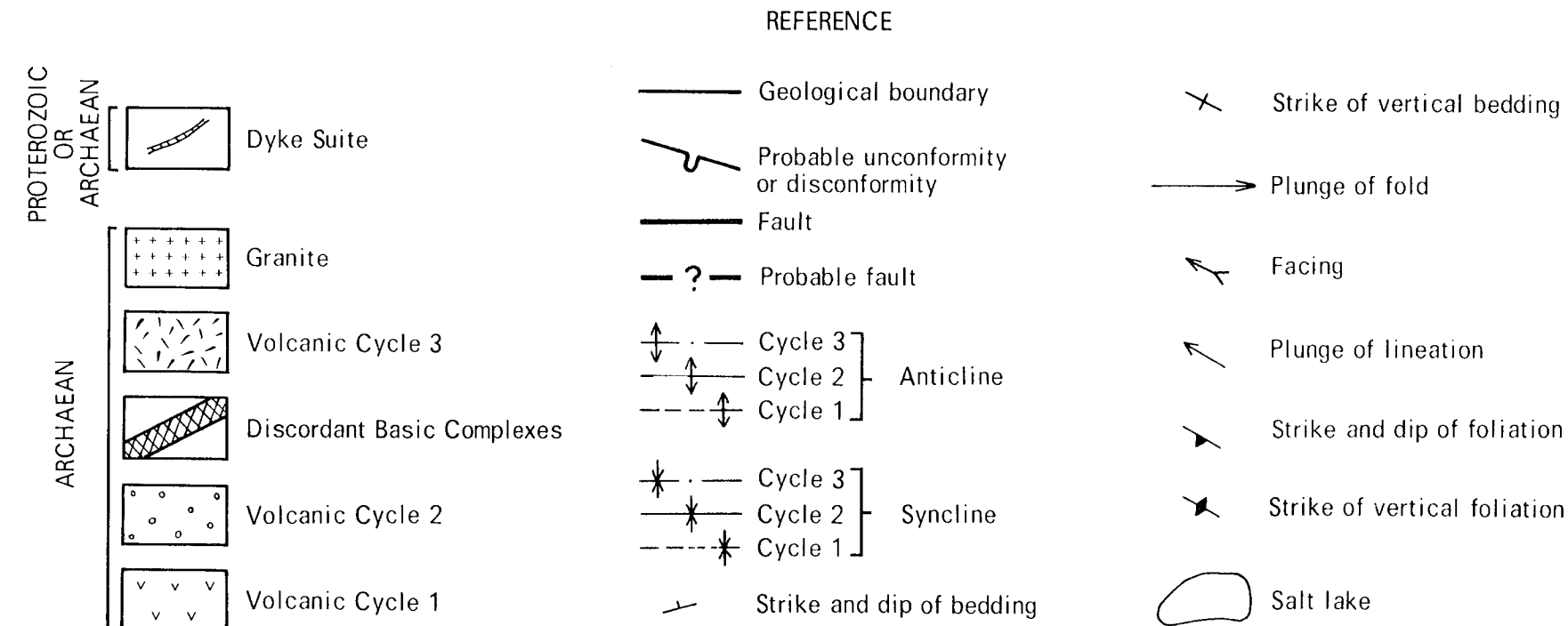


FIGURE 4
STRUCTURAL SKETCH MAP
KURNALPI SHEET SH 51-10

SCALE OF MILES
0 10 20 30



11303

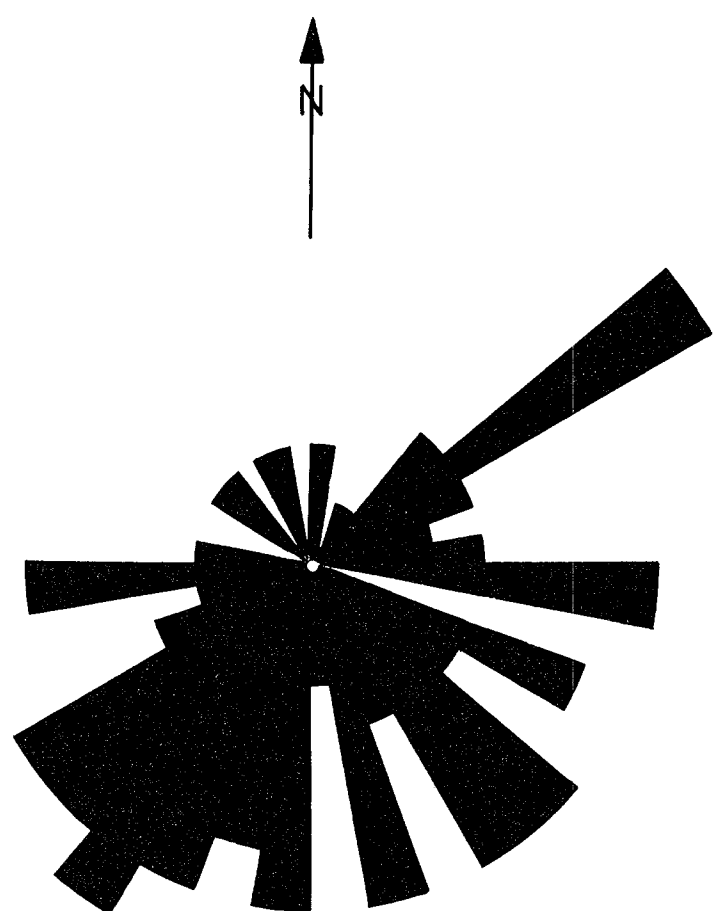


