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EXPLANATORY NOTES

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Map Reference

SI 50/2 and Part SI 50/1

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INTRODUCTION

GENERAL

The Pinjarra 1:250 000 Geological Sheet (SI/50-2 and part of SI/50-1 of the International Series) is bounded by latitudes 32°S and 33°S and longitudes 115°25'E and 117°00'E. This Record deals only with the area east of the Darling Fault (i.e. approximately east of longitude 115°54'E). The geology of the Perth Basin area to the west of the Darling Fault has previously been described by Low (1972a).

The area lies almost entirely within the "Jarrah" natural region of Clarke (1926). The land is largely uncleared in the west, but east and southeast of Boddington and Wandering extensive clearing for agriculture has taken place, with partial clearing north from Wandering to the Brookton Highway. The strip of country in the northeast part of the area, between Brookton, Beverley, and Fleays, forms part of the "Wheat Belt" natural region and has been cleared for agricultural purposes.

The town of Pinjarra lies on the coastal plain, some 8 km west of the Darling Fault; Fremantle and the southern suburbs of the Perth Metropolitan Area also lie to the west of the described area. Settlement is concentrated along the major highways, and the main population centres are at Armadale, Waroona, Dwellingup, Boddington, and Beverley. Three major highways radiate southwards from the metropolitan area (the Southwestern, Albany, and Brookton Highways), and the Great Southern Highway links Beverley with York in the north and Brookton in the south. Interconnecting sealed and unsealed roads are numerous in the eastern part of the Sheet area, but there are fewer roads in the western, northern, and central areas (except for forestry tracks).

Geological mapping was carried out by S.A. Wilde and K.J.B. Hirschberg during 1974 and 1975. The petrographic work was done by J.D. Lewis and S.A. Wilde.

CLIMATE

The Sheet area has a dry-summer, subtropical (Mediterranean) climate. Rainfall isohyets trend generally north-south, and annual precipitation ranges from 421 mm at Beverley in the northeast to around 1000 mm along the Darling Scarp; highs above 1300 mm are centred on Canning Dam, Mount William, and Dwellingup (1306 mm). Most of the rain falls during the cool winter months of May to September. The summer months of December to March are hot and dry, whereas October, November and April are warm and changeable.

VEGETATION

Rainfall and geology exert a strong control over the vegetation. A sclerophyllous forest of jarrah (Eucalyptus marginata) is characteristically developed on the laterite of the Darling Range (Gardner, 1944). Sandy areas contain abundant marri (E. calophylla), and wandoo (E. wandoo) is locally prominent, especially over dolerite dykes. Sheoak (Casuarina fraseriana) occurs on granite outcrops, or where only a thin mantle of laterite overlies rock. Marri, wandoo, and powder bark wandoo (E. accedens) become more prominent in the drier areas to the east, and the forest gives way to a temperate savannah woodland. Natural vegetation has been largely cleared from the eastern part of the sheet area, although Dryandra State Forest and Boyagin Rock Reserve are exceptions. Here, powder bark wandoo and brown mallet (E. astringens) are dominant, together with an understory of Dryandra sp., whilst jam (Acacia acuminata) and mallee (E. drummondii) are locally prominent. Throughout the sheet area, an understory of sclerophyllous shrubs and ground plants is present.

GEOMORPHOLOGY

The area falls entirely within the South West Physiographic Division (Swanland) of Jutson (1950). It forms part of the Darling Plateau and is separated from the Swan Coastal Plain by the Darling Scarp (Saint-Smith, 1912). The Darling Plateau is an ancient erosion surface that has an average elevation of about 300 m above sea-level. Bedrock is capped by extensive laterite that has been partially dissected by later drainage. In the west near the Darling Fault the laterite surface is fairly intact, but east of a line extending from Mount Saddleback northwestward to Bickley, it is strongly dissected by the Murray and Avon drainage systems.

Plateau residuals remain along the drainage divides, and remnants of an ancient drainage system (possibly Tertiary) are locally preserved, especially near the divide separating the Avon, Canning and Darkin Rivers. The trellised drainage pattern, distribution of alluvium, and extensive areas of preserved laterite suggest that river capture has occurred along the Murray-Hotham-Williams system between Marradong and the southern margin of the sheet.

A prominent range of hills extending northwestward from Mount Cooke (582 m) to Eagle Hill forms the divide between the Canning and Serpentine drainage systems, and, together with Mount Dale on the Canning-Darkin River watershed, may represent monadnocks that protruded above the Darling Plateau peneplain (Jutson, 1950).

PREVIOUS INVESTIGATIONS

There are a number of early reports dealing with dam site investigations and mineral occurrences in the Yilgarn Block, the more important of which are listed in the references. Prider (1943), Davis (1943) and Thomson (1943) mapped and described the Archaean and Proterozoic rocks of the Darling Scarp in the Kelmscott and Armadale areas; Prider (1945) also described the granitic rocks at the Canning Dam. Several years later, a number of honours theses at the University of Western Australia were compiled on other areas close to the Darling Scarp, including those of Singh (1958), Appleyard and Burdett (1962), Miezitis (1963) and Tian (1963).

Details of mineral occurrences and some comments on the geology are contained within Simpson (1948, 1951 and 1953).

The Darling Scarp area between latitudes 32°S and 33°S, and as far east as approximate longitude 116°07'E was mapped by Baxter and Doepel (1973) as part of the Perth Basin mapping programme (Low, 1972a).

Bouguer anomaly and total magnetic intensity maps of the Pinjarra Sheet have been prepared by the Bureau of Mineral Resources.

ARCHAEAN GEOLOGY

REGIONAL SETTING

The area east of the Darling Fault forms part of the Yilgarn Block. This is a stable Archaean nucleus which is composed mainly of granites and gneisses, but which encloses a number of elongate "greenstone" belts. The "greenstone" belts have a general north-northwesterly trend and consist of layered successions of felsic, mafic, and ultramafic igneous rocks, and subordinate amounts of sedimentary material. These belts appear to decrease in abundance westwards from the Eastern Goldfields region.

In the Perth sheet area of the southwestern Yilgarn Block, the layered rocks occur in two metamorphic belts (Wilde and Low, 1975). These contrast with the "greenstone" belts to the east in the higher grade of regional metamorphism, the complete lack of felsic volcanic rocks, the subordinate amount of mafic ?volcanic material, and the overall abundance of metasedimentary rocks.

In the Pinjarra sheet area, the Yilgarn Block is composed largely of granitic rocks with smaller enclosed patches of migmatite; metamorphic rocks are subordinate and confined to three distinct areas. The granites form part of a large batholith that extends north to the Swan/Avon River on the Perth sheet, and southwards onto the Collie sheet area. Individual granite types occupy fairly large areas in the west and central parts of the sheet, but relationships become increasingly complex to the east where a zone, 30 to 50 km wide, of small, complexly interdeveloped granite types and migmatite flanks the southern continuation of the Jimperding Metamorphic Belt.

In the northeast corner of the sheet, the Jimperding Metamorphic Belt extends south-southwestward from the York area of the Perth sheet and contains similar lithologies. In the southern part of the sheet area near Boddington, a previously unrecorded belt of weakly metamorphosed sedimentary, felsic and mafic volcanic, and pyroclastic rocks extends north-northwestward from Mount Saddleback to Mount Wells. These rocks have been formally named the Saddleback Group (Wilde, 1976). A narrow, discontinuous belt of metamorphic rocks crops out along the Darling Scarp. South of Pinjarra, the belt is more continuous and widens to the southern margin of the sheet. It has not been formally named, owing to its fragmented nature and more extensive development on the Collie Sheet, where geological mapping is still in progress. The belt is referred to in the text as "gneissic rocks near the Darling Scarp".

LAYERED SEQUENCES

JIMPERDING METAMORPHIC BELT

This belt extends north-northwestward for 25 km in the extreme northeast of the area, near Beverley; it has an average width of 12 km, although the eastern limit of the metamorphic belt lies beyond the sheet boundary. It extends northward onto the Perth sheet (Wilde and Low, 1975) and southeastward onto Corrigin. The strata have a regional north-northwesterly trend and moderate easterly dips, although, north of Beverley, folding has produced a local easterly trend and shallow dips to the south. Isolated remnants of the Jimperding Metamorphic Belt occur in the Dale Bridge area, up to 10 km west of the main belt. These rocks are enclosed in migmatite and granite, and indicate that, prior to granite intrusion, the belt extended much further to the west. A small isolated area of related rocks also crops out near the Brookton Highway, 5 km west of Brookton. This area is separated from the main belt by about 15 km of migmatite and porphyritic granite. The metamorphic grade of the Jimperding Metamorphic Belt ranges from amphibolite-granulite transition facies to granulite facies.

Gneisses

In the western part of the belt, the predominant rock type is a fine to medium-grained quartz-feldspar-biotite gneiss (Anb). It is chiefly well-banded with distinct biotite-rich layers, although it is locally more massive and has a discontinuous biotite foliation. Both plagioclase (andesine/oligoclase) and microcline are present, though the relative proportion varies. Some units contain abundant garnet.

Leucocratic, quartz-microcline-oligoclase (-garnet-biotite) gneiss (Anl) forms the eastern part of the belt. It is interbanded with Anb at Mount Amy and Mount Stone, and becomes predominant to the east. Thin units of quartzite and garnet-feldspar quartzite are locally intermixed. The main rock type is medium to coarse grained, and consists of long stringers and lenses of quartz interleaved with granular aggregates of microcline and oligoclase. Strongly delineated lozenges of feldspar are commonly included in the quartz stringers. Both microcline and oligoclase may form megacrysts, and garnet is a common accessory mineral. Biotite-rich bands occur locally and these may contain hypersthene and abundant oligoclase. Certain units have fewer felsic stringers, and are allotriomorphic granular to granofelsic in texture.

Porphyritic granite gneiss (Anp) crops out extensively near Bilbarin Hill, immediately northeast of Beverley; and also occurs in association with Anb, about 5 km south of Dale Bridge. At Bilbarin Hill, the gneiss is flat-lying and overlies a prominent east-trending quartzite unit. The rock is a coarse-grained quartz-microcline-oligoclase-biotite (-hornblende-garnet) gneiss with tabular megacrysts of microcline. It is similar to porphyritic granite in general appearance, but always has a strong gneissic foliation. Its outcrop does not exactly conform to the local trend of the other layered units and it may possibly have been formed by local metasomatism.

Other Rock Units

In contrast with the Perth Sheet area, units of schist are virtually absent from this southern continuation of the Jimperding Metamorphic Belt. A poorly exposed band of quartz-mica-garnet schist (Alg) crops out sporadically north-northwestward from Bilbarin Hill. It overlies quartzite to the west, and can be traced for about 7 km. Schists containing alumino-silicates have not been found in the area.

Amphibolite (Aa) occurs as thin bands within the gneissic sequence, often in association with quartzite or where Anb and Anl are finely interbanded. The rocks are typically fine to medium grained, and are composed of xenomorphic granular aggregate of hornblende and plagioclase (andesine labradorite). Quartz ranges up to 15 per cent in certain bands. At several localities the hornblende is olive-brown and associated with colourless clinopyroxene. Minor lensoid units of hornblende rock, often with relict pyroxene cores, are present locally.

Quartzite (Aqo) forms fairly narrow units that, owing to their resistance to erosion, usually stand-out as ridges. They form the most useful marker horizons in the gneissic terrain, and help define the regional structure. The most southerly outcrop is at Mount Kokeby, and the widest unit is at Mount Amy. Quartzite bands are most numerous where Anb and Anl are interbanded. The rocks are metamorphosed orthoquartzites, and are coarser grained and less flaggy than in the Perth sheet area. They consist of interlocking grains of quartz with only minor amounts of feldspar, garnet, or muscovite. Green chrome muscovite is often present, but it forms fibrous groups and does not coat the foliation surfaces (as in the Toodyay area). A quartzite band, 3 km north of Mount Kokeby, contains needles of colourless amphibole together with abundant clinopyroxene, and appears to be a more calcareous variety.

