1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

NEWDEGATE

WESTERN AUSTRALIA

SHEET SI 50/8 INTERNATIONAL INDEX

WESTERN AUSTRALIA
INDEX TO GEOLOGICAL MAPS
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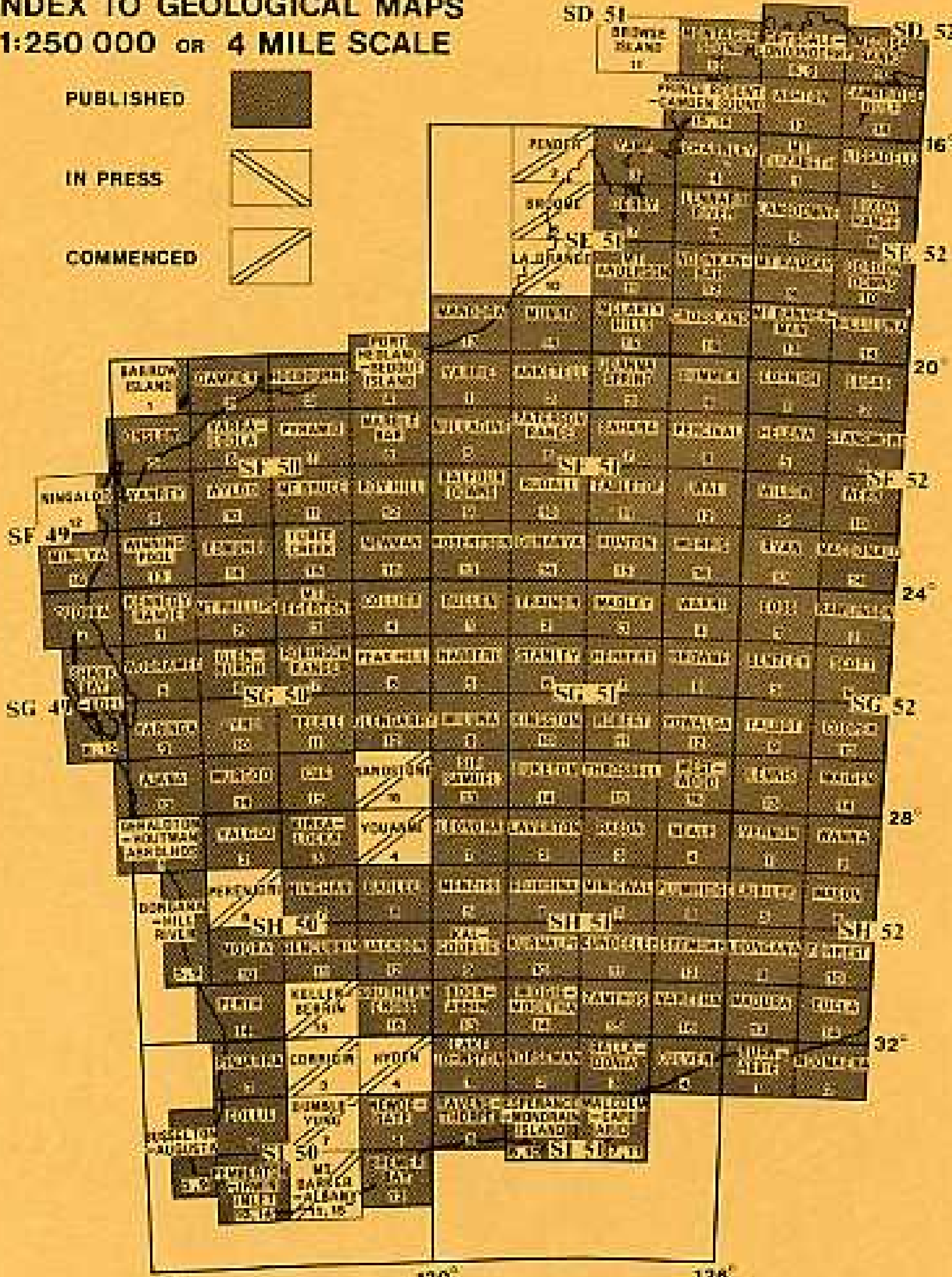

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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NEWDEGATE

WESTERN AUSTRALIA

SHEET SI 50/8 INTERNATIONAL INDEX

COMPILED BY R. THOM, R. J. CHIN, AND A. H. HICKMAN

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Explanatory Notes on the Newdegate Geological Sheet

Compiled by R. Thom, R. J. Chin, and A. H. Hickman

INTRODUCTION.

NEWDEGATE*, bounded by latitudes 33°00′S and 34°00′S and by longitudes 118°30′E and 120°00′E, is situated at the southern end of the Wheat Belt. Much of the area is under cultivation for crops and grazing and is serviced by numerous graded roads. Main roads link Jerramungup (pop. 225 in 1976 census), Newdegate (pop. less than 200) and the locality of Lake King with larger centres in the South West of Western Australia. Large tracts of land in the centre of NEWDEGATE and south of the South Coast Highway remain uncultivated, and access is by track and cut line.

NEWDEGATE straddles three tectonic provinces whose boundaries are not well defined. In broad terms, the granite-gneiss terrain forming the greater portion of NEWDEGATE is part of the Western Gneiss Terrain, and the greenstone belt on eastern NEWDEGATE is part of the Southern Cross Province (Gee and others, 1981). Both provinces have a north to north-northwesterly structural trend and are part of the Archaean Yilgarn Block. They are truncated to the south by the Proterozoic Albany-Fraser Province, which has an easterly to northeasterly structural trend and whose boundary on NEWDEGATE approximates to the northern limit of the Mount Barren Group.

Limited gold and copper production has been recorded from NEWDEGATE and several mineral occurrences, including zinc, molybdenum, lead and manganese have been reported or investigated.

PREVIOUS INVESTIGATIONS

Woodward (1909) outlined the geology of the Ravensthorpe area as it was then known, describing briefly the greenstone belts and the granitic rocks. Although mining had been active in the area for some years, geological investigation was in its infancy and information was scant.

The first detailed geological work on NEWDEGATE investigated part of the greenstone belt and adjacent granitoids near Cocanarup (Woodall, 1955). Besides giving comprehensive petrological descriptions, Woodall considered the structure and the geological history of the area. He regarded the gneiss west of the greenstone belt as granitized sediments within which mafic sediments, resistant to granitization, are preserved as amphibolite bands within "basic migmatite". The amphibolite bands delineate a west-southwesterly plunging anticline, whose associated minor structures correspond to minor structures in the greenstone belt. Woodall noted discordance between the Ravensthorpe quartz diorite pluton and the metavolcanics of the greenstone belt, and suggested that this pluton, although intruded in a magmatic state, was the result of metasomatism of amphibolitic rocks. He discussed metamorphism and recorded the occurrence of sillimanite-bearing schist.

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* Sheet names are printed in full capitals to avoid possible confusion with place names.

Sofoulis (1958a) and his co-workers mapped and described the Archaean greenstone belts that enclose the Ravensthorpe quartz diorite pluton, with particular emphasis on the Ravensthorpe greenstone belt and its copper-mining areas. Less attention was given to the greenstone belt on the eastern side of NEWDEGATE. This belt was believed to face eastwards and was considered older than the greenstone belt of the Ravensthorpe Range. Sofoulis proposed that both greenstone belts swing in an arc southwestwards to at least Naendip, but that they are only locally exposed through erosional windows in the Proterozoic cover. He considered this swing to be part of a southeasterly plunging regional anticline whose axial trace passes through Kundip and coincides with the smaller anticline at Cocanarup proposed by Woodall (1955).

The structure and age relationships of this region were discussed in broad terms by Wilson (1958a). The Ravensthorpe Range greenstone belt was part of the area mapped by Thom and others (1977). The Proterozoic sediments of the Mount Barren Group were described by Sofoulis (1958a) and in more detail by Thom (1977). Carter (1978) studied part of the Mount Barren Group on the south coast on NEWDEGATE.

PHYSIOGRAPHY

Much of NEWDEGATE is gently undulating sandplain of such low relief that granite outcrops of modest dimensions (such as Mount Madden) are landmarks for tens of kilometres around. Long palaeodrainages, containing salt lakes such as Lake King and Lake Magenta, form broad, flat-floored valleys which trend north-northwesterly and which represent the channels of ancient northerly-flowing rivers (Fig. 1). During Tertiary epeirogeny, the Jarrahwood Axis was established (Cope, 1975). This axis corresponds to a drainage divide separating extensive sandplain with northerly flowing internal drainage (Darling Plateau) from dissected topography with a southward slope (Ravensthorpe Ramp) across which youthful rivers flow southwards to the sea. Unusual river configurations in the vicinity of the divide result from stream capture and the reversal of the previous northerly flow direction.

Mount Short, near the eastern boundary of NEWDEGATE, is the nothernmost peak of the Ravensthorpe Range. The range extends along a linear greenstone belt which lies mostly on RAVENSTHORPE and which owes its prominence to the thick sequence of banded iron-formation that forms the summit ridge. In contrast, topographic relief over the West River greenstone belt is subdued because of the lack of banded iron-formation. Farther south, resistant Proterozoic quartzite and quartzitic breccia form rugged peaks such as Mount Drummond (310 m), the Whoogarup Range (up to 390 m), and Annie Peak (477 m).

CAINOZOIC GEOLOGY

In the south of NEWDEGATE, dissected flat sandplain (*Czs*) is most common over horizontal sediments of the Plantagenet Group. A few swamps (*Qrp*) occur in depressions within the sandplain.

