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

WESTERN AUSTRALIA

by M. Kriewaldt

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INTRODUCTION

The Kalgoorlie 1:250,000 Sheet, SH/51-9 of the International Series, is named after the important gold mining town of Kalgoorlie which is close to the eastern boundary.

The topography of the area is shown in Figure 1. The land surface is generally around 1,300 feet above sea level. In the west sandplains with broad valleys fall to the north and southwest, and in the east low hills with broad valleys lead to lake country. Drainage is by sheet wash and by creeks terminating in playas (dry lakes). Outstanding bed-rock hills such as Mt. Burges, bold granite rocks, low ridges capped by ironstone, sand ridges, and low escarpments (break-aways) interrupt the otherwise gently rolling landscape.

For principal references to published geological work in the Kalgoorlie district see Larcombe (1913), McMath (1953), Simpson (1948 to 1952), and Woodall (1965).

Previous workers in the area include Blatchford, J. D. Campbell, Farquharson, Feldtmann, Göczel, Gustafson, Honman, Horwitz, Jutson, Larcombe, Maclaren, McMath, Prider, Simpson, Sofoulis, Stillwell, Thomson, Turek, Woodall, and Woodward.

The accompanying geological map is largely the work of M. Kriewaldt with additions by R. C. Horwitz and J. Sofoulis.

PRECAMBRIAN GEOLOGY

An interpretation of the geological history of the Precambrian in the Kalgoorlie district is given in Table 1. The overlap in time of the events is shown in Figure 2.

The ages of the Precambrian units were determined by A. Turek at the Australian National University. They were calculated from analyses for Rb and Sr isotopes using a decay constant for Rb^{87} of 1.39×10^{-11} yr^{-1}.

The age of the boundary between Archaean and Lower Proterozoic is 2,400 m.y. (Stockwell and Williams, 1964; Horwitz, 1967), which would be approximately 2,520 m.y. when compared with the Rb-Sr age determined by the Australian National University.

The history outlined in Table 1 differs from that proposed by Turek (1966) by showing the age of gold mineralisation at Kalgoorlie closely following the alteration (dated 2,665 $\pm$ 25 m.y.), instead of being about 2,460 m.y.

To summarise the history in general terms, it is possible that the beginning of the formation of the Kalgoorlie rock assemblage was around 2,800 million years ago; that the main period of tectonism with regional metamorphism and localised metasomatic alteration had ceased 150 m.y. later; and that the final crystallization of intrusive granite with concurrent contact metamorphism took place within the next 50 m.y. (i.e. around 2,600 m.y.). Subsequently there was alteration along pre-existing conduits (at about 2,450 m.y.) and intrusion along tension-release fractures (at about 2,550 m.y. and 2,400 m.y.). Gold mineralisation together with emplacement of associated sulphides and tellurides, took place mainly before 2,600 m.y.

TABLE 1

PRECAMBRIAN GEOLOGICAL HISTORY

(Age determinations from Turek, 1966)

Age (millions of years, with 95% confidence limits)	Events	Map units represented
2,420 ± 30	Intrusion of gabbro dykes and quartz veins; local metamorphism	Pd, Pq
2,460 ± 80	Alteration of sericite in gold mineralisation (NOTE: This event is considered by Turek to indicate the age of the Kalgoorlie gold mineralisation)	not shown
?2,550 ± 160	Intrusion of felsite dykes (reverse polarized)	Az
	Intrusion of pegmatite and aplite; gold mineralisation at Bonnie Vale	Ad
2,612 ± 13	Intrusion of granite, quartz, pegmatite; contact metamorphism	Ag, Agp, Ap, Aq, Am, An
2,665 ± 25	Alteration in disturbed regions; subsequent gold mineralisation and wall-rock alteration	not shown
	Intrusion of Kalgoorlie mine porphyry	part Ay
	Tectonism. Peak of regional metamorphism (mostly greenschist facies)	
2,730 ± 90	Extrusion of felsic lavas and intrusion of sills and dykes of felsic rocks	Ax, part Ay
	Deposition of greywacke, shale, and conglomerate; extrusion of mafic lavas, and intrusions to form mafic and ultramafic rocks, with concurrent alteration; all continuing until after event immediately above.	As, Ao, AΔ, Ab, Av, Avp, Aw, Aʌ, Al, Ah, At, Ar

Structure

The regional trend of the Kalgoorlie district is north to west of north. This is the strike of the axial planes of the prominent folds, of the cleavage and the foliation, and of the longer limbs of the larger folds. The dominant dip of all these features is about vertical. Most of the folds plunge steeply and some fold plunges are overturned. An exception to the steep plunges is the gentle plunge of the main anticline to the east of Kalgoorlie (the Kalgoorlie anticline).

In the Kalgoorlie district, the very obvious regional trend has obscured an earlier trend of geography and vulcanicity during the time of formation of the rocks which were later foliated and disrupted. The paleogeographic trend (Horwitz and others, 1967) was somewhere between what is now northerly and northeasterly.

Several large faults with strikes near to the direction of the regional fold axes have been recognized near Kalgoorlie. Younger faults cut across the regional strike. Preferred mineral orientation is not known in most of the granite.

Structural interpretation

Five primary structural layers have been interpreted in the Kalgoorlie Archaean; two of the layers (the Kalgoorlie and Ora Banda layers) are predominantly altered mafic and ultramafic igneous rocks, and the other three layers contain metamorphosed shale and greywacke and also granite. The five layers are:

5. metamorphosed shale and greywacke, granite
4. altered rocks of flows and sills (Ora Banda layer)
3. metamorphosed shale and greywacke, granite

2. altered rocks of flows and sills (Kalgoorlie layer)

1. metamorphosed shale and greywacke, granite.

The structural interpretation and rock relationships are given in Figure 3 and on the 1:250,000 map.

The successions at Coolgardie and Kalgoorlie are interpreted as being parts of the one primary structural layer folded in a large syncline (the Kurrawang syncline), which has a nose to the northwest at Mt. Carnage. A probable northern extension of this syncline has an east limb through Wongi Hill, and a west limb through Davyhurst.

An anticline lies between Coolgardie and Bullabulling. The east-facing limb at Coolgardie passes northwards through Kunanalling, to the south of Carbine around a north-plunging nose, and to the west-facing limb through Jaurdi Hills and Coondarrie.