An unusual feature is the presence of undeformed regularly-dipping quartzite lenses entirely enclosed within complex migmatite and granite west of Dale Bridge. Here, variably porphyritic granite is in direct contact with quartzite without any evidence of disturbance during emplacement of the granite.

Units of banded iron-formation (BIF) are much less common than on the Perth Sheet (Wilde and Low, 1975). They are lensoid and cannot be traced over any great distance. A banded magnetite-bearing quartzite (Aiq) crops out near Wyalgima Hill. This is somewhat transitional to Aqo but has centimetre-scale banding due to concentrations of magnetite. All other occurrences are shown on the map as unassigned BIF (Ai), and include the assemblages quartz-magnetite-garnet, quartz-magnetite-grunerite, quartz-grunerite-clinopyroxene and quartz-magnetite-clinopyroxene-orthopyroxene.

A unit of mafic granulite (Ahg) crops out 7 km southeast of Beverley. It is a hypersthene-diopside-brown hornblende-plagioclase granulite and has a xenoblastic texture. A thin band, 5 km west of Brookton, has a similar mineralogy, although the hypersthene is mostly altered. A number of the amphibolite (Aa) units have mafic granulite affinities, but are always devoid of hypersthene.

Ultramafic rocks (Au) occur as small pods or lenses within the gneissic sequence. They crop out poorly and are often represented by piles of rubble. Their relations to the adjacent units are not clear, but they probably constitute a later intrusive phase that has become subconcordantly infolded with the layered succession (Wilde and Low, 1975). The rocks are variously altered to talc-tremolite, talc-chlorite, and chlorite-serpentine greenschist facies assemblages. A fragment obtained adjacent to Ai on Mount Stone is a fresher peridotite consisting of olivine, orthopyroxene and abundant pale green amphibole, together with secondary serpentine and talc.

Thin units of cordierite-bearing gneiss (Ci) occur at two localities, and are shown as mineral occurrences on the map. In the small gneissic area, 5 km west of Brookton, a cordierite-quartz-garnet-biotite gneiss crops out against a chlorite-serpentine ultramafic unit. Original cordierite is now largely altered to masses of cryptocrystalline sericite with abundant quartz inclusions. The garnet is also extensively altered to iron-stained chloritic material. In another small area of gneisses enclosed by granite, 2 km east of Fleays, a thin band of altered cordierite-quartz-biotite gneiss occurs.

SADDLEBACK GROUP

A 5 to 12 km-wide belt of weakly metamorphosed sedimentary, felsic and mafic volcanic and pyroclastic rocks extends 43 km north-northwest from Mount Saddleback, near Boddington, to Mount Wells (Fig. 1).

This sequence has been formally named the Saddleback Group, and has been subdivided into the Hotham, Wells, and Marradong Formations (Wilde, 1976). The rocks are poorly exposed and extensively faulted (Fig.1). Even-grained adamellite (Age) intrudes all three formations in the southwestern part of the belt; elsewhere the contacts with granitic rocks appear to be fault-controlled.

The Saddleback Group constitutes the only definite volcanogenic "greenstone" belt as yet recorded from the southwestern Yilgarn Block. The metamorphic grade is greenschist to lower amphibolite facies, and original textures in the mafic rocks have not been totally destroyed. Intrusive relations indicate that the group pre-dates the granite, which is presumably related to the 2660 m.y. event (Arriens, 1971). However, the rocks are less deformed and metamorphosed than granitic gneisses that are faulted against the group 4 km south of Wuraming. These features suggest that the Saddleback Group is a younger Archaean sequence, perhaps comparable to successions in the Eastern Goldfields region.

The rocks of the Saddleback Group have undergone at least one period of deformation, accompanied by the development of a schistosity, although no major folds have been detected. However, although the predominant dip of the primary foliation is steep to the east, reversals have been recorded and the formations are strictly in structural and not stratigraphic order.

Hotham Formation

This formation is named after the Hotham River and consists of 1.6 km (maximum horizontal extent) of well-banded, silty metasediments with minor pyroclastic units (Ast). It is the least extensive of the formations, and crops out over about 2.5 km^2, 3 km east of George Hill. The primary foliation has a general north to northwesterly trend and moderate to steep easterly or westerly dips. At the type area, on a ridge 4.6 km east-southeast of George Hill, a 60 m wide sequence of grey and cream metasiltstone units trends 141^{o} and dips 75^{o}E. The units range from a few millimetres to 0.2 m thick, and consist of extremely fine-grained aggregates of quartz, feldspar, and abundant sericite. A few thin bands contain ovoid lenses and felsic fragments; these probably represent deformed agglomerate horizons. Minor units of quartz-mica schist, meta-tuff, and meta-greywacke are present in the southwest, and are often rich in biotite and epidote. A number of thin granite veins lie along foliation surfaces, and are locally transgressive. These presumably emanated from the nearby intrusive granite.

Wells Formation

The formation is named after Mount Wells, 17 km northwest of Boddington. It extends for 32 km in a north-northwest direction, and attains a maximum thickness of 5.5 km. The rocks consist of interbedded lavas, tuffs, breccias, agglomerates, and minor amounts of sedimentary rocks, all variously deformed and metamorphosed. In general lavas predominate in the northern part of the belt around Mount Wells, but pyroclastic rocks are more abundant south of the Bannister River. The formation conformably overlies the Hotham Formation near the Hotham River, and the contact is marked by a rapid increase in the size and number of the agglomeratic and tuffaceous horizons. Elsewhere, the western contact of the formation is fault bounded, Felsic pyroclastic rocks are intruded by adamellite (Age) 6 km east-southeast of George Hill. A 10 m wide contact zone consists of elongate felsic-volcanic xenoliths enclosed in an extremely variable granitic matrix. Irregular areas and veins of granite occur in the Wells Formation for up to 200 m from this zone.

The felsic lavas (Afl) consist of units of andesite, dacite, and rhyodacite, that are variously porphyritic and schistose. At the type area on Mount Wells, metamorphosed dacites and rhyodacites are interbanded with tuffs and minor amounts of sedimentary rock. The lavas contain prominent quartz phenocrysts in a fairly turbid matrix of quartz, feldspar, and white mica, with secondary epidote and clinozoisite. Andesitic lavas with relict phenocrysts of plagioclase and amphibole in a fine-grained polygonal, or drusy, quartzo-feldspathic matrix occur elsewhere in the sequence.

Pyroclastic rocks (Afp) are reasonably well exposed at Farmers Crossing and near the Hotham River. They consist chiefly of agglomerate containing clasts of felsic lava, which are often in excess of several metres long. These agglomerates are interbanded with fine-grained tuffs, breccias and volcanogenic sediments which are often difficult to differentiate in the field. Certain units of tuff near the Hotham River contain appreciable pyrite. In thin section, small to large, angular felsic volcanic fragments occur in a matrix of fine-grained quartz, feldspar, and white mica. Hornblende and green biotite are common in certain units, as are pyrite, clinozoisite, and apatite.

A single, 10 m-thick band of chloritoid schist (Afo) underlies porphyritic dacite, 4.6 km south of Mount Wells. It is a greenish rock containing tabular chloritoid up to 3 mm long. The chloritoid has distinct lamellar twinning and has grown across an early foliation defined by biotite and quartz. A later strainslip cleavage cuts and slightly rotates the chloritoid grains. The unit probably represents a pelitic or tuffaceous horizon in the lava sequence.

A small, serpentinized ultramafic body (Au) occurs 4.2 km northwest of Farmers Crossing. It crops out over 50 m and lies subparallel to the lavas.

Marradong Formation (Aba)

The formation is named after the townsite of Marradong, 7.5 km south-southwest of Boddington. It consists of 3 to 8 km of metabasalt, with minor intercalations of dark metasediment and metadacite. The rocks are poorly exposed, but appear to extend almost the whole length of the belt. The formation conformably overlies the Wells Formation at Mount Wells and the contact is sharp, although a few bands and lenses of metadacite occur in the metabasalt near the contact. The eastern boundary of the formation is everywhere faulted, so its total thickness is unknown. The type area is a 400 m long section on the Mount Saddleback range, 2 km south of Marradong. Here, fine-grained, schistose metabasalt (Aba), having a general trend of 166° and a dip of 81°E is cut locally by thin quartzo-feldspathic veins that have been deformed in the schistosity. The basalt consists of a ragged mosaic of hornblende and plagioclase, and a small quantity of quartz. The basalt is extensively altered to epidote and clinozoisite, but the less altered rocks have an igneous rather than a metamorphic texture. At 4 km northwest of Mount Saddleback, metabasalt is intercalated with dark, extremely fine-grained metapelite and metasiltstone, together with minor amounts of felsic volcanic rocks. Owen and Hargreaves (1975) refer to the mafic rocks on Mount Saddleback as gabbro.

GNEISSIC ROCKS NEAR THE DARLING SCARP

With the exception of two small areas of well-banded, quartz-feldspar-biotite gneiss (Anb) near the western boundary of the Saddleback Group, all gneissic rocks outside the Jimperding Metamorphic Belt lie within 10 km of the Darling Fault. These have been grouped together for descriptive purposes, although it is not implied at this stage that they represent a single metamorphic belt equivalent in status to the Jimperding Metamorphic Belt. However, lithological differences indicate that the rocks are not a southern continuation of the Chittering Metamorphic Belt (Wilde and Low, 1975).

The gneisses occur in three main areas: around Roleystone, between Mundijong and North Dandalup, and from near Pinjarra southwards to Cookernup and thence onto the Collie Sheet. These areas are characterized by a complex mixture of lithological types, and it was generally impossible to separate them at the map scale. Many of the rock types are the result of cataclastic deformation of pre-existing granitic rocks (orthogneisses). However, definite paragneisses are present as well, although the relative proportions could not be determined. All the unassigned gneisses have been grouped as An on the map.

Roleystone Area

An irregular gneissic area of approximately 35 km^2 is centred just east of Roleystone, and is bounded on all but the northern side by migmatite; even-grained granite intrudes the gneisses in the north. The lithologies and foliation trends are similar in the gneisses and migmatite, and it appears that intrusion of granitic material has converted an originally more extensive area of gneiss to migmatite (Fig.2). The gneisses dip westward at low to high angles, and were well exposed during the construction of the Canning Tunnel between Canning Dam and Roleystone. They consist of closely interbanded mafic and felsic units, with mafic gneisses predominating. The felsic gneisses consist of quartz-feldspar-biotite assemblages which vary from well-banded to massive, and which have a wispy biotite foliation. The mafic units are chiefly amphibolite and biotite-amphibolite, with some amphibole-bearing schists. Certain units have a granofelsic texture. A dark gneiss with distinct porphyroblasts of albite oligoclase is commonly interbanded in the sequence. Several zones rich in ultramafic pods, 5 to 40 cm long, were encountered in the Canning Tunnel. These pods are zoned and have a biotite-rich margin with central cores of radial or massive tremolite, and/or talc (Drake, 1976).

Mundijong - North Dandalup Area

Gneisses occupy a narrow strip about 22 km by 2 km down the Darling Scarp from Mundijong, south to North Dandalup; a small break of 2 km occurs at Serpentine. Several shear zones are present, and the predominant style of deformation is cataclastic. The gneisses have a northerly trend and dip westward at moderate to steep angles. The chief rock-types are quartz-feldspar-biotite gneiss (Anb), porphyritic granite gneiss (Anp), and augen gneiss (Ana). The augen gneiss is coarse grained, and consists of quartz, microcline, oligoclase, biotite, and contains large microcline augen. The texture is cataclastic, and the rocks differ from Anp in having a much more intense foliation, with strongly aligned augen. Indeed, augen gneiss has often resulted from the cataclasis of Anp, and occurs in distinct shear zones. Intense shearing has resulted in the formation of blastomylonite. Many of the rocks in this area are unbanded and massive, and appear to be deformed granites (orthogneisses). However, certain of the quartz-feldspar-biotite gneisses are interbanded with amphibole-rich bands and probably represent vestiges of an earlier layered sequence.

