1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

YARRIE

WESTERN AUSTRALIA

SHEET SF/51-1 INTERNATIONAL INDEX

DEPARTMENT OF RESOURCES & ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

DEPARTMENT OF MINES, FUEL & ENERGY, WESTERN AUSTRALIA
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Explanatory Notes on the Yarrie 1:250 000 Geological Sheet

Compiled by A. H. Hickman, R. J. Chin*, & D. L. Gibson*

The Yarrie 1:250 000 Sheet area (International Grid Reference SF/51-1), bounded by latitudes 20°S and 21°S and longitudes 120°E and 121°30'E, forms part of the Marble Bar District of the Pilbara Goldfield.

Shay Gap, which is centred on Goldsworthy Mining Limited's iron-ore mining operations 21 km north-northwest of Yarrie homestead, is the only town in the Sheet area. It is connected with Goldsworthy and Port Hedland to the west by a formed gravel road and standard gauge railway. Other centres of permanent habitation are the mining centre at Bamboo, and Muccan, Yarrie, and Warrawagine homesteads. Baramine and Lochinvar homesteads had been abandoned prior to fieldwork in 1974, and Callawa was being used as an outstation when visited in 1977.

Access within the southwestern part of the Sheet area is fair, with many station roads and tracks; however, access in the rest of the area is mainly limited to a track beside a telegraph line running northeast from Callawa station, an old oil exploration track that connects the northeastern part of the Sheet area with the Great Northern Highway near Wallal Downs station (Mandora Sheet area), and tracks connecting experimental water-bores drilled by the Geological Survey of Western Australia (GSWA) in the northwestern part of the Sheet area. Shay Gap has an airport, with regular flights.

The area has a hot and dry climate, with rain falling from tropical cyclones and local thunderstorms chiefly between December and March; winter rains are infrequent. The annual rainfall is probably about 250–300 mm, and the evaporation rate is about 2500 mm per year. January average daily maximum and minimum temperatures are about 38° and 24°C respectively, and July figures are about 27° and 12°C (all figures estimated from Commonwealth Bureau of Census and Statistics contour maps).

The area is covered by vertical aerial photographs at a nominal scale of 1:85 000 (RC-9 series) flown by the RAAF in 1968; photographs flown in 1953 at a nominal scale of 1:48 000 (K-17 series) are also available. A 1:250 000 topographic map of the Sheet area was compiled by the Royal Australian Survey Corps in 1958 from the 1953 photography, and six contoured topographic maps at 1:100 000 scale covering the Sheet area were prepared from the 1968 photography by the Commonwealth Division of National Mapping in 1974–76.

These Explanatory Notes and accompanying map are based on fieldwork by A. H. Hickman and R. J. Chin (GSWA) in the Pilbara Block and Paterson Province in 1974 (Hickman & Chin, 1976), and D. L. Gibson and R. R. Towner (Bureau of Mineral Resources—BMR) and R. W. A. Crowe (GSWA) in the Canning Basin in 1977 (Towner & Gibson, 1980).

History of investigations

The area around the Oakover and Nullagine Rivers was first surveyed by F. T. Gregory in 1861, and several expeditions, including that of Colonel P. E. War-

* Geological Survey of Western Australia.

burton in 1875, began or finished in the area. Gold prospecting in the early 1890s resulted in the rapid development of mines at Bamboo, and production was first recorded in 1894. The earliest geological investigations were of a general reconnaissance nature. Reports include those by Smith (1898), Maitland (1904), Blatchford (1925), Clapp (1925), Bremner (1942), and Reeves (1949), and others dealing with areas of particular economic interest such as Bamboo Creek and Isabella Range. Geological mapping of the southwestern Canning Basin by BMR (Traves & others, 1956) included the Yarrie Sheet area and led to the publication of the Yarrie 4-mile Sheet and first edition Explanatory Notes (Wells, 1959). The Yarrie Sheet area was included in a review of the geology of the Canning Basin by Veevers & Wells (1961).

Reconnaissance geophysical surveys carried out in the Sheet area include gravity (Flavelle & Goodspeed, 1962; Flavelle, 1974; Darby & Fraser, 1969), aeromagnetic (Quilty, 1960; WAPET, 1969), and scintillograph (Parkinson & Daly, 1955) surveys.

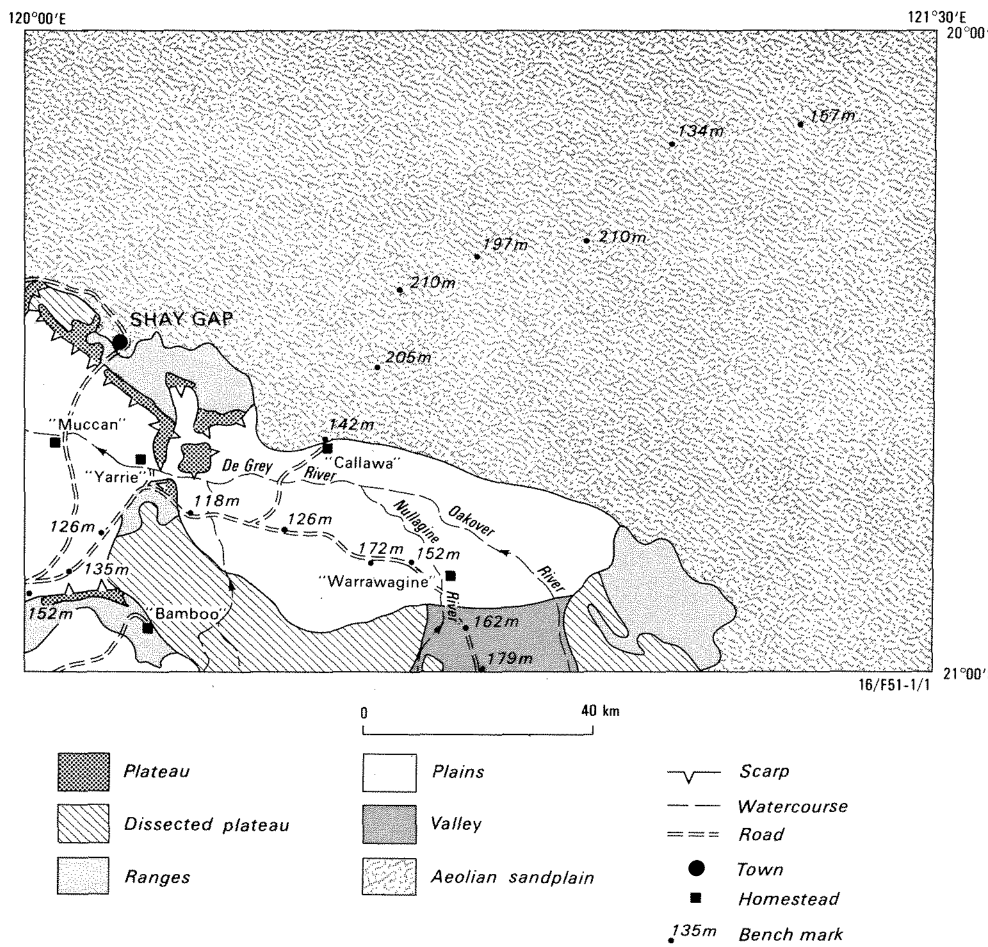

Fig. 1. Physiography.

PHYSIOGRAPHY

The northern and eastern parts of the Sheet area occupy the western part of the Great Sandy Desert, while the southwestern part lies within the upper catchment area of the De Grey River. Figure 1 illustrates the physiography of the area using six divisions: plateau, dissected plateau, ranges, plains, valley, and aeolian sandplain.

Small areas of *plateau,* corresponding to the Hamersley Surface of Campana & others (1964) and representing local remnants of Jutson's (1914, p. 68) 'Great Plateau of Western Australia', are preserved in the western part of the Sheet area. The plateau areas are underlain and effectively buttressed by Archaean chert and banded iron formation, rocks extremely resistant to erosion.

Proterozoic sedimentary rocks in the southern part of the Sheet area form a *dissected plateau* consisting of low craggy hills and V-shaped valleys and ravines. Hill tops are fairly flat and are all about the same height above sea level. Drainage is fault and joint-controlled on a local scale, but is generally dendritic.

Ranges of strike ridges occur where steeply inclined strata have been differentially eroded. Drainage is generally strike-controlled.

Plains cover much of the southwestern part of the Sheet area. Apart from isolated low outcrops and scattered inselbergs, the plains consist of flat expanses of sand, which are mainly eluvium overlying granite or old alluvium along the de Grey River. Elsewhere, colluvial or alluvial deposits make up the surface of the plains.

In the southern part of the Sheet area, the Oakover and Nullagine Rivers occupy a broad *valley,* about 25 km wide, flanked by hills of Proterozoic rocks. Mesas of Tertiary calcrete (Oakover Formation) rise up to 50 m above the valley floor.

Most of the Sheet area is *aeolian sandplain,* with seif dunes, and low rocky outcrops and breakaways. The seif dunes are simple longitudinal and chain longitudinal (terms of Crowe, 1975), and were deposited by east-southeasterly winds. They are mainly inactive now, and are stabilised by shrubs and grasses. This sandplain area is part of the Great Sandy Desert.

SUMMARY OF GEOLOGY

The Yarrie Sheet area covers the northeastern part of the Pilbara Block (Ryan, 1964; Daniels & Horwitz, 1969), the northwestern section of the Paterson Province (Daniels & Horwitz, 1969), and part of the Anketell Shelf of the Canning Basin (Gentilli & Fairbridge, 1951; Koop, 1966; Playford & others, 1975). The Fortescue and Hamersley Groups are a platform sequence forming a broken cover over the Pilbara Block. The major structural units in the Yarrie Sheet area are shown in Figure 2.

The Pilbara Block is an Archaean craton of large granitic domes separated by synclinoria of folded and sheared volcanic, sedimentary, and intrusive rocks. The granitic rocks of the Yarrie Sheet area range in composition from biotite granite to hornblende tonalite, with biotite adamellite being most common.

Archaean volcanic, sedimentary, and associated strataform intrusive rocks, collectively comprising the greenstones or 'layered succession', are divided into two major stratigraphic units in the Sheet area: the Warrawoona Group, a predominantly volcanic assemblage of mafic, felsic, and ultramafic rocks with subordinate chert; and the Gorge Creek Group, a predominantly sedimentary succession of sandstone, conglomerate, shale, and banded iron formation with subordinate basalt

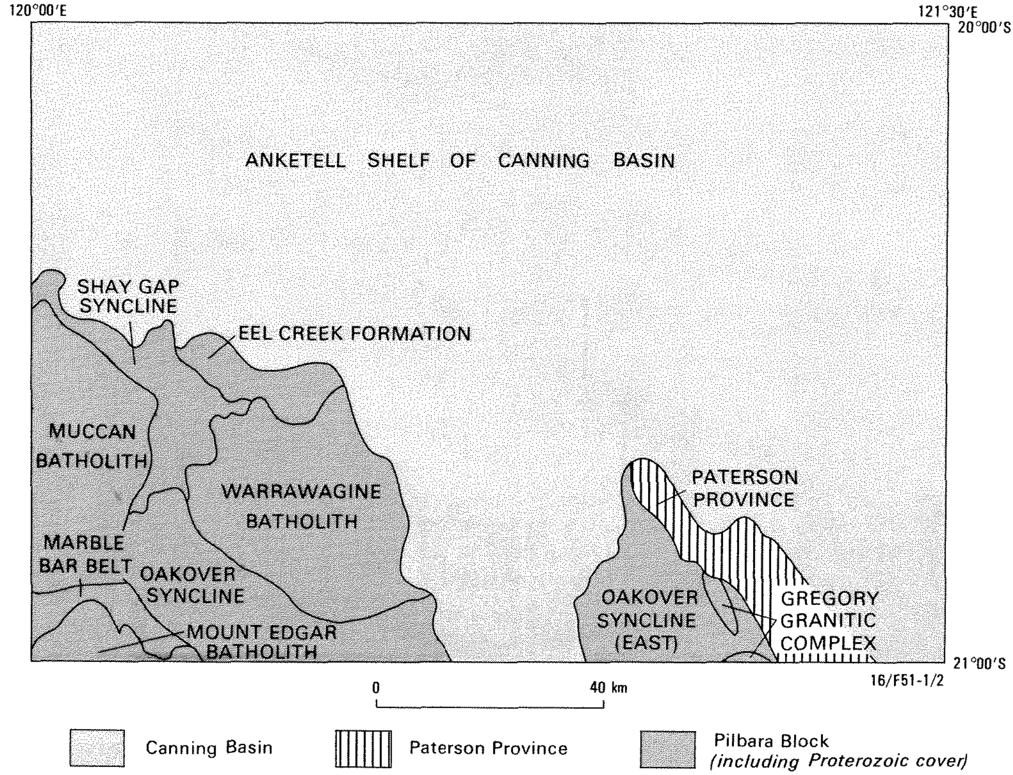

Fig. 2. Major structural units.

and gabbro. In the west Pilbara, higher Archaean stratigraphic units (the Whim Creek Group, the Louden Volcanics, and the Negri Volcanics) are preserved, and all the volcanic and sedimentary units of the Pilbara Block are now collectively referred to as the Pilbara Supergroup (Hickman, 1981, and in press). The distribution of the Warrawoona and Gorge Creek Groups within the Sheet area is shown in Figure 3.