Farther north, beyond the present limit of the Plantagenet Group, the sandplain is more undulating. This may be due to formation on an uneven palaeotopography, or perhaps reflects the erosional style of the internal drainage, where surface run-off is not confined to a small number of definite channels. Reworking and local removal of parts of the Tertiary soil profile have commonly exposed underlying gravels and

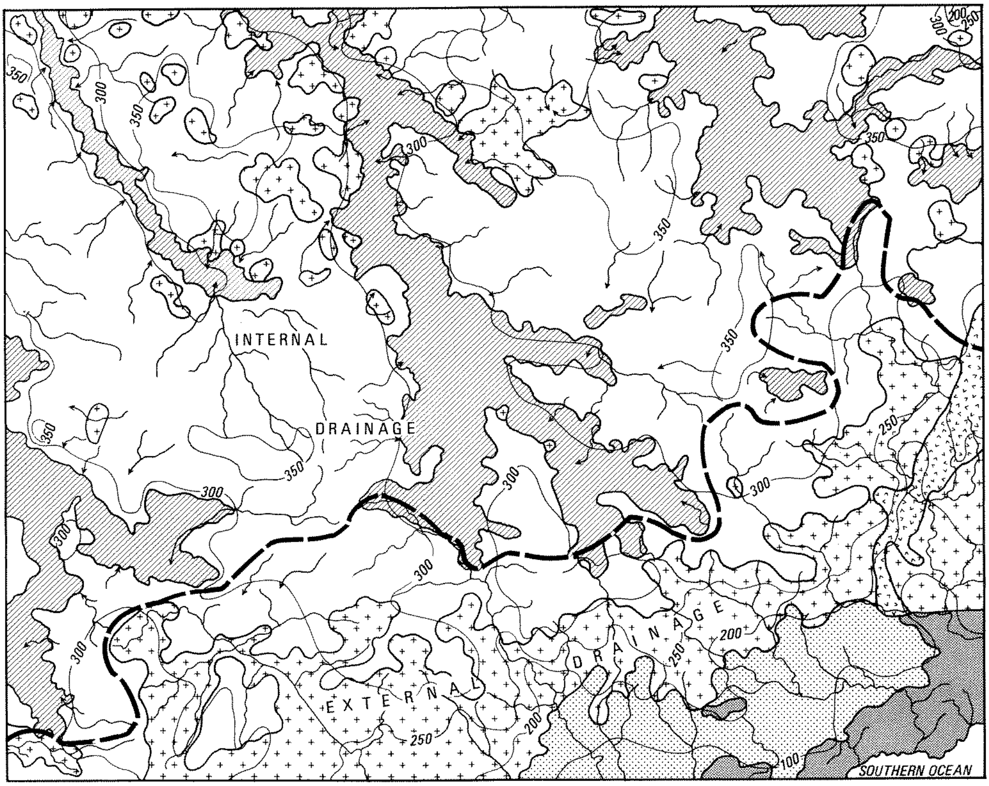


FIGURE 1

PHYSIOGRAPHY AND DRAINAGE

NEWDEGATE SHEET SI – 50 – 8

0 5 10 15 20 km.

REFERENCE

- Salt Lakes and ancient drainage flats
- Sandplain, with mild erosion by internal drainage
- Dissected plateau over Plantagenet Group sediments
- Rounded to rugged hills over Mount Barren Group sediments
- Low granite hills
- Greenstone belt with subdued relief
- Watercourse
- Major drainage divide
- 250 Generalized topographic contours in metres

form the unit distinguished as (*Czg*). Deeper erosion has exposed laterite (*Czl*) and silcrete (*Czb*) and ultimately bedrock. However, some granite domes were probably always above the level of the sandplain. Well-defined creek channels contain alluvium (*Qa*); and colluvium (*Qc*) accumulates on slopes adjoining areas of outcrop. Palaeodrainages contain mixed Quaternary deposits (*Qd*) of quartzose and gypsiferous sand and silt which are marginal to salt lake deposits (*Ql*). Calcrete deposits (*Czk*) flank the eastern side of the palaeodrainage through Lake Buchan.

Sediments of the Plantagenet Group (*Tp*), which are restricted to the southeastern corner of NEWDEGATE, consist mainly of siltstone and spongolite of the Pallinup Siltstone (Cockbain, 1968). These sediments are a continuation of those described on BREMER BAY (Thom and Chin, 1981).

PROTEROZOIC GEOLOGY

Proterozoic sediments of the Mount Barren Group, and the Cowerdup Sill which intrudes them, are restricted to the southeast corner of NEWDEGATE, where they form part of a sedimentary belt at the southern margin of the Yilgarn Block. The Mount Barren Group has been subdivided into three formations, which are listed in descending order:

(a) Kybulup Schist (*BBp*)
(b) Kundip Quartzite (*BBk*)
(c) Steere Formation (*BBs*)

The basal Steere Formation, at its type locality in the Western Steere River on RAVENSTHORPE, unconformably overlies the Archaean Ravensthorpe quartz diorite pluton. At this locality, the base is marked by a thin conglomerate (up to 5 m thick) consisting mainly of clasts of banded iron-formation in an arenaceous matrix. This is overlain by several metres of bedded grits and by 4 m of dolomite containing abundant stromatolites (Thom, 1977). On NEWDEGATE, the Steere Formation is poorly represented, and the unconformity with Archaean rocks is nowhere well exposed. Stromatolitic dolomite occurs in the Phillips River near Kybulup Pool, and dolomite, apparently devoid of stromatolites, occurs at the base of Mount Drummond.

The Kundip Quartzite is extensive in the southern part of NEWDEGATE, and mostly occurs in association with dolerite of the Cowerdup Sill. The formation originally consisted mainly of quartz arenite but is now a quartzite in various stages of recrystallization. Much of the quartzite is very pure. However, mica- and magnetite-bearing types are also present, and most of the quartzite contains some detrital tourmaline and zircon. Textures, including mosaic, amoeboid interlobate, and polygonal types, have been used to define zones of progressive microstructural development of quartz in quartzites southeastwards across the sedimentary belt (Thom, 1977). The thickness of the Kundip Quartzite at its type locality (33°41'S, 120°11'E) near Kundip on RAVENSTHORPE is only 7 m, but at some localities on NEWDEGATE the formation is 200 m thick.

In places, the quartzite has been brecciated and mylonitized during thrusting, and the resulting quartzitic breccia (*Bc*) forms a large part of the Whoogarup Range. At this locality, blocks of quartzite from a few centimetres to more than a metre across are cemented by fine-grained breccia and arenaceous matrix. Near the base of the unit, the blocks are derived from adjacent stratified quartzite and show little or no deformation or relative rotation. Elsewhere, blocks are rounded and the rock resembles conglomerate. The whole fragmental unit possibly represents a conglomerate band with a selvedge of tectonic breccia that formed during thrusting, or, alternatively, the unit may be totally tectonic in origin. At Mylies Beach, quartzitic conglomerate, generally regarded as deformed sedimentary conglomerate, could be interpreted as deformed tectonically derived breccia. In view of the difficulty of distinguishing these rock types, quartzitic conglomerate and breccia are grouped on the map as *Bc*. Breccia at a locality in the Hamersley River (33°55′S, 119°54′E) consists of both angular and rounded blocks of quartzite, some of which were plucked from adjacent stratified quartzite. This occurrence closely resembles the breccia of the Whoogarup Range.

The Kybulup Schist is derived mainly from pelitic and psammopelitic sediments. This unit increases in metamorphic grade from slate and phyllite near Cowerdup in the north, to kyanite-, staurolite- and garnet-bearing schist at West Beach. The metamorphic zonation, established from the mineral assemblages in pelitic schist, is in general agreement with the southeasterly progressive microstructural development of quartz in the quartzites (Thom, 1977). Most of the Kybulup Schist is penetratively folded, and at least three generations of folds and associated structures can be distinguished. Some of these are shown on the structural map (Fig. 2).

Blatchford (1919a) was the first to recognize that the Proterozoic succession is intruded by a dolerite sill (or, as he thought, several sills). The intrusion was later correlated with the Ravensthorpe quartz diorite pluton (Sofoulis, 1958a) and assigned to the Archaean. However, the sill was shown to be Proterozoic by Thom (1977), who also described some of its salient features. The sill is about 300 m thick along the Hamersley River and intruded the Kundip Quartzite before the onset of folding. It is strongly differentiated from ultramafic at the base to granophyre at the top, but all fractions are grouped under *Eg*. Typically, the sill is strongly altered with breakdown of the feldspar and pyroxene to saussurite, sericite, chlorite and amphibole. The sill has been named the Cowerdup Sill.

ARCHAEAN GEOLOGY

The distribution of the major Archaean rock types on NEWDEGATE is shown in Figure 2. The greater proportion of the area is underlain by granitoid rocks. The West River greenstone belt occurs in a small north-northeasterly trending zone near the eastern margin, and small enclaves of strongly metamorphosed greenstone-belt remnants are scattered throughout the northwestern, northeastern and central-southern portion of NEWDEGATE.

GRANITOIDS

Two distinct groups, the post-tectonic granitoids, and the pre- and syntectonic granitoids, are recognized on NEWDEGATE.

