1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

HYDEN
WESTERN AUSTRALIA

SHEET SI/50-4 INTERNATIONAL INDEX

WESTERN AUSTRALIA
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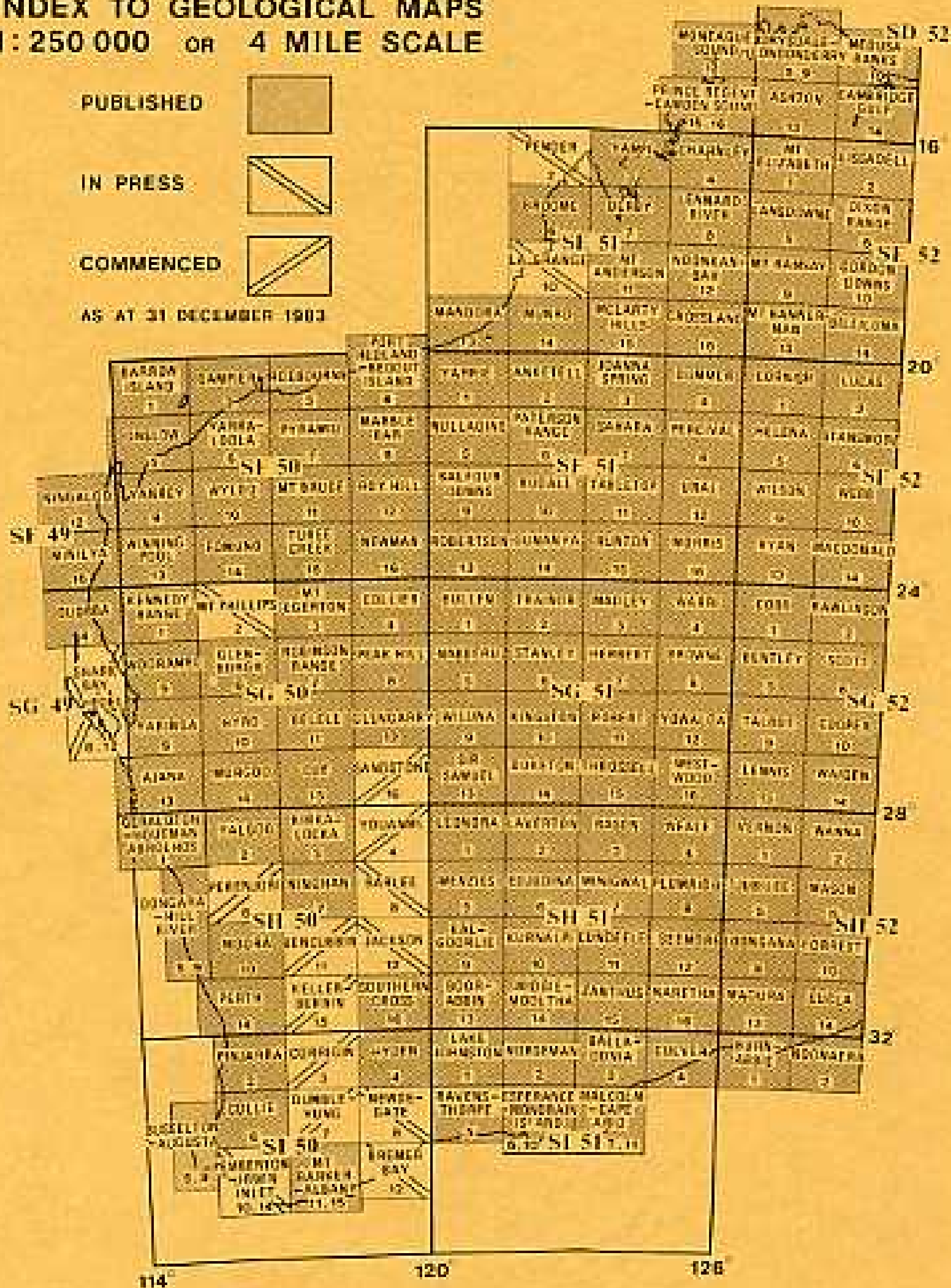

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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HYDEN

WESTERN AUSTRALIA

SHEET SI/50-4 INTERNATIONAL INDEX

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

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Explanatory Notes on the Hyden Geological Sheet

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

INTRODUCTION

The HYDEN* 1:250 000 Sheet, SI 50-4 of the International Series, is centred approximately 320 km east-southeast of Perth and extends from latitude 32°00'S to 33°00'S and from longitude 118°30'E to 120°00'E. It falls principally into the Central Agricultural Land Division, except for the lower southern part, which is part of the Southern Agricultural Land Division.

The No. 1 Vermin-Proof Fence crosses HYDEN and divides the cleared cultivated land of the South West Wheatbelt on the west from the natural bushland to the east. This fence also marks the boundary between the South West Mineral Field (to the west) and the Yilgarn Goldfield (to the east). The Phillips River Goldfield occupies a small area of HYDEN around Hatters Hill.

Agriculture land is used mainly for cereal crop cultivation and sheep grazing. This part of HYDEN is served by a network of well-maintained, graded roads. East of the vermin-proof fence, vehicle access is generally poor and is restricted to a few tracks and overgrown cut-lines. However, throughout the Forrestania Greenstone Belt, numerous tracks and cut-lines have been constructed by mining companies during exploration for base metals (particularly nickel), and these provide reasonable access for four-wheel-drive vehicles.

Hyden, the principal town on the sheet (1976 Census: population less than 200), is linked to Perth and Albany by sealed highway and narrow-gauge railway. It is a service town for the agricultural industry in the area and is a centre for tourists visiting the renowned Wave Rock. Limited town services and facilities are also available at Mount Walker, Pingaring, Holt Rock and Varley.

The climate is semi-arid and characterized by high potential evaporation (1 600 to 1 800 mm per year). Precipitation from light winter rains and occasional summer storms averages about 300 mm in the entire area of the sheet. Average temperatures range from 17° to 34°C in summer and 4° to 16°C in winter.

The vegetation on HYDEN, which largely reflects the topography, is described in detail by Beard (1972). Scrub heath occupies the sandplain ridges; mallee the middle slope, covering the largest portion of the area; and sclerophyll woodland is replaced by Ti-tree scrub while samphire is predominant in hypersaline areas. The heavy soil (*Qe* unit) of the Forrestania Greenstone Belt is mostly covered by sclerophyll woodland.

PREVIOUS INVESTIGATIONS

Previous investigations on HYDEN have been concerned mainly with the Forrestania Greenstone Belt, and particularly with the gold mines of the Forrestania mining centre. Gold was discovered in this area in 1915 and was extracted until 1923.

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

Blatchford and Honman (1917) give detailed descriptions of the individual mines and generalized regional maps (1:253 440 scale) based on fieldwork in 1915. Ellis (1939) investigated the area in 1936 and described the Mount Holland—South Ironcap section of the Forrestania Greenstone Belt in more detail but presented only a generalized geological map (1:253 440 scale).

The discovery, by Amax Pty Ltd in 1969, of anomalous nickel and copper values in a gossan in the Forrestania Greenstone Belt promoted intense exploration which culminated in the discovery of several nickel deposits. These deposits are described by Leggo and McKay (1980) and summarized by Marston (1984).

Chemical analyses from surface samples and drill core from the Forrestania Greenstone Belt have been carried out by Nesbitt and others (1975) and Hallberg (1976).

In 1972, the Bureau of Mineral Resources published a 1:500 000-scale map of Bouguer gravity anomalies based on gravity data collected during a survey in 1969. The Bureau also published 1:250 000-scale maps of total magnetic intensity in 1978, compiled from an airborne survey in 1976.

PHYSIOGRAPHY AND CAINOZOIC GEOLOGY

The physiography of HYDEN is presented in Figure 1. The main feature is a gently undulating topography over a relict duricrust peneplain, partly covered by a sandplain. Broad valleys contain salt-lake systems. Isolated, steep-sided granite monoliths, such as Wave Rock, rise up to 50 m above the peneplain. Hills and ranges of resistant rock types are prominent throughout the Forrestania Greenstone Belt. The highest area (predominantly over 400 m above mean sea level) lies northeast of the No. 1 Vermin-Proof Fence and corresponds to the Forrestania and Holleton Greenstone Belts.

Present-day drainage is internal into salt lakes. During former periods of higher rainfall, nearly all of HYDEN was drained by the Swan-Avon palaeodrainage system with the exception of the extreme eastern area which drained through Lake Cowan into the Eucla Basin. These palaeodrainage systems developed between the Early Cretaceous and the late Miocene (van de Graaff and others, 1977).

The duricrust peneplain is thought to be of Eocene age. It is predominantly a nodular laterite crust (*Czl*) which grades downwards into a leached, kaolinized zone of deeply weathered bedrock, shown on the map by the overprint (*Czo*). Textures of the parent rock are commonly preserved within this kaolinized zone. The transition from this zone into fresh bedrock occurs over a narrow interval.

