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TITLE: EXPLANATORY NOTES ON THE ARCHAEAN ROCKS OF THE PERTH 1:250 000 GEOLOGICAL SHEET, WESTERN AUSTRALIA

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EXPLANATORY NOTES ON THE ARCHAEAN ROCKS OF THE PERTH 1:250 000 GEOLOGICAL SHEET, WESTERN AUSTRALIA

by S. A. Wilde

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1. Structural Map of the Perth Sheet, showing isograds (14419)

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PLATE

Perth 1:250 000 Geological Sheet (Preliminary Edition)

GENERAL

The Perth 1:250 000 Sheet, SH/50-14 and part of SH/50-13 of the International Series, is bounded by latitudes 31°S and 32°S and longitudes 115°15'E and 117°00'E. This Record deals only with the area east of the Darling Fault, i.e. approximately east of longitude 116°00'E. The geology of the Perth Basin area to the west of the Darling Fault has been previously described by Low (1971).

The eastern portion of the sheet area falls within the "Wheat Belt" natural region of Clarke (1926) and is largely cleared for agriculture. The main town of Northam is linked by bitumen roads to Perth and the other population centres at York, Toodyay, Bolgart, Calingiri and Goomalling. These, and other smaller settlements, are interconnected by numerous sealed and unsealed roads.

The population in the western area is concentrated along the main highways and in the Kalamunda area, an eastern suburb of the State capital, Perth, which is situated on the coastal plain, 15 km to the west.

The geological mapping was carried out during 1972 and 1973. The petrographic work was done by J.D. Lewis and S.A. Wilde.

GEOMORPHOLOGY

Most of the sheet area falls within the Swanland Division of Jutson (1950). It forms part of the Darling Plateau and has an average elevation of about 300 m. It is separated from the Swan Coastal Plain by the Darling Scarp (Saint-Smith, 1912). The Darling Plateau represents an ancient erosion surface that has been dissected by streams that vary from youthful to mature. The principal river systems are the Moore and the Swan-Avon.

The northeast corner of the Sheet area, forms part of Jutson's Salinaland, with intermittent and internal drainage toward a system of salt lakes.

CLIMATE

The Perth area has a dry-summer subtropical (Mediterranean) climate with an annual rainfall of about 890 mm. Most of the rain falls during the cooler winter months of May to September; the summer months of December to March are hot and dry, whilst November and April are warm and changeable (Gentilli, 1969). Rainfall decreases rapidly east from the Darling Scarp. The annual rainfalls at Northam and Meckering are 434 mm and 384 mm respectively.

VEGETATION

Rainfall and geology exert a strong control on the vegetation. The sclerophyllous forest of jarrah (*Eucalyptus marginata*) is characteristically developed on the laterite of the Darling Range (Gardner, 1944). Smaller associated trees and an undergrowth of sclerophyllous shrubs are also present. More sandy areas have prominent marri (*E. calophylla*).

On the granitic and clayey soils of the Darling Range, wandoo (*E. redunca* var. *elata*) occurs, but is subordinate. East of the 385 mm isohyet it becomes dominant and, with its associates *E. foecunda* var. *loxephleba* and *Acacia acuminata*, forms an open, temperate savannah woodland.

Halophytic forms occur in Salinaland in the extreme northeast portion of the sheet. Species of *Atriplex*, *Bassia* and *Kochia* are most abundant (Gardner, 1944).

PREVIOUS INVESTIGATIONS

There are numerous reports pertaining to the Archaean geology of the Perth Sheet, the most important of which are listed in the references. Most of the early accounts relate to mineral occurrences and no general mapping was done prior to that of Fletcher and Hobson (1932) in the Upper Swan area. Prider (1934 and 1944) mapped a sequence of metamorphic rocks in the Toodyay district; these rocks forming part of the Jimperding "Series" of Clarke (1930). Another metamorphic sequence in the lower Chittering Valley was described by Miles (1938) and named the Chittering "Series". Later mapping by successive generations of university students under the direction of Professor R. T. Prider has extended the limit of both "Series", though mapped areas are small and rarely adjacent.

Simpson (1948, 1951 and 1952) gives details of mineral occurrences and some comments on the local geology.

Lewis (1970) mapped the eastern portion of the Perth Sheet around Meckering.

Preliminary Bouguer anomaly and total magnetic intensity maps are available from the Bureau of Mineral Resources.

PRECAMBRIAN ROCKS

REGIONAL SETTING

The area east of the Darling Fault forms part of the Yilgarn Block. This is a stable Archaean nucleus, composed of granites and gneisses enclosing a number of elongate "greenstone" belts. The "greenstone" belts of the Eastern Goldfields region consist of layered successions of felsic, mafic and ultramafic igneous rocks with varying, though minor, amounts of sedimentary material and are mainly of low metamorphic grade. In contrast, the sequences exposed on the Perth Sheet are notable for the complete lack of felsic volcanic rocks, the subordinate amounts of mafic volcanic rocks and the high grade of regional metamorphism.

The rocks occur in two distinct metamorphic belts that extend northward on to the Moora 1:250 000 Sheet.

The more extensive eastern belt stretches in a north-northwest direction right across the Sheet area and also extends beyond the Sheet area to the south and east. The rocks are essentially similar to those of the Jimperding "Series", described by Prider (1934 and 1944) from the Toodyay area, and are grouped here as the Jimperding Metamorphic Belt. The western belt occurs immediately east of the Darling Fault and extends from Upper Swan northward beyond Mogumber. This belt of rocks (the Chittering "Series" of Miles, 1938) is here referred to as the Chittering Metamorphic Belt.

These two belts are everywhere separated by granite or gneissic granite; the latter occurring north of Chittering. The granitic rocks in the southwest of the Sheet area are extensive and have only local developments of migmatite at their margins. In contrast, the granites occurring in the east and northeast portions of the Sheet area are less continuous and intimately admixed with broad zones of migmatite.

An age of 3 084 $\pm$ 191 m.y. has been obtained by pooling certain gneisses of the Yilgarn Block, including samples from the Toodyay and Northam areas (Arriens, 1971). A gneissic sample from the York area gave an age of 2 688 $\pm$ 211 m.y. A pooled age of 2 661 $\pm$ 51 m.y. was obtained from the granites of the "Wheat Belt" that intrude these gneisses (giving an isochron of 2 667 $\pm$ 27 m.y. if further pooled with granites from the Eastern Goldfields).

THE LAYERED SEQUENCES

A wide range of lithologies are present in the layered sequences. The predominant rock types are granitic gneisses and schists, with locally abundant amphibolites and quartzites, together with thin units of other varieties of gneiss, banded iron formation (BIF) and mafic granulite. Intrusive ultramafic rocks occur locally in the sequence. Many of these have been deformed and they only occasionally transgress other rock boundaries.

THE JIMPERDING METAMORPHIC BELT

This belt extends north-northwest, across the Perth Sheet for over 120 km and varies in width from 15 to 65 km. Regionally, the strata dip to the east at moderate to steep angles, though there are large areas of subhorizontally dipping strata near Toodyay and York.

Gneisses

The predominant rock type is a fine to medium-grained quartz-feldspar-biotite gneiss (Anb). It is usually well banded with distinct biotite-rich layers, but may be locally more massive. Both plagioclase (andesine/oligoclase) and microcline are present, though the relative proportions of these vary. Porphyroblasts of garnet are locally abundant.

Leucocratic, quartz-microcline-oligoclase (±garnet-biotite) gneiss (Anl) is interbanded with Anb, particularly in the southern and eastern portions of the metamorphic belt. Its boundaries with Anb are complex, and are shown in stylized form on the map. Thin units of quartzite and garnet-oligoclase quartzite are locally abundant in Anl. The chief rock type is medium to coarse grained and consists of long stringers and lenses of quartz interleaved with a granular aggregate of microcline and oligoclase. Sharply delineated lozenges of feldspar are commonly included in the quartz stringers. The overall texture is typical of the granulites. Both feldspars may occur as megacrysts, whilst garnet is a common accessory mineral. Thin bands rich in biotite are locally present and may be associated with hypersthene. In such rocks, oligoclase generally exceeds potash feldspar.

Augen gneiss (Ana) occurs in contact with quartzite at Jimperding Hill near Toodyay. It is coarse grained and consists of quartz, microcline, oligoclase and biotite, with large microcline augen. The texture suggests cataclastic deformation along the quartzite/gneiss contact, though Prider (1944) believes that the texture is protoclastic. The augen gneiss is thought to have developed from Anb.

The porphyritic granite gneiss (Anp) is a coarse-grained quartz-microcline-oligoclase-biotite(-hornblende) gneiss. It differs from the augen gneiss in containing tabular megacrysts of microcline and in having a less distinct biotite foliation. The rock approaches porphyritic granite in appearance, but always retains a gneissic foliation. Its proximity to granite and migmatite suggests that it was a gneiss that underwent metasomatism during emplacement of the granite.

Schists

Outcrop of the schist bands is poor and the rocks are usually overlain by a thick mantle of soil. Where exposed, they are mostly ferruginous or kaolinized. Quartz-mica schist (Alb) is the predominant type, with biotite normally in excess of muscovite. It may be interbanded with quartz-mica-garnet schist (Alg), though the latter also forms more extensive areas. The schist band extending from Jimperding Hill to Clackline is andalusite bearing (Ala) in the north; apparently devoid of alumino-silicates in the central portions, and sillimanite bearing (Als) at Clackline. Many schist bands contain alumino-silicate minerals, but only those with abundant concentrations are distinguished on the map.

The muscovite-chlorite phyllitic schist (Alm) seems to have been derived from other types by retrograde metamorphism. At Smith's Mill Hill, large sericite flakes appear to have replaced original andalusite crystals.

Other Rock Units

Amphibolite (Aa) occurs as thin, discrete bands within the gneissic sequence and as broader units interbanded with leucocratic quartzo-feldspathic gneiss. Typically, the amphibolites are fine to medium grained and are composed of a xenomorphic granular aggregate of hornblende and plagioclase (andesine/labradorite). Quartz is normally very minor, but ranges to 15 per cent in certain units. Clinopyroxene is generally an accessory constituent, but may be locally almost as abundant as hornblende. Some bands contain cummingtonite and not hornblende. The broad amphibolite band, 6 km west of York, is chiefly a brown hornblende-diopside-labradorite gneiss, and similar assemblages occur in the amphibolite units at Bolgart. Some thin bands consist almost entirely of hornblende and are thus hornblendites. In these, occasional cores of clinopyroxene appear to have altered piecemeal to hornblende.

Quartzite (Aqo) occurs in massive to flaggy bands that mostly form areas of high relief, owing to their resistance to erosion. They are metamorphosed orthoquartzites, consisting of interlocking grains of quartz with only minor amounts of muscovite, chrome-muscovite, feldspar, sillimanite or garnet. The green chrome-muscovite is characteristic, though variable in amount. It is most abundant in flaggy units where it coats the foliation surfaces. The foliation probably corresponds with original bedding, but it has certainly been emphasized during later structural deformation. A lineation is common on the foliation planes.

