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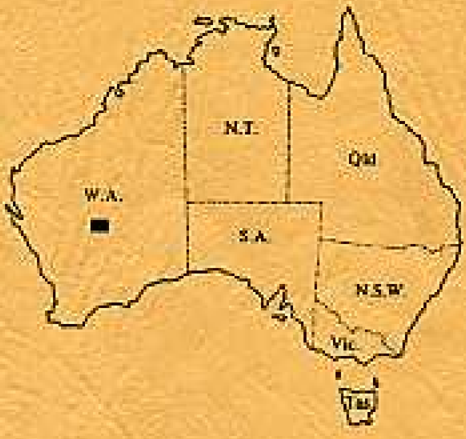
SIR SAMUEL
WESTERN AUSTRALIA



SHEET SG 51-13 INTERNATIONAL INDEX

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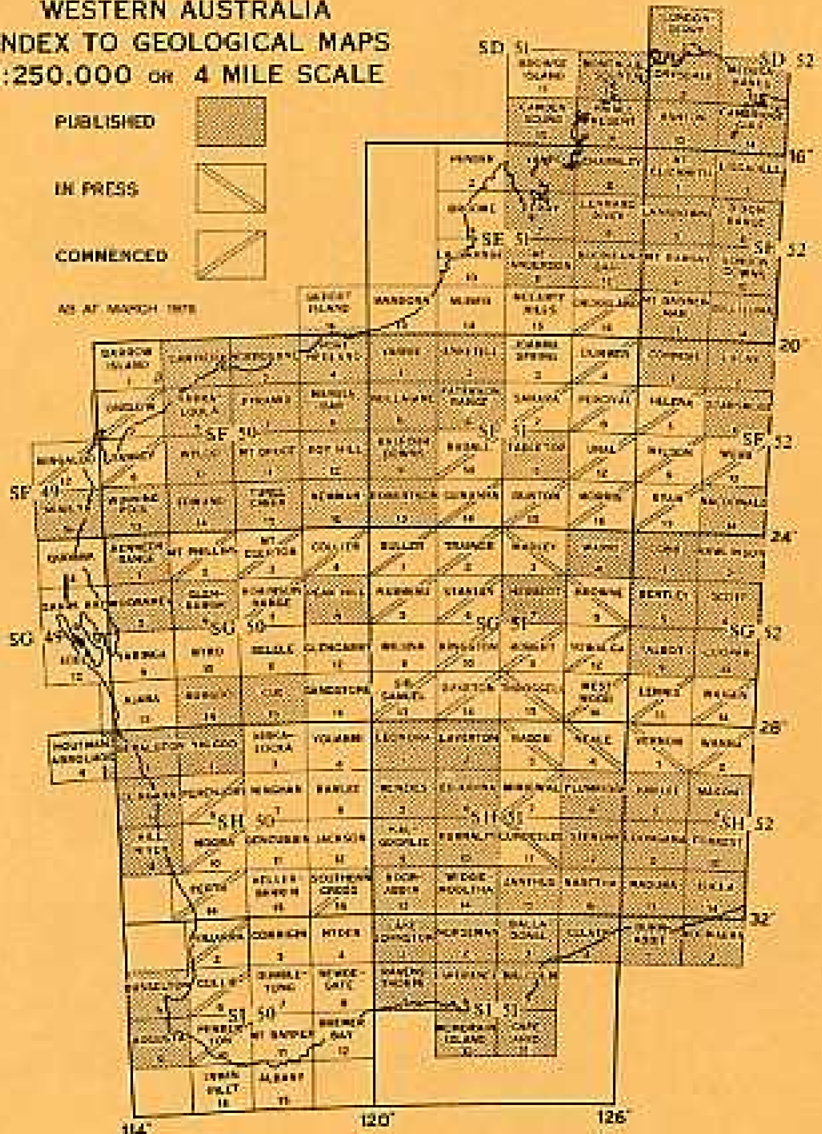

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1 : 250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

SIR SAMUEL

WESTERN AUSTRALIA

SHEET SG 51-13 INTERNATIONAL INDEX

COMPILED BY J. A. BUNTING AND S. J. WILLIAMS

PERTH, WESTERN AUSTRALIA 1979

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DEPARTMENT OF MINES, WESTERN AUSTRALIA

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Explanatory Notes on the Sir Samuel Geological Sheet

compiled by J. A. Bunting and S. J. Williams

INTRODUCTION

The Sir Samuel 1:250 000 Geological Sheet, reference SG/51-13 of the International Series is bounded by latitudes 27°00'S and 28°00'S and longitudes 120°00'E and 121°30'E. The sheet name is taken from the now abandoned mining town of Sir Samuel (see Appendix 1 for coordinates of localities).

The population of the sheet area is small and involved in the pastoral and mineral exploration industries. During the gold and copper mining era four towns were in existence: Sir Samuel, Kathleen, Vivien and Woodarra, as well as several other smaller mining centres all of which are now abandoned. However, nickel mining operations have commenced at Perseverance, and a town (Leinster) is being built near this location to accommodate mining personnel. Yeelirrie and Mount Keith are also potential mine sites.

Access within the sheet area is generally good. An all-weather, graded road linking Leonora to Wiluna passes through the sheet, and all pastoral homesteads are serviced by graded roads. Most outcrop can be reached by station and mineral exploration company tracks. Travel off the tracks usually presents no problem to four-wheel drive vehicles, except in areas of dense mulga cover or dunes.

The climate is semi-arid to arid with hot summers and cool to mild winters. the mean annual rainfall is about 215 mm, but this is unreliable and the area is subject to both drought and localized short-term floods. The first half of the year is generally the wettest. Annual potential evaporation varies from 2 500 mm to 3 500 mm. January is the hottest month with an average maximum temperature of 36°C and an average minimum of 22°C. July is the coolest month with an average maximum temperature of 18°C and an average minimum of 6°C.

Vegetation assemblages described by Burbidge (1942) occur throughout the area, and her four subdivisions largely correspond to physiographic units. Floodplain (broad areas of colluvium, alluvium and sheetwash) is characterized by small shrubs and mulga (*Acacia* spp.) with *Cassia* sp., *Eucalyptus* sp. and sandalwood (*Santalum* sp.) in defined creeks. Hills scrub (rock outcrop and adjacent colluvium) has mainly mulga (*Acacia* sp.), with some sheoak (*Casuarina* sp.), kurrajong (*Brachychiton* sp.) and shrubs. Shurb steppe (areas marginal to salt-lakes) carries halophytes such as samphire (*Arthrocnemum* sp.), saltbush (*Atriplex* sp.) and bluebush (*Kochia* sp.). Sandplain is characterized by spinifex (*Triodia* sp.) and mallee (*Eucalyptus* sp.).

PREVIOUS INVESTIGATIONS

Early regional geological reports covering part of the Sir Samuel Sheet area include Blatchford (1899), Clarke (1925) and Talbot (1928). These reports give very general descriptions of the physiography and geology, and are concerned mainly with the eastern part of the sheet. Descriptions of early gold mining centres, including some detailed work on local geology, are provided by: Reed (1897) for the Lawlers and Sir Samuel districts; Gibson (1907) for the Sir Samuel and Lake Darlot mines; Talbot (1914) for the Mount Keith Mines; and Jutson (1914, 1917) and Montgomery (1909, 1928), for the deep lead at Darlot.

The discovery of major nickel deposits in the Agnew-Mount Keith belt in 1968-71 initiated a period of intensive exploration activity. This has resulted in several papers describing the deposits and their exploration (Martin and Allchurch, 1976;

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Burt and Sheppy, 1976; Turner and Ranford, 1976; Burt and Sheppy, 1975). The discovery of uranium at Yeelirrie also produced an exploration boom, resulting in research into the genesis of calcrete-type uranium deposits (Langford, 1974; Mann, 1974).

Durney (1972) recognized a major unconformity within the Archaean succession at Jones Creek at which, for the first time in the Eastern Goldfields Province, part of the layered succession was found in unconformable contact with granitic rock.

Aeromagnetic and radiometric surveys of the Sir Samuel Sheet were carried out by the Bureau of Mineral Resources (Shelley and Waller, 1967).

PHYSIOGRAPHY

The main physiographic features are presented in Figure 1. The area is characterized by low relief with a range in elevation from about 430 m to 650 m. Two major drainage divides trend approximately northwest, splitting the area into three main trunk valley systems. The overall gradient is to the southeast and is very gentle (the Lake Miranda-Lake Darlot system falls 60 m in 175 km across the sheet area, an average fall of 34 cm/km). The trunk valleys form part of an integrated but now largely inactive drainage system of Cretaceous to Early Tertiary age which can be recognized throughout much of the arid interior of Western Australia (Bunting and others, 1974).

The drainage divides are marked for much of their length by lines of low cliffs, or breakaways, in lateritized bedrock. The breakaways define the eroding edge of an old erosion surface (Jutson, 1934) and are predominantly southwest-facing. Traces of the inactive drainage system can be found on top of the old surface. Below the breakaways, the gentle slopes of the main trunk valleys form a new erosion surface produced by active but intermittent drainage.

The presence of old and new erosion surfaces is an important feature of the region, but, while the distinction between the two surfaces is readily apparent in areas of breakaways, elsewhere the distinction is not obvious, and its usefulness as a means of describing the physiography is limited. Therefore for the purposes of this report the physiography has been divided into three groups (Fig. 1): 1) eroding areas; 2) intermediate areas; 3) saline drainages.

Group 1 includes all areas of higher relief, such as outcrop, breakaways and laterite hills, and their associated pediments. The greenstone belts form ranges of low hills which in places are very rugged. Hills in these areas are commonly elongated parallel to the strike of bedrock foliation or primary layering, whichever is dominant. Chert and banded-iron formation form long, resistant strike-ridges (e.g. Mount McClure, Mount Harold). Granitoid rocks can form spectacular tor and domed features (e.g. Mount Macdonald), but more commonly form sheets or bouldery hills. Breakaways are formed in the weathering products of most rock types, but are best developed in weathered granitic rock.

Group 2 can be subdivided into two units: a) sheet-wash plains and valley floors which unit includes flat, mulga-covered plains of clayey colluvium and alluvium, with wide, poorly defined drainages characterized by thick vegetation; and b) eolian sandplain, which is gently undulating, and contains patchy development of longitudinal dunes 3 to 5 m high, and up to 3 km long. The dunes, in three widely separate areas (west of Wonganoo, north of the Barr Smith Range, and northwest of Agnew) trend consistently northwest. The sandplain in places preserves tributary valleys of the palaeo-drainage system.

Group 3 represents the infilling of trunk drainages in the Cretaceous-Tertiary palaeodrainage system. Three physiographic units are present: a) flat, bare salt lakes containing saline clay, which collect shallow saline water after heavy rain; b) dunes and sheets of eolian and alluvial deposits marginal to salt lakes (this unit is

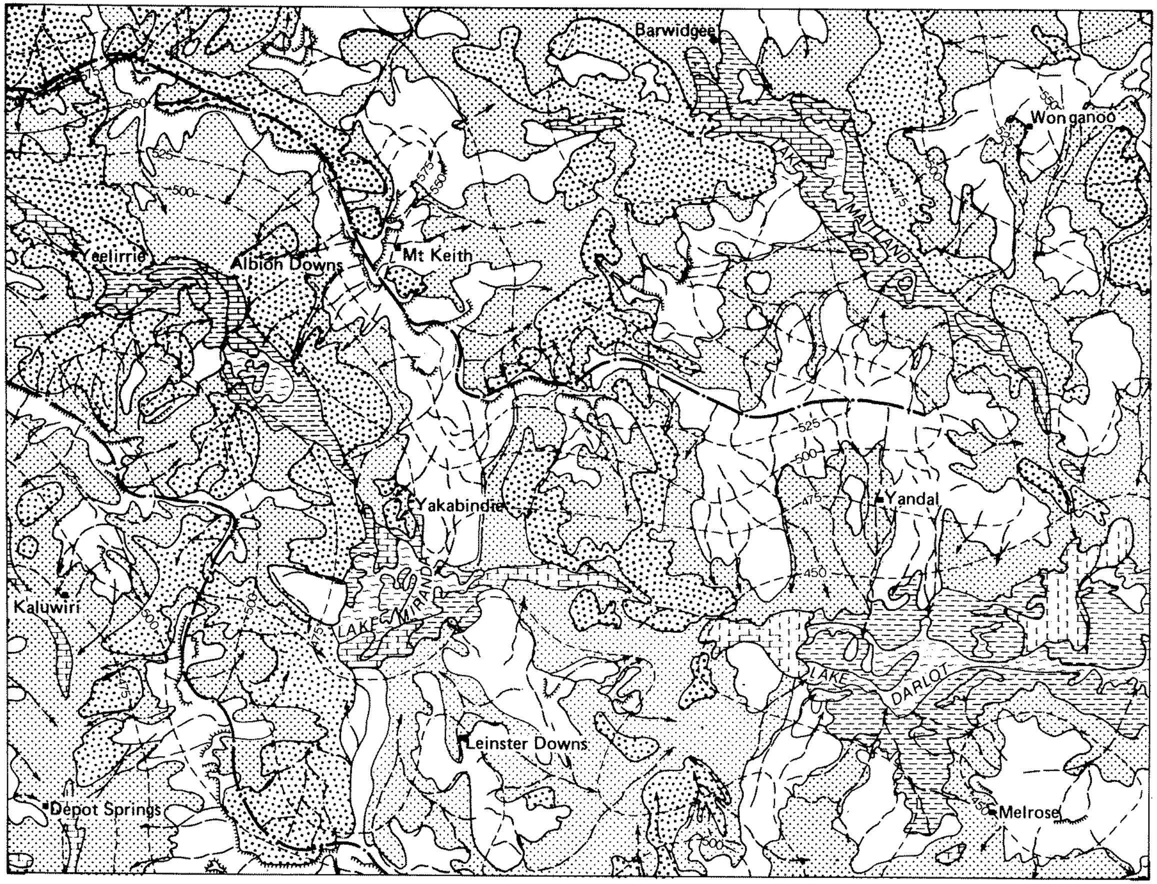

FIGURE 1

PHYSIOGRAPHY AND DRAINAGE

SIR SAMUEL SHEET SG 51–13

0 — 20 km

ERODING AREAS

1 Upland areas of outcrop, laterite and silcrete – capped mesas, and associated pediments

INTERMEDIATE AREAS

2a Flat sheet–wash plains and valley floors consisting of alluvial and colluvial material derived from 1

2b Eolian sand plain, with patchy cover of longitudinal dunes, derived from 1

SALINE DRAINAGES

3a Flat, bare salt lake surface, material derived from 1 & 2

3b Dunes and sheets of eolian and alluvial deposits marginal to salt lakes

3c Calcreted valley floors, low lying with hummocky surface

Modern drainage (ephemeral)

Ancient drainage

Breakaway

Drainage divide

475 Topographic contours (in metres)

▪Yandal Homestead

15808

usually covered by samphire or saltbush and contains numerous small claypans); and c) calcreted valley floors in which low mounds of rubbly calcrete are separated by soil-filled depressions.

ARCHAEAN

REGIONAL SETTING

The Sir Samuel Sheet area lies towards the northeast corner of the Archaean Yilgarn Block, and it contains parts of all three sub-provinces of the Eastern Goldfields Province as defined by Williams (1974). Sequences of metamorphosed sedimentary, volcanic and intrusive rocks form linear greenstone belts separated by large areas of granitoid rocks. The greenstone belts are tightly folded along north-northwest to north-northeast trending axes, have suffered low to medium-grade metamorphism, and are affected by major strike faults. Three distinct greenstone belts occur in the Sheet area. From west to east these are the Agnew-Mount Keith belt, the Yandal belt and the Dingo Range belt (informal names). The main features of the greenstone belts are summarized and compared in Table 1.

Table 1. Summary and comparison of greenstone Belts

	Agnew-Mount Keith	*Yandal*	*Dingo Range*
1.	Complex down-faulted synclinorium, generally north-plunging. NNW trend	Complex NNE-trending synclinorium	Single NNW-trending anticline
2.	Numerous major strike faults, giving overall graben structure. Faults concentrated in 'waist' at Kathleen Valley	A few major strike faults	No major faulting
3.	Major unconformity separating lower mafic sequence from coarse clastic sequence, overlain by further mafic and fine clastic sequence. Prominent conglomerates with granite clasts	Stratigraphy poorly known. No known unconformities. Conglomerate absent	No apparent unconformity. Conglomerate absent
4.	No thick felsic volcanic complexes, but abundant clastic and tuffaceous sediments	Thick calc-alkaline felsic volcanic piles with lack of clastic sedimentation. Abundant fragmental volcanics	Poorly developed tuffaceous rocks above and below the main mafic pile
5.	Chert prominent in parts of lower clastic sequence (BIF restricted to gneissic belts outside main graben)	Minor chert at top of main felsic sequence	Prominent BIF and chert throughout sequence
6.	Ultramafic extrusive rocks abundant within mafic sequence. Cumulus textured intrusive ultramafics form host for major nickel mineralization	Ultramafics extremely rare	Thin ultramafics common
7.	Flanked by linear belts of para- and orthogneiss associated with major tectonic lineaments	Flanked on W side by gneissic belt and on E by tectonic lineament	Surrounded by later intrusive granites
8.	Affected by at least 2 phases of granitic intrusion, one pre- and one post-unconformity. Later granite cuts whole sequence and may be dilational	Intruded by syn- or late-tectonic elliptical plutons of adamellite, granodiorite and quartz monzonite	Intruded along margins by foliated granodiorite and later, post-tectonic fluorite granite

Most of the granitoid rocks in the Eastern Goldfields were emplaced in the period 2700 to 2550 m.y. ago (Arriens, 1971). With the exception of some fluorite-granite and syenitic rocks on the eastern side, all the granitoid rocks in the sheet area probably fall within this range. Generally the granitoid rocks are younger than the layered succession. Gneissic rocks of possibly older age form linear belts along some greenstone belt margins.