Richards & others (1981) used the Pb-Pb method to date galena from a quartz vein cutting mafic rocks and metasediments of the Salgash Subgroup of the Warrawoona Group 3 km south of Coppin Gap at between 3341 $\pm$ 2 (t_{76}) and 3276 $\pm$ 7 (t_8) m.y. J. R. de Laeter (Western Australian Institute of Technology, personal communication, 1980) used the Rb-Sr method to date intrusive felsic rocks 1 km to the southwest of Coppin Gap at 2915 $\pm$ 207 m.y. Geochronological information relevant to the Sheet area, but obtained from sampling localities in other parts of the Pilbara Block, is summarised by Hickman (1981). This information indicates that the Warrawoona Group is 3600 to 3300 m.y. old, that the Gorge Creek Group is more than 3000 m.y. old, and that the foliated granitic rocks range in age from 3500 to 2950 m.y.

Some doubt now exists as to the precise age of the post-tectonic granitic intrusions. Rb-Sr geochronology summarised by Hickman (in press) indicates that they are approximately 2600 m.y. old, but thereby suggests that they postdate at least part of the Fortescue Group (see below). This conflicts with the long-held interpretations of probable field relationships, and requires further investigation.

Lower Proterozoic basaltic to rhyolitic volcanics and intercalated sedimentary formations of the Fortescue and Hamersley Groups were deposited on the eroded surface of the Archaean craton. Published and unpublished geochronological data from adjacent areas indicate that the oldest Proterozoic rocks of the area are between 2800 and 2600 m.y. old (Gee, 1974, 1980; Hickman & de Laeter, 1977; Richards, 1978).

Early or Middle Proterozoic sediments of the Eel Creek Formation unconformably overlie Archaean rocks east of Shay Gap. The Eel Creek Formation may correlate with part of the Fortescue Group or Middle Proterozoic Waltha Woora Formation which crops out 150 km to the southeast.

Sandstone, shale, and carbonate rocks of the Middle Proterozoic Paterson Province unconformably overlie rocks of the Fortescue Group in the Isabella Range area. These rocks are regarded as belonging to the Yeneena Group (Williams & others, 1976) which occurs in the Balfour Downs, Rudall, and Paterson Range Sheet areas. Chin & de Laeter (1981) present evidence that the Yeneena Group is between 1333 ± 44 and 1132 ± 21 m.y. old.

The Precambrian succession is deformed by northwesterly trending, tight to open folds, and is unconformably overlain by flat-lying Palaeozoic and Mesozoic sedimentary rocks of the Canning Basin. Cainozoic sediments and rocks thinly veneer most of the Sheet area.

ARCHAEAN

These Explanatory Notes follow a practice previously adopted in the Marble Bar (Hickman & Lipple, 1975, 1978) and Nullagine (Hickman, 1975a, 1980) Sheet areas in describing the Archaean layered succession on the basis of its lithological composition. Although Figure 3 presents an interpretation of Archaean stratigraphy, it should be noted that structural and metamorphic problems remain in certain areas, and in these a completely reliable stratigraphic subdivision is not yet possible. It is anticipated that future geochronological and geochemical studies, combined with more detailed mapping, will resolve many of these problems. Because most rock types occur at more than one stratigraphic level, it must be stressed that neither the map Reference nor the sequence in which lithological units are described here has any stratigraphic significance.

PILBARA SUPERGROUP

The Pilbara Supergroup is composed of ultramafic, mafic, and felsic volcanic rocks, intrusive rocks, and various types of sedimentary rocks. Greenschist facies metamorphism predominates in most areas, though amphibolite facies metamorphism is commonly developed near contacts with intrusive granites.

The stratigraphic subdivision of the Pilbara Supergroup in the Sheet area is summarised in Figure 3. The Warrawoona Group is best exposed southwest from Coppin Gap (20°53'S, 120°07'E), whereas the overlying Gorge Creek Group is most completely preserved at Shay Gap (20°31'S, 120°08'E). In the latter area, banded iron formation (Cleaverville Formation) abuts granitic rocks along what is thought to be a tectonic and locally intrusive contact (granitic sills intrude the banded iron formation near Kimberley Gap (20°38'S, 120°17'E)). At Coppin Gap the banded iron formation/granite contact is clearly tectonic. The possibility that at Shay Gap, part or all of the Warrawoona Group is absent along an unconformity cannot be discounted, especially in view of similar Gorge Creek Group/

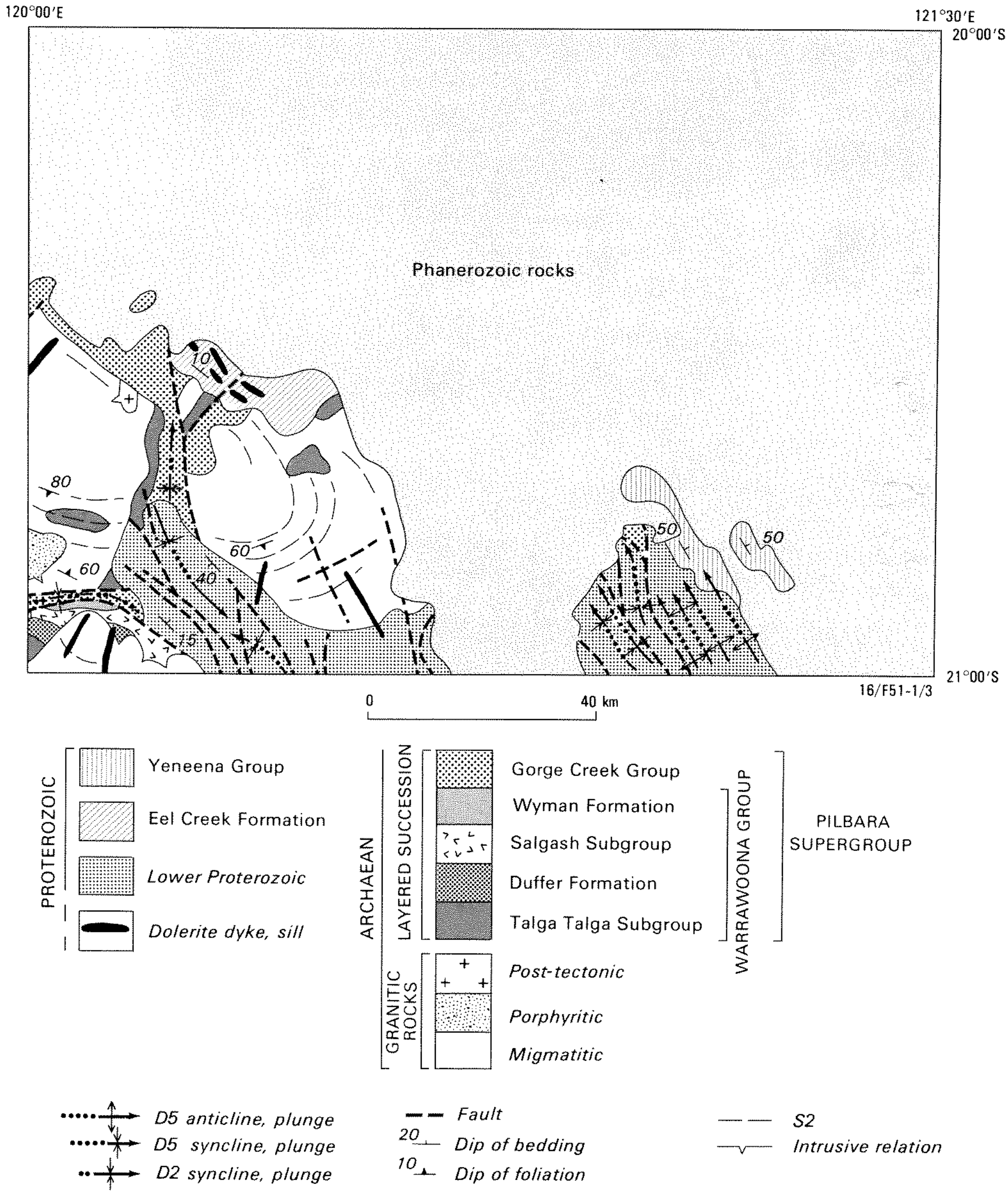

Fig. 3. Structural sketch map.

granite contacts in the northern part of the Port Hedland Sheet area which adjoins to the west (Hickman, 1977; Hickman & Gibson, 1982).

The maximum depositional thickness of the succession is approximately 15 km.

Clastic sedimentary rocks

Unsubdivided clastic sedimentary rocks (As) south of Bulletin mine (20°57′S, 120°14′E) are predominantly pelitic and cherty, while those at Cattle Well (20°31′S, 120°13′E) are fine-grained sandstone and semi-pelitic units. Metamorphosed fine-grained rocks consisting of carbonate, chlorite, quartz, and accessory minerals within a mafic-ultramafic sequence northeast of Eight Mile Well (20°36′S, 120°16′E) are interpreted as metasedimentary.

Grit, sandstone, and siltstone (Ast) form much of the Gorge Creek Group near Shay Gap. The rocks are generally well-bedded at intervals of up to 30 cm and are locally cross-stratified. Grains are composed of quartz, chert, and minor altered feldspar.

A prominent *conglomerate* bed about 2 m thick (Asc), occurs 9 km northeast of Shay Gap. Well-rounded clasts up to 5 cm in diameter, are of vein quartz, chert, and quartzite.

Ferruginous sandstone, siltstone, shale, and chert (Asf) crop out southeast of Shay Gap, in the Kimberley Gap area, and 7 km south of Yarrie homestead. In all cases the rocks are associated with banded iron formation and are stratigraphically confined to the Gorge Creek Group. The predominant lithology is grey to reddish-brown slaty shale. Interbedded ferruginous chert, banded iron formation, sandstone, siltstone, greywacke, and cherty mudstone are locally important, and dolerite sills occur southeast of Shay Gap. The rocks are folded and commonly cleaved, schistose, or phyllitic.

Chemical sedimentary rocks

Unsubdivided chert (Ac) includes homogeneous grey chert and banded chert of variable or uncertain lithology.

Black/white and grey/white banded chert (Acw) exhibits well-defined coloured laminae from 1 mm to 10 mm thick.

Green chert (Acg) occurs 1 km north of No. 11 well (20°58′S, 120°01′E) where it is flanked by a narrow ultramafic unit. The green colouration probably reflects the presence of pale-green chromian muscovite, or iron contamination.

Ferruginous chert (Acf) occurs near Shay Gap in association with banded iron formation.

Banded iron formation and jaspilite (Aci), in which iron oxide (hematite) comprises over 50 percent of the rock, crops out northeast and southwest of Shay Gap, at Mount Cecelia (20°47′S, 120°59′E) and in the Coppin Gap and Kimberley Gap areas. Hematite and chert layers alternate to produce a black or dark-brown rock. Where red jasper and iron oxide layers alternate, an attractive red-black banded jaspilite is developed. Alternating bands about 1 cm in thickness of white, pink, and grey recrystallised chert locally occur within ferruginous chert and hematite. Fine-scale banding is common. The absence of magnetite and lack of regular microbanding and mesobanding (as defined by Trendall, 1965) make these Archaean banded iron formations quite distinctive from Lower Proterozoic iron formations of the Hamersley Basin.

Felsic volcanic rocks

Rhyolite and dacite (Aa) occur in parts of the Warrawoona Group in the southwestern corner of the Sheet area. These felsic volcanic rocks form pale-grey to orange outcrops, are commonly schistose, and are closely associated with basalt and chert units. The rocks are composed of quartz, sericitised feldspar, variable amounts of secondary carbonate, minor biotite, and chlorite. Amygdales, phenocrysts, and flow structures are well preserved.

Chiefly dacitic *agglomerate, tuff, and lava* (Aav) make up the Duffer Formation which crops out in the southwest of the Sheet area (see also Fig. 3). The agglomerate contains angular fragments of felsic lava measuring up to 10 cm in diameter. Carbonation locally obscures primary mineralogy and composition.

Porphyritic felsic lava (Aal) forms a prominent orange ridge southwest of Coppin Gap. Quartz and feldspar phenocrysts 1 to 2 mm across are set in a fine-grained quartzo-feldspathic groundmass. The rock is massive and intricately veined by quartz.

Mafic volcanic rocks

Basalt, andesite, and unsubdivided mafic volcanic rocks (Ab) constitute about 50 percent of the Warrawoona Group, and form part of the Gorge Creek Group east of Coppin Gap and near Shay Gap. Units at higher stratigraphic levels in individual mafic sequences are pillowed, whereas those lower down are more massive and include many dolerite sills. Many of the metabasalts are locally schistose, a feature which is generally accompanied by an increase in metamorphic grade from greenschist to amphibolite facies.

Amphibolite-plagioclase schist (Aba) forms megascopic xenoliths within the granitic batholiths in the Cattle Gorge area (20°33′S, 120°15′E), south of Callawa (20°38′S, 120°30′E) and southwest of Bamboo. Relict textures and structures indicate that basalt, dolerite, and gabbro are all represented. The rocks are dark, fine to medium-grained, and schistose or flaggy, mainly consisting of hornblende (commonly pseudomorphed by chlorite) and plagioclase. Outer zones of the xenoliths are partly granitised, and hornfels texture is well developed.