FIGURE 1 ROSETTE DIAGRAM SHOWING DIRECTION OF FACING OF SCARPS (BREAKAWAYS) ON THE KURNALPI SHEET (118 MEASUREMENTS)

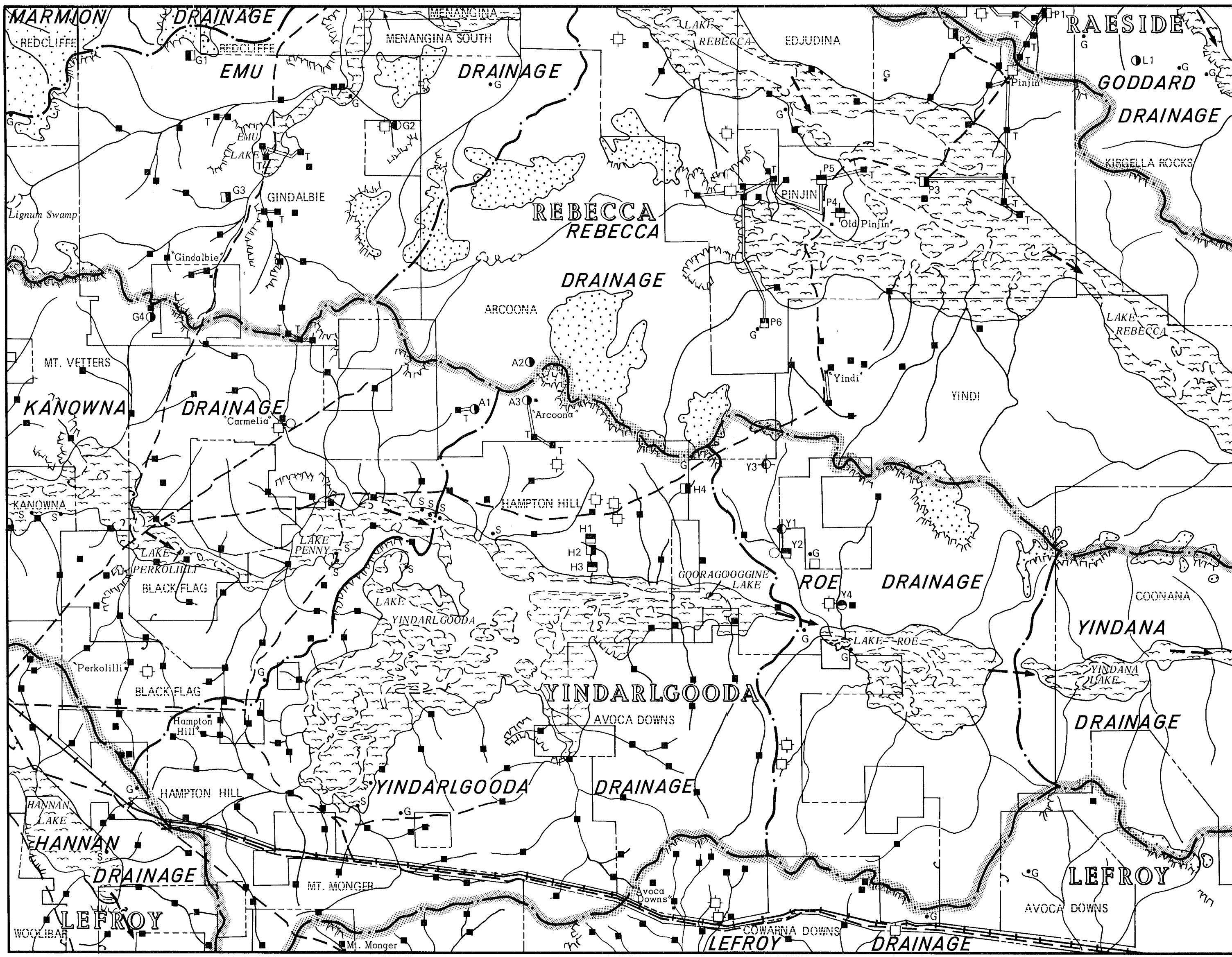
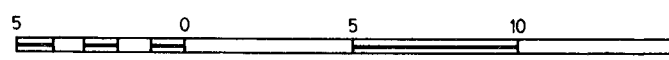