The laterite cap over amphibolite and banded iron-formation commonly grades directly into the fresh rock. Where the leached kaolinized profile has developed, it is thinner than the corresponding profile over granitic rocks. The laterite profile above ultramafic rocks is a characteristic caprock (*Czj*) which results from the deposition of silica in the form of siliceous cement and as veins and concretions of chalcedonic silica in the laterite cap.

Over granitic rocks, the lower proportion of iron and the abundance of silica leads to the formation of silcrete (*Czb*), a silica-cemented residual sandstone with angular, embayed clasts of quartz. Silcrete is commonly formed at the base of the ferruginous section of the profile, which overlies the leached zone. Erosion of the duricrust exposes the silcrete as a residual boulder deposit.

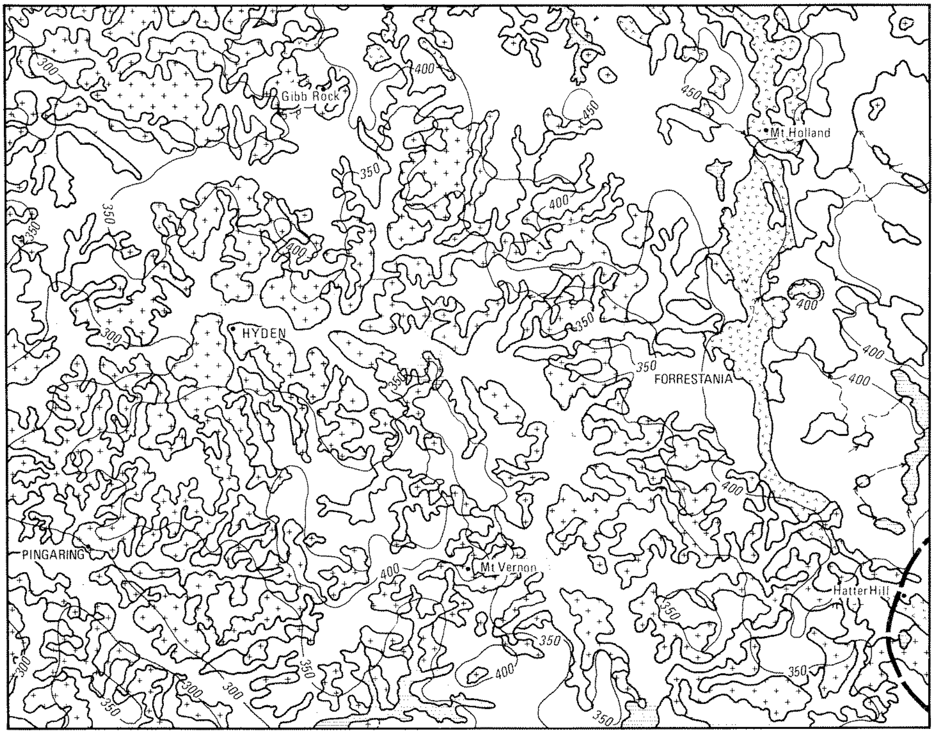


FIGURE 1

PHYSIOGRAPHY

HYDEN SHEET SI 50 – 4

0 5 10 15 20km

REFERENCE

- Salt lakes and ancient drainage flats
- Undulating sandplain overlying Tertiary duricrust
- Granite domes and flat outcrop exposed by erosion of sandplain
- Undulating hills and ranges of greenstone belts
- Main drainage divide between Avon ancient drainage system (west) and the Lake Cowan ancient drainage system (east)
- 300 Generalized topographic contour (metres)
- Ancient drainage channel

Overlying the duricrust there is generally a veneer of white to yellow sand (*Czg*), commonly containing laterite pebbles. Studies by Brewer and Bettenay (1972) indicate that the sand is derived from the degradation of the underlying duricrust and has been transported for only a short distance. That the sand veneer is thickest in valleys is due to downslope creep and wash. On some hillslopes the duricrust has been eroded, and sand from the topographically higher sandplain rests directly on Archaean bedrock.

Where the laterite duricrust overlying the granite-gneiss terrain has been completely removed by erosion, rounded and flat outcrops of fresh granite occur. These border valleys are filled with recent alluvial deposits (*Qa*) consisting of sheetwash and braided-channel deposits. The sediment is predominantly sand derived from the sandplain and the granitic rocks. In the western half of HYDEN, extensive erosion around some resistant granite outcrops has left large monoliths or inselbergs close to the major saline palaeodrainages. Concave overhangs are commonly developed by weathering at the base of monoliths. Wave Rock, a major tourist attraction 3.5 km east-northeast of Hyden, is one example, and is described by Twidale (1968).

The erosion of the laterite duricrust in the greenstone belts has left an irregular topography, with the banded iron-formations standing well above the older surface. The degradation and weathering of the layered sequence of the greenstone belt (particularly the breakdown of amphibolite) has produced a valley-and-slope deposit of red-brown colluvial and eluvial clay (*Qe*).

The broad valleys of the palaeodrainage are largely filled with playa lakes and their related sediments. The lakes are usually flooded after heavy rain and are centres for the deposition of suspended silt and clay (*Ql*). Evaporation during the remainder of the year has led to the concentration of brine within the sediments. Precipitation of gypsum crystals within the mud is common and a hard, residual, salt crust is formed during dry periods. On the southeastern side of playa lakes are stable dunes of quartz and gypsum sands (*Qd*) whose morphology indicates their formation by the prevailing northwesterly winds. Other silt and sand of mixed origin filling the channels of the ancient drainage has also been included in this unit (*Qd*).

Colluvial soils and lakeside units east of the Forrestania Greenstone Belt commonly contain layers and lenses of sandy limestone (*Czk*). Some is calcrete precipitated within the soil profile, but calcrete occurring in valleys is possibly precipitated from groundwater in the porous sands of the palaeodrainage system. It is not as extensive as the calcreted palaeodrainages in the northern and northeastern Yilgarn Block.

POST-TERTIARY FAULTING

Long lineaments prominent on airphotos of the central and eastern parts of HYDEN appear to be fault scarps. On the airphotos each is characterized by a distinct step in topography, by changes in tone and pattern due to variation in soil colour and vegetation, and by its effect on local drainage. On the ground, however, these features are less distinct.

A lineament passing 2 km west of Wheeler Rock extends for 40 km in a north-south direction and corresponds to a well-rounded but distinct rise in ground level (higher side to the west). Laterite and quartz pebbles concentrated on the upper inflection of the slope cause the variation in soil colour, while on the downslope (easterly) side, sand has accumulated, suggesting the breakdown of a former scarp.

The lineament bifurcates 10 km north of Wheeler Rock where it encloses a step segment, a characteristic of many fault scarps. Scarp formation has had a marked effect on the westerly drainage: small streams meeting the scarp 3.5 km northwest and 7 km north-northwest of Wheeler Rock now terminate in small sagponds against the scarp while larger streams (such as the one 16 km north of Wheeler Rock) have been diverted from their former channels by distances of up to 1 km along the scarp. The maximum observed throw is about 4 m but the orientation of the fault plane is not yet known.

The age of the scarp is not accurately known. It displaces the Tertiary laterite duricrust and sandplain and was in its present form when the vermin-proof fence was constructed in 1929.

A scarp 1 km west of Chalk Hill, traceable on airphotos for almost 40 km, has a similar magnitude and sense of displacement. Its position on the easterly side of a drainage divide has given rise to a line of breakaways which streams have eroded back from the scarp.

These fault scarps demonstrate that this area of the South West has been seismically active since deposition of the Tertiary deposits but there is no evidence of present-day seismic activity. The mechanism of formation and its relationship to present-day activity along the Yandanooka - Cape Riche Seismic Zone cannot yet be established. The simple plan and straightness of these scarps contrast with the irregular, curved fault scarps produced by low-angle thrusting at Meckering, Calingiri and Cadoux (Gordon and Lewis, 1980; Lewis and others, 1981) and possibly suggest a different mechanism. The fault scarps interpreted on HYDEN all have downthrow to the east while those identified further east (such as the Ford River Fault (Thom, 1972) on RAVENSTHORPE and faults on LAKE JOHNSTON) have downthrow to the west, possibly outlining a broad graben structure.

ARCHAEAN GEOLOGY

The distribution of the major Archaean rock types on HYDEN is shown in Figure 2. About 90 per cent of the area is underlain by granitoid rocks which are, on the whole, well exposed in widely spaced, clean rock surfaces. Poor outcrops, mostly within areas of colluvium, extend throughout the Forrestania Greenstone Belt.

HYDEN straddles the boundary of two Archaean tectonic provinces of the Yilgarn Block: the Southern Cross Province and the Western Gneiss Terrain, defined by Gee and others (1981). The Southern Cross Province covers the eastern part of HYDEN and includes the north-northwesterly trending Forrestania Greenstone Belt. The gneisses and granitic rocks in the western part of HYDEN are considered to be part of the Western Gneiss Terrain. Enclaves of greenstone remnants are scattered throughout the Western Gneiss Terrain.