THE LAYERED SUCCESSION

Ultramafic rocks

The ultramafic rock group comprises intrusive peridotite and dunite (*Aup*), stratiform piles of peridotite lava (*Aus*), altered high-Mg basalt (*Aur*), and alteration products of peridotite which consist of schistose talc-carbonate-chlorite-serpentine assemblages (*Aue*).

The intrusive rocks are largely serpentinized, but cumulus textures are well preserved. Peridotite-dunite bodies occur as concordant sills within piles of ultramafic flows (see below), and as sub-concordant ?post-folding intrusions. The most important of these is the Mount Keith intrusion, which extends intermittently over a distance of 200 km from Weebo in the Leonora Sheet area, through the Perseverance and Mount Keith areas to beyond Wiluna, and which contains several major nickel deposits (Fig. 2). Over most of its length the intrusion has the appearance of a near-vertically emplaced dyke (Burt and Sheppy, 1976; Binns and others, 1975) in which a nickel sulphide-bearing dunitic core is flanked by narrow peridotitic and pyroxenitic margins. At Perseverance the intrusion is dunitic, and contains massive sulphides near the western contact; this has been interpreted by Martin and Allchurch (1976) as the product of gravity differentiation in a subhorizontal (now vertical) sheet. The enigma of these two modes of formation in what appears to be the same intrusion has yet to be resolved.

The Mount Keith intrusion and nearby smaller peridotite intrusions appear to have been emplaced along faults associated with the Keith-Kilkenny Lineament. This appears to represent a major fracture zone which tapped the upper mantle, and which allowed ultramafic magma to intrude the supracrustal rocks. Within these fractures the magma differentiated to dunitic, peridotitic and pyroxenitic types. Binns and others (1975) point out that the fractionation along the length of the Mount Keith intrusion coincides with a variation in grade of metamorphism, and that this may be due to the exposure of progressively higher levels of the dyke from south to north. A tilt of only a few degrees would be sufficient to account for the variation.

Peridotitic lavas are present at Mount Roberts and northeast of Mount Keith homestead. Near Mount Keith, the flows display an upper zone of spinifex-textured pyroxene-rich peridotite containing minor tremolite and some relict olivine, and a lower zone of granular or porphyritic olivine-rich peridotite. The olivine-rich peridotite contains cumulus euhedral olivine and long-bladed grains, suggesting that the flow extruded as a crystal mush which rapidly differentiated and crystallized. Vesicles in the olivine-rich peridotite testify to its extrusive origin. At both localities, the extrusive piles are intruded by stratiform peridotite sills. A more clearly exposed pile of similar flows at Mount Clifford, 60 km southeast of Agnew, has been described in detail by Barnes and others (1974).

The high-Mg basalt suite consists of tremolite-actinolite-chlorite-talc assemblages and is similar to the komatiites of South Africa (Viljoen and Viljoen, 1969a). These rocks occur as concordant or sub-concordant units within piles of tholeiitic basalt. They are usually schistose due to alignment of amphibole and chlorite, but in places a relict texture preserves the branching form of former pyroxene.

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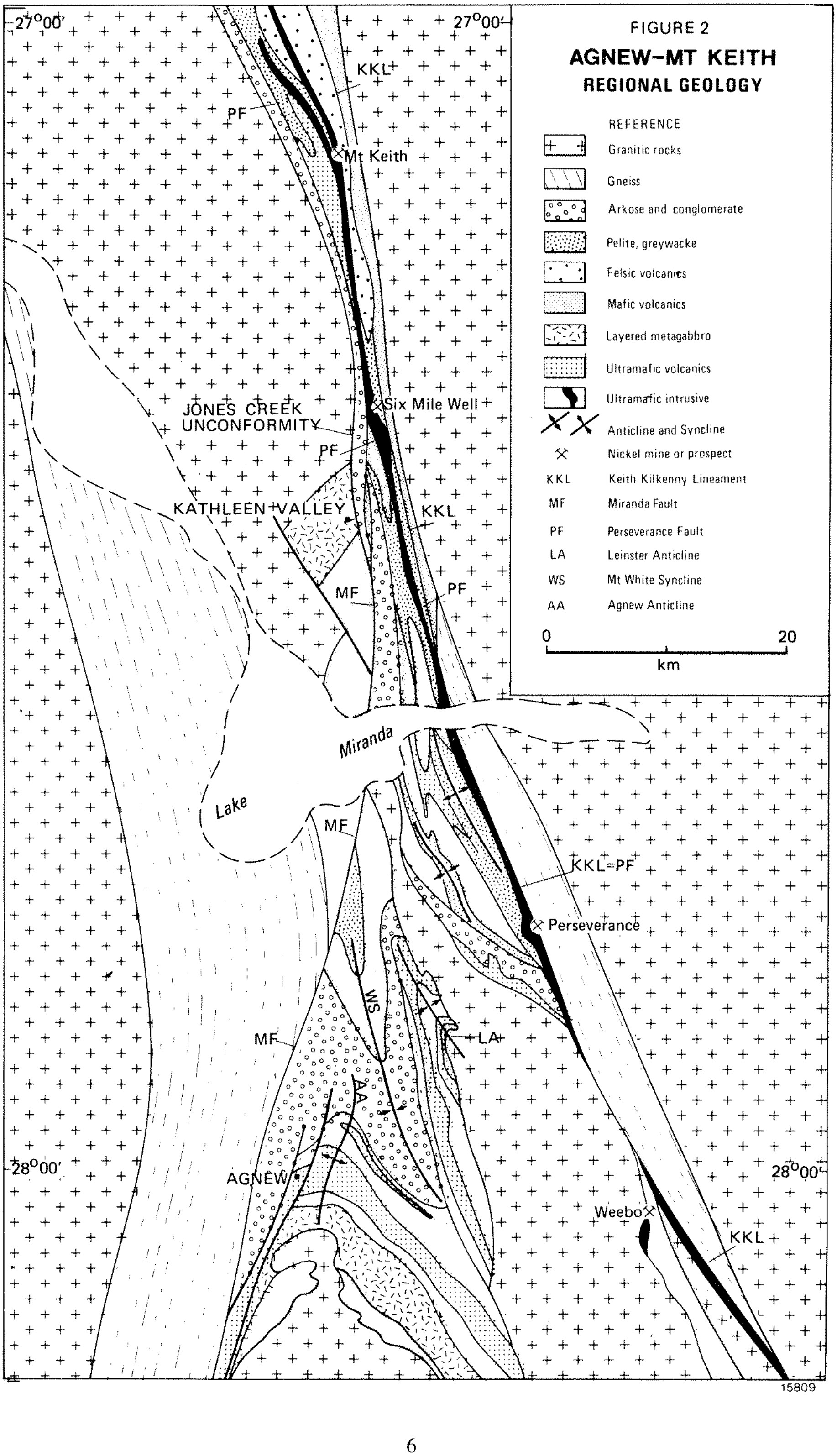
FIGURE 2
AGNEW–MT KEITH
REGIONAL GEOLOGY
REFERENCE
Granitic rocks
Gneiss
Arkose and conglomerate
Pelite, greywacke
Felsic volcanics
Mafic volcanics
Layered metagabbro
Ultramafic volcanics
Ultramafic intrusive
Anticline and Syncline
Nickel mine or prospect
KKL Keith Kilkenny Lineament
MF Miranda Fault
PF Perseverance Fault
LA Leinster Anticline
WS Mt White Syncline
AA Agnew Anticline
0 20
km
27°00′
28°00′
KKL
PF
Mt Keith
Six Mile Well
JONES CREEK UNCONFORMITY
KATHLEEN VALLEY
MF
Lake Miranda
KKL=PF
Perseverance
WS
LA
AA
AGNEW
Weebo
15809

Table 2. Chemical analyses of rocks from the layered succession

G.S.W.A. No.	*40361*	*40338*	*43332*	*42821*	*43330*	*43331*	*42820*	*42822*	*42827*
SiO_2 %	52.2	49.2	51.1	52.9	56.1	69.4	79.1	76.9	75.6
Al_2O_3	5.7	15.6	15.6	14.9	16.4	13.8	11.0	12.2	12.6
Fe_2O_3	1.4	2.1	2.4	1.8	2.4	0.6	0.2	0.0	0.5
FeO*	6.49	9.64	8.88	8.88	5.28	5.21	1.29	1.22	1.16
MgO	15.8	8.6	6.8	5.9	4.9	1.0	0.1	0.0	0.1
CaO	15.35	12.53	12.36	8.68	8.77	1.53	0.25	0.23	1.64
Na_2O*	0.16	1.46	1.48	3.16	2.19	4.73	1.69	2.43	4.13
K_2O	0.3	0.2	0.2	0.3	0.6	1.6	5.9	6.3	2.6
H_2O^{+}*	2.19	1.50	1.88	2.87	2.92	1.86	0.47	0.51	0.67
H_2O^{-}*	0.19	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.09
CO_2*	0.21	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.43
TiO_2	0.26	0.76	0.99	1.06	0.79	0.88	0.08	0.10	0.20
P_2O_5	0.11	0.15	0.20	0.22	0.26	0.23	0.06	0.07	0.08
MnO	0.25	0.27	0.24	0.29	0.13	0.11	0.03	0.02	0.06
TOTAL	100.6	102.3	102.1	101.0	100.7	101.0	100.2	100.0	99.9
Ba ppm	140	45							750
Be*			2	1	1	2	2	2	
Cr	840	340							
Cu*			190	350	140	240	60	60	108
Li*	8	16							12
MnO*			2040	2350	1195	975	220	180	580
Mo*					3.0				0.5
Ni	180	140							
Pb*			30	45	25	30	25	35	30
Rb	10	5							70
Sn*			10	10-100	10-100	10-100	10-100	1-10	3
Sr	45	80							135
Th									6
U*									2
V*	190	235	290	360	160	15	35	40	
W*			2	2	2	1	2	1	1
Zn*			148	135	72	71	17	13	52
Zr	30	45							85
F*	30	90							180
Nb			4	7	11	19	24	20	

*Analysis by chemical methods (all others by X-ray fluorescence)

		Lat	*Long*
40361	Meta-high-Mg basalt	27°28′00″	120°34′30″
40338	Metabasalt, Perseverance area	27°46′10″	120°39′10″
43332	Metabasalt, Sir Samuel	27°38′20″	120°33′20″
42821	Metabasalt, 2 km SE of Katherine Well	27°40′00″	121°10′00″
43330	Meta-andesite, Spring Well area	27°53′15″	121°10′20″
43331	Crystal-lithic tuff, Spring Well	27°53′00″	121°10′15″
42820	Crystal tuff, Katherine Well area	27°40′00″	121°09′50″
42822	Crystal-vitric tuff, 2 km SE of Katherine Well	27°40′00″	121°09′50″
42827	Mylonitized porphyry, 2 km E of Yandal Lagoon	27°41′00″	121°11′30″

A chemical analysis (Table 2) of a tremolite rock containing minor relict clinopyroxene from 4 km south of Six Mile Well shows similarities with the "Badplaas" type komatiite from South Africa (Viljoen and Viljoen, 1969a). It has an MgO content of 15.8 per cent and CaO/Al_2O_3 ratio of 2.7 which is unusually high for the Eastern Goldfields where high-Mg basalts generally have ratios of less than 1.0 (Hallberg and Williams, 1972).

Mafic extrusive rocks

Most of the metamorphosed basaltic rocks are included under the general symbol *Ab*. They are fine-grained, poorly foliated featureless rocks, although occasionally they are vesicular and porphyritic. The symbol *Abi* indicates abundant pillows. Vague pillow shapes are present in places in otherwise featureless metabasalt, and in such cases the *Ab* symbol is retained. Metabasalt with abundant secondary carbonate (*Abk*) is present southeast of Katherine Well.

The metabasalt typically has a relict igneous texture, in which small plagioclase laths, occasionally showing crude flow alignment, are set in a fine mosaic of pale-green amphibole (usually actinolite) with minor epidote, quartz and sphene. Plagioclase commonly retains its original composition of zoned labradorite-andesine, but in places it is replaced by calcic oligoclase.

With increasing dynamic regional metamorphism primary igneous texture is destroyed, a strong penetrative foliation develops and the rock is termed amphibolite (*Aba*). This unit is generally restricted to the margins of the greenstone belts, except for some amphibolite in the Kathleen Valley area which may be related to deformation associated with the convergence of major strike faults. Foliation and lineation are defined by alignment of bladed, green amphibole poikiloblasts (usually hornblende) in a mosaic of plagioclase and minor quartz. In the Kathleen Valley area some amphibolites are derived from mafic sediments and are designated *Asm*. These are described in more detail in the section dealing with metasediments. Where the origin is in doubt the symbol *Aba* is used.

Analyses of metabasalt from the Perseverance area and Mount Goode (Table 2) are comparable with tholeiites from elsewhere in the Eastern Goldfields (Hallberg, 1972). Nesbitt and others (1975) report that metabasalts from the upper and lower mafic sequences in the Agnew area (in the Mount White Syncline and Agnew Anticline respectively—Nesbitt, written comm.) are indistinguishable on chemical grounds.

Mafic intrusive rocks

Medium- to coarse-grained mafic intrusive rocks (*Ad*) are widely distributed throughout the mafic, felsic and sedimentary sequences, commonly as concordant bands or lenses. Mineralogically these rocks are similar to the metabasalts, and consist primarily of pale green amphibole (usually actinolite) and plagioclase. Primary gabbroic and doleritic textures are commonly preserved, and in some cases relict clinopyroxene occurs as cores within the actinolite prisms. The presence of oscillatory labradorite indicates a lack of recrystallization of plagioclase retrogression during the static metamorphism. As with the metabasalt, increasing dynamic metamorphism of the gabbro and dolerite produces amphibolite, but this has not been distinguished on the 1:250 000 map.

A variation in the normal mafic intrusives occurs near Mount Goode, Mount Doolette and Ockerburry Hill, where metadolerite contains altered phenocrysts of plagioclase up to 3 cm long (*Adp*).

In the Spring Well felsic volcanic complex, and 2 km east of Katherine Well, metagabbro and fine-grained metadolerite contain primary orthopyroxene and clinopyroxene, both largely replaced by tremolite-actinolite.

West of Kathleen Valley, a composite layered mafic intrusion has been informally named the Kathleen Valley gabbro. Rock types range from anorthosite to amphibolitized pyroxenite, but most of the body is gabbroic. Original igneous textures and zoned plagioclase (labradorite) are preserved, but the original mafic mineral (?clinopyroxene) is entirely altered to blue-green acicular, or fibrous, amphibole.

The body consists of four units trending east-northeast and dipping steeply north. Differentiation indicates the body is overturned. From base to top the units are:

(1) Layered gabbro with 2 to 10 m banding due to varying proportions of amphibole and plagioclase (*Adjl*). Plagioclase phenocrysts are common.

(2) Anorthositic gabbro (*Adja*). This unit varies from anorthosite to leucogabbro, but there is no banding. The original (?)clinopyroxene, now fibrous amphibole, formed poikilitic crystals up to 5 cm across which contained up to 90 per cent euhedral plagioclase and thus produced a net-like effect.

(3) Quartz gabbro (*Adjq*). This is a fairly homogeneous unit in which quartz varies from 2 to 5 per cent. A primary flow foliation of euhedral plagioclase laths is well preserved in places.

(4) Tonalite, quartz diorite and quartz gabbro (*Adjt*). In the tonalitic varieties, up to 30 per cent quartz is present, and a granophyric texture is preserved. Garnet is common close to the contact with the underlying quartz gabbro unit. The unit is interpreted as an early differentiate of the main gabbro which was statically metamorphosed by a later magma pulse.

Thus the Kathleen Valley gabbro is a multiple intrusion with at least two periods of magma emplacement. The gabbro was intruded by dolerite dykes prior to regional metamorphism. A 5-m-wide xenolith of anorthosite 4 km west of Six Mile Well, and numerous enclaves of metamorphosed porphyritic gabbro in adamellite west of Blow Well indicate that the granitic rocks to the north are younger than the gabbro.

