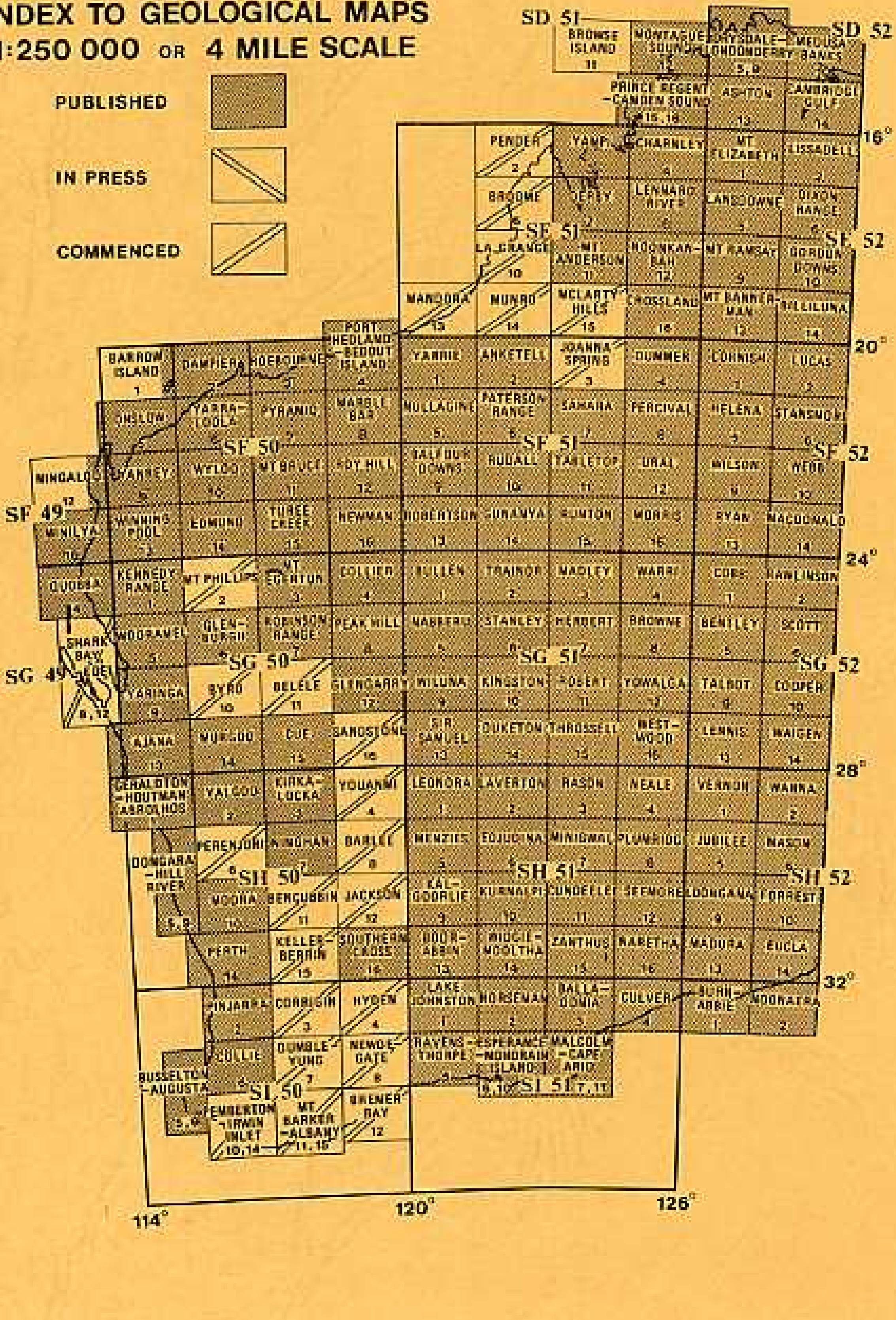
1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

NINGHAN

WESTERN AUSTRALIA

SHEET SH/50-7 INTERNATIONAL INDEX

WESTERN AUSTRALIA
INDEX TO GEOLOGICAL MAPS
1:250 000 OR 4 MILE SCALE



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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NINGHAN

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SHEET SH/50-7 INTERNATIONAL INDEX

COMPILED BY S. L. LIPPLE, J. L. BAXTER AND R. J. MARSTON

PERTH, WESTERN AUSTRALIA 1983

20392—1

DEPARTMENT OF MINES, WESTERN AUSTRALIA
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Explanatory Notes On The Ninghan Geological Sheet

Compiled by S. L. Lipple, J. L. Baxter and R. J. Marston

INTRODUCTION

The NINGHAN* 1:250 000 geological sheet, SH/50-7, is bounded by latitudes 29°00′ and 30°00′S, and by longitudes 117°00′ and 118°30′E. Main access is via the sealed Great Northern Highway and infrequently graded roads radiating from Paynes Find to station homesteads and small towns on adjacent sheets. Paynes Find, the only centre, is about 400 km northeast of Perth, and consists of a roadside tavern and a State Battery. Other access is via station tracks which vary in quality from good graded roads to poor bush tracks. Many tracks are impassable during rainy periods. Thick vegetation prevents access away from tracks in many parts. Lake Moore, Mongers Lake and the range of hills around Mount Singleton form natural barriers.

The climate is semi-desert Mediterranean (Beard, 1976, p. 3) and the 250 mm isohyet passes northwards through Lake Moore. A vegetation survey carried out by Beard (1976) on adjoining PERENJORI contains observations pertinent to NINGHAN.

Industries are pastoral activities, seasonal tourism, and some gold mining, mainly at Paynes Find. Operating station leases cover most of the sheet, but the southeast sector remains vacant Crown Land into which access is difficult.

The exploration journals of Gregory and Gregory (1884), Austin (1855), Forrest (1869) and Giles (1889) contain the earliest references to the region, including brief descriptions of the geology. In 1846, Gregory travelled around Lake Moore from Mount Churchman and recognized the pyroclastic rocks at Mount Singleton. In 1854, Austin traversed past Mount Churchman and along the Warne River, and his geological notes, especially of the Narndee Intrusion, were generally accurate.

The earliest geological reports were by Woodward (1912, 1915), Maitland (1916, 1917, 1924) and Talbot (1920).

There are few published geological reports. These are listed in the references. Geological work on the Archaean rocks has been restricted to mineral exploration or studies of small areas for university theses. Hallberg (1976) included the supracrustal belts in a geochemical review of the western Yilgarn Block. A summary of early analyses of supracrustal rocks is given by Joplin (1963). Table 1 summarizes the exploration data obtained by mining companies and held by the Geological Survey of Western Australia. Most of the supracrustal rocks have been prospected for base metals. There has been some prospecting for uranium along the Warne River and around Lake Moore.

Aeromagnetic maps at scales of 1:100 000 and 1:250 000 (Wyatt, 1975), and a Bouguer anomaly map at 1:250 000 scale have been prepared by the Bureau of Mineral Resources.

The geological mapping described in this report was completed during August-November, 1977 and April-May, 1978.

* To avoid confusion with place names, sheet names are capitalized thus: NINGHAN.

TABLE 1. SUMMARY OF MINERAL EXPLORATION REPORTS TO THE GEOLOGICAL SURVEY—NINGHAN

GSWA M FILE NO.	OPERATING COMPANY	LOCATION	DURATION	TARGET	ROCK UNITS (MAP SYMBOL)
24(a)	Australian Blue Metal	Mulgine	1961-62	Mo	*Abd,Abx,Abl*
39	Northfield Mines	Warriedar	1962	Cu	
68	Griffin Coal Mining Co Ltd (various operators)	Mount Gibson	1960-	Fe	*Aih,Asp,Afc*
137(a)	D.F.D. Rhodes	Paynes Find	1966-67	base metals, Ni	*Abx,Abl,Afv*
232	Carpentaria/Anglo	Bonnie Venture	1951	W	*Asa,Asc*
262/3(a)	Geotech/Homestake/Hanna/Union	Fields Find	1967-72	Cu,Pb,Ni,Cr	*Abg,Abd,Asp,Afs*
262/4(a)	Kennecott Exploration (Aust) Pty Ltd	Bullajungadeah Hills	1969-72		*Abl,Abd,Abx*
277	Union/Homestake/Hanna	Warriedar, Fields Find	1967-69	Cu,Ni	*Abl,Abx,Abd,Asp*
317	Western Mining Corporation	Sheet generally	ca. 1963-70		
365(a)	Newmont Pty Ltd	Warriedar Battery	1968-69	Cu,Ni	*Abg,Abx,Abl*
651	United Nickel NL	Golden Eagle	1970-71	Cu,Ni	*Abl,Abd,Abx,Asp*
656	United Nickel NL	Yeoh Hills	1971	Cu,Ni	*Abd,Ai*
660	Hawkstone Minerals Ltd	Mount Singleton	1969-73	base metals, Ni	*Abx,Abl,Abc*
666	Hawkstone Minerals Ltd	Paynes Find	1969-71	Cu,Ni	*Abx,Abl,Afv*
860	Kennecott Exploration (Aust) Pty Ltd	Retaliation	1970-71	base metals	*Abx,Ai,Aua*
1221(a)	International Nickel Aust Ltd	Warriedar Battery	1972	base metals	*Abl,Abg,Abd,Abx*
1424(a)	Consolidated Goldfields	Lake Moore	1972-73	U	*Ql,Cza,Czk*
1457(a)	Consolidated Goldfields	Mouroubra	1972-73	U	*Ql,Cza,Czc*
1513	Westfield Minerals (WA) NL	Narndee (Condon Well)	1973-77	base metals	*Asp*
1688(a)	CRA Exploration Ltd	Bonnie Venture	1974-75	base metals, U	*Asc,Asa,Asp*
1694	Esso Exploration Aust Inc	Pinyalling	1974-	base metals	*Asp,Abl*
1818	Electrolytic Zinc Co (A'asia) Ltd	Warro-Mount Gibson	1973-	base metals	*Afv,Abl*
1845	Noranda Aust Ltd	Pinyalling	1975	base metals	*Afs,Asp,Afv*
1849(a)	Union Minière	Warriedar	1974-75	base metals	*Abl*
1850(a)	Union Minière	Woodleys Find	1975	base metals	Pelitic sediments, some volcanogenic *Afs*
1904(a)	Western Mining Corporation	NW Walagnumming Hill	1974-75	base metals, Cr	*Abx,Ai*
1930	Western Mining Corporation	Woodleys Find	1974-75	base metals	*Afs*, mainly black shale, siltstone
1950	Amax/Samantha	Chulaar	1974-76	base metals	*Afs*, felsic sediments and tuffs