Pinjarra - Cookernup Area

A continuous band of gneisses, 1 to 7 km wide, extends southward from near Pinjarra to Cookernup and beyond the sheet area (a distance of 48 km on the Pinjarra Sheet). In the northern part, the rocks are chiefly augen gneisses with some mafic wisps. They trend parallel to the Darling Scarp and dip steeply westward. These gneisses appear to represent cataclastically deformed granite and migmatite. An 11 km-long zone of porphyritic granite gneiss (Anp) which extends from near the Pinjarra alumina refinery to east of Coolup has been delineated. It is mineralogically and texturally similar to rocks described previously which crop out near Bilbarin Hill, and contains narrow zones of augen gneiss. These gneisses resulted from cataclasis of porphyritic granite, from which they are separated by a mylonitized shear zone in the east. Further south near the Murray River, augen gneiss is interbanded with quartz-feldspar-biotite and amphibole-bearing gneisses, and the predominant dip is easterly. A small isolated area of augen gneiss (Ana) occurs near the Murray River, 7 km south of Dwellingup. It appears to have formed by shearing of granitic rocks.

At Waroona, broad zones, up to 1 km wide, of banded gneisses alternate with units of fairly homogeneous augen gneiss. In the southern bank of the Waroona Dam, a banded iron-formation (Ai) trends 063° and dips 65°N. It is only 0.3 m thick and consists of an equigranular aggregate of quartz, magnetite and grunerite. A few fragments of quartzite occur uphill to the south. These are the only definite metasedimentary rocks in the whole of the Darling Scarp belt, but suggest that many of the associated banded rocks are in fact paragneisses.

South of Wagerup, well-banded granitic and mafic gneisses occur close to the Darling Scarp. They dip steeply eastward or westward and are often blastomylonitic. The gneisses become more homogeneous to the east, but blastomylonite zones still occur. At Cookernup, there is a gradual eastward change from homogeneous augen gneiss into deformed porphyritic granite, and finally into undeformed porphyritic granite. Most of the augen gneisses in this section thus represent deformed granite, but it is uncertain whether the well-banded blastomylonitic gneisses are the result of more extensive cataclasis of original porphyritic granite.

MIGMATITE

The term migmatite is used here to describe gneissic rocks intimately admixed with a granitic component. The granite may occur as veins subparallel to the foliation or as more extensive areas that cut irregularly across the gneissic palaeosome. The pre-existing metamorphic foliation is often strongly contorted and disrupted. The granitic component is not everywhere obviously intrusive and may form diffuse veins that transgress a wispy metamorphic foliation. Some of this material has formed *in situ* and has often developed first in the hinges of minor folds.

Migmatite (Am) is present as an irregular, discontinuous zone developed between the granitic rocks and the Jimperding Metamorphic Belt. It consists of well-banded or more homogeneous, biotite-streaked gneisses with diffuse areas of granite. The foliation trend is frequently similar to that in the adjacent gneisses and this is well-illustrated near Dale Bridge where large lenses of quartzite are completely enclosed in migmatite rich in amphibolite streaks.

Migmatite occurs along the margin of the southern part of the Saddleback Group. It varies from well-banded to massive Anb, Anp and Ana with veins of granite to more extensive areas containing remnant blocks of gneiss; some gneissic areas were partially mobilized.

Amphibolite pods and streaks, with some hornblende rock are numerous in this area. Similar features are present in the migmatite area surrounding the gneisses at Roleystone, and the rocks at Armadale and Canning Dam were referred to as "hybrid gneiss" by Prider (1943 and 1945).

A narrow strip of migmatite separates porphyritic from even-grained granite in the southwest part of the sheet area. The unit trends north-northwestward and is a line of relative weakness that has been followed by the Murray River.

Small, enclosed areas of migmatite occur within the main granitic batholith, and are most abundant south of the Jimperding Metamorphic Belt. The rocks are predominantly mixed granite phases with biotite clusters and wisps rich in either biotite or amphibole. Near Pumphrey Bridge, dark slabs of biotite quartz diorite/tonalite form part of the palaeosome. These are only weakly foliated and may represent an earlier plutonic component caught-up in the granite.

GRANITIC ROCKS

LITHOLOGIES

The plutonic granitic rocks were distinguished in the field on the basis of their texture. Each textural subdivision varies somewhat in composition, with a maximum range from granodiorite, through adamellite, to granite. However, most rocks are within the adamellite field.

The leucocratic adamellite (Agg) is fine to coarse grained, with marked variations in the grain size. It contains abundant veins and more diffuse areas of pegmatite and aplite. The texture is allotriomorphic granular, and the rock consists of oligoclase, microcline, quartz, small amounts of biotite, and accessory muscovite and epidote. The granite crops out in small areas only, and is generally associated with migmatite. It is often rich in gneissic xenoliths, and may have a weak biotite foliation. In the Brookton to Dattening areas, this type of granite is often intimately admixed with both migmatite and porphyritic granite. Regular grain-size banding has been observed west of Brookton.

The even-grained granitic rocks (Age) are mesocratic, fine to coarse-grained, and range in composition from granodiorite to granite, although adamellite is the chief variety. Compositional variation is subtle, and the rocks are regionally fairly homogeneous. They form the most extensive granitic phase. The texture is allotriomorphic granular, and the rocks consist of andesine oligoclase, microcline, quartz, and biotite, with locally developed hornblende. Xenoliths are rare, and occur most frequently close to gradational migmatite contacts, or near sharp contacts with the layered sequences. Pegmatite and aplite veins are common, but are generally not prominent. However, close to migmatite areas and northwest of Crossman, they are extremely abundant. A weak felsic-mineral foliation, occasionally enhanced by biotite, can be discerned in most granite outcrops. An increase in the intensity of or a later second foliation is often evident near shear and fault zones. Small variations in grain-size occur in proximity to Agg and the relation between Age and Agg appears transitional.

Porphyritic granite (Agp) crops out over two large areas in the southwest part of the map, in a broadly continuous but irregular zone close to the western margin of the Jimperding Metamorphic Belt, and also in a number of small, irregularly shaped areas within Age. It forms the prominent range of hills near the Canning River (Mount Vincent, Mount Cuthbert and Eagle Hill). The rocks contain tabular megacrysts of microcline microperthite (average length 2 cm) in an allotriomorphic granular aggregate of microcline, oligoclase, quartz, and biotite, local hornblende. The megacrysts vary in abundance and are generally aligned. Contacts with Age are normally sharp, although relations are gradational with Agg in the Dattening area. Here, the grain-size of the porphyritic granite varies as much as that of Agg. South of Brookton, Agp and Agg are intimately mixed and the porphyritic granite has a strong, almost gneissic, foliation. Near Quanamining Hill and Punine, hornblende-bearing porphyritic granite has a distinctive texture; it contains megacrysts of quartz, almost square microcline, and dark, zoned plagioclase crystals are common.

Fine to medium-grained granitic rocks with scattered megacrysts of potash feldspar (Agv) occur between many areas of Age and Agp. The most extensive development is around the Canning River, southward to North Bannister. It is also a prominent phase along the western margin of the Jimperding Metamorphic Belt. This granite type was first described from the Perth Sheet (Wilde and Low, 1975), and has features transitional between Age and Agp. The rocks are mesocratic and range from adamellite to granite. They are texturally similar to Age, except for the occurrence of scattered, ragged megacrysts of microcline with numerous inclusions of plagioclase. They grade into Agp with an increase in both size and abundance of megacrysts, and into Age as these decline. At Quanamining Hill, hornblende-bearing granite varies texturally from Agv to Agp. However, several outcrops reveal that these are separate phases which are almost completely mixed.

A few small areas of intimately admixed granite whose components cannot be delineated at the map scale, occur in the eastern part of the sheet area and are shown as mixed granite (Agm). These areas commonly contain Age and Agp in roughly equal amounts and in sharp contact with one another. It is usually impossible to determine the order of intrusion or else the evidence from adjacent areas is contradictory. Most mixed granite areas contain extensive pegmatite and aplite, and there is often a large Agg component. Gneissic xenoliths and rafts are abundant near migmatite and these mixed granite areas may be the result of complex interaction between intrusive granite and mobilized gneiss.

DISTRIBUTION AND RELATIONS

The granitic rocks constitute part of a large batholith that extends northward beyond the sheet area to the Avon River and southward onto the Collie Sheet. The granite is much more variable than to the north (Wilde and Low, 1975), and a regionally complex interdevelopment of textural types takes place, particularly along the western and southern margins of the Jimperding Metamorphic Belt (Fig.2).

Overall, the predominant foliation direction in the granitic rocks is northwestward to north-northwestward. However, there are local variations, especially around the Jimperding Metamorphic Belt and close to the Darling Scarp. Near Coolaring Hill, Goonaping Swamp and Fleays, a northeasterly to east-northeasterly trend is common within all granite types. The hornblendic Agp/Agv near Quanamining Hill, Boyagin Rock and Mount Cole has a marked easterly alignment of megacrysts, and a felsic foliation in Age near Bittleyong Rocks has a similar trend. The large, discrete body of Agp in the Logue Brook - Murray River area also has a strong easterly foliation, although megacrysts lie subparallel to the contact near the margins of the pluton. Local eastward-trending foliations occur near the Darling Scarp in Agp at Oakley Dam and Dwellingup and in Agp and Age east of Pinjarra. Close to the Darling Scarp, the regional north-northeasterly trend in the granites becomes more northerly, and is perhaps the result of shearing.

There is a marked tendency towards the development of hornblende in the zone of complex granites west of the Jimperding Metamorphic Belt. Hornblende occurs within Agp, Agv and Age, but is rare in the latter. It has been recorded as far west as Little Darkin Swamp and Beraking Brook, but the main area of hornblende-bearing granites is within 40 km of the metamorphic belt. Around Mount Cole, the hornblende granite varies rapidly from Agp to Agv, and is texturally distinct from other granites of this type (Lithologies section). The occurrence of hornblende around the western margin of the Jimperding Metamorphic Belt is also a feature of the granites on the Perth Sheet between York, Northam and Clackline.

The rapid variations in texture made classification difficult in a number of areas. At Boyagin Rock, there is a gradation between Agp, Agv and Agg, and these three types also vary appreciably near migmatite.

Close to the Jimperding Metamorphic Belt, there is some evidence for the relatively passive emplacement or development of the granite. Near Dale Bridge, Granite often has a subhorizontal contact with the country rocks, and is structurally overlain by gneisses. Although the foliation in the gneisses is truncated, there has been no obvious deformation of these rocks by emplacement of granite. Similarly, gneissic rocks in this area seem to grade almost imperceptibly into Agv or Agg/Am with pegmatite. The presence of uncontorted quartzite units within Agp and Agv at Andrews Trig also indicates a relative lack of disturbance during granite emplacement.

The relations between, and relative ages of, the various granitic rocks is extremely uncertain owing to conflicting field evidence. In general, all types sharply cut the rocks of the metamorphic belts, although there are gradations in the migmatite zones. However, Agg is often gradational to the gneissic rocks, whilst Agp at Dale Bridge is pervasive into both gneisses and migmatite. Inter-granite relations are everywhere complex, and, for every example showing a relative age, the opposite case can be found. In several localities there are two distinct phases of Age. South of Boyagarring Hill, a fine, even-grained granite intruded a medium-grained phase: however, the reverse relationship occurs near Crossman. Other specific examples are: veins of Age cut Agp at Bald Hill, Youraling and Annandale Pool; whereas Agp cuts Age at Bald Hill, Goonaping Swamp, and south of Crossman; Agp cuts Agg near Bittleyong Rocks; whereas Agp occurs as blocks and xenoliths within Agg near Talbot; Agv occurs as bands within Age near Dabaderry Swamp, but they are irregularly admixed near Wandering; and, near Bartlett Trig, all the main granite types are mixed up together without any indication of their emplacement order.