Thin units of metamorphosed banded iron formation (BIF) are present throughout the sequence and are especially abundant east of Northam. The units are generally less than 30 m thick, and form good marker horizons. They may have local topographic expression, but in many places form only trains of rubble. The BIF is usually associated with map units Anl and Aqo, or with schist adjacent to quartzite. Intense minor folding is a characteristic feature of the bands.

The banded magnetite-bearing quartzite (Aiq) is somewhat transitional to the metamorphosed orthoquartzite (Aqo) but has centimetre-scale banding caused by concentrations of magnetite.

The unassigned BIF (Ai) includes the commoner assemblages of quartz-magnetite-grunerite, quartz-hematite-grunerite and quartz-magnetite-hypersthene-grunerite as well as units that have not been petrographically examined. Quartzose layers alternate with amphibole-rich and magnetite-rich bands. Fragments of Ai in migmatite near Wooroloo indicate that the Jimperding metamorphic rocks were originally much more widespread.

A distinctive suite of strongly magnetic BIFs occurs east of Northam. These quartz-magnetite-hypersthene rocks (Aiw) are medium to coarse grained and are not always well banded.

A garnet-bearing BIF (Aig) crops out 20 km east of Mogumber. It is poorly banded and consists of an assemblage of quartz-garnet-hypersthene-hornblende-magnetite. It has affinities with the mafic granulites.

The mafic granulites (Ahg) are a rather diverse group of rocks interbanded in the gneissic sequence. Some are well banded and appear similar to BIF. They differ from Aig in having considerably less magnetite and quartz. Typical assemblages are hypersthene-diopside-brown hornblende-plagioclase (± magnetite and quartz), and hypersthene-garnet-anthophyllite-magnetite-quartz. Rocks of this type crop out near Wongamine and Grass Valley.

More basic varieties consist of diopside-brown hornblende-plagioclase and hypersthene-diopside-brown hornblende-plagioclase assemblages. They have affinities with the amphibolites in the field and are not usually banded. Megacrysts of hornblende are occasionally present, as in the unit 1 km northeast of Jennapullin.

Ultramafic granulites are not common. The assemblages hypersthene-diopside-brown hornblende and hypersthene-brown hornblende ± spinel occur in association with basic granulites at Mount Bakewell near York (Stephenson, 1970). In a road cutting, 3 km south of Bolgart, diopside-brown hornblende rocks are interbanded with hornblendite, hypersthene-diopside-brown hornblende and diopside (± magnetite) assemblages.

These rocks are well banded and occur in a sequence of amphibolites. At 2 km west-northwest of Grass Valley, a thin band of hypersthene-quartz rock occurs. Quartz is not abundant and the rock is essentially hypersthenite, though related to the granulites.

Ultramafic rocks (Au) are intrusive into the gneissic sequence but are generally subconcordant and form part of the layered succession. They are generally foliated and thus predate the final deformation. No subdivision has been attempted on the map, owing to their variable mineralogy. The rocks are altered and occur chiefly as serpentinite and talcose rocks, and as serpentine-talc, serpentine-tremolite, tremolite-actinolite and tremolite-chlorite assemblages. Locally, silicified ultramafic rocks have developed, for example, at Mount Bakewell. A fresher peridotite occurs at Nunyle, 6 km east of Toodyay. It is mainly a bronzite peridotite with minor hornblende bronzitite, serpentinite and associated rhodingite (Elkington, 1963). In contrast, study of the margins of the talcose ultramafic, 9 km south-southwest of Bolgart, reveals that the original rock was a clinopyroxenite. Both peridotites and pyroxenites were therefore present in the Jimperding Metamorphic Belt.

Thin units of cordierite-bearing gneiss (Ci) within the gneissic sequence are not extensive and are shown as mineral occurrences on the map. These include cordierite-anthophyllite, cordierite-quartz-biotite, cordierite-quartz-garnet-sillimanite-biotite and cordierite-hypersthene-quartz-biotite assemblages. Most of the cordierite-bearing rocks appear to be paragneisses, though Prider (1940) suggests that the cordierite-anthophyllite rocks near Noondeening Hill resulted from the intrusion of a hypersthenite magma.

Small areas of calc-silicate rock (Cs) occur in the layered succession and are similarly shown as mineral occurrences on the map. These rocks comprise assemblages of diopside-grossular-epidote-quartz.

There are also minor developments of many rock types, especially amphibolite, that are too small to indicate on the map.

THE CHITTERING METAMORPHIC BELT

A series of metamorphic rocks extends due north from Bullsbrook East for about 75 km to the northern limit of the Perth Sheet. The average width of the belt is 10 km. The rocks have a northerly regional strike and dip steeply to east or west. The sequence consists of various gneisses and interbanded schists.

Gneisses

The chief rock type is banded quartz-feldspar-biotite gneiss (Anb), essentially similar to the type occurring in the Jimperding Metamorphic Belt. The biotite-rich layers are often extensive and increase in width toward interbanded schist units.

Two well marked bands of augen gneiss (Ana) are present. They contain microcline megacrysts and are petrographically similar to those described previously (p. 5). The texture appears to be the result of cataclasis. This is also suggested by the fact that the southern unit is along the northern extension of the Swan Gorge mylonite zone (p.29), whilst the unit at Mogumber and Wannamal is associated with thin mylonite bands and is near a cataclastically-deformed granite (p.17).

In the northern part of the belt, an interbanded sequence of melanocratic quartz-hornblende-biotite-garnet-plagioclase gneiss and leucocratic quartz-feldspar gneiss (Anc) forms the most westerly unit of the metamorphic belt. The melanocratic gneiss contains olive-brown biotite and dark green ferrohastingsite. It ranges to an amphibolite that consists entirely of a xenomorphic-granular aggregate of amphibole and plagioclase. The leucocratic gneiss consists of potash feldspar, plagioclase and quartz, with minor biotite and magnetite. Zones of cataclasis, resulting in mylonite and blastomylonite, occur throughout the sequence and appear to increase northward to Mogumber. The eastern contact with Ana is sharp.

A thin band of melanocratic quartz-feldspar-hornblende-biotite gneiss and schist (And) occurs in the eastern part of the belt from Wannamal south to Bindoon. The gneissic bands contain megacrysts of microcline, oligoclase and biotite in a fine-grained matrix of quartz, feldspar, biotite and hornblende. The schists are richer in biotite and lack megacrysts.

There is an extensive development of quartz-feldspar-biotite granofels (Anf) in the Chittering area. The rock is a fine to medium-grained, blue, melanocratic gneiss that is poorly banded, but has a strong biotite lineation. It consists of a granoblastic aggregate of quartz, microcline and oligoclase with minor biotite. The relative proportions of microcline and oligoclase vary considerably. Biotite normally forms individual crystals but may occur as cuspate wisps or, more rarely, as distinct layers. The granofels is locally interbanded with thin units of Anb.

Schists

Numerous thin units of schist are intercalated with the gneisses. Many are discontinuous, partly as a result of poor outcrop and partly because of their lensoid form. Several more extensive bands crop out south of Bindoon. The rocks are chiefly quartz-mica schist (Alb). The relative amount of biotite and muscovite varies, whilst the biotite is commonly altered to chlorite. Interbanded units of Anb are common. The schist band 4 km east of Mogumber passes northward into a more gneissose rock with discontinuous micaceous wisps defining a strong lineation.

Traces of sillimanite, kyanite and, more rarely, staurolite and garnet, may occur in Alb. Where kyanite or sillimanite are abundant and the schist bands are of sufficient size to be shown on the map, they are distinguished as kyanite schist (Alk) and sillimanite schist (Als) respectively. A single band of staurolite schist (Aln) occurs 1 km east of Chittering Lake, whilst there is a smaller outcrop (shown as a mineral occurrence) at Lower Chittering.

Other Rock Units

Amphibolite (Aa) is not abundant, being restricted to two main bands west of Bindoon. The northern band crops out at Mooliabeenee Hill where medium-grained hornblende-plagioclase amphibolite is interbanded with leucocratic quartz-feldspar gneiss. The southern unit is exposed in a roadway, 2 km further southwest where amphibolite, containing long needles of hornblende, occurs with buff, quartz-feldspar granofels and hornblende-bearing gneiss.

In the Chittering Valley, shearing of the margins of certain dolerite dykes has produced amphibolite (Mong, 1964).

Quartzites have been recorded from the Chittering Metamorphic Belt (Geary, 1950; Jones, 1950 and Mong, 1964), but they are extremely thin and do not form mappable units. Rocks approaching quartzite in megascopic appearance form part of the granofels (Anf) sequence. However, thin sections reveal that feldspar is generally as abundant as quartz. Metamorphosed orthoquartzite similar to that occurring in the Toodyay area, has not been recorded.

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 paleosome. The original 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 appears to have developed first at the hinges of minor folds.

Migmatite (Am) occurs as a narrow, sporadically developed marginal zone to the granitic rocks in the southern part of the Perth Sheet. It also occurs within the granite area and is particularly extensive around Wooroloo and near the Darling Scarp, where it forms a number of subparallel north-northeast trending zones. In the northern part of the Sheet area migmatite is more extensive and forms a broad, irregular zone between the layered succession and the granitic rocks.

The migmatite of the Toodyay area is not directly related to intrusive granite but has resulted from mobilization of the gneisses. Migmatite and Anp are closely associated, the latter grading into migmatite with an increase in the amount of granitic neosome.

Certain portions of the migmatite containing abundant amphibole crystals, together with bands and "xenoliths" of amphibolite appear on the map as Amh. The zones near York and Coondle are along strike extensions of amphibolite units and were probably derived from these by mobilization. The large area at Clackline is away from known amphibolite occurrences. Here, blocks of amphibolite are enclosed in a swirling granitic medium. Discrete areas of porphyritic hornblende granite also occur within the migmatite, but are too small and irregular to indicate separately on the map. They appear to cut the migmatite, but were probably derived from it at a lower structural level.

GRANITIC ROCKS

The plutonic granitic rocks were distinguished in the field on the basis of their textures. There is some compositional variation within each unit, with a maximum range from granodiorite through to granite. The rocks constitute a discrete batholith in the southern portion of the Sheet area, where they have sharp, intrusive contacts with the layered succession. The granitic rocks of the eastern and northern areas are associated with more extensive migmatite and may have sharp or diffuse contact relations. The various textural types are irregularly interdeveloped.