LAYERED GREENSTONE SEQUENCE

Forrestania Greenstone Belt

The Forrestania Greenstone Belt is the southern extension of the Southern Cross Greenstone Belt described by Gee (1979). The belt trends northwards through Mount Holland in the eastern part of HYDEN and swings to the southeast near its southern termination at Hatters Hill. It comprises two major sequences: a lower sequence of dominantly basic amphibolite with numerous ultramafic and banded iron-formation units; and an upper sequence of pelitic and psammitic schist. Purvis (1978) describes the sequences in the vicinity of Digger Rocks.

Fine- and medium-grained mafic amphibolite (*Aab*) is the dominant basic rock type in the Forrestania Greenstone Belt. Most of this unit is derived from basaltic lava but a small amount represents metamorphosed dolerite sills and dykes. Pillow structures are preserved 8 km north of Middle Ironcap but most of the amphibolite is massive and variations in flow texture and structure are seen only rarely and with difficulty in the predominantly rubbly outcrop.

The texture of the amphibolite is metamorphic, ranging from granoblastic to lepidoblastic or nematoblastic. Plagioclase is interstitial to hornblende which forms porphyroblasts and clusters often replaced by actinolite in areas of greenschist metamorphism. In many areas, two distinct generations of amphibole are present, the earlier possessing ragged edges where it has been partly replaced by a younger generation. Metamorphic clinopyroxene is found 23 km northwest of Mount Holland, suggesting a higher grade of amphibolite-facies metamorphism there.

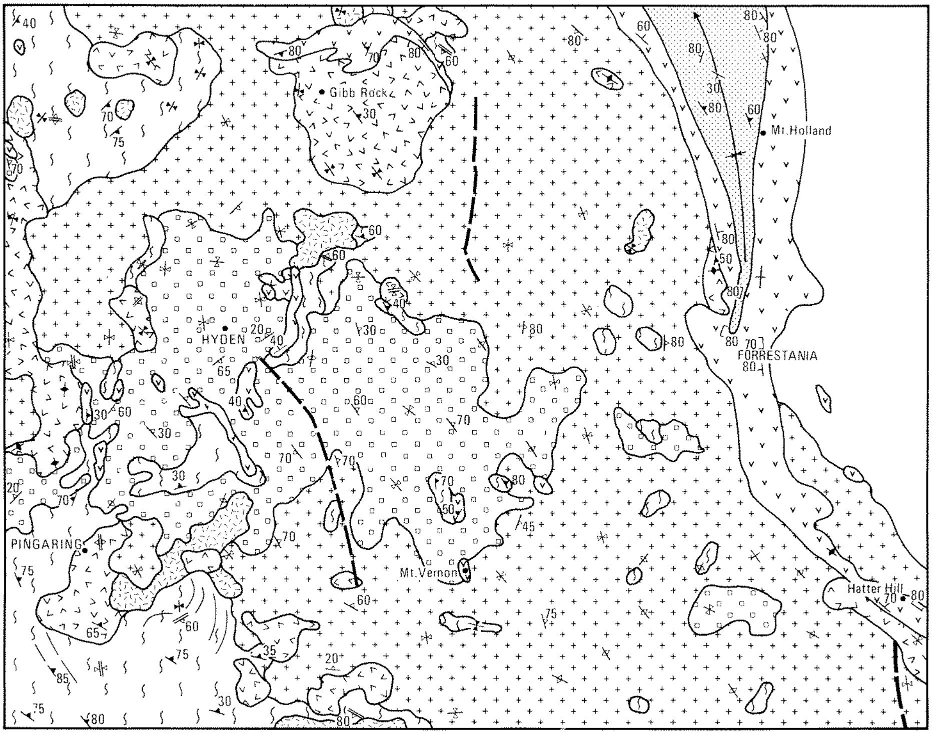


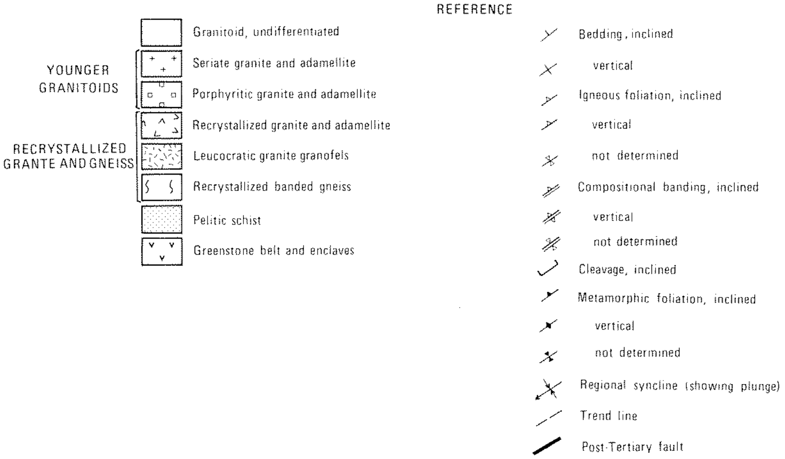
FIGURE 2

STRUCTURAL INTERPRETATION

HYDEN SHEET SI 50 – 4

0 5 10 15 20 Km

REFERENCE



Hallberg (1976) presents analyses of basic and ultrabasic rocks from drill-core samples from the Forrestania Greenstone Belt. Amphibolites plotted on AFM diagrams fall within the field of tholeiitic basalts but show a wide variation in composition. The tholeiitic character of the basaltic rocks was also noted by Nesbitt and others (1975). They observed that while part of the succession is a monotonous pile of amphibolite with tholeiitic chemistry, other parts include "high magnesian basalts (10-25 per cent MgO), normal Archaean tholeiite and tholeiitic andesites". This association is common in the greenstone belt north of Lake Cronin.

Medium- and coarse-grained mafic amphibolite and metagabbro (*Aad*) with some metadolerite are derived from homogeneous dykes and sills within the mafic sequence. Relict primary igneous textures are preserved by metamorphic hornblende which replaces igneous clinopyroxene in areas of amphibolite-facies metamorphism. Metagabbro 5 km southwest of Lake Cronin is in the greenschist facies. Ragged actinolite almost completely replaces clinopyroxene and the plagioclase groundmass is strongly saussuritized.

Ultramafic rocks, generally poorly exposed, form extensive sequences at more than one stratigraphic level throughout the Forrestania Greenstone Belt. It is these units that contain the important nickel prospects (*see* section on economic geology). However, thin units of komatiitic basalt occur interbedded with tholeiitic basalts throughout the major mafic sequence and emphasize the close affinity between these rock types. These rocks are principally tremolite-chlorite schists (*Aur*) with relict spinifex texture, suggesting that they formed as lava flows, thin dykes or sills. They consist chiefly of pale-green, lepidoblastic amphibole; scattered, orientated flakes of chlorite; and subordinate interstitial plagioclase.

The more extensive ultramafic sequences are composed of diverse ultramafic rock types. Most consist of tremolite (-chlorite) schist derived from komatiitic extrusive and intrusive rocks containing various proportions of accessory cummingtonite, clinopyroxene, talc and plagioclase. Fresh and partially serpentinized dunite and peridotite, together with serpentinized peridotite and dunite (*Aup*) containing relict igneous textures, form a large part of the northerly trending, ultramafic sequence 5 km east of Mount Holland. They are the hosts to nickel mineralization in the Forrestania area. Metadunite from drill core from the Cosmic Boy nickel prospect, 1 km southeast of Middle Ironcap, contains partially serpentinized igneous and metamorphic olivine. The igneous olivine forms anhedral grains and aggregates surrounded by masses of fine-grained talc. The metamorphic olivine is porphyroblastic and is surrounded by fine-grained talc and minor chlorite. In most of the ultramafic sequences, however, the rocks are altered to talc schist (*Aue*) containing accessory carbonate, anthophyllite, tremolite and chlorite.

Metapyroxenite (*Aux*), made up of relict crystals of bronzite that have partially retrogressed to a colourless amphibole (probably anthophyllite), was found in a single outcrop 4.5 km west-northwest of South Ironcap.

Banded iron-formation (*Aiw*) forms several units up to 30 m thick in the stratigraphic succession close to and within the ultramafic units. At the surface, the banded iron-formation consists of well-defined bands of iron-poor red, yellow and white quartzite alternating with limonite-rich and hematite-rich bands on the scale of about 1 cm. Fresh samples from drill core 2 km north of Middle Ironcap have bands of quartz alternating with grunerite-magnetite-quartz bands. Grains of carbonate and rosettes of pumpellyite indicate low-grade metamorphism following amphibolite facies metamorphism. This banded iron-formation is different from the jaspilite further north on SOUTHERN CROSS, described by Gee (1979), which consists mostly of quartzite with iron-silicate minerals predominant over magnetite.

The banded iron-formation is the main ridge-forming rock in the Forrestania Greenstone Belt. The hills of Mount Holland, North Ironcap and South Ironcap consist of units of banded iron-formation thickened by folding.

Banded chert (*Aic*) is common throughout both the sedimentary and mafic sequences of the Forrestania Greenstone Belt. It generally forms thinner and less continuous units than those of banded iron-formation. Within the sedimentary sequence, thin chert bands (from as thin as 1 cm up to 3 cm) are interlayered with schist derived from siltstone and shale and are not mapped separately.