Until there is definite evidence to the contrary, the above relations suggest that the granites are best considered as being penecontemporaneous phases of the same general intrusion.

PROTEROZOIC GEOLOGY

CARDUP GROUP

A sequence of weakly metamorphosed, shale, siltstone, sandstone and minor amounts of conglomerate crops out sporadically along the Darling Scarp from Maddington south to Serpentine, a total distance of 37 km. The group attains a maximum width of 1 km, and forms a narrow strip that trends parallel to the present scarp. The rocks were first recorded by Gregory (1849) and originally named the "Armadale Shales" by Honman (1912). After several changes of name, they were finally raised to group status following the work of Williams and McKellar (*in* Playford and Willmott, 1958), Singh (1958) and Low (1972).

The Cardup Group unconformably overlies Archaean granite and migmatite; however, the contact is normally obscured, and the only exposure is in a clay quarry, 4 km east of Maddington. There, a 3 m thick unit of pebble conglomerate and interbedded grit rests unconformably on foliated Archaean granite. Pebbles of quartz, 1 cm average diameter, are set in a gritty matrix of quartz and feldspar, with interstitial silt. Thin bands of siltstone and sandstone are present, and these predominate after 3 m. The siltstones pass upward into pale cream-grey shales after 5 m. The unconformity trends 146^{o} and dips 62^{o}W; its surface is gently undulating.

In most outcrops, the bedding dips at moderate to steep angles to the west, although locally steep easterly dips were recorded at Cardup. A slaty cleavage is normally sub-parallel to the bedding and a strong bedding/cleavage lineation developed. North of Wungong and south of Cardup, the lineation plunges north at low to moderate angles, but in between it plunges steeply to the south. A strain-slip cleavage, 2 km south of Cardup, is axial planar to minor folds, and indicates that the rocks lie on the eastern limit of a north-plunging anticline. Playford and others (in press) report that structural evidence elsewhere indicates that the rocks lie on the eastern limb of a syncline.

The Cardup Group has been subdivided into three formations (Low, 1972a). In stratigraphic order, these are the Whitby Sandstone, Neerigen Formation and the Armadale Shale.

The Whitby Sandstone which ranges up to 40 m thick (Singh, 1958) is named after Whitby Falls on Manjedal Creek. The type section is in a railway cutting, 3 km east of Mundijong (32^{o}18'20"S, 116^{o}00'40"E); it consists of conglomerate and fine to coarse-grained sandstone that unconformably overlie Archaean migmatite. The unit is lenticular and represents the basal portion of a transgressive marine sequence.

The Neerigen Formation which conformably overlies the Whitby Sandstone or unconformably overlies Archaean granitic rocks (Playford and Willmott, 1958) is named after Neerigen Brook. It is up to 73 m thick, and at the type locality (32^{o}08'45"S, 116^{o}01'08"E), 300 m north of the "Olde Narrogin Inn" at Armadale, it consists of interbedded fine to medium-grained micaceous sandstone and ripple-marked shale.

The Armadale Shale (Playford and Willmott, 1958) is 483 m thick at the type section in the Cardup Quarry (32^{o}14'35"S, 116^{o}00'55"E). It conformably overlies the Neerigen Formation but is overlain by Quaternary piedmont deposits and its total thickness is unknown. The formation consists of black shale overlain by white shale with lesser amounts of sandstone and orthoquartzite.

The age of the Cardup Group is uncertain, though circumstantial evidence suggests that it is Middle to Late Proterozoic. The rocks are cut by dolerite dykes (Prider, 1943) of believed Late Proterozoic age, and overlie the more deformed and metamorphosed Archaean gneisses and migmatites. They also have features in common with, and occupy a similar structural position to the Proterozoic Moora Group, 200 km to the north (Low, 1972b). Fairbridge (1953) reported the fossil Collenia, from the Armadale Quarry, although this is now in dispute (Playford and others, in press).

PRECAMBRIAN UNDETERMINED

MINOR INTRUSIVE ROCKS

GRANITIC DYKES AND VEINS

Veins and small dykes up to a few metres wide of fine to medium-grained adamellite and granite occur in the granitic rocks around Wandering. They have a general easterly trend; as do similar dykes and veins in the Perth Sheet area (Wilde and Low, 1975).

PEGMATITE AND APLITE VEINS

Veins and more irregular areas of pegmatite with minor aplite occur throughout the sheet area, and probably make up between 5% and 10% of the granitic batholith. They are particularly abundant north of Crossman and close to migmatite areas. The veins have a general easterly trend, similar to the granite veins to which they may be genetically related. However, a vein of fine grained granite cuts a pegmatite vein near Dwarda. Pegmatite and aplite are abundant in the eastern part of the area around the western and southern margins of the Jimperding Metamorphic Belt. They are most numerous within Agg.

DOLERITIC DYKES

Tholeiitic, quartz dolerite dykes intrude all the Precambrian rock-types exposed on the Pinjarra Sheet, including the Proterozoic Cardup Group. The dykes average about 10 m, but range from a few centimetres to 200 m thick. They are commonly fine-grained and melanocratic, although some coarser grained gabbroic varieties are present. The gabbroic types may have a chilled margin of finer grained material, or remain coarse grained over their entire width. Fresh dykes are rare, and most are extensively altered and/or sheared. The primary mineralogy consists of plagioclase (andesine-labradorite), augite, hornblende, minor quartz, and accessory epidote, sphene, and apatite. Near the Darling Scarp, a number of dykes have sheared margins (see Klenowski, 1975), but, east of Pinjarra, whole dykes have been sheared and converted to amphibolite.

Distinctive fine-grained, malanocratic, plagioclase-phyric dolerites are present within and around the Jimperding Metamorphic Belt (Wilde and Low, 1975). They are not abundant and no overall trend was observed. These dolerites are fresh and consist of elongate laths of labradorite and augite phenocrysts, in an aphanitic to fine-grained groundmass of plagioclase, augite, quartz, dendritic iron ore and occasional devitrified glass.

Only one xenolith-bearing dolerite dyke (dx), similar to those recorded from the Perth Sheet (Lewis, 1970; Wilde and Low, 1975), was discovered. It occurs 17 km south of Congelin and has an east-northeasterly trend. It reaches 400 m maximum width and consists of fine-grained plagioclase-phyric dolerite with abundant quartzo-feldspathic xenoliths in various stages of digestion. The dyke bifurcates and encloses enclaves of partially remelted granite.

Cross-cutting relations suggest several relative ages of dolerite emplacement, though the dykes are often similar and there may have been only one general period of intrusion. Dolerite cuts the Proterozoic Cardup Group, and these dykes must be upper Proterozoic or younger. Confirming this is a Rb-Sr age of 560 to 590 m.y. obtained from sheared and metasomatized dyke margins (Compston and Arriens, 1968).

However, a dolerite dyke exposed in the wall of the Serpentine Dam is net-veined by granite. This is either an Archaean dolerite (see Appleyard and Burdett, 1962) or the result of late-stage mobilization of the granite.

Dykes near the Darling Scarp have a general northerly trend which is emphasized by shearing. The trend in the southeast part of the area is predominantly westward to west-northwestward. This is also the trend of photolineaments in the massive laterite area further west, and occasional rock fragments indicate that most of these lineaments are dolerite dykes. Northward from Dattening to the Beverley area, the overall trend is north-northwestward, but a number of coarse-grained dykes have an east-northeasterly trend. Between Brookton and Beverley (and further north around York), many of the dolerites have metamorphosed the hornblende granite host. The metamorphosed portions are more resistant to erosion, and stand out like parallel walls, the more eroded dolerite between looks like man-made tracks.

QUARTZ DYKES AND VEINS

There are numerous small quartz veins throughout the Precambrian area. These have only been shown on the map where they are numerous and have a fairly constant trend. Larger quartz dykes are less frequent. In the eastern part of the sheet area, prominent dykes occur near Talbot, Dale Bridge, and Dattening; these have a general northerly or northeasterly trend. Quartz dykes are most numerous along the Darling Scarp, where they trend north-northwestward or northward; they often mark the junction between rock types, and some are mylonitized. Quartz dykes and veins are numerous in the Cardup Group and often mark the contact with the underlying Archaean rocks.

METAMORPHISM

The obvious effects of regional metamorphism are confined to distinct metamorphic belts, and are largely absent from the granitic terrains. Garnet occurs in the migmatite in the Mount Cooke-Mount Solus area, and, more rarely, near Dale Bridge. Elsewhere, only later cataclastic effects were observed locally in the granite, as near the Darling Scarp.

The rocks of the Jimperding Metamorphic Belt have amphibolite-granulite transition facies to granulite-facies mineral assemblages. These facies appear to be irregularly admixed and reflect local and minor changes in conditions. Garnets within mobilized <u>Anl</u> 5 km west of Brookton, have partially broken-down to clusters of biotite. Although diagnostic schist units are rare, other mineral assemblages are similar to the northern extension of the belt (Wilde and Low, 1975), and indicate low pressure conditions in the andalusite-sillimanite facies series (Miyashiro, 1961).

The Saddleback Group rocks have been metamorphosed to greenschist-facies assemblages, with a possible extension to lower amphibolite facies. The basaltic rocks consist mainly of actinolite-albite-epidote, actinolite-albite-epidote-chlorite-sphene and albite-epidote-clinozoisite assemblages. The amphibole is usually ragged, and only rare examples of hornblende are present. The texture of the basalts is igneous, not metamorphic. The pelitic rocks and some of the finer grained felsic volcanic rocks have undergone more extensive recrystallization. Typical pelitic assemblages are quartz-muscovite-chlorite-albite, quartz-muscovite-biotite-albite-epidote, whilst quartzo-feldspathic schists contain quartz-albite-muscovite (-biotite-epidote). The distinctive chloritoid-rich band occurring 4.6 km south of Mount Wells has an assemblage of chloritoid-biotite-quartz (-muscovite- epidote). The association of chloritoid and biotite places these rocks firmly in the quartz-albite-epidote-biotite subfacies of the greenschist facies (Turner and Verhoogen, 1960). A single sample of schist from the Hotham Formation has an assemblage of quartz-albite-biotite-almandine-epidote, indicating an extension into the quartz-albite-epidote-almandine subfacies.

Ultramafic rocks in the Jimperding Metamorphic Belt and Saddleback Group have retrograde, greenschist-facies assemblages, and consist typically of tremolite-chlorite and talc-tremolite (-serpentine).

The metamorphic grade of the gneissic rocks near the Darling Scarp is amphibolite facies. There are few diagnostic rock types present and most amphibolites have a hornblende-andesine (-biotite-quartz-epidote) paragenesis. The BIF at the Waroona Dam has the amphibolite facies assemblage of quartz-magnetite-grunerite. Later shearing along the Darling Fault has resulted in retrogression to greenschist facies (viz. granitic rocks to quartz-sericite schist and mafic rocks to an albite-epidote-chlorite-actinolite assemblage).

STRUCTURE

The structure and solid geological interpretation of the area are illustrated in Figure 2. Relations between granite types in the batholith have already been discussed.

FOLDING

The structure within the Jimperding Metamorphic Belt appears more uniform than in the Perth sheet area (Wilde and Low, 1975). Bands of quartzite provide the only reliable marker horizons, although breaks in outcrop and boudinaging make it difficult to trace and correlate individual horizons. Quartzite occurs in two distinct areas, and has a general north-northwesterly trend.

