1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

MOORA

WESTERN AUSTRALIA

SHEET SH/50-10 INTERNATIONAL INDEX

WESTERN AUSTRALIA
INDEX TO GEOLOGICAL MAPS
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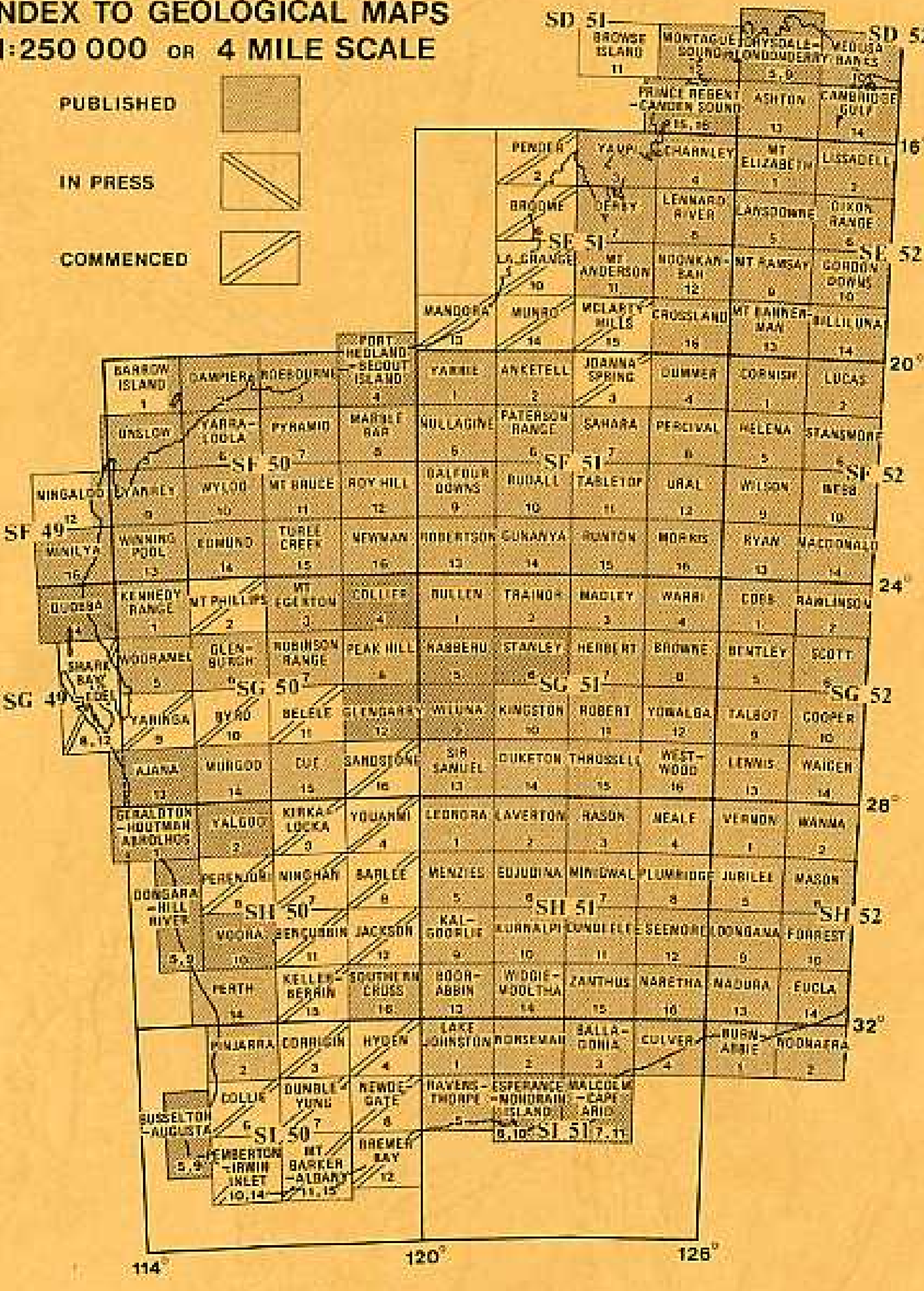

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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MOORA
WESTERN AUSTRALIA

SHEET SH/50-10 INTERNATIONAL INDEX

COMPILED BY J. D. CARTER AND S. L. LIPPLE

PERTH, WESTERN AUSTRALIA 1982

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Explanatory Notes On The Moora Geological Sheet

Compiled by J. D. Carter and S. L. Lipple

INTRODUCTION

GENERAL

The Moora 1:250 000 Geological Sheet, SH/50-10 of the International Series, is bounded by latitudes 30°S and 31°S, and longitudes 115°30′E and 117°00′E. The sheet embraces two distinct geological regions separated by the Darling Fault. East of the fault, that is, east of a line approximating longitude 116°00′E, Archaean and Proterozoic rocks are present. To the west of the fault lies the Perth Basin, which is principally occupied by Phanerozoic rocks. Most of the country is cleared for agriculture, a rich industry whose beginnings are associated with the founding of the Benedictine Mission Station at New Norcia in 1846. The main town, Moora, has a population of about 1 500. It is linked by bitumen roads to Perth and other population centres such as Wongan Hills, Dandaragan, Dalwallinu and Yerecoin.

There is no history of mining activity of any importance, and apart from heavy-mineral sands and bauxite, no mineral deposits of large commercial potential are known.

PREVIOUS GEOLOGICAL INVESTIGATIONS

There are many reports on various aspects of the geology, relating however, principally to Proterozoic and Phanerozoic rocks, and a number are in the reference list.

Very little geological work had been done on the Archaean rocks, although early reports exist such as a description of the Wongan Hills by Maitland (1899a). No general mapping of these rocks had been attempted. Early work consists of small-scale investigations of mineral occurrences, such as asbestos near Bindi Bindi and copper in the Wongan Hills, and a description of metamorphic rocks near Gillingarra prepared by Ivanac (1946) under the direction of Professor R. T. Prider.

The first systematic investigation of the Proterozoic rocks, the Moora Group, was made by Logan and Chase (1961) in the vicinity of Moora and Coomberdale.

Most of the early reports on the Perth Basin were concerned with superficial or shallow deposits, and prior to 1948 knowledge of the geology at depth was obtained from shallow water-bores. The great thickness of sediments underlying the coastal plain was not recognized until the gravity investigations of Vening Meinesz (1948). In recent years, geological surveys (Playford and Willmott, 1958) and seismic and exploratory wells for West Australian Petroleum Pty Ltd have further clarified the sedimentary structure of the Basin.

Bouguer anomaly and total magnetic intensity maps of the sheet have been published by the Bureau of Mineral Resources.

The geological mapping now explained was carried out at invervals between 1967 and 1976. G. H. Low mapped the Proterozoic rocks of the Moora Group in 1967. Low's terminology has been changed as an outcome of a re-examination of these rocks. The Perth Basin sediments were mapped by G. H. Low and D. C. Lowry in 1968 (Low, 1972). The Archaean rocks were mapped by J. D. Carter and S. L. Lipple between 1972 and 1976. Petrographic examinations were done by W. G. Libby, J. D. Lewis, D. F. Blight and R. Peers of the Geological Survey.

CLIMATE AND VEGETATION

The climate is similar to that of Perth: a subtropical (Mediterranean) climate with dry summers and wet winters, although summers are hotter and rainfall less. The rain falls mainly during the months of May to September.

Much of the original vegetation has disappeared following clearing for agriculture. As indicators of lithologies, the remnant vegetation is of little value although a possible exception is salmon gum (*Eucalyptus salmonophloia*) whose preference for heavy soils on Archaean rocks such as those derived from amphibolite and banded iron-formation (BIF) serves to mark these outcrops in areas dominated by granitic soils.

GEOMORPHOLOGY

The eastern third of the sheet lies within the Salinaland Division of Jutson (1950), and the western part within his Swanland Division. Five main physiographic units are recognized. From east to west, these are the Darling Plateau which occupies some two-thirds of the area, the Yarra Yarra Region, the Dandaragan Plateau, the Arrowsmith Region, and the Swan Coastal Plain. The Darling Scarp, which forms the eroded western edge of the Darling Plateau, degenerates into low hills near latitude 31°S, and its northward continuation is represented by features such as Gillingarra Hill. The low hills extend northwards to Moora and beyond. Scarps bound the Dandaragan Plateau to the west and southwest. These are the Dandaragan and Gingin Scarps, both fairly prominent topographic features which rise up to 50 m and 75 m respectively.

TABLE 1. PHYSIOGRAPHIC UNITS

Unit	*General elevation (m)*	*Topographic expression*	*Principal drainage*	*Other features*
Darling Plateau	300	Undulating plains	Seasonal Moore and Mortlock Rivers	Wongan Hills, Flat-topped (400-435 m); low granitic hills, saline lakes
Yarra Yarra Region	180 to 210	Lowlands, swamps, lakes	Intermittent and internal	
Dandaragan Plateau	200 to 300	Flat or gently undulating plateau surface	(Poorly developed drainage)	
Arrowsmith Region	Usually between 100 and 200	Dissected	Intermittent westward drainage	Carries laterite-capped remnants of Dandaragan Plateau
Swan Coastal Plain	Usually less than 100	Gently undulating	Westward or internal	Incorporates three small subdivisions: Pinjarra Plain (McArthur and Bettenay, 1960), Bassendean Dunes and Tamala Limestone sand dunes

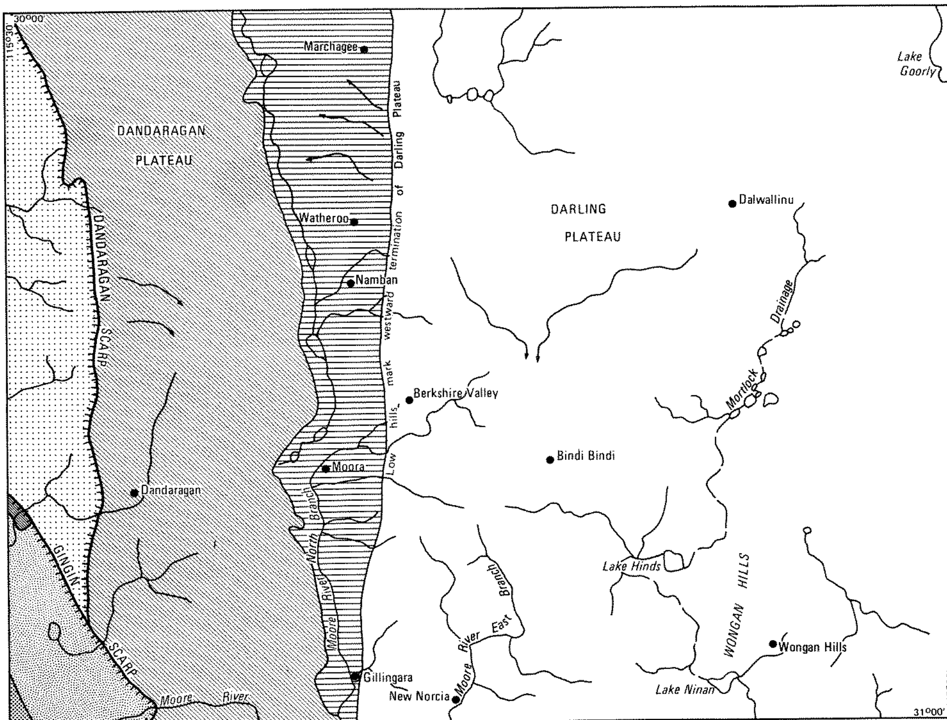

FIGURE 1

PHYSIOGRAPHIC DIAGRAM

MOORA SHEET SH 50-10

SCALE

10 0 10 20 30 40 km

REFERENCE

Coastal Belt	SWAN COASTAL PLAIN	ARROWSMITH REGION
Bassendean Dunes		DANDARAGAN PLATEAU
Pinjarra Plain		YARRA YARRA REGION

EXPOSURE

Within country underlain by Archaean rocks particularly, mapping problems are created by poor exposure and disruption of aerial photograph patterns by agriculture. Aeromagnetic data are of little help in determining boundaries. Exposure is generally of the order of less than 5 per cent, outcrops tend to be sporadic, and many are too small to represent at map scale. However, evidence in the form of fragments often enables the underlying rock type to be determined, and allows the linking of exposures with a reasonable degree of certainty. These areas are denoted by a soil overprint symbol on the map.