The pretectonic and syntectonic granitoids (*Ann, Ang, Angx, Agg, Anf, Amf, An*) predominate in the northwestern part of NEWDEGATE and in the area adjoining the West River greenstone belt. Although the older granitoids in the northwestern

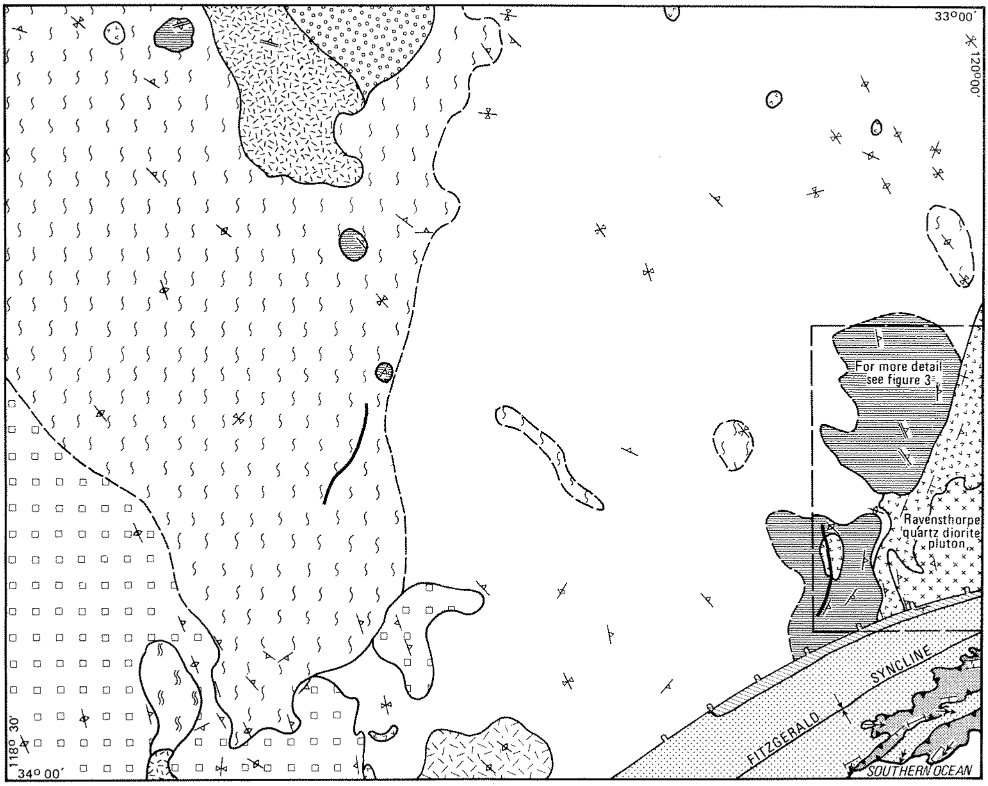


FIGURE 2

SOLID GEOLOGY AND STRUCTURAL INTERPRETATION

NEWDEGATE SHEET SI–50–8

0 5 10 15 20 km

REFERENCE

PROTEROZOIC

MOUNT BARREN GROUP
- Autochthonous quartzite
- Allochthonous quartzite
- Schist and metamorphosed shale

ARCHAEAN

POST AND SYN-TECTONIC GRANITOIDS
- Seriate and even-grained granite and adamellite
- Porphyritic granite and adamellite
- Hornblende monzodiorite
- Quartz diorite

PRE-TECTONIC GRANITOIDS
- Paragneiss
- Unfoliated gneiss and granofels
- Moderately to strongly foliated gneiss
- Banded gneiss
- Metamorphosed migmatite

- Greenstone belt and enclaves

- Strike and dip of inclined foliation
- Strike of vertical foliation
- Strike of foliation, dip unknown.
- Strike and dip of banding
- Strike of vertical banding
- Strike and dip of bedding
- Strike and dip of cleavage
- Strike of vertical cleavage
- Plunge of minor fold
- Major synclinal axis
- Thrust fault
- Fault
- Interpreted geological boundary
- Unconformity.

area are irregularly distributed, their banding and foliation trend dominantly northwesterly. Similar rocks adjacent to the West River greenstone belt tend to be domal and have banding and foliation parallel to the body margins.

It is evident from field relationships that the post-tectonic granitoids intruded after the major metamorphic and structural events which deformed the rocks of the West River greenstone belt and the gneisses of the granite-gneiss terrain. These later granitoids (*Agl, Agv, Agt, Agz*) locally show some development of foliation and partial recrystallization indicating that they have undergone some metamorphism. As far as can be determined from available exposure, post-tectonic granitoids underlie more of NEWDEGATE than do the pre-tectonic and syntectonic granitoids (Fig. 2).

Post-tectonic granitoids

The unit (*Agl*) is predominantly porphyritic granite and adamellite. Its chemical composition is partly dependent on the abundance of phenocrysts. The rock consists of subhedral microcline phenocrysts, several centimetres long, set in a matrix of quartz, microcline and plagioclase with lesser amounts of clinopyroxene and biotite. Much of the unit (*Agl*) is considerably recrystallized. The tabular phenocrysts are commonly aligned in a foliation which is particularly strong near the contact with the gneiss (*Agg*). This foliation is an alignment of minerals oriented parallel to the contact and is possibly of primary origin. Porphyritic granitoid sampled at a quarry 7 km east-northeast of Jerramungup is relatively poor in quartz, and although hypersthene has not been identified in thin section, it is present in the CIPW norm (Table 1, sample 57013). The chemical analyses suggest a granodioritic rather than adamellitic composition for these samples. Variation in composition and local paucity of quartz in this "adamellite" have been noted by earlier workers. Wilson (1958b) described and named the Jerramungup Adamellite, a porphyritic granitoid which roughly corresponds to the unit *Agl* delineated on NEWDEGATE, and noted that while one analysis (Table 1) indicates a monzonitic rock with a low proportion of quartz, samples from other localities have a much higher proportion of quartz and are typical adamellites. He described the porphyritic granitoid at Calyerup Creek as hornblende-salite-biotite adamellite with mafic clots which may represent reconstituted micro-xenoliths (salite is clinopyroxene approximately $Wo_{37}En_{34}Fs_{19}$). Near the Gairdner River bridge, 5 km east of Jerramungup, the adamellite is a coarse-grained, porphyritic hypersthene-biotite-salite adamellite, which Wilson suggests has undergone upper amphibolite or granulite facies metamorphism.

The remainder of the post-tectonic adamellite consists of weakly porphyritic and seriate types, which are grouped as *Agv*. The relationship between *Agl* and *Agv* is uncertain, as intrusive relationships that do exist are inconsistent, and in some areas the change from *Agl* to *Agv* is clearly gradational. They may be variants of the same intrusion and the position of the boundary between them is consequently arbitrary and approximate. The unit *Agv* principally includes seriate adamellite with a variable texture and a range of grain size. It also includes weakly porphyritic adamellite, in which phenocrysts are sparse and large (several centimetres long), or abundant and small (less than about 10 mm). Petrographically *Agv* resembles *Agl*.

The agmatite (*Amv*) is an intimately mixed unit resulting from the intrusion of the seriate adamellite (*Agv*) into the older pretectonic and syntectonic granitoids. It occurs most commonly at the margin of the post-tectonic bodies.

TABLE 1. ANALYSES OF ARCHAEAN GRANITOIDS

Oxides (%)	*Geological Survey Sample Numbers*						
	(a) 57013	(a) 57014	(a) 57015	(a) 28385	31303	8139	8151
SiO_2	62.7	75.2	57.1	70.0	62.08	70.27	68.11
Al_2O_3	15.0	13.8	14.5	15.2	15.94	16.11	15.77
Fe_2O_3	2.4	0.1	3.2	1.2	0.76	0.97	0.11
FeO (b)	2.44	0.22	3.95	2.30	3.56	1.22	2.99
MgO (b)	2.65	0.02	5.17	1.4	2.88	1.87	1.75
CaO	4.34	1.17	6.07	3.15	4.32	1.76	3.79
Na_2O (b)	3.83	3.67	3.72	4.10	3.56	4.64	4.58
K_2O	4.46	4.84	4.18	1.2	5.12	0.64	0.76
H_2O^+ (b)	0.60	0.26	0.74	1.14	0.58 }	1.08	0.86
H_2O^- (b)	0.15	0.08	0.19	0.09	0.00 }		
CO_2	0.14	0.04	0.11	0.00	0.00	0.20	0.21
TiO_2	0.65	0.05	0.96	0.37	0.54	0.12	0.74
P_2O_5	0.49	0.02	0.75	0.10	0.51	0.12	0.28
MnO	0.08	<0.01	0.12	0.06	0.08	0.20	0.16
Total	99.9	99.5	100.8	100.31	99.93	99.39	100.39
Trace elements (ppm)							
Ce	220	<20	250				
La	120	<20	160				
Pb(c)	20	20	10				
Rb	150	140	170	120			
Sr	850	800	750	130			
Th	40	20	30	10			
U(c)	10	8	20	2			
Zr	240	60	285	210			
CIPW Norms							
Q	12.64	32.86	2.71	31.76	8.5		
C		0.54		1.67			
Or	26.36	28.60	24.70	7.09	30.23		
Ab	32.41	31.05	31.47	34.69	30.11		
An	10.57	5.42	10.52	14.97	12.38		
Di	5.47		11.15	0.00	4.90		
Hy	5.57	0.28	10.82	6.22	9.91		
Mt	3.48	0.14	4.64	1.74	1.11		
Il	1.23	0.09	1.82	0.70	1.03		
Ap	1.16	0.05	1.78	0.24	1.21		
Ca	0.32	0.09	0.25				

57013 Porphyritic biotite-clinopyroxene adamellite (33°54′13″S, 118°59′06″E)

57014 Fine-grained leucocratic granite (38°54′13″S, 118°59′06″E)

57015 Porphyritic biotite-clinopyroxene monzonite (33°54′13″S, 118°59′06″E)

28385 Hornblende-biotite-quartz diorite (Ravensthorpe pluton) (Thom and others, 1977)

31303 Porphyritic pyroxene adamellite (the Jerramungup Adamellite) (Wilson, 1958b)

8139 } 8151 } "Sodic-granite" (Ravensthorpe pluton) (Woodward, 1909)

(a) Analyses by the Mineral Division, W.A. Govt. Chem. Labs

(b) Analysis by chemical methods. All other analyses by XRF techniques.

The unit *Agt* is confined to the eastern edge of NEWDEGATE, where it forms part of a pluton enclosed by the Ravensthorpe Range and West River greenstone belts. The pluton has been informally referred to as the Ravensthorpe quartz diorite pluton, but the composition is variable and includes, granodiorite and tonalite as defined by Streicheisen (1973). Although parts of the pluton are relatively quartz deficient, there is more than 20 per cent quartz in samples from many localities and the overall composition of the pluton may be tonalite rather than quartz diorite (Table 1). The quartz diorite is grouped with the post-tectonic granitoids because it has intruded the West River greenstone belt and cuts across the deformed layered succession. Moreover, recrystallization is only weak, and, in most samples, the igneous texture is still evident. Foliation is strong adjacent to the greenstone belt only, and is generally weak elsewhere within the pluton. Typically the pluton is medium- to coarse-grained quartz diorite and tonalite, and consists of quartz, saussuritized plagioclase, hornblende, and biotite (partially altered to chlorite), minor opaques, and a trace of apatite. Near its contact with the West River greenstone belt, the pluton contains xenoliths of mafic rock, usually partially assimilated. This granitoid has been discussed by Woodall (1955) and Sofoulis (1958a), and its age may be close to the age of the pegmatite at Cattlin Creek, which has been recalculated from Jeffery (1956) to be about 2 700 m.y.