A *green, granular epidote-quartz rock* (Abe), possibly an altered dolerite, forms part of the Gorge Creek Group southeast of Shay Gap.

Actinolite/tremolite/hornblende-chlorite-plagioclase rock (Abm) is medium-grey in colour, and contains fans and sheaves of acicular actinolite, tremolite, or hornblende, up to 1 cm long in a finely crystalline groundmass of plagioclase, clinozoisite, chlorite, carbonate, epidote, and rare quartz. The rock is probably a metamorphosed high-magnesia basalt. A joint BMR-GSWA geochemical study has revealed the presence of unmapped high-magnesia basalt and high-magnesia gabbro within the Gorge Creek Group at Shay Gap (R. Davy, GSWA, personal communication, 1982).

Ultramafic rocks

Unsubdivided ultramafic rock (Au) occurs both as stratiform bodies within the Pilbara Supergroup, and as isolated rafts within the granitic batholiths. Intrusive and extrusive units are thought to be represented. Most of the rocks are schistose and are altered by carbonation, serpentinisation, chloritisation, and silicification. The largest unit is south of Yarrie homestead where carbonate-chlorite-quartz schist is all that remains of probably what was originally a succession of ultramafic and mafic rocks.

Actinolite/tremolite + chlorite rock (Aua) is distinguished near Callawa and in the hills northeast of Yarrie. The rock is schistose, medium-grained, and composed of varying proportions of tremolite, chlorite, serpentinite, talc, and carbonate. Rarely, hornblende, and either pargasite or cummingtonite, are present. The carbonate is mostly siderite, and less commonly ankerite. Relict igneous textures indicate that some units are metamorphosed peridotite. Serpentine preserves the outline of original olivine grains, and chlorite replaces intercumulus material.

Peridotite (Aup) forms a 1000 m-thick sill 7 km southwest of Coppin Gap, is associated with amphibolite southwest of Callawa (unmapped), and occurs as dykes northwest of Coppin Gap. The sill near Coppin Gap outcrops as an east-west strike ridge, is medium to coarse-grained, serpentinised, and contains a few chrysotile veins.

Serpentinite (Auc) bodies are distinguished east of Nobb Well (20°59′S, 120°11′E), west of Kittys Gap (20°53′E, 120°05′E), and 12 km north of Kittys Gap. East of Nobb Well, a large mass of chromiferous serpentinite (probably after peridotite, although no relict textures are visible in thin section) forms a wedge-shaped intrusion between felsic agglomerate and basalt. One sample of the rock contains 3.15% Cr and 0.18% Ni.

Pyroxenite (Aux) occurs as a dyke in ultramafic schist 3 km south of Yarrie homestead. The rock is extremely altered and now contains hornblende and minor carbonate with accessory sphene, allanite, and plagioclase.

Carbonate-talc rock (Aue) is restricted to the Bamboo mining centre area. The largest outcrop forms a narrow arcuate belt from the mining centre to Coppin Gap. Locally stratiform, this unit is discordant on a regional scale, and is composed chiefly of carbonated and silicified ultramafic and mafic intrusive rocks. Principal minerals are carbonate, quartz, chlorite, and talc. Relict plagioclase confirms that parts of the unit are altered dolerite, and pseudomorphed olivine-pyroxene assemblages are also preserved. A thin section of one sample taken from the Bulletin mine shows interstitial glass and acicular pyroxene surrounding euhedral olivine crystals up to 1 mm across. This rock passes into a skin of glass with small acicular crystals of olivine and pyroxene. The sample may represent the top of a peridotite lava flow, but could be interpreted as part of an intrusive contact.

GRANITIC ROCKS

Four types of granitic rock (Agc, Agp, Agm, and Agmx) are distinguished on the map. In general, Agp intrudes Agm and Agmx, while Agc (only two small outcrops southeast of Shay Gap) is younger still, and is correlated with the post-tectonic granites near Marble Bar (e.g. Moolyella Adamellite dated by de Laeter & Blockley (1972) at 2670 ± 95 m.y. (recalculated to 2614 ± 95 m.y. by de Laeter & others, 1981) with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7397 ± 0.0419).

Poorly to non-foliated granite and adamellite (Agc) intrudes Agm southeast of Shay Gap. The rock is massive, medium to coarse-grained, and seems relatively potassic in hand specimen.

Medium to coarse-grained, foliated porphyritic biotite adamellite (Agp) is restricted to a pluton 10 km northwest of Coppin Gap. Emanating dykes of Agp (not shown on map) intrude Agm near Wattle Well (20°47′S, 120°02′E), and blocks of Agm (not shown on map) occur in the pluton's centre 3 km to the south. Composition varies, from mainly leucocratic adamellite to minor granodiorite. It is characterised by large euhedral phenocrysts of microcline, which in places are aligned. Stromatic and nebulitic varieties are present, and greenstone xenoliths are numerous. Several generations of pegmatite dykes are present; early ones are folded and broken by fault planes whereas later ones are straight and continuous.

Foliated *biotite adamellite and biotite granodiorite* (Agm) make up over 90 percent of the granitic rocks, but this unit includes plutons of various ages. De Laeter & Blockley (1972) dated Agm from Moolyella, just south of the Sheet area, at 3125 ± 366 m.y. with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7016 ± 0.0047.

In fresh exposures the rocks are typically pale-grey, medium to coarse-grained, and equigranular with a conspicuous biotite foliation. Individual outcrops are relatively homogeneous and massive, but stromatic, nebulitic, veined, gneissic, and agmatitic varieties are locally prominent. Hornblende adamellite and tonalite occur near the margins of the batholiths, and probably reflect contamination from the adjacent greenstones during intrusion of the batholiths. In such rocks hornblende is replaced by chlorite and epidote.

Granite-greenstone contacts are commonly marked by a zone of lit-par-lit injection and migmatisation up to 3 km in width. Within such zones, granitic rock and rafts of metamorphosed greenstone material (generally amphibolite or ultramafic schist) occur in approximately equal proportions and the symbol Agmx has been employed. About 15 km north-northwest of Coppin Gap, an east-striking belt of Agmx bears no obvious relationship to the batholith margin and probably represents a root zone. Here, as at the margins, the unit is more sheared than typical Agm.

Deformation of the batholiths has imposed a strong, in places gneissic, foliation. Constituent minerals are granulated and strained, but only biotite shows significant regrowth parallel to the foliation.

MINOR INTRUSIVE ROCKS

Gabbro (Ao) and *dolerite* (Ad) sills and dykes are widespread in the Pilbara Supergroup and in the batholiths. Some are schistose and all are metamorphosed, commonly to amphibolite facies.

A *norite sill* (An) separates pillow basalt from gabbro east of Shay Gap. In thin section, elongate prisms of orthopyroxene up to 6 mm long and 1 mm in diameter are pseudomorphed by serpentine in a matrix of saussuritised plagioclase laths, interstitial augite (partly altered to amphibole), minor quartz, and red-brown biotite.

Small stocks of *porphyritic felsic rock* (Ar) occur near Kimberley Gap. Phenocrysts of rounded quartz up to 2 mm in diameter are set in a matrix of microcline and oligoclase with minor biotite and muscovite. The texture is xenomorphic to granular, quartz elongation and biotite alignment outlining a foliation.

A *feldspar-phyric felsic sill* (Apf), approximately 1 km in thickness, intrudes the Pilbara Supergroup where Eight Mile Creek crosses the western margin of the Sheet area. The rock is fine to medium-grained, grey, and contains abundant euhedral plagioclase phenocrysts up to 5 mm long.

ARCHAEAN OR PROTEROZOIC

Felsic porphyry (p€p) stocks intrude the Warrawagine Batholith in the Ngarrin Creek (20°50′S, 120°28′E) area. The intrusions occur in an east-northeasterly trending belt approximately 15 km long. Two distinctive rock types are present: coarse porphyry containing large phenocrysts of quartz, feldspar, and vugs of dark-blue fluorite; and fine porphyry containing phenocrysts of quartz and perthite in a fine rhyo-dacite matrix. At the fluorite occurrence indicated on the map (20°52′S, 120°25′E), the fine porphyry intrudes the coarser variety (Hickman, 1976). Some of these intrusions may be part of the same suite as the Bamboo Creek Porphyry (Ep).

Sodic porphyry containing aegirine (p€ps) forms a small dyke-like mass 7 km north of Yarrie homestead. In thin section the rock is crowded with phenocrysts of feldspar and aegirine-augite in a fine-grained matrix of quartz, plagioclase, K-feldspar, and numerous small laths of aegirine.

Dykes and veins of *dolerite* (d), *quartz* (q), *pegmatite* (p), and *granite* (g) ubiquitously intrude the batholiths. The dolerites are relatively undeformed yet are not demonstrably Proterozoic in age. In some cases (e.g. 5 km northeast of Helen Well; 20°52′S, 120°21′E) they clearly pre-date similar dykes known to be Proterozoic in age.

EARLY TO MIDDLE PROTEROZOIC

Before describing the Proterozoic succession, it is appropriate to note that a considerable amount of new geochronological information has been obtained since the map was compiled. Published and unpublished data, some of which are referred to in these Notes, now suggest that the Fortescue Group is actually between 2800 and 2600 m.y. old, instead of 2400–2200 m.y. as thought prior to 1978. This revised estimate of the unit's age places it within the 'Archaean'. More limited data on the Hamersley Group indicate that its age is about 2500 m.y., that is, close to the Archaean-Proterozoic time boundary recommended by the Subcommission on Precambrian Stratigraphy (James, 1978). This time boundary now appears to lie somewhere within the Fortescue Group or Hamersley Group, but there is no known regional stratigraphic break either within or between these units.

The Fortescue Group is an intrinsic part of the Hamersley Basin (Trendall & Blockley, 1970), the rocks of which form a 'cover sequence' to the extensively deformed granite-greenstone terrain of the Pilbara Block. Accordingly, the generally accepted Archaean-Proterozoic time boundary would appear to have little stratigraphic significance in the Pilbara.

As these Notes go to press, geochronological and stratigraphic studies are continuing on the Fortescue Group, and any redefinition of the Archaean-Proterozoic time boundary is deferred pending completion of this work.

FORTESCUE GROUP

The Fortescue Group (MacLeod & others, 1963) contains basalt, andesite, dacite, rhyolite, pyroclastic rocks, and subordinate sedimentary units, all about 2800 to 2600 m.y. old. Facies changes between Bamboo and the Isabella Range are similar to changes in the Nullagine Sheet area (Hickman, 1975a), and stratigraphic correlations are as follows:

(west) Bamboo area	*Isabella Range (east)*
Lewin Shale	Lewin Shale
Maddina Basalt	Pearana Basalt (upper)
Kuruna Siltstone	not present
Nymerina Basalt	Pearana Basalt (lower)
Tumbiana Formation	Tumbiana Formation
Kylena Basalt	Kylena Basalt
Hardey Sandstone	not present
Mount Roe Basalt	Koongaling Volcanics

The *Mount Roe Basalt* (Ᵽfr; Kriewaldt, 1964) reaches a maximum thickness of about 300 m. It is composed of amygdaloidal, vesicular, columnar jointed, and massive basalt and andesite. *Agglomerate and tuff* (Ᵽfrv) forms the lower part of the formation northeast of Coppin Gap and along part of the southern margin of the Warrawagine Batholith. Angular clasts of andesite-dacite up to 20 cm across are quite common. About 8 km southwest of Warrawagine, a thin, laminated, *dark-grey siliceous limestone and dolomite* (Ᵽk) unit with associated pisolitic tuff (unmapped) occurs close to the base of the formation.

A gently dipping amygdaloidal and porphyritic *basalt* (Ᵽb) unit rests unconformably on the Archaean rocks at Cattle Gorge, and appears to underlie the Eel Creek Formation (see below). This basalt resembles the Mount Roe Basalt.

The *Koongaling Volcanics* Ᵽfi; Hickman, 1957a) is composed of felsic and intermediate lava with subordinate pyroclastic rocks. Bedding is rarely preserved, and a cataclastic foliation generally overprints the rocks.

Rhyolite flows show well-developed, commonly contorted, flow banding, with phenocrysts of perthite. Tuffaceous varieties are now chiefly represented by chlorite or sericite schist but relict pyroclastic textures are normally preserved. Agglomerate composed of angular rhyolite clasts is a rare constituent.

The base of the Koongaling Volcanics is not exposed, but east of the Isabella Range the formation grades downwards into granophyre (Ᵽgy). The contact between the two rock types is difficult to map accurately because the rocks are of similar appearance, a reflection of their similar chemical composition (Table 1).

The *Hardey Sandstone* (Ᵽfh; MacLeod & others, 1963) conformably overlies the Mount Roe Basalt between Bamboo and Yarrie homestead. It attains its maximum thickness of 1000 m, 10 km northeast of Coppin Gap. Eastwards, the Hardey Sandstone wedges out rapidly, offlapping against the Mount Roe Basalt and overlapped by the Kylena Basalt.