The interpretation of the area between Bullabulling and Ryans Find is based on aeromagnetic maps. Northwesterly from Bullabulling a magnetic high extends to the west of Callion with no outcrop of Archaean rocks along most of this high. It is flanked to the west by granite outcrops. The structure beneath the high is interpreted as a south-plunging anticline. To the west of Callion the north end of the east limb of this anticline dips 60^{o} to the east, and there is a nose of this fold to the southwest of Callion. The north end of the west limb of this anticline has been placed to include a small outcrop of banded iron formation 21 miles to the west of Callion.

An anticline is interpreted between the successions of amphibolites and banded iron formations at Ryans Find and Coorara Soak. No direct facing evidence has been seen to support this interpretation.

This structural interpretation shows that granite is present in three structural layers, and that the Ora Banda structural layer is higher than the Kalgoorlie layer.

The structural layer at Mt. Jewell and the layer further to the northeast are shown in the interpretation as being part of the lowest unit and to be west-facing. However, it could well be that both these layers are east-facing and that the rocks at Mt. Jewell are part of layer 2.

Metamorphosed sedimentary rocks

The Kalgoorlie Archaean includes thick sequences of slate, phyllite, cleaved greywacke, and other metamorphosed sedimentary rocks. Metamorphic biotite is common in these rocks.

Close resemblances (of twinning, inclusions, grain size, and weathering) between albite clasts in the greywacke and albite crystals in associated porphyritic felsite have been noted by Trendall (1964).

Various schists have been formed from the sedimentary rocks. Examples are quartz-feldspar schist, quartz-mica schist, andalusite schist, and biotite-sillimanite schist.

Toward the bottom of the sedimentary succession thin layers of pyritic, carbonaceous slate and phyllite are commonly intercalated between basalt lava flows. Many of these pyritic beds are oxidized near the ground surface, and the outcrop is a banded jasper.

Banded chert, ferruginous chert, jaspilite, and jasper weathered from rocks containing varying proportions of magnetite, pyrite, iron silicates, and quartz (or chert) are present at Ryans Find, Coorara Soak, and west of Callion. In these areas the beds lie within assemblages of amphibolites derived from basalt lava flows and sills of dolerite and gabbro. Ferruginous cherts east of Goongarrie are interbedded with greywacke, intercalated with altered mafic rock (lavas and sills), and intruded by serpentinite sills.

At several levels within the sedimentary succession there are conglomerates with felsite clasts in a greywacke matrix. In places the conglomerates grade into breccias. These monoclastic rocks have their provenance in felsite flows.

Toward the top of the stratigraphic pile there are beds of polymictic conglomerate with clasts of quartz, quartzite, jaspilite, and felsite.

Metamorphosed extrusive rocks

Intercalated within the sedimentary succession is an assemblage of altered felsic lava flows, with associated flow breccias, agglomerates, and tuffs. Most of the felsites are light-coloured, although some are blue. Many are porphyritic, with small phenocrysts of quartz or feldspar. Others have hornblende phenocrysts or pseudomorphs of chlorite after hornblende and appear to be andesites.

Basalt lava flows have been recognized by pillow structures, flow breccias, and variolitic textures. The basalts have been metamorphosed to fine-grained amphibolites. Some have large feldspar phenocrysts. The flows interfinger with the sedimentary beds.

Metamorphosed intrusive rocks

Intruding the layered succession of sedimentary and extrusive rocks are sills of felsic, mafic, and ultramafic rocks. Commonly the sills are intruded at the junctions between flows as marked by thin beds of black phyllite.

The mafic rocks are now medium-grained amphibolite derived from gabbro and from quartz gabbro, and fine-grained amphibolite (from dolerite and quartz dolerite). The tops of some of the sills of mafic rock are granophyres with long blades of amphibole in a granophyric groundmass. The bottoms of the sills are in places a felted, meshed aggregation of acicular amphibole. Where the amphibole rocks are sheared and altered, chlorite schist and talc schist are developed.

There are many sills of serpentinite derived from peridotite in the succession. Most of the serpentinites are blue, fine-grained, hard and dense rocks, but in some the peridotite texture is easily seen.

Also present in sills is another ultramafic rock type, an amphibole-chlorite rock which has a distinctive chevron pattern in hand specimen. Possibly these amphibole-chlorite rocks were derived from pyroxenite.

Felsic rocks, very similar to the felsic flow rocks mentioned earlier, are present as dykes and sills. The oldest of these are probably feeders for the felsic flows.

Unconformities

Breaks in the record of formation of the layered succession are indicated by unconformities at several localities; one instance, at the northwest end of Brown Lake a body of porphyritic felsite is overlain by greywacke with a basal breccia of felsite. Similar occurrences can be seen by studying map units 'Ax', 'Ao' and 'AΔ'.

An angular unconformity is indicated near the Banham and Surprise mines (southeast of Coolgardie) by the termination along strike of bodies of amphibolite and ultramafic rocks against unconformably overlying sediments.

It is possible that these unconformities have more than a local significance and could be connected with a structural break in the sequence truncating a previously folded sequence.

Granite and related rocks

Rocks ranging in composition from granite to tonalite are present in large intrusive bodies which are extensive in structural layers 1, 3, and 5 in the west, and restricted mainly to layers 1 and 3 in the east. Most of these rocks are even-grained with a medium grain size, and are light-coloured. Muscovite, biotite, and in some instances chlorite are present. There is a porphyritic facies near Smithfield, gradational into the even-grained variety. Granites at Mungari and Bullabulling have contact metamorphic aureoles.

Pegmatite dykes of quartz and feldspar are common through the granite. Pegmatites at Coondarrie have lithium minerals. Quartz veins are common through the metamorphosed rocks. Two dykes of porphyritic felsite, one at Binduli and the other north of Kalgoorlie, are probably younger than the granites and pegmatites.

Cross-cutting dykes

Several small outcrops of dolerite in cross-cutting dykes have been mapped in the area. The largest of these is at White Flag Lake. A large cross-cutting quartz dyke is present south of this dyke.

CAINOZOIC GEOLOGY

Surface materials in the Kalgoorlie district are grouped together according to their relative ages as follows:

Age	Type	Map Symbol
Recent	Fluvial and eolian deposits	Qr
Recent	Eolian and fluvial deposits	Qa
Pleistocene	Mostly fluvial deposits with some eolian	Qp
Pleistocene	Fluvial and eolian deposits, and soils	Qq
Pleistocene	Hardened weathered rocks, fluvial deposits, and soils	Qt
Pleistocene or Tertiary	Fluvial deposits	Qu
Tertiary	Deeply weathered rocks and laterite	To
Tertiary (Eocene)	Continental deposits	Te

Rock relationships are given in Figure 4.