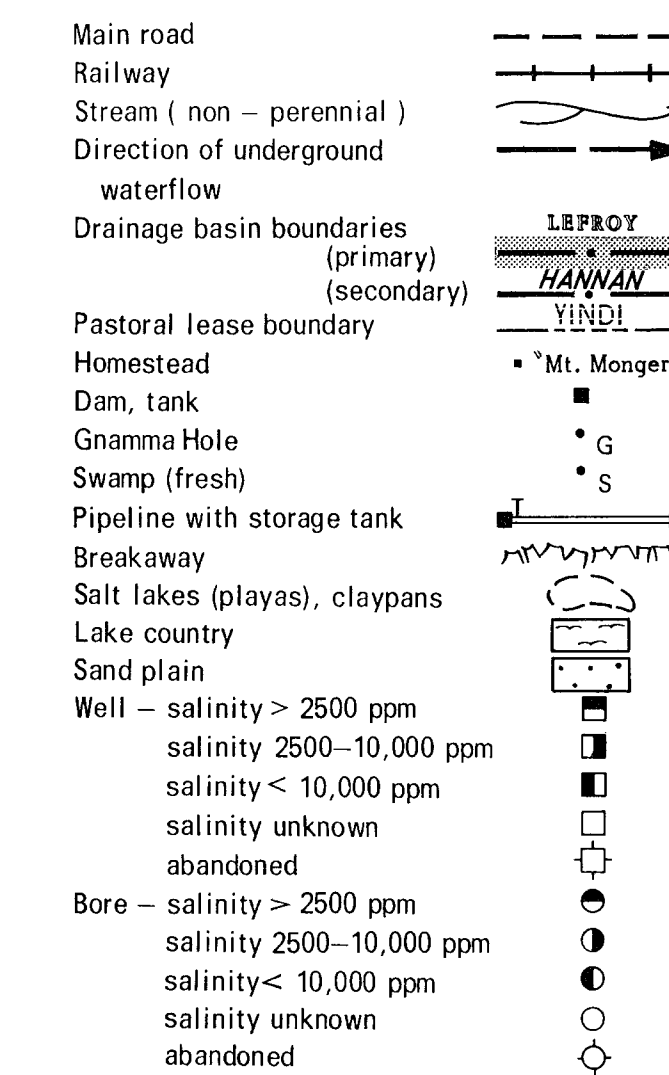
FIGURE 2
DRAINAGE PROVINCES
AND
WATER SUPPLIES

KURNALPI SHEET SH 51-10

SCALE OF MILES



REFERENCE



10778

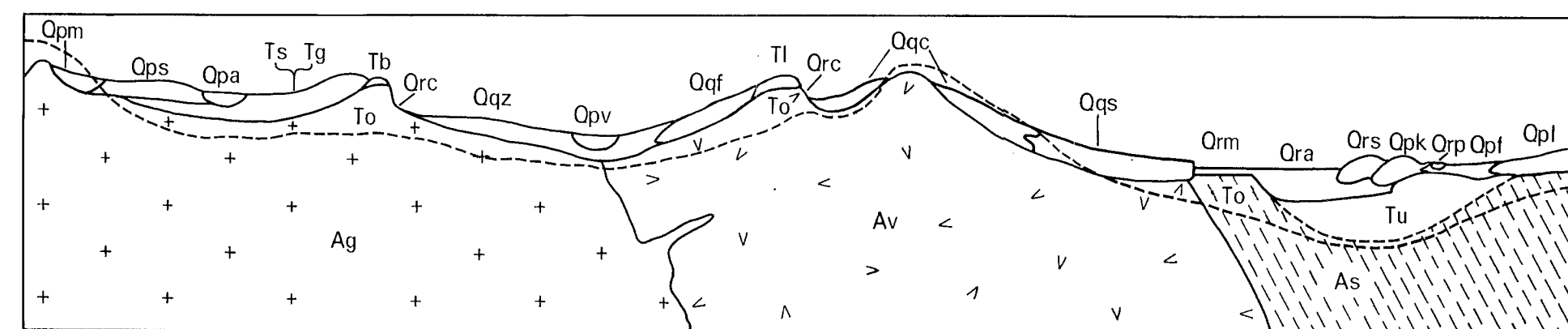


FIGURE 3
CAINOZOIC ROCK UNIT RELATIONSHIPS
KURNALPI SHEET SH51-10

SYMBOLS AS IN MAP REFERENCE.

Grouping	Description
Or	: Alluvium, eolian and colluvium deposits
Op	: Alluvium, colluvium and eolian deposits
Oq	: Colluvium, alluvium and eluvium deposits
T	: Colluvium, alluvium and deeply weathered bedrock
Ag	: Granitic rocks
Av	: Volcanic rocks
As	: Sediments

11189

11309