TABLE 1—*continued.*

GSWA M FILE NO.	OPERATING COMPANY	LOCATION	DURATION	TARGET	ROCK UNITS (MAP SYMBOL)
1971	Dampier Mining Co Ltd	Narndee	1973-74	base metals	*Asp,Ai,Afc*
1993(a)	Esso Exploration Aust Inc	Fields Find	1974-75	base metals	*Abl,Abx,Asp,Afs*
2019(a)	Newmont Pty Ltd	Woodleys Find	1974-76	base metals	*Abl,Abx,Abd,Abg,Afs*
2035	Australian Anglo American Ltd/North Broken Hill Ltd/North Flinders Mines Ltd	Mount Gibson Well	1976-77	base metals	*Afc*
2062(a)	Australian Selection Pty Ltd	Retaliation Yandhanoo-Waroo Well	1974-77	base metals	*Abx,Asa,Asp,Aih*
2106(a)	Noranda Australia Ltd	Bonnie Venture	1976-77	base metals	*Asa,Asc,Asp,Abl*
2197	Universal Milling Co Pty Ltd	Lake Moore (NE)	1976-77	W,U	*Ql*
2256(a)	Noranda Australia Ltd	Mount Singleton	1977	base metals	*Abc*
2266	Dampier	Fields Find	1977-	base metals	*Abg, Abd*
2285	Newmont Pty Ltd	Narndee	1976-	base metals	felsic volcanics
2344	Kia Ora Gold Corporation	15 km S Mouroubra	1970-71	Ni	*Au*

(a) Open file (microfilmed) report. Other reports will be progressively placed on open file when tenements are relinquished, but access is currently restricted.

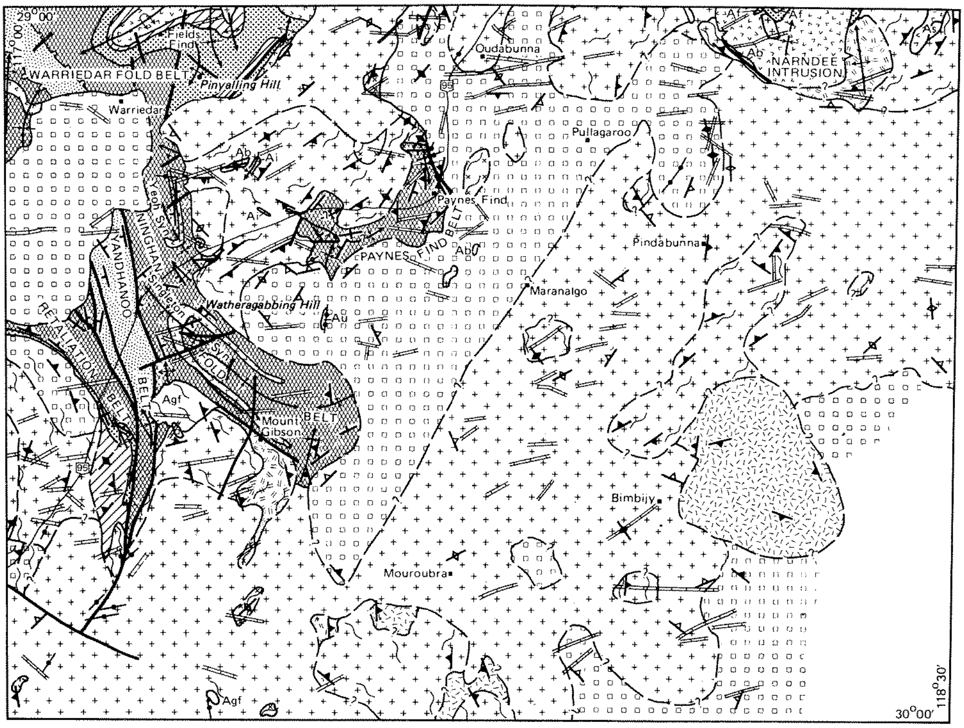


FIGURE 1

GSWA 17955

INTERPRETED PRECAMBRIAN GEOLOGY

NINGHAN SHEET SH 50-7

0 10 20 30 km

REFERENCE

Undeformed granitoid

Deformed granitoid

Texture:
- Porphyritic
- Medium-grained mixed types
- Even-grained
- Agf — Medium-grained granodioritic

Gabbro intrusion

Unassigned gneiss

Orthogneiss

FOLD BELT ASSOCIATIONS

Upper sedimentary

unconformity

Upper mafic volcanic

Lower sedimentary

Lower mafic volcanic

UNASSIGNED UNITS

Ab	Mafic volcanic rock
Au	Ultramafic rock
Ai	Banded iron formation
As	Sedimentary rock
Af	Felsic volcanic rock

Mafic dyke – commonly dolerite; coarse-grained leoucogabbro dyke

Quartz veins

Bedding; inclined 30-70

vertical

Platy (igneous) mineral foliation; inclined 30-70

vertical

Metamorphic foliation; inclined 30-70

vertical

Anticline, with plunge

Overturned anticline, with plunge

Syncline, with plunge

Geological boundary

Approximate boundary

Inferred boundary

Intrusive contact, barb to intruded phase

Town or settlement

GEOLOGICAL SUMMARY

Thick Archaean supracrustal rocks are preserved in major fold belts (Fig. 1) separated by large granitoid intrusions characteristic of the Murchison Province (Williams, 1974). Within the batholiths, remnants of a gneissic terrain consisting of orthogneiss and paragneiss with supracrustal rocks are metamorphosed to amphibolite facies. Similar remnants are more extensive on adjoining PERENJORI and MOORA (Baxter and Lipple, 1979; Carter and others, 1978).

Within each of the major fold belts the supracrustal rocks can be broadly divided into successions consisting either of predominantly mafic volcanic rocks or of predominantly sedimentary rocks. Such successions appear to be arranged in a similar order of superposition in all fold belts, although not all successions are necessarily represented in each belt.

It is considered that within each belt each of these successions may eventually prove to have the same status as a "group" in formal stratigraphic nomenclature. However, because of the reconnaissance nature of this mapping and the inherent complexity of Archaean geology, we presently prefer the informal term "association" as defined by Williams (1970) and Muhling and Low (1973). It is unlikely that former continuity of these associations between belts will ever be established, and indeed it is possible that some or all represent parallel evolution of separate trenches, rather than being remnants of formerly continuous sheets.

In all, four associations are recognized in the sheet area—two of mafic volcanic affinities and two of sedimentary rocks (Fig. 1). A summary of the distribution of the associations in the different fold belts and similar schemes proposed for adjacent areas are given in Table 2. The associations are described below in an apparent ascending stratigraphic order.

1. The lower mafic volcanic association (Fig. 1) consists of tholeiitic basalt and dolerite with interlayered horizons of banded iron-formation. It is best exposed around the Bullajungadeah Hills.
2. The lower sedimentary association (Fig. 1) comprises pelitic and felsic sedimentary rocks which are best exposed near Pinyalling Hill. The unit is characterized by the presence of fine-grained volcaniclastic sediments, and locally, as near Mount Gibson, felsic volcanic rocks.
3. The upper mafic volcanic association (Fig. 1) resembles the lower volcanic association in being of mainly tholeiitic composition. Some of its distinguishing features are: a greater abundance of pyroclastic rocks; a greater proportion of Mg-rich basalts; a lower content of banded iron-formation; and a generally lower amount of deformation. However, distinction between the upper and lower volcanic associations is not always possible. The unit is well exposed at Mount Singleton. Locally it contains felsic volcanic rocks.
4. The upper sedimentary association (Fig. 1) comprises mainly shale and siltstone with interbeds of sandstone and conglomerate. It contains horizons of banded iron-formation near its base. Muhling and Low (1973) placed this unit below the upper mafic volcanic unit equivalent on YALGOO, but the present mapping indicates that it unconformably overlies all of the other associations.