Felsic extrusive, intrusive and fragmental rocks

The predominant rock type is a fine to medium-grained tuffaceous rock (*Afx*), with or without a sedimentary clastic component. In the Spring Well area such rocks contain large volcanic fragments and have the symbol *Afv*. Felsic lava (*Afl*) has been mapped at numerous localities, but thin section examination has shown many of them to tuffaceous. Where felsic volcanic rocks are too schistose to be subdivided they are given the symbol *Afs*. Quartz-feldspar porphyry (*Ap*) intrudes mafic or felsic rocks; in places it is difficult to distinguish from quartz and feldspar-phyric lava or crystal tuff. Compositionally most of the felsic volcanic rocks are dacite or rhyodacite, although rhyolite is present east of Katherine Well.

The Spring Well complex west of Melrose is a major felsic volcanic centre comprising a thick pile of coarse fragmental rocks with associated tuffs, lavas and intrusive rocks, which overlie a thick mafic sequence to the southeast. The complex occupies the area betweeen Mount Doolette, Jarrah Well and Overland Well, with possible extensions across strike to Ockerburry Hill and along strike to the vicinity of Katherine Well. The fragmental rocks in the main part of the complex contain abundant fiamme and glassy shards which exhibit eutaxitic textures and may in part be ignimbritic. The coarser fragmentals contain angular blocks up to 50 cm across of quartz and feldspar-phyric lava and crystal tuff. These fragments commonly possess reaction rims and must therefore have been cold when incorporated into the hot matrix. The matrix contains quartz and feldspar crystals, small devitrified glass shards, and larger fiamme which are probably collapsed pumice fragments. A streaky flow foliation is developed in the matrix. The finer-grained fragmental rocks are similar to the matrix of the coarser varieties, and can be described as welded crystal-vitric tuffs. The fragmental rocks are interpreted as a pile of ignimbritic ash flows that in places carried along cold blocks. The lack of any clastic sediments or cherts and welding of the tuffs suggest a subaerial environment.

The felsic volcanic rocks of the Spring Well complex are laced with sinuous dykes of vesicular andesite and basalt that truncate the primary layering. A faint original flow alignment of plagioclase laths is preserved, along with relict clinopyroxene and occasionally orthopyroxene.

To the northwest of the Spring Well complex, across the strike of the primary layering, the rocks become finer grained, and the tuffaceous rocks acquire a sedimentary clastic component. At Ockerburry Hill, tuffaceous sediments interbedded with chert and pyritic black shale probably mark the top of the felsic volcanic pile.

East of Katherine Well, along strike from the main centre of activity, coarse fragmentals are rare, and there is a clastic component in some of the rocks. To the north the proportion of clastic material increases until the rocks are predominantly shales, siltstones and fine sandstones.

Chemical analyses of felsic volcanic rocks are given in Table 2. The agglomerate matrix from Spring Well (Sample 43331) is typical of the flow-banded crystal-vitric tuff at this locality, and its chemical composition is that of a dacite. Two fine- to medium-grained crystal-vitric tuffs (42820, 42822) from southeast of Katherine Well are similar in appearance, both in thin section and outcrop, to the finer grained rocks at Spring Well, but chemically are rhyolites. Recent work by Gower (1974) and Hallberg and others (1976) has revealed the presence of calc-alkaline felsic volcanic centres at Laverton and Marda respectively. The occurrence of rocks ranging from basalt (sample 42821) through andesite (43330), dacite and rhyolite at Spring Well places this complex in the calc-alkaline field alongside Laverton and Marda. Comparison with the AFM plot of the Marda complex (Hallberg and others, 1976) shows that the Sir Samuel rocks, with the exception of the rhyolites, are slightly alkali deficient and iron rich. The good exposure and lack of secondary alteration in the Spring Well area makes this a highly suitable area for further work on the genesis of Archaean felsic volcanic complexes.

In the Mount Keith belt felsic tuffaceous rocks with minor lavas form the bulk of the sequence north of Mount Keith, but elsewhere they are restricted to a tuffaceous component in some of the metasediments. The sequence north of Mount Keith is predominantly dacitic to andesitic (Burt and Sheppy, 1976) and in places a flow alignment of plagioclase laths is well preserved. In the Dingo Range belt, the only representatives of the felsic volcanic suite are a few small porphyry bands near Mount Mundy and some tuffaceous rocks northwest of Wonganoo.

Clastic metasedimentary rocks

Polymictic conglomerate (*Asc*) contains clasts of granitic rocks, felsic porphyry, chert, minor metabasalt, metagabbro and chlorite-amphibole schist, in an arkosic, mafic, or ultramafic matrix. The clasts are commonly flattened within the matrix schistosity, particularly where the matrix is mafic and the matrix:clast ratio is high. Arkosic matrix is similar to that in the oligomictic conglomerate (described below). Mafic or ultramafic matrix is strongly schistose and consists of chlorite and tremolite/actinolite, with variable amounts of quartz and plagioclase.

The clasts in the oligomictic conglomerate (*Aso*) are almost entirely granitic. They are commonly well rounded, very closely packed, and range in size from a few centimetres to over 1.5 m. The unconformity with the underlying adamellite is well exposed at Jones Creek (Durney, 1972). In embayments in the unconformity, the blocks are angular and lithologically identical to the underlying adamellite. The unconformity is less well exposed in the Kathleen Valley area, where it is in part strongly sheared, but in places a band up to a few metres thick contains mafic fragments where the conglomerate overlies mafic rocks. The matrix of the granite-clast conglomerate consists of quartz, plagioclase microcline, biotite, muscovite and epidote. Textures are largely recrystallized, and there is a preferred orientation of quartz, feldspar, and secondary mica.

Arkose (*Asa*) occurs as bands within conglomerate in the Jones Creek-Kathleen Valley area, but near Agnew it predominates over conglomerate. Feldspathic sediment near the eastern margin of the Yandal belt, north of Yandal, has been included under *Asa,* and probably derives from erosion of penecontemporaneous felsic volcanic rocks.

The arkose in the Jones Creek-Kathleen Valley area and northwest of Agnew is similar to the matrix of the oligomictic conglomerate. It grades into the conglomerate by the incorporation of scattered pebbles and also grades into fine sandstone and shale. Cross-bedding and scour structures are common.

In the Agnew-Mount Keith belt, and to a lesser extent the Yandal belt, there are rare bands up to about 100 m thick of schistose mafic and ultramafic rocks with unusual compositions and textures. A fine banding is common. Northwest of Agnew, and in the Jones Creek-Kathleen Valley area, these rocks contain scattered granitic pebbles and grade into mafic- and ultramafic-matrix conglomerate. They are thus regarded as metamorphosed mafic and ultramafic sediments (*Asm*). A common assemblage is tremolite and chlorite, with variable amounts of plagioclase and quartz. De la Hunty (1960) recognized the sedimentary origin of ultramafic schist from drillholes west of Agnew, because of the presence of small porphyry and quartz pebbles. Immediately southeast of Mount Mann quartz-chlorite schist and intercalated quartz-andalusite-muscovite schist contain abundant rutile.

The depositional environment of the conglomerates and related arkose is discussed by Marston and Travis (1976) and Donaldson and Platt (1975). Marston and Travis suggest accumulation as alluvial fans along a fault-controlled elongate basin. Donaldson and Platt recognize a progradational sequence west of Agnew, from a lower deltaic environment through a braided river, or alluvial-fan or sheet-flood environment (pebbly arkose), to an upper conglomeratic alluvial fan environment. In most of the oligomictic conglomerate the granite boulders are too rounded and too closely packed for normal alluvial fan conditions. The roundness also precludes a talus deposit, although angular clasts in the unconformity embayments may be of such an origin. The high degree of roundness indicates a high-energy environment, and the very close packing suggests that the clasts may have accumulated as an openwork gravel such as a beach or river gravel (R. D. Gee, pers. comm.). The voids would then be filled in by matrix sand associated with arkose development. Bedding lamination is recognizable in the sandstone filling some of the voids. A possible mode for the development of the Jones Creek Conglomerate in the Jones Creek-Kathleen Valley area is as follows: a rapidly subsiding, fault-bounded, elongate trough was flanked, at least to the west, by a rapidly eroding upland area. The erosion products were transported a very short distance (via talus slopes and small alluvial fans) to a high-energy shoreline. Periods of emergence produced more extensive alluvial fans, with associated sheet-flood deposits which occasionally covered the underlying beach deposits.

Fine-grained clastic rocks of various types are designated *Ass.* They include black shale, mudstone, siliceous shale, feldspathic shale, and their metamorphosed phyllitic and schistose equivalents. The shales are commonly finely laminated and fissile, and may contain thin greywacke bands. Where greywacke is predominant over shale the symbol *Asg* is used. As well as forming major units by itself, shale can occur as thin bands scattered throughout most rock types of the layered succession. Graded bedding is common in some greywacke/shale units, but sedimentary structures are generally lacking. Porphyroblastic andalusite is common in some quartz-muscovite schists, giving them a knotted appearance. Fine-grained, quartz-sericite-chlorite-kaolin schists are commonly associated with felsic volcanic rocks, and are thought to be pelitic sediments with a minor tuffaceous component (*Ast*).

Banded iron-formation and related rocks

Rocks within this group include banded quartz-magnetite rock (*Aiw*), banded chert (*Aic*) and jaspilite (*Aif*). All are susceptible to ferruginization during Cainozoic weathering, and where the original nature is obscure the rock is simply termed *Ai*. All of these rock types form resistant strike ridges which are useful indicators of primary bedding direction in metamorphic terrain.

Banded chert is by far the most abundant rock type. Banding, on a scale of millimetres to several centimetres, is due to small amounts of finely disseminated iron oxide. In the Dingo Range greenstone belt the chert forms distinct bands within metabasalt. Elsewhere the chert is generally associated with fine-grained clastic or volcanoclastic sequences. At Ockerburry Hill, non-ferruginous chert bands up to 3 m thick are associated with pyritic, black shale grading into schistose pyroclastic rocks which form the top of the Spring Well felsic volcanic complex. The chert at Ockerburry Hill contains hexagonal holes which possibly contained carbonate. At Mount Sir Samuel and Mount McClure the chert has recrystallized to a granular quartz mosaic resembling a quartzite.

Banded quartz-magnetite rock occurs as resistant bands within gneissic granitoid rocks and east and north of Mount Keith, and 12 km west of Agnew. At the latter locality some of the banded iron-formation contains grunerite and orthopyroxene (probably ferrohypersthene). The lack of banded iron-formation between the Ida and Keith-Kilkenny Lineaments is in accordance with Williams (1974) who states that this rock type is rare in the Kalgoorlie Sub-province. The banded quartz-magnetite rock localities on the Sir Samuel Sheet lie outside this area, and they may be related to older gneissic belts which flank the two lineaments.

Jaspilite, or banded magnetite-red jasper, occurs at only one locality in the Sheet area, at Mount Harold in the Dingo Range belt, where it is interbedded with banded ferruginous chert.

GNEISSIC ROCKS

Gneissic rocks form three linear belts. Two flank the southern part of the Agnew-Mount Keith greenstone belt and the third forms the western margin of the Yandal greenstone belt. These belts contain a mixture of paragneiss (*Anp*), orthogneiss (*Ang*) and amphibolite (*Anh*). Commonly, a genetic interpretation cannot be made, and the symbol *An* refers to quartzo-feldspathic gneiss of uncertain origin. A sedimentary parent for the paragneiss has not been conclusively established, but it is indicated by the lateral continuity of thin compositional banding, 1 to 20 cm thick, and a high proportion of quartz (40-50 per cent). The orthogneiss is generally adamellitic or granodioritic in composition. It has a strong foliation due to elongation of quartz and feldspar and alignment of small biotite flakes, but lacks the banding of the paragneiss. Unlike the strongly foliated granitic rocks (*Agg*), described below, the orthogneiss shows little evidence of cataclastic or blastomylonitic texture; west of Yandal a blastomylonitic texture is superimposed on thin gneissic banding.

Each of the three gneissic belts has distinctive characteristics. West of Agnew, amphibolite in small pods within the gneiss has a granoblastic or foliated xenoblastic texture. The amphibolite consists of hornblende, quartz, diopside, garnet (up to 50 per cent) and minor plagioclase. In one specimen idioblastic garnet has grown in the cores of patches of foliated hornblende and plagioclase, which indicates a period of post-tectonic static recrystallization. The abundant garnet and diopside indicate that metamorphism reached upper amphibolite facies. At the northern end of the same gneissic belt, east of Little Well (Yeelirrie), amphibolite bands contain quartz, diopside, hornblende and andesine, but no garnet. Minor components of the gneissic belt west of Agnew include banded iron-formation, lenses of talc schist and lenses of chlorite schist.

The gneissic belt east of Perseverance is largely deeply weathered but is well banded and probably paragneiss. Amphibolite occurs as narrow lenses and contains quartz, hornblende and minor oligoclase. Relict diopside cores in the hornblende indicate that these rocks suffered upper amphibolite facies metamorphism.

The belt west of the Yandal greenstone belt consists mainly of orthogneiss and rare lenses of quartz-muscovite schist and amphibolite. In places the orthogneiss has a platiness in outcrop due to bands of quartzo-feldspathic material separated by thin films of biotite. Some bands of amphibolite (up to 10 m wide) are traceable over several kilometres. The amphibolite is fine grained and displays a strong foliation which, unlike the adjacent greenstone belt amphibolites, is defined by alignment of elongate plagioclase and quartz grains as well as hornblende.

The tectonic and stratigraphic significance of the gneissic belts is not fully understood. The two belts adjacent to the Agnew-Mount Keith greenstone belt show evidence of polymetamorphism of a higher grade than the greenstone belt, and are separated from it by the Ida and Keith-Kilkenny tectonic lineaments (see STRUCTURE). It seems likely that they represent rocks of an earlier cycle of basin development which were intruded and metamorphosed, and became the foreland for the rifting that accompanied development of the Agnew-Mount Keith greenstone belt. An unlikely alternative is that the belts are reworked parts of the Agnew-Mount Keith greenstone belt, either as metamorphosed and sheared margins, or as high-grade root zones of the greenstone belt, which have been brought to higher crustal levels. The arguments against this are that the gneissic belts contain only minor mafic and ultramafic material, and that the Agnew-Mount Keith belt contains no banded iron-formation.

GRANITOID ROCKS

Lithology

Non-porphyritic granites and adamellites are subdivided into fine- to medium-grained (*Age*), and medium- to coarse-grained (*Agb*). These rocks contain microcline and plagioclase (usually oligoclase) in approximately equal amounts, but microcline is dominant in the granitic varieties. Biotite (commonly chloritized) is the predominant mafic mineral. The porphyritic granite and adamellite (*Agl*) contains phenocrysts of microcline and rarely oligoclase, in a groundmass which is similar to *Agb*. Contacts between these three units are commonly gradational.

The granodiorite and tonalite (*Agt*) are medium- to coarse-grained and generally non-porphyritic. Microcline forms less than one-third of the total feldspar. Oscillatory zoning in plagioclase (oligoclase) is common. Mafic minerals are hornblende and olive-green biotite.

Quartz monzonite (*Agh*) is well exposed in the vicinity of Mount Macdonald. Its principal minerals are microcline and oligoclase with 15 to 20 per cent quartz and minor biotite and hornblende. Sphene is abundant and forms yellow euhedral crystals up to 2 mm long.

Quartz syenite (*Ags*), and related pyroxene-amphibole granite, contain quartz, microcline, minor plagioclase, and green aegerine-augite which is altering to blue-green amphibole (arfvedsonite). In some rocks plagioclase is sufficiently abundant for the rock to be classified as quartz monzonite.

Textures in all the above rock types are allotriomorphic granular. Near the margins of the major batholiths cataclasis has produced a tectonic foliation. Where the original rock type is recognizable this shearing is indicated on the map. Where the foliation obscures the original rock type the symbol *Agg* is used. The blastomylonitic fabric of these rocks serves to distinguish them from most of the granitic gneiss within the gneissic belts (*Ang*), although the distinction is not always clear.

These granitoids will now be discussed in relation to four zones bounded by tectonic lineaments (Fig. 3).

Zone 1 (West of Ida Lineament)

This zone is occupied by a large batholith of adamellite which is in part porphyritic, and which grades from fine- to coarse-grained over distances of several kilometres. The adamellite intrudes the gneissic belt west of Agnew. East of Little Well (Yeelirrie) this contact is a line of strong shearing. Foliation within the batholith is poorly developed, but generally strikes north-northwest. Local deviations may be due to flow cells.

The batholith belongs to a group of major post-tectonic batholiths of adamellite composition (Table 3), which occur in an almost continuous belt south from here, through the western sides of the Leonora, Menzies and Kalgoorlie Sheet areas and into the Lake Johnstone Sheet area (Williams, 1974; Archibald and Bettenay, 1977). They separate the greenstone belts of the Kalgoorlie Sub-province from those of the Southern Cross Province.

Zone 2 (Between Ida and Keith-Kilkenny Lineaments)

The main granitoid body of this zone extends from Jones Creek westwards along the Barr Smith Range, and probably at least as far north as Nuendah. The importance of this body lies in its position below the unconformity at Jones Creek. Relationships are not clear on the western side, where it is in contact with nebulitic-structured tonalite. Roddick and others (1976) named that part of the body between Jones Creek and Mount Keith Homestead the Mount Keith Granodiorite, and reported a Rb/Sr age of $2\,689 \pm 17$ m.y. However, much of the body is petrographically plagioclase-rich adamellite, despite a generally granodioritic chemistry (Table 4, samples 40382, 40388 and 42856). The rock contains microcline phenocrysts except in outcrops of even-grained granodiorite/adamellite around Beale Well and Jones Creek. Microcline:plagioclase (including albite) ratio ranges from 1:1.5 to 1:4.5 in samples collected during the mapping, but Roddick and others (1976) reported a range of 1:2.5 to 1:4.5. Textures in thin section have been considerably modified by alteration, deformation and recrystallization.