Medium- to coarse-grained hornblende granodiorite or hornblende monzodiorite (*Agz*) occurs in the southern part of NEWDEGATE. It is characterized by phenocrysts of pink microcline, set in a matrix of quartz, saussuritized plagioclase, microcline, hornblende, biotite, subordinate opaques, apatite and a trace of zircon. Secondary epidote is evident in the field.

Pre- and syntectonic granitoids

This group embraces a wide variety of granitoids, which include compositionally banded gneiss, foliated gneiss lacking compositional banding, and recrystallized granofels that lacks both banding and foliation.

The unit (*Ann*) is a thoroughly recrystallized leucocratic granodiorite containing plagioclase, microcline, quartz, and a small proportion of biotite. The rock is medium to coarse grained and has a granoblastic texture. Field relationships indicate that, prior to recrystallization, the granodiorite (*Ann*) intruded banded gneiss (*Ang*). Xenoliths of banded gneiss are scarce within the granodiorite in the vicinity of Mount Short, but further south, especially marginal to the banded gneiss, they are more abundant. The actual proportion of xenoliths to host rock can be difficult to estimate because of extensive recrystallization of both phases and because of different degrees of assimilation of the xenoliths. Where xenoliths are more abundant, the granodiorite grades into banded gneiss and consequently the boundary between these two units is arbitrary.

The unit *Ang* in the Cocanarup area is recrystallized, strongly banded granodiorite gneiss of medium to coarse grain size. The continuous banding consists of alternating biotite-rich and quartz-feldspar-rich layers a few millimetres thick. A metamorphic foliation defined by alignment of biotite, inequant quartz and inequant feldspar is axial planar to folds in the banding. Veins of leucocratic adamellite gneiss, slightly oblique to, and cross-cutting the banding, are folded with the banding. In localized high-strain zones, banding and veining are transposed. Mafic amphibolite (rarely pyroxenite) xenoliths are scattered throughout the banded gneiss and "trail out" into nebulous biotite schlieren. Xenoliths are more abundant on the eastern side adjacent to the West River belt where a specific amphibolitic unit (*Angx*) is identified.

The unit (*Ang*) in the Newdegate area is similar to that near Cocanarup, but is weakly foliated granofels. It has a granoblastic texture because of high-grade static metamorphism which attains granulite facies in most of this area. Nebulous banding and biotite schlieren are locally present, and are well developed around xenoliths of mafic amphibolite, banded iron-formation and quartzite. Elsewhere in the Newdegate area, the unit has banding defined by a variable concentration of biotite in zones 5 mm to 1 m wide, or by broad leucocratic layers separated by thin biotite layers. Adjacent layers may have contrasting grain size. Where the granofels (*Ang*) is invaded by the leucocratic granofels (*Anf*), the resulting migmatite is denoted *Amf*.

The unit (*Angx*) is banded granodiorite gneiss (*Ang*), in which xenoliths of amphibolite form about half of the rock. The mafic xenoliths are rafts of metabasalt and metadolerite stoped off from the West River greenstone belt by the granodiorite gneiss (*Ang*) when it was emplaced as a granodiorite pluton. The mafic material is now virtually equigranular and contains hornblende and calcic plagioclase, minor quartz, opaques and secondary epidote. Weak banding is defined mainly by variations in the proportion of hornblende and plagioclase, and there is an early foliation parallel to the banding. The amphibolite is extensively veined by leucocratic adamellite (now adamellite gneiss). The veins are up to 30 mm wide and parallel to the banding. A later metamorphic foliation is developed axial-planar to folded banding. The amphibolite xenoliths do not appear to have undergone metamorphism in excess of amphibolite facies.

The unit (*Amf*) is agmatite in which the neosome is granoblastic granofels (separately distinguished as *Anf* where it occurs in large homogeneous units), and the palaeosome consists of blocks or rafts of the gneisses (*Ang* and *Agg*). On NEWDEGATE, the agmatite (*Amf*) is most abundant in the vicinity of Newdegate in the broad contact zone between the units (*Agg* and *Anf*), but also occurs on the southern margin of NEWDEGATE as the northern extremity of a considerable expanse of agmatite located mainly on BREMER BAY (Thom and Chin, 1981). Mineralogy diagnostic of granulite facies has been recognized only in the palaeosome of the agmatite, but textures in the neosome indicate high-grade static metamorphism and this too may have attained granulite facies. Both neosome and palaeosome locally contain garnet.

The unit *Anb* is strongly banded, fine- to medium-grained quartzo-feldspathic gneiss, commonly quartz-rich and leucocratic. The composition of the rock and the well-developed banding may reflect a sedimentary origin, but there is so far no good evidence of its parentage. Nevertheless, of all the gneisses on NEWDEGATE, *Anb* is the variety which has characteristics more typical of paragneiss. On the basis of field appearance, *Anb* is compositionally similar to paragneiss derived from psammitic and quartzitic sediments. A sample of *Anb* contains quartz and plagioclase (labradorite) with minor olive-green hornblende and a trace of epidote and opaques. The rock has been metamorphosed to amphibolite facies and has a moderate fabric.

The unit (*Agg*) is fine- to medium-grained, granoblastic gneiss, strongly foliated but poorly banded. The composition is generally adamellitic, but, in some cases, is granitic or granodioritic. The gneiss consists of quartz, perthite (in stringlet form), saussuritized plagioclase and minor biotite. Inequant quartz and feldspar, and lenses of randomly oriented biotite, are aligned to form a foliation and a lineation. Banding, where present, tends to be discontinuous, and local flagginess of this gneiss is attributed to weathering along the foliation. Some of the gneiss has attained granulite facies.

The unit (*An*) is used to group strongly foliated granitoids that occur in a zone along the western edge of the West River greenstone belt. The zone seems to be the product of intense deformation restricted to the edge of the greenstone belt, and is perhaps a consequence of diapiric emplacement of granodiorite (*Ann*, now metamorphosed to granofels). The intensity of deformation progressively decreases westwards. These strongly foliated granitoids are generally thoroughly weathered and poorly exposed, but where the South Coast Highway intersects the unit, road cuttings reveal good exposure of coarse-grained granodiorite whose strong foliation is defined by plates of metamorphic mica. Other rock types within the unit are difficult to recognize, but considerable textural variation indicates lithological heterogeneity.

The unit (*Anf*) is fine- to medium-grained leucocratic granofels of granitic, less commonly adamellitic, composition. A typical sample has a granoblastic, seriate texture with interlobate to amoeboid grains of quartz and microcline (strongly perthitic), with some plagioclase, minor biotite and opaques. Biotite occurs as scarce, randomly oriented plates, and the rock is characteristically unfoliated. Although the present mineral assemblage is not diagnostic, metamorphism is high grade and may have reached granulite facies. This granofels is only distinguished as a separate mappable unit northeast of Newdegate, where it forms a fairly homogeneous body about 7 km across. The same granofels occurs throughout NEWDEGATE as the neosome of a metamorphosed agmatite (*Amf*).

The unit (*Amw*), which is restricted to the Gairdner River area, is agmatite in which the neosome is generally adamellite and the paleosome is schistose metasediment. Some metasediment retains thin sedimentary layering, and other examples are more thickly bedded and siliceous. The paleosome occurs as swarms of xenoliths and as rafts up to a kilometre across. Pelitic schist contains quartz, calcic plagioclase (around An_{50}) and biotite with poikiloblastic porphyroblasts of cordierite and garnet. Accessory minerals include apatite, opaques, and zircon. Calc-silicate xenoliths are composed of plagioclase, diopside, subordinate microcline, and sparse opaques and zircon. Hypersthene in some of these samples indicates that the metasediments have attained granulite-facies metamorphism. The relationship of the neosome to other granitoids in the vicinity is uncertain. Another possibly related granitoid in the vicinity of the sedimentary rafts is a granodiorite gneiss with a barely discernible fabric which contains some garnet and cordierite. The unit (*Amw*) occurs south of the amphibolite-mafic granulite mass at Calyerup Creek, and, if these mafic rocks are high-grade metamorphic analogues of the West River greenstone belt, the granodiorite gneiss may be equivalent to the granodiorite granofels *Ann* which intruded the greenstone belt.

LAYERED GREENSTONE SEQUENCE

West River greenstone belt

The West River greenstone belt is situated at the eastern margin of NEWDEGATE. The southern end is separated from the Ravensthorpe Range greenstone belt, which lies predominantly on RAVENSTHORPE, by a quartz diorite pluton. North of the pluton the greenstone belts merge. Southwards, these Archaean units are overlain by Proterozoic sediments of the Mount Barren Group. The stratigraphic successions of the West River and Ravensthorpe Range greenstone belts are now reasonably well established, and a correlation of units is proposed (Table 2).