The basaltic rocks are essentially tholeiitic, as indicated by field and microscopic observations of texture and by Hallberg's (1976) chemical analyses. Ultramafic rocks are minor. The presence of differentiated basalt flows (*Abx*) is a notable

TABLE 2. REGIONAL STRATIGRAPHIC CORRELATIONS AND THICKNESSES

1:250 000 Sheet	NINGHAN				**PERENJORI (a)**		**YALGOO (b)**	Mineralization on **NINGHAN**
Locality, / *Association*	*Ninghan Belt (Mount Singleton)*	*Paynes Find Belt*	*Retaliation Belt*	*Warriedar Belt*	*Warriedar Belt*	*Koolanooka Synform*		
					As 1 km			
Upper sedimentary			*As* 2.5 km	*As* 1-2 km	*As* 2 km		Assn 3 1 km	
Upper mafic volcanic	*Ab* 4 km	*Af* *Ab* ≤3.5 km	*Af* 8.5 km *Ab*	*Ab* 10 km	*Ab* 10 km	*Ab* 5 km	Assn 4 2.7 km	Gold at Paynes
Lower sedimentary			*As* *Ai* 0.5 km *Af*	*As* 2 km *Af*	*As* 0.5 km	*As* 1 km	Assn 2 1-2 km	Copper & iron
Lower mafic volcanic			*Ab* 2.5 km	*Ab* 2 km		*Af* 4 km	Assn 1 2-3.5 km	Gold
Total thickness	4 km	3.5 km	14 km	15 km	13 km	10 km	6.5-9 km	

Symbols as for Figure 1.

Assn = Association

(a) Baxter and Lipple (1979)

(b) Muhling and Low (1973)

feature of both mafic volcanic associations in all fold belts. Evidence for an extrusive origin is best preserved in the Retaliation Belt. Several massive to layered gabbros occur at various stratigraphic levels and are assigned to their enclosing association without age implications, except that all preceded folding. At least some gabbros were subvolcanic sills. The largest body, the Narndee Intrusion, appears to intrude orthogneiss but is cut by syntectonic granitoid.

Regional metamorphism of the supracrustal rocks generally attained greenschist to low amphibolite facies. Primary textures are widely preserved. Limited contact metamorphism is associated with granitoid intrusions.

Folds in the supracrustal rocks are of symmetrical, open, cylindroidal style in the mafic volcanic associations and close, angular, similar style in the sedimentary associations. A late phase of weak buckling to open concentric folding, with axial trends towards the north to northeast, is probably related to intrusion of post-tectonic granitoid masses.

Strongly foliated and granoblastically recrystallized granitoids (Fig. 1) are regarded as syntectonic intrusions. Some orthogneiss, such as that near Mount Gibson homestead, is partly the result of more intense deformation and thorough recrystallization of these granitoids. Samples thought to have been collected mainly from syntectonic granitoid by Arriens (1971) on a traverse from Perenjori (in the west) to Paynes Find, have yielded an age of 2 764±264 m.y.($\lambda = 1.39 \times 10^{-11} y^{-1}$).

Massive, equigranular to porphyritic granitoids (Fig. 1) represent a major phase of post-tectonic intrusion. Textural variation within comagmatic masses is common, and transitions between types may be abrupt. Discordant relationships between distinct intrusions are also present. Arriens (1971) reported an age of 2 664 ± 68 m.y. ($\lambda = 1.39 \times 10^{-11} y^{-1}$) from samples collected from Paynes Find northwards to Cue.

A major zone of longitudinal faults isolates the upper sedimentary association (Yandhanoo Belt) in a faulted synclinal structure. Rocks adjacent to these faults in the south have a strong foliation, and minor folds inconsistent with regional structure may be related to fault movement. Other minor faults cut the fold belts at high angles to layering. Several strike faults are present in the limbs of the Singleton Syncline.

Dolerite and coarse-grained leucogabbro have widespread distribution, apparently in irregular zones of concentration. The dykes mainly strike east to northeast. Some leucogabbro dykes contain abundant granitoid and vein-quartz xenoliths, suggesting intrusion along fracture zones.

Cainozoic deposits are widely developed and stem from several generations of landscape development.

ARCHAEAN SUPRACRUSTAL ROCKS

Archaean supracrustal rocks occur in several major structural units (fold belts) (Fig. 1) which are discussed below. Brief lithological descriptions of distinct rock units appear in the map reference.

WARRIEDAR FOLD BELT.

The Warriedar Fold Belt occupies the adjacent corners of YALGOO (Muhling and Low, 1973), PERENJORI (Baxter and Lipple, 1979), KIRKALOCKA (Baxter and others, 1980) and NINGHAN. Metamorphosed supracrustal rocks more than 10 km thick occur on NINGHAN (Table 2). The base of the sequence has been removed by emplacement of granitoid plutons.

Metamorphism

The widespread development of actinolite, epidote and sodic plagioclase in the mafic rock suites and the absence of cordierite and garnet in the pelitic rocks indicate low grade regional metamorphism (below amphibolite facies). Andalusite has developed in some pelitic rocks and hornblende in some mafic rocks, but this is taken to reflect local effects due to granitoid intrusions.

Layering

Four associations are recognized (Fig. 1).

The lowermost mafic volcanic association is predominantly a rhythmically layered metagabbro (*Abg*) with lesser amounts of thin metabasaltic flows (*Abl*); thick differentiated flows (*Abx*); and metadolerite sills and flows (*Abd*). Thin banded iron-formations (*Aia*) separate some of the flows. Differentiation of the gabbro and dolerite units has produced thin basal pyroxenite (now actinolite-tremolite rocks and serpentinite). The best exposures of the association are in the vicinity of Fields Find.

Poorly exposed, deeply weathered fine-grained semipelitic to pelitic slates and schists (*Asp*) with thin cherty metasediments and banded iron-formations (*Aih*) comprise the lower sedimentary association. A thick wedge of fine-grained felsic rocks (*Afs*) occurs in the sequence. Pinyalling Hill contains rocks with the best preservation of primary textures.

A pile of probably cogenetic flow rocks (*Abl, Abx, Abd*) and subvolcanic intrusions (*Abd, Abg*) with thin interlayered banded iron-formations occurs in the upper mafic volcanic association. Some dolerite (*Abd, Abx*) and gabbro (*Abg*) units are weakly differentiated with thin basal tremolite-actinolite rock (*Aua*) or serpentinite (*Aus*) after pyroxenite. Olivine pseudomorphs are preserved in some serpentinites. A thickness of approximately 6 km of this association is exposed north of Hurley well.

The upper sedimentary association is composed of a thin basal quartz wacke, fine-grained pelitic metasediments (*Asp*) and banded iron-formations (*Aih*), overlain by thick fine-grained felsic metasediments (*Afs*). The pelitic metasediments contain abundant andalusite in places. The base of the association is exposed in Warriedar Hill.

Structure

In the mafic volcanic associations, large scale, symmetrical, open, cylindroidal anticlines and synclines have developed. A weak layer-parallel foliation is common on fold limbs, particularly in ultramafic units. The remainder of the two associations has been statically recrystallized with random growth of pale amphibole in some rocks. Recrystallization is stronger in the lowermost association.

In the lower sedimentary association the folds are commonly symmetrical, close to open, and angular, and tend to be similar style. The fine-grained pelitic and semi-pelitic members are cleaved parallel to the axial surface of the folds. Minor folds are common in the banded iron-formations.

The upper sedimentary association unconformably overlies the sequence on KIRKALOCKA (Baxter and others, 1980), but the contact relationships are uncertain on NINGHAN. Folds in this association are similar to those in the lower sedimentary association. Cleavage throughout develops parallel to the axial surface of the folds. Andalusite porphyroblasts pre-date cleavage formation.

Minor faults cut the folded sequence. They are more common on the fold limbs and tend to cut the layering at a high angle.

NINGHAN FOLD BELT

The Ninghan Fold Belt is a thick sequence of particularly well-exposed, little deformed or metamorphosed tholeiitic basalt flows, agglomerate, and subvolcanic sills. Minor ultramafic and sedimentary rocks form thin marker horizons.

The sequence is preserved in synclines trending southeast for 40 km from Wylacoopin Hill (Singleton Syncline) and northwards from near Ninghan woolshed for 25 km through the Yeoh Hills (Yeoh Syncline). The volcanic rocks are unconformably overlain to the west by steeply east-dipping but west-facing sedimentary rocks of the Yandhanoo Belt. The limits of the fold belt are elsewhere defined by granitoid intrusions.

Metamorphism

Metamorphism is essentially static (excellent preservation of primary textures), and mainly of Abukuma-type greenschist facies with low volatile pressure (Hallberg, 1976). Metamorphosed basalt typically contains tremolite-actinolite, chlorite, clinozoisite and secondary quartz. Ultramafic rocks are altered to serpentine, chlorite, carbonate and tremolite. Banded iron-formation contains actinolite.

Layering

The volcanic sequence is best preserved in the Singleton Syncline (Fig. 1) and studies on part of the syncline were made by Perkins (1977) and Tomich (1978). A similar sequence is preserved in the Yeoh Syncline, the main differences being a reduced proportion of agglomerate, greater deformation, and general alteration of ultramafic rocks to talc-carbonate units or amphibole schists. Metabasalt is typically fine grained, amygdaloidal, and either massive or variolitic and pillowed. Agglomerate is generally massive. Clasts are angular (even concave), up to 0.2 m in diameter, and consist of various volcanic types (mainly fine-grained basalt) set in a tuffaceous matrix of similar composition. Shardy and eutaxitic tuffs were reported by McCall (1971, p. 437). Thin, well-bedded and graded metasiltstones exhibit low-angle cross-bedding, microscours, solemarks, slump folding and bedding disruption.