Tertiary sediments

Upper Eocene continental deposits, up to 400 feet thick, fill a small basin about 1½ miles southeast of Coolgardie. These are covered by younger alluvium. Plant fossils from these Tertiary deposits have been described by Balme and Churchill (1959).

Tertiary weathering

Many of the basement rocks are deeply weathered. It is thought that the deep weathering took place during the early part of the Tertiary period. Commonly the rocks are weathered to a depth of 30 feet or so; and in some places to more than 200 feet below the present land surface. Only a few remnants of primary laterite remain above the deeply weathered rocks.

Pleistocene or Tertiary sediments

Several small deposits of conglomerate and white clay, older than the bulk of the surface deposits of the Kalgoorlie district but younger than the time of deep weathering, are thought to be Pleistocene, although they could be as old as Tertiary.

One type of conglomerate of this age contains quartz pebbles and ironstone gravel with a ferruginous cement. Another type has only quartz pebbles and does not have a ferruginous cement. Quartz pebble conglomerates at Paddington and Kintore carry alluvial gold.

In places the conglomerates are overlain by white clay deposits, presumably derived from deeply weathered rocks. Some of the white clay deposits grade upwards into deposits with ironstone gravel. Others are overlain by younger alluvium.

Old weathering products and deposits

Some of the deeply weathered rocks have been exposed by erosion, and subsequently hardened by silicification in some places, and by ferruginization in others. The exposure and hardening is mostly an old feature, although the same process has taken place at more than one time.

Jasper is present as a rubble lag on the top of fresh serpentinite. It is thought that the jasper formed as veins and fillings within weathering serpentinite. A common associate of this jasper is magnesite. Where the serpentinite has sufficient nickel or chromium, chrysoprase has been formed in a similar manner.

Silicification and ferruginization have taken place also in deposits eroded from deeply weathered rocks. For instance some silcrete near Ryans Find incorporates a conglomerate.

There are many deposits of limonite-cemented ironstone gravel (detrital laterite) in the Kalgoorlie district. Sheets of kankar limestone are common in the bottom part of these deposits.

Covering large areas in the west of the Kalgoorlie sheet is a yellow sandy loam containing limonite-cemented nodules. Some of these nodules have formed around the cocoons of insect larvae. In general, this material overlies deeply weathered rock, but in places it is separated from the deeply weathered rock by deposits of conglomerate and clay. It is thought that the sandy loam and ironstone were formed in deeply weathered rocks and in material eroded from deeply weathered rocks; but after the time of deep weathering.

Kankar deposits

There are several types of deposit in the Kalgoorlie district that contain kankar limestone in sheets or in nodules. One detrital laterite with a basal kankar cement was mentioned earlier. These kankar-bearing deposits occupy a position in time between older ferruginous materials and younger alluvial deposits. They are thought to be Pleistocene.

Deposits of loam, with ironstone gravel veneer and sheet kankar beneath, mantle low ridges. Much of the ironstone is magnetic. Surface wash and wind winnowing have concentrated the ironstone gravel as a lag deposit. Some gravel has become cemented in the sheet kankar.

In the North Coolgardie Goldfield there is a red to brown loam to sandy loam with a compact hardpan layer near the surface. In some places this layer is sheet kankar, and generally directly beneath the hardpan is kaolinized granite. Black stains of manganese minerals are common on the layer.

Bordering many ridges of fresh bedrock in the area of the Kalgoorlie Sheet there are colluvial and alluvial deposits cemented with sheet kankar. The parts closest to the ridges are in most instances covered by a younger colluvium washed from the ridges, but unlike the older deposits this younger material is not cemented.

Kankar nodules are abundant in old valley fills and wind-blown deposits of buff to pink loam.

Younger Pleistocene deposits

Many of the broad valleys in the Kalgoorlie Sheet area are floored with younger Pleistocene alluvium. The alluvium consists of clays, loams, and gravels, and is up to 50 feet thick. Shells of land snails are present in these deposits 12 miles northerly from Coolgardie.

Other younger Pleistocene deposits are:

1. yellow sand and loam washed from the older deposits that contain limonite nodules

2. washes of quartz and feldspar from felsic rocks (usually granite)

3. low-lying deposits of sand and loam derived largely from granite washes by further weathering

4. veneers on old pediment erosion surfaces.

Recent deposits

Two groupings of Recent deposits have been recognized in the Kalgoorlie district.

The oldest of these are eolian deposits of kopi (impure gypsum) which interfinger with sheet deposits of saline sand and silt. The kopi was blown from desiccated surfaces of old playas. Possibly of the same age as the kopi deposits are sand ridges on the deposits of yellow sandy loam that contain limonite nodules, and sand ridges on some kankar nodule deposits.

Younger than the kopi and saline sheet deposits are:

1. deposits of silt and clay with gypsum and halite in playas
2. veneers on pediments cut into weathered rocks to the west of playas, and on the western side of playa floors
3. fluffy saline deposits of sand, silt, and clay bordering playas
4. dunes and sheets of white and yellow quartz sand, mainly on the eastern side of playas
5. claypan deposits
6. alluvial deposits in aggraded channels and old claypans.

ECONOMIC GEOLOGY

Gold

Gold has been mined at Kalgoorlie district for nearly 75 years. At present about 2 million tons of ore are mined each year for the production of some 500,000 oz of gold, worth about $A20 million. Reserves are being maintained at around 12 million tons averaging 4 dwt per ton.

In all about 40 million oz of gold have been produced from within the area of the Kalgoorlie Sheet; over 30 million oz have come from Kalgoorlie and Boulder (Table 2).

The principal mining centres of the Kalgoorlie Sheet are shown on Figure 5.

Gold in the Kalgoorlie district occurs mostly along shears and tension fractures through the country rock, either as replacements or in veins, commonly in ultramafic rocks. Gold-quartz mineralisation occurs in granite at Bonnie Vale. Maclaren and Thomson (1913) and Ward (1950) noted that much of the gold mineralisation is located near or within intrusive 'porphyries'. Gold is known also from altered basalt pillow lavas. The gold mineralisation at Kalgoorlie has long been known to be mainly within the rock body now called the Golden Mile Dolerite.

Variable quantities of pyrite, galena, sphalerite, pyrrhotite, arsenopyrite, scheelite, and tourmaline are present in some of the gold ores. There is remarkably little silver in most occurrences of gold ore except in the Golden Mile ore in which the ratio of gold to silver is 6 to 1 (see Table 2).