ARCHAEAN

REGIONAL SETTING

The Archaean rocks are part of the Yilgarn Block, a stable nucleus composed of granites and gneisses enclosing a number of "greenstone belts" of metamorphosed layered rocks. An age of 3 084 ± 191 m.y. was obtained by pooling samples of gneisses, including some from near Toodyay and Northam, approximately 60km south of the sheet (Arriens, 1971). A pooled age of 2 661 ± 5 m.y. was obtained from granites, including some from the Wongan Hills district, which intrude the gneisses.

Within the Yilgarn Block three major provinces are recognized: the Eastern Goldfields, the Murchison, and the Southwestern (Geological Survey of Western Australia, 1975). The Moora Sheet straddles the rather ill-defined boundary between the Murchison and Southwestern Provinces. The "greenstone belts" of the Murchison and Eastern Goldfields Provinces consist of layered successions of felsic, mafic, and ultramafic igneous rocks, and varying, though minor, amounts of sedimentary material. In the main, they are of low metamorphic grade. In contrast, the layered rocks of the Southwestern Province, as described by Wilde and Low (1975) from the Perth Sheet, "are notable for the abundance of metasediments, the complete lack of felsic volcanic rocks, the subordinate amount of mafic ?volcanic rocks and the high grade of regional metamorphism". These layered rocks occur in two metamorphic belts which are termed the Jimperding Metamorphic Belt, and the Chittering Metamorphic Belt.

On the Moora Sheet, the Yilgarn Block is composed largely of granitic rocks with some locally important developments of migmatite. Metamorphosed layered rocks are a subordinate component, but two groups are distinguished which have not been formally named. These are provisionally called the Berkshire Valley succession, a group representing the northward continuation of both the Jimperding and Chittering Metamorphic Belts of the Perth Sheet, and the Wongan Hills succession. The terms Jimperding and Chittering Metamorphic Belts are not employed. Unlike the metamorphic belts to the south on the Perth Sheet, the corresponding metamorphic rocks on the Moora Sheet are not distinct units separated by granitic rocks.

The Berkshire Valley succession crops out in the western and central parts of the Archaean, between Carani and Gillingarra, and extends northwards to Bindi Bindi, Berkshire Valley, and Gunyidi. Its continuity is broken almost everywhere by granitic and migmatitic rocks.

The Wongan Hills succession (Lipple, 1982), exposed in the north-south trending range of hills west of the town of that name, compares in lithology more closely to the "greenstone belts" of the Murchison and Eastern Goldfields Provinces than to the lithology of the Berkshire Valley succession. For example, metamorphosed mafic volcanic rocks, a conspicuous feature of the Wongan Hills succession and of the Murchison and Eastern Goldfields Provinces, are not prominent in the Berkshire Valley succession, either in the form of metabasalt, or as possible metamorphic equivalents, such as amphibolite. The Berkshire Valley succession, on the other hand, includes a high proportion of quartz-feldspar-biotite gneiss, a subordinate species at Wongan Hills.

The two-fold separation of layered rocks does not reflect well-defined demarcations of geology. For example, a characteristic lithology of the Berkshire Valley succession, quartz-feldspar gneiss, crops out as small bodies throughout the sheet generally. Such gneisses are found in the Wongan Hills "greenstone belt", and are closely associated with isolated bodies of "greenstone belt" north of the Wongan Hills, such as that at Lake Goorly.

THE LAYERED SUCCESSIONS

A wide range of lithologies is represented in the layered rocks. In the Berkshire Valley succession, granitic gneisses and, to a lesser degree, mica schists are the principal constituents. The Wongan Hills succession contains a large proportion of metamorphosed mafic igneous rocks, smaller developments of metamorphosed felsic igneous rocks, and metasedimentary rocks such as BIF and chert. Minor occurrences of metamorphosed layered rocks, generally similar in lithology to the Wongan Hills succession, crop out at a number of localities north of the hills. These are described with the Wongan Hills succession under the heading "Minor layered sequences".

Wongan Hills succession

The layered rocks in the Wongan Hills, a few kilometres west of the town, strike northwards for about 28 km, narrowing from some 10 km near Lake Ninan in the south, to a kilometre or so at the isolated exposures of Little Wongan Hill in the north. Metamorphic grades lie within middle and upper amphibolite facies. Metamorphosed mafic igneous rocks, including metabasalt, metadolerite and metagabbro are accompanied by metamorphosed felsic volcanic rocks, metasediments including recrystallized BIF and chert, quartz-plagioclase-hornblende rocks and garnet-mica schists. Among subordinate lithologies are cordierite rocks, quartz-feldspar gneiss, and ultramafic rocks. Most of the northwestern segment of the hills is underlain by metamorphosed, mafic igneous rocks while felsic metavolcanic rocks, BIF and garnet-mica schists are prominent in the southeastern segment.

Metabasalt (*Abl*), and metadolerite and metagabbro (*Ada*), are major components. These occur principally along the western margin of the hills, and are particularly well exposed near Mount Rupert homestead. Metabasalts usually display sufficient relict textures, either in outcrop or thin section, to allow the original nature of the rock to be determined. South of Mount Rupert homestead, there are probable pillow structures approximately one metre long. These fine-grained rocks are composed of actinolitic hornblende and fresh, untwinned, calcic plagioclase (locally, fresh albite) accompanied by accessory minerals. Metadolerite and metagabbro are medium to coarse grained, and usually sillform. They consist chiefly of amphibole (blue-green hornblende or actinolitic hornblende) showing many pseudomorphs after pyroxene, and usually fresh, untwinned calcic plagioclase.

An important unit, amphibolite (*Aa*), is commonly associated with *Abl* and *Ada*. It consists of dark-grey or green, fine-grained to medium-grained, granoblastic or foliated, plagioclase-amphibole rocks with variable minor constituents.

Schistose felsic metavolcanic rocks (*Afv*) of dacitic composition crop out in the western ranges of the southern part of the hills, and are well exposed near Bald and Ochre Hills. Among these are fine-grained quartz-plagioclase rocks containing phenocrysts of hornblende, and small amounts of epidote, clinozoisite, chlorite, biotite, sphene, and opaques. Quartz-muscovite rock and quartz-tremolite-clinozoisite schists, included in *Afv*, may represent metamorphosed tuffs.

Metamorphosed BIF (*Ai* and *Aia*) and chert (*Aic*) are widely developed, particularly in hills immediately west of the Wongan Hills town. The rocks appear banded because of variations of colour, grain size, and mineralogy. Magnetite and quartz compose *Ai*, with minor grunerite, muscovite, pyrite, chlorite, and carbonate. *Aia* consists of quartz and magnetite with prominent grunerite assemblages. Grey or white *Aic* is composed essentially of quartz laminae, usually accompanied by a little magnetite. Small occurrences of muscovite bearing quartzite (*Aqo*) are found near the margins of the belt.

A variable suite including schistose and gneissose quartz-plagioclase-hornblende rocks, and quartz-biotite-plagioclase schist and hornfels are grouped together under *Alh*. Bedding features suggest some representatives may have been derived from sedimentary rocks such as sandstone and sandy shales. Near Bald Hill, the unit includes schists, predominantly quartz-biotite-plagioclase rocks, which commonly carry accessory tourmaline. The unit is widely developed in the northern part of the hills near Mount Rupert. Here *Alh* includes flaggy, mesocratic, fine- to medium-grained rocks containing quartz, actinolite, or tremolite, or hornblende, and, variously, chlorite and opaques. Acicular amphibole (up to 10 mm long) forms prominent foliations and lineations.

Garnet-mica schists (*Alg*) occur only in the south. Fresh exposures are rare, and found only in the hills immediately west of the town and northwest of Bald Hill. This unit was intersected in diamond-drill holes 1.5 km north of Lake Ninan. A variety of mineral assemblages are present, including almandine, andalusite, sillimanite, muscovite, biotite, and quartz. Garnet occurs as porphyroblasts up to 5 mm in size, and sillimanite forms scattered clumps about 10 mm wide. A narrow schist band near Bald Hill consists of spinel-bearing, almandine-biotite-quartz schist with sericite pseudomorphs after cordierite. Blue-grey, fine-grained to medium-grained cordierite rock (*Alc*) forms distinctive bands distributed from Little Wongan Hill to Bald Hill. The rock, which may be massive or schistose, occurs in layers up to 5 m thick within *Alh*. Four kilometres southwest of Elphin Siding, the rock is massive, and is composed of chlorite-talc-cummingtonite and cordierite, with minor biotite and magnetite. Near Bald Hill, the rock carries aggregates of (0.3 mm) cordierite porphyroblasts, set in a mass of finer grained cordierite and quartz. Unusual variations in this locality carry garnet and spinel.

Leucocratic fine-grained to medium-grained quartz-muscovite or biotite-feldspar gneiss (*Anl*) is present southwest of Bald Hill and near Elphin Siding. Typical specimens consist of quartz, oligoclase, perthitic microcline, minor biotite, opaques and a trace of secondary epidote.

Minor developments of ultramafic rocks (*Au*) occur as dykes and sill-form bodies, and include thin hornblendite (tremolite) dykes found near Mount Rupert and west of Bald Hill, and small sills composed of serpentinite and hornblendite, near Elphin.

Minor layered sequences: North of the Wongan Hills, small bodies of layered sequences enclosed in granitic rocks crop out at a number of localities near Dalwallinu and Wubin. Among the larger are those at Wilgie Hill and near Barrabarra, some 15 and 25 kilometres respectively, east of Dalwallinu; at Wandano Hill and Bera Bera Rockhole, about 15 and 20 km northeast of Wubin; and at Lake Goorly. In general, these rocks are similar in lithology to members of the Wongan Hills succession, but there are differences, represented notably by occurrences of rocks of high metamorphic grade, mafic granulites, and metasediments such as graphite schist and metaconglomerate.

The principal rock types, BIF (*Ai*) and amphibolite (*Aa*), are similar to those of the Wongan Hills succession though *Ai* at Barrabarra contains garnet. Of lesser importance are quartz-feldspar schists and gneisses of *Alh*, represented at all the localities other than Lake Goorly. At Bera Bera Rockhole and Wandano Hill *Alh* includes subordinate quartz-muscovite-sericite-graphite schist, and at Bera Bera Rockhole, metaconglomerate. The highly altered polymictic metaconglomerate is a fine-grained rock consisting of quartz, sericite, chlorite, and opaque minerals. Several types of fragments are scattered through it, and these include large cobbles of coarse-grained quartz-feldspar-chlorite rock which may represent an altered granitic species.