The leucocratic adamellite (Agg) is fine to medium grained with marked variations in the grain size. Veins and irregular areas of pegmatite are abundant and often associated with aplite. The rock has an allotriomorphic granular texture and consists of oligoclase, microcline and quartz, with minor biotite and accessory muscovite and epidote. It is almost invariably associated with migmatite and in many places occurs between this and other granitic rocks. Gneissic xenoliths are common near migmatite contacts and the adamellite may have a weak biotite foliation. Northwest of Calingiri, patches of Agg within migmatite contain large garnets that show marginal alteration to biotite. This feature, together with the overall distribution, suggests that Agg may have developed from gneisses of the Jimperding Metamorphic Belt under the influence of granite emplacement.

The even-grained granitic rocks (Age) are fine to coarse grained and mesocratic. They range in composition from granodiorite to granite, but true granite is rare. The rocks are homogeneous on a regional scale but reveal much minor variation in well exposed quarry faces, for example, in the Boya area. The chief constituents are andesine/oligoclase, microcline, quartz and biotite. The texture is allotriomorphic granular, with a tendency for microcline to form large interstitial areas up to 6 mm in diameter that enclose a number of smaller plagioclase crystals. Myrmekite is often present here. Xenoliths of country rock occur near contacts with migmatite and the layered succession, but are nowhere abundant. There may be a weak foliation defined by biotite and/or the felsic minerals which, close to the granite contacts, is generally subparallel to the regional metamorphic trend; but elsewhere is more random. Near the Darling Scarp, a strong shear foliation, defined by biotite and epidote, parallels the mylonite zones (p. 30).

Grey porphyritic granite (Agp) forms a number of small irregularly shaped areas within the granite complexes. Contacts with the country rock and adjacent Age are generally sharp. Tabular megacrysts of microcline microperthite average 1.5 cm in length and occur in an allotriomorphic granular aggregate of microcline, oligoclase and quartz, with accessory biotite and hornblende. The megacrysts vary in abundance and are commonly aligned. The granite south of York and at Bakers Hill contains up to 15 per cent hornblende. Mafic schlieren are abundant and the hornblende probably resulted from contamination by amphibolite xenoliths. Thin veins and irregular areas of pegmatite and aplite cut the porphyritic granite. Near York, Konnongorring and Uberin Rock, veins of fine to medium-grained adamellite traverse the granite. However, at Walyormouring Lake, veins of porphyritic granite cut Age. This suggests at least two periods of intrusion for Age and/or Agp.

Although the junctions between Age and Agp are sharp, there are areas where the two types are intimately admixed and cannot be separated on the map. Such areas of mixed granite form part of the Agm unit. It is generally impossible to determine the order of intrusion, but scanty evidence from several areas suggests that Age intrudes Agp. However, most of the mixed granite areas (Agm) also have portions of Agg and an extensive development of pegmatite and aplite.

Gneissic xenoliths and rafts are abundant near migmatite contacts and it would appear that such areas arose from a complex interaction between intrusive granite and the migmatitic gneisses.

Fine to medium-grained granitic rocks with scattered megacrysts of potash feldspar (Agv) are particularly extensive in the southern portion of the sheet area. They are areally associated with Age and Agp and appear to represent a transitional phase between these two varieties. The rocks are mesocratic and range from adamellite to granite. They are texturally and compositionally similar to Age except for the occurrence of microcline megacrysts. Only rarely are the megacrysts aligned and they are mostly ragged, with numerous inclusions of plagioclase. A few mafic schlieren and clots of biotite are present in rocks near the Avon River. The rocks grade into Agp with an increase in both size and abundance of the megacrysts, and into Age as these decline.

A large, discrete mass of foliated gneissic granite (Agn) occurs in the Bolgart-Mogumber-Bindoon area. There is evidence of strong cataclasis, though the foliation and abundance of epidote shears decreases eastward. Indeed, the rock near Bolgart and Julimar Brook, although forming part of the same granitic mass, is a medium-grained granite with only a weak foliation and has been shown as Age on the map. Where least deformed, the granite consists of an allotriomorphic granular aggregate of microcline, orthoclase, albite/oligoclase and biotite. The orthoclase is perthitic and tends to enclose plagioclase. Further to the west, the granite is coarser grained and consists of perthitic orthoclase, albite, quartz and biotite. The perthite often forms elongate aggregates and has corroded plagioclase. Quartz has slightly undulose extinction and occurs as stringers parallel to the perthite clusters. In the field, biotite most clearly defines the foliation. It occurs as cusplike aggregates that partially enclose compound felsic areas. Frequently, these cusps have a consistent plunge on foliation surfaces. In the west the gneissic granite consists largely of perthite and quartz with minor albite and biotite. The quartz has strongly undulose extinction and is criss-crossed by thin bands of granulation. Zones of complete quartz granulation occur. Cuspate biotite is distinct in hand samples and is intergrown with chlorite. More advanced cataclasis results in the partial granulation of the perthite, together with complete granulation of the quartz. The latter now occurs as a granular aggregate of subgrains with weakly undulose extinction. There is a tendency for areas of perthite enclosed in quartz to be rounded.

A distinctive variant of the granite crops out in a road-cutting, 5 km east of Mogumber. The rock is medium grained and contains rounded grains of quartz and feldspar. In thin section, these crystals of undulose quartz and perthitic orthoclase are sharply separated from a matrix of graphically intergrown potash feldspar, plagioclase and quartz. Certain areas consist of a coarser intergrowth of orthoclase and quartz, whilst megacrysts of orthoclase up to 1 cm long are cut by parallel bands of undulose quartz.

Around Bindoon and Chittering, the gneissic granite is commonly blue and much finer grained. It has a mortar texture of rounded grains of undulose quartz and potash feldspar in a matrix of graphically intergrown potash feldspar, plagioclase and quartz. Abundant biotite forms wispy aggregates that define a crude foliation. Locally, only the quartz megacrysts are distinct and the matrix is so fine grained that the rock becomes a blastomylonite.

DIORITIC AND SYENITIC ROCKS

A number of small outcrops of rock ranging in composition from quartz diorite, through monzonite (Agd), to syenite and quartz syenite (Ags) occur scattered throughout the Perth Sheet area. With the exception of the dykelike intrusions at Grass Valley and Northam, they are associated with migmatite or mobilized gneiss of the Jimperding Metamorphic Belt. There are marked variations in grain size within small areas and amphibolite xenoliths are invariably present.

The most dioritic rock crops out near the Avon River, 4 km west of Toodyay. It consists of hornblende and plagioclase, with minor quartz. Xenoliths of amphibolite and hornblendite are abundant and many are net-veined by the diorite. Appinite veins are locally present.

The monzonites and syenites consist of microcline, oligoclase, augite and hornblende, with minor quartz, sphene and apatite. Some of the rocks are even grained and occur as irregular patches in close proximity to amphibolite or hornblende-bearing gneiss. However, more gneissose syenitic rocks also occur, with a foliation marked by stringers of mafic minerals, blades of quartz and microcline, or differences in grain size. The large syenite body at Katrine which is of this type, is interbanded with leucocratic quartz-feldspar gneiss (Anl). Its texture is identical to these gneisses (p.5) and there are no intrusive contacts. Streaks of amphibolite occur near the northern margin.

Although some of the dioritic and syenitic rocks are pre and some post-deformation their origin was probably similar. Their association with migmatite, amphibolite and mobilized gneiss suggests that they resulted from potash metasomatism and hybridization of an amphibolite - quartzo-feldspathic gneiss sequence.

The syenite at Grass Valley is texturally and compositionally similar to a syenite dyke occurring in migmatite, 2 km west of Northam. The latter is suborizontal, 1 to 2 m thick and has a distinct chilled margin. The margins consist of a fine-grained aggregate of microcline, oligoclase, green clinopyroxene and hornblende, with abundant sphene and apatite. The mafic minerals are of similar size in the centre of the dyke, but are enclosed in plates of microcline more than 5 mm long.

MINOR INTRUSIVES

GRANITIC DYKES AND VEINS

A number of fine or medium-grained, black and white granitic dykes occur in the vicinity of York. They are only a few metres wide and occur within the gneissic sequence. Biotite and/or hornblende are generally present.

Smaller dykes and veins of granite and adamellite are abundant around the plutonic intrusions. They are fine-grained and range to aplite. A notable feature is their grouping about an easterly strike direction. They is evident at Clackline, Meenar, Goomalling and Konnongorring. Some veins also occur within Agp and Agm, for example, at Uberin Rock.

Veins of pegmatite and associated aplite are common in the gneisses and migmatite. They are subparallel to the metamorphic banding and, at Konnongorring, are at right angles to the fine-grained granitic veins.

DIORITIC DYKES

A small number of fine to medium-grained dykes within the tonalite-diorite-monzonite compositional range occur in the Jimperding Metamorphic Belt and the nearby migmatite and granitic areas. The dykes are generally less than 10 m wide and are unfoliated. Their age is uncertain, though the dyke at Walyormouring Lake cuts Age.

DOLERITIC DYKES

Tholeiitic, quartz dolerite dykes (d) intrude all the Archaean rock types throughout the Sheet area. They are particularly prominent in the granitic terrains and appear to increase in abundance toward the Darling Scarp. The dykes are generally around 2 to 10 m thick, but range up to 200 m maximum thickness. The smaller dykes are mostly fine grained and melanocratic. Material of this type also forms the margins of the coarser grained gabbroic varieties, though some of these dykes have no finer grained margins. Most dykes, especially in the western part of the area, show some alteration. They consist of saussuritized plagioclase, augite, hornblende and minor quartz, with accessory epidote, sphene and chlorite. Near the Darling Scarp, certain dykes have sheared margins, whilst, at places in the Chittering Valley, they are completely sheared (Mong, 1964).

Cross-cutting relations indicate several relative ages (Martin, 1961), though there may have been only one general period of dyke intrusion. The larger dykes have an overall north trend in the western part of the area whilst easterly and east-northeasterly trends are more prominent in the east. A Rb-Sr age of 560 to 590 m.y. has been obtained from sheared and metasomatized dyke margins (Compston & Arriens, 1968).

A distinctive suite of fine-grained, melanocratic, plagioclase-phyric, basaltic dolerites occurs in the eastern portion of the Sheet area. These dykes have not been distinguished separately on the map. They consist of labradorite and augite phenocrysts in an aphanitic to fine-grained groundmass of plagioclase, augite, quartz, dendritic iron ores and occasional devitrified glass. Most of these dykes have a northeasterly trend.

A set of unusual xenolithic dolerite dykes (dx) is similarly restricted to the eastern part of the Sheet area. The dykes trend northeast, with the exception of two north-northwest-trending dykes at Wongamine and Northam. They have been described by Lewis (1969, 1970), who attributes the abundance of granitic xenoliths to intrusion of dolerite along shear-zones. The doleritic matrix to the xenoliths is similar to the plagioclase-phyric dolerites.

QUARTZ DYKES AND VEINS

Innumerable small, pre and post-tectonic quartz veins are present in all Archaean rock types. A number of quartz dykes also occur, the largest extending for 30 km from Botherling south to the Salt River. Several other north-northeast-trending quartz dykes are associated with it near Burabadji Some lensoid quartz "blows" are present in the schist unit east of Cockman Bluff, in the Chittering Valley. Several other quartz dykes and veins throughout the Sheet area are associated with lines of faulting or shearing.