Practically all the tellurides of the field are restricted to the Golden Mile, apart from some at Ora Banda. The Golden Mile is at the centre of a zone of gold-bearing rocks that extends at least 10 miles, from Hannan Lake to the North End. Throughout this zone, and particularly evident at the North End, the gold is in quartz veins filling tension fractures; the adjacent country rock is bleached and contains conspicuous pyrite crystals up to 2 mm across. In the Golden Mile, the gold-quartz mineralisation is swamped by gold-telluride mineralisation as replacement lodes along shears in the Golden Mile Dolerite. The wall rock bordering the lodes is bleached, and contains small crystals of pyrite. Tellurides from the Golden Mile (Boulder Belt) have been described by Stillwell (1931).

It was suggested by Simpson (1902) that sulphides at Kalgoorlie were concentrated into lode channels from the country rock. Chewings (1896) had considered a similar origin for the gold. A distinction between gold mineralisation in areas of intense metasomatism and in areas of slight metasomatism has been drawn and maintained by Prider (1945, 1965), along with the corollary that the first type is related directly to the parent magma of the host rock, whereas the second type is related to granite. Campbell (1965) states

TABLE 2

KALGOORLIE SHEET SH/51-9

Summary of reported gold and silver production to December 1963 (approximate figures)

		Alluvial Fine oz	Dollied and specimen Fine oz	Tons Treated	Gold recovered Fine oz	Silver recovered Fine oz
North Coolgardie Goldfield	*Ularring District	130	7,200	530,000	444,000	22,000
Broad Arrow Goldfield		22,000	28,000	1,370,000	744,000	5,000
North-east Coolgardie Goldfield	*Kanowna District	107,000	14,000	1,010,000	627,000	3,000
East Coolgardie Goldfield	*East Coolgardie District	34,000	41,000	84,000,000	36,000,000	5,600,000
Coolgardie Goldfield	*Coolgardie District	17,000	19,000	3,000,000	1,530,000	49,000
	Kunanalling District	1,500	5,800	365,000	253,000	760
Yilgarn Goldfield (within area of Kalgoorlie Sheet)		-	-	-	-	-
Kalgoorlie Sheet SH/51-9 (approximate figures)		182,000	115,000	90,300,000	39,600,000	5,680,000

Note: * Partly outside area of Kalgoorlie Sheet that: "Due to the predominance of granitic rocks, there is inevitably a close association of gold mineralisation with granitic contacts, but this relationship is generally so close as to seem more than accidental".

Other minerals

Apart from gold there has been very little mineral production from within the area of the Kalgoorlie Sheet.

Lithium pegmatite minerals have been mined at Coondarrie, and magnesite from Coolgardie. A few parcels of copper minerals have been shipped from Goongarrie and from east of Mt. Pleasant.

Clays, sands, and stone from several localities are used industrially and for construction work. There is a shortage in the Kalgoorlie district of easily exploitable sand for concrete work.

Small quantities of semi-precious stones, including chert, jasper, and chrysoprase, have been produced. Good quality precious opal occurs about three miles northeasterly from Coolgardie in fractures in carbonaceous phyllite and vein quartz.

For further information on Kalgoorlie minerals see Kalix and others (1966), Maclaren and Thomson (1913), McLeod (1965), and Simpson (1948 to 1952).

Prospecting recommendations

The search for nickel and other base metals is now overshadowing gold prospecting in the Kalgoorlie district. The best places to look for either gold or nickel in the district are in the areas of the old gold mines and gold shows. The search for base metal sulphides (including those of nickel) in the Kalgoorlie district need not be restricted to the neighbourhood of serpentinite, but should be extended throughout the areas containing intrusive bodies of ultramafic and mafic rocks, in the country rock adjacent to these intrusions, and also even in the sills and dykes of felsic rocks. First priority in nickel exploration should be given to examining the bottoms of serpentinite sills; in particular where the serpentinite is folded into the country rock.

Chrysoprase, a green chalcedony, weathers from nickeliferous serpentinite and forms a rubble on them. It shows that there is nickel in the serpentinite, but is not necessarily an indicator of sulphide mineralisation.

Various investigators have recommended particular areas within the Kalgoorlie district for gold prospecting. For examples see Gray and Ward (1953). Others have emphasized various controls considered useful in the search for gold; such as the type of host rock, the rock associations, and the structural setting. Particularly, the concept of looking for gold along cross-fold axes has been recommended and used with some success. A prospecting guide is given in Table 3.

Underground water

Wells, bores, soaks, and gnammas are shown in Figure 1, along with surface drainage basins and directions of movements of underground water. Average annual rainfall is about 10 inches.

At present there are some 20 bores and wells within the Kalgoorlie Sheet area that are being used for watering sheep. The prospects of getting good quality underground water in large supplies are very small.

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TABLE 3

KALGOORLIE SHEET SH/51-9

PROSPECTING GUIDE

Map Unit	Description	Comments
Qra	Playa ('dry lake') sediments	Gypsum and halite present in playas. Not economic
Qrb	(a) Veneers on pediment (b) Eolian sand (c) Creek sand and gravel	Gold-bearing bedrock exposed in places Some is suitable for foundry use Some is suitable for concrete
Qas	Sand	Only some is suitable for concrete. The section beneath is worth testing to bedrock for non-metallic materials and deep leads
Qak	Kopi deposits	Millions of tons of impure gypsum
Qpv	Valley fill alluvium	Alluvial gold rare in these deposits; some useful for brick clay. Sites for earth tanks for water storage. The section beneath these deposits is worth testing for non-metallic materials and deep leads
Qpa	Slope wash deposits	Alluvial gold found in places close to bedrock. Sites for earth tanks. Some suitable sites for stock water.
Qpy	Veneers on deeply weathered bedrock	Bedrock exposed in places. Eluvial and alluvial gold in these deposits
Qpm	Gritty sands near granite	Shallow soaks for water near granite rocks
Qps	Yellow sand and loam	Some sandy parts are suitable for concrete
Qqs	Loam with hard kankar (limestone) nodules	Suitable for road formation. Some has been burnt for lime. The section beneath these deposits is worth testing for non-metallic minerals
Qqf	Ironstone gravel with sheet kankar ('cement')	Suitable for road gravel. Some gold is found above and below and in the sheet kankar

TABLE 3 (continued)