The banded chert unit is composed of fine-grained, banded quartzite with strongly marked granoblastic texture. The quartzite is relatively iron-poor within the sedimentary sequence, but ferruginous varieties are commonly seen in other rock types.

Within the mafic sequence, the unit comprising graphitic schist and phyllite (*Alg*) forms rare, thin, interlayered units derived from black shale. These units are more prominent in the greenstone enclaves and are more fully described in the relevant section.

The highest sequence in the Forrestania Greenstone Belt is a metasedimentary sequence consisting predominantly of quartz-mica schist (*Alp*) with a small amount of quartzite. In the northern part of HYDEN, west of Mount Holland, the schist alternates with 1 cm bands of quartz-rich metasediments. Weathered voids, inferred to represent porphyroblastic cordierite, have been recorded from an area 15 km north of Mount Holland. Large knots of muscovite are commonly retrogressive products after andalusite. Sillimanite is seen in drill core from the New Morning nickel prospect, 11 km south of North Ironcap. Sericite and chlorite are abundant prograde minerals in areas of lower grade metamorphism but elsewhere are retrogressive products after high-grade minerals.

The unit comprising quartz-rich schist and micaceous quartzite (*Alm*) is similar to quartz-mica schist (*Alp*) but contains a greater amount of quartzite. The principal outcrop area, 15 to 20 km north of Mount Holland, is strongly lateritized but the well-bedded nature of the outcrop is preserved.

Greenstone enclaves

The term "enclave" has been used by Thom and others (1981) to describe the outlying greenstone remnants within the granite-gneiss terrain. Most of these outliers are remnants of former layered greenstone sequences which have been dissociated by the intrusion and doming of granitic bodies. Others are possibly eroded outliers of formerly continuous greenstone sequences and some of the enclaves, particularly medium-grained amphibolites, possibly have been derived from intrusions emplaced into the granite or gneiss. However, the relationship of the enclaves to the greenstone belts in adjoining areas to the east has not been established.

On HYDEN, numerous greenstone enclaves are scattered throughout the granite-gneiss terrain east of the Forrestania Greenstone Belt. Those in the southwestern half have undergone granulite-facies metamorphism. However, the large S-shaped enclave north of Gibb Rock, in the northwestern part of the map, shows evidence of amphibolite-facies metamorphism. It is dominantly composed of mafic amphibolite and is possibly an outlying extension of the enclave at Holleton on SOUTHERN CROSS.

Strongly foliated, fine- and medium-grained amphibolite (*Aab*) composed dominantly of hornblende and plagioclase with minor quartz and opaques is similar to the fine-grained amphibolite of the Forrestania Greenstone Belt. Primary textures and structures are not preserved to help identify the primary rock type but the interlayering of metamorphosed banded iron-formation and graphitic schist, described below, suggests that most of the amphibolite is derived from basalt.

Medium- and coarse-grained amphibolite (*Aad*), 7 km north-northwest of Gibb Rock, contains coarse-grained hornblende crystals and aggregates in a medium-grained matrix of plagioclase and hornblende. This texture suggests a relict porphyritic texture, possibly derived from dolerite or gabbro.

Banded iron-formation (*Aiw*), graphitic schist (*Alg*) and tremolite-chlorite schist (*Aur*) are minor but important rock types in this enclave. They resemble rock types in the Forrestania Greenstone Belt. The banded iron-formation is characterized by alternating quartz-rich and magnetite-rich bands, each about 1 cm thick. The graphitic schist contains principally quartz, graphite, muscovite and chlorite with abundant thin bands of quartzite (derived from chert) throughout the unit. Thin tremolite-chlorite schist bands are interlayered with fine-grained amphibolite 8 km northeast of Gibb Rock.

The enclosing granitoids are not well exposed and the contact relationships with the greenstone enclave are obscured. On the eastern and northern margins, strongly recrystallized banded gneiss and garnetiferous adamellite granofels are predominant and on the southwest margin, foliated medium-grained adamellite bounds the enclave.

Medium-grained mafic granulite (*Ahf*) is the most common rock type within the enclaves in the southwestern portion of HYDEN. The texture is invariably granoblastic and the rock comprises plagioclase, hornblende, hypersthene and clinopyroxene. Reddish biotite is abundant and olivine was recorded in one sample 5.5 km southeast of Karlgarin. Relict foliation, defined by elongated composite mineral lenses, and compositional banding are commonly seen.

Most minerals are affected by patchy retrogression. Fine-grained intergrowths of epidote and carbonate partially replace plagioclase, whereas chlorite and tremolite partially replace hornblende and pyroxenes.

Granulite derived from banded iron-formation, (quartz-hypersthene-garnet-magnetite granulite (*Ahi*), forms units flanked by mafic granulite and outlines structures within the enclaves. Quartz-rich bands have recrystallized to a granoblastic interlobate texture, while the iron-rich bands have recrystallized to a granoblastic mosaic of quartz, magnetite, grunerite, garnet and hypersthene. A nearly continuous unit of banded iron-formation 11 km east of Hyden trends north-south over a strike length of 12 km. It corresponds to a strong aeromagnetic anomaly.

At Mount Vernon, a thinly banded, recrystallized acid gneiss (*Ahs*) is interbanded with banded mafic granulite gneiss. The acid gneiss consists of a polygonal mosaic of quartz and plagioclase with sparse crystals of hypersthene, clinopyroxene, biotite, hornblende and opaques. Its origin is unknown.

The granulite gneiss at Mount Vernon is extensively intruded by medium- and coarse-grained leucocratic adamellite dykes. These dykes are part of the younger mobile phase of the migmatite which is well developed on the western side of the enclave. The migmatite (*Amx*) is best exposed at the summit of Mount Vernon. It results from the partial assimilation of the banded acid gneiss (*Ahs*) by the leucocratic adamellite and forms an anastomosing network of banded adamellite with biotite schlieren. The rocks show later static recrystallization with the growth of porphyroblastic garnet up to 20 mm in diameter.

The large enclave of mafic granulite (*Ahf*) in the vicinity of Powder Puff Hill contains bands of gneiss of unusual composition. These include gneisses composed of quartz, plagioclase, microcline and hornblende with minor secondary chlorite, actinolite, muscovite, epidote and biotite. Scapolite and diopside occur in rocks which contain calcite. This gneiss may be derived from either felsic volcanics (possibly dacites) or volcanogenic sediments interlayered with basaltic volcanics.

The greenstone enclave 16 km south of Hyden comprises poorly exposed graphitic schist (*Alg*) made up of quartz, muscovite and 10 per cent graphite forming disseminated flakes. Spots of fine-grained secondary sericite and chlorite pseudomorph porphyroblastic andalusite and cordierite.

Ultramafic rocks including serpentinized peridotite (*Aup*) have been intersected by drill holes 2 km south-southeast of the graphitic schist outcrop.

STRUCTURE AND METAMORPHISM

General

The generalized structure and distribution of the major rock types on HYDEN are shown in Figure 2. The major tectonic features are delineated by Bouguer gravity anomalies, and aeromagnetic intensity maps outline some of the major structural features on HYDEN.

High Bouguer gravity anomalies occur across the northerly trending Forrestania Greenstone Belt and the area of the greenstone enclave south of Holleton. Elsewhere the granite-gneiss terrain corresponds to lower Bouguer anomalies. Aeromagnetic anomalies are more complex. High anomalies of up to 11 116 nT outline the Forrestania Greenstone Belt. In particular the banded iron-formation has a high magnetic susceptibility and its distribution helps delineate the structure of the greenstone belt. Many anomalies with restricted areal distribution throughout the granite-gneiss terrain correspond to known greenstone enclaves. Other anomalies are over areas covered by laterite or superficial deposits.

Outstanding features are the well-defined linear east-west and east-northeasterly trending anomalies which correspond to large dykes and dyke suites. A major lineament through Karlgarin Hill can be traced for approximately 600 km from the northwest corner of DUMBLEYUNG to the eastern margin of WIDGIEMOOLTHA where it corresponds to the Binneringie Dyke.

Forrestania Greenstone Belt

The essential structure of the Forrestania Greenstone Belt has been deduced from the regional distribution of lithologies and structural data from the Forrestania and Southern Cross areas.

Figure 2 shows that the northern part of the belt consists of a central outcrop of metasediments flanked by ultramafic and mafic rocks. The outcrop of metasediments becomes progressively narrower southwards until it terminates against the ultramafic and mafic sequence. This lithological pattern suggests that the greenstone belt corresponds to a single major fold.

That this fold is a syncline is suggested by the fact that strata on the eastern limb are either vertical or dip steeply westwards, whereas strata on its western limb are generally inclined steeply eastwards. Most examples of lithological layering on the eastern limb are consistent with stratigraphic younging toward the west. Although ultramafic intrusions produce local variations, individual lithological cycles typically consist of an eastern ultramafic unit passing west into tremolite-chlorite rock, amphibolite and finally chert or banded iron-formation.