METAMORPHISM

The metamorphic mineral assemblages have been used to roughly delineate regional metamorphic facies zones on the structural map (Fig.1). The Chittering and Jimperding Metamorphic Belts have quite distinct mineral assemblages and there are also differences within each belt.

The abundance of kyanite and sillimanite, together with minor staurolite, in the schists of the Chittering Valley, the calcic plagioclase composition of the amphibolitic rocks and the scattered occurrence of garnet throughout the quartz-feldspar-biotite gneiss, indicates amphibolite facies conditions within the kyanite-sillimanite metamorphic facies series of Miyashiro (1961). This facies series is characteristic of moderate to high pressure. However, the occurrence of chloritic schists and rocks rich in epidote indicates lower temperatures and a range down into the greenschist facies. Such rocks are only developed locally and appear to have resulted from retrograde metamorphism associated with shear zones parallel to the trend of the Darling Fault.

In contrast, the Jimperding Metamorphic Belt contains schists rich in andalusite and sillimanite, and generally poor in kyanite. Cordierite is a rare but widely distributed mineral in certain gneisses. The plagioclase in the amphibolites is calcic and often associated with cummingtonite, whilst orthopyroxene is common in the BIF and mafic granulite. These minerals indicate low pressure conditions of the andalusite-sillimanite facies series (Miyashiro, 1961) with a range from amphibolite to granulite facies metamorphism. The quartz-microcline-oligoclase(-garnet-biotite) assemblage of the leucocratic gneisses (Anl) is also characteristic of the granulite facies, whilst the rocks are texturally similar to the classic granulites of Saxony.

The metamorphic zones shown in Fig.1 have been extended and slightly modified from Stephenson (1970). Within the granulite facies zone there are areas that correspond more nearly to the amphibolite-granulite transitional facies (Turner, 1968). These have not been separated, owing to the lack of detailed information. A larger area in this facies zone occurs west of York, between the granulite facies isograd and the migmatite zone surrounding the granitic rocks. It seems possible from the relict cores of pyroxene in many amphibolites and hornblendites (p. 6) that much of the Jimperding Metamorphic Belt attained granulite facies conditions at some stage and that the present amphibolite facies zones could reflect later retrogressive effects. The later development of migmatite and intrusion of the granitic rocks could have been important in this respect.

The ultramafic rocks within the Jimperding Metamorphic Belt only rarely retain their original mineralogy and are usually altered to greenschist facies assemblages.

RELATIONS BETWEEN THE JIMPERDING AND CHITTERING METAMORPHIC BELTS

The various features described in previous sections suggest that there are fundamental differences between the Jimperding and Chittering Metamorphic Belts and that they are not equivalent in age.

The important differences are listed below:-

	Jimperding Belt		Chittering Belt
1.	Numerous bands of BIF, orthoquartzite and amphibolite	:	No BIF or orthoquartzite; rare amphibolite
2.	Large areas of leucocratic quartz-feldspar-garnet gneiss	:	No quartz-feldspar-garnet gneiss
3.	No occurrence of granofels	:	Extensive unit of granofels

4.	Widespread granulite facies metamorphism	: No granulite facies metamorphism
5.	Within andalusite-sillimanite metamorphic facies series	: Within kyanite-sillimanite metamorphic facies series
6.	Presence of ultramafic rocks	: No ultramafic rocks.

There are no isotopic age dates on the Chittering Metamorphic rocks and data for the Jimperding Metamorphic Belt are sparse. However, the lack of evidence for granulite facies rocks in the Chittering Valley, even allowing for the later, extensive retrograde effects, could imply a fundamental age difference between the belts. There is some evidence to suggest that, although only parts of the Jimperding Metamorphic Belt are now of granulite facies, most of the rocks at some time approached or attained this grade of metamorphism and that present differences may be due to a westward increase in retrograde effects. Further, hypersthene-bearing BIF occurs less than 10 km from the Darling Fault north of Gillingara, on the Moora 1:250 000 Sheet (J.D. Carter, unpublished data). These rocks are of Jimperding type and are apparently unaffected by northerly shearing in the area.

It is tentatively suggested that the rocks of the Chittering Metamorphic Belt may be younger than those of the Jimperding Metamorphic Belt. They occur close to the Darling Fault and thus have a similar distribution to the Middle or Upper Proterozoic rocks of the Cardup and Moora Groups (Low, 1972a and 1972b, respectively). The position of these three distinct groups of strata suggests possible marginal accretion onto the early Archaean nucleus of the Yilgarn Block, of which the Jimperding Metamorphic Belt forms part. This suggestion was also made by Wilson (1958), although on somewhat different grounds.

CAINOZOIC ROCKS

GENERAL

The Cainozoic deposits have been mapped on the basis of their lithology and morphological features. Genesis is complex and the distinction between Tertiary and Quaternary deposits is often doubtful in the field. No subdivision of the Quaternary is implied by the second letter of a "Q" unit symbol. The relationships of the units are illustrated in Fig. 2.

TERTIARY AND UNASSIGNED UNITS

The most extensive deposit is laterite (Czl). In the west, it forms an extensive capping to the granitic rocks. The surface is flat to undulating and is strongly dissected by streams, especially south of the Avon River. The deposit is generally pisolitic and may be massive or uncemented. It has formed *in situ* from the weathering of underlying rocks and passes downward through a pallid zone into weathered bedrock. Only local redistribution has occurred.

The eastern limit of the massive laterites is the 950 mm isohyet (Mulcahy, 1967). Further east, laterite is more sporadically developed. A number of deposits have developed on colluvial slopes above alluvium and are chiefly lateritized sands. It is not certain whether these deposits are coeval with the massive laterites.

A special type of siliceous duricrust (Czq) is developed over some of the larger quartzite units. It corresponds to the main laterite surface but is not ferruginous. It consists of a pavement of white quartzite rubble and *in situ* quartzite.

Overlying the laterite, particularly in the eastern portion of the sheet, are deposits of yellow, grey or white sand (Czs) of variable thickness. There has been some redistribution of this material into eolian dunes. Where it overlies the massive laterite of the Darling Range the unit is much less extensive, is grey or white but not yellow, and is invariably associated with the drainage courses.

A unique deposit, shown on the map as Czg, occurs 6 km south of Calingiri. It is a subhorizontal, flaggy "silcrete" that contains large quartz and kaolinized feldspar fragments in a cemented sandy matrix, and is associated with sand rich in quartz cobbles. The exact age of the deposit is unknown but it has been lateritized in part. It occurs on the drainage divide between the Moore, Avon and Mortlock systems and may represent the product of a pre-Pleistocene drainage system (Balleau, 1972).

A compact, partially lateritized gritty sandstone (Czf) is associated with Czg and also occurs at the head of present drainage channels in the Calingiri area. It overlies Czg 5 km east-southeast of Wyening Mission.

QUATERNARY UNITS

In the northeast portion of the Sheet, buff sand with distinct bands and lenses of ferruginous pisoliths (Qsp) forms a thin mantle over rock. The relief and photopattern are similar to soil-covered areas, and dykes can often be detected beneath the deposits. Areas of Qsp are particularly abundant around the Moore, Avon and Mortlock drainage divide and usually flank drainage channels, giving way upslope or laterally to laterite or rock outcrop. The deposits appear to be redistributed residual products whose position is closely related to an early Quaternary drainage system.

Hummocky deposits of bright yellow sand (Qs) occur marginal to alluvial areas in Salinaland. They are probably of eolian origin, Similar yellow sand also overlies laterite in much of this area. Older sandy alluvium (Qaf) and reworked sand (Qas) associated with old stream channels are extensive upstream of the more recent alluvium of the Mortlock drainage system and near the drainage divides. The older alluvium has a flat surface and is dissected, whereas Qas has an undulose surface and is often traversed by dunes. The more recent alluvium (Qra) has a fairly flat surface and lies above the normal level of the present streams. The deposits associated with the Mortlock River (North Branch) and the salt lakes of Salinaland are particularly extensive.

Salt lake deposits (Qws) occur in the broad alluvial areas of Salinaland and with Qas in the eastern portion of the Mortlock drainage system. Minor salt lakes have also developed in sand over laterite north of Meckering.

Swamp and lacustrine deposits (Qrw) are generally associated with Qas to the west of the Mortlock River (North Branch). They also occur with thin bands of alluvium and colluvium (Qa) that have developed on the laterite of the Darling Range. The deposits form rounded clay pans and swamps. Lacustrine deposits also occur in the Brockman River between Chittering and Mogumber.

In the east, colluvium (Qrc) consists of shallow dipping sheets of sand on valley sides upslope from alluvium and below rock or laterite outcrops. In the western area of more active erosion, colluvium occurs between valley alluvium and rock outcrop (separated from both by a marked change of slope) and also occurs as scree deposits in valleys that are actively incising the laterite surface of the Darling Range.

In the eastern part of the Sheet area, bed-rock is often largely or almost completely obscured by soil. However, occasional outcrops and rock fragments enable the underlying rock type to be determined. Such areas are denoted by an overprint on the map.

STRUCTURE

FOLDING

The structure of the Jimperding Metamorphic Belt is complex and difficult to interpret. In the portion east of York and Northam and its northward extension through Bolgart and Calingiri, the structure is superficially simple: a zone of gneisses with abundant BIF and quartzite trends north-northwest and has a regional dip to the east. A strong lineation generally plunges at moderate angles to the south-southeast. However, paucity of outcrop, the lensoid nature of many units and the complexity of minor structures mean that individual horizons cannot be traced over large distances. At Jennapullin, a mafic granulite band is isoclinally folded about north-trending axes with the minor fold closures plunging steeply (70-85^{o}) to the north. Shearing-out of limbs parallel to the axial trend and transposition of structures occurs. Similar features are evident south of Bolgart, where occasional transposed fold cores in quartzite and amphibolite plunge steeply to the north or south. The distribution of strata in the Bolgart-Wattening area also suggests that local variations in plunge occur.

It would appear from the minor structures that, although there is a continuity of broad lithological zones in the eastern part of the belt, the rocks have undergone intense isoclinal folding, accompanied by shearing-out of limbs and transposition. A series of later east-trending cross-folds probably accounts for variations in plunge.

In the Toodyay and York areas, the metasediments trend east and thus strike almost at right angles to their trend in the eastern part of the belt. Quartzite is dominant in both areas and its foliation is subhorizontal over much of the outcrop. The major folding varies from open to isoclinal, with evidence of overturning (Prider, 1944; Stephenson, 1970). The earliest phase (F_1) is now represented only by rootless isoclines. At least three, and possibly four, phases of folding have affected the rocks and several interpretations are possible on the available data. A structural interpretation of the Toodyay area is presented in Fig. 3. The relation between these east-trending rocks and the north-northwest-trending rocks to the east is not clear, but there is evidence of strong shearing-out of structures east of Toodyay.