Southwest of Perseverance fine- to medium-grained granite separates the Mount Roberts area from the Perseverance area. Structures in the two flanking greenstone sequences are broadly comparable, and the granite probably intruded dilationally. The margins of the intrusion show a strong cataclastic deformation, but with this exception the intrusion is post-tectonic in style and post-dates the main period of folding.

Zone 3 (between Keith-Kilkenny and Celia Lineaments)

West of the Yandal greenstone belt this zone consists of a large adamellite batholith similar to that of Zone 1. Again fine, coarse and porphyritic varieties are present, with gradational contacts. The western side is marked by a zone of shearing where the adamellite is adjacent to the Keith-Kilkenny Lineament. In the southern part of the sheet area the adamellite is bounded on the east and west by older gneissic belts.

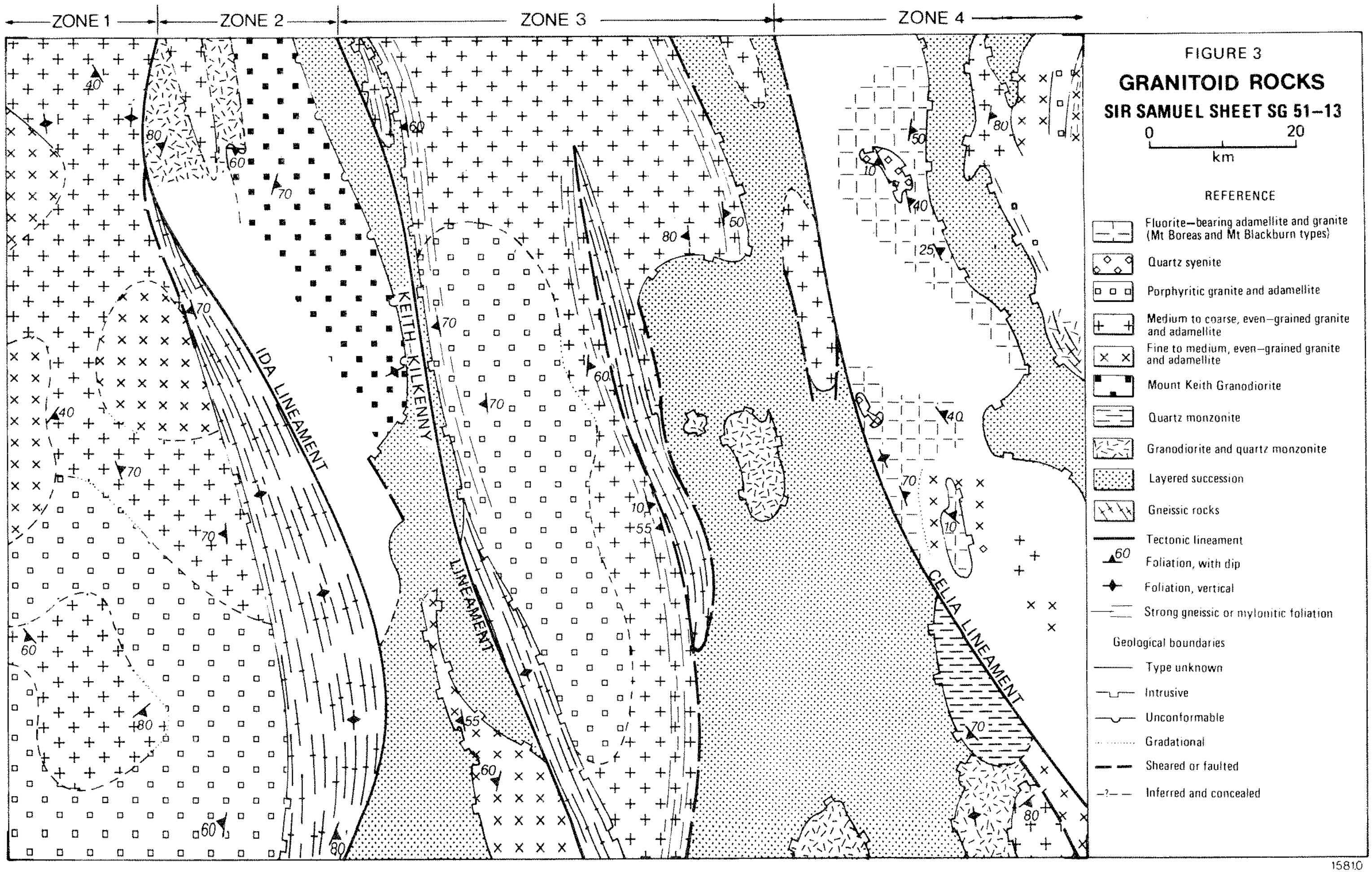
ZONE 1
ZONE 2
ZONE 3
ZONE 4
FIGURE 3
GRANITOID ROCKS
SIR SAMUEL SHEET SG 51–13
0 20
km
REFERENCE
Fluorite–bearing adamellite and granite (Mt Boreas and Mt Blackburn types)
Quartz syenite
Porphyritic granite and adamellite
Medium to coarse, even–grained granite and adamellite
Fine to medium, even–grained granite and adamellite
Mount Keith Granodiorite
Quartz monzonite
Granodiorite and quartz monzonite
Layered succession
Gneissic rocks
Tectonic lineament
Foliation, with dip
Foliation, vertical
Strong gneissic or mylonitic foliation
Geological boundaries
Type unknown
Intrusive
Unconformable
Gradational
Sheared or faulted
Inferred and concealed
IDA LINEAMENT
KEITH–KILKENNY LINEAMENT
CELIA LINEAMENT
15810

Table 3: Chemical analyses of granitoid and gneissic rocks from Zone 1

G.S.W.A. No.	*42859*	*40341*	*40389*	*40342*	*40343*	*42861*
SiO_2 %	72.1	74.2	71.5	66.6	64.2	69.3
Al_2O_3	15.5	14.3	15.6	17.5	20.7	14.4
Fe_2O_3	0.9	0.7	0.9	1.1	0.6	1.4
FeO*	1.29	0.96	1.03	1.86	0.84	2.70
MgO	0.2	0.2	0.4	1.0	0.6	0.8
CaO	1.93	1.39	2.02	4.09	4.37	2.29
Na_2O*	4.53	3.86	4.59	5.09	7.92	3.04
K_2O	3.3	4.4	3.6	1.3	1.2	4.6
H_2O^{+}*	0.46	0.52	0.44	0.55	0.30	1.61
H_2O^{-}*	0.10	0.10	0.13	0.09	0.11	0.00
CO_2*	0.39	0.24	0.18	0.15	0.09	0.00
TiO_2	0.22	0.21	0.26	0.33	0.08	0.64
P_2O_5	0.13	0.13	0.15	0.12	0.19	0.31
MnO	0.05	0.04	0.04	0.06	0.04	0.10
Total	101.1	101.3	100.8	99.8	101.2	101.2
Ba ppm	1250	1025	1380	815	1285	
Cu*	15					265
Li*	28	20	12	8	2	
MnO*	445					950
Mo*	1.0					
Pb*	40					60
Rb	160	205	110	40	5	
Sn*	3					10-100
Sr	530	220	715	660	1655	
Th	23					
U*	5					
V*						100
W*	0.5					9
Zn*	77					100
Zr	165	170	165	125	5	
F*	760	580	510	390	80	

*Analysis by chemical methods (all others by X-ray fluorescence)

		Lat	*Long*
42859	Coarse-grained adamellite	27°55′00″	120°16′05″
40341	Coarse-grained adamellite	27°34′50″	120°10′40″
40389	Coarse-grained adamellite	27°06′40″	120°09′10″
40342	Tonalitic gneiss	27°41′10″	120°24′30″
40343	Granodioritic clinopyroxene-hornblende gneiss	27°40′00″	120°24′40″
42861	Granophyric quartz micro-granodiorite (Proterozoic dyke)	27°49′30″	120°16′45″

Granitic rocks in the southern part of this zone are characterized by relatively small, discrete, ellipsoidal plutons of granodiorite, adamellite, porphyritic granite and quartz monzonite which have intruded the greenstone belt. This zone continues southeast into the Laverton Sheet area, where Gower (1974) has recognized an order of intrusion of the plutons from granodiorite, through adamellite to porphyritic granite. The long axes of the plutons are aligned parallel to the regional strike of the adjacent greenstone belts. There is a tendency for the plutons to intrude anticlinal positions, but this is more apparent in the Laverton Sheet than in the Sir Samuel Sheet.

Zone 4 (east of Celia Lineament)

Zone 4 extends eastwards as far as the Laverton Lineament in the Laverton and Duketon Sheet areas (Gower, 1974; Bunting and Chin, 1975). It comprises a complex batholith of various granitoid rocks. The predominant rock type between the

Table 4: Chemical analyses of granitoid rocks from Zone 2

G.S.W.A. No.	*35 823*	*35 886*	*40 382*	*40 388*	*42 856*	*42 858*
SiO_2 %	71.5	72.0	71.9	70.7	70.7	66.9
Al_2O_3	15.6	15.1	14.9	15.5	16.0	17.0
Fe_2O_3	0.9	0.9	0.9	1.0	0.9	1.3
FeO*	1.29	1.29	1.09	1.22	1.48	2.06
MgO	0.3	0.3	0.4	0.4	0.9	1.3
CaO	2.22	2.12	1.98	2.21	2.81	3.56
Na_2O*	4.74	4.54	4.55	4.89	4.07	6.12
K_2O	3.0	3.0	3.0	2.7	2.5	1.5
H_2O^+*	0.43	0.50	0.58	0.51	0.62	0.51
H_2O^-*	0.04	0.08	0.11	0.10	0.12	0.09
CO_2*	0.08	0.13	0.25	0.16	0.17	0.17
TiO_2	0.34	0.29	0.27	0.28	0.29	0.37
P_2O_5	0.16	0.15	0.13	0.16	0.16	0.16
MnO	0.05	0.05	0.05	0.04	0.04	0.06
Total	100.7	100.5	100.1	99.9	100.8	101.1
Ba ppm	850	1210	1060	1280	1340	330
Cu*					25	25
Li*	54	30	36	26	18	26
MnO*					400	580
Mo*					0.5	1.0
Pb*					30	30
Rb	115	105	105	100	80	65
Sn*					3	3
Sr	565	500	470	540	550	565
Th					16	18
U*					2	4
W*					0.5	0.5
Zn*					87	110
Zr	165	145	145	175	155	145
F*	880	520	730	460	410	1100

*Analysis by chemical methods (all others by X-ray fluorescence)

		Lat.	*Long.*
35823	Strongly foliated granite	27°55′50″	120°41′30″
35886	Porphyritic granodiorite (Mount Keith Granodiorite)	27°22′20″	120°31′10″
40382	As for 35886	27°26′00″	120°32′00″
40388	As for 35886	27°11′30″	120°24′10″
42856	As for 35886	27°07′15″	120°18′40″
42858	Tonalite	27°07′30″	120°14′45″

Dingo Range greenstone belt and the Celia Lineament is a pink adamellite (*Agb*) locally granite, which is characterized by finely disseminated fluorite, chloritized biotite, lack of tectonic foliation, and a high K_2O content (range 4.8-5.8 per cent, Table 5). Principal exposures are east of Ninnis Bore, and west of Wonganoo. It is similar to the Mount Boreas Adamellite in the Duketon and Laverton Sheet areas, which has been dated by Roddick (written comm.) at 2480 ± 30 m.y. The features described above indicate a fractionated, post-tectonic granite, and Bunting and Chin (1975) have compared it with the potassic hood granites of South Africa (Viljoen and Viljoen, 1969b). The shape of the individual intrusions in the Sir Samuel Sheet area is difficult to establish; however, a primary flow foliation which strikes consistently north-northwest and dips shallowly east may indicate a sheet-like body similar to the Mount Boreas Adamellite.

At Mount Blackburn, a small, irregular body of potassic adamellite (Table 5, samples 42831, 42832, 42833) contains abundant fluorite. It is similar to the

Table 5: Chemical analyses of granitoid rocks from Zone 3

G.S.W.A. No.	*35825*	*35874*	*35885*	*43301*	*35891*	*42854*	*42855*
SiO_2 %	71.8	72.3	72.5	73.4	71.5	70.6	69.0
Al_2O_3	14.8	14.2	14.8	13.5	15.1	16.1	15.8
Fe_2O_3	0.7	1.0	0.7	1.2	1.0	1.0	1.2
FeO*	1.16	1.74	0.96	1.35	1.35	1.42	2.00
MgO	0.0	0.6	0.0	0.6	1.1	1.1	1.1
CaO	1.27	2.45	1.53	1.80	2.51	2.91	3.12
Na_2O*	3.71	3.72	4.20	3.77	4.46	5.24	4.62
K_2O	5.2	3.1	4.1	3.2	3.0	2.1	2.4
H_2O^+*	0.53	0.78	0.56	0.58	0.72	0.57	0.59
H_2O^-*	0.10	0.15	0.11	0.11	0.14	0.13	0.11
CO_2*	0.43	0.49	0.09	0.24	0.12	0.19	0.23
TiO_2	0.27	0.29	0.21	0.27	0.30	0.31	0.43
P_2O_5	0.11	0.16	0.09	0.09	0.18	0.15	0.15
MnO	0.04	0.07	0.03	0.06	0.05	0.05	0.06
Total	100.1	101.1	99.9	100.2	101.5	101.9	100.8
Ba ppm	1200	465	860	620	690	500	520
Cu*				40	80	35	40
Li*	20	44	50	40	58	73	33
MnO*				440	385	385	480
Mo*				1.0	1.0	1.0	1.0
Pb*				30	40	20	40
Rb	210	140	175	110	140	70	75
Sn*				3	1-10	10	3
Sr	225	145	295	115	415	460	370
Th				23	15	2	2
U*				2	14	4	4
W*				0.5	0.5	1	1
Zn				48	79	64	74
Zr	225	145	160	165	125	115	125
F*	300	430	290	540	410	560	420

*Analysis by chemical methods (all others by X-ray fluorescence)

		Lat.	*Long.*
35825	Medium-grained adamellite	27°47′40″	120°48′50″
35874	Adamellite	27°19′35″	121°10′50″
35885	Porphyritic adamellite	27°31′50″	120°42′50″
43301	Medium-grained adamellite	27°30′30″	120°55′00″
35891	Biotite-hornblende granodiorite	27°29′00″	121°00′30″
42854	Boitite-hornblende granodiorite	27°57′10″	121°24′15″
42855	Biotite-hornblende granodiorite	27°56′15″	121°20′45″

Mount Boreas type, but possesses a tectonic lineation, which plunges gently south, along with an 070° trending fracture cleavage. The eastern contact is sharp, and indicates intrusion of the potassic adamellite into fine-grained adamellite. The westen contact is very irregular.

Quartz syenite and related pyroxene granite occur as irregular bodies around Red Hill and 2 km northeast of Woorana Well. At both localities the syenitic rocks are intruded by Mount Boreas type potassic adamellite.

Northeast of Wonganoo, an intrusion of adamellite consists of a north-south trending even-grained core with porphyritic margins. The body appears to have intruded dilationally, splitting the northern end of the Dingo Range greenstone belt.

Table 6: Chemical analyses of Mount Blackburn and Mount Boreas type granite/adamellite, zone 4.