In contrast to the Ravensthorpe Range succession, parts of which have undergone only greenschist-facies metamorphism, the whole West River greenstone belt has undergone amphibolite-facies metamorphism. A minimum age for these successions

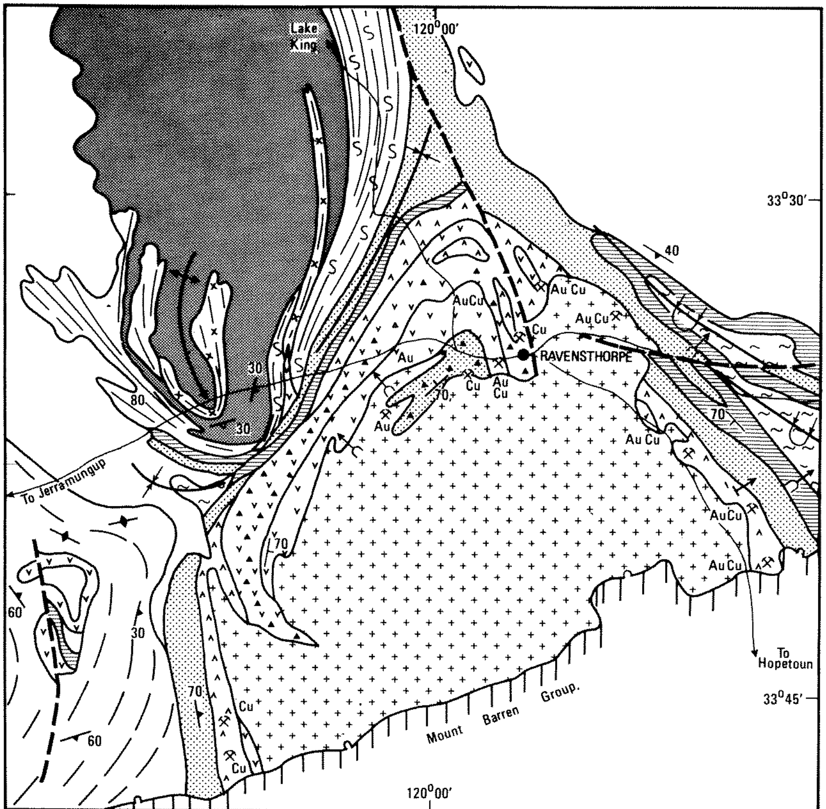


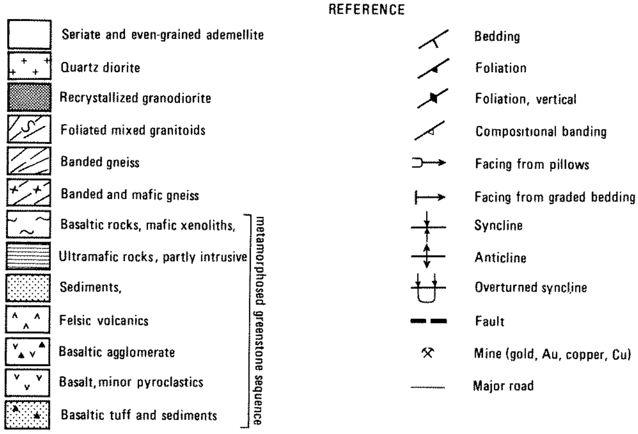
FIGURE 3 GSWA 19376

INTERPRETATION OF THE WEST RIVER– RAVENSTHORPE AREA AND PRINCIPAL MINING CENTRES (GOLD AND COPPER)

NEWDEGATE SHEET SI - 50 – 8

0 10 Km

REFERENCE



is limited by mineral ages in a cross-cutting pegmatite dyke near Ravensthorpe to about 2 700 m.y. The lithological units of the West River greenstone belt are described below.

Amphibolite: Various types of metamorphosed basaltic rocks (*Aah, Aak, Aab, Aad, Aaa*) occur throughout this greenstone belt (Fig. 3). Preserved textures and structures (such as pillows) indicate the volcanic origin of most of these rocks, but in some areas all primary textures have been obliterated by recrystallization during static and dynamic metamorphism. Amphibolite of indeterminate parentage is grouped as *Aah*.

The oldest rocks of the West River succession occur 5 km southwest of Ravensthorpe, in the vicinity of Annabel Creek, where about 1 500 m of basaltic pyroclastics (*Aak*) are intruded by apophyses of the Ravensthorpe quartz diorite pluton. The pyroclastics are generally fine-grained tuffs, but beds of lapilli tuff and agglomerate are common. The centre of the unit contains a fine-grained quartz-feldspar-biotite metasediment with large (up to 5 cm) porphyroblasts of cordierite. Parts of the pyroclastic sequence are well bedded and show some degree of reworking by water. The tuff is overlain by about 1 000 m of basalt (*Aab*) with intercalations of agglomerate and tuff. Pillow structures are preserved in some creek sections, and, although most pillows are too deformed for unequivocal facing evidence, interpretation of the least deformed pillows indicates that the sequence faces to the northwest. Other preserved primary structures include vesicles and quartz-filled amygdales. Both these structures are particularly common in the area 10 km south of Mount Short. In the field, massive basalt (*Aab*) can be difficult to distinguish from massive basaltic tuff (*Aak*), but relict textures can generally be identified in thin section. The mineralogy of the basaltic rocks is typically plagioclase and hornblende, minor amounts of biotite and quartz, and accessory sphene, apatite and opaques. The metamorphic hornblende is commonly acicular and may show partial retrogression to cummingtonite.

TABLE 2. STRATIGRAPHIC CORRELATION OF THE ARCHAEAN SUCCESSIONS AT WEST RIVER AND RAVENSTHORPE

West River Succession		*Ravensthorpe Succession (a)*
Succession not preserved	?CORRELATION	Siltstone and shale
Amphibolite west of Cocanarup		Basalt with local conglomerate
Pelitic and psammopelitic schist		Komatiitic peridotite
Peridotite northwest of Cocanarup	CORRELATION	Chert, siltstone and shale
Pelitic and psammopelitic schist with thin units of ferruginous chert		Banded iron-formation
Psammitic metasediments		Quartzite
Felsic lava and pyroclastics		Felsic lava and pyroclastics
Mafic agglomerate with minor basalt		Mafic pyroclastics with intercalatations of basalt and felsic pyroclastics
Basalt with minor mafic pyroclastics		Succession intruded by quartz diorite
Mafic tuff with minor metasediments		

(a) Based on Thom and others, 1977

The upper portion of the mafic volcanic pile is chiefly composed of basaltic agglomerate (*Aak*), which is well exposed at localities in the Phillips River 1.5 km southeast of Cocanarup and on the South Coast Highway near the eastern boundary of NEWDEGATE. North of the highway, the *Aak* intertongues with dacitic pyroclastic rocks, and less deformed examples (*Aak*) show angular fragments of felsic to intermediate lava set in a totally recrystallized basaltic groundmass. These fragments are generally 1 cm to 5 cm in diameter, but larger blocks are up to 2 m across. In the Phillips River, strongly deformed agglomerate has a striped appearance owing to flattening of the felsic clasts. The well-rounded felsic clasts in some units exposed in the Phillips River could result from explosive abrasion in a volcanic vent, but the presence of well-developed compositional layering and grading in the unit point to reworking by water. In the western part of the Phillips River section, stratigraphically high units have dark basaltic clasts with a pale-grey pyroclastic matrix of basaltic to intermediate composition.

Sills of dolerite and gabbro (*Aad*) intrude the mafic and felsic volcanic rocks throughout the West River greenstone belt. In these massive, medium to coarse-grained rocks, original ophitic texture is partly preserved despite amphibolite-facies metamorphism. The present mineralogy is ragged hornblende, partly saussuritized plagioclase, and minor opaques.

In the vicinity of West River mine, concordant and partly discordant bodies of dark-grey anthophyllite-cordierite-biotite-quartz rock (*Aaa*) are interlayered with felsic volcanics, metasediments, and dolerite. This rock is characterized by rosettes of anthophyllite up to 3 cm across. Although its origin is uncertain, its composition is consistent with derivation from a komatiitic magma. The slight discordance of this rock in the sequence may reflect an intrusive origin, but could equally be due to strike faulting or to syn-depositional erosion.

Metamorphosed felsic rock: The most extensive outcrops of metamorphosed felsic rock (*Af*, *Afx*, *Afp*) occur north of West River mine, but poorly exposed, intermediate to felsic volcanics have also been traced across a broad arc of country north and northwest of Ravensthorpe. Though forming a relatively small part of the total succession, the felsic rocks are economically significant, as they host some of the copper mineralization at West River mine on NEWDEGATE and at Kundip, Elverdton and Ravensthorpe on RAVENSTHORPE (Sofoulis, 1958b; Marston, 1979).

Felsic volcanic rocks (*Af*) of the West River area exhibit flow-banding, brecciation and pyroclastic textures. Lapilli tuff and agglomerate are relatively uncommon, indicating that this felsic sequence may be distal to a volcanic vent. Part of the felsic volcanic sequence is dacitic tuff (*Afx*), which is composed principally of quartz, plagioclase, hornblende, minor K-feldspar and biotite, and contains fragments of fine-grained mafic amphibolite. This unit interfingers with mafic pyroclastic and extrusive rocks in the northern part of the greenstone belt.

Porphyritic dacite (*Afp*) occurs both within the pile and along the boundary of the Ravensthorpe quartz diorite pluton. Porphyritic dacite and pegmatite, which intrude the mafic succession, are exposed in the Phillips River, and these may be genetically related to the Ravensthorpe quartz diorite pluton. However, a genetic relationship between the entire felsic volcanic pile and the Ravensthorpe quartz diorite pluton is less likely, since a large tongue of quartz diorite intrudes the felsic sequence 8 km north of West River (Fig. 3).

Clastic metasediments: The upper part of the West River succession is composed of clastic metasediments (*Alp, Alm, Alg*) ranging from pelitic schist to flaggy siliceous sediments. Deformation and metamorphism have obliterated most sedimentary structures although bedding is commonly preserved as compositional layering.

Pelitic and psammopelitic metasediments (*Alp*) on the western side of the greenstone belt north of Cocanarup, include garnetiferous schist with varied amounts of quartz, andalusite, plagioclase, sericite, biotite, hornblende and opaques. The schistosity wraps around the garnet and andalusite which form idioblastic porphyroblasts up to 5 mm in diameter. The porphyroblasts are most abundant near intrusive contacts with granite rocks. Laminated phyllite and graphitic schist form part of this unit in the Mount Short area where they contain small pods of lateritic manganese, similar to those in equivalent sediments on RAVENSTHORPE (Thom and others, 1977). At Cocanarup, Woodall (1955) noted sheared metasedimentary rocks that contain almandine, staurolite, sillimanite and kyanite.