In the west, the units extend north from Mount Kokeby to the Dale Bridge area. However, the Jimperding Metamorphic Belt is extensively disrupted along this western margin by the development of both migmatite and granite. Although some of the quartzite units are partially enclosed in granite, they have a fairly constant and regular, low to moderate westerly dip.

The eastern zone of quartzites is more continuous, and extends northward from the Babbyalla Hills to Wyalgima Hill. The units dip eastward at low to moderate angles, and this may indicate that they represent the same bands which are exposed to the west, but folded anticlinally about a north-northwestward trending axis approximately along the line of the Avon River. This would be a late phase of folding, as the low dips indicate an open style which is at variance with the rootless isoclinal folds observed rarely in the quartzites and the adjacent gneisses.

The eastern zone of quartzites is asymmetrically folded near Mount Stone. The lithologies trend eastward in this area for about 5 km before swinging north-northwestward. Lineations plunge south at low to moderate angles, and suggest that the whole zone represents the western limb of a southward plunging regional syncline. Several kilometres north of Mount Stone, lineations plunge at shallow angles to the north and indicate later minor, open style refolding of the sequence.

No overall fold pattern is evident in the Saddleback Group, and the regional dip is steeply westward. However steep easterly dips are present north of Mount Saddleback and near the Hotham River, indicating that some contortion has occurred. Pink quartzo-feldspathic veins are locally abundant in the metabasalt and are tightly, but irregularly, folded in the schistosity. The unit of chloritoid schist near Mount Wells has an early series of crenulations defined by biotite and these are overgrown by the chloritoid. A later strain-slip cleavage is developed along the axes of these crenulations, and has disrupted the chloritoid. The felsic volcanic rocks are often cut by a braided schistosity that confines "eyes" of quartz or quartzo-feldspathic aggregates, but folding has not been observed.

Only occasional minor, tight to isoclinal folds are present in the gneissic rocks near the Darling Scarp and no pattern is evident. However, there is folding of the cataclastic foliation at Waroona.

The Proterozoic Cardup Group has undergone at least one period of deformation, although cleavage and bedding are subparallel in most outcrops, and, although there is evidence of folding, no major fold axes were discovered.

FAULTING

A marked feature is the abundance of faults in the Boddington area. These control the outcrop of the volcanogenic Saddleback Group, as well as displacing formations within the group. The major boundary faults trend from west-northwestward to north-northwestward, and have themselves been displaced by later faults which trend north-northeastward to northeastward. The fault along Mooradung Brook (trend 150^{o}) is marked by extensive shearing and alteration of the adjacent granitic rocks. There is little direct evidence for many of the other faults, except for lineaments (often followed by stream courses) and abrupt changes in rock type. Related faults with northwesterly to northeasterly trends also occur in the granitic rocks east of the Saddleback Group, especially near Wandering and Dattening. They sometimes mark the contact between different rock types, but often there is no evidence of displacement. A few faults, again of similar trend, occur elsewhere in the sheet area, but are mainly recognizable by displacement or truncation of units.

DARLING FAULT ZONE

The Darling Fault separates Precambrian rocks of the Yilgarn Block from Phanerozoic strata of the Perth Basin. Its position has been determined from gravity data and modified slightly from Low (1972), because of the occurrence of more westerly exposures of Archaean rock at North Dandalup, Waroona, and Cookernup. The fault has an estimated maximum displacement of 15 km and, owing to erosion, lies approximately 1 to 2 km west of the present scarp. Several facts suggest that the fault zone was initiated during the Archaean, and that subsequent periodic movement occurred, as was evident further north on the Perth sheet (Wilde and Low, 1975).

At Cookernup, porphyritic granite has undergone progressively increasing cataclasis westward toward the Darling Scarp. The first signs of deformation are evident near Sampson Brook Dam and Mount William, where occasional zones of cataclasis, 30 cm wide, have reduced the granite to augen gneiss with a central 1 to 3 cm wide ribbon of mylonite. These zones become more abundant westerly toward Cookernup where the porphyritic granite is totally altered first to porphyritic gneiss, then to augen gneiss, and finally to blastomylonite and mylonite. It is uncertain whether the banded blastomylonite sequence at Cookernup (shown as <u>An</u> on the map) is entirely derived from sheared granite, or whether pre-existing gneisses extended south into this area. However, the metamorphic grade, as shown by the mafic units, is amphibolite facies.

A similar progressive sequence from porphyritic granite to porphyritic and augen gneiss occurs east of Pinjarra. However, a narrow mylonitic shear-zone separates deformed granite from unaffected rocks to the east.

Several shear zones and mylonitized quartz veins occur within the granitic rocks near North Dandalup. However, even-grained granite (Age) with only a weak felsic foliation occurs on the scarp between Keysbrook and Serpentine: there is no cataclasis.

Further north, the Proterozoic Cardup Group (Low, 1972a) crops out sporadically along the scarp. The rocks show evidence of at least one period of deformation, and a number of quartz veins within the group and adjacent Archaean rocks are mylonitized. Furthermore, dolerite dykes often have sheared margins close to the Darling Scarp (Klenowski, 1975).

The amphibolite-facies metamorphic grade of the blastomylonite sequence suggests that this deformation occurred during the Archaean, as it did in the northern part of the Chittering Metamorphic Belt (Wilde and Low, 1975). However, deformation of the Proterozoic Cardup Group, shearing of the, presumably, late Proterozoic dolerite dykes, and shearing of ?Proterozoic pegmatite veins (Compston and Arriens, 1968) at Pinjarra and Waroona, indicates re-activation during the Proterozoic or later. The occurrence of undeformed granite near Keysbrook is difficult to explain, though the cataclastic foliation in the granitic gneisses 4 km south of Waroona is itself folded about north-trending axes. Folding of the Archaean cataclastic foliation could thus account for the present sporadic distribution of mylonitic rocks along the present line of the Darling Scarp: the Darling Fault is therefore only subparallel to the earlier Archaean deformation zone.

CAINOZOIC GEOLOGY

GENERAL

The Cainozoic deposits have been mapped primarily on the basis of their morphological features. Thus sand has been classified as eluvial, colluvial or alluvial, and has not been distinguished as a lithological type. Genesis of the deposits is complex and the distinction between Tertiary and Quaternary deposits is often doubtful in the field. No subdivision of the Quaternary Period is implied by the second letter of a "Q" unit symbol. Many of the Quaternary units are associated in what appear to be remnants of an earlier drainage system. Although re-worked during the Quaternary, the deposits probably formed in the Tertiary. The relationship of the units is illustrated in Figure 3.

TERTIARY AND UNASSIGNED UNITS

The most extensive Tertiary deposit is laterite (Czl). In the west it forms an extensive capping over granitic and gneissic rocks. The surface is flat to undulating and has only been moderately dissected, chiefly by the Canning and Murray Rivers. Further east, dissection is much more complete, and plateau residuals are often isolated or else form irregular ribbons that are best preserved at watersheds (especially between the Dale/Avon and Murrah River systems). The laterite is chiefly massive and cemented; and may be either pisolitic or vesicular. It averages about 4 to 5 m in thickness, and the upper portions may locally consist of loose, uncemented pisolites. A maximum thickness of 14 m has been recorded in bauxite pits at Del Park, Pinjarra.

Most of the laterite has developed _in situ_ by weathering of underlying rocks, and passes downward through a pallid zone of variable thickness into weathered bedrock. Differences in colour, texture and composition can be observed between laterite developed over felsic and mafic rocks, whilst the foliation in the metabasalts of the Saddleback Group is often preserved in the overlying laterite. Chemical changes in the laterite profiles are also consistent with formation _in situ_ (Sadleir and Gilkes, 1975; Davy, in prep.). These views are at variance with Grubb (1971), who postulated the laterite developed from a sedimentary layer overlying the granite, and Mulcahy (1967), who grouped the area in his zone of "detrital laterites". There is no sedimentary layer and, although transported laterite does occur, it is principally confined to steep slopes, where it forms colluvial fans. Many transported laterites appear to have undergone further lateritization after transport. Some laterite in the eastern part of the sheet overlies eluvial and colluvial sand that have been lateritized _in situ_.

Sporadically overlying the laterite are small deposits of yellow, grey or white sand (Czs) which are associated with present or ancient drainage courses. They are absent from the massive laterites near the Darling Scarp. The sand often passes downslope into colluvial sand or sandy alluvium. The deposits are best developed between the Avon and Dale Rivers near Mount Kokeby where they are associated with possible Tertiary drainage systems.

A few small deposits of unsorted conglomerate (Czc) occur near the foot of the Darling Scarp at Kelmscott, Armadale, and North Dandalup, and on the flanks of valleys incised into the scarp at Roleystone and west of Jarrahdale. The deposits appear similar but need not be equivalent in age. They consist of irregular to rounded clasts up to large boulder size in a matrix ranging from clay to coarse sand. The matrix is fairly coherent, except near Jarrahdale, The deposits are similar to the Harvey Beds (Playford and others, in prep.) of presumed Tertiary age, although Churchward and Bettenay (1973) suggest that the deposits may be of Mesozoic age.

QUATERNARY UNITS

Alluvium (Qra) is present in the upper reaches of the major rivers in the eastern part of the sheet area, but is notably absent from the more youthful rivers and streams that dissect the Darling Range. Here, and further west near Little Darkin Swamp, portions of alluvium are separated from the present drainage channels and associated with swamps and reworked sand. These features suggest that much of the alluvium formed prior to the development of the present drainage.

A single area of hummocky, bright yellow sand (Qs) occurs 6 km south-southeast of Mount Kokeby. It is marginal to alluvium and is similar to presumed eolian deposits on the Perth sheet. Areas of reworked sand (Qas) are confined to the northeastern part of the sheet, and appear to represent older stream channels. The deposits have an undulose surface, and often link-up separated areas of alluvium. They appear to define an earlier Cainozoic drainage pattern.

Swamp and lacustrine deposits (Qrw) occur in rounded clay pans and sandy swamps in the northeastern part of the area. They are present within, or marginal to, the broad areas of older reworked alluvium at Mount Kokeby and at Little Darkin Swamp. Smaller swamps are present in Qas in the Mount Kokeby area.

In the Darling Range, colluvium (Qrc), consisting of scree or finer-grained products, often fills the heads of valleys whose streams are actively incising the laterite surface. Similar deposits are abundant between laterite and alluvium near Boddington. In the eastern part of the area, colluvium often occurs in broad valleys upstream from alluvium, or as a sporadic development between alluvium and rock outcrop.

Distinctive units of sandy colluvium (Qrcs) are associated with the older drainage deposits near Mount Kokeby and Little Darkin Swamp, and also occur in the upper part of the Canning River system and around Fourteen Mile Brook, near Congelin. These are valley-fill deposits that represent, at least in part, extensively reworked drainage deposits. They bridge the Dale/Avon and Darkin/Helena River watershed and may indicate that these were once part of the same system. The unit often passes downslope into alluvium and upslope into sand overlying laterite (Czs).

Thin ribbons of alluvium with minor colluvium (Qa) overlie the laterite of the Darling Range and form the heads of present valley systems. They are flat deposits that pass downstream into colluvium or rock outcrop. Occasionally, thin mantles of sand extend over minor drainage divides and link-up separate areas of Qa. Such deposits are well-developed in the North and South Dandalup catchment areas.

Areas where bedrock is largely or almost completely obscured by soil are denoted by an overprint on the map. Occasional outcrop or rock fragments enable the underlying rock types to be determined. These areas are more abundant east of the massive zone of laterite and away from areas of strong active erosion.