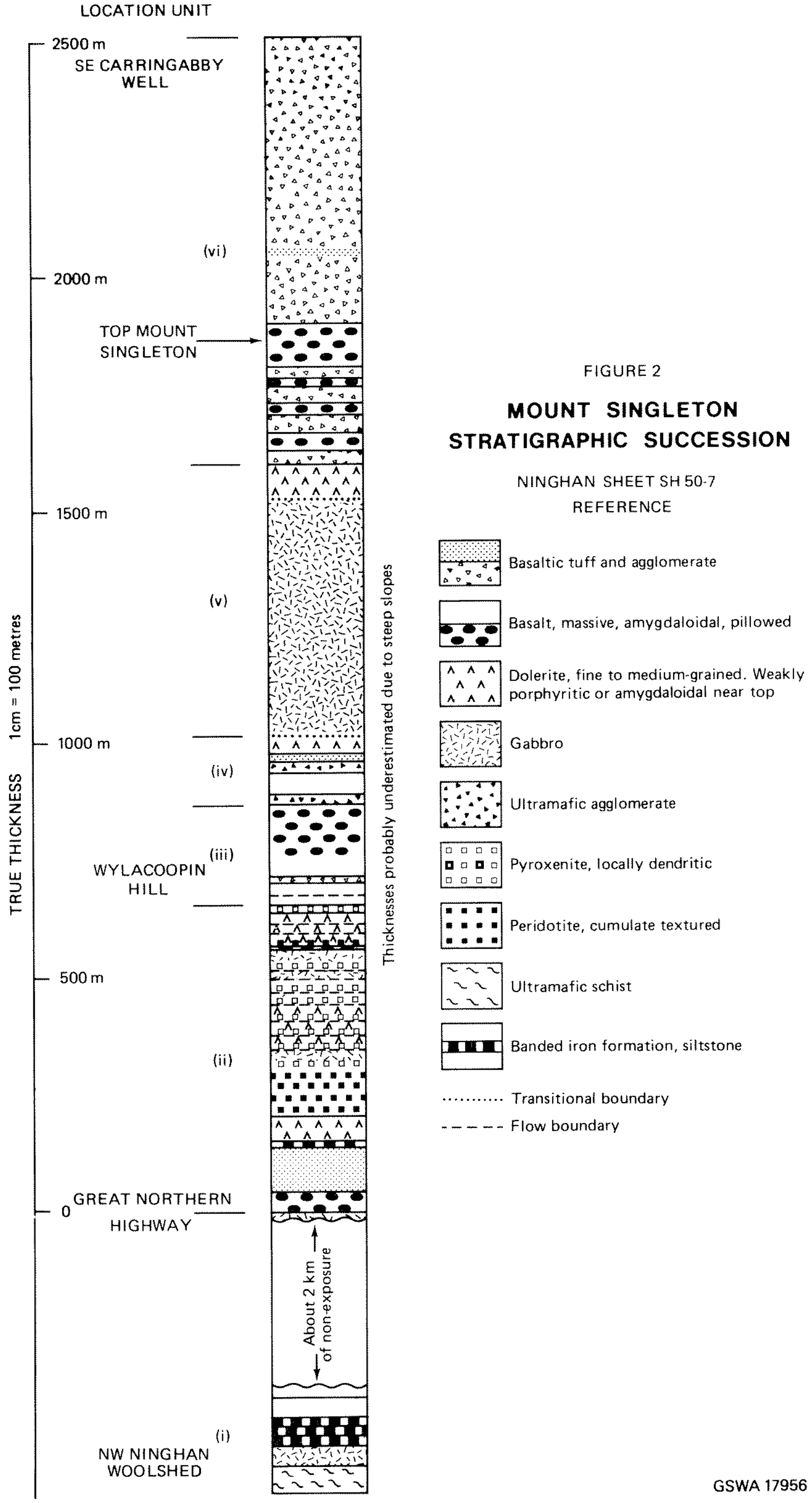
The sequence can be divided into five lithological parts, which are described below. The localities given are those used to complete the column in Figure 2. Differentiated, coarse-grained units are concentrated near the base whilst pyroclastic units increase in proportion upwards. Similarly basalt becomes very fine grained and predominantly pillowed.

(i) The oldest rocks are thick banded iron-formation and associated metagabbro and ultramafic schist exposed in a small anticline near Ninghan woolshed.

FIGURE 2

MOUNT SINGLETON STRATIGRAPHIC SUCCESSION

NINGHAN SHEET SH 50-7



(ii) Between the Great Northern Highway and Wylacoopin Hill, massive and pillowed metabasalt (*Abl*), tuff (*Abc*) and thin metasiltstones interbedded with metamorphosed differentiated peridotite to gabbro or dolerite (*Abx*), form the base of the Singleton Syncline succession. Differentiation of essentially mafic rocks forms a single cycle (partial or complete) of progressive lithological and textural variation, but lacks mineral banding and development of feldspathic types. Cumulate textures dominate near the base. Poorly developed, acicular, porphyritic or amygdaloidal chill textures occur towards the top. Medium- to coarse-grained dark metaperidotite (wehrlite of McCall, 1971, 1973) forms a thin basal layer consisting of aggregates of polygonal olivine (partially pseudomorphed by serpentine), and fresh augite set in a devitrified (tremolite-chlorite) groundmass with abundant accessory brown amphibole.

Metaperidotite passes rapidly up into medium-grained, granular or dendritic metapyroxenite, then into fine- to medium-grained metagabbro. Metapyroxenite contains tremolite after cumulate pyroxene and some serpentine pseudomorphs after olivine. In some instances, metamorphosed quartz leucogabbro or weakly vesicular dolerite occur at the top.

(iii) Fine-grained, massive metabasalt flows with thin breccia tops, and impersistent agglomerate near the top of Wylacoopin Hill pass up to a thick sequence of pillowed metabasalt (*Abl*). A thin zone of metamorphosed ultramafic agglomerate (*Auv*) and banded tuff, and banded iron-formation (*Aia*) with interbedded basaltic tuff separates the pillow basalt from a thick metagabbro unit (*Abg*). The ultramafic agglomerate is well exposed west of Ninghan homestead and south of Mount Singleton. Serpentinized fragments contain abundant antigorite pseudomorphs after olivine phenocrysts, angular chlorite aggregates and accessory pyrite set in a very fine-grained tremolite matrix.

(iv) Metagabbro near Ninghan homestead appears to form a large, undifferentiated sill, with a medum- to coarse-grained dendritic texture near the base changing upwards into a fine- to medium-grained subophitic texture. The margins are fine grained. Marlow (1973) reports layering distinguished by accumulations of elongate hornblende. The metagabbro consists of green hornblende, oligoclase-andesine with interstitial quartz, much accessory apatite and a little secondary clinozoisite. Large volcanic xenoliths occur south of Coonigal Well, and southwest of Mount Singleton. Small, partially assimilated, altered granitoid xenoliths were seen near the base, west of Mount Singleton.

(v) Interbedded pillowed or massive metabasalt, basaltic agglomerate and tuff overlying the metagabbro have excellent exposure on the slopes of Mount Singleton. At the northeast foot of Mount Singleton, coarse mafic breccia with irregular, contorted lava fragments suggests derivation as a blocky lava ('aa'), or post-depositional slumping of viscous lava. Hyaloclastic breccia is commonly associated with pillow basalt, as illustrated in a gorge exposure 2 km south of Coonigal Well, where well-formed pillows grade into pillows with brecciated margins, which, with increasing fragmentation, become a massive chaotic breccia. Agglomerate is thickly bedded, coarse and unsorted. Locally it grades into tuff, and, rarely, into waterlain tuffaceous metasiltstone. McCall (1971, p. 437) also mentions chloritoid-andalusite rocks of obscure sedimentary origin.

Structure

Open, concentric- to similar-style folding is the dominant structural feature. Three main fold traces are present (Fig. 1). The Singleton Syncline plunges 30° southeast at the nose, flattening to 5° to 10° near Mount Singleton. It merges with synclinal trends plunging north from near Carringabby Waterhole, and southwest from near Serpent Rocks. The Yeoh Syncline plunges north-northwest, with the plunge steepening from 45° to 75° northwards. A subordinate anticline, separating the two major synclines, can be traced about 3 km northwest from Ninghan woolshed. It has tight similar-style folding, and plunges about 50° northwest. Several minor synclinal and anticlinal closures east of the woolshed are related to the major structures but are more westerly plunging.

Dips are generally moderate to steep. Ultramafic rocks commonly exhibit a strong layer-parallel foliation. Minor, mild concentric to tight similar folds, parasitic to the major synclines, have a weakly developed axial-plane crenulation cleavage with a streaky mineral lineation along the intersection with bedding. Equivalent folds parasitic to the anticline are tight, similar to isoclinal folds with a strongly developed axial-plane cleavage and mineral lineation. Cleavage is best seen in tuffs and sedimentary or ultramafic rocks. This cleavage crenulated the earlier foliation in ultramafic schists. A pronounced lineation, defined by clast elongation and preferred orientation of actinolite, is notable in agglomerate in the southeast part of the Singleton Syncline. This lineation is not parallel to the fold axis.

A widespread, but weak, buckling and crenulation cleavage which affects earlier foliation and cleavage, trends northeast to north-northeast. It is mainly visible in ultramafic schists and banded iron-formation.

Several northeast-trending faults are present. Strike-slip faults near Mount Gibson homestead deform ultramafic rocks.

RETALIATION BELT

The Retaliation Belt is west of the Ninghan Fold Belt and separated from it by the Yandhanoo Belt. The belt consists of an arcuate, northwest-striking metamorphosed sequence of dominantly mafic volcanic rocks with substantial sedimentary-felsic volcanic components in the middle and at the top. Available evidence suggests that the sequence is broadly conformable and that it youngs consistently to the northeast. Dips are commonly steep towards the northeast.