Stratigraphic and structural information on the adjacent SOUTHERN CROSS sheet (Gee, 1979) indicates that a 3 to 5 km succession of ultramafic and mafic volcanic rocks underlies a 3 to 5 km sequence of metasediments. These units appear to extend southwards on to HYDEN where they correspond to the same two lithological subdivisions outlined above. Moreover, the southern closure of the sedimentary core testifies to a general northerly plunge.

The syncline is complicated and disrupted by subordinate folding, and probably also by strike-slip faults. The distribution of many of the important units lacks symmetry across the axis of the belt. This is partly explained by the fact that many of the ultramafic units on the eastern limb contain intrusive ultramafic bodies, and that part of the western limb has been removed by granitoid intrusions. The banded iron-formation at North Ironcap cannot be traced northwards either on the ground or by its magnetic anomaly.

Two main periods of deformation are recognized. The first accompanied amphibolite-facies metamorphism, produced the main synclinal structure of the belt and an axial-planar foliation defined by the planar alignment of constituent minerals. Later deformation formed crenulation cleavage throughout the belt but the crenulation is most pronounced in pelitic schists.

Metamorphism during the first period of deformation was predominantly amphibolite facies but ranges from greenschist facies (actinolite-epidote assemblages in basaltic rocks) to upper amphibolite facies (metamorphic clinopyroxene-hornblende assemblages in basaltic rocks). In pelitic rocks, cordierite, andalusite and sillimanite indicate amphibolite-facies metamorphism.

Retrograde tremolite-actinolite, sericite and chlorite in mafic rocks and pelitic schists result mainly from metamorphism that accompanied the second period of deformation.

Greenstone enclaves

The structure of the greenstone enclave north and northeast of Gibb Rock is unusual. It shows an essentially east-west elongation, large-scale open folding of a strong metamorphic foliation and parallel primary layering which is S-shaped in plan. The foliation is defined by a planar mineral orientation and, in many amphibolites, a lineation formed by the preferred orientation of amphibole needles (nematoblastic texture). Whether the lineation is a first- or second-generation fabric has not been determined.

The second deformation formed open to tight northwesterly trending folds of the foliation and layering. These folds and associated crenulation cleavage are most prominent in graphitic schist 8 km northeast of Gibb Rock. This deformation is possibly the cause of the S-shaped folding of the enclave.

Metamorphism accompanying the first deformation period is dominantly low amphibolite facies. Ragged, slightly recrystallized hornblende in rocks in the eastern side of the enclave is possibly contemporaneous with the second deformation period.

The granulite-facies metamorphism which overprints the greenstone enclaves and the granitic gneiss in the southwestern half of HYDEN resulted in the static recrystallization of all rock types into an equigranular mosaic. Relict foliation defined by recrystallized mineral lenses and streaking are commonly preserved, indicating earlier deformation of the layered rocks within the enclave, but it is difficult to determine the style of deformation or whether there were several periods of deformation.

The genesis of metamorphic orthopyroxene (dominantly hypersthene) and clinopyroxene in the mafic rocks is indicative of granulite-facies metamorphism. Accessory biotite, when present, is fox-red in colour. Scapolite occurring in calcsilicate gneiss at Powder Puff Hill has remained stable in the granulite facies because of the presence of abundant carbonate in the form of calcite. In banded iron-formation, hypersthene and grunerite form an equilibrium assemblage with quartz and magnetite.

GRANITOIDS

The granite-gneiss terrain on HYDEN is arbitrarily divided into two main parts. The first contains the gneisses and granites which are largely deformed and recrystallized by static metamorphism and the second contains younger granites which intruded as large, irregular plutons after the major structural and metamorphic events and thus have escaped significant deformation or metamorphism. The distribution of granitoids is shown in Figure 2. The recrystallized granitoids form large areas in the southwestern and northwestern corners of HYDEN, and also occur as numerous outliers enclosed by the younger granitoids which comprise the large area in the central part of HYDEN west of the Forrestania Greenstone Belt.

East of the Forrestania Greenstone Belt, Cainozoic sediments mask most of the exposure except for sparse, inaccessible outcrops. These are mapped as undifferentiated granitoids, interpreted from airphotos (*Ag*). In the adjoining areas of LAKE JOHNSTON (Gower and Bunting, 1976) and SOUTHERN CROSS (Gee, 1979) most of the granitoid rock is mapped as homogeneous gneiss, banded gneiss with flow folds and amphibolitic banding, and migmatite. These rocks probably underlie the northeastern part of HYDEN and are compositionally similar to the recrystallized gneiss in the western part of HYDEN but lack the overprint of the strong static metamorphism.

Recrystallized granite and gneiss

The distribution of recrystallized granite and gneiss is irregular owing to the intrusion of the younger granite plutons. The banding and foliation trend north to northwesterly but are locally bowed into broad arcs around the younger plutons.

The oldest and most commonly seen gneiss is banded and is of granitic and adamellitic composition (*Ang*) with a small amount of granodiorite gneiss. The gneiss is predominantly heterogeneous and leucocratic with weakly defined banding outlined by variations in the concentration of biotite and variations in grain size and texture. A small proportion of the gneiss is weakly banded biotite adamellite gneiss with up to 10 per cent biotite.

The gneiss has a strong relict foliation defined by strongly flattened lenses 10 to 20 mm in length and 1 mm wide of either biotite, quartz or feldspar. The banding is older than the foliation and results from diverse processes. Some is primary flow-banding with flow folds and biotite schlieren, but much consists of intrusive veins and "sweat out" veins parallel to the gneissic foliation, while other types of banding are due to different metamorphic and deformational processes.

A characteristic banded gneiss (an example is located 12 km east of Hyden) is composed of layers of leucocratic granite and adamellite from 5 mm to 1 m in width. The layers are continuous over tens of metres and vary little in width. Thin biotite partings (1 mm thick) separate many of the leucocratic layers but textural criteria account for most of the differences. The rock is generally fine- to medium-grained but coarse-grained varieties occur locally. Seriate and porphyritic textures predominate over even-grained phases.

In all outcrops the gneiss contains a stockwork of thin (up to 50 mm) leucocratic granite veins with sharp margins. Occasionally the gneiss has sparse biotite clots and biotite schlieren. It has a similar composition and time relationship to the leucocratic granofels (*Anf*) described below, and the inference is that they are equivalent. The ubiquity of the veining suggests that this phase may be a mobile neosome derived by local anatexis.

The texture of all phases within the banded gneiss (*Ang*), including the cross-cutting leucocratic veining, is granoblastic, mainly within the seriate and interlobate textural subdivisions. Many larger mineral grains have recrystallized into a number of smaller grains. The dominant mineralogy is quartz and feldspar with biotite as the main mafic mineral. Hypersthene and clinopyroxene are minor constituents, and are important indicators of granulite-facies metamorphism. Porphyroblasts of garnet (up to 5 mm in diameter) are common. Leucocratic veins possess a similar texture to the gneiss, suggesting that they have also undergone granulite-facies metamorphism despite the fact that hypersthene and clinopyroxene have not been recognized in this phase. Absence of these indicator minerals is probably a consequence of the rock's leucocratic composition.

Fine- and medium-grained leucocratic granofels of dominantly granitic composition (*Anf*) forms discrete plutons within the gneissic terrain. Biotite is restricted to a few sparse flakes except in some areas where clots of biotite plates and wispy biotite schlieren are present. Overall the granofels is homogeneous and xenoliths of gneiss are rare. Scattered phenocrysts of potassic feldspar, recrystallized at the margins, are also present in some areas. Thin sections reveal that little of the original igneous texture remains. The texture is now granoblastic interlobate owing to high-grade static metamorphism. This texture is identical to the texture in the adjoining gneiss which has mineralogical associations indicative of granulite-facies metamorphism. Incipient melting indicated by quartz-feldspar graphic intergrowth and corroded and embayed margins to quartz and feldspar grains was observed in samples from 22 km east-northeast of Pingaring.

There is little evidence of strain in this rock type. The biotite clots are commonly elongate owing either to primary alignment or to overprinting deformation. Textural evidence for deformation is not present but has possibly been destroyed by recrystallization which has annealed most of the early fabric. There are no relict trails or platy clusters of quartz or feldspar similar to those retained in the host banded gneiss and indicative of deformation prior to the recrystallization. The appearance, in some areas, of slightly lensoid feldspar and quartz grains possibly reflects localized strain during granulite-facies metamorphism.

The mixed unit (*Amx*) is restricted to the area of Mount Vernon. It is chiefly derived from leucocratic granite dykes and veinlets which invaded and partially assimilated the margins of the greenstone enclave to form a migmatite. The leucocratic phase closely resembles the leucocratic stockwork which intrudes the recrystallized granite and gneiss. Near the summit of Mount Vernon, fine-grained, quartzose metasedimentary or metavolcanic gneiss is cut by an intimately anastomosing network of leucocratic granite containing abundant mafic schlieren and euhedral garnets up to 3 mm in diameter. Some of the older intruded phase is mafic (dominantly biotite) schist studded with euhedral garnet up to 20 mm in diameter. All the phases which comprise this unit are strongly recrystallized by late static metamorphism.