Mafic granulites (*Ahg*) include, at Barrabarra, medium-grained to coarse-grained andesine-hypersthene-hornblende rock, and at Lake Goorly, ultramafic tremolite-hypersthene hornfels.

Berkshire Valley succession

The Berkshire Valley succession extends northwards from between Carani and Gillingarra to the Berkshire Valley and Gunyidi, and beyond. The poorly exposed layered rocks of the Bindi Bindi and Pithara districts are included in this succession, together with isolated bodies of various quartz-feldspar gneisses which sporadically crop out in the granitic country extending from Dalwallinu and Wubin westwards to the Moora Group. South of Barberton, the succession is terminated to the west by the Darling Fault. North of the siding, the layered rocks abut, or are faulted against, the Moora Group. Although more than 70 km in width in the central and northern portions of the sheet, the succession is everywhere broken up by granitic and migmatitic rocks into irregular strips and patches, rarely more than a few kilometres across.

The rocks have an overall north and northwesterly strike, but in the central portion of the belt, around the Berkshire Valley, over some 20 km of strike, the regional trend is northeast. The grade of metamorphism is high, and the succession includes representatives of the amphibolite and granulite facies. Gneisses are the dominant rock type, but mica schist is important near Gillingarra and metamorphosed BIF forms prominent layers in several localities. Subordinate members include amphibolite, quartzite and ultramafic rocks.

Gneisses: The more important species are quartz-feldspar-biotite-hornblende gneiss (*Anb*), leucocratic quartz-feldspar (biotite) gneiss (*Anl*) and augen gneiss (*Ana*). Unclassified gneissic rocks (*An*) represent weathered gneissic material or exposures where gneisses, usually *Anb* and *Anl*, are intermixed. Apart from *Ana*, an important species in the Berkshire Valley, there is no obvious preferential distribution of the principal categories of gneiss.

Quartz-feldspar-biotite gneiss and less frequently quartz-feldspar-biotite-hornblende gneiss (*Anb*) comprise a diverse suite of fine-grained, medium-grained, and coarse-grained rocks. These may be well banded with distinct, usually biotitie-rich layers, or massive with irregular foliations defined by biotite. Augen, often formed from feldspar, may be present. Plagioclase (albite/andesine/oligoclase) and microcline occur together in varying proportions, and are accompanied by biotite and, less commonly, biotite-hornblende. Rarely is hornblende the dominant or sole mafic mineral. Some gneisses, such as those composed of plagioclase, garnet, tremolitic amphibole, epidote and quartz arranged in layers of varying composition, are apparently sedimentary in origin. Gneisses of the unit are interbanded with *Anl* and *Ana*, and there are transitions from *Anb* to *Anl* as a result of variation of mafic mineral content, and to *Ana* accompanying textural transformation.

Fine-grained to medium-grained, leucocratic quartz-feldspar gneiss (*Anl*) is a texturally diverse group, characterized by a uniform, predominantly felsic mineralogy. It includes species similar to the *Anl* of the Wongan Hills succession. The rocks may be thinly banded or massive, and typically display a variety of textures, many in which stringers, lenses and eyes of quartz are interleaved with a granular aggregate of microcline and plagioclase, indicating cataclastic deformation. In composition, the essential mineralogy is similar to that of a leucocratic adamellite, with microcline and oligoclase in roughly equal proportions. Sometimes a little biotite is present. Thin layers of quartz-rich gneisses are locally developed in *Anl*.

Augen gneiss (*Ana*) is found throughout the succession, but the larger mappable bodies are confined chiefly to the Berkshire Valley district where *Ana* includes numerous bands of amphibolite. A typical example consists of augen (up to 10 mm long), quartz, and saussuritized oligoclase set in a groundmass of quartz, saussuritized oligoclase, microcline and altered biotite. The texture is granoblastic inequigranular elongate. An unusual variation, diopside-sphene augen gneiss (*Ans*), crops out on Penance Hill immediately east of Berkshire Valley homestead. The rock is composed of microcline (43%), oligoclase (28%), diopsidic clinopyroxene (15%), quartz (5%), opaque minerals (5%) and idioblastic sphene (3%).

Two minor categories of gneiss, restricted in extent, are porphyroblastic granite gneiss (*Anp*) and quartz-hornblende-biotite-garnet-plagioclase gneiss (*Anc*). In the vicinity of Berkshire Valley particularly, small bodies of *Anp*, coarse-grained quartz-microcline-plagioclase-biotite (hornblende) rocks, are present and are similar to porphyritic granite. These evidently represent gneisses which have undergone metasomatism during granite emplacement. In the extreme southwest, a small outcrop of medium-grained *Anc* extends southwards onto the Perth Sheet.

Schists: Schist forms large bodies only near Gillingarra; elsewhere it is uncommon. North of Berkshire Valley, small bodies of schistose quartz-plagioclase (amphibole) rocks (*Alh*), which are similar to the rocks of this unit in the Wongan Hills succession, crop out.

Near Gillingarra, a suite of cataclastically deformed schists of varied mineralogy forms the westernmost unit of the Archaean. These rocks strike northwards from the Perth Sheet and are terminated to the north near Panchery Pool by faulting. These schists are subdivided into three types: quartz-garnet-mica schist (*Alg*), quartz-muscovite schist (*Alm*), and quartz-(mica-feldspar) schist (*Alq*). Both *Alg* and *Alm* are reddish-brown, fine-grained to medium-grained schistose rocks. In *Alg*, red garnet, (probably almandine) porphyroblasts, up to 5 mm in diameter, form subhedral crystals, but the bulk of the schist is composed of quartz, biotite, muscovite, and chlorite. Quartz-muscovite schist at Gillingarra, which may contain some garnet, appears to have been derived by retrograde metamorphism from andalusite-rich rocks in which andalusite was replaced by sericite. Both *Alg* and *Alm* may contain staurolite and, occasionally, kyanite.

Near Gillingarra, a diverse group of grey, fine-grained quartz-(mica-feldspar) schist (*Alq*) forms bands interlayered with *Alg*. To the north, the unit is exposed in hills east of Summer Valley homestead. These schists, cataclastically deformed and often intensely contorted, are composed of quartz and feldspar (both microcline and plagioclase) together with varying amounts of biotite, muscovite, and chlorite. Schistosity is poorly developed, and, in structure, the rocks are more nearly gneissic and granofelsic than schistose. At Summer Valley, apparent bedding features suggest that *Alq* includes metasedimentary rocks, specifically, metamorphosed psammitic rocks.

Other units: Metamorphosed BIF (*Ai, Aia, Aiw*) occurs as relatively thin (maximum 50 m) units, but forms useful marker horizons which often show conspicuous topographic expression. Rock types are essentially similar to the BIF of the Wongan Hills succession. Unassigned BIF (*Ai*) includes assemblages of quartz, magnetite, and minor grunerite, as well as units which have not been petrographically examined. Grunerite-bearing BIF (*Aia*) is best seen in the Carani to Mount Yule BIF horizon about 12 km northwest of Carani in the hilly country immediately north of the Yerecoin to New Norcia road. Assemblages include grunerite, grunerite-quartz, and magnetite-grunerite-quartz. At Choral Well pyroxene-bearing BIF (*Aiw*) contains quartz, magnetite and grunerite together with both clinopyroxene and orthopyroxene.

Although thin bands of amphibolite (*Aa*) are frequently found within the gneissic and schistose sequences, these rocks assume importance only around Berkshire Valley where amphibolite outcrops prominently immediately west and south of Kallaroo homestead. Large bodies of *Anb* and *Ana* are incorporated within *Aa* at Kallaroo. In the Gillingarra district, the schistose rocks contain many thin, discrete bodies of amphibolite. Typically *Aa* embraces fine- to medium-grained rocks composed of xenomorphic granular aggregates of hornblende (often altered to tremolite-actinolite) and plagioclase with occasionally a little quartz. Quartzite (*Aqo*) found in narrow bands, probably represents metamorphosed orthoquartzite. It is widely distributed and is often closely associated with BIF. Only east of Koojan and near Berkshire Valley are the rocks sufficiently thick to produce sharp topographic expression.

As *Aqo* is resistant to processes of granite emplacement, its remnants in granitic country, highly altered and locally mobilized, are sometimes difficult to distinguish from quartz dykes (*q*). East of Koojan, *Aqo* contains a little green, chromiferous muscovite.

Ultramafic rocks (*Au*) which intrude the layered rocks are subconcordant, and, essentially, form part of the layered succession. Although found throughout the succession, the unit is more commonly represented within the layered rocks between Joyce Well, Berkshire Valley and Bindi Bindi. Except at Joyce Well, *Au* is invariably poorly exposed, and thicknesses are difficult to assess, though it is considered that possibly apart from the occurrence at Lake Bindi Bindi, individual bodies do not exceed 50 m. The rocks may be foliated, and some examples are schistose; they are wholly altered. Mineral assemblages include serpentine, talc-tremolite-actinolite-chlorite-serpentine, and talc-anthophyllite. Relict textures suggest that peridotites and pyroxenites were among the ultramafic species.

Relationship between Wongan Hills and Berkshire Valley successions

Although there is no well-defined demarcation of geology between the Wongan Hills and the Berkshire Valley successions, differences in overall lithologies are considerable. However, no firm conclusion can be reached on relations between the successions. There is no information on the age of the Wongan Hills succession (or the various minor layered sequences north of it) and these rocks are isolated by enveloping granitic bodies.

In metamorphism, lithology, and regional trend, there are similarities and differences. Metamorphic grades overlap; both successions contain predominantly representatives of amphibolite facies with lesser developments of granulite-facies rocks. Differences in lithology between rocks of the two facies are great. The Berkshire Valley succession is characterized by a high proportion of quartz-feldspar-biotite (hornblende) gneiss, an unimportant lithology at Wongan Hills.

Some 40 per cent of the Wongan Hills outcrop is composed of amphibolitic rocks and BIF, both subordinate species in the Berkshire Valley succession. The overall northern and northwestern regional trend of the Berkshire Valley succession contrasts with the dominant northern and north-northeastern strike of the Wongan Hills succession. Gee (1975) states that the Murchison Province of the Yilgarn Block "... is characterized by north to northeasterly trends of the volcanogenic belts". Descriptions of lithologies of the volcanogenic belts in the Murchison Province are generally reminiscent of those of the Wongan Hills succession. In regional trend and lithology, the latter show affinity to Murchison Province volcanogenic belts, rather than to rocks of the Berkshire Valley succession which represents the northward continuation of the Jimperding and Chittering Metamorphic Belts.

MIGMATITIC ROCKS

Rocks formed by mixtures of gneissic and granitic components in which neither phase is predominant are classed as migmatite. Two types are distinguished: layered or banded migmatite (*Amm*) where the paleosome and neosome are distinct; and nebulitic migmatite (*Am*) with indistinct paleosome and neosome. There is complete gradation between the two types, and they occur in approximately equal proportions. The units are developed principally in the western half of the Archaean outcrop, but south of Namban they are also an important constituent. There is some tendency for the rocks to form irregular zones situated between the Berkshire Valley succession and granitic rocks. Paleosome components vary from well-banded to massive biotite-rich and sometimes hornblende-rich *Anb* and *Ana*. Granitic components include mesocratic, equigranular, and porphyritic, fine-grained to coarse-grained material ranging from granite to granodiorite in composition.