ECONOMIC GEOLOGY

METALLIC MINERALS

GOLD

Several shafts and adits were sunk for gold in quartz veins along the Darling Scarp at Gosnells, Armadale, Mundijong, Serpentine and North Dandalup. Extensive work was carried out at North Dandalup and the area was declared a goldfield in 1896. There are no records of production from any of the shafts in the area. Indeed, an examination of gold discovered in a creek 6 km east of the townsite led Honman (1916) to state that "I cannot arrive at any other conclusion than that the gold was put in the creek"! Later work indicated traces of molybdenite in some of the shafts.

Small pits for gold were dug in a quartz vein at Marradong and near an ultramafic rock at Edwards Crossing, Beverley. No traces of gold were detected.

LEAD

Galena and associated sphalerite are present in a quartz vein within migmatite 3 km southeast of Mundijong (Esson, 1927; Blockley, 1971). The prospect was worked sporadically from 1846 (it was the first lead mine in the State) although there is no record of the amount of ore produced. The main workings are along a 450 m section of a major quartz vein that trends northwestward and dips eastward. Minor copper mineralization, in the form of malachite and azurite, is evident. Simpson (1948) records occurrences of galena and sphalerite at Armadale, Cardup and Serpentine, but the exact localities are unknown.

VANADIUM

A small east-trending dolerite dyke near the Murray River, 10 km east-southeast of Spion Kop, contains vanadium-bearing titaniferous magnetite. Several dykes in the sheet area have high vanadium contents (Davy, in prep.); they seem to be members of the dolerite suite, and unrelated to the Coates Siding gabbro (Wilde and Low, 1975).

BAUXITE

Bauxitic laterite is extensive over the granitic rocks of the Darling Plateau. The major portions of the Alcoa mineral lease ML1 SA and the Alwest Agreement Area occur on the sheet, and the main orebodies defined to date are in this area. Mining of bauxite started at Jarrahdale in 1960 and 32 800 066 t have been produced to the end of 1975. The bauxite is transported by rail to the alumina refinery at Kwinana, on Cockburn Sound. A second bauxite operation commenced at Del Park, Dwellingup in 1972 and production to the end of 1975 amounted to 8 834 891 t. The ore is transported by conveyor belt to a refinery at Pinjarra. Total alumina production from both refineries has amounted to 11 806 002 t up to the end of 1975. Published ore reserves amount to 500 Mt of bauxite at an average grade of 32 per cent available alumina.

The main ore bodies in the Alwest Agreement Area are at Mount Saddleback, near Boddington. These are developed over the metabasalt of the Marradong Formation of the Saddleback Group. Reserves are estimated at over 200 Mt of bauxite at around 32 per cent available alumina.

INDUSTRIAL ROCKS AND MINERALS

BARITE

Barite occurs in veins and along joint surfaces in the Cardup Group at Armadale and Mundijong. Pits were opened up at Armadale, but there is no record of production.

CLAY

Brick, pipe, and tile clay is obtained from kaolinized granitic rocks close to the Darling Scarp at Bickley, Byford, and Cardup. It forms in localized pockets of deep weathering over Archaean granite and migmatite. Total recorded production from the Byford area amounted to 558 105 t to the end of 1975. In the same period, total recorded production from the Archaean rocks of the Cardup area was 439 797 t.

Pisolitic laterite gravel, which is used in cement manufacture for its alumina content, is mined at several localities in the Gosnells to Byford area. This material is often referred to as cement clay. No attempt has been made to distinguish pits of this type from gravel pits on the map.

KAOLIN

A small deposit, 13 km southwest of Mount Kokeby townsite, has produced 5 363 t of kaolin up to June 1976. It was first worked in 1941 by shafts and later by open cut. The main kaolin horizon is 3 m thick and covered by up to 6 m of loose sandy overburden. The deposits are lacustrine in origin and associated with an early Quaternary, or Tertiary drainage system.

SHALE

The Proterozoic Cardup Group sediments are worked extensively along their length for brick-making shale. Quarries have been opened up at Maddington, Armadale, Byford, Cardup, and Mundijong. Total annual production from the Cardup Group is around 233 kt (Archer, 1975).

BUILDING STONE

Cemented laterite, and granitic rocks have been used in the past for home construction and are occasionally used for foundations at the present time. Flat slabs have often been removed from granite outcrops for this purpose. Porphyritic granite has been obtained for building purposes from 4 km north-northwest of Bald Hill. Extensive use is made of laterite and granite in landscape gardening.

A quartz vein, 5 km east of Serpentine, was quarried for ornamental stone.

AGGREGATE, BALLAST AND ROAD METAL

Abundant supplies of rock suitable for crushed aggregate are available. Quarries within granite (Age) have been opened up along the Darling Scarp between Maddington, and Gosnells and within migmatite (Am) at Armadale, Wungong, Byford, and Mundijong. Fill material for the major dams was obtained on site, whilst railway ballast was provided from the Dale Bridge Quarry.

Smaller workings in weathered granitic and gneissic rocks have provided gravel for local road making in the eastern part of the area. Extensive use of uncemented pisolitic laterite for road gravel has been made throughout the area and many pits are opened up from time to time.

SAND

Small amounts of yellow sand have been obtained from deposits associated with the Hotham River at Boddington, Dwarda, and Pumphrey Bridge. A few small pits have been worked in the northeast part of the area where there are large supplies of variable quality sand available.

WATER SUPPLIES

SURFACE WATER

Rivers and streams in the eastern part of the Pinjarra Sheet area are intermittent and brackish, and are unsuitable for domestic use or irrigation. However, the more youthful drainage systems actively eroding the Darling Scarp and Plateau have uncleared catchments and are fresh. Most of the larger rivers have been dammed for domestic water supply or irrigation. The Helena/Darkin system flows into the Helena Reservoir, and water is pumped from Mundaring by pipeline to the Eastern Goldfields region. Dams on the Canning, Serpentine and South Dandalup Rivers supply a major part of the Perth Metropolitan water, and are supplemented by the older Bickley Brook and Victoria Reservoirs. Further dams are proposed on the Upper Canning and North Dandalup Rivers and on Wungong Brook. Along the southern part of the Darling Scarp, the Waroona, Drakes Brook, Samson Brook, and Logue Brook Dams supply water for domestic purposes and for the Harvey-Waroona Irrigation Scheme.

Inland from the Darling Scarp, the towns are supplied by their own dams, although Beverley is linked to a branch of the Eastern Goldfields pipeline and Brookton is supplied from the Wellington Dam.

GROUNDWATER

Groundwater occurrence varies with rainfall and geomorphology. Along the Darling Scarp, a reliable seasonal rainfall of 800 to 1 300 mm per year falls onto the laterite surface and supplies perennial streams and rivers. Small amounts of potable groundwater are available from bores and wells sunk through the laterite to bedrock, although yields are often less than 15 kl/day. Larger yields of more saline water (up to 3 000 mg/l, total dissolved solids) may be available in valleys dissecting the laterite surface.

Little is known concerning the hydrogeology of the Darling Plateau area, because much of the land is uncleared and lacks bores or wells. A number of bores are being monitored in areas of bauxite mining (Bestow, 1976) close to the Darling Scarp. In the eastern part of the sheet area, experience is needed in siting bores, since the distribution of saline and potable water is extremely variable. Residual sands in the Brookton to Beverley area and southwest of Talbot provide a local source of potable water which is recharged from surface runoff and direct intake. Many of these sands are associated with an older ?Tertiary drainage system.

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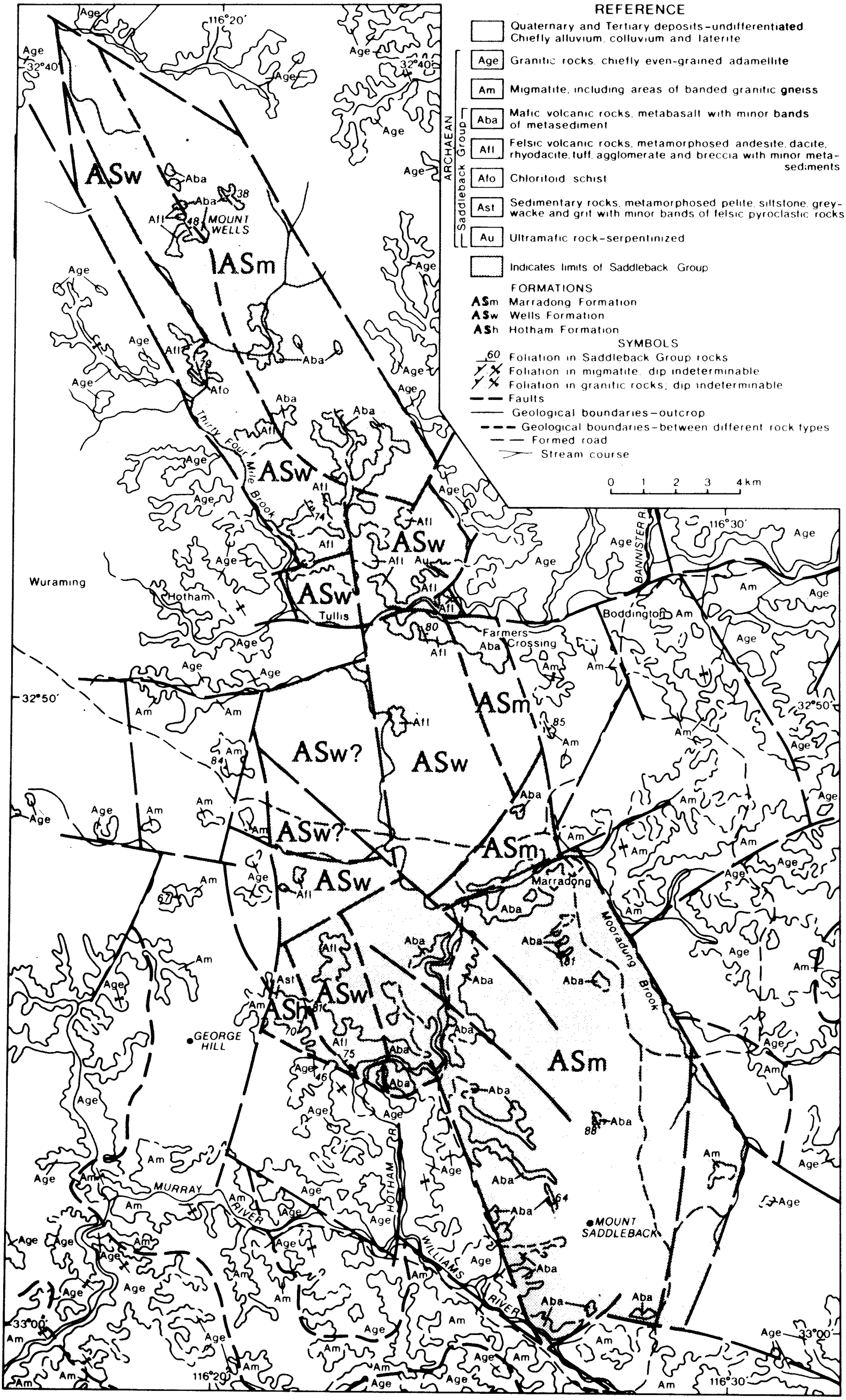
FIGURE 1.