The Hardey Sandstone consists principally of *sandstone, grit, and conglomerate* (mapped as Ᵽfhg). *Wacke and poorly sorted sandstone with minor tuff and shale* (mapped as Ᵽfhw) forms a basal unit in the Bamboo Creek area. Minor intercalations of *shale, mudstone, siltstone, and tuff* are mapped as Ᵽfhs.

The *Kylena Basalt* (Ᵽfk; MacLeod & de la Hunty, 1966) conformably overlies the Hardey Sandstone at Bamboo and is separated from the Mount Roe Basalt by the Bamboo Creek Porphyry southwest of Warrawagine. In the Isabella Range, the contact with the Koongaling Volcanics appears to be conformable but a hiatus (the period of time in which, elsewhere, the Hardey Sandstone was deposited) may be present. The formation varies in thickness from 300 to over 500 m and is composed of massive amygdaloidal and vesicular basalt, andesite, and minor felsic volcanic rocks.

TABLE 1. CHEMICAL COMPOSITION OF THE KOONGALING VOLCANICS AND ADJACENT GRANOPHYRE

GSWA No.	Koongaling Volcanics (Ꝑfi) 38018	38023	Granophyre (Ꝑgy) (38004A, 38007, 38012)
MAJOR OXIDES (%)			
SiO_2	70.1	70.7	73.9
TiO_2	0.41	0.44	0.27
Al_2O_3	12.1	12.4	12.0
Fe_2O_3	2.8	2.3	2.3
FeO	2.42	3.23	1.74
MnO	0.08	0.10	0.06
MgO	0.4	0.3	0.1
CaO	1.53	0.93	0.75
Na_2O	3.40	3.45	3.83
K_2O	5.1	5.9	5.4
H_2O^+	0.49	0.35	0.22
H_2O^-	0.17	0.15	0.13
CO_2	1.13	0.58	0.07
P_2O_5	0.12	0.11	0.05
TOTALS	100.25	100.94	100.82
TRACE ELEMENTS (ppm)			
Ba	1090	1410	950
F	140	350	340
Li	10	10	10
Rb	125	180	220
Sn	5	5	5
Sr	40	50	35
U	1	1	3
Zr	720	760	640
Rb/Sr	3.1	3.6	6.3

Sample locations: Column 1. Lat. 21°03′40″S, long. 121°07′40″E.
2. Lat. 21°03′40″S, long. 121°06′00″E.
3. Mean of three samples from the Nullagine Sheet area.

Flows are coarser grained at their bases and vesicular near their tops, and rarely exceed 4 m in thickness. Carbonation is widespread, and mafic minerals may be replaced by tremolite and chlorite while epidote or clinozoisite commonly replace feldspar.

Agglomerate (Ꝑfkv) locally forms a central part of the Kylena Basalt, a feature also noted in the adjacent Nullagine and Marble Bar Sheet areas. *Laminated limestone and dolomite* (Ꝑk), including cross-bedded sandy dolomite, form units up to 30 m thick in the Ulalling Hills area. Within the Kylena Basalt, units of ripple-bedded carbonate (generally only a few metres thick) are widespread, and in the Isabella Range contain stromatolites similar to those in the overlying Tumbiana Formation. *Black shale and siltstone* (Ꝑz) and *tuff, tuffaceous shale, mudstone, and siltstone* (Ꝑt) form minor parts of the Kylena Basalt in the Isabella Range.

The *Tumbiana Formation* (Ꝑft; Noldart & Wyatt, 1962) is made up of two members, the lower *Mingah Tuff Member* (Ꝑftt) and the *Meentheena Carbonate Member* (Ꝑftc), both defined by Lipple (1975). The tuff is pisolitic, and the carbonate unit is a dark-grey siliceous rock characterised by wavy lamination and stromatolites. Between Bamboo and Warrawagine, the Mingah Tuff Member is about 100 m thick and the Meentheena Carbonate Member varies from 20–50 m. In the Isabella Range the total thickness of the formation is generally about 20 m. Here, thin units of banded chert, bedded pisolitic tuff, and mudstone are interbedded with the carbonate member; the Mingah Tuff Member is not present.

Thick, massive flows of vesicular and amygdaloidal basalt make up the *Nymerina Basalt* (Ꮲfn; MacLeod & de la Hunty, 1966). Some flows are coarse-textured, containing interlocking oligoclase laths and glomeroporphyritic clinopyroxene phenocrysts. The formation is 200–300 m thick between Bamboo and Warrawagine.

The *Pearana Basalt* (Ꮲfp; Hickman, 1975a) conformably overlies the Tumbiana Formation in the Isabella Range area. Most of the formation is indistinguishable from the Kylena Basalt but large phenocrysts of plagioclase near the top of the formation may be diagnostic. Interbedded micaceous siltstone, banded chert, pisolitic tuff, and dolomite also occur at this level, heralding a long period of sedimentation in which the Lewin Shale was deposited.

The *Kuruna Siltstone* (Ꮲfs; MacLeod & de la Hunty, 1966) is up to 20 m thick and comprises sandstone, siltstone, and shale.

The *Maddina Basalt* (Ꮲfm; MacLeod & de la Hunty, 1966) is about 100 m thick, and is lithologically similar to the Kylena Basalt.

Outcrops of *Lewin Shale* (Ꮲfl; de la Hunty, 1964) occurring 15 km east of Bamboo and 13 km south-southwest of Warrawagine consist of shale, mudstone, and chert with intercalations of sandstone and dolomite. *Basaltic lava* (Ꮲflb) occurs 15 km south of Baramine. The succession resembles that in the Braeside area of the Nullagine Sheet area. Northwards from Braeside, felsic and intermediate lava and pyroclastic units are developed in place of the basalt.

In the Baramine homestead area, the Lewin Shale comprises a lower felsic volcanic sequence, herein formally named the *Baramine Volcanic Member* (Ꮲfly), and an upper sequence of fine-grained clastic rocks. The Baramine Volcanic Member conformably overlies the Pearana Basalt and is approximately 250 m thick in the type area 5 km southeast of Baramine homestead (20°52′S, 120°58′E). A basal unit of banded chert and dolomite is overlain by carbonated tuff, breccia, and agglomerate of felsic and intermediate composition. Carbonated mafic and felsic lavas are dispersed throughout the member. Greywacke derived from these rocks exhibits cross-bedding and turbidite structures. Near the top of the member are lenses of coarse agglomerate containing angular fragments of intermediate lava and occasional blocks of stromatolitic dolomite. Fine-grained dolerite dykes and sills are relatively common in the member. The upper, clastic part of the Lewin Shale in this area is composed of well-bedded cherty mudstone, shale, and cross-bedded siltstone.

The Lewin Shale is correlated with at least part of the Jeerinah Formation (de la Hunty, 1965) while the Baramine Volcanic Member may be a lateral equivalent of the Nallanaring Volcanic Member (Williams, 1968) of the Yarraloola Sheet area.

Hamersley Group

The *Carawine Dolomite* (Ꮲhc; Talbot, 1920; Noldart & Wyatt, 1962) conformably overlies the Lewin Shale and is unconformably overlain by the Pinjian Breccia. Varying in true thickness up to 100 m, the formation consists of brown-weathered, massive to well-bedded, grey dolomite. In most exposures, bedding is difficult to recognise but some intervals are finely laminated. Cherty silica forms thin beds and veins near the top and base of the formation. L. Golding (Electrolytic Zinc Company of Australasia Ltd, personal communication, 1982) discovered well-preserved stromatolites 8 km east-southeast of Chukuwalyee Pool (20°53′S, 120°53′E). K. Grey (GSWA, personal communication, 1982) describes these as small domes developing into small branching columns containing very fine lamination. The stromatolites probably represent a new group and form requiring systematic description.

Stromatolites were also noted during the 1974 mapping, at a locality 3 km to the west-northwest of that referred to above.

Early or Middle Proterozoic sedimentary units

The *Pinjian Breccia* (Pcb; redefined from Pinjian Chert Breccia of Noldart & Wyatt, 1962; see Appendix 1) is an irregular residual and replacement deposit unconformably overlying the Carawine Dolomite. Angular chert fragments are cemented by a cherty matrix locally rich in manganese and iron oxides. Where fragments are absent, the rock is indistinguishable from Tertiary cap rock *Tr*. In the Nullagine Sheet area, this unit is unconformably overlain by Middle Proterozoic rocks.

The *Eel Creek Formation* (Pe), herein named and defined, derives its name from Eel Creek (20°34′S, 120°20′E), the headwaters of which constitute the type area. The formation is 475 m thick and contains gently dipping shale, sandstone, and conglomerate units intruded by dolerite sills. The basal member is a *hematite conglomerate* (Pec), up to 50 m in thickness, composed of sub-rounded clasts of hematite and chert (up to 5 cm in diameter) in a ferruginous matrix. Ferruginous siltstone, sandstone, and grit are interbedded with the conglomerate, the whole unit resting with high angular unconformity on Archaean rocks.

Fissile, dark-grey shale and grey-green mudstone overlying the conglomerate attains a thickness of approximately 300 m. Minor siltstone and lithic sandstone also occur in this unit, and Traves & others (1956) recorded dolomite.

Quartz sandstone (Pes), at least 125 m thick, forms the highest part of the Eel Creek Formation exposed. It is composed of medium to coarse-grained, cross-bedded sandstone beds up to 2 m thick with fine sandstone and rare shale. The sandstone is well sorted but contains sparse clay pellets and pebbly lenses. Asymmetrical ripple marks and weathered pyrite casts are common. The member is unconformably overlain by Permian rocks.

An Eel Creek Formation–Hardy Sandstone correlation cannot be discounted, as the former appears to overlie unnamed basalt (Pb), which resembles the Mount Roe Basalt, at Cattle Gorge. Hickman (in press) has suggested that the unit might be correlated with the Waltha Woora Formation of the Nullagine Sheet area.

Minor intrusive rocks

Gabbro (Po) and *dolerite* (Pd) dykes and sills intrude the Fortescue Group and the Eel Creek Formation. Most of the masses are relatively fresh and undeformed.

Quartz-plagioclase porphyry (Pp) forms dykes and sills intruding the Proterozoic succession. A sill up to 1000 m thick within the Hardey Sandstone between

Bamboo and Warrawagine was named the 'Bamboo Creek Porphyry' by Noldart & Wyatt (1962). Its intrusive nature is indicated by the existence of a Ᵽp dyke in the Tumbiana Formation 10 km northeast of Bamboo and, according to Traves & others (1956, pp. 15–16), by feldspathisation of the overlying Hardey Sandstone at the sill's upper contact. Hornblende adamellite (Ᵽgh) stocks intrude the sill 10 km northeast of Coppin Gap, and also cut the porphyry (Ᵽp) dyke in the Tumbiana Formation (noted above). The porphyry of the sill consists of corroded and sericitised plagioclase and carbonated microcline phenocrysts.

Trendall (1975) dated ten samples collected from Bamboo at 2820 ± 516 m.y. (recalculated to 2760 ± 516 m.y. by de Laeter & others, 1981), and R. T. Pidgeon (ANU, personal communication, 1980) used the U-Pb method to date zircon from the Spinaway Porphyry (a correlated unit, Hickman, 1978, p. 14) at 2768 ± 24 m.y. A Rb-Sr date of 2124 ± 195 m.y. has also been obtained on the Spinaway Porphyry (Trendall, 1975).

Hornblende porphyry (Ᵽph) dykes and sills associated with *hornblende adamellite and quartz-monzonite* (Ᵽgh) intrude Archaean rocks and the lower part of the Fortescue Group west of Miningarra Creek (20°55′S, 120°20′E). The porphyry contains phenocrysts of euhedral oligoclase and hornblende within a fine groundmass of quartz and feldspar. The hornblende adamellite is a medium, even-grained granitic rock with randomly oriented hornblende laths partly altered to chlorite. Where it invades mafic igneous rocks, assimilation is common.

Granophyre (Ᵽgy) thought to represent a high-level intrusive feeder of the Koongaling Volcanics, crops out east of the Isabella Range. Large, rounded phenocrysts of microcline are set in a granophyric intergrowth of quartz and perthite with clots of biotite.

Middle Proterozoic rocks

Sandstone, shale, and carbonate rocks (Ᵽq, Ᵽc, Ᵽs below) in the sand country east of the Ulalling Hills (20°49′S, 121°00′E) form a probable extension of the Middle Proterozoic Yeneena Group (Williams & others, 1976).

Poorly bedded *quartz sandstone* (Ᵽq) with siliceous cement occurs at several levels in the group. The basal unit is a thin sandstone tentatively correlated with the Coolbro Sandstone (formerly Bocrabee Sandstone of de la Hunty, 1964).

Carbonate rocks (Ᵽc), including well-bodied dolomite, dolomitic sandstone, limestone, and arenaceous and shaly beds, onlap northwards across the Fortescue Group. All the arenites contain discrete grains of dolomite and quartz with accessory muscovite, tourmaline, and opaques. Cross-bedding and scour structures are common.

Intercalated *shale* units (Ᵽs) within the group lack bedding but possess a well-developed slaty cleavage.