Foliation trends, especially in *Amm*, generally correspond to those of adjacent gneisses, though there are divergences such as the conspicuous easterly trends some 6 km north of Walebing. Large bodies of migmatite are not directly related to intrusive granite. An example is *Amm* on the Kiaka Spring road west of Berkshire Valley, where the rocks appear to have been produced by the mobilization and reconstruction of gneisses with the formation of granitic material *in situ*.

GRANITIC ROCKS

Lithologies

Granitic rocks are estimated to constitute more than two-thirds of the lower Precambrian. They are particularly well developed south and east of Wongan Hills, and northwards to Lake Goorly. East of Namban, porphyritic granite forms prominent outcrops.

In mineral composition, the rocks range from granite to granodiorite. The dominant mafic material is biotite, but many examples contain hornblende. There is a considerable degree of uniformity of mineral composition, and to distinguish the granitic rocks, textures were employed. An exception is the separation of the distinctive, porphyritic Namban Granite, which is characterized by an unusual coloration imparted by pale-green plagioclase feldspar. Unclassified granitic rocks (*Ag*) represent weathered granitic material, or outcrops visible on aerial photographs, but not examined in the field.

Within the granitic rocks examined, two distinct textural types occur: even-grained granitic rocks (*Age*), and porphyritic granitic rocks (*Agp, Agb*). These are closely related in the field, and are intimately associated with granitic rocks (*Agv*) containing scattered megacrysts of potash feldspar. The latter represents a transitional phase between the even-grained and porphyritic types. Frequent variations in texture make separation of the granitic rocks difficult. On a regional basis there is no apparent preferential distribution of the principal units.

An explanation is necessary of the use of the unclassified granitic units (*Ag*) on Figure 2. Most of the areas shown as *Ag* are nearly devoid of exposure, but they usually contain minor outcrops of dominantly granitic and migmatitic material. This factor, considered together with the variably granitic composition of peripheral exposures, and the results of the BMR magnetic interpretation of the sheet area, led to the designation of largely unexposed country as *Ag*. The direct evidence, however, is slight.

Even-grained granitic rocks (*Age*) are ubiquitous, and exposures may be massive or show mineral foliation of varying intensity. Typically they are mesocratic rocks, and range from fine to coarse in grain size. In composition, there is variation from granite to granodiorite, though mineralogies of commoner types fall in the zone of transition from granite to adamellite. Textures are allotriomorphic granular; minerals are plagioclase (in many examples albitic), microcline, quartz, biotite and, less frequently, hornblende. Accessory minerals include opaques, apatite, zircon, metamict allanite, muscovite, and sphene. Myrmekite is often present. Small biotitic clots and schlieren are common, but granitic xenoliths are rare. Minor developments of pegmatite and aplite are fairly common, but not conspicuous features.

Pale-grey porphyritic granite (*Agp*) occurs in bodies of varying magnitude. East of Namban a pink and green prophyritic granite of striking appearance, referred to as the Namban Granite (*Agb*), forms a well-defined pluton. Exposures of *Agp* and *Agb* may be massive or foliated, though quite often they are very strongly foliated by reason of the alignment of conspicuous megacrysts (average length of 20 mm) which are usually microcline microperthite, the characteristic textural feature of the units. In *Agp*, xenoliths are rare except near margins; biotite clots and schlieren, although found, are generally of minor importance. Xenoliths are common in *Agb*, and representatives of adjacent gneissic and amphibolitic suites are easily recognized. In both *Agp* and *Agb*, intrusions of pegmatite, aplite, and small dykes and veins of equigranular, fine-grained granitic phases are present, but not prominent features.

Their mineral composition is similar to that of *Age*. The principal minerals in *Agp* are quartz, microcline, plagioclase, and biotite. Hornblende is less common than biotite. The Namban Granite (*Agb*) has granodioritic variations which contain megacrysts of plagioclase. Its attractive appearance is caused by colours of feldspars. Microcline crystals are varying shades of pink because of hematite inclusions, and plagioclase may be pale green as a result of inclusions of chlorite and epidote. Where microcline predominates, the rock appears pink, but where plagioclase is abundant the rock is green.

Fine-grained to coarse-grained granitic rocks with scattered magacrysts of potash feldspar (*Agv*) are intimately associated with many occurrences of *Age* and *Agp*. The unit's distinguishing feature is the variation in the frequency of megacrysts. These may be sparse, or locally abundant, but their frequency is such that the rock is neither even-grained nor porphyritic. With decrease or increase in megacryst abundance, the rocks pass into *Age* or *Agp*. Other features of the unit resemble those of the even-grained and porphyritic groups.

Intimately admixed granitic rocks comprising *Age*, *Agp* and *Agv* whose components cannot be separated at map scale occur in all parts of the sheet area and are shown as *Agm*.

Strong, and in places extreme cataclasis has produced suites of deformed granitic rocks (*Agn*), which locally include augen gneisses and protomylonites. The chief representatives are found near Gillingarra where cataclastic granite produces conspicuous features in the Babilion Range. The rocks display a variety of textures including augen development, and vary in grain size from coarse-grained to extremely fine-grained material of mylonitic appearance. The rocks are composed of angular fragments of microcline, the predominant feldspar, some plagioclase, and quartz set in a crushed and partially recrystallized matrix of quartz.

Relationships

A general separation of granitic rocks into two zones is apparent. In the western part of the Archaean outcrop, certain granitic rocks form more or less well-marked bodies such as cataclastic granite (*Agn*) near Gillingarra and the Namban Granite (*Agb*) pluton. In this zone migmatites are well developed. To the east, where migmatite is subordinate, the granitic rocks appear to constitute a batholith, in which there is a regionally complex interdevelopment of textural types. In both zones, contacts of granitic rocks with the layered sequences appear to be sharp and intrusive, but there is also indirect evidence of diffuse contact relations. Porphyritic granite gneiss (*Anp*) in several localities approaches porphyritic granite in appearance; and migmatite, apparently derived from the layered sequences, often passes from well-banded rocks with a conspicuous paleosome content into equigranular granite by pervasive introduction of granitic material.

Inter-granite relations are complex, particularly in the batholithic granites. Within *Age* for example, there are phases showing minor textural variations and mutual contacts, but for almost any relationship suggesting a relative age, exposures displaying the reverse relationship are usually present. Multiple intrusion of similar textural types is assumed. Relationships between *Age* and *Agp* are similarly conflicting. These units not only intrude one another, corroborating evidence for multiple intrusions of *Age* at least, but, by variation in the abundance of microcline megacrysts, there are transitions between them. Overall, however, there is evidence suggesting that *Agp* complexes represent later phases of granitic emplacement, although until there is more definite evidence, the granitic rocks are best considered as penecontemporaneous phases of the same general intrusion.

PROTEROZOIC

MOORA GROUP

Sedimentary rocks of the Middle Proterozoic Moora Group occur in a strip up to 14 km wide between the Darling Fault and the Archaean basement rocks from Mt Lamb northwards, well onto the adjoining Perenjori 1:250 000 Sheet (Baxter and Lipple, 1979). The group consists of chert, siltstone, sandstone, and arkose, and has about 1 500 m exposed thickness near Watheroo. It was first named by Logan and Chase (McWhae and others, 1958).

The presence of rocks assigned to the Moora Group has been known and reported on at various times since Maitland (1899a, b). No fossils, except stromatolites and "trace" fossils, have been discovered. Fairbridge (1950) described algal-like structures, which he called *Collenia*, in chert near Gunyidi railway siding. One specimen from this area resembles *Conophyton* (K. Grey, 1979)

The Moora Group consists of a lower Billeranga Subgroup which contains material of volcanic origin, and an upper Coomberdale Subgroup of shelf carbonates and clastics. The regional strike is generally about 20 degrees west of north and dips are westward. The group is intruded by dolerite dykes and is broken up considerably by strike and transverse faults.

The term Billeranga Subgroup is derived from the formerly used Billeranga Group (Geological Survey of Western Australia, 1975, p. 74), and is defined by Baxter and Lipple (in press). It is composed of the basal Capalcarra Sandstone and Dalaroo Siltstone, and is disconformably overlain by the Coomberdale Subgroup. The term Coomberdale Subgroup is derived from the Coomberdale Chert formation as defined by Logan and Chase (1961). It is defined by Baxter and Lipple (in press), and consists of the Mokadine Formation, Noondine Chert, Noingara Siltstone and Winemaya Quartzite. The Coomberdale Chert has been renamed Noondine Chert. Within the subgroups, the formations are conformable.

Billeranga Subgroup

Capalcarra Sandstone: The Capalcarra Sandstone (Logan and Chase, 1961) is a poorly exposed sequence of arkosic sandstone, breccia, and conglomerate, lying nonconformably on the Archaean basement. It has been recognized east and southeast of Moora, and 3.2 km northwest of Watheroo. The type section lies about 4.3 km east of Moora railway station (30°38′S, 116°03′E) and is about 49 m thick.

Dalaroo Siltstone: The Dalaroo Siltstone (Logan and Chase, 1961) consists of purple lithic wacke, siltstone, and claystone which contains minor arkose. Certain sequences are tuffaceous, and contain devitrified glass and fragments of fine-grained igneous rocks. The siltstone contains detrital carbonate in places. Both the siltstone and claystone are commonly finely current-bedded, and show ripple marks and graded bedding. The type section lies 4 km east of Moora railway station (30°38′S, 116°03′E) and is 153 m thick, but the maximum thickness of the formation may be as much as 400 m (Low, 1969). The Dalaroo Siltstone conformably overlies the Capalcarra Sandstone and is disconformably overlain by the Mokadine Formation, the Noondine Chert or the Winemaya Quartzite.

Coomberdale Subgroup

Mokadine Formation: The Mokadine Formation (Logan and Chase, 1961) is well-sorted, current-bedded (commonly trough cross-bedded) arkose which contains interbedded sandstone, siltstone, thin chert and chert breccia beds. The type section lies to the east and west of Mokadine Spring (30°38′S, 116°02′E), 2.7 km east-northeast of Moora railway station and is about 100 m thick. Elsewhere the formation may be as much as 240 m thick (Low, 1969). The formation thins northward, and, in the Watheroo area, is only about 10-20 m thick. The trace fossils in ripple-marked red siltstone 8 km southeast of Moora are described by Cockbain (1967) and are thought to be burrows. Minor algal-mat fabric in thin chert occurs northwest of Watheroo.

Noondine Chert: The Noondine Chert was originally called the Coomberdale Chert by Logan and Chase (1961) but has been renamed by Baxter and Lipple (in press). It consists of bedded chert, chert breccia, orthoquartzite, silicified limestone and dolomite and contains significant siliceous siltstone and sandstone beds, and minor claystone. It conformably overlies the Mokadine Formation. The type section is exposed in a series of fault blocks 3.2 to 8.0 km south of Coomberdale (30°25′S, 116°03′E). This complete section is 1 006 m thick (Low, 1969) but elsewhere the unit may reach a thickness of 1 400 m.