Qqq	Kankar cemented alluvial and colluvial gravel	Some gold found in these deposits. Suitable for road formation. Magnesite in places near ultramafic rocks
Qts	Yellow sandy loam	Mostly not suited for concrete. Bore sites for stock water in some places within this sandy material
Qtg	Ironstone gravel	Suitable for road formation
Qtl	Limonite cemented ironstone gravel (detrital laterite)	Some gold found in the nodules and some in the matrix
Qtb	Jasper with chrysoprase over serpentinite	Chrysoprase indicates nickel but not necessarily sulphides. Jasper can disguise gossan. Some small pieces of tiger eye (silicified, ferruginised chrysotile cross fibre)
Qu	(a) Quartz pebble conglomerate (b) White clay	Alluvial gold in deep leads of this conglomerate Possible use as earthenware clay
To	Deeply weathered rock	(a) Most of the shallow gold workings of the field are within the zone of deep weathering of gold lodes (b) Where primary laterite cap is present over gold lode, gold can be incorporated in the laterite (c) Surface nickel deposits (nickeliferous ochre, garnierite) can be looked for in deeply weathered serpentinite and in their neighbourhood (see units Qtb and Ar) (d) Opal can be looked for in this material especially where cut by fractured quartz veins (e) Some use as industrial clay. Kaolin and Halloysite (f) Some use as building freestone (g) Small deposits of alunite known in this material (h) Many gnamma holes are formed in hardened deeply weathered rock
Te	Continental deposits at Coolgardie	Small quantity of poor quality brown coal. No economic value. Possibility of further Tertiary deposits beneath parts of units Qas, Qpv, Qqs, ~~Qts~~, and Qtg
Ap	Pegmatite	Pegmatites, especially those through metamorphosed mafic rocks can be prospected for lithium minerals. Small quantities of columbite and cassiterite have been found
Aq	Quartz	Many quartz veins carry gold. Others are barren
Ag	Granite	Used as building stone. Can be searched for molybdenite (traces at Bullabulling)

TABLE 3 (continued)

Ay	Felsite sills and dykes	Many of these are gold bearing and many carry sulphides. Good prospecting country for gold
Ats	Talc schist	Talc deposits could be found in these rocks
AA	Medium-grained amphibolite	Host rock for most of the Kalgoorlie gold mineralisation including tellurides
At	Acicular amphibole rock	Host rock for much of the gold and sulphide mineralisation at Coolgardie
Ar	Serpentinite	(a) Carries traces of nickel (see unit Qtb and To). Sulphides can be looked for particularly on the bottom contact of serpentinite sills (b) Poor quality asbestos-slip fibre and cross fibre known (c) Magnesite in weathered material
As	Cleaved shale and greywacke	Deeply weathered shale and greywacke has been used for brick clay
Ak	Conglomerate	Use as decorative stone
Av, Avp	Fine-grained amphibolite	Host rock for some gold
Ab	(a) Jaspilite	Iron deposits in the weathered portion of jaspilite and in the associated Cainozoic canga
	(b) Black pyritic slates with jasper cap	Many small gold workings in jasper-capped black slates, especially where intruded by porphyritic felsite sills. The slates are commonly intercalated between lava flows which have been intruded by sills of mafic and ultramafic rocks. Gold is found in all these rocks, and the slates give a good line to follow. Opal can be looked for in this material where shattered and in and below the zone of deep weathering