PALAEOZOIC

The *Paterson Formation* (Pa; Talbot, 1920; Traves & others, 1956) consists of a basal unit of massive to poorly bedded blue-grey sandy mudstone containing abundant clasts of Proterozoic and Archaean rocks up to 1 m in diameter (dropstones), some of which are faceted and striated (Pal), and an upper unit of fine to coarse-grained cross-bedded sandstone and conglomerate (Paf). Varved(?) shale with dropstones and graded sandy units overlies the lower unit 6 km northwest of Cabbage Tree Well (20°36′S, 120°24′E). The lower unit weathers rapidly leaving eluvium and colluvium mapped as Qep.

The thickness of the formation ranges up to 250 m, a figure recorded in a drillhole 16 km east of Warrawagine (drilled by Sentinel Mining Company). Spore and pollen grains in samples from drillholes 18 km northeast of Warrawagine give an Early Permian (late Sakmarian) age, and suggest a non-marine origin for the host mudstone (Backhouse, 1976). The lack of sorting, a mud matrix, the presence of faceted and striated clasts, and the great variety of rock types present in the lower unit indicate a glacial origin. The varved(?) shale near Cabbage Tree Well may be of lacustrine origin. The upper unit is interpreted to be fluviatile, possibly deposited by braided streams.

The *Grant Group* (Pg; Guppy & others, 1952; Crowe & Towner, 1976) was intersected in GSWA groundwater bore 25C in the Mandora Sheet area, about 10 km north of GSWA bore site 24. A section drawn between these bores (see accompanying map) indicates that the Grant Group may extend into the Yarrie Sheet area. In bore 25C, it is at least 357 m thick, and consists of interbedded siltstone, claystone, and sandstone. Palynomorphs indicate an Early Permian age (Leech, 1979).

The *Poole Sandstone* (Pp; Guppy & others, 1952) is present in the extreme southeast of the the Sheet area. Traves & others (1956) originally mapped this as the 'Cuncudgerie Sandstone', but Towner & others (1976) showed that outcrops of this unit in the south Canning Basin correlate with the Poole Sandstone, and suggested the term 'Cuncudgerie Sandstone' be dropped. This correlation was confirmed by mapping in 1977 (Towner & Gibson, 1980).

The Poole Sandstone in the area consists of very fine to fine-grained sandstone interbedded with mudstone. The sandstone is poorly sorted, and cross-bedding, ripple marks, and burrows are present. Macrofossils from Cuncudgerie Hill, Paterson Range Sheet area, indicate an Early Permian (late Sakmarian) age (Dickins & Thomas *in* Traves & others, 1956). It is probably a shallow-marine deposit.

MESOZOIC

The *Wallal Sandstone* (Jl; McWhae *in* WAPET, 1961) is the basal unit of the Jurassic-Cretaceous rocks in the area. It is not known to crop out in the western Canning Basin, but has been recognised in water-bores drilled by GSWA in the northwestern part of the Sheet area, where it underlies fine-grained rocks of the Jarlemai Siltstone. It was defined from core taken from BMR 4A (Wallal) drillhole (Henderson & others, 1963), in the Mandora Sheet area, and is made up of sandstone with minor siltstone and conglomerate; it is probably a continental to marginal marine deposit.

The maximum known thickness of the formation in the Sheet area is 151 m in GSWA bore 24A (Leech, 1979). Micropalaeontological examination of palynomorphs and microplankton from the Wallal Sandstone in GSWA water-bores in the Yarrie and Port Hedland Sheet areas indicate a Late Jurassic (Oxfordian) age (J. Backhouse, GSWA, personal communication, 1979). However, determinations from BMR Wallal 4A (Henderson & others, 1963) and WAPET Samphire Marsh 1, which is about 55 km north of the Sheet area (WAPET, 1961), indicate that the Wallal Sandstone is probably of Middle to Late Jurassic age.

The *Jarlemai Siltstone* (JKr; Brunnschweiler, 1954) is a unit of marine mudstone and minor sandstone deposited at the height of the Jurassic-Cretaceous marine transgression in the Canning Basin. It does not crop out in the western Canning Basin, but has been recognised in the GSWA water-bores in the Sheet area. It is not known whether it conformably or disconformably overlies the Wallal Sandstone in the area. Maximum known thickness of the Jarlemai Siltstone in the Sheet area is 74 m in GSWA bore 24A (Leech, 1979); it pinches out in the subsurface near the basin margin. Palynomorphs and microplankton from GSWA drilling in the area indicate a Late Jurassic (late Oxfordian to Kimmeridgian) age (J. Backhouse, GSWA, personal communication, 1979).

The *Callawa Formation* (JKc; Reeves, 1951; Traves & others, 1956) disconformably or unconformably overlies the Jarlemai Siltstone and Wallal Sandstone. It overlaps these units and unconformably overlies the Paterson Formation near the edge of the Canning Basin. It consists of cross-bedded, very fine to coarse-grained sandstone and conglomerate, and minor siltstone. It was probably deposited in a fluviatile environment. Conglomerate dominates over sandstone at the type section of the unit near the head of Eel Creek (20°31′S, 120°21′E).

The thickness of the complete formation is about 70 m near the Shay Gap borefield (20°18′S, 120°13′E) and incomplete sections up to 61 m thick were measured by Traves & others (1956). Maximum thickness is probably about 100 m. Plant fossils present in the Callawa Formation in the Sheet area have been considered to be Triassic or Jurassic (Brunnschweiler *in* Traves & others, 1956), and Late Jurassic or Early Cretaceous (White *in* Veevers & Wells, 1961); the latter age is more likely, as the underlying Jarlemai siltstone is of Late Jurassic age.

The *Parda Formation* (Kp; Lindner & Drew *in* McWhae & others, 1958) disconformably overlies the Callawa Formation. This unit was erroneously identified as Anketell Formation by Wells (1959) on the first edition of the Yarrie Sheet. It consists of thin-bedded to massive mudstone with some fine sandstone lenses, and in many places grades up into pisolitic laterite (Czd). The Parda Formation is white in outcrop, and is easily recognised on aerial photographs. The formation probably reaches 20 m in thickness in the Sheet area. It is thought to be of Aptian age because outside the Sheet area it overlies and underlies rocks of probable Aptian age (Towner & Gibson, 1980). It is probably a shallow-marine deposit; unidentifiable bivalves have been found in it outside the Sheet area (Towner, 1982c).

Outcrops of ferruginised, partly bioturbated, poorly sorted, coarse-grained sandstone, with conglomerate and minor siltstone in the far northeast of the Sheet area may belong to the *Frezier Sandstone* (Kf; Lindner & Drew *in* McWhae & others, 1958). A maximum of 15–20 m is exposed. Observations elsewhere in the Canning Basin indicate that the Frezier Sandstone probably overlies the Parda Formation disconformably, and is probably a fluviatile to deltaic deposit (Towner & Gibson, 1980). It has been dated as Early Cretaceous (possibly Aptian) by Dickins (*in* Veevers & Wells, 1961) on the basis of rare bivalves.

CAINOZOIC

The *Oakover Formation* (To; Noldart & Wyatt, 1962) is a 5–30 m thick, vuggy silicified calcrete (opaline silica) containing beds of calcareous sandstone. Generally the formation forms mesas, but east of the Isabella Range large expanses of calcrete, which may be part of the Oakover Formation, crops out at the same level as the sand plain of the desert.

The formation is thought to be a chemical precipitate deposited over, and adjacent to, rocks rich in calcium and magnesium (e.g. Carawine Dolomite and carbonate rocks of the Yeneena Group). It may have been deposited on a poorly drained terrain, or be lacustrine in origin.

Fine-grained *siliceous cap-rock* (Tr), commonly chalcedonic, and in places passing laterally into the Oakover Formation, replaces carbonate rocks of the Carawine Dolomite and Yeneena Group. Part of the Pinjian Breccia which lacks angular chert clasts is indistinguishable from the siliceous cap-rock and may have been mapped in this unit.

Flat-topped benches and mesas of *pisolitic limonite, goethite, and hematite* (Tp) containing fossil wood, are correlated with the Poondano Formation (McWhae & others, 1958; Hickman & Gibson, 1982). This unit is usually developed near Archaean banded iron formations.

Pedogenic sand and gravel (Czs) overlying laterite forms undulating areas devoid of aeolian sand, especially in the northeastern part of the Sheet area. The gravel is sandy and poorly consolidated, and contains ironstone pisoliths and pebbles of ferruginised sandstone.

Laterite (Czd) overlies a range of rock types but is best developed over the Parda Formation and Archaean banded iron formation. The laterite is a ferruginous duricrust, locally including consolidated breccia and ferruginous sandstone.

Calcrete (Czk) is a pedogenic accumulation of carbonate in soils, and occurs as massive, nodular, and vuggy sandy limestone.

Aeolian sand (Qs) chiefly occurs as seif dunes and sand sheets in the Great Sandy Desert. In other areas Qs has banked up on the windward (southeast) side of northerly trending rock ridges. The unit is composed of fine to medium-grained red-brown and yellow quartzose sand with minor reddish-brown silt.

Eluvial sand (Qeg) over granitic rocks consists of quartz and feldspar grains with scattered fragments of granite, pegmatite minerals, and vein quartz. The sand may be partly reworked by wind action.

Eluvial and minor colluvial pebbly sand and silt (Qep) blankets much of the Oakover valley and forms isolated patches in the Great Sandy Desert. Grains are well-rounded (in contrast to those of colluvium) and of mixed lithology. Qep overlies the Paterson Formation and river gravels.

Aeolian sand containing laterite pebbles (Qp) occurs in areas of aeolian sand close to outcrops of laterite. The pebbles of lateritic material are sub-rounded, measure less than 5 mm in diameter, and are concentrated in the upper 10 mm of the deposit.

Colluvium (Qc) of lithic sand, gravel, and boulders, forms scree and outwash fans along the margins of hills. Clasts are angular and derived locally. Much of the colluvium is dissected by the present drainage system.

Alluvium (Qa) comprises sand, silt, and gravel in rivers and creeks. The unit also includes sediments no longer being reworked, such as those of the alluvial plain of the De Grey River. In many areas this older alluvium forms ground 10–20 m higher than the present river bed.

Heavy soil (Qb) or 'black soil' is a clay deposit containing pebbles and boulders, developed on poorly drained flats in the Oakover and De Grey valleys; it is particularly common on abandoned drainage courses and flood plains. Gilgai structures (with 'melon' or 'crab' holes) are common in this unit.

STRUCTURE

PILBARA BLOCK

Mapping of the Marble Bar (Hickman & Lipple, 1975, 1978) and Nullagine (Hickman, 1975a, 1978) Sheet areas has revealed five generations of major and minor structures.

D1: Polyphase isoclinal interfolding of greenstone and granitic material accompanied by granitic intrusion, migmatisation, and development of schistosiy S1.

D2: 'Main' deformation forming diapiric granitic domes (emplaced tectonically) and synclinoria containing the layered succession; regional schistosity S2; greenschist to amphibolite facies metamorphism (domes and synclines probably formed at slightly different times in different areas); climax of deformation and metamorphism reached at about 3070 to 2950 m.y.; granitic intrusion; post-tectonic granitic intrusion (about 2600 m.y.) followed.

D3: Conjugate folding and faulting; associated crenulation cleavage (S3) deforms S2; dyke and quartz intrusion.

D4: Minor open recumbent folding; relations to D3 uncertain.

D5: Proterozoic deformation (post-2500 m.y.).

Figure 2 delineates the major structural units, and Figure 3 shows main folds, faults, and stratigraphic units.

In the Yarrie Sheet area, D1 structures are confined to the Muccan and Warrawagine Batholiths and are represented by ultramafic dykes and xenoliths shown on the map, dolerite dykes penetrated by S2, and gneissic and stromatic banding within the granitic rocks. This banding is locally folded by structures of probable D2 age. Fold structures similar to these, found in the adjacent Port Hedland Sheet area, possess an axial plane schistosity which grades into S2. The S2 overprinting establishes that the granitic complex largely pre-dates D2.

The granitic domes and greenstone synclinoria were formed by differential vertical movements during D2. The domes are ovoid in plan and up to 100 km in diameter. Surface geology and Bouguer gravity anomaly patterns suggest steep-sided walls to the domes which merge at depths of 10–20 km. The intervening greenstone synclines are intruded at deeper structural levels by pegmatitic, syntectonic granitic intrusions, and are generally characterised by amphibolite facies metamorphism.

In comparison with most granite domes of the Pilbara Block, granitic batholiths in the Yarrie Sheet area are unusual because S2 does not rim the domes, as is generally the case elsewhere (Hickman, 1975b), and because the northern margin of the Mount Edgar Batholith is clearly intrusive. As can be seen in Figure 3, the orientations of S2 (foliations on the accompanying map) indicate that the Warrawagine and Muccan Batholiths may be structurally parts of the same dome, despite the intervening Shay Gap Syncline. The angular margins of the Muccan Batholith may thus reflect horst movement between normal faults. Such fault-controlled emplacement of domes is evident in the Nullagine Sheet area at the eastern contacts of the Mount Edgar Batholith. The northern margin of the Mount Edgar Batholith is clearly intrusive because several plutons and stocks penetrate the Warrawoona Group. Because S2 extends through these plutons and stocks, and because they are passive intrusions (the adjacent Warrawoona Group having been digested rather than forced aside), it is concluded that they probably pre-date the main doming event. Their emplacement contrasts with the forceful, essentially solid state diapirism evident in most of the Pilbara batholiths.