G.S.W.A. No.	*42830*	*42831*	*42832*	*42833*	*42841*	*42845*	*42850*	*†Average*
SiO_2%	72.2	75.3	73.3	72.3	71.0	73.0	72.9	72.00
Al_2O_3	14.3	13.8	14.2	14.1	15.0	14.1	14.5	14.00
Fe_2O_3	0.8	0.5	0.8	1.3	0.9	0.8	1.0	1.19
FeO*	1.09	0.90	0.84	0.71	1.48	1.09	1.29	0.86
MgO	0.4	0.1	0.2	0.1	0.5	0.2	0.5	0.46
CaO	1.26	0.89	0.86	0.91	1.40	1.02	1.06	1.00
Na_2O*	4.03	3.83	4.48	4.82	3.74	3.33	3.57	3.89
K_2O	4.9	4.8	4.8	4.9	5.3	5.6	5.8	5.16
H_2O^+*	0.52	0.35	0.40	0.35	0.64	0.52	0.67	0.63
H_2O^-*	0.09	0.07	0.08	0.07	0.07	0.07	0.07	0.09
CO_2	0.33	0.13	0.20	0.22	0.26	0.24	0.37	0.07
TiO_2	0.26	0.14	0.17	0.27	0.35	0.21	0.27	0.28
P_2O_5	0.12	0.09	0.09	0.15	0.16	0.08	0.12	0.08
MnO	0.04	0.05	0.05	0.04	0.04	0.04	0.03	0.02
TOTAL	100.3	101.0	100.5	100.2	100.8	100.3	102.2	
Ba ppm	900	440	550	780	1 300	760	1 010	1 460
Cu*	90	100	155	90	70	110	40	
Li*	34	92	75	41	62	31	14	31
MnO*	340	385	420	350	295	335	285	
Mo*	1.0	1.5	1.0	1.0	1.0	1.5	2.0	
Pb*	60	60	70	60	50	60	50	
Rb	255	415	415	335	295	265	190	220
Sn*	10	10-100	10-100	1-10	1-10	1-10	1-10	
Sr	250	120	130	290	265	170	225	285
Th	46	58	73	80	88	88	97	
U*	6	10	4	4	16	20	2	
W*	1	1	3	2	1	2	1	
Zn*	72	58	115	92	77	66	78	
Zr	260	145	205	350	310	230	305	119
F*	620	920	1 900	2 100	740	340	320	1 100

*Analysis by chemical methods (all others by X-ray fluorescence)

		Lat.	*Long.*
42830	Coarse-grained adamellite (Mount Boreas type)	27°28′30″	121°13′05″
42831	Sheared granite (Mount Blackburn)	27°36′30″	121°19′30″
42832	Fluorite adamellite (Mount Blackburn)	27°36′00″	121°20′00″
42833	Fluorite adamellite (Mount Blackburn)	27°36′40″	121°21′30″
42841	Adamellite (Mount Boreas type)	27°28′00″	121°17′40″
42845	Adamellite (Mount Boreas type)	27°17′30″	121°18′05″
42850	Adamellite (Mount Boreas type)	27°09′40″	121°12′55″

† Average Mount Boreas Adamellite, Duketon and Laverton Sheet areas (Bunting and Chin, 1975)

Chemistry

Chemical analyses of granitoid rocks are presented in Tables 3 to 7.

Two chemical suites, termed calc-alkaline and alkaline, are apparent in the granitoid rocks (Fig. 4). The calc-alkaline suite which is evident over much of the Eastern Goldfields Province, forms a fractionation trend from tonalite to granite. Most rocks are in the adamellite range. The trend is sub-parallel to the corresponding trend of average compositions of Nockolds (1954), but is relatively enriched in sodium and deficient in calcium.

This trend embraces rocks from the syntectonic ellipsoidal plutons of Zone 3, and the syn- to late-tectonic Mount Keith Granodiorite, and post-tectonic batholiths of Zones 1 and 3. The trend has therefore operated throughout the main

FIGURE 4

CHEMICAL & NORMATIVE VARIATION DIAGRAMS OF GRANITIC ROCKS

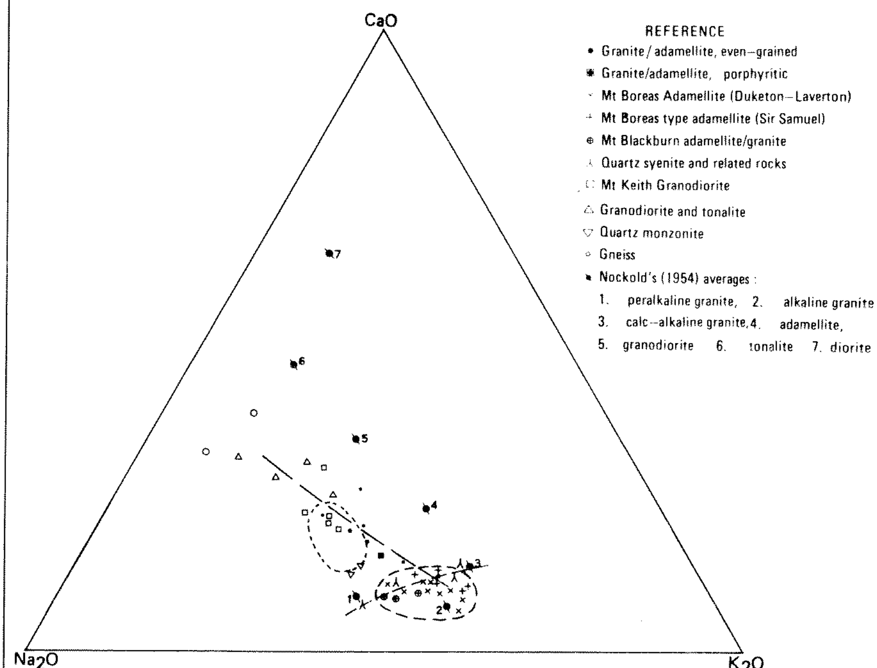

Fig 4a Chemical variation diagram of granitic rocks

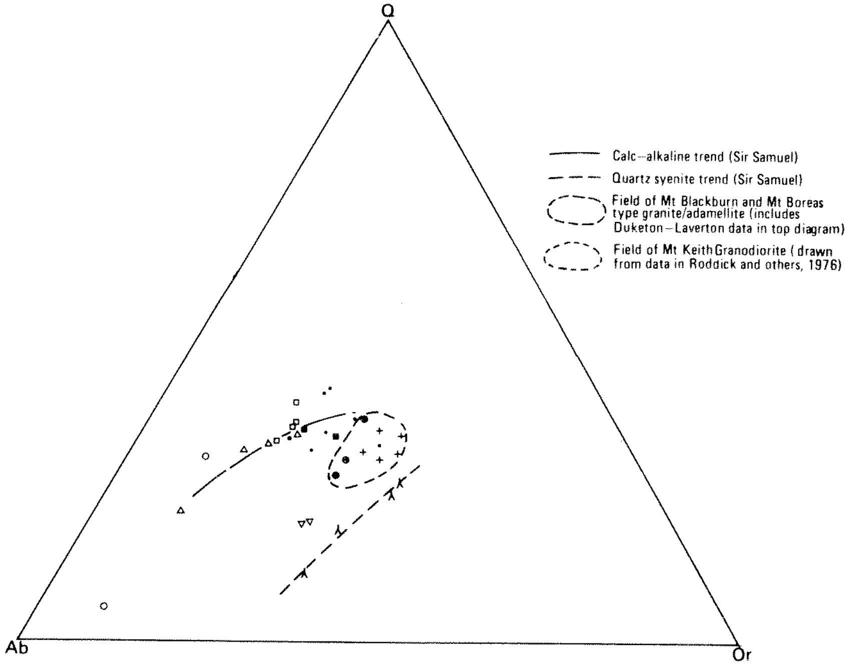

Fig 4b Normative variation diagram of granitic rocks

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Table 7: Chemical analyses of syenitic and monzonitic rocks (Zones 3 and 4) and miscellaneous granitoid rocks (zone 4)

G.S.W.A. No.	*40397*	*42834*	*42848*	*42849*	*42852*	*32887*	*42824*	*42828*	*42846*
SiO_2 %	69.6	67.4	72.4	71.1	69.5	68.5	72.7	73.8	68.0
Al_2O_3	14.9	16.2	14.0	14.2	16.3	16.4	14.5	14.3	14.8
Fe_2O_3	1.2	1.8	0.7	0.9	1.1	1.3	0.9	0.5	1.7
FeO*	0.90	0.71	0.84	1.03	0.97	1.03	1.09	1.09	1.61
MgO	0.3	0.6	0.4	0.4	0.4	0.1	0.4	0.1	1.0
CaO	1.39	1.00	1.64	1.37	1.43	1.63	1.79	1.10	1.78
Na_2O*	5.15	6.12	3.79	3.98	5.52	5.32	4.32	3.70	3.89
K_2O	5.5	5.4	6.2	6.3	4.5	4.6	3.8	5.2	5.4
H_2O^+*	0.33	0.23	0.30	0.28	0.23	0.34	0.59	0.54	0.59
H_2O^-*	0.11	0.07	0.04	0.09	0.09	0.08	0.12	0.09	0.07
CO_2*	0.06	0.20	0.42	0.14	0.06	0.16	0.39	0.28	0.33
TiO_2	0.34	0.26	0.19	0.31	0.26	0.31	0.27	0.21	0.69
P_2O_5	0.21	0.18	0.16	0.16	0.11	0,13	0.17	0.13	0.18
MnO	0.06	0.07	0.05	0.10	0.05	0.05	0.05	0.04	0.04
TOTAL	100.1	100.2	101.1	100.4	100.5	99.9	101.1	101.1	100.1
Ba ppm	825	280	964	1 120	1 290	1 300	970	810	2 300
Cu*		80	80	40	70		155	75	190
Li*	32	13	10	10	39	50	34	59	21
MnO*		540	440	840	425		515	380	360
Mo*		1.0	0.5	1.5	1.0		1.0	1.5	1.5
Pb*		20	40	40	40		40	70	70
Rb	205	250	205	235	165	180	130	290	190
Sn*		10	1-10	3	3		10	1-10	10-100
Sr	405	65	600	625	1 170	1 145	560	210	395
Th		7	4	2	9		16	60	71
U*		2	2	2	8		2	16	10
W*		2	0.5	0.5	1		1	0.5	1
Zn*		77	53	84	60		76	65	125
Zr	70	130	10	15	155	195	140	185	580
F*	160	170	160	220	690	860	760	690	1 300

*Analysis by chemical methods (all others by X-ray fluorescence)

		Lat.	*Long.*
40397	Pyroxene-quartz monzonite (Ags)	27°28′30″	121°02′30″
42834	Pyroxene-quartz syenite	27°36′45″	121°21′30″
42848	Pyroxene adamellite (Ags)	27°10′35″	121°15′05″
42849	Pyroxene-quartz syenite	27°09′40″	121°14′20″
42852	Biotite-hornblende-quartz monzonite (Agh)	27°51′50″	121°21′05″
32887	Biotite-hornblende adamellite (Agh)	27°52′10″	121°21′50″
42824	Sheared adamellite	27°05′45″	121°22′15″
42828	Coarse-grained adamellite (possibly Mt. Moreas type)	27°33′40″	121°15′30″
42846	Sheared adamellite	27°11′45″	121°16′30″

period of Archaean crustal development in this area. Elsewhere in Archaean terrains the fractionation trend has been shown to be partly time-dependent (Glikson, 1971, Viljoen and Viljoen, 1969b), the earlier rocks being predominantly granodiorite (sodium rich) and the post-tectonic rocks, adamellite or granite (potassium rich). This evolutionary trend may also operate on Sir Samuel. It is also true of more restricted time spans, for example the intrusive sequence granodiorite-adamellite-porphyritic granite in the ellipsoidal plutons of Zone 3.

The alkaline suitę is confined to Zone 4 and is illustrated by the trend of the syenitic rocks. In Figure 4a the field of the Mount Boreas type adamellite/granite (including data from the Duketon and Laverton Sheet areas) is elongate sub-parallel to the syenite trend and also the join of the average alkaline and peralkaline granites, although some of the Mount Boreas type rocks could equally well be end-members of the calc-alkaline trend. Most rocks of the alkaline suite are post-tectonic, and the Mount Boreas Adamellite has been dated at 2 480 m.y. (Roddick, written comm.); thus, in late Archaean, granitic magmas whose fractionation history differs from that of the main granitic rocks, intruded this part of the Eastern Goldfields Province.

The quartz monzonite at Mount Macdonald does not fit either of the main trends. Although it shows chemical affinities to the alkaline trend, it is spatially and petrographically related to the granodiorite and adamellite plutons of Zone 3.

The analyses in Table 3 to 7 illustrate a problem with the name "adamellite" in the northeast Yilgarn Block. As used by the Geological Survey of Western Australia, the term is used for a granitoid rock in which the ratio alkali feldspar: plagioclase is between 1:2 and 2:1. In the Sir Samuel Sheet area this term embraces most of the granitoid rocks, which range from plagioclase-dominant adamellites in the Mount Keith Granodiorite, through the "normal" adamellites to the alkali feldspar-dominant adamellites of the Mount Boreas type. The analyses show an even greater range; many of the Mount Keith "adamellites" are chemically granodiorite while those of the Mount Boreas type are chemically granite. A possible explanation (which has not been investigated) is that the albite feldspar component has gone preferentially into perthitic microcline in the Mount Keith body, and into plagioclase in the alkaline rocks.

STRUCTURE

The structure is dominated by north-northwest-trending lineaments, faults and tight folds. These are shown on a generalized structural interpretation map (Fig. 5). In Figure 2, the Agnew-Mount Keith belt is shown in more detail.

Tectonic lineaments

Tectonic lineaments are major zones of disruption across which there is no obvious correlation of lithology, stratigraphy, or structure. They can be traced over much of the Eastern Goldfields Province, and have a history of movement commencing in early Archaean and culminating in vertical movements in late Archaean times. The lineaments also show as zones of intense foliation. In the Sir Samuel Sheet area they commonly mark greenstone/granite or granite/gneiss contacts. The intrusion of ultramafic magmas along the Keith-Kilkenny Lineament and its subsidiary strike faults suggests that they are fractures which may have penetrated the crust and tapped the mantle. The Ida and Keith-Kilkenny Lineaments bound a graben structure that preserves the younger rocks in the greenstone belt.

Faults

Major strike faults splay from the tectonic lineaments (Fig. 5) and dislocate the fold patterns. The Perseverance Fault (Martin and Allchurch, 1976) is coincident with the Keith-Kilkenny Lineament at Perseverance, but diverges north of Lake Miranda. Similarly the Miranda Fault diverges from the Ida Lineament, truncates the northern end of the Mount White Syncline, and connects with the Perseverance Fault near Six Mile Well. This convergence of the Miranda and Perseverance-Keith-Kilkenny Fault systems has resulted in the structural complexity of the Kathleen Valley area.

In the Yandal greenstone belt, a major fault (the Ockerburry Fault) is postulated along the centre of the belt, connecting the Celia Lineament with the Keith-Kilkenny Lineament in the Leonora Sheet. The two faults postulated along the west-

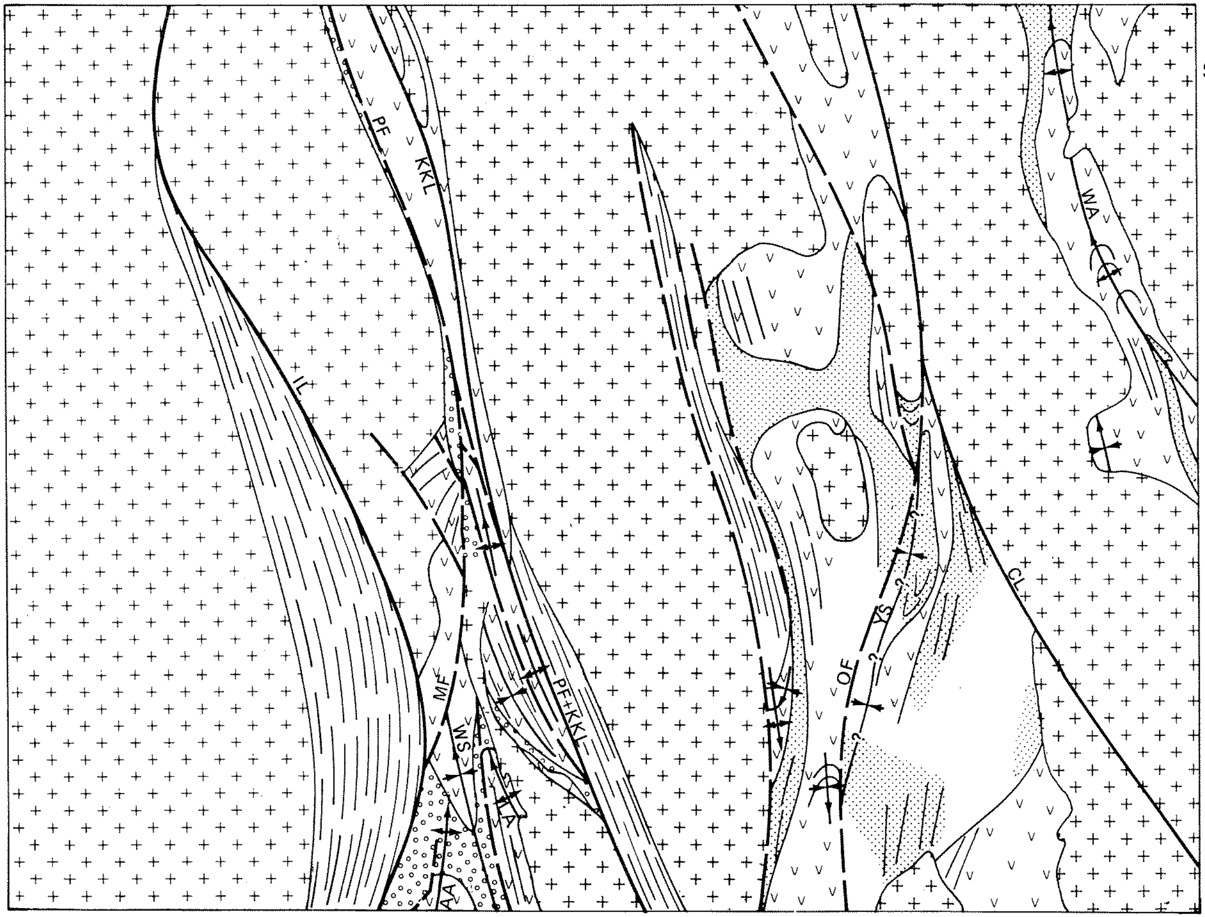

FIGURE 5

STRUCTURAL INTERPRETATION

SIR SAMUEL SHEET SG 51–13

0 20
km

REFERENCE

- Granitoid rocks
- Gneissic rocks
- Felsic volcanic and sedimentary rocks (included under mafic symbol in Agnew – Mt Keith belt)
- Conglomerate and arkose
- Mafic and ultramafic rocks
- Tectonic lineament
- Fault or major shear zone
- Anticline with plunge
- Syncline with plunge
- Trend line

IL	Ida Lineament
KKL	Keith Kilkenny Lineament
CL	Celia Lineament
PF	Perseverance Fault
MF	Miranda Fault
OF	Ockerburry Fault
AA	Agnew Anticline
LA	Leinster Anticline
WA	Wonganoo Anticline
WS	Mt White Syncline
YS	Yandal Syncline

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ern side of the greenstone belt are apparent mainly as zones of shearing within the granitic and gneissic rocks. The western fault truncates structure in the greenstone belt south of Calowindi Well.