A further complicating factor is the regional development of migmatite and local mobilization of the granitic gneisses. In general, the regional north-northwest trend of the metamorphic rocks tends to swing approximately easterly in the migmatite zones, especially where marginal to intrusive granites. The predominant foliation in these granites is also easterly. Although the intrusion of the granites is post-metamorphic, there is a marked parallelism of the granite contact and the metamorphic units between Clackline and the Malkup area. It is possible that the emplacement of granite had some effect on the structural style of neighbouring areas.

In the Chittering Metamorphic Belt, the metamorphic foliation is subparallel to the lithological banding. The predominant trend is north with steep dips to east or west. Minor folding is complex within the schist units and the bedding in some places is at an angle to the schistosity. A strain-slip cleavage (S_2) is locally developed, but its regional significance is not known.

The earliest and main phase of folding (F_1) produced a series of north-trending tight to isoclinal folds. A number of fold axes are present in the lower and middle Chittering Valley but to the north, only one major anticlinal fold has been recognized. Congruent minor folds suggest some overturning to both east and west. It is not possible to match lithologies either side of the fold axes and it seems likely that a lot more isoclinal folds remain undetected.

A series of easterly trending cross-folds (F_2), as recognized by Geary (1950) at Wattle Flat, occur throughout the belt. They generally have little effect on the isoclinal folds, except for an open-style folding of the associated lineation. An exception occurs 5 km southwest of Bindoon, where an anticlinal cross-fold appears to have caused a local westerly deflection of the lithologies and F_1. Again, many more cross-folds than are shown in Fig.1 are probably present.

An important feature is the development of both F_1 and F_2 folds in the cataclastic gneissic granite (Agn). The F_2 folds cause variations in the plunge of the distinctive biotite lineation (p.16). That the granite intrusion was pre or syn-F_1 is further suggested by the subparallelism of its contacts with the trend of the metasedimentary units. A marked positive Bouguer anomaly over the granite is also difficult to explain unless it forms a shallow, high level intrusion with much denser material at depth.

FAULTING

Few definite faults were recognized in the Sheet area, but it is likely that many more exist. Most of the faults have a northeast to northwest trend, but directions of displacement were hard to determine. Many of the larger quartz dykes appear to follow faults or crush and shear zones, as in the Malkup area (Cole and Gloe, 1940) and southeast of Mogumber. In the latter area, broad zones of intense quartz-veining occur within Agn and partially coincide with its eastern margin. The area of Age west of Bolgart is similarly terminated on its northern side by a quartz-veined fault. A number of shear zones in the granite between the Swan River and Kalamunda, striking 060° or 120°, have reduced the granite to quartz-sericite schist (Whincup, 1970).

A north-northeast-trending shear zone is followed by the Swan River immediately east of the Darling Scarp. The original rock has been intensely mylonitized but appears to have been migmatite. A few unaltered pods of granitic gneiss are totally enclosed in strongly foliated mylonite. The adjacent granite has a strong shear foliation and contains abundant epidote. The northeastward continuation of this shear zone into the Chittering Metamorphic Belt is represented by the mylonitic "feldspathic quartzite" of Miles (1938).

Bands of mylonite, blastomylonite and sheared rock occur in the western portion of the Chittering Metamorphic Belt, parallel to the Darling Fault. Near Mogumber, the metamorphic grade in the mylonite bands is similar to that of the adjacent gneisses, indicating that the shearing was pre or synmetamorphic. At Bullsbrook, the deformation postdates the granite intrusion, whilst in the Chittering Valley, some of the dolerite dykes have been extensively sheared (p.19). It seems likely that the present Darling Fault runs subparallel to an ancient zone of north to north-northeast shearing that has perhaps been re-activated at various times.

A marked aeromagnetic anomaly trending 035° extends northeasterly from South Chittering to about 16 km west of Bolgart. Exposure is poor, but the surface rocks are chiefly migmatite and gneissic granite (Agn). The lineament is subparallel to shear foliations in the adjacent rocks and to a fault postulated by Wilson (1958) in this area. The lineament is also approximately coincident with the southeastern limit of the cataclastically deformed granite.

Recent fault scarps in the area were produced at Meckering (1968) and Calingiri (1970) as a result of earthquakes, though little surface trace of the later fault is evident (Everingham and Parkes, 1971). The arcuate fault scarp at Meckering (Everingham, 1968; Gordon, 1971) is still a marked feature in the area and was probably the result of east-west compression. The fault dips 45°E. Both these faults lie within a seismically active zone termed the Yandanooka-Cape Riche Lineament (Everingham, 1966). Epicentres of numerous earthquake shocks are spread over a fairly broad zone some 50 km in width, mostly within the Jimperding Metamorphic Belt. However, if the events at Meckering and Calingiri are a guide, the more intense seismic activity is possibly associated with the contact zone between the Jimperding Metamorphic Belt and the migmatite and granite complex to the northeast.

ECONOMIC GEOLOGY

METALLIC MINERALS

Mineral production has been negligible, except for industrial products such as clay and aggregate. A little gold and lateritic iron ore has been produced and minor occurrences of other minerals have been recorded.

GOLD (Au)

Shafts and adits were sunk for gold at Chittering, Bolgart, Wongamine, Grass Valley and Jimperding Hill. Total recorded production amounted to 327 ounces of lode gold from Jimperding Hill, together with 237 ounces of alluvial gold from Jimperding Hill and Wongamine. The lode gold was extracted from quartz-veined aluminous schist and appears to have been concentrated at the base of the laterite profile. The alluvial workings at Bolgart, Wongamine and Grass Valley were in eluvial and colluvial deposits in close proximity to BIF. The shaft at Chittering was sunk through quartz-veined schist.

TUNGSTEN (W)

Scattered boulders of wolfram occur 6 km north-northwest of Grass Valley (Blatchford, 1918). The country rock is leucocratic granitic gneiss (Anl) and quartzite (Aqo), together with tourmaline-bearing ?vein quartz. Traces of reinite (ferrous tungstate) have been found associated with the gold at Jimperding Hill (Simpson, 1950). The deposits are not economic.

MOLYBDENUM (Mo)

The first discovery of molybdenite in Western Australia was at Swan View. It occurs with pyrite and epidote in shear zones through Age. There are also several small occurrences in the Spencers Brook area. Simpson (1952) records mining of the deposit in the Mokine railway cutting, though no production figures are available.

IRON (Fe)

The first production of iron ore in the State was from lateritized BIF at Clackline. Between 1899 and 1907, recorded production was 18 545 tonnes, though Hobson (1946) indicates that larger quantities were mined. The ore is high-grade limonite and was treated at the Fremantle Smelting Works. Some ore from the Wundowie-Coates Siding area was also treated at Fremantle, though most of the 82 273 tonnes produced from this area was smelted at Wundowie between 1948 and 1955.

Several of the larger quartz-magnetite-hypersthene BIF bands east of Northam have been drilled and tested, but not mined.

VANADIUM (V)

A lateritized gabbroic intrusion at Coates Siding contains vanadium-bearing titaniferous magnetite. The intrusion trends west-northwest but has little surface expression except for some relict textures in the laterite. Drilling has revealed cumulate textures and a compositional range from gabbro to anorthosite. This gabbro intrusion is the only one of its type known in the Perth Sheet area. The fresh rock contains an average of 0.54 per cent V_2O_5 and published ore reserves for the prospect amount to more than 227 000 tonnes of V_2O_5.

BAUXITE (Bx)

Bauxitic laterite is extensive on the Darling Plateau. Portions of the Alcoa mineral lease ML1 SA and the Alwest Agreement area extend northward onto the Perth Sheet. The Pacminex deposits are centred on the area east of the lower Chittering Valley. A bulk sample from here has been tested and over 100 million tonnes of bauxite at around 32 per cent available alumina has been proved in the area.

RUTILE (R)

At Yulgering Well, 8 km northeast of Calingiri, a small concentration of rutile was discovered in colluvium overlying migmatite (Jutson, 1912). Individual crystals reach 40 mm in length, but the amount of material is small.

INDUSTRIAL ROCKS AND MINERALS

VERMICULITE (Ve)

Vermiculite of varying quality is present in minor amounts throughout the area. Small lenses occur in the broad schist unit, 8 km northeast of Bullsbrook East. It is also recorded from a serpentinite at Goomalling (Simpson, 1950).

ASBESTOS (Aa)

At Goomalling, asbestiform anthophyllite is associated with a talc-serpentine band within migmatite. Two prospecting areas were worked in 1922, but no production was recorded.

TALC (T)

Both talc and asbestos occur in minor amounts in certain altered ultramafic intrusions. The only talc deposit worked is situated 9 km south-southwest of Bolgart. The recorded production is 275 tonnes between 1946 and 1952, although the deposit is still worked sporadically.

KYANITE AND SILLIMANITE

Concentrations of almost pure kyanite and sillimanite occur as lenses in the schists and gneisses of the Chittering Metamorphic Belt. Large quantities of kyanite are available at Wattle Flat and sillimanite at Goyamin Pool, but would require crushing and special beneficiation. Sillimanite is also a constituent of many schists in the Jimperding Metamorphic Belt. The only recorded production is 2 tonnes of sillimanite from Clackline in 1948.

CLAY (Cl)

Large quantities of clay have been obtained from the area and abundant supplies are available. Structural clay is obtained from the pallid zone, formed during lateritic weathering of the granitic rocks. Most quarries are close to the Darling Scarp. Recorded production of structural clay is 117 161 tonnes to the end of 1972. Fireclay is obtained from the pallid zone and from weathered aluminous schists. Production of fireclay from weathered granitic rocks in the Glen Forest-Mahogany Creek area amounted to 236 045 tonnes to the end of 1972. A small quantity of fireclay (1 670 tonnes to 1972) has also been produced from the pallid zone overlying porphyritic granite, 2 km south-southeast of Clackline. To the end of 1972, 108 486 tonnes of fireclay was produced from weathered sillimanite-bearing schists at Clackline. Smaller amounts of clay have been obtained further north along this schist belt, but the material is generally less aluminous than at Clackline.

Total production of clay from the Perth Sheet area has been much greater, but no exact figures are available.

KAOLIN (Ck)

A small amount of residual kaolin for use as a filler material has been obtained from the pallid zone of the laterite profile at Glen Forest. Recorded production was 2 786 tonnes prior to 1952.

A flooded claypan (Qrw), 17 km west of Goomalling has yielded 29 176 tonnes of good quality ceramic clay up to 1972. Four clay horizons up to 2 m thick are interstratified with unconsolidated sand and grit. The deposits are probably of lacustrine origin. A number of similar claypans between Goomalling and Bolgart are potential sources of ball and semi-ball ceramic clay.