Fairbridge (1950) first discovered algal structures in the Noondine Chert at Moora and Gunyidi. Logan and Chase (1961) reported many more occurrences, including small biohermal developments, in the Moora-Coomberdale area. The same workers also recorded the presence of poorly preserved, tubular organisms ("Fossilium problematicum") in three horizons of the Noondine Chert. Stromatolite occurrences recorded during this mapping include those at Kiaka Brook, Jingemia Cave and north of Longreach homestead, next to the highway.

Noingara Siltstone: The Noingara Siltstone (Low, 1975) consists of massive to thin-bedded, well-cleaved, red-brown lithic siltstone conformably intercalated with the Winemaya Quartzite. The type section lies 3.4 km south-southeast of Noingara Well (30°13′56″S, 115°59′08″E). The unit has about 350 m total thickness within the type section.

Winemaya Quartzite: The Winemaya Quartzite (Low, 1975) consists of bedded and trough cross-bedded, light-grey orthoquartzite and quartz pebble conglomerate with minor siliceous grey siltstone. It is highly sheared and brecciated in places. The basal portion consists of lenticular arkosic grit and more extensive upward-fining quartz siltstone and sandstone. The type section (30°14′S, 115°59′E) is 10.5 km south of Winemaya Spring. The Winemaya Quartzite disconformably overlies the Dalaroo Siltstone, but the top of the formation is not exposed. Measurement of the true thickness of the type section is complicated by a synclinal fold but thickness is about 700 m. It is likely that the further extent of the unit is concealed by colluvium between the outcrop area and the Darling Fault.

PRECAMBRIAN UNDETERMINED

MINOR INTRUSIVES

Mafic dykes

All Precambrian rocks are intruded by mafic dykes (*d,dx*), which increase in abundance near the western limits of the Archaean outcrop and in several localities, such as Barberton, constitute dyke swarms. The dykes are generally between 1 m and 10 m thick, but the largest may be up to 50 m or more.

Some dykes approach 5 km in length, but the majority do not exceed 1 or 2 km, and they are usually much shorter. Overall, the dykes have north and northwest trends, and many are subparallel to the principal foliation directions of the layered rocks, but there are many exceptions, among these being prominent east-west dykes.

In composition, the dykes are doleritic and often contain a small amount of quartz. Grain size varies from fine, to medium, to coarse. No petrographic distinction is apparent between a number of northward and eastward trending dykes. Those examined may be co-magmatic.

Cross-cutting relationships demonstrate several relative ages, though there is no reason to believe that there has been more than one general period of dyke intrusion. In general, foliation is absent, but in many localities such as near the Darling Fault, dykes are completely sheared.

Xenolithic dolerite dykes (*dx*) are rare. One example east of Wongan Hills contains granitic xenoliths. A second, near New Norcia, incorporates xenoliths of *Anl* and other gneisses. Lewis (1969; 1970) considers that similar dykes on the Perth Sheet to the south were intruded along shear zones.

Quartz dykes and veins

Many, usually small quartz veins (*q*) cut the Precambrian rocks. Some extend for a few kilometres and various trends are represented.

PHANEROZOIC

Phanerozoic sedimentary rocks are present in the Perth Basin, an elongate, graben structure that extends for almost 1 000 km along the western side of the Australian continent (Playford, Cockbain, and Low, 1977). The basin varies in width from 80 to 175 km, and is bounded on the east by the Darling Fault.

Pre-Jurassic sediments have not been reported from the sheet, either at the surface or in drill holes. However, evidence from elsewhere in the Perth Basin suggests that representatives of the Ordovician-Silurian, Devonian, Permian, Triassic, and further formations of the Jurassic are likely to be present in the subsurface (Low, 1972).

JURASSIC

Exposures of sandstones and minor shales northwest of Dandaragan are thought to represent part of the Yarragadee Formation (Middle Jurassic to Lower Cretaceous), although these outcrops could possibly belong to the lowest part of the Leederville Sandstone (Lower Cretaceous). In this area, the unconformity between these formations is not clear from surface mapping.

CRETACEOUS

Cretaceous sediments occur extensively throughout the Perth Basin, and crop out over a large area in the southwest corner of the sheet, where six formations, ranging from Lower to Upper Cretaceous, are recognized. The Yarragadee Formation of the Lower Cretaceous may also be present.

Yarragadee Formation

The Yarragadee Formation ("Yarragadee Beds") of Fairbridge (1953), amended by Playford and Willmott (McWhae and others, 1958) is now known to extend upwards into the Neocomian in the offshore area opposite Perth and in the Dandaragan Trough north of Perth. Exposures of weathered continental sandstone and minor shale, located mainly west of the Dandaragan Scarp, are thought to belong to the uppermost part of the Yarragadee Formation and to be Neocomian in age. However, these outcrops could belong to the lowest part of the Leederville Sandstone.

Warnbro Group

The Warnbro Group (Playford and others, 1975) includes the South Perth Shale and the Leederville Sandstone, which together correspond to the "South Perth Formation" of McWhae and others (1958), and the Dandaragan Sandstone. Only the Leederville Sandstone and the Dandaragan Sandstone are known to occur in the area.

Leederville Sandstone: The Leederville Sandstone (Fairbridge, 1953) is a sequence of sandstone, frequently feldspathic and occasionally glauconitic, and conglomerate, with subordinate siltstone and shale. The type section is between 198 and 433 m in the Leederville Valley water bore in the Perth sheet area (Pudovskis, 1962). The formation is poorly exposed along the valley of the Moore River. In the sheet area, it rests unconformably on what may be the Neocomian part of the Yarragadee Formation, and is overlain by the Dandaragan Sandstone, probably with a conformable relationship.

The Leederville Sandstone is usually continental and unfossiliferous; however, within the Agaton Spring exploratory borefield, it is marine and contains a microflora of Neocomian-Aptian age.

Dandaragan Sandstone: The Dandaragan Sandstone (Fairbridge, 1953) is a unit of massive to thickly bedded, ferruginous, feldspathic, medium-grained to coarse-grained sandstone which crops out discontinuously along the eroded western edge of the Dandaragan Plateau. The type section is 6.4 km west of Dandaragan (30°41'30"S, 115°38'30"E) where the formation is 33 m thick. It was not recognized in the Agaton Spring water bores and is apparently missing in parts of the sheet.

The Dandaragan Sandstone probably overlies the Leederville Sandstone conformably, and is disconformably overlain by the Molecap Greensand. Fossil wood is present in a cave formed in the unit 9.0 km southwest of Dandaragan, but no diagnostic fossils have been found in the formation. It is believed to be of Lower Cretaceous age because of its stratigraphic position.

Coolyena Group

The succeeding, marine glauconite-bearing formations are predominantly Late Cretaceous. The Osborne Formation, Molecap Greensand, Gingin Chalk, and Poison Hill Greensand constitute the Coolyena Group of Playford and others (1975). The Osborne Formation crops out in the Moore River valley and for some distance to the north. The Molecap Greensand, Gingin Chalk, and Poison Hill Greensand are discontinuously exposed over a large part of the Dandaragan Plateau, south and southeast of Badgingarra. Those formations are also present in the Agaton Spring bore field (Passmore, 1969).

Osborne Formation: The Osborne Formation (McWhae and others, 1958) is a unit of interbedded sandstone (often fine-grained to medium-grained and calcareous in part), siltstone, shale and claystone. The formation is characteristically glauconitic, and the argillaceous sediments are usually dark grey to black. Its relationship with the Dandaragan Sandstone is not certain, but it is probably disconformable. It overlies the Leederville Sandstone disconformably, and conformably underlies the Molecap Greensand. The formation is about 60 m thick in the sheet area, and it ranges from Cenomanian to Albian in age in the Agaton Spring water bores (Passmore, 1969).

Molecap Greensand: The Molecap Greensand (Fairbridge, 1953) consists of greensand and glauconitic sandstone up to 12 m thick. Thin phosphate beds are present at the top and bottom of the formation in the Dandaragan area (Matheson, 1948). Teichert and Matheson (1944) found ichthyosaurian and plesiosaurian bones in the formation. Pelecypods and belemnites are reported from Gingin. Late Cretaceous microplankton were recorded by Deflandre and Cookson (1955), and this dating has since been confirmed by B. S. Ingram (pers. comm.).

Gingin Chalk: The Gingin Chalk (Glauert, 1910) consists of slightly glauconitic chalk, which contains thin beds of greensand in some areas. It is 19 m thick in its type section at Gingin, and may reach a comparable thickness in the mapped area; but it is lenticular, and may pinch out altogether in some places. At Gingin, it is rich in fossils including the Santonian (Middle Senonian) foraminifers *Globotruncana marginata*, species of the *G. lapparenti* group and *Rugoglobigerina* spp. (Belford, 1960). Other fossils and references are given in McWhae and others (1958).

Poison Hill Greensand: The Poison Hill Greensand (Fairbridge, 1953) consists of greensand and glauconitic sandstone with dark grey-green to black glauconitic clay in places. The exposures are usually strongly lateritized. Drilling has shown that the unit is at least 40 m thick in the Dandaragan area (Low, 1965). The formation rests conformably on the Gingin Chalk, and is overlain by laterite and Quaternary deposits.

The Poison Hill Greensand is poorly fossiliferous. However, a sample from a shot-hole a few miles south of the mapped area (31°03′30″S, 115°47′41″E), yielded an assemblage of foraminifers including *Dentalina confluens* Reuss, *Haplophragmoides* sp., *Verneuilina parra* Cushman, and *Spiroplectammina grzybowskii* Frizzell, considered by A. E. Cockbain to be Senonian, possibly Campanian, in age (pers. comm., 1969).

CAINOZOIC

Most of the area is covered by Cainozoic sediments, which are generally thin, rarely more than 50 m thick. The genesis of many deposits was complex and probably protracted. Distinctions, therefore, between Tertiary and Quaternary deposits are often doubtful. Morphological features were used in mapping some units, and on this basis, sand for example, is assigned divisions representing eolian, colluvial, and alluvial accumulations.

Continual reworking of Cainozoic sediments has resulted in the merging of one unit with another, and their limits are usually poorly defined. This is demonstrated by colluvial deposits: rock fragments on hills (*Qcf*) become smaller in size down-slope towards drainages and pass into lithic sands (*Qcs*) which in turn merge with clayey colluvial material (*Qcl*) and alluvium (*Qra*). Consequently boundaries, with few exceptions such as laterite cappings and lacustrine deposits, are only approximate.