Recrystallized, foliated, even-grained and seriate granite and adamellite (*Anv*) is confined to the gneissic terrain in the southwest part of HYDEN. Its boundary relationships with the surrounding gneiss are obscure and no investigation has been made to ascertain whether the recrystallization that is prominent in hand specimen attained the granulite-facies grade of metamorphism that is found in the adjoining gneiss.

The unit (*Anv*) is predominantly medium-grained granite and adamellite with a strong, relict foliation and tends to be leucocratic (about 3 per cent biotite) with primary banding defined by nebulous biotite concentrations. Phenocrysts of potassic feldspar, enclosed by ragged, recrystallized margins as a consequence of deformation, are abundant in some phases. The position of this granitoid in the tectonic sequence on HYDEN is unclear. On one hand, the lack of veining by leucocratic granite and adamellite granofels suggests that it may be younger than that phase, while on the other hand, its characteristic foliation is not observed in the leucocratic granofels.

The unit comprising recrystallized, coarse, even-grained and seriate granite and adamellite (*Agn*) is widely distributed throughout the western half of HYDEN. The largest body extends for 25 km along the central part of the western margin of the sheet. The rock is homogeneous, consisting of quartz, plagioclase, microcline and biotite forming a granoblastic interlobate to amoeboid texture. Scattered phenocrysts of microcline up to 15 mm in length are recrystallized along their margins. Retrograde minerals, chlorite, muscovite and amphibole, have replaced previous high-grade static metamorphic minerals but no conclusive evidence of granulite-facies metamorphism has been found. Prior to static metamorphism, this granitoid rock was a coarse, even-grained to seriate adamellite pluton that intruded the gneiss.

Part of the granitoid (*Agn*) may be equivalent to part of the recrystallized foliated adamellite (*Anv*): neither is intruded by the leucocratic granite-granofels stockwork. Nebulous biotite banding and schlieren (rarely found with mafic xenoliths) outline primary foliation.

Relict igneous texture is well preserved at Pingaring Rock. Textural variation from even-grained to seriate is preserved across the nebulous banding. Intrusive phases of adamellite, similar in composition and texture to the host, lie parallel to the nebulous banding.

Outcrop of foliated, medium- and coarse-grained biotite granite and adamellite (*Agg*) is not extensive. It is restricted mainly to the margins of greenstone belts and enclaves outside the area of high-grade static metamorphism. Exposure in these regions is poor and this rock type may be more extensive than indicated by its surface outcrop.

Near North Ironcap, leucocratic even-grained and seriate varieties are predominant. A strongly overprinted deformational fabric is defined by granulation and recrystallization of quartz and feldspar into lensoid grains and by the planar orientation of biotite. This foliation parallels the foliation in the adjoining Forrestania Greenstone Belt and is folded by the same second-generation folding.

The contact with the greenstone belt is sharp and provides no indication of the relative ages of the granitoid and the greenstone belt. Other evidence, such as primary fabric, schlieren and xenoliths, is also lacking. Because of the abundance of younger seriate and porphyritic adamellite, it is not possible to trace the deformation in this granitoid and relate it to the timing of the static metamorphism further to the west.

Fine- and medium-grained, muscovite-bearing adamellite (*Agm*) forms two small bodies that intrude the Forrestania Greenstone Belt 7 km northwest and 12 km south of Mount Holland. Approximately equal proportions of biotite and muscovite are distributed in a predominantly even-grained quartz-feldspar matrix. Texture is variable across the outcrop owing to grain-size variations and pegmatitic phases. The body 12 km south of Mount Holland is deeply weathered but quartz phenocrysts up to 4 mm in diameter are well preserved. The distinct foliation which overprints this body is not obvious in the granitoid 7 km northwest of Mount Holland.

Younger granitoids

The youngest granitoids within the southwestern Yilgarn Block are variably textured, medium- and coarse-grained seriate granite and adamellite (*Agv*) and the porphyritic equivalent (*Agl*). There is continuous gradation between the types and together they form the irregularly shaped batholith that extends north-northwesterly for almost 500 km across the southwest Yilgarn Block. They postdate the deformation and metamorphism of the recrystallized granite and gneiss and are only locally deformed in rarely seen shear zones. These younger granitoids amount to almost 70 per cent of the total area of granitoids on HYDEN (Fig. 2).

The seriate granite and adamellite (*Agv*) are characterized by euhedral phenocrysts of perthitic microcline which, even across single outcrops, vary in abundance and range in size up to 5 cm. The texture of the matrix ranges from allotriomorphic to hypidiomorphic and in a few places is partly recrystallized. The matrix is composed principally of anhedral and subhedral microcline, subhedral oligoclase and anhedral quartz. Biotite is an accessory. Minor sericitization of microcline, chloritization of biotite and saussuritization of plagioclase are commonly observed.

The unit comprising porphyritic granite and adamellite (*Agl*) is dominant in the area around the town of Hyden. It is similar to the seriate types but larger phenocrysts are more abundant, forming up to 60 per cent of the rock.

Both of the younger granitoids have a magmatic foliation strongly defined by the orientation of the large, platy microcline phenocrysts and a few plate-like schlieren composed of biotite. It strikes northwesterly to north-northwesterly except near enclaves or adjacent to pluton boundaries which cut across the general trend. In these areas the foliation becomes parallel to the pluton margins. Internal variations in the attitude of the foliation were observed in similar rocks on BENCUBBIN (Blight and others, 1981) and JACKSON (Chin and Smith, 1981) and inferred to outline flow cells or discrete plutons. These variations were not observed on HYDEN.

Parts of the seriate adamellite (*Agv*) are strongly layered parallel to the phenocryst alignment. Medium- to coarse-grained leucocratic granite and adamellite layers alternate with seriate varieties. Boundaries between these phases are diffuse, suggesting that the textural difference is either a primary igneous feature or is formed by the partial assimilation of the even-grained phase by the seriate phase. This textural feature is commonly seen at The Humps and extends for about 10 km to the northwest. With this heterogeneous phase there are abundant patches of pegmatite which carry graphic intergrowths of quartz and potassic feldspar.

The margins of the younger granitoids are predominantly sharp. Large xenoliths of older gneiss and greenstones over 1 km in diameter are abundant within the granitoid but small xenoliths are rarely seen. However, some margins are complex zones in which veins and tongues of seriate and porphyritic granitoids intruded the older recrystallized granitoid phases (*Agn*, *Ang*, and *Anv*). The boundaries between these phases are sharp intrusive contacts. Where these areas cannot be subdivided on a regional scale, the mapping unit (*Amv*) has been employed. This unit is most common in the central part of HYDEN and near the eastern side of the seriate and porphyritic granitoids.

ECONOMIC GEOLOGY

MINERAL DEPOSITS

Gold and silver

Gold has been produced with silver as a by-product (Table 1) from the Forrestania and Hatters Hill mining centres, both situated in the Forrestania Greenstone Belt. (Note that the figures in Table 1 for Hatters Hill also include mines on the adjoining part of LAKE JOHNSTON.)

The mines of the Forrestania mining centre (Yilgarn Goldfield) situated northeast and east-northeast of Middle Ironcap were in operation between 1917 and 1923. Their geology is described by Blatchford and Honman (1917). The gold mainly occurs in east-northeasterly striking quartz veins (up to 0.5 m thick). The country rock is deeply weathered, foliated, biotite granite containing mafic amphibolite lenses concordant with the foliation.

Prospects 2 km north-northwest of Lake Cronin were being worked between 1961 and 1963. Sofoulis (1962) reports on the geology and the development of the prospects. The gold occurs in quartz veins (locally up to 0.3 m thick) within a northerly trending zone 2 to 3 m wide, over a length of approximately 40 m. The host rock is mafic schist. Owing to the presence of prominent banding parallel to the foliation, Sofoulis considers that the schist was sedimentary. It is equally possible that the banding is metamorphic in origin and that the schists are derived from a basaltic parent.

Some of the mines of the Hatters Hill mining centre (Phillips River Goldfield) are located on HYDEN and some on LAKE JOHNSTON. Gower and Bunting (1976). record that the gold is located in sheared quartz veins at the margins of felsic intrusions within the greenstone sequence. Of the total production, sundry claims have yielded 99.374 kg of gold from 6 003.99 t of ore. This amount is abnormally large in comparison with the individually listed mines but its source is not recorded.

Nickel

Exploration by Amax (Australia) Inc., Endeavour Oil and Amoco Minerals has located several nickel prospects in the Forrestania Greenstone Belt, following the initial discovery of anomalous Ni and Cu values in a gossan in 1969. The deposits are described in detail by Leggo and Mackay (1980) and by Marston (1984). Further investigations have been carried out by Witt (1972), Lawn (1977) and Purvis (1978), who concentrate mainly on the petrology of their thesis areas at Middle Ironcap, North Ironcap and Digger Rocks respectively. Reserves shown in Table 2 are taken from Marston (1984).