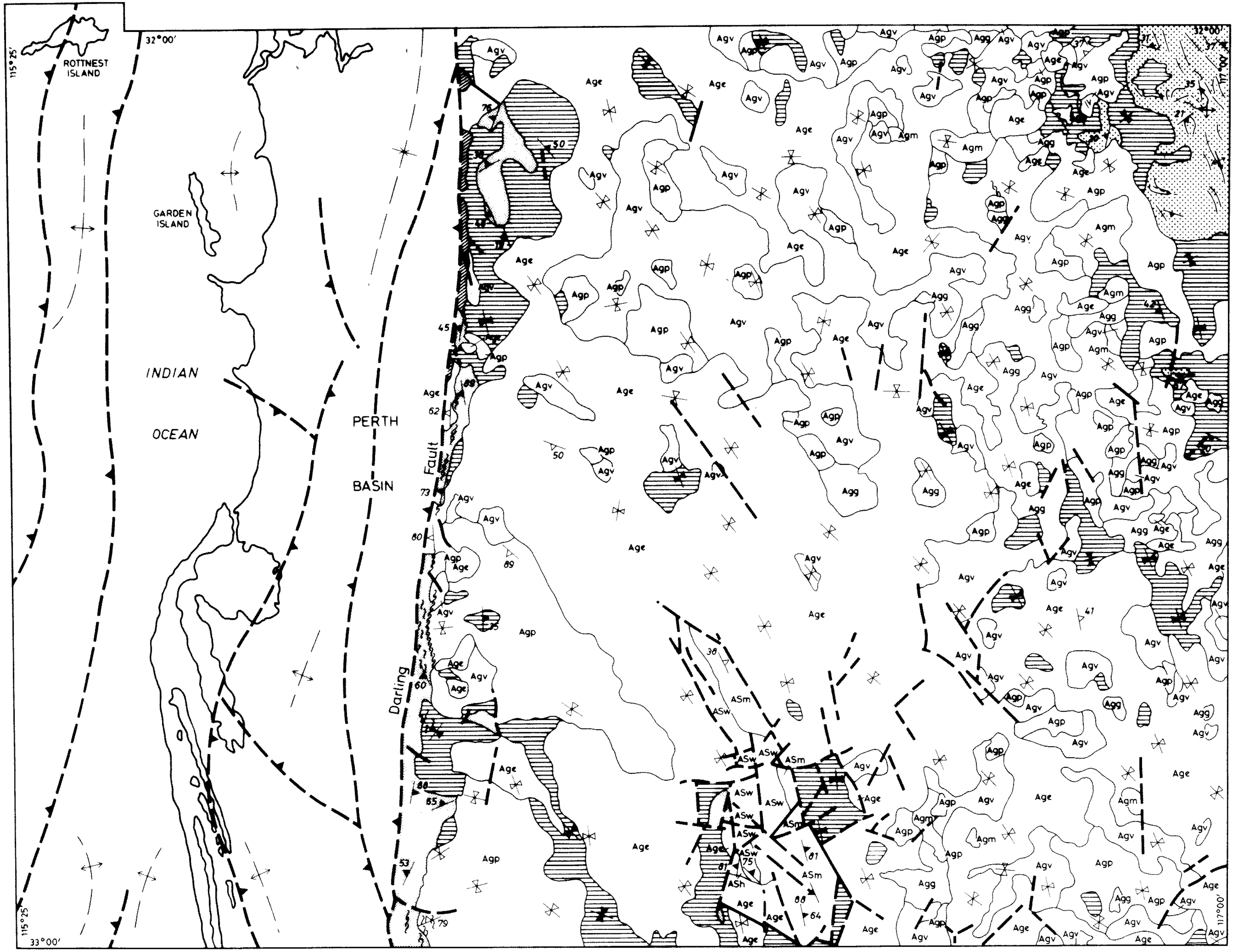
GEOLOGY OF THE SADDLEBACK GROUP SHOWING FORMATIONS



(16114)

FIGURE 2

STRUCTURAL MAP OF THE PINJARRA SHEET



10 0 10 20 30
KILOMETRES

REFERENCE

PERTH BASIN

CARDUP GROUP

GRANITIC ROCKS

- Age — Even-grained adamellite
- Agv — Even-grained adamellite with megacrysts
- Agp — Porphyritic granite
- Agm — Mixed granite
- Agg — Leucocratic adamellite

MIGMATITE

SADDLEBACK GROUP

- ASm — Marradong Formation
- ASw — Wells Formation
- ASh — Hotham Formation

JIMPERDING METAMORPHIC BELT

- Granulite facies

OTHER GNEISSIC ROCKS

- Fault, with direction of hade
- Geological boundary
- Fold axis
  - anticline, with plunge direction
  - syncline, with plunge direction
- Shear zone
- Sheared rock
- Foliation in metamorphic rocks
  - direction of dip
  - undeterminable
- Foliation in igneous rocks
  - direction of dip
  - undeterminable
- Lithological trend lines

Faults in Perth Basin from seismic data on the Cattamarra Reflector

(16115)

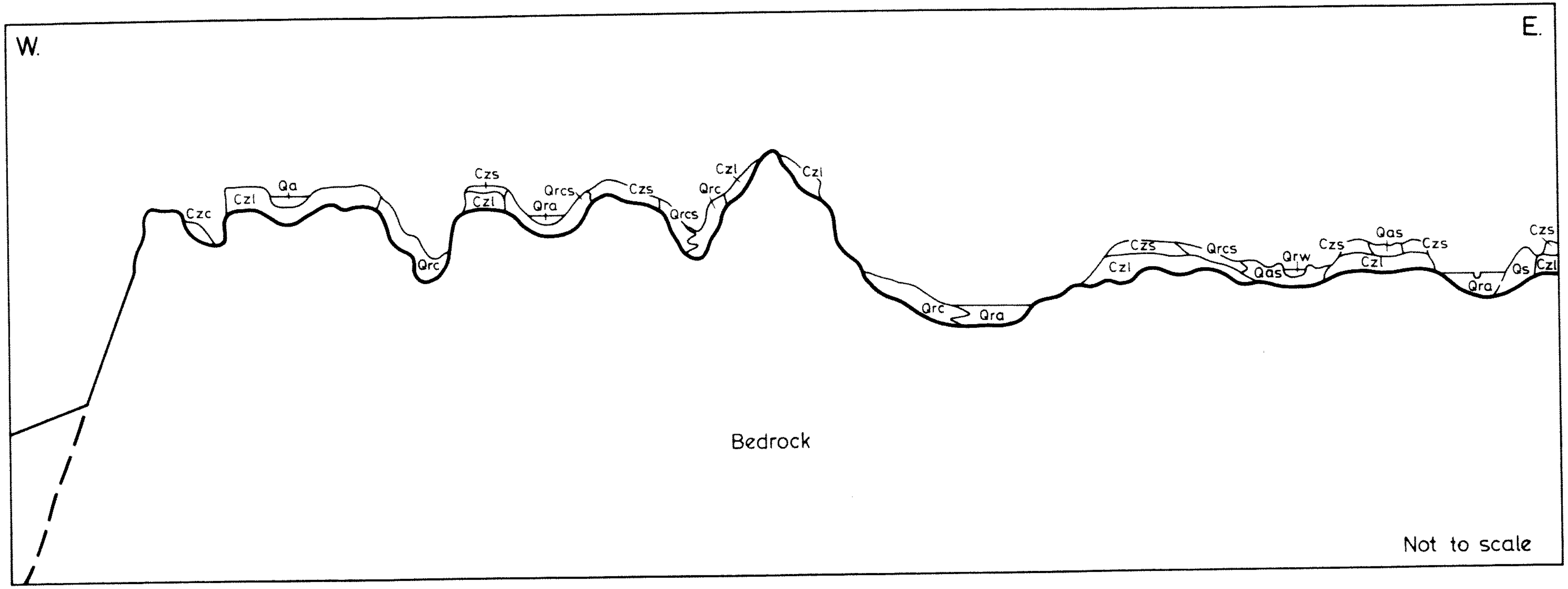


FIGURE 3

CAINOZOIC ROCK UNIT RELATIONSHIPS EAST OF THE DARLING SCARP

PINJARRA SHEET SI 50-4

(Cainozoic Symbols as on Map Reference)

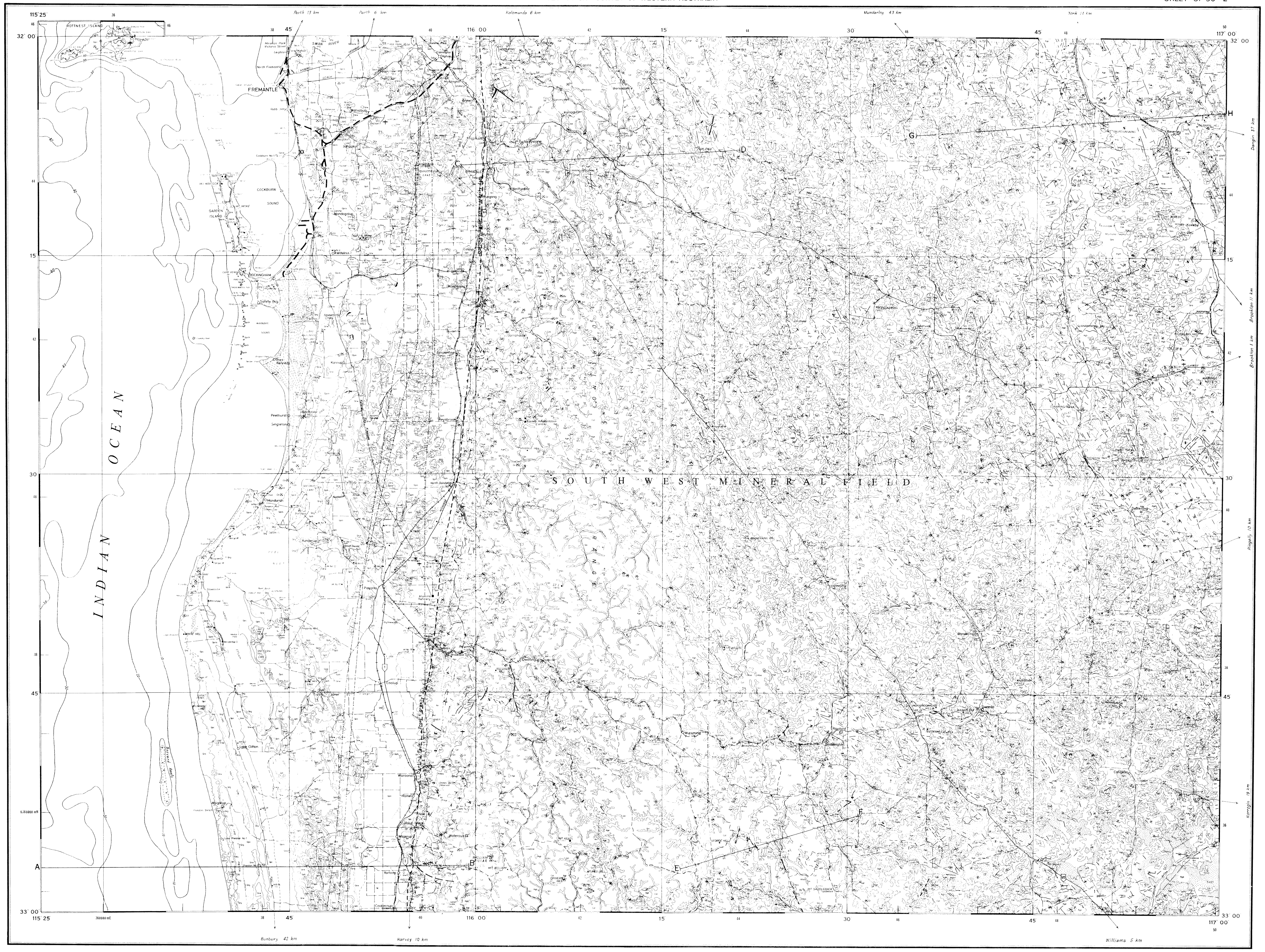
(16116)

AUSTRALIA 1 : 250 000 GEOLOGICAL SERIES

PINJARRA

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SI 50-2



SYMBOLS

Geological boundary
- Accurate
- Approximate

Fault
- Accurate
- Approximate
- Normal and concealed

Plunge of minor fold

Gneissic foliation
- Inclined
- Dip indeterminate

Mineral foliation in plutonic rocks
- Inclined
- Vertical
- Dip indeterminate

Schistosity
- Inclined

Direction and plunge of lineation

Shear foliation in plutonic rocks
- Dip indeterminate

Mylonitized shear zone

Sheared plutonic rocks

Attitude of laterite surface

Air photo lineament

Type-section locality

Ancient beach lines

Highway with national route marker

Formed road

Track

Railway 4′8½″
- 3′6″
- Disused
- Station or siding

Bridge

Power line

Townsite, gazetted
- Population 10 000 and over — FREMANTLE
- 1 000–10 000 — ROCKINGHAM
- Under 1 000 — Yalgorup