BUILDING STONE (Bs)

Local stone, especially cemented laterite and granitic rock, has been used for home construction in past decades, and to a lesser extent is employed at the present time. Porphyritic granite 6 km south of York has been quarried for facing stone. Extensive use is made of laterite and granite in landscape gardening.

The quartzite band extending southward from Jimperding Hill to Clackline is quarried sporadically along its length for building and facing stone ("Toodyay Stone"). Portions of this unit are fissile along planes crowded with green chrome mica. The best quality facing stone has extremely smooth partings devoid of crenulations. The main quarry is situated 9 km south-southwest of Toodyay.

AGGREGATE, BALLAST AND ROAD METAL

There are abundant supplies of rock suitable for crushed aggregate (Rc) and large quarries have been opened up along the Darling Scarp close to the metropolitan area. Railway ballast has been provided by quarries in close proximity to the railway lines. Innumerable small workings in weathered granitic rocks (Rm) and uncemented pisolitic laterite (Gr) provide gravel for road making.

SAND (Sd)

Large quantities of sand are available, especially in the eastern part of the area. The most homogeneous material overlies laterite. Sand from the more recent alluvium (Qra) is used locally.

WATER SUPPLIES

SURFACE WATER

With the exception of the Swan-Avon River and Ellen Brook, all streams within the Sheet area are intermittent.

The Swan-Avon River flows at a greatly reduced rate during the dry season and is too saline for town water supply. East of the Darling Scarp, innumerable small dams have been constructed along minor watercourses for stock use. There is a limited and local potential for further impounding of streams in this area and in the Piedmont Zone, at the foot of the Darling Scarp.

Perth's main water supply comes from dams on the Canning and Serpentine Rivers, south of the Sheet area. The Helena Reservoir lies partly within the mapped area and water from here is pumped along a pipeline to the Eastern Goldfields. The main pipeline extends eastward through Northam and Meckering and, through a network of smaller subsidiary pipes, supplies water to these and other towns of the "Wheat Belt".

GROUNDWATER

Groundwater distribution varies with the following geological and geomorphological environments:

1. Piedmont Zone - alluvial-fan material consisting of lenticular conglomerate, gravel, sand and clay bands yields local supplies of potable water. Many bores have silt problems and yield less than 450 litres an hour.
2. Darling Scarp and Plateau - favourably sited bores and wells yield limited supplies of potable water from both fresh and weathered granitic rock. Supplies may be obtained from the laterite-pallid zone interface, the weathered rock below the pallid zone and from joints and fissures within fresh granitic rock. However, unsuccessful bores are not uncommon.
3. Residual sands - accumulations of variously reworked sands (Qas), provide reservoirs of potable water in the eastern part of the Sheet area. The sands are not related to present drainage channels and are

often accompanied by soaks (Qrw). The Bolgart township water supply is obtained from saturated sands of this type and those at Yenart Soak have been tested (Balleau, 1972). Other residual sand reservoirs are probably present near permanent soaks along the upper portions of the Avon, Mortlock and Moore drainage systems.

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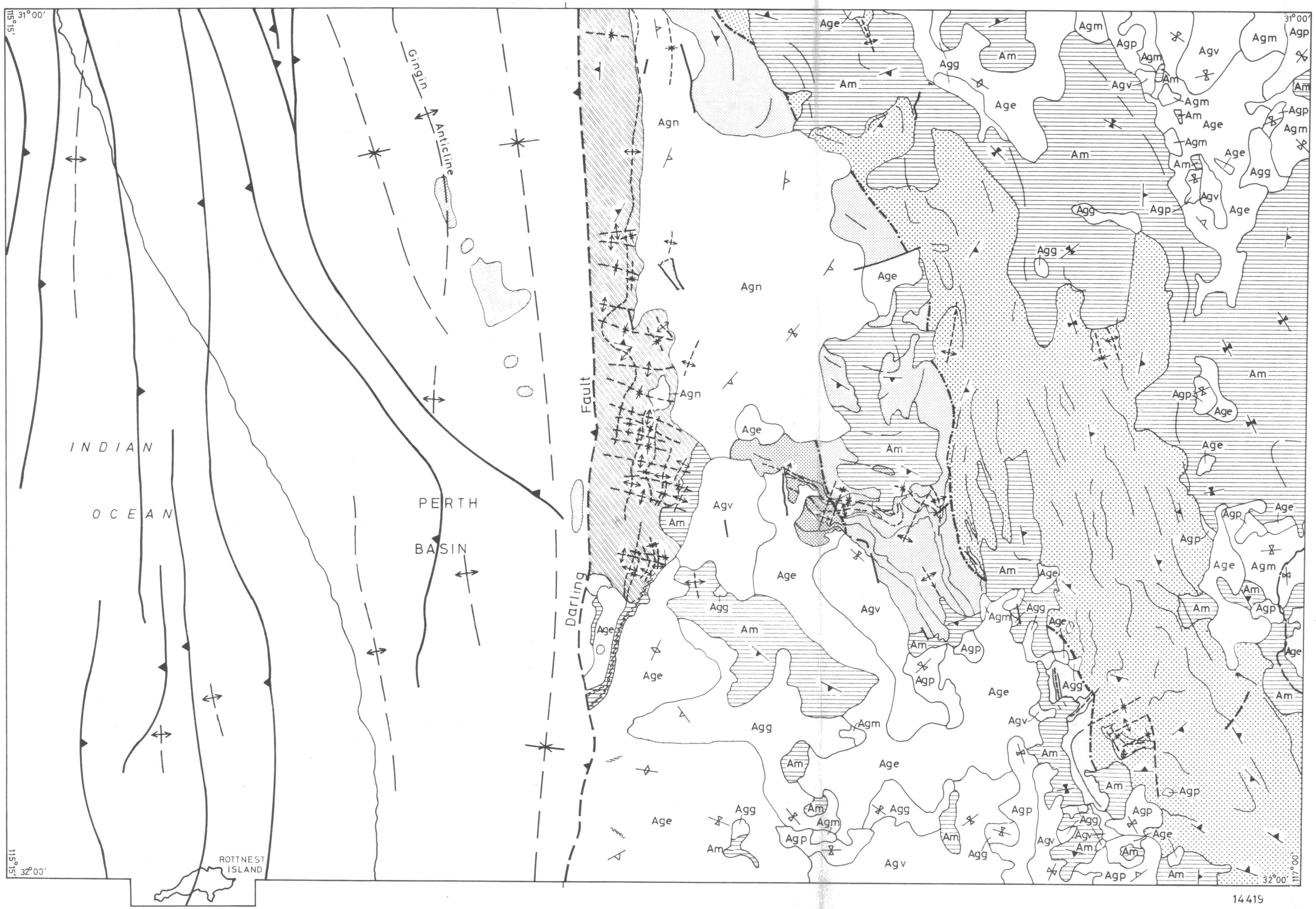

FIGURE 1
STRUCTURAL MAP OF THE PERTH SHEET

SCALE

10 0 10 20 30
KILOMETRES

REFERENCE

PERTH BASIN
Cretaceous rocks

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

Am — MIGMATITE

CHITTERING METAMORPHIC BELT
Upper amphibolite facies - maximum grade

JIMPERDING METAMORPHIC BELT
- Lower amphibolite facies
- Upper amphibolite facies
- Amphibolite-granulite transition facies
- Granulite facies

- Fault, with direction of hade
- Geological boundary
- Fold axis
  - anticline, with plunge direction
  - syncline, with plunge direction
- Shear zone
- Foliation in metamorphic rocks
  - direction of dip
  - vertical
  - undeterminable
- Foliation in igneous rocks
  - direction of dip
  - vertical
  - undeterminable
- Metamorphic isograd (approximate)
- Lithological trend lines

Faults in Perth Basin from seismic data on the Cattamarra Reflector

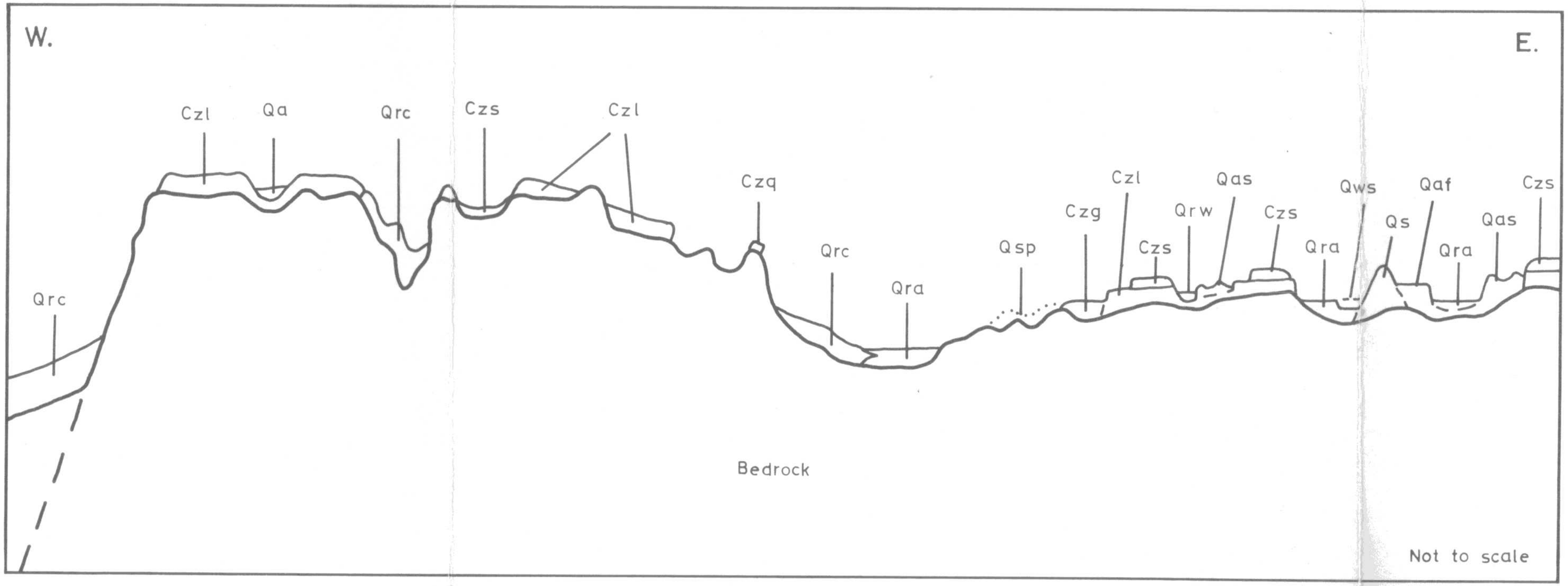

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FIGURE 2

CAINOZOIC ROCK UNIT RELATIONSHIPS EAST OF THE DARLING SCARP

PERTH SHEET SH 50-14 & PART OF SH 50-13

(Cainozoic Symbols as on Map Reference)