D2 minor folds are best displayed in banded iron formation and ferruginous sediments. Northeast and southeast from Yarrie homestead minor D2 folds plunge in opposite directions, in harmony with the geometry of the Shay Gap Syncline. Minor D2 folds are also excellently displayed in the gorge walls of Coppin Gap.

Three important D2 faults have been recognised. The Marble Bar Belt (Fig. 2) in the southwestern corner of the Sheet area is separated from the Muccan Batholith by a tectonic slide. This slide is a normal fault replacing the northern limb of a westerly trending syncline. Between Bamboo and Coppin Gap an arcuate normal fault, subsequently intruded by ultramafic and mafic rocks, displaces part of the southern limb of the same syncline, bringing the Warrawoona Group into tectonic contact with the Gorge Creek Group. The third fault is a northerly striking vertical plane of movement close to the axis of the Shay Gap Syncline. The direction of movement on this and an associated branch fault through the Eel Creek area have not been deduced but the outcrop pattern suggests that Archaean movement on the branch fault was west-block-up, while the main fault was either west-block-down or a sinistral wrench.

D3 structures are rare in the Yarrie Sheet area. Angular kinks and conjugate minor folds occur sporadically in banded iron formation. Faults (commonly occupied by quartz veins), unrelated to D2, resemble structures of D3 generation in other Sheet areas.

D4 structures have not been noted in the area.

Proterozoic deformation (D5) of two types has affected the district. Between Bamboo and Warrawagine the Oakover Syncline is an open, southeasterly plunging syncline, whereas its eastern flank in the Isabella Range area is dislocated by a series of northwesterly striking normal faults that downthrow to the southwest. These faults are genetically related to intervening fold-pairs. The folds are upright, plunge gently northwards, and are open to tight in style. Western limbs of anticlines are systematically slid out along the faults, which are typically bordered by steep-dipping and extensively cleaved beds. Shearing in fault zones has produced a cataclastic foliation. In less deformed areas between the faults, the axial plane cleavage of the fold system is only weakly developed.

Paterson Province

In style and orientation, folds in the Middle Proterozoic Yeneena Group east of Ulalling Hills resemble the folds in the Lower Proterozoic rocks of the Isabella Range. An axial plane cleavage is developed in sandstone and shale units, but faulting assumes a relatively minor role in the deformation. It is uncertain if the folds are of D5 age or belong to a later episode of deformation. If the latter alternative is accepted, the Lower Proterozoic rocks must have remained extremely stable during this episode since they contain no refolded folds and S5 is not visibly deformed.

Canning Basin

Phanerozoic rocks in the Yarrie Sheet area are only gently deformed. The Permian Paterson Formation was gently folded or tilted before deposition of the Jurassic to Cretaceous Callawa Formation. GSWA water-bore drilling in the northwest of the area (Leech, 1979) shows that the Mesozoic rocks dip at less than 1° to the north, and similar low dips are probably present over the rest of the Canning Basin in the area. No faults have been observed.

GEOLOGICAL HISTORY

Deposition of the Archaean layered succession (now referred to as the Pilbara Supergroup, Hickman, in press) commenced at about 3600 to 3550 m.y. (Hamilton & others, 1980; Jahn & others, 1981). The oldest unit, the Talga Talga Subgroup, is up to 4 km thick and consists of massive tholeiite, pillow tholeiite, dolerite sills, and minor chert, banded iron formation, carbonate schist, siltstone, shale, felsic lava, and komatiite. Outcrops of this unit in the Yarrie Sheet area are restricted to the southwest where it is intruded by granodiorite and adamellite of the Mount Edgar, Muccan, and Warrawagine Batholiths. The underlying basement to this volcanic pile was probably a thin sialic crust composed of reworked granitic, volcanic, and sedimentary material (Hickman, 1975b, and in press; Hickman & Lipple, 1978). Following local deformation, a calc-alkaline sequence of andesitic, dacitic, and rhyolitic lavas, pyroclastics, and breccia flows was erupted at various volcanic centres across the Pilbara Block. This formation, the Duffer Formation, has been dated at 3452 ± 16 m.y. by the U-Pb method on zircons (Pidgeon, 1978a), 3500 m.y. by the Pb-Pb method on galena (Sangster & Brook, 1977), 3450 m.y. by the Pb-Pb method on galena (15 precise isotopic assays by Richards & others, 1981), and 3550 ± 30 to 3520 ± 30 m.y. by the Sm-Nd method (M. McCulloch, California Institute of Technology, written communication, 1979), all samples coming from outside the Sheet area. Contemporaneous intrusion of granodiorite occurred in certain areas. Stable conditions then prevailed across the Pilbara Block, with the deposition of a 4 km-thick tabular succession of chert, pillow tholeiite, komatiite, and minor felsic volcanics (Salgash Subgroup). Sedimentary structures and stromatolites in chert units outside the Sheet area are indicative of shallow-water deposition.

Between about 3400 m.y. and 2950 m.y. (the latter date being the time of a major metamorphic event recognised by Oversby, 1976) large-scale domes and synclines began to develop in response to inverted density stratification (Hickman, 1975b). Early deformation and upward diapiric movement of the granitic substratum (already a plutonic complex) was followed by erosion, extrusion of rhyolite (Wyman Formation), and deposition of banded iron formation and clastic sediments (Gorge Creek Group). The precise age of the Gorge Creek Group is still poorly defined within the 3400–3000 m.y. range. Following a culmination of deformation at 2950 m.y., post-tectonic adamellite and granite plutons were intruded in the southwest (dated by most Rb-Sr geochronology at about 2600 m.y.).

Another period of extensive erosion at about 2800 m.y. preceded deposition of the Lower Proterozoic Fortescue and Hamersley Groups. The Mount Roe Basalt and the Hardey Sandstone are present only above the Archaean layered succession, indicating that at the beginning of Proterozoic times the landscape consisted of granitic hills with intervening lowlands underlain chiefly by mafic rocks.

Most of the lava flows forming the Fortescue Group were extruded from fissures, although vent eruptions were responsible for local agglomerate and tuff units. The Hardey Sandstone contains fluviatile and probably also lacustrine sediments (Hickman & de Laeter, 1977). Its thickness is extremely variable owing to its deposition in local basins which it appears to have almost filled. Subsequent formations covered most of the area, including the eroded granitic domes. The Tumbiana Formation is never more than 200 m thick yet it extends from the Isabella Range in the Yarrie Sheet area to Cape Preston in the west Pilbara (Hickman, in press), a distance of more than 500 km. This sheet-form geometry, its content of carbonate rocks, and the presence of algal fossils suggest that the Tumbiana Formation was deposited in fairly warm water on a shallow shelf. Shelf or lacustrine conditions were also responsible for the Lewin Shale and the Carawine Dolomite, formations which can be traced westwards over similar distances.

Emergence of the Carawine Dolomite was followed by chemical weathering, development of a karst topography, and deposition of the Pinjian Breccia, a silicified residual deposit. Proterozoic deformation, in the form of gravitational downwarping, commenced during infilling of the early basins, but tectonic activity at about 2300–2200 m.y. is indicated by a widespread metamorphic event across the Pilbara Block, and took place after deposition of the Carawine Dolomite. Intrusion of hornblende porphyry dykes and stocks may have occurred at the same time.

In the Nullagine Sheet area the Pinjian Breccia is unconformably overlain by the Waltha Woora Formation which is lithologically similar to the Eel Creek Formation (Hickman, in press). The Waltha Woora Formation may be older than, or form part of, the Yeneena Group (Hickman, in press), and the following sequence of events is suggested. Extensive erosion of the Pinjian Breccia and underlying formations of the Hamersley and Fortescue Groups was followed by deposition of conglomerate, sandstone, and dark-grey mud of the Eel Creek Formation in the Eel Creek area. The basal conglomerates were derived by erosion of local Archaean banded iron formation, and the sequence probably accumulated under fluviatile-lacustrine conditions. In the east, around the area now occupied by the Isabella Range, sandstone, carbonate, and mud (Yeneena Group) accumulated in a shallow-shelf environment, probably at about 1300 m.y. Dolerite sills intruded the Eel Creek Formation and the entire Proterozoic succession was deformed by northwesterly trending folds at about 1200 m.y. (a metamorphic event recognised by de Laeter & others, 1977).

There is no record of Lower Palaeozoic deposition in the Sheet area, and the oldest Phanerozoic rocks preserved are Permian fluvio-glacial deposits. Silt and sand with striated clasts up to boulder size were laid down in lakes and rivers under the influence of a glacial climate in Early Permian (Sakmarian) times (Paterson Formation). A transgression followed, and sand and mud were laid down in a shallow-marine environment probably in the north and east of the Sheet area (Poole Sandstone) in Early Permian (Artinskian) times.

The sea then retreated, and erosion followed. Deposition re-commenced in the Jurassic, with continental to marginal marine sand, gravel, and minor mud (Wallal Sandstone) being laid down. A relative rise in sea level in the Late Jurassic (Oxfordian) resulted in deposition of marine muds (Jarlemai Siltstone) over the coarser sediments. The sea then regressed from the area probably in Kimmeridgian times, and some erosion of the Jarlemai Siltstone may have taken place before the alluvial sand, gravel, and minor silt of the Callawa Formation was deposited in the

Late Jurassic to Early Cretaceous by rivers flowing from, and eroding, exposed basement areas and Paterson Formation to the south.

Most of the Sheet area was again inundated by the sea probably in Early Cretaceous (Aptian) times, and mud and very fine sand (Parda Formation) were deposited. After the sea withdrew from the area, probably still in the Aptian, alluvial to deltaic sediments (Frezier Sandstone) were deposited over the Parda Formation.

In the Cainozoic, thick calcrete (Oakover Formation) was deposited as a chemical precipitate in the Oakover/Nullagine valley. This unit has since been partly silicified. In addition, a variety of thin surficial sediments were deposited by alluvial, aeolian, and pedogenic processes.

ECONOMIC RESOURCES

Gold

Gold production from the Bamboo mining centre prior to 1976 was 2287.121 kg from 83 412 tonnes of ore. Of this, approximately two-thirds came from the Kitchener, Mount Prophecy, and Bulletin mines. During 1974 the Kitchener mine produced 7.533 kg and the Mount Prophecy mine 0.287 kg. Included in the centre's production is a small quantity of gold from mines 8 km south of Yarrie homestead, where 1.351 kg was dollied at the Friendly Stranger mine and 0.485 kg was obtained from 56 tonnes of ore at the Battler mine. Carbonated schist from the Battler mine assayed 2.4 ppm gold, 8.3 ppm silver, 2.56% zinc, 2700 ppm lead, 1400 ppm copper, and 440 ppm arsenic. An apparently untested quartz vein 4 km south of Yarrie homestead was also found to be auriferous during the 1974 mapping; maximum values from three samples were 3.7 ppm gold, 74.5 ppm silver, 6.4% copper, 295 ppm zinc, and 150 ppm lead.

Iron Ore

To the end of 1981, total production of iron ore from the Shay Gap mine was 26 100 000 tonnes with an average grade of about 63-64% Fe. The ore is high-grade hematite, essentially free from deleterious impurities (e.g. P content approximately 0.03%). According to Matheson & others (1965, p. 133) the main deposits at Shay Gap are similar to the No. 1 deposit at Mount Goldsworthy (70 km to the west-northwest) previously described by Brandt (1964, 1966). They are conformable lenticular lodes of massive hematite several hundred metres long, up to 50 m wide, and locally over 150 m deep. The deposits are believed to have formed by Archaean (clasts of ore are present in the Eel Creek Formation) supergene enrichment of the steeply dipping banded iron formation (Cleaverville Formation, part of the Gorge Creek Group) in which they occur.

Because the largest iron ore deposits of the Pilbara (e.g. Tom Price and Newman) are of Proterozoic age there has been speculation that the banded iron formation at Shay Gap might not be Archaean. However, two lines of evidence establish its Archaean age beyond reasonable doubt: (1) the Cleaverville Formation (Aci and Asf) 10 km south of Yarrie homestead is overlain with high angular unconformity by the Hardey Sandstone; and (2) the succession conformably overlying the Cleaverville Formation at Shay Gap is the same as that in the Gorge Creek Group in its type area (Lipple, 1975).

Other iron deposits occur at Cundaline Gap (Tertiary detrital goethite, Tp), 6 km northeast of Kimberley Gap (Proterozoic detrital hematite of Ꞓec), and at Cattle Gorge (hematite and goethite outcrop replacement of uncertain age; not shown on accompanying map).

Copper

No copper production has been officially recorded, although small-scale workings occur in the Isabella Range. Shallow workings 2 km southwest, 3 km south, and 11 km southeast of Baramine have been described by Blatchford (1925, p. 81) and Finucane (1938, pp. 7–8). Malachite, chalcocite, chalcopyrite, and cuprite occur in northwesterly striking quartz veins that intrude tuff, shale, and basalt of the Fortescue Group.