Schist and flaggy psammite (*Alm*) occur between the pelitic schists and the felsic volcanic rocks of the West River area. The flaggy psammite is dominantly composed of quartz, feldspar, biotite and muscovite, and probably represents metamorphosed siltstone and sandstone. The bedding is from 20 mm to 0.2 m thick and contains biotite-rich pods and layers. Quartz-muscovite schist and quartz-cordierite-biotite schist are the metamorphic equivalent of finer-grained, probably more clayey sediments. Cordierite is locally present as poikiloblastic knots within an otherwise planar micaceous foliation.

Thinly-bedded quartzite (*Alq*) forms a very small part of the West River succession and is restricted to the northern part of the greenstone belt in the Cocanarup area and to a locality about 5 km south of Mount Short.

Chert: Banded ferruginous chert (*Alc*) forms several units up to 3 m thick within the pelitic and psammopelitic schists (*Alp*) west and northwest of West River mine and along the western margin of the greenstone belt. On the surface these rocks commonly have a gossanous appearance, and company drilling has established that at depth they pass into black shale containing pyrite and pyrrhotite.

Ultramafic rock (Aur, Aup): Ultramafic rocks in the West River greenstone belt are not extensive and occur at a stratigraphically lower level than the extrusive and intrusive komatiitic peridotite bodies which are a feature of the Ravensthorpe Range greenstone belt (Table 2). The West River ultramafic rocks consist of either serpentinized peridotite, talc-chlorite schist, or chlorite-tremolite schist.

North of the South Coast Highway and 8 km west of Ravensthorpe, a band of ultramafic rock is inferred from the presence of siliceous caprock (*Czj*). Occasional exposures of chlorite-tremolite rock and scarcer talc-chlorite schist (*Aur*) are the only indicators of its composition. This band is up to 400 m wide, and apparently cross-cuts the strike of the adjacent rock units, possibly indicating an intrusive origin. It is flanked by metadolerite intrusions. A thin, anthophyllite-tremolite-talc unit extends eastwards and northeastwards from a quarry near Cocanarup.

Sills or flows of metamorphosed peridotite (*Aup*) occur at localities 5 km east, 2 km northwest, and 15 km southeast of Cocanarup. Apart from serpentine these rocks contain varying amounts of clinopyroxene, orthopyroxene, amphibole, tremolite, chlorite and opaques.

Greenstone enclaves within granite-gneiss terrain

In several areas the granite-gneiss terrain contains discrete masses of igneous and sedimentary rock metamorphosed to amphibolite and granulite facies. It is generally uncertain if such bodies represent xenoliths, outliers or even deformed intrusions. Individual enclaves may be composed of one or several rock types, and measure from a few hundred metres to several kilometres in length. Large enclaves are commonly surrounded by smaller, stoped segments suggesting progressive disintegration by granite intrusion, and some enclaves form trains oriented parallel to the banding or tectonic foliation of the enveloping gneiss.

At Calyerup Creek, 15 km east of Jerramungup, a 4 km-long enclave consists of mafic granulite, amphibolite and metamorphosed conglomerate. The amphibolite, commonly banded, has alternating amphibole-rich and pyroxene-plagioclase-biotite-rich layers up to 10 mm thick, and is interpreted as a metasediment. The enclave also contains amphibole-biotite-orthopyroxene-clinopyroxene(-diopside) gneiss which may represent a calcium-rich sedimentary rock metamorphosed to low granulite facies. Migmatite to the south of the enclave includes blocks of finely laminated calc-silicate gneiss, cordierite-bearing pelitic schist, and other metasediments.

A large enclave of amphibolite and serpentinized ultramafic rocks occurs 15 km southwest of Cocanarup. The enclave is surrounded by granodiorite gneiss and intruded by seriate adamellite, and probably represents a detached segment of the West River greenstone belt in the form of a mega-xenolith.

In the northeastern part of NEWDEGATE a train of enclaves extends northwards from Mount Short (Fig. 2). Exposure is poor, but aeromagnetic anomalies suggest the presence of ultramafic rocks or banded iron-formation. At Baanga Hill, a metasedimentary enclave includes banded chert, ferruginous chert, grey quartzite, and sedimentary schist containing voids, which are probably after garnet. On the northwest shore of Lake King, an enclave of felsic and mafic granulite is surrounded and intruded by seriate adamellite.

A poorly exposed enclave near Burngup, about 33 km west-northwest of Newdegate, contains quartzite, amphibolite, mafic granulite gneiss and metamorphosed banded iron-formation. Sillimanite in the quartzite and hypersthene in the metamorphosed banded iron-formation and mafic gneiss indicate predominant granulite-facies metamorphism. Lithological layering and metamorphic banding have been isoclinally folded, and similar structures are preserved in adjacent agmatite, which contains xenoliths derived from the enclave.

Similar enclaves to those on NEWDEGATE have been noted elsewhere in the southwestern part of the Yilgarn Block. There is general agreement that they represent metamorphosed volcanic and sedimentary rocks of the type that occur in the large greenstone belts farther east and north, but their age is the subject of some debate. One view is that they are older than the rocks of the greenstone belts and, together with the gneiss that encloses them, they represent part of the basement upon which the greenstone successions of the Eastern Goldfields type were laid down (Gee and others, 1981). Another interpretation is that they originated as mega-xenoliths which were stoped from the greenstone belts, and subjected to a higher grade of metamorphism deep in the crust (Glikson and Lambert, 1976). Field evidence on NEWDEGATE suggests that the Cocanarup and Mount Short—Baanga Hill enclaves are rafts from the West River and Ravensthorpe Range greenstone belts. In the absence of isotopic data, the age relations of the other enclaves cannot be determined.

STRUCTURE

The structure and distribution of the major rock types, (Fig. 2) clearly shows the widespread intrusion of post-tectonic seriate and porphyritic adamellite (*Agv* and *Agl*). These intrusions separate the areas of granitoid gneiss and the greenstone belt enclaves from the West River greenstone belt, and, consequently, make it difficult to relate the two areas structurally.

Structural elements within the enclaves generally reflect two or more tectonic events—at least one of these elements is generally concordant with deformation in the enclosing granitoid. Subsequent high-grade static metamorphism (characteristically granulite facies) is recorded by an imposed granoblastic texture.

The gneissic terrain on the western half of NEWDEGATE has undergone at least one major period of deformation. Foliation and banding trend predominantly northwesterly to north-northwesterly throughout the area, but local departures are common. The banding and foliation are cut by a stockwork of leucocratic granite. This stockwork does not appear to have a marked tectonic alignment. Both the leucocratic phase and the foliated and banded gneiss have been strongly recrystallized by high-grade static metamorphism which attains granulite facies.

The alignment of phenocrysts in the post-tectonic seriate and porphyritic adamellite (*Agv* and *Agl*) is predominantly northwesterly to north-northwesterly except near the margins of the pluton, where phenocrysts tend to be aligned parallel to the contact. The internal structure of the post-tectonic adamellite is not known, but a number of discrete plutons probably constitute a granitoid of this size.

WEST RIVER AREA

Although facing evidence is scarce, and there is no symmetrical distribution of lithologies, the West River succession is interpreted as a synclinal keel whose eastern limb is largely preserved and whose western limb has been removed during emplacement of granodiorite, now represented by amphibolite-rich migmatitic gneiss (*Ang*) (Fig. 3). The West River greenstone belt, as it is now preserved, is mainly a west-facing succession. It also lies on the western side of an anticline or dome which has the Ravensthorpe quartz diorite pluton at its core and part of the Ravensthorpe Range greenstone belt as its eastern limb. This structural interpretation, which is the basis for the correlation of units presented in Table 2, differs from an earlier interpretation (Sofoulis, 1958a, p.108-112).

Where the West River greenstone belt meets the Ravensthorpe Range greenstone belt north of the Ravensthorpe quartz diorite pluton, the structure is uncertain (mainly because of poor exposure), but there is some evidence, particularly aeromagnetic evidence, for a faulted contact between the two greenstone belts.

Near Cocanarup, an east-northeasterly trending part of the greenstone belt flanked by two domal granitoids (*Ann* and *Ang*) is interpreted as a minor syncline. There is limited symmetry across the proposed synclinal axis and no direct facing evidence for the structure. The rocks may also have been wedged northwestwards away from the main greenstone belt by emplacement of the granodiorite now represented by *Ang*.

Just north of this minor syncline is a long, arcuate outcrop of amphibolite-rich gneiss (*Angx*), which is perhaps the vestige of a complementary minor anticline. An anticline in this position was first proposed by Woodall (1955), who also noted that some lineations within the greenstone belt are parallel to the southeasterly plunging anticline axis. This anticline coincides with a structure proposed by Sofoulis (1958a) as a "superimposed tectonic axis" responsible for his proposed regional refolding of the greenstone belts in the Ravensthorpe area.

Three principal tectonic fabrics occur in the West River area. Two of these, the penetrative metamorphic foliation of the greenstone belt and the schistosity of the marginal granitic gneisses, were formed contemporaneously during development of major domes and synclines. Both foliations trend parallel to the arcuate granite-greenstone contacts. Thus the observation that the foliation of the West River greenstone belt trends north at West River Mine, northeast between Cocanarup and Ravensthorpe, but southeast beyond Ravensthorpe in the Ravensthorpe Range greenstone belt does not constitute evidence of refolding. The third fabric is a northerly to northwesterly trending crenulation cleavage which overprints the earlier fabrics.

Woodall (1955) identified two sets of lineations. The southeast-plunging set he related to the amphibolite-gneiss anticline, but no corresponding axial-plane foliation was recognized. This set is preserved with the marginal schists and therefore either post-dates the schistosity or is contemporaneous with it. Sofoulis (1958a) noted that this southeasterly plunging lineation is regionally widespread. The second set of Woodall's lineations plunges to the southwest and seems to be a relatively late feature.

The outward-dipping banding around the margin of the recrystallized granodiorite (*Ann*) and the outward-dipping metamorphic foliation around the migmatitic granodiorite gneiss (*Ang*) indicate that both these bodies are domal structures, but the former dome is the older structure because its metamorphic foliation is cross-cut by the granodiorite (*Ann*).