FIGURE 1
KALGOORLIE SHEET SH51-9
DRAINAGE BASINS

FIG 2

KALGOORLIE SHEET SH 51–9

PRECAMBRIAN GEOLOGICAL HISTORY

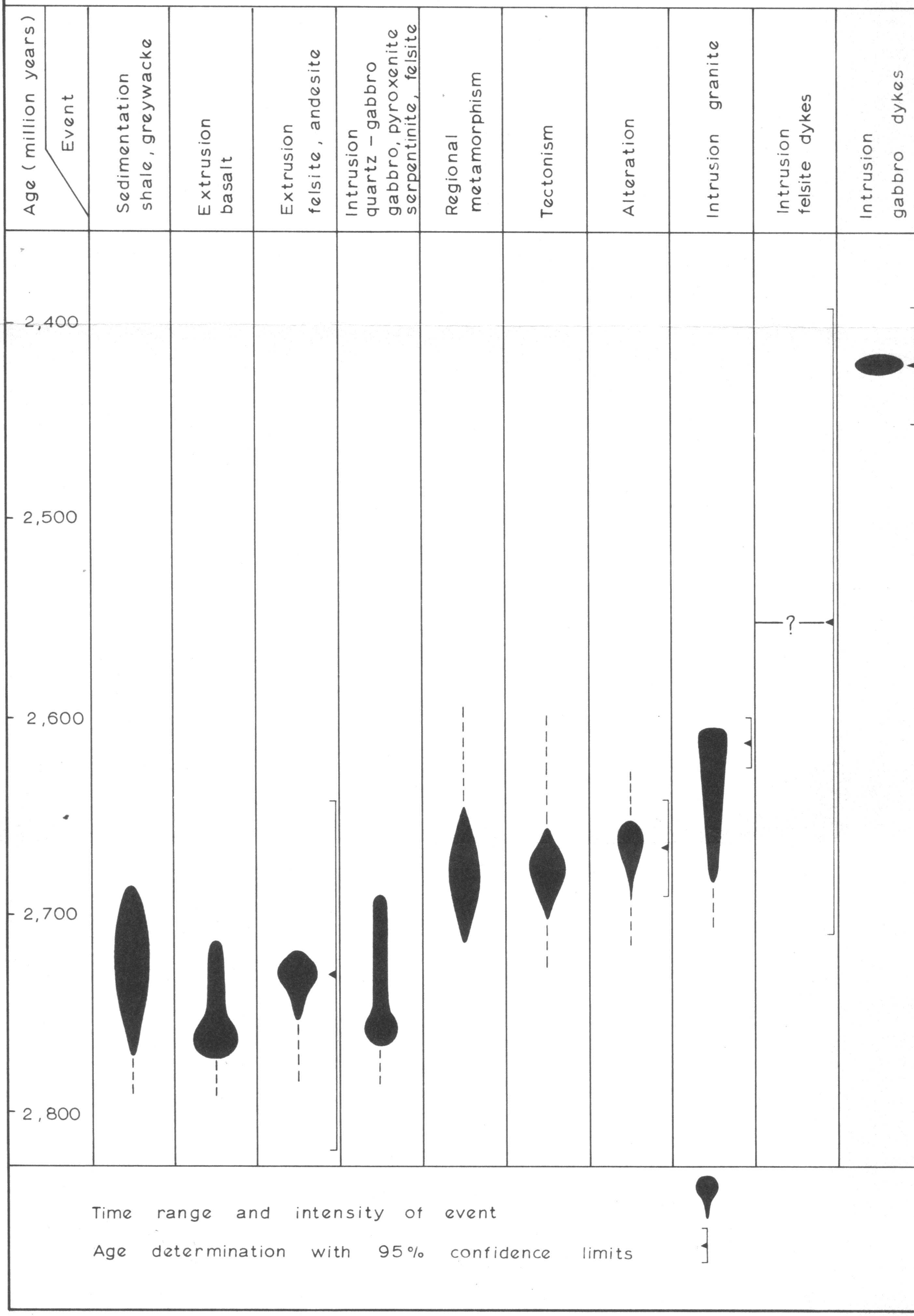


FIGURE 3

KALGOORLIE SHEET SH 51-9
STRUCTURAL INTERPRETATION

Scale
10 0 10 20 30 MILES

STRUCTURAL LAYERS

Cross-cutting magnetic anomalies

positive +

negative -

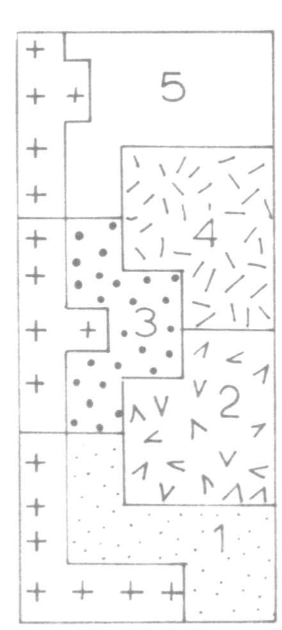
Folds

syncline

anticline

Boundaries

Interpreted facing ⇒



Ora Banda layer

Kalgoorlie layer

+ Granite

1,3,5 Metamorphosed shale and greywacke

2,4 Altered rocks of flows and sills

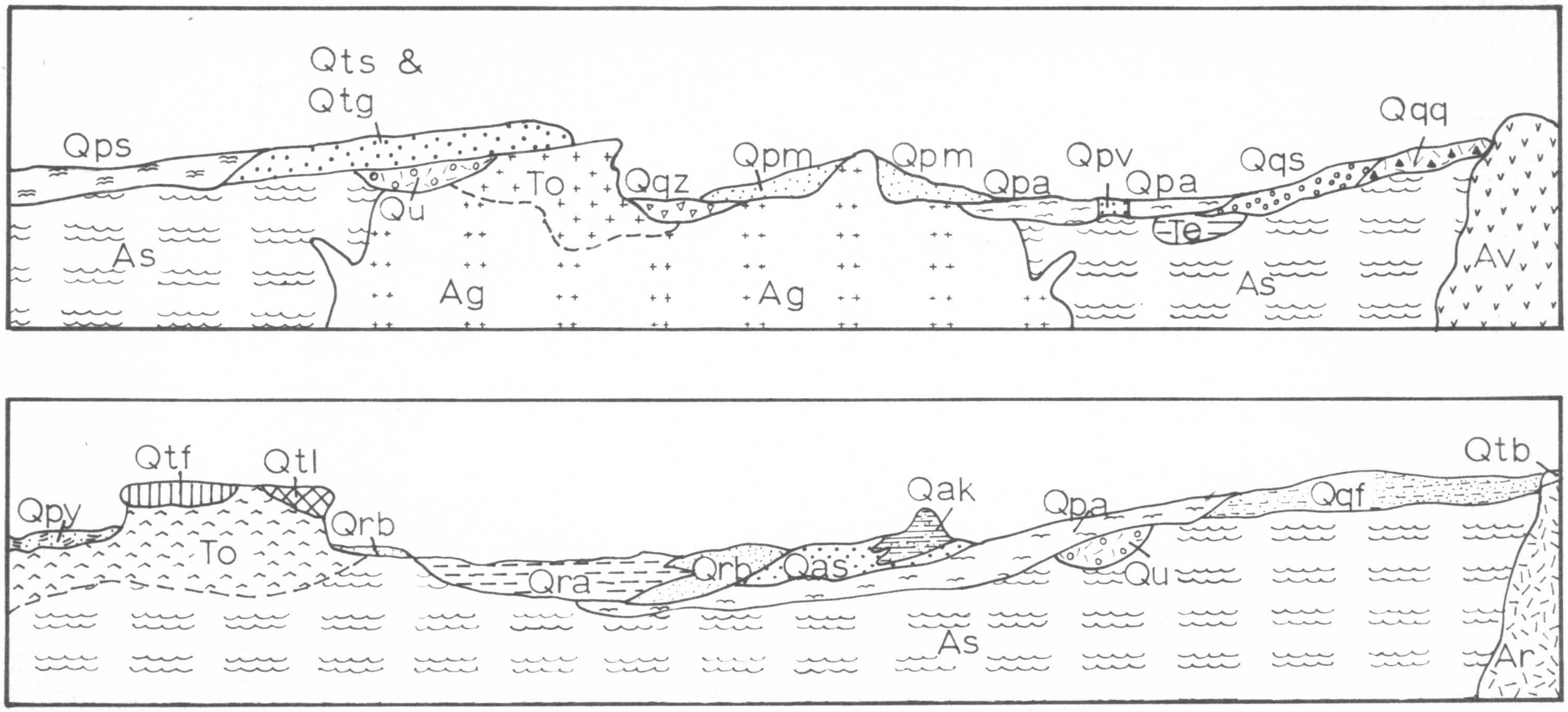


FIGURE 4

KALGOORLIE SHEET SH 51-9

CAINOZOIC ROCK UNIT RELATIONSHIPS

(Symbols as in Map Reference)

Grouping	Description
Qr	Fluvial and eolian deposits
Qa	Fluvial and eolian deposits
Qp	Mainly fluvial deposits
Qq	Fluvial and eolian deposits
Qt	Fluvial deposits and weathered bedrock
Qu	Fluvial deposits
To	Deeply weathered rocks
Te	Alluvial and lacustrine deposits