Folds

Folds in the southern part of the Agnew-Mount Keith greenstone belt are tight and plunge north. Donaldson and Platt (1975) report two periods of isoclinal folding from the metasediments (equivalent to Jones Creek Conglomerate) west of Agnew. The Agnew Anticline probably relates to the second of these. The Mount White Syncline is confirmed by facing evidence from pillow lavas and cleavage-bedding relationships.

The Leinster Anticline has been split along its eastern limb by the dilational intrusion of granite. Facing evidence from pillow lavas and graded bedding indicates a synclinal structure northwest of Perseverance in an area complicated by strike faults parallel to the Keith-Kilkenny Lineament. A north-plunging anticline at Mount Sir Samuel is possibly only of local significance. Martin and Allchurch (1976) report differentiation in the Perseverance ultramafic intrusion which indicates east facing; thus, a major anticlinal structure to the west has been cut out by the strike faults. Associated with all of these folds is a strong sub-vertical axial-surface foliation which is the dominant directional fabric in the rocks, and a 20° to 50° north-plunging lineation. A persistent later crenulation cleavage trends 040° to 060°.

North of Lake Miranda strike faulting has severely disturbed the fold pattern of the belt. On structural evidence a north-plunging antiform is present through the mafic rocks at McDonoughs Lookout. The western side of the belt faces east, and the "Western Greenstone" and granite of Durney (1972) is unconformably overlain by conglomerate. A faulted-out syncline must exist between this and McDonoughs Lookout, possibly along the eastern margin of the conglomerate, where facing in spinifex-textured ultramafic is westerly (Marston and Travis, 1976; Naldrett and Turner, 1977). In the Six Mile Well area the "Eastern Greenstone" of Durney contains east-facing spinifex zonation and forms an attenuated syncline. A fault must be present between this and the McDonoughs Lookout sequence. In the Yandal greenstone belt, facing evidence is almost entirely lacking. The main structure of the belt is thought to be a north-northeast-trending syncline (the Yandal Syncline). Much of the core and western limb are cut out by the Ockerburry Fault. Evidence for this syncline lies in the facies gradation within the Spring Well felsic volcanic centre which indicates west-facing. There is no apparent folding whithin the central part of the complex which probably acted as a stable block during folding.

West of the Ockerburry Fault, the gross structure is problematical. The shape of the lithological units suggests a north-northwest-trending fold through Bates Range, and the presence of an elliptical syntectonic granitoid intrusion suggests the fold may be anticlinal. South of Calowindi Well structural evidence indicates that a tight southwest-plunging synform has been refolded by an open south-plunging antiform. An antiform is indicated at Ockerburry Hill by parasitic folds in chert, but this is probably a minor fold near the core of the regional Yandal Syncline.

The Dingo Range belt is unusual in that the dominant structure is an anticline (the Wonganoo Anticline) surrounded by intrusive granitoid rocks. Only at Stirling Peaks is there the suggestion of a flanking syncline. Evidence for the Wonganoo Anticline is abundant and includes: northerly dip and bedding around the fold closure in the Dingo Range, parasitic folds in chert bands, northerly plunging mineral elongation lineation associated with axial-plane foliation, and facing from pillows and graded bedding in the vicinity of Wonganoo.

Structural sequence

We have not attempted a detailed structural analysis, but several events can be distinguished. The following sequence refers to the greenstone belts only, not the gneissic belts, and deals mainly with the Agnew-Mount Keith belt.

(1) An early phase of folding is demonstrated by the high angle unconformity between the mafic sequence and the younger conglomerate at Kathleen Valley.

(2) A second period of deformation comprising at least two phases, resulted in the main sub-vertical, north-northwest-trending folds and foliation. Most granitoid intrusion occurred during this period, as did the main movements along the major lineaments and faults. In most areas the dominant schistosity parallel to the axial surfaces of the major folds, but in the Kathleen Valley area the schistosity is deformed by chevron and crumple folds of the second phase. These later folds are associated with a major north-plunging synform 4 km south of Six Mile Well; these two phases may correspond to the two phases of isoclinal folding postulated by Donaldson and Platt west of Agnew, and to the folded fold south of Calowindi Well.

(3) This event was characterized by brittle to semi-brittle deformation, producing crenulation and fracture cleavage. Cleavage is generally at a high angle to the dominant north-northwest foliation thus in the Agnew-Perseverance area a regional crenulation cleavage trends 010° to 060° and in the Bates Range-Mount McClure area crenulation and fracture cleavages trend 080°

(4) Crenulations with sub-horizontal axes occur along the Keith-Kilkenny Lineament zone east of Kathleen Valley. The axes trend parallel to the lineament, and vergence of the asymmetrical crenulations suggests they may represent late vertical movements of the lineament zone, in which the eastern block rose.

METAMORPHISM

No systematic study of metamorphism was attempted during the 1:250 000 mapping, but several points have emerged. The pelitic rocks have limitations as metamorphic indicators due to their susceptibility to surface weathering. Andalusite is common in pelitic schists in the Perseverance-Mount Sir Samuel and Kathleen Valley areas where it displays rolling effects and is syntectonic with the main foliation. However, immediately southeast of Mount Mann, porphyroblastic andalusite in pelites associated with chlorite schist is a product of static metamorphism, possibly due to the nearby intrusion of the Kathleen Valley gabbro. Mafic rocks in the greenstone belts are characterized in the lower grades by actinolitic amphibole, with hornblende being restricted to the higher grade margins. Plagioclase composition is not a good metamorphic grade indicator in the mafic rocks, because at medium and lower grades it may retain its original magmatic composition and form. Binns and others (1975) attribute this phenomenon (and the presence of relict olivine in some medium grade ultramafic rocks) to a non-progressive type of static, low pressure metamorphism in which the medium grade rocks did not pass through phases of alteration in the lower grades.

Because of the problems outlined above, metamorphic grades based on mineral assemblages are of dubious value in surface regional mapping. A more workable tool is the variation in fabric produced by different metamorphic styles. In the central parts of greenstone belts, primary textures are largely preserved. Plagioclase laths in mafic volcanic rocks retain their igneous textures and in places (for example the Dingo Range) and original flow texture. The mafic minerals have generally recrystallized to a directionless mat of actinolite. In mafic rocks along greenstone belt margins a penetrative foliation developed due to alignment of recrystallized hornblende grains while the felsic minerals recrystallized to a granular mosaic. In fine-grained mafic rocks, the symbols *Ab* and *Aba* distinguish these two styles of metamorphism. Binns and others (1975) refer to static and dynamic style domains in this context.

In the Agnew and Kathleen Valley areas, tremolite-chlorite schists commonly contain random or stellar aggregates of tremolite blades growing across an earlier chlorite-tremolite foliation. This indicates either a period of static metamorphism after the period of foliation development, or that static recrystallization continued after deformation had ceased.

Metamorphic grade of the gneissic belts is higher than in the adjacent greenstone belts. This is best shown west of Agnew, where mafic enclaves in the gneiss contain garnet (up to 50 per cent), hornblende, diopside and quartz, indicative of upper amphibolite facies metamorphism. Textures are predominantly granoblastic. One sample shows high grade static growth of garnet and diopside superimposed on an earlier period of dynamically metamorphosed foliated amphibolite (hornblende-quartz-plagioclase). No confirmed granulites have been found in this belt. Ferro-hypersthene occurs in grunerite-bearing banded iron-formation, but the unusual rock composition suggests the assemblage may have a chemical as well as metamorphic control. Further north in the same belt (west of Lake Miranda and near Little Well) and in the gneissic belt east of Perseverance, the garnet is missing from the mafic rocks, but they have the same granoblastic textures. Near Charlie Well (Lake Way) small garnets are common in gneissic adamellite near the margin of the greenstone belt, close to the Keith-Kilkenny Lineament.

STRATIGRAPHY

Stratigraphic successions of varying degrees of confidence can be set up for each of the greenstone belts (Fig. 6). Because of the spatial separation and contrasting lithologies of the three belts, correlation between them is impossible. In fact, the differences are so striking (Table 1), that we suggest that these belts were never physically joined across strike, but developed in separate linear basins or rift valleys branching off a main basin to the south. The gneissic belts may represent the older material between the linear basins.

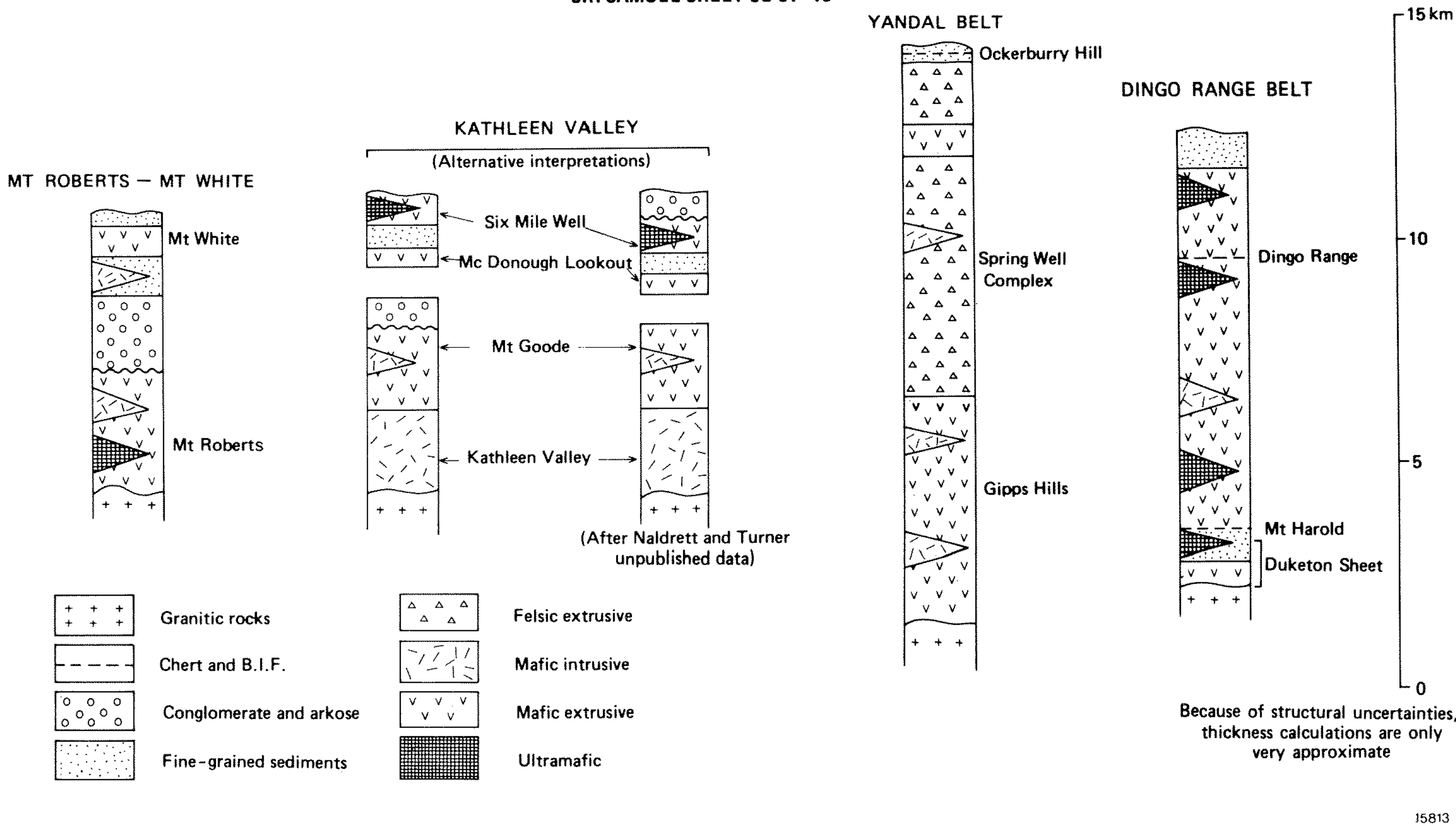
Agnew-Mount Keith belt

The stratigraphy in the southern half of the belt is relatively simple, and can be represented by sections from the core of the Agnew or Leinster Anticlines to the core of the Mount White Syncline. A lower mafic/ultramafic sequence (at Agnew and Mount Roberts) is overlain by feldspathic sediments and conglomerate, which grade upwards into pelitic sediments. These are overlain by pillow basalts at Mount White. The core of the syncline is occupied by pelite and greywacke. Williams (pers. comm.) correlates the mafic succession at Agnew with the Morelands Formation of the Kurnalpi Sheet (Williams, 1970); thus, the overlying sedimentary unit may equate with the Gindalbie Formation, the pillow basalts at Mount White with the Mulgabbie Formation, and the overlying pelite and greywacke with the Gundockerta Formation. These correlations are extremely tenuous, and imply a lateral continuity of lithological associations throughout the Eastern Goldfields Province.

The mafic rocks in the syncline northwest of Perseverance probably correlate with the pillow basalts at Mount White, while the feldspathic sediments between Perseverance and Mount Sir Samuel may correlate with the Sediments below the Mount White basalts.

No such simple picture emerges from the Kathleen Valley area. Durney (1972) proposed a succession which an older "Western Greenstone" (Kathleen Valley gabbro and Mount Goode basalt), which probably correlates with the mafic succession at Agnew, is unconformably overlain by the Jones Creek Conglomerate

FIGURE 6
STRATIGRAPHIC SUCCESSIONS
SIR SAMUEL SHEET SG 51–13



which is conformably overlain by "Eastern Greenstone". Because of the structural complexity of the area this view is oversimplified, and some controversy exists over the stratigraphic position of the conglomerate. Marston and Travis (1976) and Naldrett and Turner (1977) propose that the conglomerate is the youngest unit in the area, sitting in a complex syncline and deriving material from both the eastern and western greenstones. Spinifex zonation in ultramafics east of the conglomerate face east near Six Mile Well and west near Mount Goode (Turner, pers. comm.) suggesting that the eastern contact of the conglomerate is a major fault. An alternative hypothesis is that the conglomerate is, as Durney suggests, in the middle of the succession, but that the eastern contact is a major fault separating the east-facing conglomerate from, in the south, an anticline through McDonough Lookout, and in the north an east facing younger mafic succession south of Six Mile Well. There are detailed arguments for and against both theories, and the stratigraphic interpretation of the Kathleen Valley area is by no means finalized. The two alternative successions are set out in Figure 6.

Marston and Travis (1976) consider the Jones Creek Conglomerate to be the youngest unit not only in the Kathleen Valley area but also west of Agnew, proposing that it lies in a young fault-bounded basin, and that the conglomerate which is folded around the Agnew Anticline is an older unit. However, we believe that there may be only one conglomerate unit, and that it is older than the rocks in the Mount White Syncline.

The development of the Agnew-Mount Keith belt can be briefly summarized as follows.

(1) Rifting of gneissic basement, accompanied by mafic and ultramafic volcanism, and layered gabbro intrusion.

(2) Folding, and intrusion of adamellite and granodiorite plutons.

(3) Downfaulting, producing a graben structure between tectonic lineaments, which rapidly filled with conglomeratic, feldspathic, and mafic sediments; and was accompanied by minor felsic volcanism.

(4) Mafic volcanism, followed by marine sedimentation.

(5) Main period of tight folding, in several phases, accompanied by new and re-activated strike faulting; followed by ultramafic intrusion along major fractures; and a final phase of granitic intrusion, some dilational.

(6) Late vertical movements along tectonic lineaments prior to uplift and erosion of Yilgarn Block.

Yandal belt

East of the Ockerburry Fault a thick mafic sequence (Gipps Hills) is overlain by the thick, Spring Well, felsic volcanic complex. The felsic unit thins to the north away from the volcanic centre, and a band of mafic volcanic rock up to 2 km wide occurs within the felsic rocks east of Yandal. Interbedding with similar felsic volcanic rocks along both sides of the mafic band indicates that it represents only a hiatus in felsic volcanic activity.

West of the Ockerburry Fault the simplest hypothesis is that the sequence east of the fault (and the Yandal Syncline) is repeated to the west, with an anticlinal structure through the Bates Range. Thus, there are again two major units—a lower mafic unit and an upper felsic unit.