Foliations within the Ravensthorpe quartz diorite pluton are best developed at the margin of the pluton, where they are outward-dipping and indicative of a domal structure. The quartz diorite intrudes the basal part of the West River succession and has displaced and possibly digested mafic material in the vicinity of the West River mine. The igneous fabric in the western half of the pluton is recrystallized, and the western margin is sheared.

MOUNT BARREN GROUP

The major fold structure of the Mount Barren Group is the Fitzgerald Syncline, deduced mainly from facings defined by crossbedding in the Kundip Quartzite (Fig. 2). It is a southwesterly plunging overturned syncline with an axial plane dipping steeply southeasterly. The complementary anticline to the southeast has been thrust over the Fitzgerald Syncline in several thrust sheets of quartzite and gabbro.

Thrust planes are marked by breccia derived from the overthrust sheet in some areas such as at the Whoogarup Range, Mylies Beach and in the Hamersley River.

Several generations of folds have been recognized, but are not separately represented on the map. Some are shown diagrammatically in Figure 2. The latest folds which are related to the Fitzgerald Syncline plunge predominantly southwesterly and are abundant within the Kybulup Schist. An earlier group of folds and associated lineations plunge at low angles to the east and southeast.

ECONOMIC GEOLOGY

GENERAL SETTING

The Ravensthorpe area was one of Western Australia's main copper mining centres: 19 600 t of contained copper, which is nearly half of the total State production to 1971, has been produced. From this area, too, has come about 4 000 kg of gold, much of it from mines worked principally for copper. The gold and copper mines are located within the Archaean layered greenstone sequence close to the Ravensthorpe quartz diorite pluton. The proximity of the mines to this pluton possibly suggests some relationship between mineralization and the intrusion. The most productive mines are on RAVENSTHORPE, within the Ravensthorpe Range greenstone belt. Those on NEWDEGATE, within the West River greenstone belt, are comparatively small.

The lithium-enriched pegmatites at Cattlin Creek on RAVENSTHORPE and near Cocanarup on NEWDEGATE may be late-stage differentiates of the Ravensthorpe quartz diorite pluton. The mineral ages of around 2 700 m.y. obtained from the Cattlin Creek Pegmatite may be the approximate age of the Ravensthorpe quartz diorite pluton and possibly the age of the gold and copper mineralization.

During exploration for nickel in the early 1970's, small nickel sulphide deposits were discovered on RAVENSTHORPE (Marston, in press.). However, no nickel sulphide deposits have been reported in the West River greenstone belt on NEWDEGATE, where ultramafic units form only a small proportion of the layered greenstone sequence.

Mineralization is also associated with the Proterozoic sediments of the Mount Barren Group. These include manganese deposits at McCulloch's prospect and minor occurrences of scheelite, sphalerite, galena, and chalcopyrite.

GOLD

Most of the gold has come from the West River greenstone belt, but a small amount has been produced from a large enclave of mafic and pelitic rocks within granite-gneiss terrain near Calyerup Creek. The discovery of potentially economic gold mineralization at Griffin's Find, 14 km west-northwest of Lake Grace on DUMBLEYUNG, has renewed interest in the Calyerup Creek area and in the smaller enclaves throughout NEWDEGATE.

West River greenstone belt

The Phillips River Goldfield has produced about 4 000 kg gold, of which only about 45 kg have come from the West River greenstone belt (Table 3). Much of the gold from the Ravensthorpe Range greenstone belt came from mines worked principally for copper (Sofoulis, 1958a, Table 8). However, the gold content in the ore was low. For example, Sofoulis cites 1.5 dwts per ton—about 2 g/t—for ore from the Elverdton mine. In contrast, most of the gold from the West River greenstone belt came from ore worked principally for gold, although there was usually some copper mineralization (Sofoulis 1958a).

Most gold mines of the West River area were sited in metabasaltic or amphibolite rocks of the greenstone belt, although some were in enclaves of similar lithologies within the Ravensthorpe quartz diorite pluton. As far as can be ascertained, quartz veins were always present. Details of the geological setting of some of these mines are recorded in earlier publications (e.g. Woodward, 1909; Sofoulis, 1958a).

Jerramungup area

Gold was first discovered at Calyerup Creek in 1948, when rock samples submitted to the Government Chemical Laboratory for analysis were found to contain gold equivalent to 5 g/t. The geology of this area was examined by Johnson (1950), who considered the most favourable horizon for gold mineralization to be coarse-grained amphibolite, particularly where this contains abundant sulphide (including arsenopyrite) adjacent to quartz veins. Johnson concluded, on the basis of his field inspection and several assays, that other and richer ore bodies would have to be discovered to make gold mining economic at Calyerup Creek. Since then, 3.2 kg of gold from 184 tonnes of ore have been recorded from the Jerramungup area, mostly in 1969.

A rock sample collected from a small amphibolitic pod near the contact of porphyritic adamellite and fine-grained gneiss between Calyerup Creek and Jerramungup was found to contain 1 g/t of gold.

TABLE 3. TOTAL GOLD PRODUCTION FROM MINES IN WEST RIVER GREENSTONE BELT (PART OF PHILLIPS RIVER GOLDFIELD) ON NEWDEGATE

Lease	*Mine*	*Period*	*Ore treated (t)*	*Gold Produced kg*
GML 52	Princess Royal	1902	60	0.93
GML 88	Mount Eliza	1906	103	2.37
GML 201	Mount Doran	1925	17	0.36
GML 93	Ellen Tommy	1901-04	35	0.44
GML 94	The Amazement	—	NR	NR
GML 117	Ellen Terry	—	NR	NR
GML 237	Jim Dunn East	—	NR	NR
GML 26	James Henry	1901-04	413	16.01
ML 345	James Henry	1912	28	0.24
GML 9 PP	James Henry	1936	77	0.56
ML 13	Cousins Glory	1902	81	1.01
GML 15	Bridgetown	1902	15	0.27
GML 159	Bridgetown	1911	11	0.19
GML 212	Bridgetown	1934-39	366	4.68
GML 255	Charmaine	1939-40	206	3.05
GML 213	Charmaine	1934-36	211	2.76
GML 240	South Charmaine	1936	22	0.25
ML 293	Last Venture	1908-09	(for copper)	0.32
GML 245	Jim Dunn	1936-38	1 015	5.57
GML 21	Lucy	1902-04	273	5.44
GML 166	Lucy	1911	9	0.20
Total			2 942	44.65

NR—not recorded GML—gold mining lease ML—mining lease PP—private property
1kg=32.151 oz.

COPPER

Copper mines in the West River area have produced approximately 1 000 t of copper ore yielding approximately 100 t of contained copper. This production represents about 0.5% of the total production from the Ravensthorpe area. The copper mines of the West River group differ from most other mines in the Ravensthorpe area in that they are stratabound copper-zinc deposits, and the main economic mineral association is chalcopyrite-sphalerite-pyrite-pyrrhotite-quartz (Marston, 1979).

The Netty copper mine near Jerramungup is sited on the southern margin of an easterly-trending mafic dyke which intrudes foliated, biotite-rich adamellite (*Agl*). Only 3.13 t of contained copper were won from this mine. The occurrence is close to the contact of porphyritic adamellite (*Agl*) with gneissic granite (Agg), a geological setting similar to the gold occurrence at Jerramungup, some 8 km to the south. Samples collected from the Netty mine in 1978 contained 1.0 to 1.6% Cu, 230 to 3 900 ppm Ni, and small amounts of manganese, lead and zinc. Malachite veins were noted in porphyritic granite and fine-grained dolerite of the dump material.

MANGANESE

A manganese deposit in the Hamersley River (McCulloch's prospect) has been examined by Montgomery (1914), Blatchford (1919b), Gray and Gleeson (1951), and Sofoulis (1958a). It occurs in three outcrops, one of which has been tested by a shaft to about 10 metres. The manganiferous horizon is steeply dipping. The deposit is thought to be syngenetic with some surface enrichment. Ten surface samples from this prospect averaged 31.4 per cent Mn. Sofoulis considered the average grade would not exceed 32.5 per cent, and estimated that there is about 135 000 tonnes of ore available. De la Hunty (1963) has summarized details of this and other deposits in the area. Mapping by Thom (1977) indicates that this deposit is in schist of Proterozoic rather than Archaean age.

MOLYBDENUM

Molybdenite has been recorded "from a place 4 miles (7 km) west of Ravensthorpe", in association with quartz, ferrimolybdite and a little chalcopyrite (Simpson, 1952). The exact location and the geological setting are unknown.

During the mapping of NEWDEGATE, flakes of molybdenite up to 20 mm across were noted in a fine-grained pegmatite intruding gneiss (*Anb*) of possible metasedimentary origin at a locality 3 km west of Needilup.

LITHIUM

Exotic pegmatite veins in an area 1 km southwest of Cocanarup homestead contain beryl, columbite and the lithium-bearing minerals amblygonite, lepidolite and zinnwaldite. Zinnwaldite has been mined at one locality in this area. These pegmatites are much smaller than the lithium pegmatite at Cattlin Creek on RAVENSTHORPE (Sofoulis, 1958a) and appear to lack spodumene. All of these pegmatites may have a common origin as late-stage differentiates of the Ravensthorpe quartz diorite pluton. Pegmatite dykes are common in the West River greenstone belt, but most are small and barren.

SMALL OCCURRENCES

Small lead, copper and zinc occurrences have been reported in the Hamersley Gorge (Blockley, 1971), and sphalerite has been reported from the vicinity of Annie Peak, (Simpson, 1948). Available data indicate that these occurrences are very small.

BUILDING STONE

Spongolite, an attractive building stone of low density and moderate strength, has been quarried 22 km southwest of Ravensthorpe. Of the State's total production of 4 193 t to 1979, 2 994 t have come from this quarry, and the stone has been used in the construction of buildings in the Ravensthorpe area.