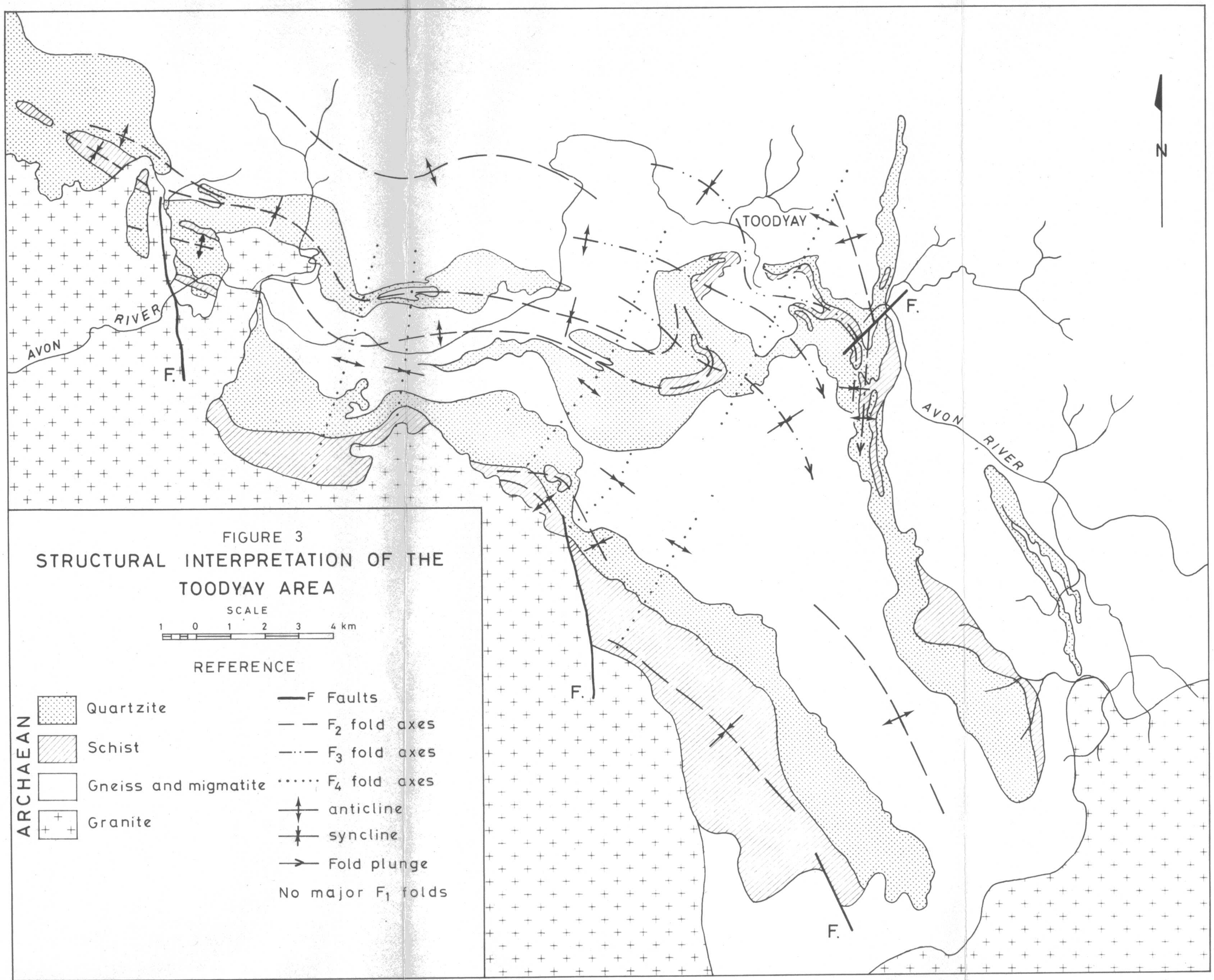

FIGURE 3
STRUCTURAL INTERPRETATION OF THE TOODYAY AREA

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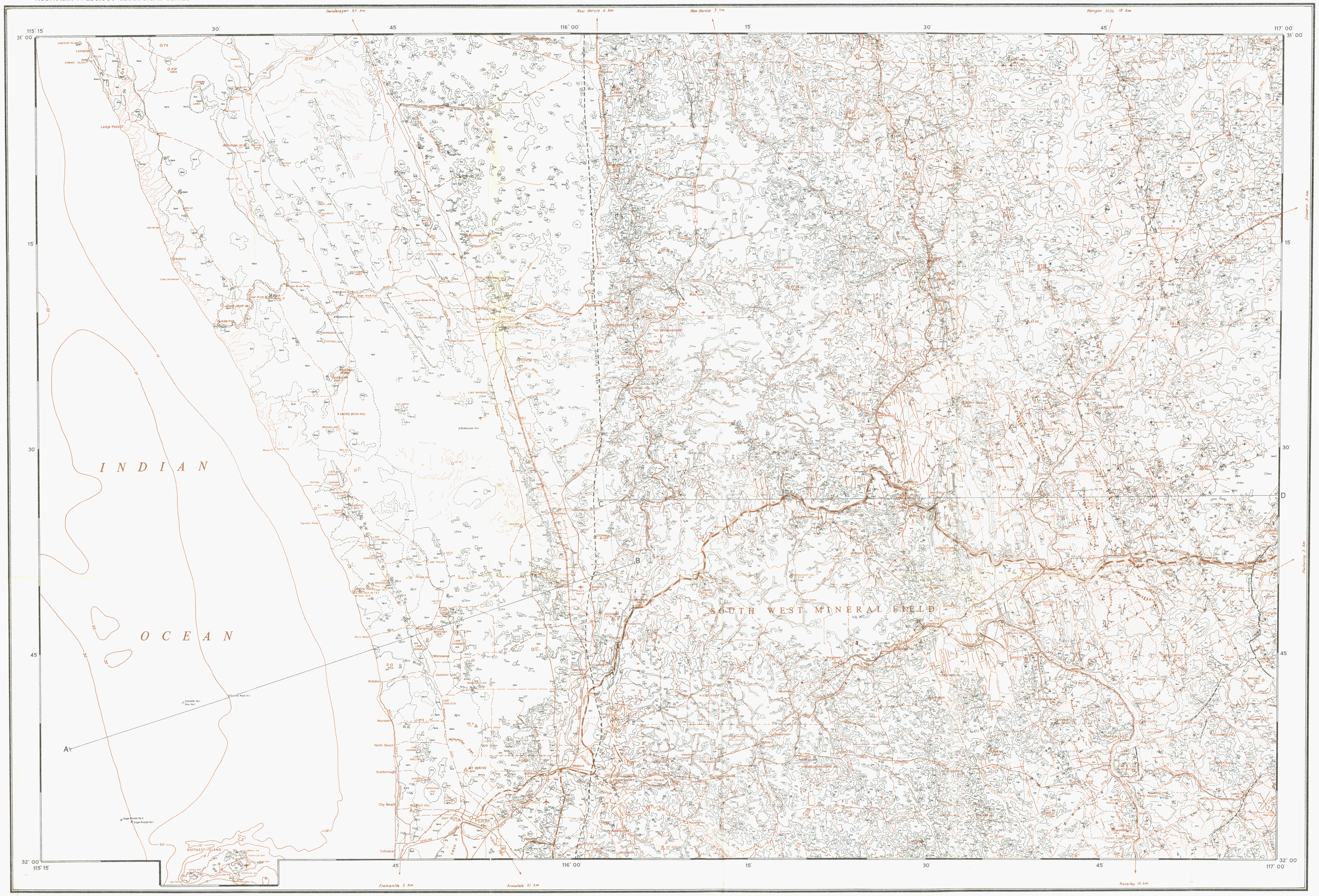
PERTH

AUSTRALIA 1 : 250,000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SH 50-14 AND PART OF SH 50-13



SYMBOLS

Geological boundary
- Accurate
- Approximate
- Inferred and concealed (Cretaceous / Archaean boundary only)

Fault
- Accurate
- Inferred
- Normal and concealed

Plunge of minor fold

Gneissic foliation
- Inclined
- Vertical
- Dip indeterminate

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

Schistosity
- Inclined
- Vertical

Direction and plunge of lineation

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

Mylonitized shear zone

Sheared plutonic rocks

Attitude of laterite surface

Air photo lineament

Trend line (interdunal depression)

Type-section locality

Highway with national route marker

Formed road

Track

Railway 4'8½"
3'6"

Station or siding

Power line

Townsite, gazetted — Glen Forrest

Airport

Airfield

Landing ground

Horizontal control : major, minor

Bench mark, height accurate — M.S.L 23 49m.

Lighthouse

Sand dune

Watercourse

Bore

Pool

Pipeline

Bathymetric contour line, depth in fathoms

Gas condensate well

Show of oil, abandoned

Dry hole, abandoned

Mine, abandoned

Quarry

Quarry, abandoned

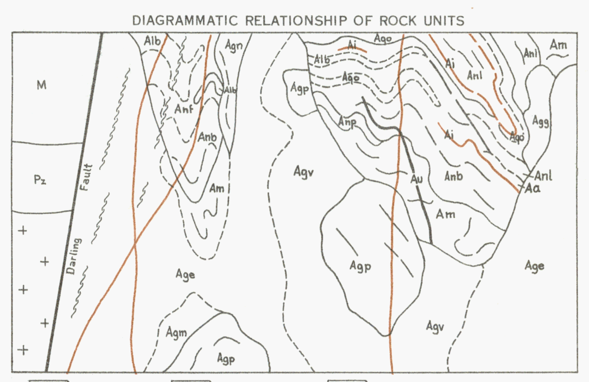
Alluvial workings, abandoned

Prospect

Mineral occurrence

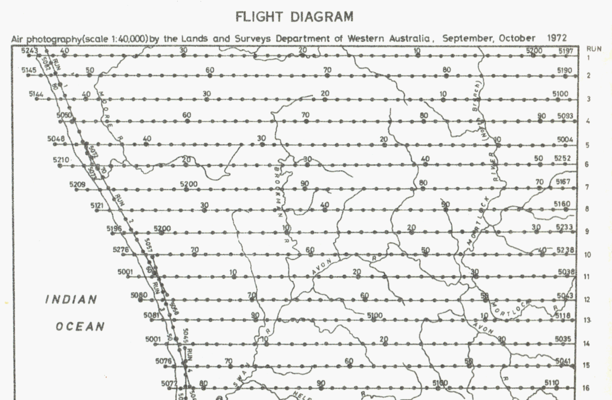
Asbestos	Aa
Bauxite	Bx
Building stone	Bs
Calc silicate	Cs
Chalk (industrial)	Lm
Clay	Cl
Cordierite	Ci
Corundum	Cn
Crushed rock aggregate	Rc
Diatomite	Dt
Glauconite	Gl
Gold	Au
Iron	Fe
Kaolin	Ck
Kyanite	Ky
Limestone	Ls
Molybdenum	Mo
Peat	P
Pisolitic laterite gravel	Gr
Road material (gravel)	Rm
Rutile	R
Sand for glass	Sg
Sand, various purposes	Sd
Sillimanite	Sm
Shale	Sh
Slate	Sl
Staurolite	St
Talc	T
Vanadium	V
Vermiculite	Ve
Wolfram	W