Dingo Range belt

Interbedded metabasalt and high-Mg basalt (mainly in the Duketon Sheet area) in the core of the Wonganoo Anticline passes upwards into a prominent chert and banded iron-formation horizon with interbedded shale and weathered felsic volcanic rocks. Above this is a thick metabasalt unit containing chert and intrusive peridotite. Poorly exposed tuffaceous and shaly sediment forms the top of the sequence.

PROTEROZOIC

DYKE SUITE

Dykes trending about 080° cut granitic rocks near Kaluweerie Hill. They are mainly granodioritic in composition, with small oligoclase phenocrysts, biotite and muscovite set in an interstitial granophyric intergrowth of quartz and microcline. Pyrite is a common accessory. The dykes are sub-vertical, up to 10 m wide, and, in the larger examples, display a vertical primary layering 10 to 50 mm thick. In an exposure east of Langford Well this layering displays complex flow folding, presumably because of turbulence within the magma.

A small east-trending post metamorphic dolerite dyke has been reported from the Mount Keith area (Burt and Sheppy, 1976). A small dolerite dyke trending 080° cuts granitic rocks 10 km east of Melrose.

All of the dykes are presumed to be related to the Widgiemooltha Dyke Suite of the Kalgoorlie-Norseman area which has been dated at about 2 400 m.y. The dykes probably intruded along a tensional fracture system which may also relate to a suite of quartz-filled fractures in the same direction (e.g. Wild Cat Hills).

KALUWEERIE CONGLOMERATE

Near Kaluweerie Hill an outlier of presumed Proterozoic sediments lies unconformably on Archaean granitic rocks. Present exposure forms a sinuous east-trending belt 15 km long by 1.5 km wide. In drillholes 10 km west of Kaluweerie Hill the conglomerate is 35 m thick, but the maximum exposed thickness is 25 m.

Two lithological types are present:

(1) polymictic conglomerate and pebbly lithic arenite, and

(2) fine- to coarse-grained lithic arenite.

The conglomerate generally forms a lower unit, whereas arenite is dominant in the upper part of the sequence. The deposit is described in detail by Allchurch and Bunting (1976). Important features are the high proportion of mechanically unstable clastic grains (e.g. carbonate, epidote, chlorite, amphibole, felsic lava) in the sand fraction, and the variety of igneous and metamorphic rock types in the conglomerate. Bedding structures in both conglomerate and arenite are poorly developed.

Allchurch and Bunting (1976) consider the deposit to be derived locally from the west, possible in a partly confined channel or as a valley-fill deposit. The conglomerate shows some features characteristic of the rapid flow of water-lubricated material found in debris flow deposits close to areas of strong erosion. The upper (arenite) part of the sequence may be transitional into a marine environment.

PERMIAN

Scattered outliers of fluviatile and glacigene deposits are equated with the Lower Permian Paterson Formation of the Office Basin (Lowry and others, 1972). As in the Officer Basin, three facies have been recognized: (1) poorly sorted sandstone, conglomerate and minor siltstone (*Paf*) probably of fluviatile origin; (2) claystone and siltstone (*Pal*) of lacustrine origin; (3) clay-matrix conglomerate, probably tillite.

In breakaways in the western part of the sheet area horizontally bedded grits overlie deeply weathered granitic rock. About 13 km north of Albion Downs this consists of 8 m of poorly bedded, poorly sorted grit, in which coarse, subangular quartz grains are set in a clay matrix overlying 1 m of silicified quartz pebble conglomerate. These deposits are considered to be of Permian age, but they may be Tertiary.

Permian rocks near Ockerburry Hill were first described by MacLeod (1969). Archaean schists and chert are unconformably overlain by up to 50 m of gently folded sediments, with an overall dip of about 5° west. A 2 m-thick basal unit of coarse-grained, poorly sorted quartz-rich sandstone, with subangular to sub-rounded grains is overlain by 5 m of tillite consisting of angular to sub-rounded boulders in a silty clay matrix. The clasts are mostly of granitic rock, but include mafic and felsic volcanics, metasediment, vein quartz and chert. Some of the boulders are striated and faceted. The tillite is disconformably overlain by a thin unit of laminated (?varved) siltstone, followed by 42 m of well-bedded sandy mudstone and siltstone. The lower 10 m of this siltstone has spectacular liesegang banding and is popularly known as "Weebo Stone".

Northwest of Agnew, on the Sir Samuel-Leonora Sheet boundary, there are boulder beds and associated sub-horizontal gritty sediments with thin claystone intercalations. These beds are probably Permian glacial deposits, and represent the most westerly recorded encroachment of such rocks over the Yilgarn Block.

CAINOZOIC

Mapping of Cainozoic units is based on lithology and morphological expression. For the purpose of continuity with other 1:250 000 sheets in the Eastern Goldfields, the middle letter of the Q units has been retained, but it does not have any significance here. The stratigraphic relationship of the various Cainozoic units is shown in Figure 7.

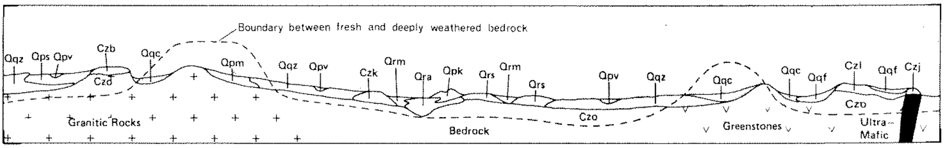


FIGURE 7

CAINOZOIC ROCK UNIT RELATIONSHIPS

SIR SAMUEL SHEET SG 51–13

Unit symbols as in map reference

Undifferentiated

The *Cz* units, with the exception of calcrete (*Czk*), form part of the deep weathering profile. *Czo* denotes deep-weathered kaolinized rock, which is partly ferruginized and silicified. Bedrock textures may be preserved, depending on the depth of weathering. Silcrete (*Czb*), a hard siliceous duricrust containing angular quartz grains, may occur above the kaolinized zone over granitic rocks.

Laterite (*Czl*), a ferruginous, pisolitic, duricrust, is most commonly developed over mafic and ultramafic rocks, though it may form over any rock type. Laterite caps over iron-rich rocks are usually darker. The name "caprock" (*Czj*) is a collective term for a variety of weathering products developed over ultramafic rocks. It consists of a dark-brown limonite deposit containing chrysoprase, magnesite, chalcedony and opaline silica. This type is best developed over massive serpentinites, whereas a massive, yellow to pale brown siliceous deposit is more common over talc-carbonate rocks.

Calcrete (*Czk*) is a carbonate and opaline silica rock formed in ancient drainage systems. It commonly outcrops at the margins of present day salt lakes. The thickness of calcrete deposits in the centre of ancient valleys ranges from 15 to 50 metres.

Quaternary

Colluvium, consisting of angular to rounded rock and quartz fragments contained in calcareous loam (*Qqc*), occurs marginal to rock outcrops and forms a thin veneer over fresh and weathered rock. Ironstone gravel and laterite debris contained in calcareous loam (*Qqf*) forms eluvial and colluvial deposits, commonly mantling low hills over mafic rocks. Quartz and feldspar sand (*Qpm*) occurs adjacent to, or overlying, granitic rock and its presence usually indicates shallowly buried, fresh granite.

All of the above deposits grade transitionally into coalesced alluvial fans and broad sheet-wash areas, consisting of clay and loam (*Qqz*). This unit is the most extensive Quaternary deposit in the sheet area. Alluvial deposits in drainage channels are grouped as (*Qpv*). Both *Qpv* and *Qqz* units support fairly dense mulga and shrub growth.

The *Qq* units and *Qpv* are commonly underlain by hardpan, and indurated colluvial deposit cemented by silica, iron oxide or carbonate (Bettenay and Churchward, 1974).

Eolian deposits of red-brown sand (*Qps*), unrelated to salt lakes, are widespread. The sand forms extensive gently undulating sheets characteristically vegetated by spinifex, and only occasionally are distinct dunes developed. Most of the sand plain is probably underlain by granite.

Several distinct Quaternary deposits are associated with the saline, ponded environment of ancient drainage systems. The term "salt lake" is usually restricted to bare, expansive flats with lacustrine deposits of saline, silty clay (*Qra*) which often contains large gypsum crystals. This unit grades into coarser grained, saline alluvium and lacustrine deposits (*Qrm*) which occupy samphire, salt-bush flats and claypans. Both of the above units may be up to 100 metres thick in the larger salt lakes.

Eolian lake units include: *Qrs*, a saline, calcareous and gypsiferous sand which occurs in sheets, and occasionally in dunes, marginal to salt lakes; and *Qpk*, a calcareous and gypsiferous loam deposited in dunes, which flank and encroach upon salt lakes. The material deposited in *Qpk* dunes is derived by deflation of gypsum from salt lake surfaces and by deflation of calcium carbonate from nearby eroding calcarete deposits. The large expanses of calcrete on the Sir Samuel Sheet account for the significant calcareous component in these eolian deposits compared with similar deposits further south in the Eastern Goldfields, where calcarete is not common and the calcareous component in eolian lake units is insignificant.

Silty clay deposits in non-saline to brackish clay-pans from the *Qrp* unit.

MINERAL DEPOSITS

GOLD AND SILVER

Most of the gold and silver recovered from the Sir Samuel Sheet area was associated with quartz reefs and lenses. Host rocks for these reefs vary, they include: sheared metabasalts for the Sir Samuel, Bronzewing, Lake Darlot mine groups, and some of the Lawlers group; sheared conglomerate and arkose for the Kathleen Valley group and some of the Lawlers Group; sheared felsic volcanics at Mount Keith; and granite-metabasalt contacts, for the Corboys group and the Brilliant mine of the Lawlers group. Significant amounts of gold have also been recovered from shallow alluvial deposits, and a deep alluvial lead near Lake Darlot. Some of the early workings are described by Reed (1897), Gibson (1907), Talbot (1914); Jutson (1914, 1917) and Montgomery (1928).

Production figures are given in Table 8. Only minor production has been reported since the 1940s; however, at the time of preparation of this report active exploration for gold was proceeding in the area to the north of the E.M.U. mine, near the Sir Samuel-Leonora Sheet boundary.

NICKEL

All the major nickel discoveries in the sheet area are confined to ultramafic intrusive rocks along the Keith-Kilkenny Lineament and its subsidiary faults (Fig. 2). The geology of these rocks is discussed earlier in this report.

The Perseverance ore body (Martin and Allchurch, 1976) occurs in a lens of massive serpentinized dunite intruded into metasediments. The lens, which strikes north-northwest and dips steeply west, is 3 500 m long and has a maximum width of 800 m. Mineralization, in the form of massive and disseminated sulphides, occurs along the western contact and in some younger fault zones cutting the metasediments. Primary sulphides consist mainly of pyrrhotite and pentlandite; some secondary sulphides (e.g. violarite and pyrite) also occur. Indicated reserves (December, 1973) are 45 Mt at a grade of just over 2% Ni using a 1% cut-off.

The Mount Keith orebody, which is larger and of lower grade than that at Perseverance, has been described by Burt and Sheppy (1976). Disseminated pentlandite occurs in the centre of a near vertical to steeply westward-dipping, serpentinized dunite body with pyroxenite margins. Burt and Sheppy have interpreted the dunite as a dyke-like body emplaced in previously folded metavolcanics and metasediments. Mineralization occurs in a zone 1 830 m long with an average width of about 180 m. Approximately 65% of the ore is present in a mass of black, magnetite-rich, serpentinite, which is centrally located within the dyke-like body. Pentlandite is the predominant sulphide; and pyrrhotite, millerite and violarite are subordinate sulphides. Some accessory minerals are chromite, stichtite and cobalt sulphides. Calculated reserves are 290 Mt at 0.60% nickel.

Several small deposits are clustered around Six Mile Well, along the same line of ultramafic intrusion. The principal deposit has been described by Turner and Ranford (1976).

URANIUM

The Yeelirrie uranium deposit occurs in calcarte in a relict drainage channel which straddles the sheet boundary northwest of Yeelirrie homestead. The uranium occurs in carnotite deposited in cavities, fractures, and on grain boundaries (E. Cameron and C. I. Fletcher, written comm.) The mineralized zones form irregular sub-horizontal sheets that are related to present or past water tables. The origin of uranium ores in calcrete-type environments, with special reference to Yeelirrie, is discussed by Dall'Aglio and others (1974), Langford (1974) and Mann (1974). Drilling by Western Mining Corporation has proven an estimated 30 Mt of ore, at an average grade of 0.15 per cent, i.e. 46 kt of contained U_3O_8. Average depth to the deposit is 8 m.

A similar, but smaller, deposit occurs in calcrete at Lake Maitland (Lorimer, 1973).

The ultimate source of the uranium is probably the Archaean granitoid rocks, and it is noteworthy that the drainage area of the Lake Maitland prospect embraces some of the Late Archaean potassic granites of the Mount Boreas type which have moderately high uranium values (Table 6 and 7). Proterozoic conglomerate in drill-holes west of Kaluweerie Hill contains traces of carnotite (Allchurch and Bunting, 1976) and it is possible that the Yelirrie uranium went through an intermediate, concentrating cycle in the Proterozoic sediments which possibly covered much of this part of the Yilgarn Block.

Table 8: Summary of reported gold and silver

Goldfield	*District*	*Locality*	*Alluvial (g)*	*Dollied (g)*	*Ore treated (t)*	*Gold therefrom (g)*	*Average grade (g/t)*	*Total gold recovered (g)*	*Silver recovered (g)*
EAST MURCHISON GOLDFIELD	LAWLERS	KATHLEEN VALLEY	446.95	20 866.38	88 197.62	1 608 555.72	18.24	1 629 869.05	27 837.81
		BRONZEWING	-		475.51	9 891.69	20.80	9 891.69	
		LAWLERS	-	5 677.85	243 651.26	3 552.636.29	14.58	3 558 314.14	approx. 93 309.00
		SIR SAMUEL	1 792.78	13 604.14	287 815.01	4 557 044.23	15.83	4 572 441.15	318 333.61
	WILUNA	MT. KEITH	149.61	8 454.73	12 643.73	296 470.69	23.45	305 075.03	30.79
		CORBOY FIND	834.18	38.88	24 414.30	505 345.99	20.70	506 219.05	155.52
MOUNT MARGARET GOLDFIELD	MOUNT MALCOLM	LAKE DARLOT	4 040.90	167 863.20	99 060.38	1 859 509.96	18.77	2 031 414.06	1 934.61
			7 264.42	216 505.18	756 257.81	12 389 454.57	16.38	12 613 224.17	441 601.34

COPPER

The earliest recorded copper production was in 1908 from workings in the Kathleen Valley (Montgomery, 1909). This area remained the major copper producer until operations closed in 1966. Other copper deposits near the Sir Samuel townsite were worked between 1942 and 1967. Total copper production for the Sheet area amounts to 435 t, mainly as cupreous ore. Of this 424 t are from the Kathleen deposits.

The ore bodies are pyrite-chalcopyrite-quartz veins, often containing significant gold and silver, which have intruded mafic rock along north-trending shear zones. Secondary enrichment is common, and Low (1963) records malachite, azurite, chrysocolla, oxides, bornite, chalcocite and covellite in the workings.

TIN

A cassiterite-bearing lepidolite-albite-pegmatite 3 km south-southwest of Kathleen Valley was mentioned by Miles and others (1945). This and another small tin deposit 0.4 km southwest of Sir Samuel townsite were worked between 1945 and 1953, and together produced about 8 t of ore, containing 0.2 t of tin.

CORUNDUM

Corundum occurs in a massive granular deposit inter-mixed with andalusite 1 km south-southeast of Mount Mann (Carter, 1976). The only production recorded is for 1952 when 55 t of ore were mined.

TUNGSTEN

Production of 15.3 t of scheelite ore yielding 63 kg of concentrate (equivalent to 23.87 kg WO_3) was recorded in 1952 from Moriarty's Mine, 5 km north-northwest of Kathleen.

WATER RESOURCES

The area is one of low irregular rainfall, and it has an internal drainage system. Surface run-off is channelled into internal drainage lines leading to extensive salt lake systems, where ponded water soon evaporates. Surface water supplies are confined to pools in creeks, water holes, soaks, rock holes and gnamma holes, which are of limited capacity and quickly dry up. Low rainfall, high evaporation and low topographic relief prevent the establishment of any large surface water storage area.

The best quality water is found furthest from the salt lakes near drainage divides, especially in areas of granitic rock. Nearer to the salt lakes, salinities increase markedly. Colluvial aquifers have the best quality water, but these are usually small. Calcrete aquifers, on the other hand, have water of variable quality, often with high salinites, but because they have efficient recharge characteristics during short duration floods, they have the capacity to yield large quantities of water, and thus represent the major potential source of water for possible future mining and metallurgical use. Sanders (1969) includes the Sir Samuel Sheet area in a discussion of the hydrogeology of calcrete in the East Murchison and Mount Margaret Goldfields. The Perseverance nickel project will utilize very large quantities of groundwater in calcrete in the depot springs area. Cowan and Omnes (1975) discuss the exploration of the Depot Springs aquifers with special reference to resistivity techniques.