TABLE 2. CAINOZOIC GEOLOGY

Formation or unit	*Symbol*	*Characteristics*	*Approx. max. thickness (m)*	*Remarks*	
Salt lake deposits	*Qws*	Saline silt and clay	(a)	Gypsum and other evaporite minerals may be present	
Swamp and lacustrine deposits	*Qrw*	Peat, sand and clay	(a)	Bentonite near Marchagee; diatomite may be present in some swamps	
Alluvium	*Qra*	Clay, silt and sand	(a)	River and stream deposits	
Colluvium	*Qc*	Clay, sand and gravel	(thin)	Unassigned colluvium	Over Archaean rocks
	Qcf	Rock fragments	"	Provides evidence of underlying rock types	
	Qcs	Lithic sand	"		
	Qcl	Clay and loam	"	Passes into clayey alluvium	
Eolian sand	*Qs*	Fine quartz sand	(a)	May occur in irregular dunes	
Sand, variously re-worked	*Qsy*	Yellow and white quartz sands	(a)	Associated with lakes and former drainages	
Colluvium, soil and sand over laterite	*Qpo*	Loam, sand and clay	6		Over Phan-erozoic and Proter-ozoic rocks
Eolian Sand	*Qpe*	Fine quartz sand	18	Derived from lakes, swamps and watercourses	
Kankar	*Qk*	Chalky limestone	2	Perth Basin: scattered outcrops in low-lying areas	
Tamala Limestone	*Qpcs*	Predominantly quartz sand	45	Leached dunes	
Bassendean Sand	*Qpb*	Podsolic quartz sand	30	Leached older coastal dunes, modified in shape, fixed by vegetation	
Silcrete	*Czi*	Pale-grey, porcellanous conglomerate	5	Small patches in a few localities	
Residual clay, sand and gravel	*Czgs*	Clay, lateritic gravel bands and some sand	10	Small-scale but common source of road gravel	
Residual sand	*Czs*	Yellow, sometimes white quartz sand	(a)	Source of sand and minor water supplies	
Colluvial laterite	*Czg*	Laterite gravel, crudely stratified	15	Occurs below laterite cappings of the Wongan Hills; source of gravel	
Laterite	*Czl*	Principally ferruginous laterite	6	Pisolitic and vesicular; source of gravel; locally bauxitic	

(a) not known

Furthermore, mapping of Cainozoic sediments on a regional scale in the Wheatbelt is necessarily somewhat speculative as a result of agricultural practices which tend to modify the often slight morphological expressions peculiar to thinner units, or by development of soils over the years which effectively mask the nature of underlying Cainozoic sediments. Cainozoic units are listed in Table 2.

STRUCTURE

Structural elements are illustrated on Figure 2. The principal feature, the Darling Fault, had its greatest movement during the period from Upper Triassic to the Lower Cretaceous. It separates the Archaean and Proterozoic outcrops on the east from the Phanerozoic rocks of the Perth Basin. Each has distinct structural styles. Archaean rocks are complexly faulted and folded. Faulting is the main structural feature of the relatively simply disposed Proterozoic Moora Group, whereas the gently folded Phanerozoic rocks are also disrupted by large faults. An active tectonic belt, the South West Seismic Zone, extends northwestwards across the sheet area, incorporating portions of each structural region. Within this zone, since 1949, earthquakes have occurred at Walebing, Yerecoin and Carani (Gordon, 1972).

ARCHAEAN ROCKS

In both the Berkshire Valley and the Wongan Hills successions, paucity of outcrop and complexity of structure are such that it has not been possible to define any large-scale fold axes. Although the overall structure of these successions is superficially simple, as suggested by some continuity of broad lithological zones, from minor structures it is apparent the rocks have undergone intense isoclinal folding accompanied by a shearing-out of limbs and transposition. Near Gillingarra, superimposed on the northward trend of the Berkshire Valley succession, are a series of easterly trending cross-folds which generally have little effect on the earlier isoclinal folds. In the Wongan Hills, there is a suggestion of later open folding which accounts for the present distribution of earlier tight folds.

Definite faults are difficult to recognize. In the west, two major fault directions are evident, east-west and northwest-southeast. A number appear to be strike-slip faults with sinistral displacement. An example is the fault that terminates the northward extension of the schistose rocks near Gillingarra, where displacement could be up to 10 km. Main faults in the Wongan Hills trend northwest, and there are displacements in both senses.

PROTEROZOIC ROCKS

The Moora Group strikes generally about 20 degrees west of north. Contacts with Archaean rocks are either unconformable or faulted. Strike faults are common and these are usually high-angle normal faults. Logan and Chase (1961) report displacements of up to 450 m in the Moora area.

PHANEROZOIC ROCKS

Gentle folding is present in the pre-Cretaceous strata, and these structures trend parallel to the Darling Fault and other major faults. The Gingin Anticline, a major structure to the south, extends for a few kilometres on to the sheet area. Movements of the Darling Fault, which has dominated the structure of the Perth Basin probably since the Silurian, have resulted in a half-graben structure, the Dandaragan Trough. This may contain 12 to 15 km of sediments. The Urella Fault is thought to extend southwards into the sheet (Playford, Cockbain, and Low, 1977).

GSWA 16919

FIGURE 2

DISTRIBUTION OF ARCHAEAN ROCKS, MOORA GROUP, PHANEROZOIC ROCKS, AND STRUCTURAL ELEMENTS

MOORA SHEET SH 50-10

SCALE

10 0 10 20 30 40 km

REFERENCE

- K — CRETACEOUS ROCKS
- JKy — YARRAGADEE FORMATION
- MOORA GROUP
- GRANITIC ROCKS
  - Agp — Porphyritic
  - Agb — Namban granite
  - Agv — Megacrystic
  - Age — Even-grained
  - Agn — Cataclastic
  - Ag — Unassigned: largely poorly exposed; direct evidence slight
- Am — MIGMATITE
- WONGAN HILLS SUCCESSION
  - Minor layered sequences
- BERKSHIRE VALLEY SUCCESSION
  - Predominantly schistose
  - Predominantly gneissose
  - Gneissose with subordinate BIF and amphibolite

- Geological boundary
- Fault with direction of hade (? inferred)
- Anticline (?inferred)
- Syncline
- 70 Bedding in sedimentary rocks, strike and dip measured
- Foliation in metamorphic rocks
  - direction of dip and plunge
  - vertical
  - undeterminable
- Foliation in granitic rocks
  - direction of dip
  - vertical
  - undeterminable
- Faults in Perth Basin from seismic data on the Cattamarra Reflector

ECONOMIC GEOLOGY

Mineral production has been negligible. Among current exploration ventures are drilling for petroleum in the Perth Basin where gas shows have been encountered, and exploration for copper in the Wongan Hills.

METALLIC MINERALS

Bauxite

Bauxitic laterite occurs on the Darling Plateau east of Gillingarra and on the Wongan Hills. Near Gillingarra, exploration was conducted by Pacminex Pty Ltd (Chittering Alumina Project) and small reserves of bauxite were indicated. The deposits extend southwards into the Perth Sheet area. In the late 1960s Vam Limited sank 180 shallow boreholes in laterite cappings on the Wongan Hills. Alumina grades of between 30 and 35 per cent were recorded in only seven holes and the prospect was relinquished.

Copper

Copper from quartz reefs in the Wongan Hills was described by Maitland (1899a; 1900). An account of recent drilling at a Wongan Hills prospect 1.5 km north of Lake Ninan mentioned chalcopyrite, and a drill hole intersected 9.8 metres averaging 0.66 per cent copper, 75 g/t silver, and 0.34 g/t gold (Otter Exploration N.L. Annual Report, 1975). At Berkshire Valley a small copper occurrence on former M.C. 1603H was shown to be due to secondary enrichment at a contact of granitic rock and a mafic dyke. Copper minerals occur in small quantities in Jingemia Cave, a few kilometres northwest of Watheroo (Simpson, 1952).

Gold

Gold was reported from the Wongan Hills in 1888 (Fraser, 1906). Very small quantities were won. The most recent production was in 1936 when 82.05 t of ore crushed at the Paynes Find battery yielded 190.35 g of gold. A site referred to as the New Norcia goldmine is located on "BIF hills" some 6 km west of Yerecoin, but there is no record of production.

Iron Ore

An enriched BIF immediately west of Waddington was examined in the early 1970s by Luke Prospecting Pty Ltd. The prospect was abandoned prior to drilling.

Nickel

Nickel associated with ultramafic rocks was the target of operations which included diamond drilling between Moora and Bindi Bindi in the late 1960s. No nickel values in excess of one per cent and no sulphide mineralization were reported.

Silicon

Near Kiaka Brook two small quarries have been established in pure chert of the Noondine Chert. The chert is to be used as a source of silicon and for producing ferrosilicon.

Titanium

Deposits of heavy-mineral sand carrying ilmenite, zircon, and monazite are associated with the Gingin Shoreline, which follows the foot of the Gingin Scarp (Baxter, 1977). At Regans Ford, sand contains up to 15 per cent heavy minerals. Along the shoreline to the northwest at Cataby, drilling has indicated a more substantial deposit estimated to contain 700 kt of heavy minerals (70% ilmenite, 7% rutile, 12% zircon and 1.5% monazite).

Uranium

Autunite was discovered in very small quantities in borehole sludges at Location 4176 immediately southwest of Kalguddering. "Ore prospects are nil" according to Noldart (1955).

INDUSTRIAL ROCKS AND MINERALS

Asbestos

Small quantities of asbestos have been won from mines near Bindi Bindi and Indarrie. Production figures for Bindi Bindi from 1942 to 1948 show some 511 t of anthophyllite asbestos valued at $13 465 were raised. The mine was described by Johnson (1950).

Bentonite

Claypans and small lakes 11 km southwest of Marchagee have been mined for bentonite (de la Hunty, 1955a, and b). Since 1942, 13 365 t valued at $99 100 has been produced.

Building and construction materials

Rock and road materials, lateritic gravel, and sand, are widely distributed. Of the building stones, the green and red Namban Granite (*Agb*) is especially attractive (Connolly, 1962). Stone from the Mokadine Formation, Dalaroo Siltstone, and Noondine Chert have been used for building purposes, and the latter formation is a source of road and railway ballast. Cream and brown chert pebbles are also sold for decorative cover for the garden. Pisolitic laterite is a commonly available souce of gravel.

Diatomaceous earth

Thin, impure deposits of diatomaceous earth, not known to be economic, occur in some of the small swamps, as for example those 18 km west of Watheroo.

Kaolin

Some kaolin was produced from a weathered profile overlying granitic rocks near Piawaning in 1943. About 406 t valued at $400 was obtained for use as a filler (Lipple, 1977.)

Semi-precious stones

Coloured varieties of Noondine Chert are polished for this purpose.

Petroleum

The potential of the Perth Basin is currently being investigated at Warro where shows of natural gas have been encountered.

Phosphate

Thin beds in the Molecap Greensand near Dandaragan have been investigated (Low, 1965).

WATER SUPPLIES

Aspects of hydrogeology are described in published and file reports of the Geological Survey. Generally pools in rivers and streams are brackish or saline, and are unsuitable for irrigation or domestic purposes, and are of little use for stock. While some surface water supplies are obtained from springs or soaks, groundwater is the principal source of supply. It occurs within the three main geological environments.

On the Archaean block, bores usually supply small quantities of saline water, often not even suitable for stock. In places where the localized subsurface conditions are more than usually favourable, stock water can be obtained by drilling. Isolated pads of yellow or white sand (*Czs* and *Qsy*) are a source of low salinity water suitable for domestic use, although these are not common.

Wall (1968) described the hydrogeology of the Moora Group. These sediments usually produce only stock-water supplies and not domestic quality water. The most important unit is the Noondine Chert, but this is difficult to drill. It yields stock water, and in favourable conditions, quite large supplies of water low enough in salinity for domestic use. Coomberdale township uses this water as did Moora until recently.