Other copper occurrences are located 8 km southwest of Callawa, 4 km and 7 km south of Yarrie, and 2 km and 3 km west of Coppin Gap. The Callawa and Yarrie occurrences are in quartz veins in ultramafic rocks, but at Coppin Gap, copper-molybdenum mineralisation is associated with porphyritic felsic and intermediate lava intruded by adamellite.

Silver, lead, and zinc

Up to the end of 1975, 14.917 kg silver had been produced as a by-product of gold mining at Bamboo. Silver has not been mined elsewhere but several occurrences were detected during the 1974 mapping. Apart from the auriferous quartz vein 4 km south of Yarrie homestead (noted above), samples from a cupriferous quartz vein 3 km west of Coppin Gap assayed 158 and 163 ppm silver.

Blatchford (1925, p. 81) states that a small 'lead vein' was worked near 'Camel Hump' (possibly at the copper mine 11 km southeast of Baramine), but no production is recorded and only traces of galena are now to be found (Finucane, 1938; Blockley, 1971). Two lead occurrences were discovered during the 1974 mapping, one 14 km east of Bamboo, and the other 3 km south of Coppin Gap. At the former, galena is disseminated through sheared Kuruna Siltstone. A 2 kg sample selected on the basis of its high galena content assayed 7.6% lead, 10.6 ppm silver, 530 ppm zinc, and 510 ppm copper while a gossan from the deposit returned 1.32% lead, 3.8 ppm silver, 930 ppm zinc, and 170 ppm copper. All four samples collected contained trace (0.2 ppm) gold. The Coppin Gap occurrence was found in a 1 m wide quartz vein intruding Archaean basaltic rocks. Maximum values obtained from three specimens of quartz were 1.35% lead, 11.9 ppm silver, 9200 ppm zinc, and 640 ppm copper.

No zinc production is recorded but values of over 1% zinc have been determined in sections of the copper-molybdenum deposit 2 km west of Coppin Gap, and a sample of gold ore from the Battler mine assayed 2.56% zinc. A low-grade zinc deposit may exist 2 km west-northwest of Myola Bore (21°00'S, 120°39'E) where gossanous quartz along a fault between Kuruna Siltstone and Maddina Basalt assayed 8500 ppm zinc.

Other minerals

A chromite-bearing serpentinite 7 km south of Bamboo assayed 3.15% chromium, 1800 ppm nickel, and trace gold and silver. Impersistent veins of talc about 30 cm thick are also present at this locality. Molybdenite occurs 2 km west

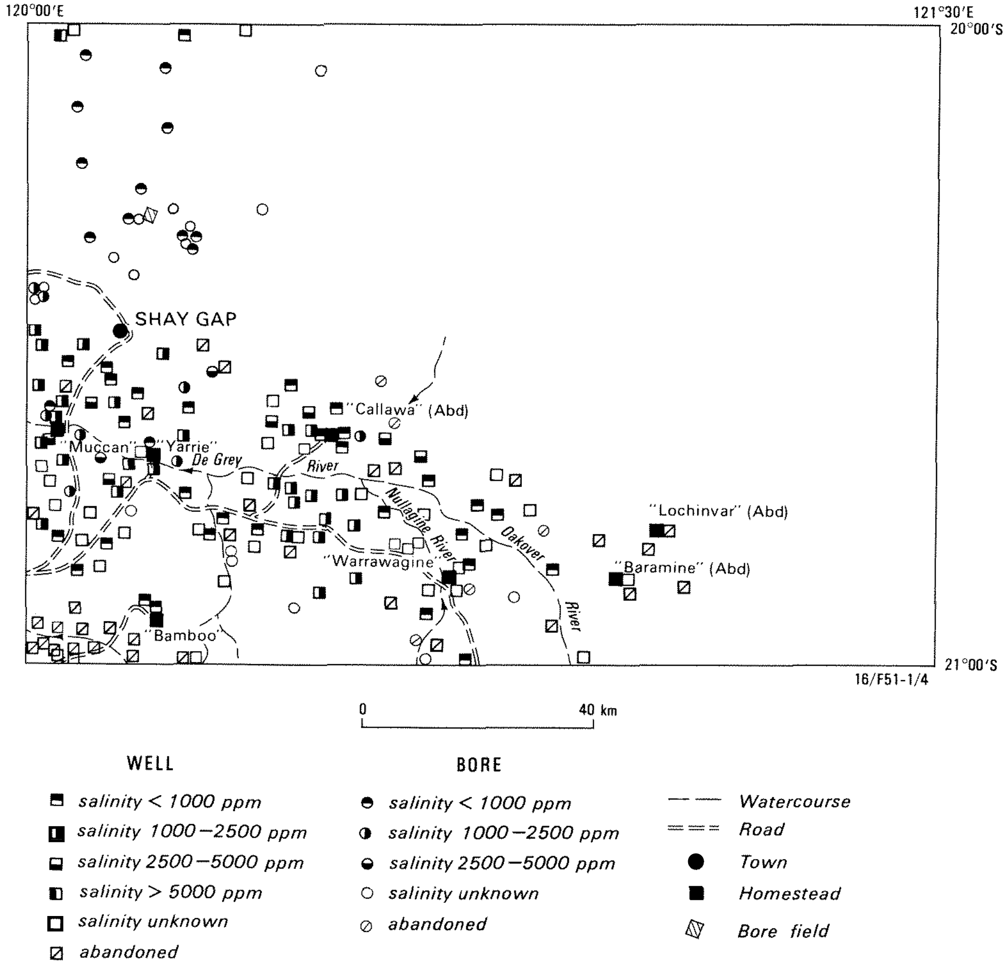

Fig. 4. Water supplies.

of Coppin Gap (Baxter, 1978), and fluorite is present in felsic porphyry (pЄp) near Ngarrin Creek at 20°52'S, 120°25'E (Hickman, 1976). De la Hunty (1963) records a 30 cm-thick stratiform manganese deposit (not shown on accompanying map) approximately 11 km north of Yarrie homestead.

Road-building materials

Numerous shallow pits for road-building materials have been developed (chiefly in colluvium and laterite) along the main roads and the Shay Gap railway. Crushed rock aggregate could be obtained from fresh outcrops of granite and dolerite across the Muccan Batholith.

Water supplies

Rivers and creeks flow intermittently during the wet season, but contain only isolated pools and rock holes for the remainder of the year. More than 150 wells and bores have been sunk in permeable surficial sediments, weathered rocks of the Pilbara Block, and aquifers in the Canning Basin sequence, chiefly for stock water requirements. The town of Shay Gap obtains good quality water from the Wallal Sandstone in a borefield about 22 km to the north.

A study has been made of the hydrology of the Canning Basin in the western part of the Sheet area, and in the adjoining Port Hedland Sheet area (Leech, 1979). This study shows that 58×10^9 m^3 of groundwater is present, mainly in the Wallal Sandstone, with salinities of 240 to 13 000 $mg.l^{-1}$. The Wallal Sandstone has a larger groundwater resource than any known aquifer in the Pilbara and West Kimberley regions of Western Australia.

An indication of groundwater quality in wells and bores in the Sheet area is given in Figure 4. Most salinities were measured in the field in 1974 using a conductivity meter.

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APPENDIX 1. Definition of Pinjian Breccia

NAME DERIVATION: Pinjian Pool, 20°59′S, 120°39′E, Yarrie 1:250 000 Sheet area.

DISTRIBUTION: Crops out between Pinjian Pool and Carrowina Pool (22°35′S, 121°02′E, Balfour Downs 1:250 000 Sheet area), and over an area of approximately 3000 km^2.

TYPE LOCALITY: Pinjian Pool (Noldart & Wyatt, 1962, p. 77).

LITHOLOGY: A residual and replacement deposit consisting of angular chert fragments cemented by a chert matrix. Local concentrations of manganese and iron oxides.

THICKNESS: Up to 100 m.

RELATIONSHIPS: Unconformably overlain by the Waltha Woora Formation (Noldart & Wyatt, 1962) and unconformably overlies the Carawine Dolomite (Maitland, 1919) (Carawine Dolomite Series; Talbot, 1920).

AGE: Lower or Middle Proterozoic, but see comments.

SYNONYMY: Named 'Pinjian Chert Breccia' by Noldart & Wyatt (1962). Renaming is necessary because only binomial names are acceptable under the New Stratigraphic Code.

COMMENTS: Where unconformities with overlying Middle Proterozoic and Permian formations are not preserved, it is difficult to distinguish the Pinjian Breccia from Tertiary cap rock (both contain the same components and were formed by the same mechanism).

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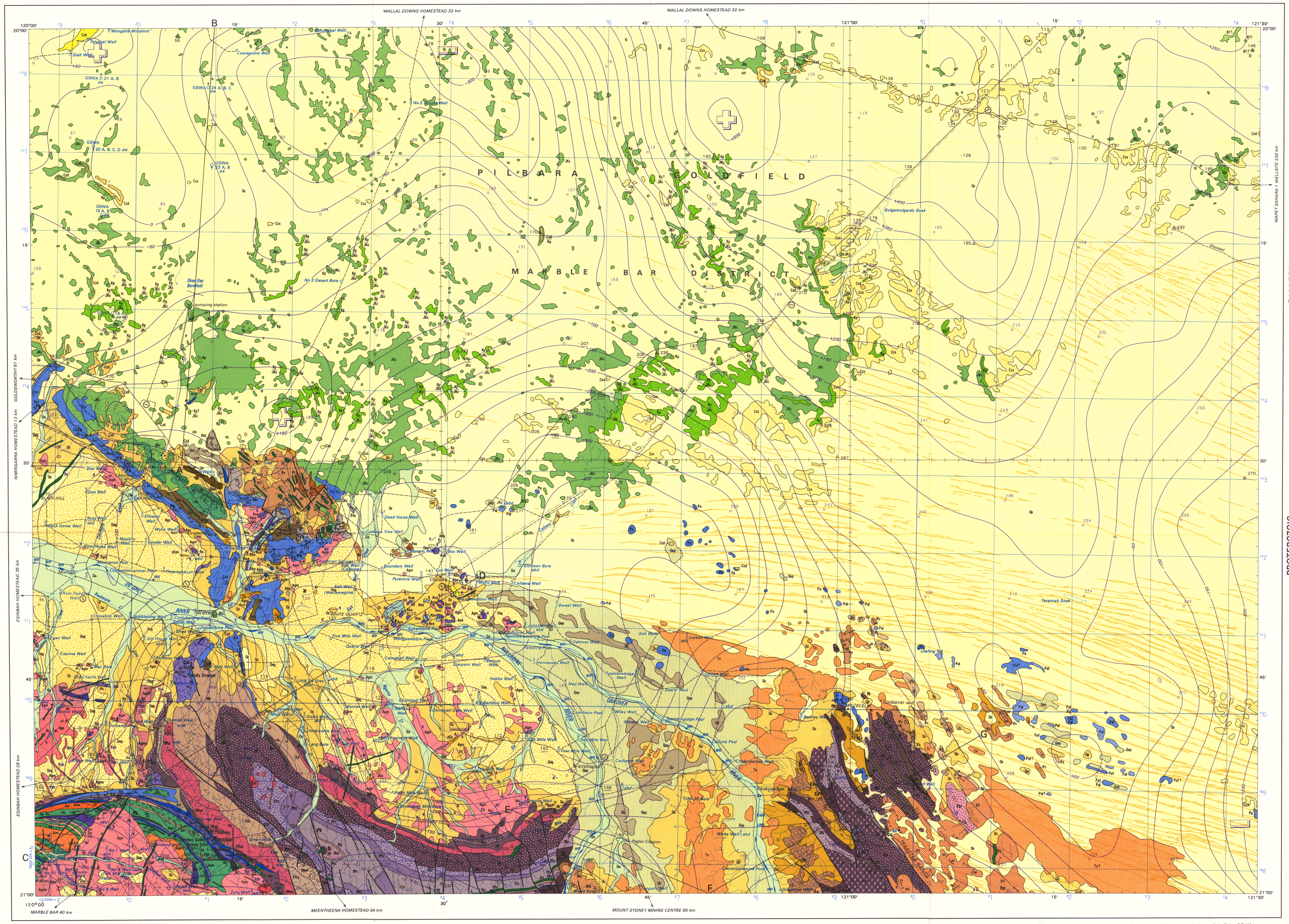
YARRIE