TABLE 1. GOLD AND SILVER PRODUCTION FROM THE FORRESTANIA AND HATTERS HILL AREA

Centre	*Lease name*	*Lease No.*	*Period*	*Dollied (kg)*	*Ore treated (t)*	*Gold (kg)*	*Silver (kg)*
Forrestania	Black Prince	3223	1922		125.99	2.138	
	Great Southern West	3180	1921-22		148.34	0.474	
	Great Southern	2909	1917-25		929.68	6.661	
	Margaret Ellen	4506	1962-63		85.35	0.678	0.022
	Sundry Claims		to 1980	0.015	598.64	8.999	0.263
	TOTAL			0.015	1 888.00	18.950	0.285
Hatters Hill	C and H	217	1934-35		167.65	2.798	
	Crooked Mick	217	1934-35		43.18	2.336	
	Gladys	238	1935		79.25	1.498	
	King George	243	1936		50.80	1.846	
	The Little Gladys	214	1933-34		211.85	6.044	
	North and South	210	1933-35		91.95	0.807	
	Two Bar	209	1933-35		326.15	7.166	
	Sunday Gift	244	1936-37		201.18	5.175	
	Sundry Claims (a)		to 1980	0.891	6 003.99	99.374	0.812
	TOTAL			0.891	7 176.00	127.044	0.812

(a) Alluvial gold 2.330 kg.

1. Source of statistics: **Hobson and Matheson (1940), Sofoulis (1958), Department of Mines Annual Reports, Mines Statistics Branch**

TABLE 2. RESERVES AND GRADES OF NICKEL ORES AT PROSPECTS WITHIN THE FORRESTANIA GREENSTONE BELT

Prospect	*Reserve (a) (Mt)*	*Mean Ni tenor (per cent)*
Cosmic Boy		
Upper Zone	3.37	2.87
Lower Zone	2.096	2.12
Digger Rocks	1.232	2.21
South Digger Rocks	3.2	1.41
Flying Fox	0.53	4.6
New Morning	0.569	2.91

After Marston, 1984 (a) Using 1 per cent Ni cut off.

All the major deposits consist principally of disseminated, brecciated and massive sulphide ore composed of pentlandite, pyrrhotite, pyrite and chalcopyrite together with pyrite and violarite as supergene minerals. The basal zone at the Cosmic Boy deposit also contains some millerite. The massive and brecciated ores are typically near the structural (and probably stratigraphic) base of the ultramafic host. Discrete bodies of disseminated ore occur in the central portions of dunite-olivinite lenses. The host rock is described in the section on the layered greenstone sequence.

Copper

Simpson (1948; 1952) reports azurite and malachite staining in auriferous reefs in gold prospects of the Hatters Hill area. It is not clear whether this mineral occurrence is on HYDEN or LAKE JOHNSTON.

Molybdenum and tungsten

Blatchford (1916) reported molybdenite and scheelite in acid dykes in the Hatters Hill area but gives no indication of their mode of occurrence or precise location.

Graphite

Simpson (1951) reports the occurrence of graphite in schists "20 miles" southeast of Karlgarin, presumably corresponding to the graphite prospect 19 km south of Hyden. Disseminated flakes of graphite comprise up to 10 per cent of the schist (*Alg*).

WATER RESOURCES

Town and augmentative water supplies on HYDEN are mainly provided by dams and tanks constructed to trap rainfall runoff from granite monoliths. No large quantities of good quality, underground water have yet been located. However, small quantities of good quality water have been obtained from the deepest Quaternary and Tertiary sands on the slopes flanking large granite outcrops. Groundwater salinities are higher at greater distances from the recharge area and are mostly too high for agricultural use.

Berliat (1965) describes the results of an exploratory drilling project 65 km east of Hyden. Many of the problems encountered there are possibly applicable to the search for water throughout HYDEN.

Lord (1971), in assessing the results of the 1969/70 drought-relief programme, reports that good yields of stock-quality water were located in as few as one hole out of 106 holes drilled in the South Yilgarn and Mount Walker districts but in as high as one in five drilled in the Holt Rock district, which suggests reasonable groundwater prospects in this district.

APPENDIX

LOCALITIES MENTIONED IN TEXT

LOCALITY	*LATITUDE*	*LONGITUDE*
Camel Peaks	32°19′	118°49′
Chalk Hill	32°32′	118°58′
Cosmic Boy Prospect	32°35′	119°45′
Digger Rocks	32°42′	119°49′
Gibb Rock	32°07′	119°01′
Hatters Hill	32°49′	119°59′
Holleton	31°57′	119°01′
Holt Rock (locality)	32°41′	119°24′
Hyden	32°27′	118°51′
Karlgarin	32°30′	118°42′
Karlgarin Hill	32°29′	118°33′
Lake Cronin	32°23′	119°46′
Middle Ironcap	32°34′	119°44′
Mount Holland	32°10′	119°44′
Mount Vernon	32°47′	119°16′
Mount Walker (locality)	32°04′	118°49′
New Morning Prospect	32°27′	119°40′
North Ironcap	32°21′	119°39′
Pingaring	32°45′	118°37′
Pingaring Rock	32°45′	118°38′
Powder Puff Hill	32°37′	118°39′
South Ironcap	32°43′	119°47′
The Humps	32°20′	118°57′
Varley	32°48′	119°30′
Wave Rock	32°27′	118°53′
Wheeler Rock	32°20′	119°17′

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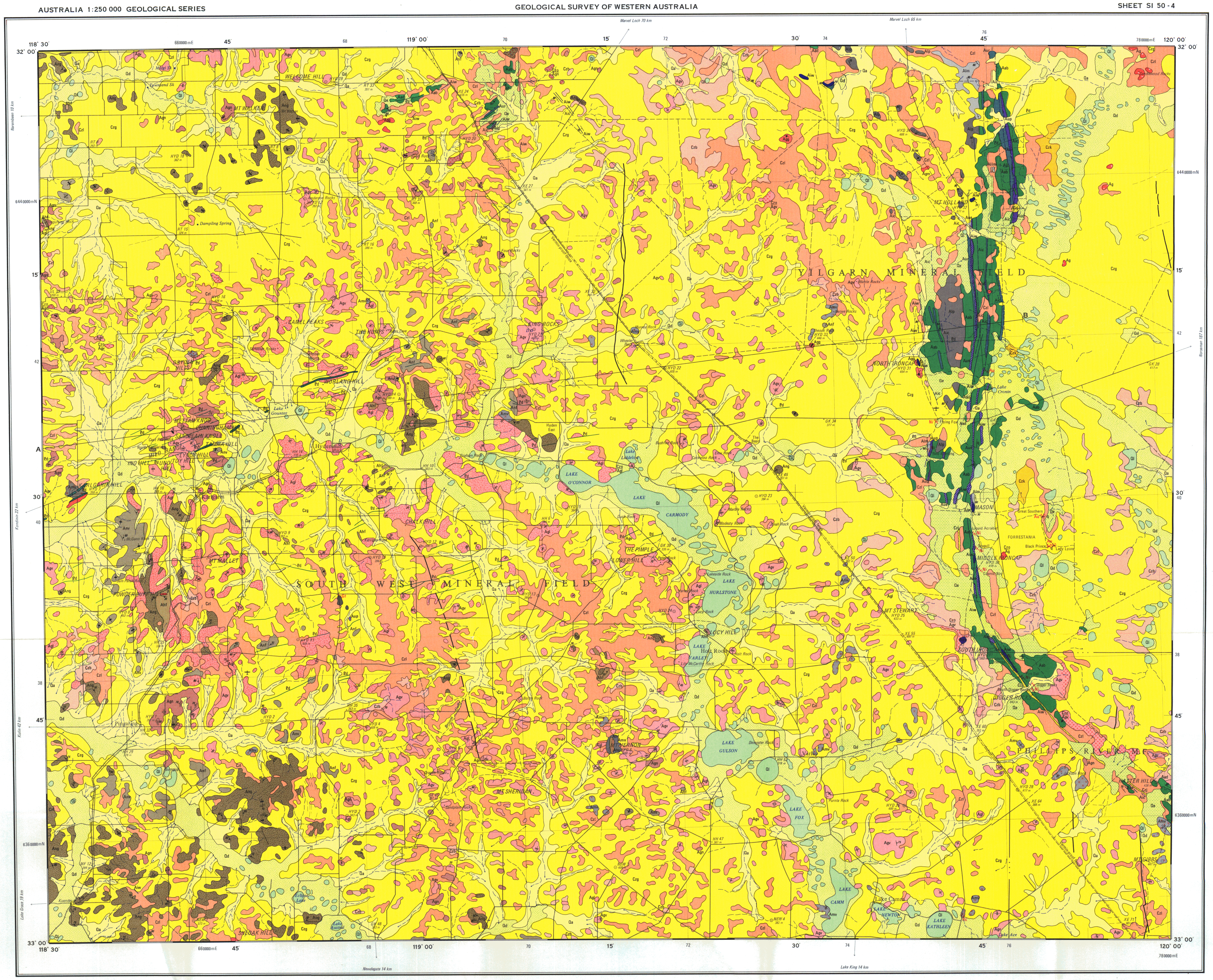
HYDEN