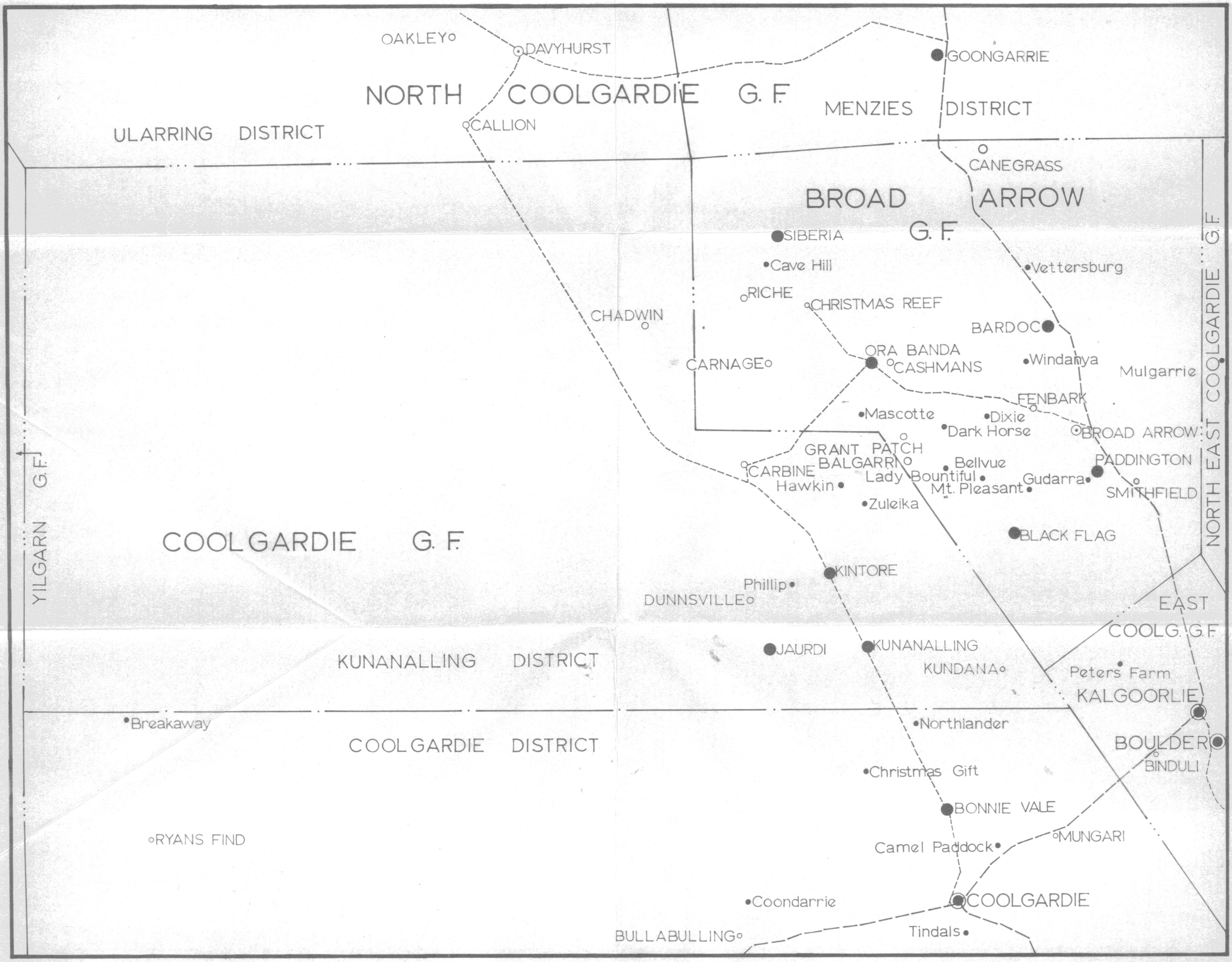


FIGURE 5

KALGOORLIE SHEET SH 51-9

MINING CENTRES

SCALE OF MILES

0 5 10 15 20 25

REFERENCE	
Main road	— — — — —
Minor road	- - - - - - -
Goldfield boundary	——— · · · ———
Goldfield District bdy.	——— · — ———

GOLD PRODUCTION		
Mt. Pleasant	•	included in mining centre
BINDULI	•	less than 1,000 oz
CARBINE	○	to 10,000 oz
JAURDI	●	to 100,000 oz
BROAD ARROW	⊙	to 1,000,000 oz
KALGOORLIE	◉	over 1,000,000 oz

AUSTRALIA 1:250.000 GEOLOGICAL SERIES

KALGOORLIE

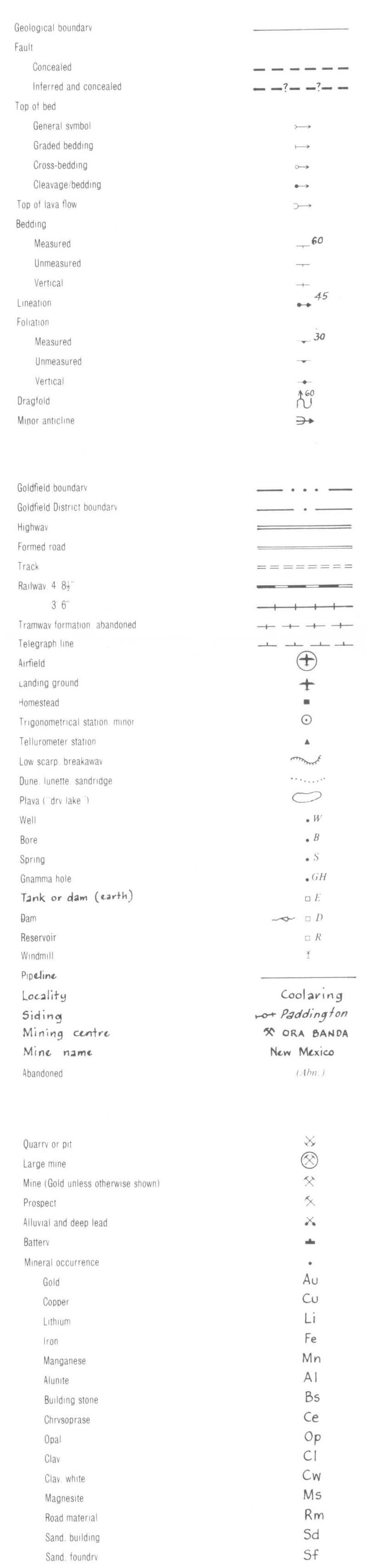
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SH 51-9

PRELIMINARY PRINTING, 1969.