Metamorphism

A static style of regional metamorphism, probably of low greenschist facies (sodic plagioclase, actinolite and stilpnomelane in metatholeiites), is most common. However, in the south and along the western margin of the belt the presence of metamorphic foliations and amphibolites indicates higher grade dynamic recrystallization.

Layering

Four associations are recognized (Fig. 1, Table 2):

(i) The lower volcanic association of poorly exposed, tholeiitic metabasaltic flows (*Abl*) and differentiated flows (*Abx*), considered equivalent to the well-exposed basal association of the Warriedar Fold Belt, occurs at the base of the sequence.

(ii) The lower sedimentary association is typified by banded iron-formations (*Aih*) and chert (*Aic*), with subordinate felsic tuff and agglomerate (*Afc*) and semipelitic schist (*Asp*) in the south where maximum development occurs in a series of large parasitic folds at Mount Gibson. North of the Great Northern Highway the association thins rapidly to a single iron-formation accompanied by magnesian amphibolite (*Aba*) abutting deformed granitoid to the southwest.

(iii) The upper volcanic association is well exposed and closely comparable with its counterpart in the Warriedar Fold Belt (Baxter and Lipple, 1979). Differentiated tholeiitic flows (*Abx*) averaging some 50 m in thickness, make up the bulk of the 5 km mafic volcanic sequence of the association. Undifferentiated metabasalt (*Abl*) and serpentine- or talc-bearing amphibole-chlorite rocks (*Aua*) are minor components, and thin (1 to 5 m) banded iron-formations (*Aih*) or cherts (*Aic*) form numerous marker bands throughout the sequence. These bands mark the flow boundaries in the sequence, a typical differentiated flow being as follows:

	banded iron-formation
	* * * * * * * * * * *
flow top:	thin zone of fine- to medium-grained acicular actinolite (after pyroxene), plus plagioclase and quartz; sheaves of actinolite prisms coarsening downwards
doleritic centre:	monotonous medium-grained, stubby prismatic actinolite, plus plagioclase and quartz
cumulus pyroxenitic base:	subequant tremolite-chlorite pseudomorphing clinopyroxene and lesser orthopyroxene accessory plagioclase (increasing at top)
	* * * * * * * * * * *

Such flows are comparable in some features with layered flows described from Ontario (Arndt, 1977).

(iv) At the top of the previous association, and probably representing the upper sedimentary association, is a weathered, poorly exposed sequence of metamorphosed felsic tuffs and lavas (*Afv*) accompanied by thin, impersistent, banded cherts or iron-formations, volcaniclastic metasedimentary rocks and pyritic slates. A lens of mafic metavolcanic rocks occurs within the sequence in the north.

The felsic rocks are commonly cleaved.

YANDHANOO BELT

The Yandhanoo Belt of metasedimentary rocks occupies a north-northwesterly striking tract flanked by the mafic volcanic terrains of the Ninghan Fold Belt to the east, and the Retaliation Belt to the west. A study of part of the sequence was made by Turner (1978). Evidence of facing from many observations of cross-stratification in the psammites shows that the bulk of the sequence faces west. Bedding dips steeply to the east or west. The only fold structures recognized are steeply to moderately south-plunging parasitic folds in the north whose vergence is consistent with a major south-plunging syncline; and north-plunging parasitic folds at Yandhanoo Hill consistent with a major north-plunging syncline. The gross structure of the sequence is apparently a double-plunging ("boat-shaped"), overturned syncline, whose southern plunge termination appears to be present to the east of Mount Gibson. However, apart from this area, the western limb of the syncline seems to be largely removed by a major strike fault (Fig. 1).

In contrast to rocks of the adjacent belts, a higher grade of metamorphism (?greenschist-amphibolite-facies transition) probably characterizes the sequence. Semipelitic and pelitic rocks contain andalusite and, more rarely, almandine porphyroblasts. The cherts and banded iron-formation are thoroughly recrystallized.

Fine-grained, bedded, pelitic to semipelitic rocks (*Asp*) are the most common rock type, although most outcrops are weathered, and fresh rocks are restricted to

Yandhanoo Hill and the extreme north. Quartz, biotite, feldspar, chlorite, muscovite, andalusite and almandine-bearing assemblages have been recorded there. Ridge-forming psammitic units of thick-bedded, fine-grained quartzite (*Asa*), some of which are micaceous or feldspathic, are interbedded with the more pelitic rocks, and exhibit small-scale cross-stratification. Some psammitic units contain chert pebbles or lenses of grit. Lensoid units of chert conglomerate (*Asc*) also form ridges. Subangular, banded-chert clasts, occasionally containing tight, minor folds, are set in a fine, recrystallized, quartz-sand matrix.

Banded iron-formations (*Aih*), generally thin but forming a thick unit north of Roys Bore and at Yandhanoo Hill, occur at the base of the sequence. Conglomerate (*Asy*) with metabasalt, chert, or quartz clasts occurs in the extreme south, east of Mount Gibson.

PAYNES FIND BELT

Interlayered basaltic and dacitic metavolcanic rocks with subordinate banded iron-formations and ultramafic schist in the Paynes Find Belt (Fig. 1) are intruded by strongly deformed equigranular and porphyritic granitoids. Although the two main outcrop areas are separated by a tract of thick alluvium, the belt is probably continuous. The geology and gold mineralization around Paynes Find was discussed by Clarke (1920, 1925).

Metamorphic grade is probably about upper greenschist to lower amphibolite facies, with widespread development of tremolite, actinolite, some calcic plagioclase and, locally, biotite and grunerite. Although the rocks are generally foliated, relict primary textures are common. Amygdales and agglomerate clasts are typically rotated or deformed into a linear orientation in the foliation plane. Strain is greatest in ultramafic rocks, which are commonly altered to pale amphibole schists. Chlorite porphyroblasts or actinolite fans in the foliation planes suggest that weak static metamorphism continued after deformation ceased.

Basaltic metavolcanic rocks consist of amygdaloidal lava (*Abl*), tuff and agglomerate (*Abc*), and differentiated flows (*Abx*) with thin, basal, altered ultramafic units. Dacitic metavolcanic rocks include massive amygdaloidal lava (*Afv*), banded and crystal tuff and agglomerate (*Abc*). Schistose metadacite (*Afo*) exposed 5 km northwest of Mount Edon contains euhedral quartz phenocrysts. At Paynes Find an unusual hornblende-biotite-quartz-oligoclase tonalite gneiss, which is a host to quartz-vein gold mineralization, is thought to represent complete recrystallization of a felsic metatuff with relict banding. A less-reconstituted form of this felsic metatuff is exposed along strike at Goodingnow. Rare pyroclastic texture was noted in fine-grained ultramafic rocks 5 km northwest of Paynes Find. Banded, ?tuffaceous, ultramafic rocks occur 1 km south of Mount Harry and east of Warrdagga Hill. The banded iron-formations south of Mingarby Well may include thin fine-grained dacitic granofels or schist. Northwest of Paynes Find banded iron-formation layers are gradational with actinolitic amphibolite bands.

Distribution of rock types is irregular with dacitic metavolcanics being best developed near Paynes Find, and ultramafic schists and banded iron-formations being more common around Mount Harry.

Structural elements of the belt are poorly defined, but include a synclinal fold trace (Fig. 1) plunging north from near Warrdagga Hill and southeast past Mount Harry. In the eastern part of the belt, the structure appears to be synformal, with a south-plunging closure north of Paynes Find, but the position of the axial trace southwards is uncertain.

Parasitic minor folds, mostly in banded iron-formation, indicate two fold generations. An earlier main phase of steeply plunging, tight, similar to isoclinal folding has an axial-plane cleavage and a strong mineral lineation coaxial to fold plunges. A later, open, concentric folding exhibits plunges of less than 30 degrees with a weak south-trending coaxial mineral lineation, and some bedding brecciation. This concentric phase has folded and crenulated foliation in ultramafic schists.

NARNDEE BELT

The Narndee Belt consists of well-exposed layered metagabbro, defined as the Narndee Intrusion and thought to be equivalent to the Windimurra Intrusion (de la Hunty, 1973; Ahmat, 1971; and Hockley, 1971), intruding metasedimentary and felsic metavolcanic rocks and amphibolite. Gently dipping igneous layering in the metagabbro outlines a north-plunging syncline. The metasedimentary rocks are well cleaved and folded to form a small dome associated with the emplacement of equigranular granitoid. Metamorphism is generally static and predominantly of amphibolite facies. Pyroxene-hornfels facies contact metamorphism of gabbro (augite-hypersthene-green hornblende) occurred next to a granitoid intrusion, north of New Well. Deformation is mostly confined to metasedimentary rocks and thin ultramafic units in the Narndee Intrusion.

Metamorphosed sedimentary rocks near Condon Well consist of metasandstone (*Asa*), quartz-muscovite-chlorite semipelite (*Asp*) with interbedded banded grunerite iron-formations (*Aia*). Felsic metavolcanic rocks in this area consist of strongly foliated, banded rhyolitic tuff and dacitic crystal tuff (*Afc*) with beta-quartz, oligoclase and biotite crystals set in a fine quartzo-feldspathic matrix. Flow-banded, variolitic metadacite occurs north of Kockalocka Well.