Underground water provides the main source of supply for domestic and stock purposes. Aquifers are mainly shallow and include: weathered bedrock and colluvial aquifers near the base of large outcrop hills; alluvial aquifers in drainages; and calcrete aquifers in ancient drainage systems.

Wells and bores are present over most of the area and as many as possible of these were sampled for total dissolved solids (TDS). The results together with generalized salinity contours are shown in Figure 8. Full chemical analyses were carried out on 11 water samples and the results for representative samples are given in Table 9.

Table 9: Representative chemical analyses of groundwater

Well Name	*Anderson Well Leinster Downs Station*	*Scottie Well Albion Downs Station*	*No. 5 Well Wonganoo Station*	*Galowindi Well Yandal Station*
Water level	—	25.9 metres	5.9 metres	3.8 metres
Total dissolved solids (by evaporation)	720 mg/l	1 340 mg/l	1 240 mg/l	5 350 mg/l
Total hardness (calculation as $CaCO_3$)	220	408	436	1 130
Total alkalinity (calculated as $CaCO_3$)	208	80	148	303
Calcium	22	76	92	145
Magnesium	40	53	50	186
Sodium	164	260	242	1 470
Potassium	9	25	21	60
Bicarbonate	223	98	180	369
Carbonate	15	nil	nil	nil
Sulphate	85	134	238	566
Chloride	161	498	340	2 430
Nitrate	79	104	137	90
Silica	34	84	82	74
Remarks	Colluvial aquifer near drainage divide in greenstones	Aquifer within or above deep-weathering profile in granite	Alluvial aquifer on major drainage off granitic rocks	Calcrete aquifer adjacent to salt lake

Analyses by Government Chemical Laboratories, Perth.

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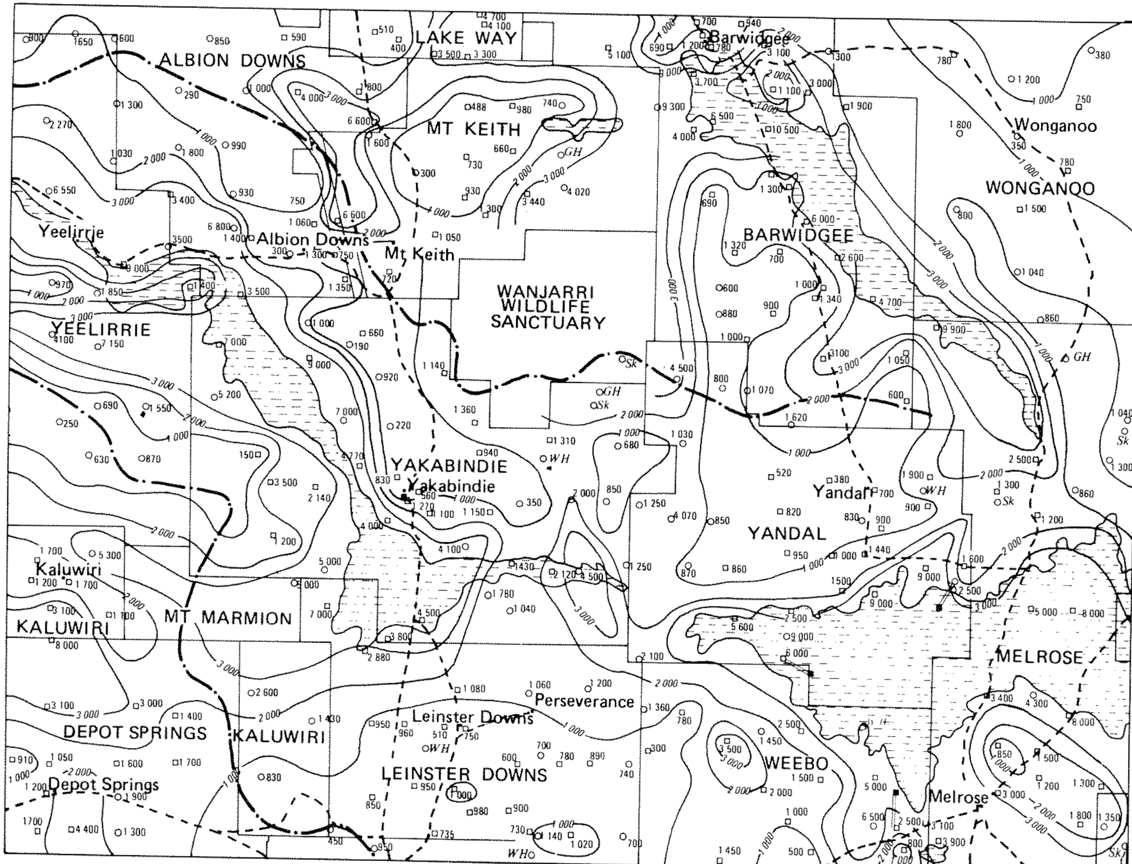

FIGURE 8

WATER RESOURCES

SIR SAMUEL SHEET SG 51–13

0 20 km

- Eolian, alluvial and lacustrine deposits in saline ancient drainages
- ○ 1 800 Bore, field salinity in parts per million total dissolved salts
- □ 1 300 Well, field salinity in parts per million total dissolved salts
- ○ W.H. Waterhole
- ○ G.H. Gnamma hole
- ○ Sk. Soak
- ○ Spring, intermittent
- ■ Tank
- • Locality
- —800— Salinity contour (generalized)
- —·— Drainage divide
- Pipeline
- Pastoral lease or government reserve boundary
- - - - Formed road

15815

Appendix: Co-ordinates of localities mentioned in text

Name	*Latitude*	*Longitude*
Agnew (Leonora Sheet)	28°00′45″	120°30′45″
Albion Downs	27°17′15″	120°23′15″
Anderson Well	27°51′00″	120°36′30″
Arnold Bore	27°36′00″	120°56′30″
Barr Smith Range	27°06′00″	120°17′00″
Bates Range	27°28′00″	121°03′00″
Beale Well	27°20′00″	120°53′30″
Blow Well	27°19′15″	120°26′15″
Brilliant (mine)	27°58′30″	120°41′30″
Bronzewing (mine)	27°18′45″	120°59′30″
Calowindi Well	27°43′00″	120°57′45″
Charlie Well (Lake Way)	27°02′15″	120°30′45″
Corboy Find (mine)	27°05′00″	120°57′30″
Depot Springs	27°56′10″	120°03′10″
Dingo Range	27°16′00″	121°24′00″
E.M.U. Mine (Leonora Sheet)	28°00′30″	120°30′00″
Gipps Hills	27°53′00″	121°18′00″
Jarrah Well	27°57′15″	121°09′15″
Jones Creek	27°30′00″	120°30′00″
Kaluweerie Hill	27°50′30″	120°09′30″
Katherine Well	27°38′30″	121°08′30″
Kathleen	27°31′00″	120°33′00″
Kathleen Valley (mine)	27°30′30″	120°33′00″
Lake Darlot	27°45′00″	121°29′00″
Lake Darlot (mine)	27°55′45″	121°17′45″
Lake Maitland	27°10′00″	121°05′00″
Lake Miranda	27°41′00″	120°30′00″
Langford Well	27°50′00″	120°13′15″
Leinster Downs	27°51′00″	120°36′00″
Little Well (Yeelirrie)	27°20′00″	120°14′00″
McDonough Lookout	27°37′30″	120°37′00″
Melrose	27°55′45″	121°18′00″
Mt. Blackburn	27°35′15″	121°19′45″
Mt. Doolette	27°51′45″	121°07′30″
Mt. Goode	27°34′30″	120°33′00″
Mt. Grey	27°25′00″	121°09′15″
Mt. Harold	27°23′00″	121°27′15″
Mt. Joel	27°13′30″	121°02′30″
Mt. Keith	27°10′30″	120°32′15″
Mt. Keith (homestead)	27°16′45″	120°30′30″
Mt. Keith (gold mine)	27°10′15″	120°31′45″
Mt. Keith (nickel prospect)	27°14′20″	120°32′50″
Mt. Macdonald	27°50′30″	121°19′30″
Mt. McClure	27°39′00″	120°59′15″
Mt. Mann	27°28′45″	120°33′00″
Mt. Mundy	27°30′45″	121°27′15″
Mt. Roberts	27°52′00″	120°36′45″
Mt. Sir Samuel	27°43′00″	120°38′30″
Mt. White	27°52′30″	120°34′15″
Ninnis Bore	27°35′00″	121°13′30″
Nuendah	27°02′15″	120°21′30″
No. 5 Well (Wonganoo)	27°13′30″	121°20′15″
Ockerburry Hill	27°51′00″	121°03′30″
Overland Well	27°54′15″	121°05′15″
Perseverance (nickel mine)	27°49′15″	120°42′00″
Red Hill	27°09′45″	121°14′15″
Scottie Well	27°06′00″	121°22′30″
Sir Samuel	27°37′45″	121°32′45″
Six Mile Well	27°26′00″	120°34′30″
Spring Well	27°53′75″	121°09′30″
Stirling Peaks	27°29′15″	121°22′45″
Vivien	27°59′00″	120°33′15″
Wild Cat Hills	27°51′00″	121°08′00″
Wonganoo	27°08′30″	121°20′00″
Woodarra	27°56′00″	121°17′30″
Woorana Well	27°29′45″	121°11′30″
Yandal	27°33′45″	121°08′45″
Yandal Lagoon	27°41′00″	121°10′00″
Yeelirrie (homestead)	27°17′00″	120°05′30″

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SIR SAMUEL

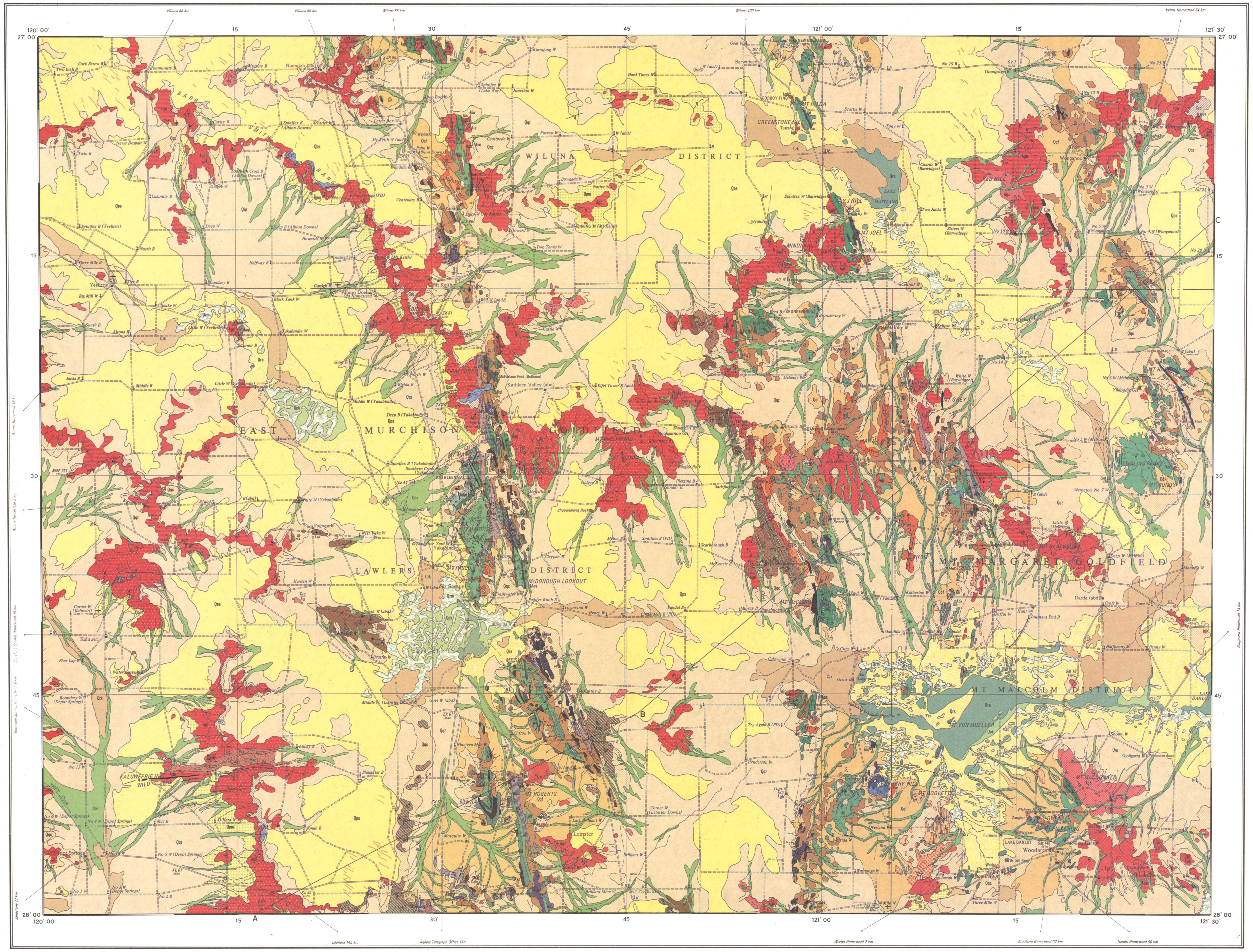
AUSTRALIA 1 : 250 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

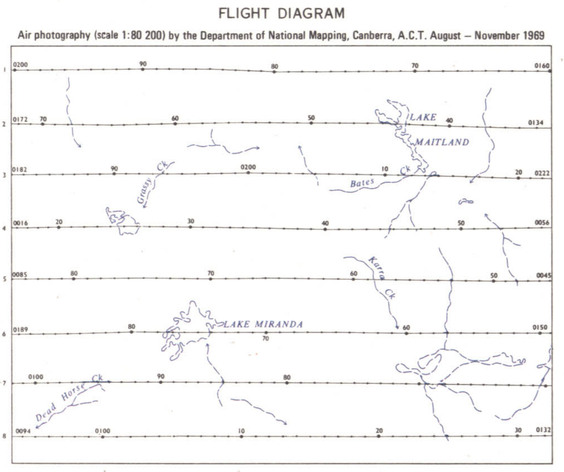
SHEET SG 51 - 13

SYMBOLS

REFERENCE



FLIGHT DIAGRAM



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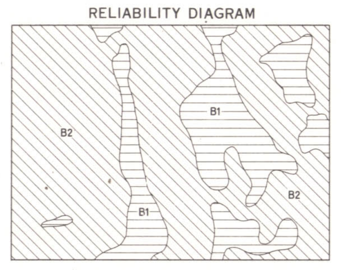
Copies of this map may be obtained from the Geological Survey of Western Australia, 66 Adelaide Tce., Perth.

RELIABILITY DIAGRAM



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

HON. A. MENSAROS, M.L.A.
MINISTER FOR MINES
J. H. LORD, DIRECTOR, GEOLOGICAL SURVEY

SCALE 1 : 250 000

TRANSVERSE MERCATOR PROJECTION
ZONE 2 AUSTRALIA SERIES

INDEX TO ADJOINING SHEETS

GLENGARRY SG 50 - 12	WILUNA SG 51 - 9	KINGSTON SG 51 - 10
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YOUANMI SH 50 - 4	LEONORA SH 51 - 1	LAVERTON SH 51 - 2

Geology by J. A. Bunting and S. J. Williams 1974
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DECLINATION DIAGRAM

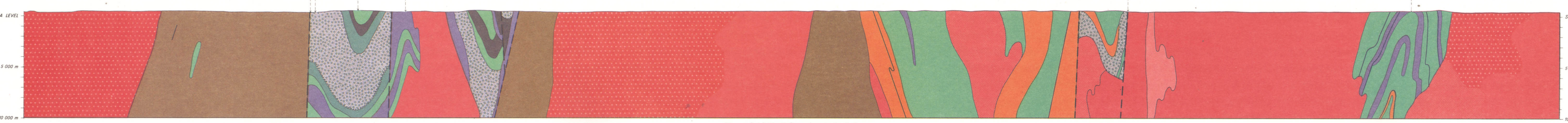
The lines indicate magnetic declination, 1970. + means declination is east and correction must be added to compass bearing to give true bearing. − means declination is west and correction must be subtracted from compass bearing to give true bearing.

Annual change is -1' westerly

DIAGRAMMATIC SECTION

NATURAL SCALE
Cainozoic units omitted

SECTION A - B - C



Note: see Rock Relationship Diagram for explanation of units

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

KALUWEERIE CONGLOMERATE (Pk)	Fine-grained sediments, tuffs (As, Ass, Asg, Ast, Asm)
Quartz syenite (Ags)	Felsic volcanic rocks (Af, Ap)
Porphyritic granite to adamellite (Agl)	Mafic intrusive rocks (Ad)
Even-grained granite to adamellite (Agb, Age)	Mafic extrusive rocks (Ab)
Granodiorite and quartz monzonite (Agt, Agh)	Ultramafic rocks (Au)
Gneissic rocks (An, Agg)	Mafic dyke
Banded iron formation and chert (Ai)	Unconformity
Conglomerate and arkose (Asc, Aso, Asa)	Tectonic lineament or fault

SIR SAMUEL
SHEET SG 51 - 13

FIRST EDITION 1977

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