Geology by M. Kriewaldt 1964 - 65

SYMBOLS



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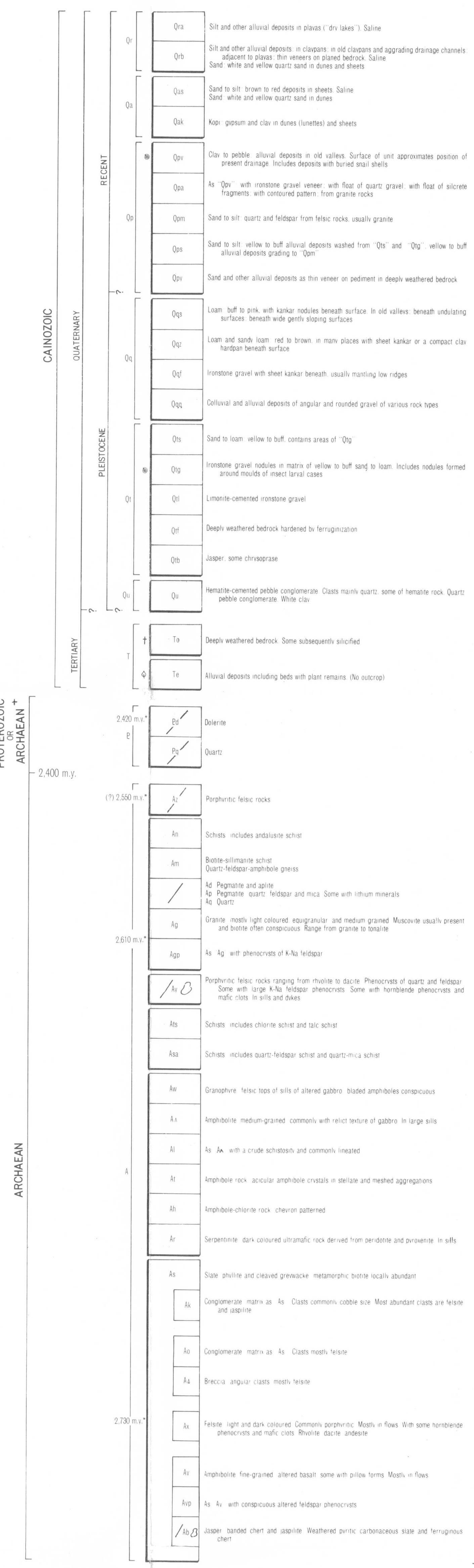
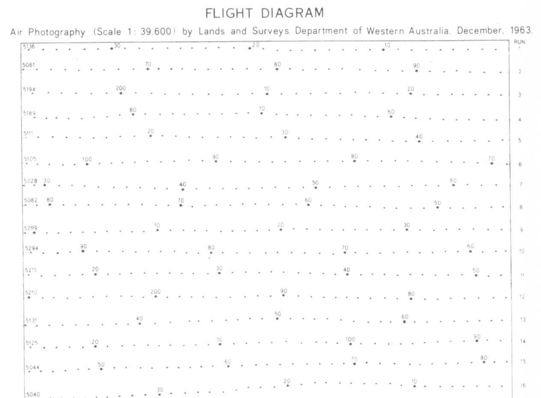


Compiled by Geological Survey of Western Australia. Cartography by Geological Drafting Section, Mines Department. Topographic base from compilations by Lands and Surveys Department.
Published by Bureau of Mineral Resources, Geology And Geophysics, Department of National Development, Canberra, A.C.T.
Copies of this map may be obtained in Perth from the Geological Survey of Western Australia: or the Bureau of Mineral Resources, Geology and Geophysics in Canberra, A.C.T.

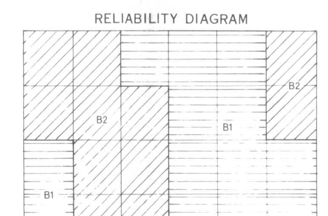
HON. A. F. GRIFFITH, M.L.C.
MINISTER FOR MINES
J. H. LORD, DIRECTOR, GEOLOGICAL SURVEY

FLIGHT DIAGRAM

Air Photography (Scale 1: 39.600) by Lands and Surveys Department of Western Australia. December, 1963.



RELIABILITY DIAGRAM



B1 Numerous traverses with air photo interpretation
B2 Air photo interpretation with a few traverses

Scale 1:250,000

0 5 10 15 20 Miles
0 10,000 20,000 30,000 Yards
0 5 10 15 20 25 30 Kilometres

TRANSVERSE MERCATOR PROJECTION
ZONE 2 AUSTRALIA SERIES.

INDEX TO ADJOINING SHEETS

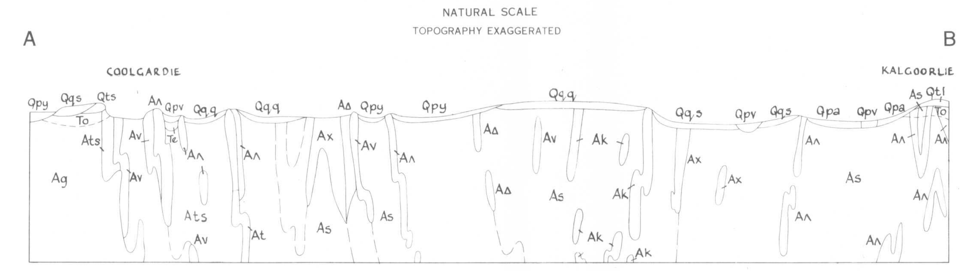
BARLEE SH 50-8	MENZIES SH 51-5	EDJUDINA SH 51-6
JACKSON SH 50-12	KALGOORLIE SH 51-9	KURNALPI SH 51-10
SOUTHERN CROSS SH 50-16	BOORABBIN SH 51-13	WIDGIEMOOLTHA SH 51-14

DECLINATION DIAGRAM

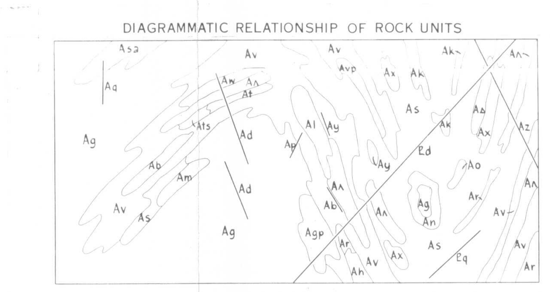
Annual change is 02' Easterly

DIAGRAMMATIC CROSS SECTION A-B

NATURAL SCALE
TOPOGRAPHY EXAGGERATED



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



KALGOORLIE
SHEET SH 51-9

10297