The Narndee Intrusion appears to cut granitic gneiss (*Ang*) north of Soak Bore. Elsewhere, the gabbro is intruded by massive and strongly foliated equigranular granite (*Age, Agef*) and pegmatite. A small diopside diorite plug intrudes the gabbro 3 km northeast of Tandy Well. The gabbro is a medium- to coarse-grained, slightly deformed metagabbro, consisting of numerous layers with thin, basal metaperidotite and metapyroxenite. The exposed thickness amounts to 5 to 6 km. Mineral layering has not been observed. Occassionally fine-grained metadolerite (or amphibolite) occurs at the margins of some layers. Metagabbro generally consists of augite (replaced by actinolite and hornblende) and labradorite, which may form a primary foliation. Ultramafic units are commonly altered to massive or schistose actinolite-hornblende-chlorite rocks, but may have relict cumulate olivine and bytownite, with intercumulus augite replaced by hornblende.

ARCHAEAN GRANITOID AND GNEISSIC ROCKS

GRANITOID ROCKS

The granitoid rocks (*Ag*) are subdivided primarily on textural characteristics. There has been no attempt to separate granitoid rocks of different ages, although some age relationship can be assumed, with the foliated rocks (suffix *f*) generally being older than the more massive varieties.

Large batholiths make up most of the sheet area. They consist of irregular-shaped plutons of porphyritic and even-grained adamellite (*Agp, Agv, Age*) which have complex intrusive and transitional relationships. Some plutons have a consistent texture, whereas others consist of intimate mixtures of textural types. Complex mixtures are mapped as a composite unit (*Agm*). Xenoliths of a fine- to medium-grained granodiorite (*Agf*) are common, particularly in the composite granitoid unit. Feldspar megacrysts in porphyritic types commonly have ragged replacement margins indicating a partly metasomatic origin. Xenoliths commonly exhibit irregular development of feldspar porphyroblasts.

Zones of strongly deformed granitoid are generally developed on the margins of the fold belts. This is particularly so on the western margin of the Narndee Belt. However, the strongly foliated types are not restricted to fold-belt margins: a strongly foliated granitoid occurs at some distance from a fold-belt margin in the area 10 to 20 km northeast of Ninghan homestead.

GNEISSIC ROCKS

Most gneissic rocks (*An*) are recrystallized and deformed older granitoid rocks, but there are subordinate areas of paragneiss. There are three main areas of exposure.

(1) South of the Ninghan Fold Belt there is an exposure of orthogneiss, apparently derived by recrystallization of mixed granitoid (*Agm*), and containing amphibolite lenses near its intrusive contact with the belt. A mineral lineation is developed in the gneiss around the margin.

(2) East of the Narndee Belt a well-foliated, homogeneous, medium, even-grained leucocratic gneiss is exposed in a shallow north-plunging antiform. A weak foliation parallel to the axial surface of the fold cuts the gneissosity.

(3) South of Mouroubra and east of Bimbijy, deeply weathered gneissic rocks (with interfoliated quartzite, amphibolite and ultramafic schist) resemble better exposed orthogneiss and paragneiss on adjacent PERENJORI (Baxter and Lipple, 1979).

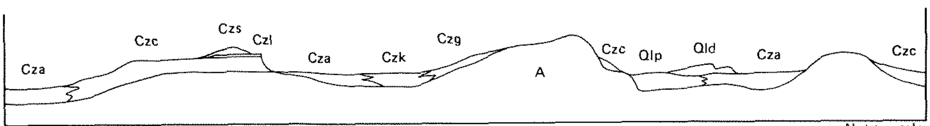
MINOR INTRUSIONS

Mafic rocks intrude all the Archaean rocks exposed on the sheet. The dykes have a predominantly east-northeast trend. Dolerite dykes are most common, but several coarse-grained leucogabbro dykes occur within the Ninghan Fold Belt and the Paynes Find Belt, some containing xenoliths of granite, pegmatite and vein quartz. No fresh pyroxene has been recognized from the dykes, which indicates that the rocks have been metamorphosed.

Pegmatite and aplite veins are common at the contacts of granitoid batholiths. They rarely exceed 2 m in width. However, at Paynes Find the pegmatites are well developed only on the eastern side of the belt (Clarke, 1925). Accessory beryl, amazonite, lepidolite, tantalite-columbite and garnet have been reported in the Goodingnow feldspar quarry.

Quartz veins intrude both the supracrustal sequences and the granitoid plutons. They tend to fall into two sets: one trending north-northeast and one with an easterly trend. Some appear to be filling dilation fissures whereas others occupy shear zones. In general the quartz veins have been recrystallized.

In the supracrustal sequences quartz-feldspar porphyry occurs in thin lenses parallel to the layering in the surrounding rock. Commonly these lenses are moderately to strongly sheared parallel to the layering. At Paynes Find, porphyry veins discordant to the host rock layering are only weakly deformed.



Not to scale

FIGURE 3

DIAGRAMMATIC CROSS-SECTION SHOWING RELATIONSHIPS BETWEEN CAINOZOIC UNITS

NINGHAN SHEET SH 50-7

REFERENCE

Ql	Qld	Qlp

Ql Lacustrine deposits
Qld Dunes
Qlp Playas

Czc	Cza	Czk	Czg	Czf

Czc Alluvial and colluvial deposits
Cza Alluvium
Czk Calcrete
Czg Lateritic gravel
Czf Quartz-feldspar sand

Czr	Czl	Czs

Czr Residual deposits
Czl Laterite
Czs Sandplain

A

A Archaean basement

GSWA 17957

CAINOZOIC DEPOSITS

Deposits assigned to the Cainozoic era are extensive. The origin of these deposits is complex, involving soil formation, eolian and water transport, and mass-wasting processes. Three depositional groups have been established on the basis of geomorphic and lithological characteristics (Fig. 3). The groups are residual deposits (*Czr*), alluvial and colluvial deposits (Czc) and lacustrine deposits (*Ql*). Eolian reworking of all groups is widespread, and, where extensive, is shown as dune traces on the map face. Exposure of the underlying Archaean rocks commonly occurs at the boundary between residual and colluvial units.

The residual deposits include silcrete (*Czi*), sandplain (*Czs*), laterite (*Czl*), and minor lithified grit remnants. They generally occur as a degraded plateau. In many places the sandplain and laterite have been removed or are thin ($\leqslant$ 2 m), and are associated with an arkosic grit. This grit may form a subsidiary scarp up to 1 m high behind the main line of breakaways. In other places silcrete is all that remains of the duricrust. A relationship between laterite development and underlying rock type is not apparent.

Alluvial and colluvial deposits are common in gently sloping valleys of active or infilled drainage channels. The composition of the deposits bears no relationship to the underlying rocks. There are several distinct generations of alluvial deposits which, in many locations, (e.g. 8 km east of Pindabunna homestead, and 7 km west of Goodingnow) indicate erosive relationships. The sediments may have moved by soil creep, sheet flooding or channel flow. Large alluvial fans are common in areas of high relief, particularly in the vicinity of well-developed, rugged supracrustal belts. In some places the deposits have been lithified and detrital laterite has developed. Calcrete (*Czk*) is common in the lower reaches of the drainage basins (particularly in the courses of palaeodrainage channels).

The lacustrine deposits are associated with a saline palaeodrainage system (Beard, 1973; van de Graaff and others, 1977). A notable representative of these deposits is Lake Moore, which is a large playa occupying 5.5 per cent of NINGHAN. The lake sediments are weakly lateritized about 0.5 m below the playa surface. On the eastern side partially stabilized, isolated barchan dunes on the playa contain kopai. The dunes onshore from the lake are generally stabilized and composed of quartz sand. Lake Monger is a discontinuous series of playas connected by narrow drainage channels. Lake Moore formerly drained into Lake Monger, although rejuvenation has now formed a low divide between the two lakes (van de Graaff and others, 1977).

No maximum age has been determined for these deposits. It is likely that some colluvial deposits in infilled drainage channels are older than the Cainozoic, whereas other deposits are modern.

MINERAL DEPOSITS

METALS

Gold has been the main metal produced. Exploration for nickel and base metals has not yielded important mineralization as yet (Table 1). Mineral occurrences of specimen interest are summarized by Simpson (1948, 1951).

Gold

The few references to gold mineralization are by Feldtmann (1921), Clarke (1920, 1925) and Hallberg and others (1976).

The Goodingnow centre has produced the greatest quantity of gold (2 204.13 kg) in the area (Table 3). The ore is mined from quartz veins which intrude hornblende-biotite schist and gneiss (*Afq*) (Clarke, 1925). Gold has also been mined from shear zones and fracture systems in metabasalt (*Abl*) and associated metasedimentary rocks at the Fields Find, Warriedar and Nyounda mining centres. At the Bonnie Venture centre gold was mined from a conglomerate (*Asc*).