Airfield

Landing ground

Horizontal control : major, minor

Bench mark, height accurate — BM47 6m

Transmitting station

Lighthouse

Abandoned — (Abd)

Watercourse

Bore, artesian bore — B

- Garden Island bores shown as — G
- Mandurah — M
- Byford — By
- Woodman Point — WP

Well — W

Pool — P

Waterhole — WH

Spring — S

Pipeline — P

Bathymetric contour line, depth in metres — 20

Permanent water

Reef exposed, submerged

Petroleum exploration wells
- Dry hole, abandoned
- Stratigraphic well — St

Mine, abandoned

Quarry

Quarry, abandoned

Prospect

Mineral occurrence
- Barytes — Ba
- Bauxite — Bx
- Building stone — Bs
- Clay — Cl
- Cordierite — Ci
- Crushed rock aggregate — Rc
- Gold — Au
- Kaolin — Ck
- Lead — Pb
- Limestone — Ls
- Pisolitic laterite gravel — Gr
- Road material (gravel) — Rm
- Sand, various purposes — Sd
- Shale — Sh
- Vanadium — V

REFERENCE

PHANEROZOIC — CAINOZOIC — QUATERNARY — RECENT

Qrw | Qra | Qrg | Qro | Qrs | Qrsm

- Qrw Swamp and lacustrine deposits — peat, peaty sand and clay
- Qra Alluvium — clay, sand and loam
- Qrg Estuarine, lagoonal and lacustrine deposits — clay, silt, marl with shell beds
- Qro Shell beds of Rottnest Island — fossiliferous limestone and unlithified shell beds
- Qrs **SAFETY BAY SAND**: eolian and beach lime sand, slightly lithified
- Qrsm calcareous quartzose sand (mobile dunes)

PLEISTOCENE - RECENT

Qrc | Qrcs | Qa | Qas | Qs

- Qrc Colluvium, including valley-fill deposits, variably lateritized and podsolized
- Qrcs Colluvium, sand associated with older drainage courses
- Qa Alluvium and minor colluvium developed on laterite of the Darling Range
- Qas Sand — variously reworked, associated with older stream channels
- Qs Sand — bright yellow, hummocky deposits marginal to stream channels

PLEISTOCENE

- Qpc **COASTAL LIMESTONE**: eolian calcarenite, variably lithified, kankarised, and leached to quartz sand
- Qpcs predominantly quartz sand
- Qpck predominantly calcarenite and kankar
- Qpm **MUCHEA LIMESTONE**: lacustrine limestone
- Qpb **BASSENDEAN SAND**: quartz sand (fixed dunes)
- Qpa **GUILDFORD FORMATION**: alluvium (clay, loam, sand, gravel) variably lateritized and podsolized
- Qpr **YOGANUP FORMATION**: leached or ferruginised beach sand, conglomerate and dunes
- Qph **RIDGE HILL SANDSTONE**: ferruginised beach sand with minor conglomerate

? TERTIARY

Czl | Czs | Czc

- Czl Laterite — chiefly massive, but includes overlying pisolithic gravel and lateritized sand
- Czs Sand overlying laterite — yellow, white or grey
- Czc Conglomerate — unsorted clay, sand, cobbles and boulders

PRECAMBRIAN UNDETERMINED

- Mafic dykes — fine to coarse-grained doleritic and gabbroic dykes, variously altered
- dx Xenolithic mafic dykes — doleritic dykes with abundant quartzofeldspathic xenoliths
- g Granitic dykes and veins
- p Pegmatite veins
- q Quartz dykes and veins

PROTEROZOIC

- Ꝑc **Cardup Group**: predominantly white to black shale, with bands of conglomerate, orthoquartzite and sandstone

ARCHAEAN

Age | Agp | Agv | Agg | Agm

- Age Even-grained granitic rocks — fine to coarse-grained granodiorite, adamellite and granite
- Agp Porphyritic granite — medium to coarse-grained granite with microcline megacrysts
- Agv Fine to medium-grained adamellite and granite with scattered microcline megacrysts
- Agg Leucocratic adamellite, fine to coarse-grained with abundant pegmatite
- Agm Mixed granitic rocks, chiefly interdeveloped even-grained and porphyritic granite
- Au Ultramafic dykes and sills — peridotite and pyroxenite, often foliated and variously altered to greenschist facies metamorphic assemblages
- Am Migmatite — banded and nebulitic, often strongly contorted

Saddleback Group

- Aba **MARRADONG FORMATION**: mafic volcanic rocks, metabasalt with minor bands of metasediment
- **WELLS FORMATION**:
  - Afl Felsic lavas, metamorphosed andesite, dacite and rhyodacite with minor bands of pyroclastic and sedimentary rock
  - Afp Felsic pyroclastic rocks, metamorphosed tuff, agglomerate and breccia with minor units of felsic lava and sediment
  - Afo chloritoid schist
- Ast **HOTHAM FORMATION**: sedimentary rocks, metamorphosed pelite, siltstone, greywacke and grit, with minor bands of felsic pyroclastic rocks

An | Anp | Ana | Anb | Anl

- An Gneissic rocks of Darling Scarp — chiefly hornblende gneiss and blastomylonite, with some paragneiss and porphyritic/augen gneiss
- Anp Porphyritic granite gneiss, coarse-grained with abundant tabular megacrysts of microcline
- Ana Augen gneiss, coarse-grained with microcline augen, strong cataclastic foliation
- Anb Quartz-feldspar-biotite gneiss, generally well-banded, may contain garnet
- Anl Quartz-feldspar (-garnet-biotite) gneiss, leucocratic, often with elongate felsic areas
- Alg Quartz-mica-garnet schist
- Aa Amphibolite, hornblende-plagioclase, some cummingtonite-plagioclase rocks, also includes minor hornblendite
- Aqo Quartzite, metamorphosed orthoquartzite, often with green chrome muscovite

Banded iron formations:
- Ai Undifferentiated — chiefly quartz-magnetite-grunerite-clinopyroxene assemblages
- Aiq Banded magnetite-bearing quartzite

- Ahg Mafic granulite, hornblende and/or pyroxene-rich assemblages

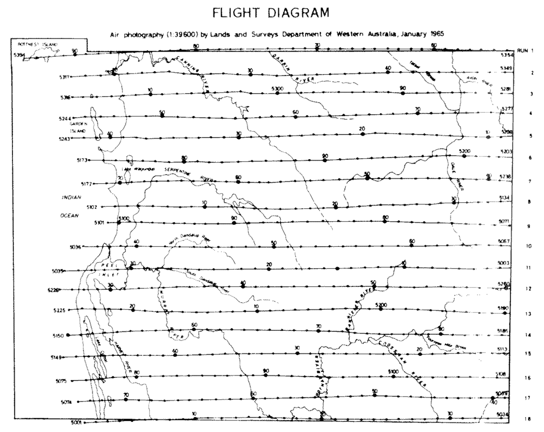
Overprint, indicating bedrock largely obscured by residual and colluvial deposits

Compiled and published by Geological Survey of Western Australia. Cartography by Geological Mapping Section, Department of Mines. Topographic base from compilations by Lands and Surveys Department. Printed by Government Printing Office, Perth. 1976

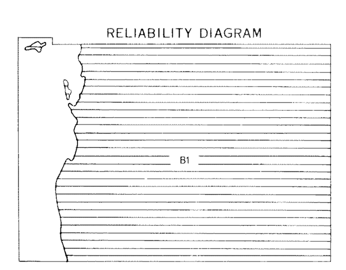
Copies of this map may be obtained from the Geological Survey of Western Australia, Perth.

Geology by: Perth Basin — G. H. Low, D. C. Lowry, and R. W. Lake 1965-67
Yilgarn Block — S. A. Wilde and S.-J. B. Hirschberg 1974-75.

FLIGHT DIAGRAM



RELIABILITY DIAGRAM



B1 Numerous traverses with air photo interpretation

HON. A. MENSAROS, M.L.A.
MINISTER FOR MINES
J. H. LORD, DIRECTOR, GEOLOGICAL SURVEY

SCALE 1 : 250 000

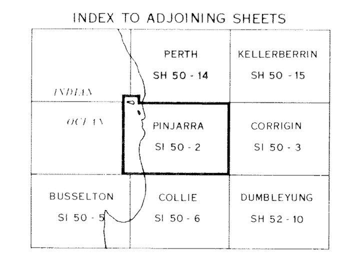
5 0 5 10 15 20 25 30 Kilometres

TRANSVERSE MERCATOR PROJECTION

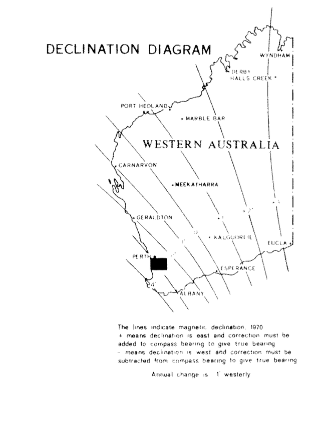
ZONE 1 AUSTRALIA SERIES

Ticks inside the sheet edge represent 10000 metre intervals of the superimposed Australian Map Grid, Zone 50. AUSTRALIAN NATIONAL SPHEROID

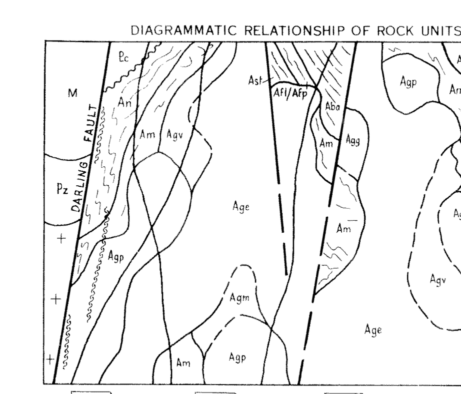
INDEX TO ADJOINING SHEETS



DECLINATION DIAGRAM

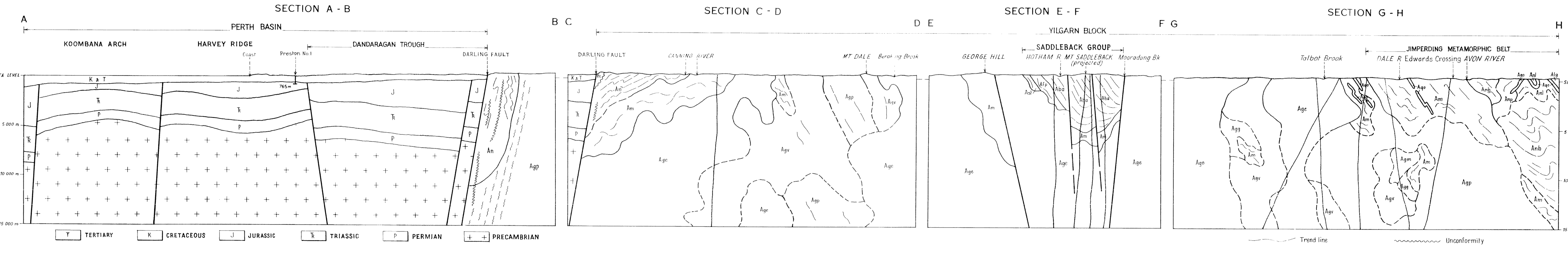


DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



DIAGRAMMATIC SECTIONS

NATURAL SCALE



PINJARRA

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