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SI 50-4



SYMBOLS

- Geological boundary
- Fault, accurate
- Fold, multiple
- Bedding, (facing not implied)
  - inclined
  - vertical
- Air photo lineament or trend line
- Crenulation and fracture cleavage
  - inclined
- Metamorphic foliation
  - inclined
  - vertical
  - undetermined
- Lineation (mineral alignment)
- Primary igneous foliation
  - inclined
  - vertical
  - undetermined
- Compositional layering in granitoids
  - inclined
  - vertical
  - undetermined

- Mineral field boundary
- Formed road
- Track
- Railway (3'6") with station or siding
- Townsite, gazetted
  - population less than 1000 — Hyden
- Locality — Hyden North
- Landing ground
- Horizontal control : minor — HYD 7
- Bench mark, height accurate — 358 m

- Watercourse, intermittent
- Soak — Sk
- Tank — T
- Dam — D

- Mining centre — FORRESTANIA
- Gold mine, abandoned
- Quarry
- Prospect
- Mineral occurrence
  - Gold — Au
  - Graphite — Gt
  - Nickel — Ni
  - Crushed rock aggregate — Rc

REFERENCE

CAINOZOIC

QUATERNARY

- Qa — Alluvium — silt, sand and gravel in streams and sheetwash areas
- Ql — Lacustrine deposits — saline and gypsiferous clay and silt in playa lakes
- Qd — Eolian and alluvial deposits — silt and sand, gypsiferous in part, adjacent to playa lake systems
- Qe — Colluvium and eluvium — red-brown clay and silt derived from mafic amphibolite

TERTIARY

- Czg — Remnant sandplain — yellow and white sand containing locally abundant limonite pebbles : derived from Czl
- Czk — Nodular calcrete — sandy limestone in lenses and sheets adjacent to Ql and Qd
- Czl — Laterite — limonite cemented duricrust overlying deeply weathered bedrock ; minor silcrete
- Czb — Silcrete — subvitreous silica-cemented duricrust characterized by embayed quartz clasts; commonly part of laterite profile
- Czj — Siliceous and limonitic caprock — chalcedonic silica and siliceous limonitic duricrust over ultramafic rocks
- Czo — Deeply weathered bedrock — leached, kaolinized zone of duricrust profile with remnant bedrock structure and texture

PROTEROZOIC

- Pd — Dolerite and gabbro dyke

ARCHAEAN

- q — Quartz vein
- p — Pegmatite vein

- Ag — Granitoid, interpreted from air photos
- Agl — Medium and coarse-grained porphyritic granite and adamellite
- Agv — Variably textured, medium and coarse-grained seriate granite and adamellite; locally porphyritic
- Agm — Fine and medium-grained, muscovite-bearing granite and adamellite
- Agg — Foliated medium and coarse-grained biotite granite and adamellite

- Agn — Recrystallized coarse, even-grained and seriate granite and adamellite; common biotite schlieren and textural layering
- Anv — Recrystallized, foliated even-grained and seriate granite and adamellite; common biotite schlieren and textural layering
- Anf — Fine to medium-grained leucocratic granofels of granite and, rarely adamellitic composition; local relict foliation
- Ang — Banded gneiss of granitic to granodioritic compositon, recrystallized to granoblastic texture; commonly veined by Anf

- Amv — Mixed granitoid composed of a granoblastic or gneissic phase (Anf, Ang and Anv) extensively intruded by seriate or porphyritic adamellite (Agv, Agl)
- Amx — Migmatite with mafic and metasedimentary granulite palaeosome and leucocratic granofels neosome

- Aic — Banded chert
- Aiw — Banded iron-formation, quartz-grunerite-magnetite rock

- Alp — Muscovite-quartz schist; commonly contains biotite, garnet, andalusite and cordierite; metamorphosed shale and siltstone
- Alm — Quartz-rich schist and micaceous quartzite; metamorphosed siltstone and sandstone
- Alg — Graphite-muscovite schist and phyllite

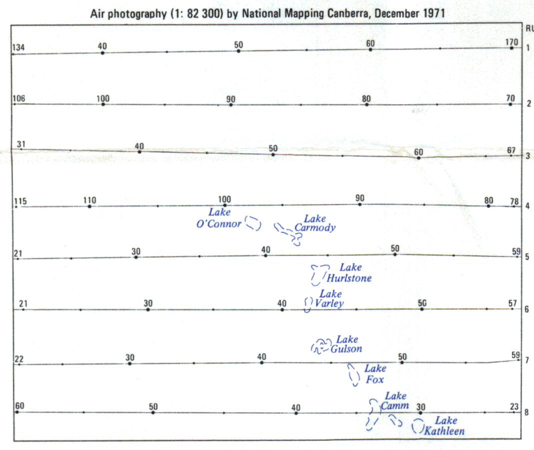
- Aab — Fine and medium-grained mafic amphibolite and metabasalt
- Aad — Medium and coarse-grained mafic amphibolite and metagabbro

- Aur — Tremolite (-chlorite-talc) schist
- Aup — Serpentinite; derived from peridotite
- Aue — Talc (-carbonate-tremolite) schist
- Aux — Coarse-grained amphibole (-chlorite) schist derived from pyroxenite

- Ahf — Pyroxene-plagioclase (-amphibole) granulite; derived from mafic rock
- Ahi — Quartz-hypersthene-garnet-magnetite granulite; derived from banded iron-formation
- Ahs — Quartz-plagioclase-hypersthene granulite; derived from felsic sediment or volcanic

FLIGHT DIAGRAM

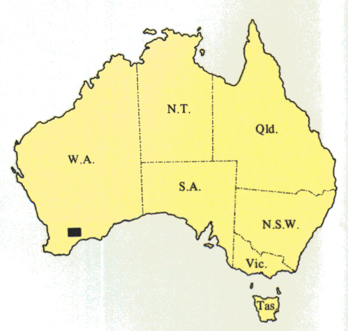
Air photography (1: 82 300) by National Mapping Canberra, December 1971



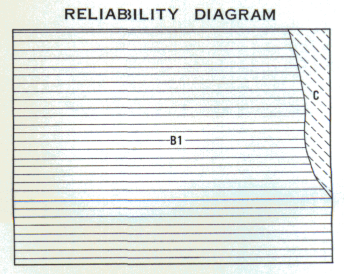
Compiled and published by the Geological Survey of Western Australia. Cartography by the Geological Mapping Section, Department of Mines. Topographic base from compilations by the Department of Lands and Surveys.

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

Printed by the Government Printing Office, Perth.



RELIABILITY DIAGRAM



B1 Numerous traverses with air photo interpretation

C 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

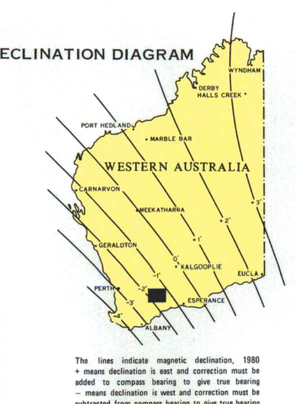
ZONE 50 AUSTRALIAN MAP GRID

INDEX TO ADJOINING SHEETS

KELLERBERRIN SH 50-15	SOUTHERN CROSS SH 50-16	BOORABBIN SH 51-13
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

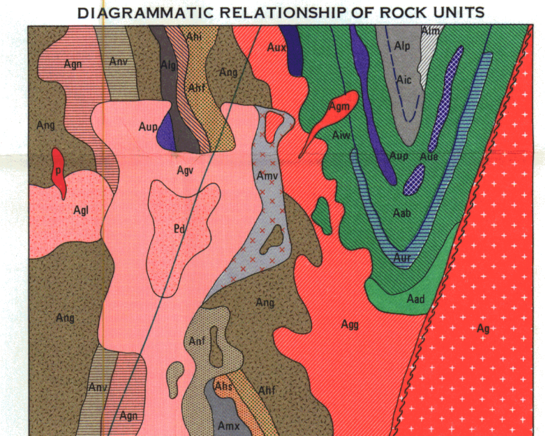
Geology by R.J. Chin, A.H. Hickman and R. Thom, 1978

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

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

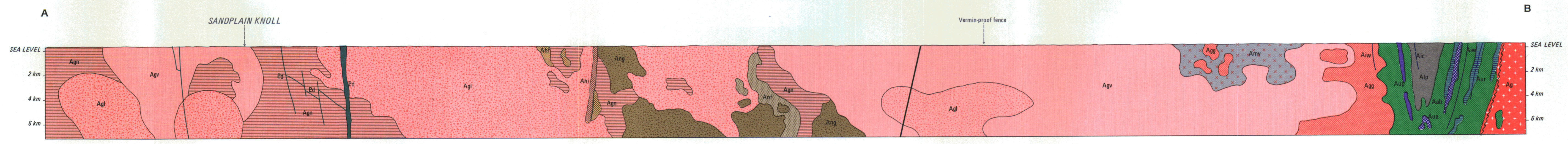


Shear zone

DIAGRAMMATIC SECTION

NATURAL SCALE

SECTION A-B



HYDEN

SHEET SI 50-4

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