TABLE 3. GOLD PRODUCTION

Mining Centre	*Alluvial and Dollied (kg)*	*Ore Treated (tonnes)*	*Gold (kg)*	*Total Gold (kg)*
WARRIEDAR				375.880
Mugs Luck group		10 821.25	110.208	
St Patricks Day group		96.50	1.313	
Sundry leases	0.088	9 010.14	264.271	
FIELDS FIND				1 151.922
Fields Find group	2.371	40 992.6	843.058	
Browns Reward group		6 627.4	135.530	
Mt Guthrie group	0.218	401.2	2.449	
Sunflower group		7.8	0.114	
Golden Eagle group	4.261	1 695.3	26.896	
Rose Marie group	0.244	3 358.2	75.281	
Sundry leases	6.040	5 648.0	55.460	
PINYALLING				62.291
Baron Rothschild group		725.9	10.252	
Sundry claims	13.990	1 567.3	38.049	
GOODINGNOW				2 204.130
Pansy group		493.7	7.593	
Ark-Sweet William group	9.397	39 081.3	861.286	
Carnation-Marraposa group	4.862	50 274.8	1 320.992	
NYOUNDA				21.421
Nyngan		1.0	0.197	
McLoughlins group	6.796	441.9	5.722	
Sundry claims	.960	1 248.7	7.746	
RETALIATION				69.022
Julie group		2 082.3	24.471	
Atlas group		3 117.3	32.438	
Winifred group		154.4	2.113	
Sundry claims		927.9	10.000	
BONNIE VENTURE		339.2	3.878	3.878
PAYNES CRUSOE	1.714	1 576.7	41.089	41.089
LEAKES FIND		79.8	1.245	1.245
TOBIAS FIND		98.5	1.071	1.071

TOTAL GOLD PRODUCTION FOR NINGHAN: 3 931.949 kg

Iron

A deposit of hematitic iron ore in an oxidized magnetite-carbonate banded iron-formation at Mount Gibson (Connolly, 1959; MacLeod, 1963) has been tested. Canavan (1965) reported resources of 55 Mt with a surface grade of 65 per cent iron. Morrison (1978) assessed demonstrated high-grade (> 60% Fe) low-phosphorus reserves to be 12 Mt, and inferred resources of low-grade (37% Fe), potentially beneficiable magnetite-bearing iron-formation to total about 450 Mt.

Copper

Copper mineralization is described by Low (1963) and Marston (1979).

The Warriedar copper mine produced 2 207 t of cuprous ore averaging 9.83 per cent copper from a cupriferous limonite-quartz vein which infills a fracture system in metabasalt (*Abl*) (Marston, 1979). Copper ore was produced as a by-product of gold mining from Fields Find (30.94 t ore assaying 13.39% Cu) and Rose Marie (9.5 t ore assaying 13.48% Cu) (Marston, 1979). The Mount Gibson-Paynes Crusoe area has produced 5.07 t of copper ore assaying 22.1 per cent copper from a deposit of uncertain location.

Copper prospects on the southern limb of the Singleton Syncline occur in metabasalt and metagabbro (Marlow, 1973).

Tungsten

The Yandhanoo King wolframite deposit produced 1 598 kg of concentrates containing 676.78 kg of WO_3. Small parcels have also been won from the Wolfram Queen (57 kg WO_3 in 172 kg concentrates). The ore is in quartz veins intruding metasediments of the Yandhanoo Sequence (Ellis, 1954; Baxter, 1979).

A small parcel (0.3 t containing 20.3 kg WO_3) of scheelite has been produced as a by-product from the Ark gold mine.

Uranium

The Lake Moore and the Warne River drainages have been prospected for sedimentary uranium deposits. No positive results have been reported.

NON-METALS

Pegmatites

One thousand and twenty-three tonnes of feldspar and 5.85 t of beryl with 69.15 units of BeO have been mined from pegmatites at the Goodingnow mining centre. The largest mine is 1.5 km southeast of Paynes Find where a pegmatite intrudes the eastern margin of the Paynes Find Belt. A small quantity (29.5 kg) of tantalo-columbite was obtained from about 30 m^3 of eluvium shed from pegmatite about 800 m northwest of Mullagee Well. This may be the source of material mentioned by Miles and others (1945).

Gypsum

Kopai dunes occur on the eastern shore of Lake Moore. The deposits contain abundant silt and are probably unsuitable for plaster production.

Roadmaking material

Sub-base material has been obtained from most of the *Czc* and *Czr* groups of units. The best material is obtained from *Czg* and *Czk* areas. A talc-carbonate rock (*Aua*) has been quarried near Ninghan woolshed as a base-course material.

Construction stone

Equigranular granite (*Age*) has been obtained from a quarry 4 km north of Oudabunna homestead for use in road surfacing and for local construction purposes.

WATER

In the alluvial and colluvial (*Czc*) group of units groundwater is fairly abundant. However, saline water predominates, particularly in the lower reaches of the drainages. Bores and wells established near hills of rock generally contain useful water. A list of typical wells and bores is given in Table 4.

Exploration for water supplies for the Mulgine tungsten deposit and the Mount Gibson iron-ore deposits has been carried out in the alluvial units, but no results have been published.

TABLE 4. TYPICAL WATER SUPPLIES *(all wells are in Czc units)*

Well or bore name	*Depth (m)*	*Water table (m)*	*Salinity (mg/L)*
Tootawarra		15.6	5050
Jarvee	7.2	4.2	1850
Paynes Tavern			1550
Pindimidgie	10.7	8.9	7000
Paddys	12	11.75	3700
Bullamania	22.7	17.0	7050

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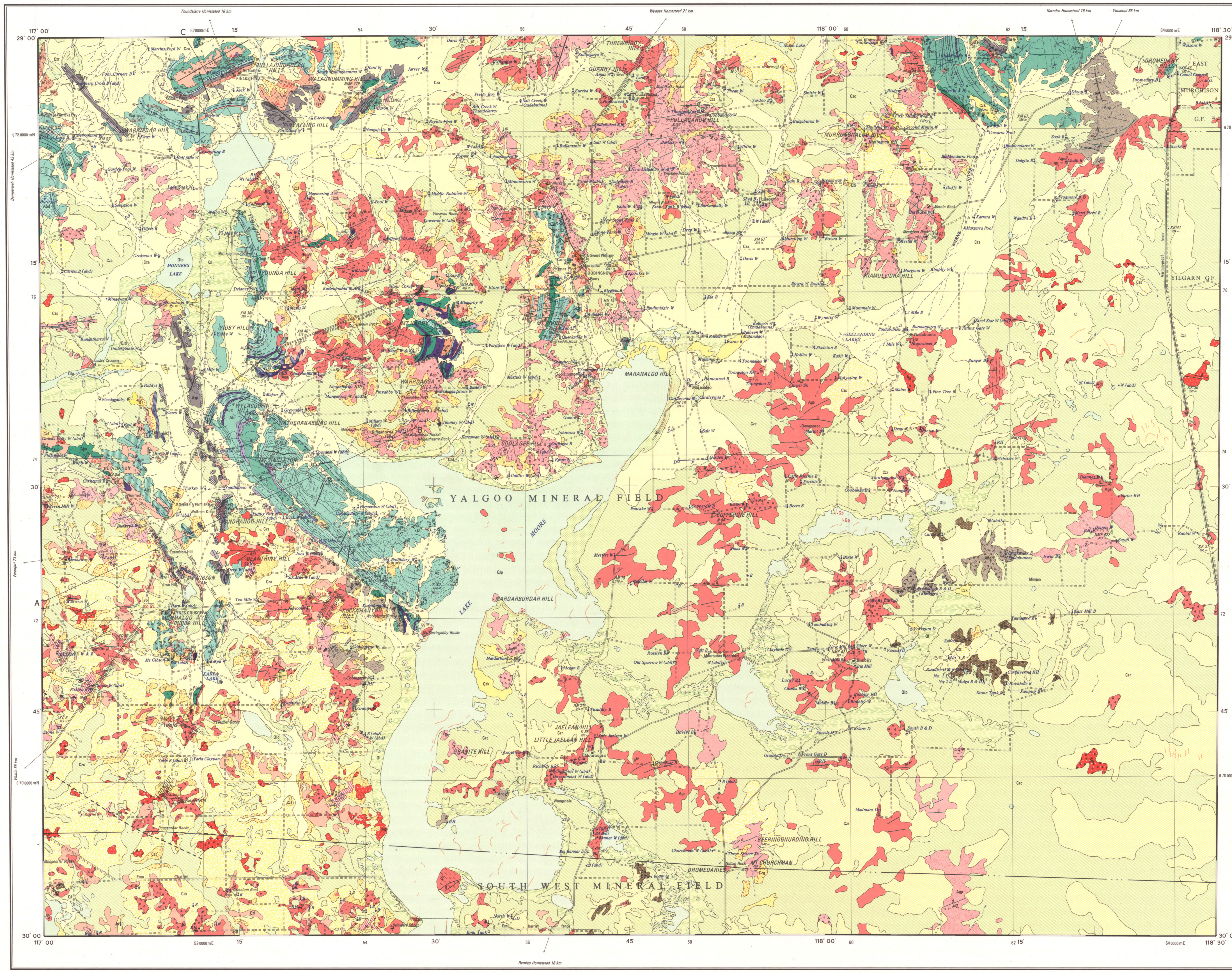
NINGHAN