Since 1968, the Geological Survey has investigated groundwater in the Phanerozoic sediments of the Perth Basin. The main projects are the Agaton exploratory bore field (Balleau and Passmore, 1972), the Watheroo bore line (Harley, 1974) and the Moora bore line, which is still under investigation. Pressure water of fairly low salinity is available from sandstones of both the Warnbro Group and the Yarragadee Formation. The latter has an upper and lower aquifer system separated by a thick mudstone sequence. West of the Dandaragan scarp, bores draw their water from the lower aquifer, at depths varying from 50 to 200 metres depending on the height of the land surface. The salinity is usually less than 1 000 mg/litre. East of the Dandaragan scarp, water occurs in Warnbro Group sandstones and also the upper Yarragadee aquifer, the salinity being generally less than 600 mg/litre. Farm bores may exceed 100 metres in depth. Moora township is supplied from two bores 13 km to the west, drawing from the Yarragadee Formation.

Over the whole coastal plain, high-level patches of Cainozoic sand sometimes contain a shallow, perched water table, which supplies springs and soaks many of which dry up in summer. A few maintain farm bores less than about 30 metres deep, the salinity being less than 500 mg/litre.

REFERENCES

Arriens, P. A., 1971, The Archaean geochronology of Australia: Geol. Soc. Australia Special Pub. No.3, p.11-23.

Belford, D. J., 1960, Upper Cretaceous foraminifera from the Toolonga Calcilutite and Gingin Chalk, Western Australia: Australia Bur. Mineral Resources Bull. 57.

Balleau, W. P., and Passmore, J. R., 1972, Geology and groundwater at the Agaton exploratory bore field: West. Australia Geol. Survey Rec. 1972/11 (unpublished).

Baxter, J. L., 1977, Heavy mineral sand deposits of Western Australia: West. Australia Geol. Survey Mineral Resources Bull.10.

Baxter, J. L., and Lipple, S. L., 1979, Explanatory notes on the Perenjori 1:250 000 geological sheet, Western Australia: West. Australia Geol. Survey Rec. 1978/16, 47p.

——(in press), Geological map of Perenjori 1:250 000 sheet (SH50-6 International Grid) with explanatory notes.

Cockbain, A. E., 1967, Fossils from the Moora Group: West. Australia Geol. Survey Palaeont. Rept 58/67 (unpublished).

Connolly, R. R., 1962, Report on M.C. 720H for building stone near Watheroo, S. W. Land Division: West. Australia Geol. Survey Ann. Rept, 1960.

Deflandre, G., and Cookson, I. C., 1955, Fossil microplankton from Late Mesozoic and Tertiary sediments: Australia Jour. Marine and Freshwater Res. 6.

de la Hunty, L. E., 1955a, Report on bentonite on M.C. 456H, Marchagee, South West Division: West. Australia Geol. Survey Ann. Rept. 1952.

——1955b, Report on bentonite on M.C. 452H, Marchagee, South West Division: West. Australia Geol. Survey Ann. Rept 1952, p.32-33.

Fairbridge, G. W., 1950, Precambrian algal limestone in Western Australia: Geol. Mag. v.87, No.5, 324p.

——1953, Australian stratigraphy: Univ. West. Australia Text Books Board.

Fraser, M. A. C., 1906, Western Australian Yearbook 1902-1904: Perth, Govt. Printer, p.830-834.

Gee, R. D., 1975, Regional geology of the Archaean nucleii of the Western Australian Shield, in Knight, C.C. (Ed.), Economic Geology of Australia and Papua New Guinea—Metals; Australasian Inst. Mining Metall. Mon. 5, p.43-55.

Geological Survey of Western Australia, 1975, Geology of Western Australia: West. Australian Geol. Survey, Mem. 2, 541p.

Glauert, L., 1910, The geological age and organic remains of the Gingin Chalk: West. Australia Geol. Survey Bull. 36.

Gordon, F. R., 1972, Earthquake hazard in Western Australia: West. Australia Geol. Survey Ann. Rept 1971.

Grey, K., 1979, Preliminary results of biostratigraphic studies of Proterozoic stromatolites in Western Australia: West. Australia Geol. Survey Rec. 1979/2 26p.

Harley, A. S., 1974, The hydrogeology of the Watheroo-Jurien Bay Line, Perth Basin: West. Australia Geol. Survey Rec. 1974/23 (unpublished).

Ivanac, J. F., 1946, The geology and geomorphology of the Gillingarra area: Univ. West. Australia Hons Thesis (unpublished).

Johnson, W., 1950, A deposit of anthophyllite asbestos two miles north of Bindi Bindi, South-West Division: West. Australia Geol. Survey Ann. Rept 1948.

Jutson, J. T., 1950, The physiography (geomorphology) of Western Australia: West. Australia Geol. Survey Bull. 95 (third edition).

Lewis, J. D., 1969, The geology of the country around Meckering: West. Australia Geol. Survey Rec. 1969/18 (unpublished).

——1970, Petrography and significance of some xenolith-bearing basic dykes of the Meckering district, Western Australia: West. Australia Geol. Survey Ann. Rept 1969, p.46-54.

Lipple, S. L., 1977, Kaolin occurrences in the southwest of Western Australia: West. Australia Geol. Survey Rec. 1976/17 (unpublished).

——1982, Geology of the Wongan Hills: West. Australia Geol. Survey Rec. 1982/4.

Logan, B. G., and Chase, L. R., 1961, The stratigraphy of the Moora Group, Western Australia: Royal Soc. West. Australia Jour. v.44, pt 1, 1961.

Low, G. H., 1965, Drilling of Upper Cretaceous glauconite deposits at Dandaragan, Gingin, and Bullsbrook: West. Australia Geol. Survey Rec. 1965/6 (unpublished).

——1969, The geology of the Moora Group, Western Australia: West. Australia Geol. Survey Rec. 1969/5 (unpublished).

——1972, Explanatory notes on the Proterozoic and Phanerozoic rocks of the Moora 1:250 000 geological sheet, Western Australia: West. Australia Geol. Survey Rec. 1972/21 (unpublished).

——1975, Proterozoic rocks on or adjoining the Yilgarn Block *in* Geology of Western Australia: West. Australia Geol. Survey, Mem.2, p.71-81.

Maitland, A. G., 1899a, The Wongan Hills: West. Australia Geol. Survey Ann. Rept 1898, p.31-34.

——1899b, The artesian water prospects in the vicinity of Moora: West. Australia Geol. Survey Ann. Rept 1898, p.34-35.

——1900, The mineral wealth of Western Australia: West. Australia Geol. Survey Bull.4, p.82.

Matheson, R. S., 1948, The Dandaragan phosphate desposits: West. Australia Geol. Survey Mineral Resources Bull.4.

McArthur, W. M., and Bettenay, E., 1960, The development and distribution of the soils of the Swan Coastal Plain, Western Australia: Australia CSIRO Soil Publication No. 16.

McWhae, J. R. H., Playford, P. E., Lindner, A. W., Glenister, B. F., and Balme, B. E., 1958, The stratigraphy of Western Australia: Geol Soc. Australia Jour. v.4, pt 2.

Noldart, A. J., 1955, Report on uranium occurrence on location 4176, Kalguddering, S. W. Division, W.A.: West. Australia Geol. Survey Bull.112, p.94-96.

Passmore, J. R., 1969, Exploratory drilling—Agaton Project, Watheroo area preliminary report: West Australia Geol. Survey Ann. Rept 1968.

Playford, P. E., and Willmott, S. P., 1958, Stratigraphy and structure of the Perth Basin, Western Australia: West. Australian Petroleum Pty Ltd Rept (unpublished).

Playford, P. E., Cope, R. N., Low, G. H., Lowry, D. C., and Cockbain, A. E., 1975, Phanerozoic *in* Geology of Western Australia: West. Australia Geol. Survey Mem.2.

Playford, P. E., Cockbain, A. E., and Low, G. H., 1977, Geology of the Perth Basin, Western Australia: West. Australia Geol. Survey Bull. 124.

Pudovskis, V., 1962, Sub-surface geology of the Perth metropolitan area: West. Australian Petroleum Pty Ltd Rept p.5 (unpublished).

Saint-Smith, E. C., 1912, A geological reconnaissance of a portion of the South-West Division, Western Australia: West. Australia Geol. Survey Bull.74.

Simpson, E. S., 1952, Minerals of Western Australia: Vol.3 Perth, Western Australia Government Printer.

Teichert, C., and Matheson, R. S., 1944, Upper Cretaceous ichthyosaurian and plesiosaurian remains from Western Australia: Australia Jour. Science, v.VI, no.6.

Vening Meinesz, F. A., 1948, Gravity expeditions at sea, 1929-1939: Delft, Drukkerij Waltman (A. F. Mulder).

Wall, L. N., 1968, Preliminary Hydrologic report on the Moora Group: West. Australia Geol. Survey Rec.1968/5 (unpublished).

Wilde, S. A., and Low, G. H., 1975, Explanatory notes on the Perth 1:250 000 geological sheet, Western Australia: West. Australia Geol. Survey Rec.1975/6, 67p (unpublished).

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MOORA

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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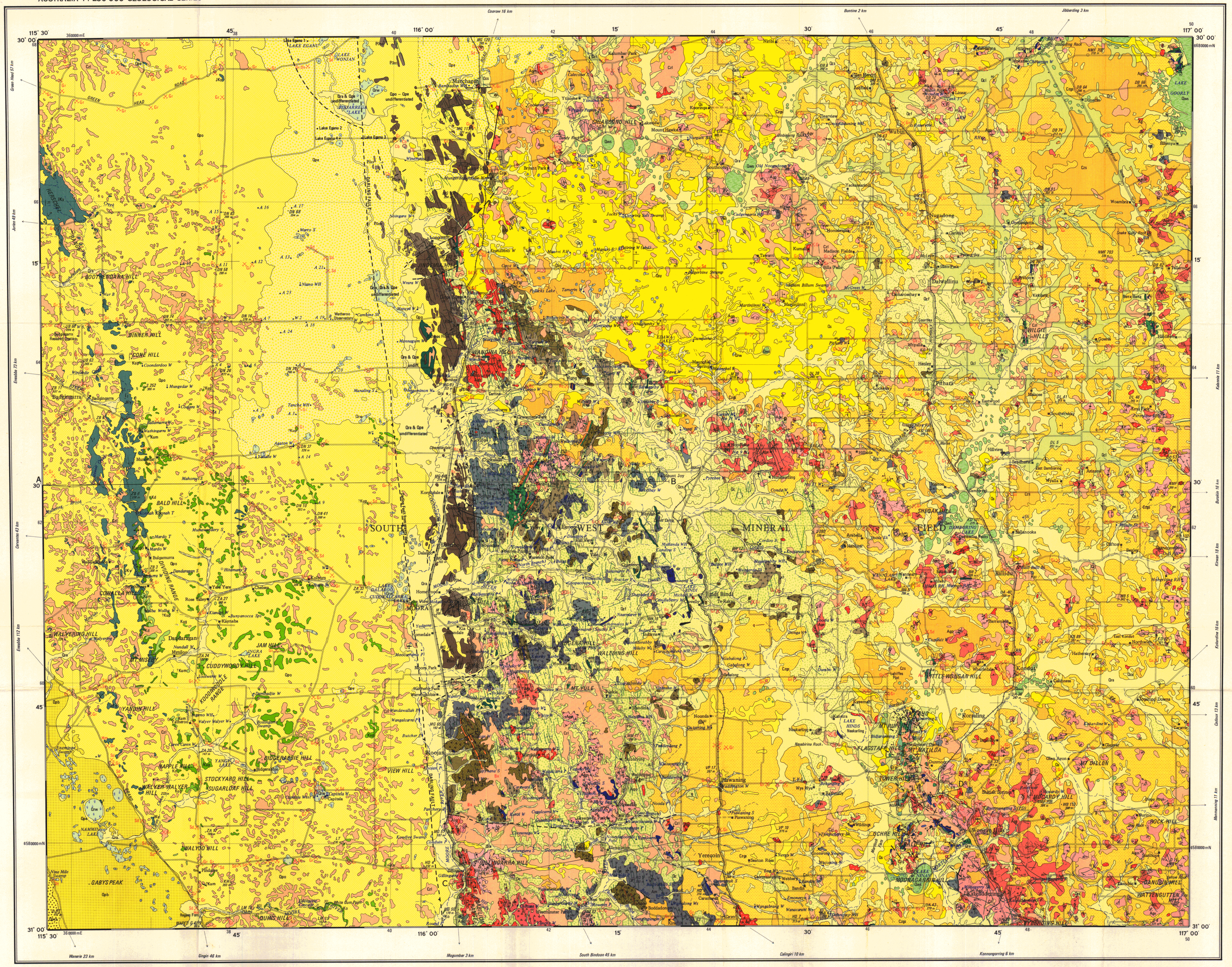