APPENDIX
LOCALITIES MENTIONED IN TEXT

LOCALITY	*LATITUDE (S)*	*LONGITUDE (E)*
Annabel Creek	33°36′	119°59′
Annie Peak	33°51′	119°59′
Baanga Hill	33°10′	119°52′
Calyerup Creek	33°55′	119°04′
Cattlin Creek	33°34′	120°02′
Cocanarup	33°38′	119°53′
Cowerdup	33°49′	119°57′
Elverdton	33°38′	120°09′
Gairdner River	33°51′	118°52′
Hamersley River	33°48′	119°40′
Jackilup Creek	33°35′	119°48′
Jerramungup	33°56′	118°55′
Kundip	33°42′	120°11′
Kybulup Pool	33°47′	119°57′
Lake Buchan	33°08′	119°04′
Lake King (Lake)	33°06′	119°35′
Lake King (Locality)	33°05′	119°41′
Lake Magenta	33°26′	119°11′
McCulloch's Prospect	33°54′	119°54′
Mount Drummond	33°54′	119°36′
Mount Madden	33°14′	119°50′
Mount Short	33°28′	119°59′
Mylies Beach	33°56′	119°59′
Naendip	33°05′	119°37′
Netty Copper Mine	33°53′	118°58′
Newdegate	33°05′	119°01′
Phillips River	33°22′	119°49′
Ravensthorpe	33°35′	120°03′
Ravensthorpe Range	33°31′	120°03′
West Beach	33°58′	119°58′
Western Steere River	33°48′	120°10′
West River	33°38′	119°39′
West River Mine	33°47′	119°53′
Whoogarup Range	33°56′	119°50′

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NEWDEGATE

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

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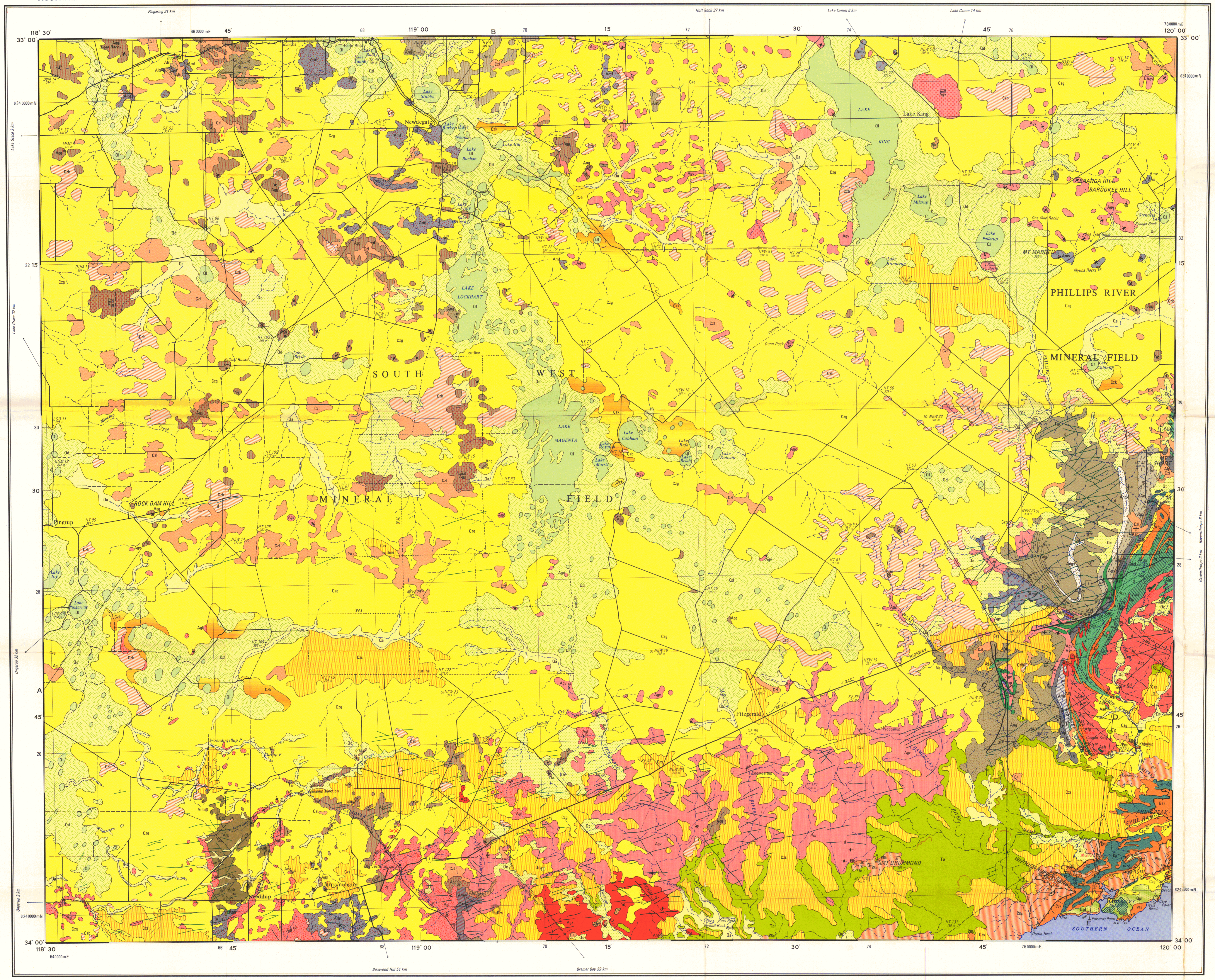
SHEET SI 50-8



REFERENCE

CAINOZOIC — QUATERNARY — TERTIARY — EOCENE

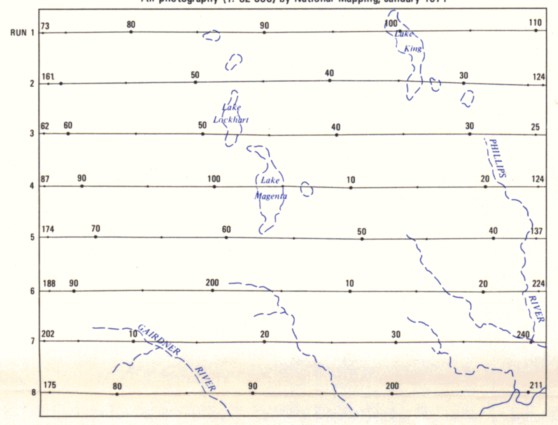
PROTEROZOIC

ARCHAEAN

SYMBOLS

FLIGHT DIAGRAM

Air photography (1: 82 000) by National Mapping, January 1971



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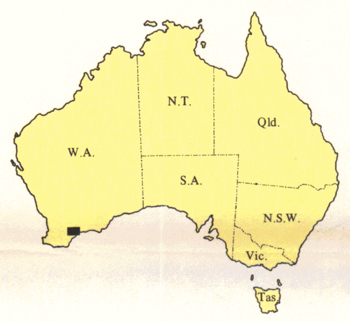

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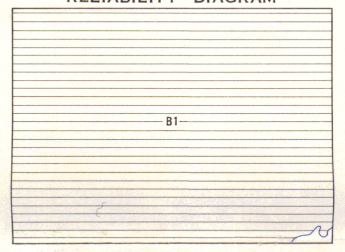


B1 Numerous traverses with air photo interpretation

HON. DAVID PARKER, M.L.A.
MINISTER FOR MINERALS AND ENERGY
A. F. TRENDALL, DIRECTOR, GEOLOGICAL SURVEY DIVISION

SCALE 1 : 250 000

5 0 5 10 15 20 25 30 Kilometres

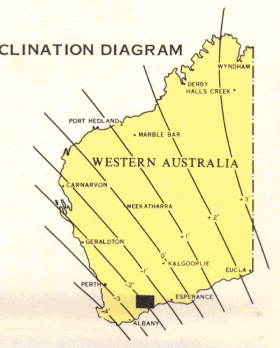
TRANSVERSE MERCATOR PROJECTION
ZONE 50 AUSTRALIAN MAP GRID

INDEX TO ADJOINING SHEETS

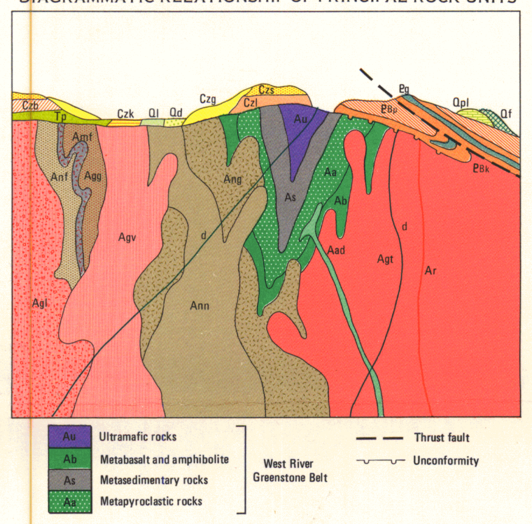
CORRIGIN SI 50-3	HYDEN SI 50-4	LAKE JOHNSTON SI 51-1
DUMBLEYUNG SI 50-7	NEWDEGATE SI 50-8	RAVENSTHORPE SI 51-5
MT BARKER SI 50-11	BREMER BAY SI 50-12	SOUTHERN OCEAN

Geology by R. Thom, A.H. Hickman and R.J. Chin, 1978

DECLINATION DIAGRAM



DIAGRAMMATIC RELATIONSHIP OF PRINCIPAL ROCK UNITS



Au	Ultramafic rocks	West River Greenstone Belt
Ab	Metabasalt and amphibolite	
As	Metasedimentary rocks	
Aa	Metapyroclastic rocks	

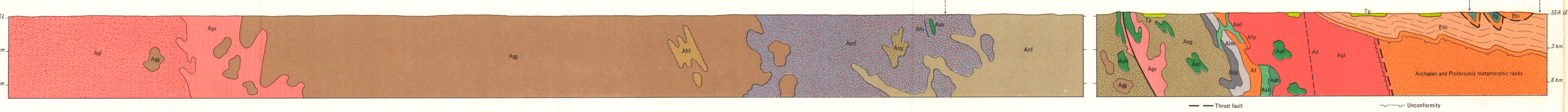
— — Thrust fault

Unconformity

DIAGRAMMATIC SECTIONS

NATURAL SCALE

SECTION A-B SECTION C-D-E



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