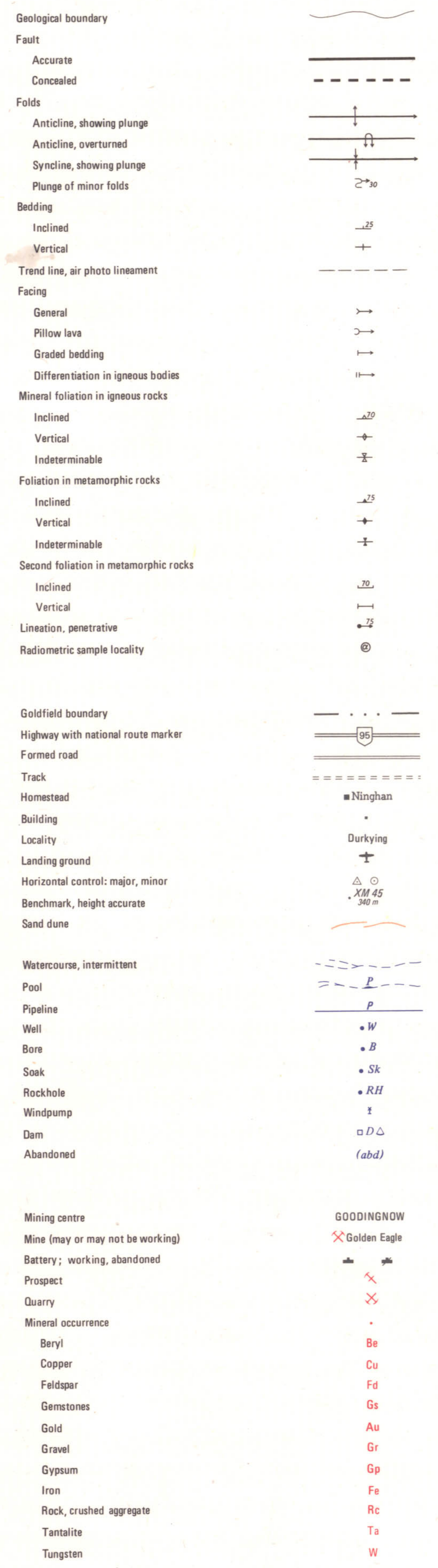
AUSTRALIA 1:250 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SH 50-7



SYMBOLS



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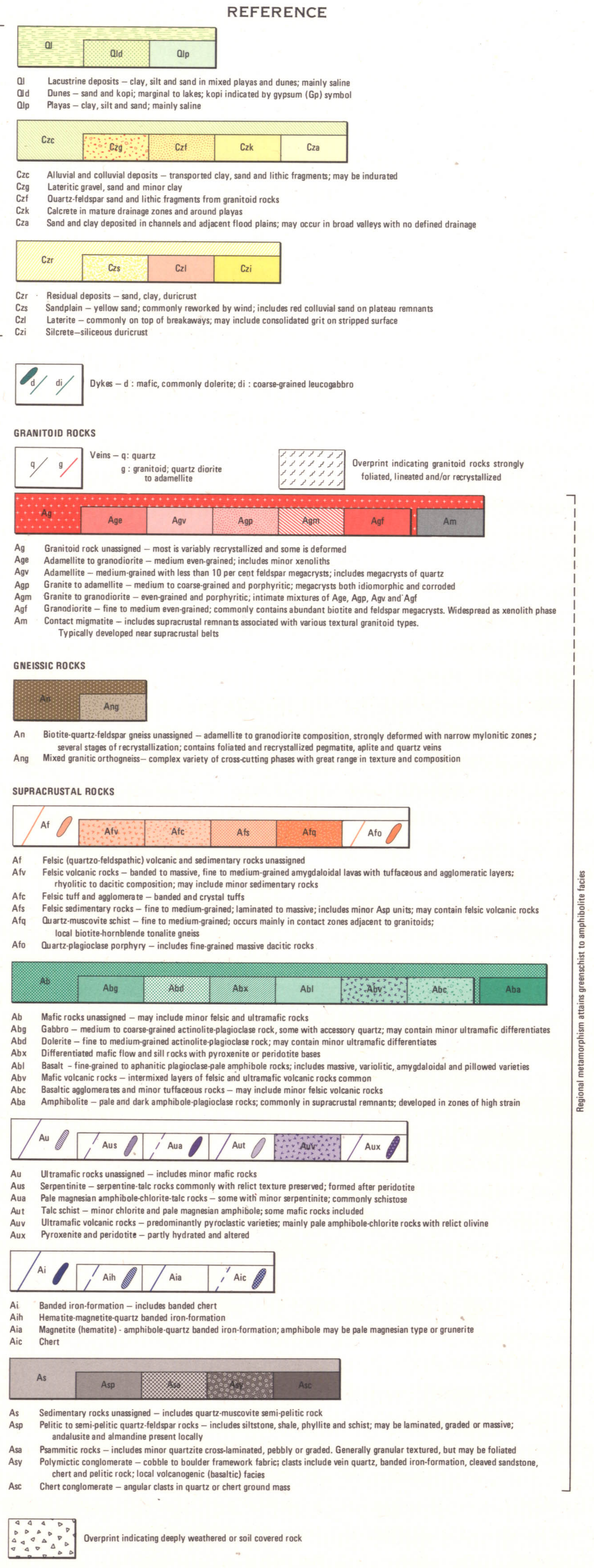
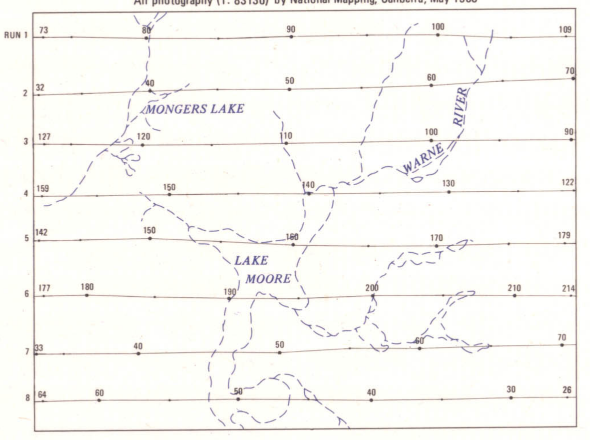


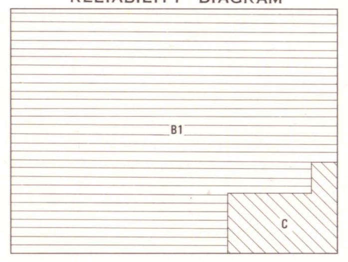
FLIGHT DIAGRAM



Compiled and published by the Geological Survey of Western Australia. Cartography by the Geological Mapping Section, Department of Mines. Topographic base from compilations by the National Mapping, Canberra. A.C.T.

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

C Air photo interpretation

HON. P.V. JONES. M.L.A.

MINISTER FOR MINES

A.F. TRENDALL, DIRECTOR, GEOLOGICAL SURVEY

SCALE 1:250 000

0 5 10 15 20 25 30 Kilometres

TRANSVERSE MERCATOR PROJECTION

ZONE 1 AUSTRALIA SERIES

Grid represents the 10000 metre superimposed Australian Map Grid

INDEX TO ADJOINING SHEETS

YALGOO SH 50 - 2	KIRKALOCKA SH 50 - 3	YOUANMI SH 50 - 4
PERENJORI SH 50 - 6	NINGHAN SH 50 - 7	BARLEE SH 50 - 8
MOORA SH 50 - 10	BENCUBBIN SH 50 - 11	JACKSON SH 50 - 12

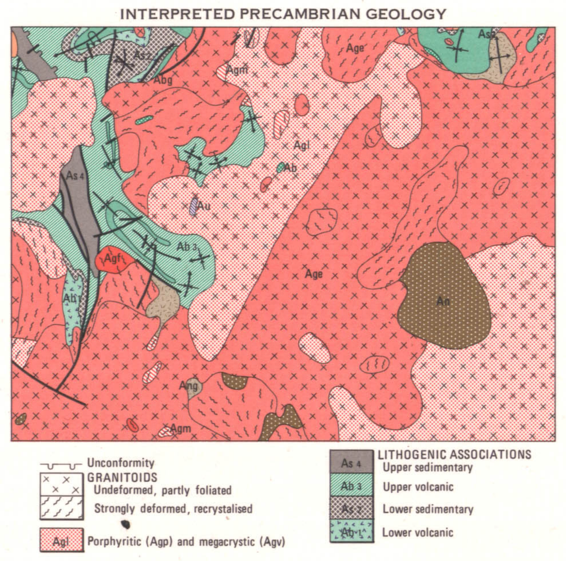
Geology by S.L. Lipple and J.L. Baxter, 1977-8
R. J. Marston, 1978

DECLINATION DIAGRAM

The lines indicate magnetic declination, 1980 + 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

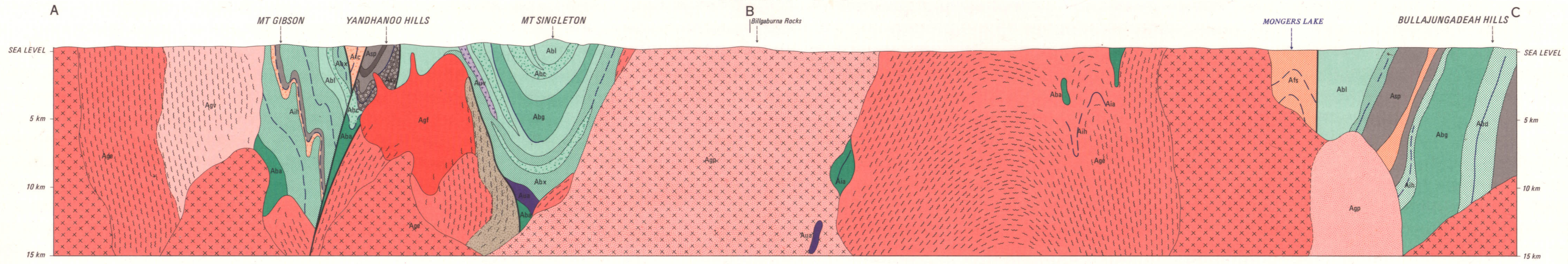
INTERPRETED PRECAMBRIAN GEOLOGY



DIAGRAMMATIC SECTION

NATURAL SCALE

SECTION A - B - C



NINGHAN

SHEET SH 50-7

FIRST EDITION 1982