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

WESTERN AUSTRALIA

SHEET SF 51-1

Geological boundary
Anticline
Minor anticline
Minor syncline
Drag - fold
(arrowhead indicates trend of plunge and value indicates plunge value of fold axis)
Contorted bedding, showing plunge of minor folds
Fault
Shear zone
Where location of faults is inferred, line is broken and queried; where folds are concealed, line is dotted
Strike and dip of strata
Vertical strata
Horizontal strata
Strike and dip of strata, dip 5°–15° (airphoto interpretation)
Trend-line (airphoto interpretation)
Joint pattern (airphoto interpretation)
Top of bed indicated by cross-bedding
Top of bed indicated by graded bedding
Facing of pillow lava top
Strike and dip of foliation
Vertical foliation
Strike and dip of cleavage
Vertical cleavage
Trend and plunge of lineation
Pillow structure, elongated along strike of bedding
Schistosity, showing prevailing strike
Gossan
Stromatolite locality
Plant fossil locality
Minor mineral occurence
Prospect
Abandoned prospect
Open-cut prospect
Mine
Mine, not being worked
Open cut
Battery, smelter, not operating
Au — Gold, Cr — Chromium, Fe — Iron, Fl — Fluorite, Mo — Molybdenum, Pb — Lead, Zn — Zinc, Cu — Copper
Bore
Well
GSWA 21 A, B Geological Survey of Western Australia groundwater bore
Artesian bore, flowing
Sub-artesian bore
Windpump
Water tank
Waterhole
Rockhole
Sand dune
Minor road
Vehicle track
Railway, bridge
Telegraph line
Power line
Landing ground
Building
Trigonometrical station
138 Elevation in metres, approximate
133 Elevation in metres, accurate
abd Abandoned
pa Position approximate
182 Selected gravity station with elevation in metres
+150 Bouguer anomaly contour (micrometres sec^{-2}), computer-plotter produced
Gravity anomaly — relative high
Gravity anomaly — relative low



CAINOZOIC

QUATERNARY

Qs Aeolian sand
Qeg Eluvium: quartz – feldspar sand, containing scattered rock fragments, over granitic rocks; partly transported
Qep Eluvium and minor colluvium: pebbly sand and silt derived chiefly from underlying alluvial gravel and locally from the **PATERSON FORMATION**
Qp Aeolian sand containing laterite pebbles (derived as eluvium or colluvium from Czd)
Qc Colluvium: sand and gravel forming outwash fans and scree. Includes dissected colluvium
Qa Alluvium: sand, silt and gravel
Qb Heave soil: clay containing pebbles and boulders

Czs Sand, silt, ferruginous nodules; minor clay: pedogenic gravel plains overlying Czd
Czd Ferruginous duricrust: includes massive and nodular laterite, ferruginous sandstone and consolidated breccia
Czk Calcrete — massive nodular and vuggy sandy limestone

TERTIARY

To **OAKOVER FORMATION:** vuggy white opaline silica (silicified calcrete) and calcareous sandstone
Tr Fine-grained siliceous (commonly chalcedonic) capping, chiefly over carbonate rocks. In places passes laterally into To. Locally includes undistinguished Proterozoic siliceous capping correlated with the **PINJIAN BRECCIA**
Tp Pisolitic limonite, goethite and hematite; contains fossil wood in places

MESOZOIC

EARLY CRETACEOUS

Kf **FREZIER SANDSTONE:** poorly sorted coarse-grained partly bioturbated sandstone, some conglomerate, minor siltstone. Fluviatile to deltaic
Kp **PARDA FORMATION:** mudstone with minor lenses of fine-grained sandstone. Thinly bedded or massive. Shallow marine (?)
JKc **CALLAWA FORMATION:** very fine to coarse-grained sandstone with conglomerate and minor siltstone. Cross-bedded and contains plant fossils. Fluviatile

LATE JURASSIC

JKr **JARLEMAI SILTSTONE:** mudstone with minor sandstone lenses. Marine
Jl **WALLAL SANDSTONE:** sandstone, minor siltstone and conglomerate. Continental to marginal marine
(Section and rock relationship diagram only)

PALAEOZOIC

EARLY PERMIAN

Pp **POOLE SANDSTONE:** very fine to fine-grained sandstone interbedded with mudstone. Shallow marine
Pg **GRANT GROUP:** siltstone, claystone, sandstone. Section and rock relationship diagram only
Pa **PATERSON FORMATION:** mudstone, sandstone, conglomerate, varved (?) shale
Paf Fine to coarse-grained sandstone and conglomerate; cross-bedded. Fluvio-glacial?
Pal Mudstone with scattered coarse sand grains and dropstones; massive. Lacustrine-glacial?

PROTEROZOIC

MIDDLE PROTEROZOIC

Ꝑq Fine to medium-grained quartzite and sandstone, massive to well-bedded. May include the **COOLBRO SANDSTONE**
Ꝑc Carbonate rocks — bedded limestone and dolomite with arenaceous and shaley beds. Sedimentary structures include cross-bedding and graded bedding.
Ꝑs Shale

Intrusive rocks:
Ꝑo Gabbro dyke or sill
Ꝑd Dolerite dyke or sill
Ꝑp Quartz-plagioclase porphyry dyke. Includes **BAMBOO CREEK PORPHYRY** (major sill intruding Ꝑfh)
Ꝑph Hornblende porphyry dyke, related to Ꝑgh
Ꝑgh Hornblende-adamellite/quartz-monzonite
Ꝑgy Granophyre, related to Ꝑfi

EARLY PROTEROZOIC

Ꝑe **EEL CREEK FORMATION:** black shale and grey-green mudstone with sandstone and locally basal hematite conglomerate. Restricted to Eel Creek area
Ꝑes Sandstone
Ꝑec Hematite conglomerate — rounded pebbles of hematite in a hematite matrix

Hamersley Group:
Ꝑcb **PINJIAN BRECCIA:** chert breccia and banded chert overlying Ꝑhc; may include silicified breccia of younger age
Ꝑhc **CARAWINE DOLOMITE:** banded grey dolomite with thin intercalations of chert towards the top and bottom

Fortescue Group:
Ꝑfl **LEWIN SHALE:** shale, mudstone and banded chert with local sandstone, dolomite and basalt. Partly correlated with the **JEERINAH FORMATION**
Ꝑflv **Baramine Volcanic Member:** felsic to intermediate pyroclastic rocks and lava
Ꝑflb Basalt, dolerite and felsic units. Stratigraphically equivalent to Ꝑflv
Ꝑfm **MADDINA BASALT:** vesicular and amygdaloidal basalt
Ꝑfs **KURUNA SILTSTONE:** sandstone, siltstone and shale
Ꝑfn **NYMERINA BASALT:** massive and coarse-textured basalt with common vesicular flows
Ꝑft **TUMBIANA FORMATION:** undivided. Sections and rock relationship diagram only.
Ꝑftc **Meentheena Carbonate Member:** banded dark grey siliceous limestone, some tuff. Stromatolites
Ꝑftt **Mingah Tuff Member:** pisolitic tuff with mudstone, shale and local basalt
Ꝑfk **KYLENA BASALT:** vesicular and amygdaloidal basalt; some columnar jointing. Local carbonate (Ꝑk) members
Ꝑfka Agglomerate
Ꝑfh **HARDEY SANDSTONE:** sandstone, grit and conglomerate, commonly arkosic and containing current structures. Minor shale, tuff and mudstone
Ꝑfhg Sandstone, grit and conglomerate (well-sorted)
Ꝑfhw Wacke, sandstone (poorly sorted), tuff and shale
Ꝑfhs Grey shale, mudstone, siltstone and tuff
Ꝑfr **MOUNT ROE BASALT:** amygdaloidal, vesicular, columnar jointed and massive basalt and andesite, common plagioclase-phyric flows
Ꝑfra Agglomerate and tuff

Isabella Range Area:
Ꝑfp **PEARANA BASALT:** vesicular and plagioclase-phyric basalt with intermediate to felsic flows near top. Correlate of **NYMERINA BASALT AND MADDINA BASALT**
Ꝑftc **TUMBIANA FORMATION: Meentheena Carbonate Member**
Ꝑfk **KYLENA BASALT**
Ꝑfi **KOONGALING VOLCANICS:** felsic and intermediate generally porphyritic lava with local tuff and agglomerate. Correlate of **MOUNT ROE BASALT**

Not assigned to a formation:
Ꝑk Laminated dark grey siliceous limestone and dolomite
Ꝑz Black shale and siltstone
Ꝑt Tuff, tuffaceous shale, mudstone and siltstone
Ꝑb Basalt

pꞒp Felsic porphyry. May be related to Ꝑp
pꞒps Sodic porphyry containing aegirine
d Dolerite dyke
q Quartz vein
p Pegmatite
g Granite dyke/vein

ARCHAEAN

Regional greenschist facies metamorphism

Intrusive rocks:
Ao Gabbro dyke or sill
Ad Dolerite dyke or sill
An Norite sill
Ar Porphyritic felsic rock
Apf Feldspar – phyric felsic sill

Sedimentary rocks:
As Clastic sedimentary rocks (not subdivided)
Ast Grit, sandstone and siltstone
Asc Conglomerate
Asf Ferruginous sandstone, siltstone, shale and chert, closely interbedded
Ac Chert (not subdivided)
Acw Black-white and grey-white banded chert
Acg Green chert
Acf Ferruginous chert
Aci Banded iron formation and jaspilite

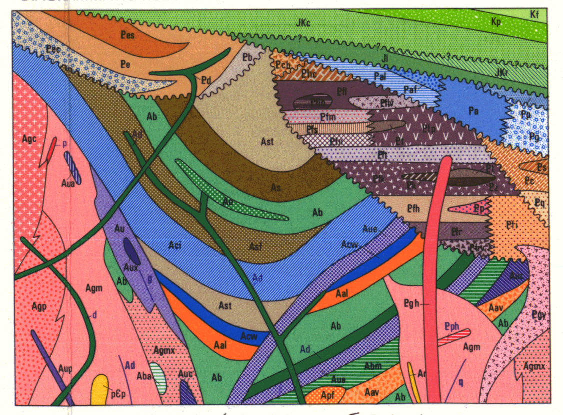
Felsic rocks:
Aa Rhyolite to dacite lava
Aav Agglomerate, tuff and lava, chiefly dacitic
Aal Fine-grained lava with quartz and feldspar phenocrysts

Mafic rocks:
Ab Basalt, andesite, and unsubdivided mafic volcanic rocks, commonly pillowed and vesicular but also massive. Includes mafic schist
Aba Amphibole – plagioclase schist
Abe Altered mafic rock rich in epidote
Abm Actinolite/tremolite/hornblende – chlorite – plagioclase rock; probably metamorphosed magnesia – rich basalt

Ultramafic rocks:
Au Ultramafic rock (not subdivided)
Aua Tremolite/actinolite ± chlorite rock. Generally schistose
Aup Peridotite
Auc Serpentinite. Primary mineralogy uncertain
Aux Pyroxenite
Aue Carbonate – talc rock. Primary mineralogy generally indeterminate

Granitic rocks:
Agc Medium to coarse, even-grained granite and adamellite. Poorly foliated
Agp Medium to coarse-grained, foliated porphyritic biotite adamellite; minor porphyritic granodiorite
Agm Biotite adamellite and biotite granodiorite, well foliated, commonly gneissic and migmatitic
Agmx Greenstone xenoliths and Agm in approximately equal proportions

DIAGRAMMATIC RELATIONSHIP OF MESOZOIC AND OLDER ROCK UNITS



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GRID ZONE DESIGNATION: 51K
100,000 METRE SQUARE IDENTIFICATION: ST TT UT / SS TS US
IGNORE the SMALLER figures of any grid number; these are for finding the full co-ordinates. Use ONLY the LARGER figures of the grid number; example: 19 0000mE

TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 1000 METRES
SAMPLE POINT: • Shay Gap
1 Read letters identifying 100 000 metre square in which the point lies: TT
2 Locate first VERTICAL grid line to LEFT of point and read LARGE figure labelling the line either in the top or bottom margin, or on the line itself: 0
3 Estimate tenths from grid line to point: 4
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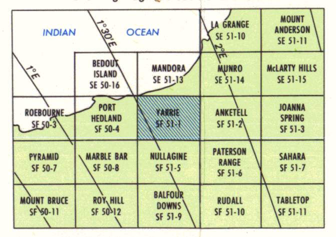

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TRANSVERSE MERCATOR PROJECTION

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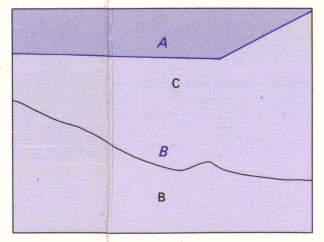

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C General reconnaissance: few traverses; mainly airphoto interpretation
Gravity A Detailed survey
B Reconnaissance

Geology 1974 by A.H. Hickman, R.J. Chin, GSWA
1977 by D.L. Gibson, R.R. Towner, BMR; R.W.A. Crowe, GSWA
Compiled 1975-79 by A.H. Hickman, R.J. Chin, D.L. Gibson
Gravimetry 1956-77 by BMR and private companies
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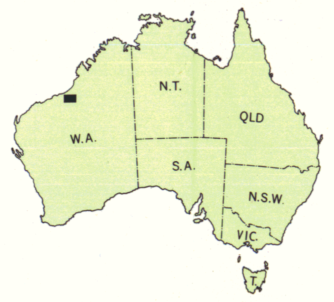

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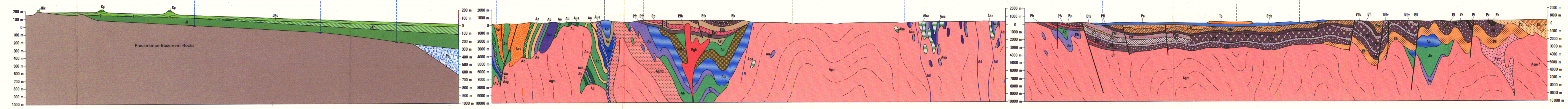

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SECOND EDITION 1982