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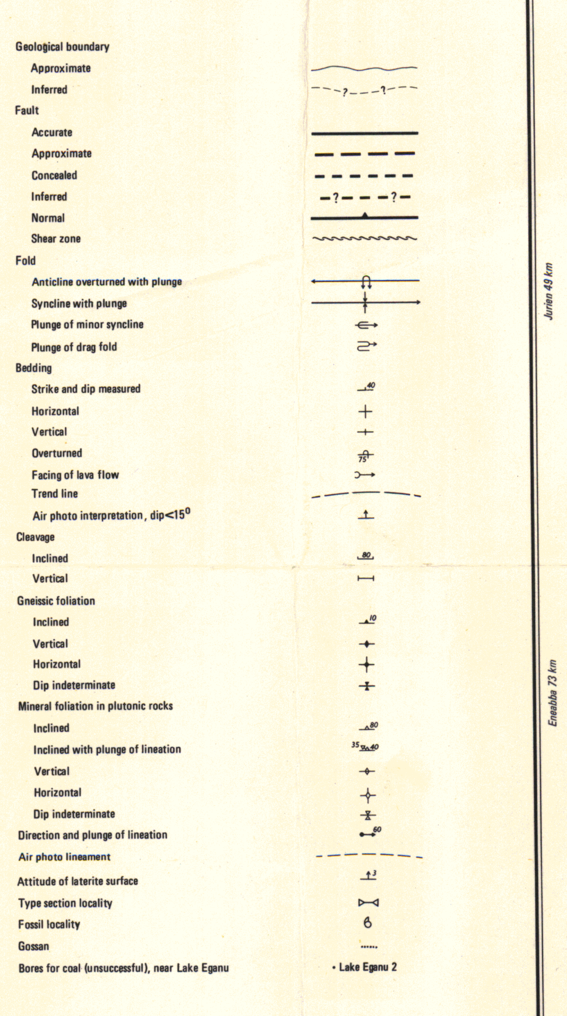

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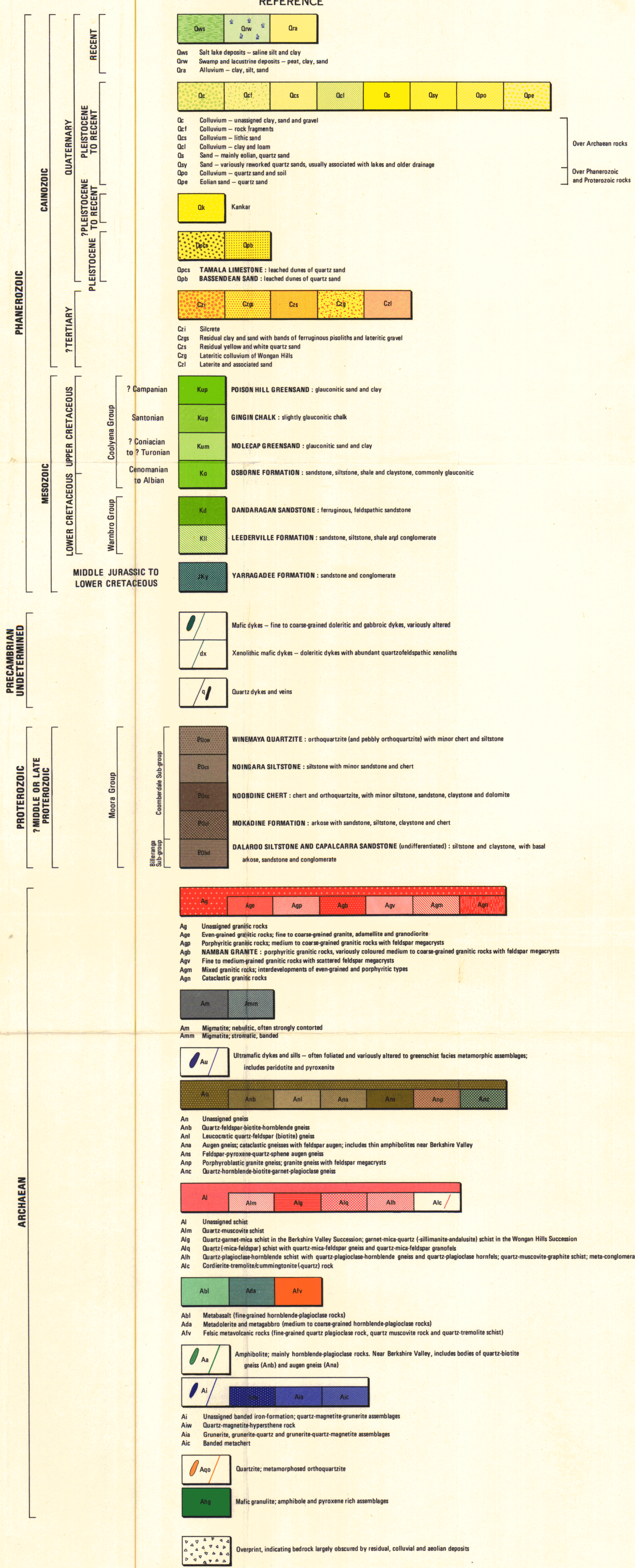

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Copies of this map may be obtained from the Geological Survey of Western Australia, 66 Adelaide Tce., Perth.

HON. P.V. JONES, M.L.A.
MINISTER FOR MINES
A.F. TRENDALL, DIRECTOR, GEOLOGICAL SURVEY

SCALE 1 : 250 000

TRANSVERSE MERCATOR PROJECTION
ZONE 1 AUSTRALIA SERIES

Grid represents the 10000 metre superimposed Australian Map Grid

Geology : Perth Basin – G.H. Low and D.C. Lowry 1968
Yilgarn Block – J.D. Carter and S.L. Lipple 1972-76

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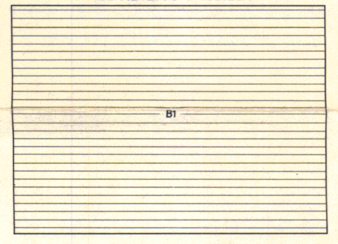
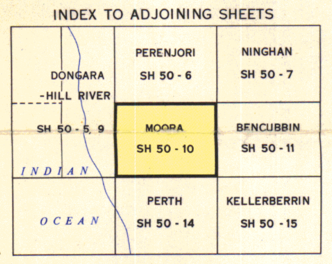


B1 Numerous traverses with air photo interpretation

INDEX TO ADJOINING SHEETS



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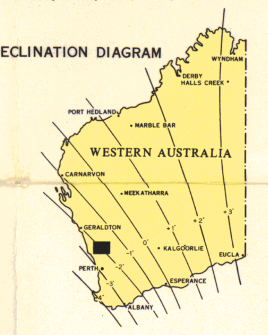

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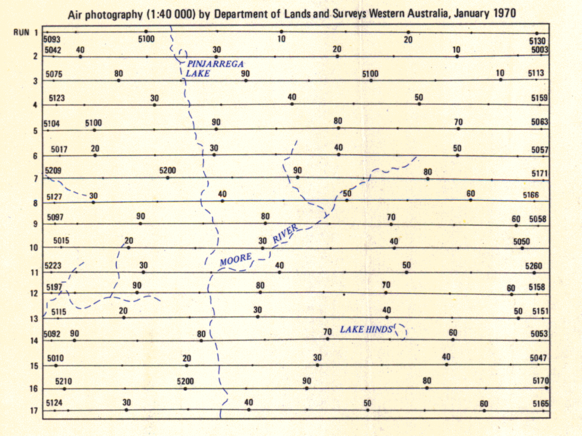

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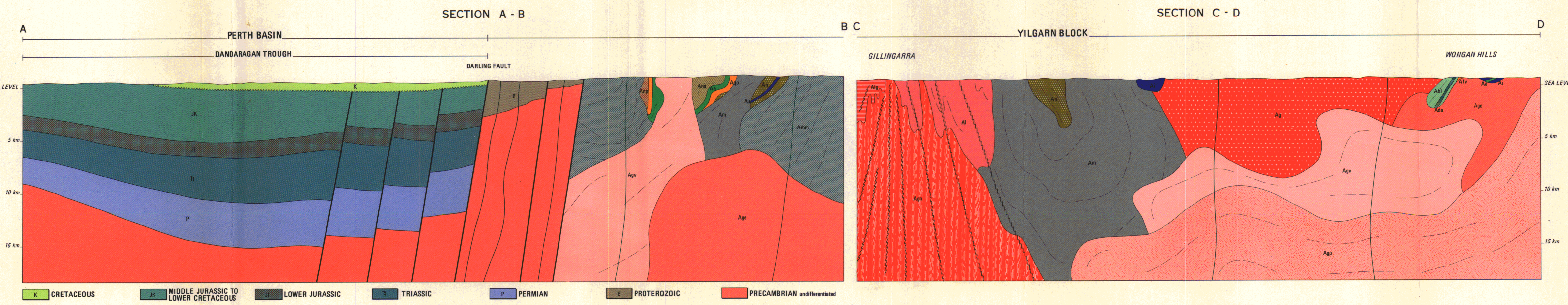

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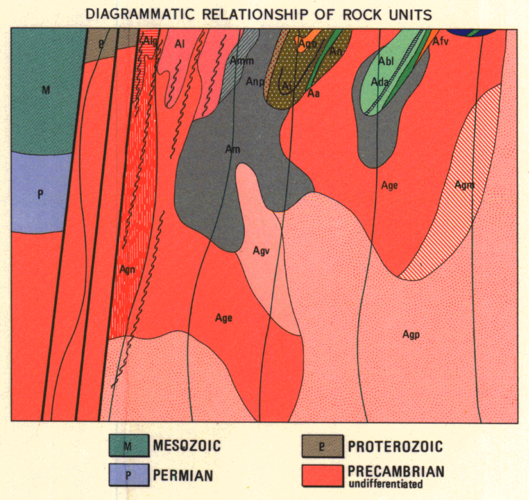

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