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



M Mesozoic   Ps Palaeozoic   + Precambrian undifferentiated

FLIGHT DIAGRAM



REFERENCE

CAINOZOIC — QUATERNARY — RECENT

Qrw Swamp and lacustrine deposits — peat, peaty sand and clay
Qra Alluvium — clay, sand and loam
Qws Salt lake deposits — saline silt and clay
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 calcereous quartzose sand (mobile dunes)

PLEISTOCENE - RECENT

Qrc Colluvium, including valley-fill deposits, variably lateritized and podsolized
Qa Alluvium and minor colluvium developed on laterite of the Darling Range
Qaf Older sandy alluvium in eastern part of Sheet, dissected by present drainage
Qas Sand — variously reworked, associated with older stream channels
Qs Sand — bright yellow, hummocky deposits marginal to stream channels
Qsp Thin veneer of sand, with bands of ferruginous pisoliths, overlying Archaean granitic rocks
Qm Sandy colluvium from Cretaceous rocks, variably lateritized
Qpo Colluvium, soil and undifferentiated sand over laterite of Coastal Plain. Includes minor alluviated areas

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 Laterite — chiefly massive, but includes overlying pisolithic gravel and lateritized sand
Czs Sand overlying laterite — yellow, white or grey and often associated with drainage courses
Czq Quartzose duricrust developed over Archaean quartzite bands
Czg Flaggy "silcrete" and associated boulder deposit
Czf Ferruginous grit and sandstone, associated with drainage channels
Czc Conglomerate — unsorted clay, sand, cobbles and boulders

MESOZOIC — CRETACEOUS

UPPER CRETACEOUS (Coolyena Group)
- ? CAMPANIAN — Kup POISON HILL GREENSAND: glauconitic sand and clay, variably lateritized
- SANTONIAN — Kug GINGIN CHALK: slightly glauconitic chalk with some thin discontinuous beds of greensand
- ? CONIACIAN TO ? TURONIAN — Kum MOLECAP GREENSAND: glauconitic sand and clay with two thin discontinuous phosphate beds
- CENOMANIAN TO ALBIAN — Ko OSBORNE FORMATION: glauconitic siltstone, claystone, shale and sandstone

Warnbro Group
- Kd DANDARAGAN SANDSTONE: feldspathic sandstone, with minor claystone and shale
- Kls LEEDERVILLE FORMATION: sandstone, shale and siltstone with minor conglomerate

Undifferentiated — Kb BULLSBROOK BEDS: interbedded, poorly sorted sandstones and siltstones

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
- di Dioritic dykes
- q Quartz dykes and veins

ARCHAEAN

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 medium-grained with abundant pegmatite
Agm Mixed granitic rocks, chiefly interdeveloped even-grained and porphyritic granite
Agn Gneissic granite, with cataclastic foliation

Au Ultramafic dykes and sills — peridotite and pyroxenite, often foliated and variously altered to greenschist facies metamorphic assemblages

Ags Syenitic rocks, range from monzosyenite to syenite
Agd Dioritic rocks, range from monzonite to diorite

Am Migmatite — banded and nebulitic, often strongly contorted
Amh Amphibole-bearing migmatite, rich in amphibolite lenses and rocks

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
Anf Quartz-feldspar-biotite granofels, melanocratic and poorly banded
Anc Interbanded quartz-hornblende-biotite-garnet gneiss, quartz-feldspar gneiss and amphibolite, some mylonite zones
And Quartz-feldspar-hornblende-biotite gneiss and schist

Alb Quartz-mica schist, biotite generally in excess of muscovite
Als sillimanite-bearing schist
Alk kyanite-bearing schist
Ala andalusite-bearing schist
Aln staurolite-bearing schist
Alg Quartz-mica-garnet schist
Alm Muscovite-chlorite phyllitic 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 — includes quartz-magnetite-grunerite assemblages
Aiw Quartz-magnetite-hypersthene rock
Aig Garnetiferous iron formation
Aiq Banded magnetite-bearing quartzite

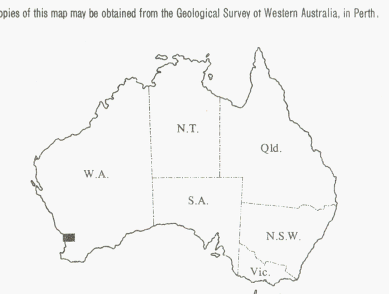
Ahg Mafic granulite, hornblende and/or pyroxene-rich assemblages

Overprint, indicating bedrock largely obscured by residual and colluvial deposits

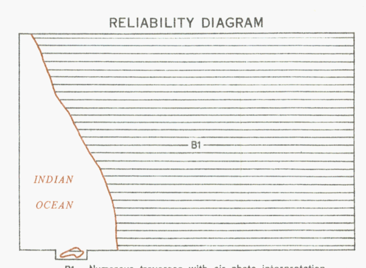
Compiled and published by Geological Survey of Western Australia. Cartography by Geological Drafting Section, Mines Department. Topographic base from compilations by Lands and Surveys Department. Printed by Government Printing Office, Perth, 1974.

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

Geology by : Perth Basin — G. H. Low and R. W. Lake 1965-67
Yilgarn Block — S. A. Wilde 1972-73



RELIABILITY DIAGRAM



B1 Numerous traverses with air photo interpretation

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

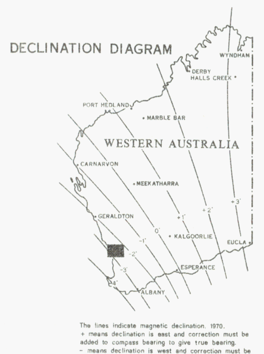
SCALE 1 : 250,000

TRANSVERSE MERCATOR PROJECTION
ZONE 1 AUSTRALIA SERIES

INDEX TO ADJOINING SHEETS

HILL RIVER SH 50-9	MOORA SH 50-10	BENCUBBIN SH 50-11
	PERTH SH 50-14	KELLERBERRIN SH 50-15
INDIAN OCEAN	PINJARRA SI 50-2	CORRIGIN SI 50-3

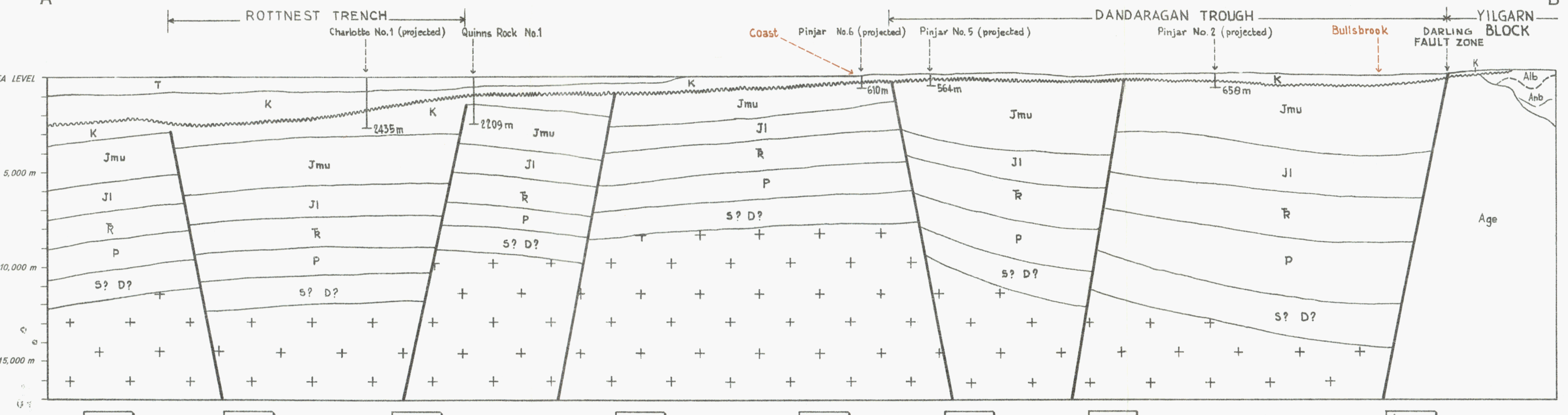
DECLINATION DIAGRAM



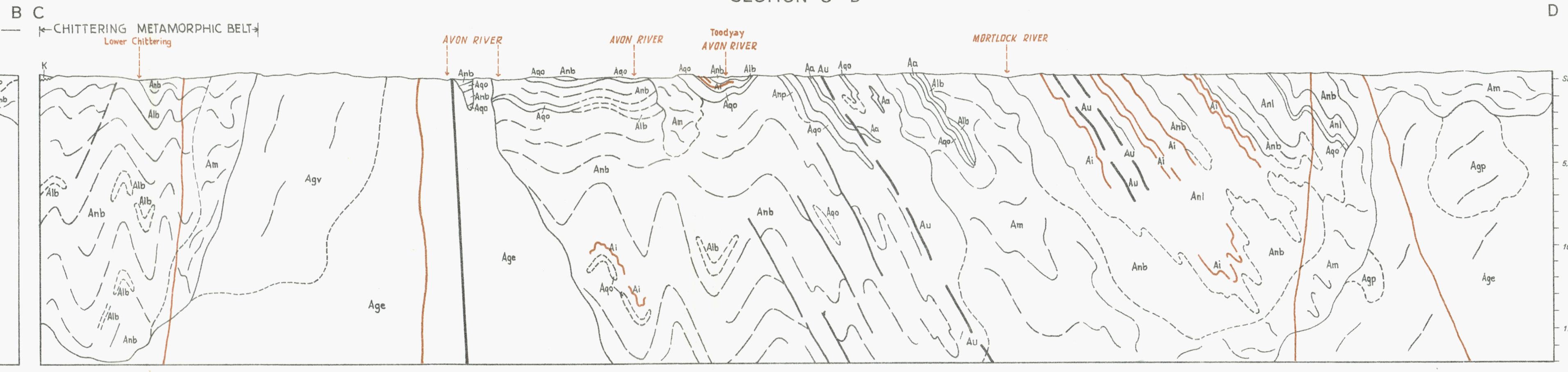
DIAGRAMMATIC SECTIONS

NATURAL SCALE

SECTION A - B



SECTION C - D



T Tertiary   K Cretaceous   Jmu Middle - Upper Jurassic   Jl Lower Jurassic   Tr Triassic   P Permian   S? D? Possible Devonian and/or Silurian   + Precambrian

Unconformity   Trend line

PERTH

SHEET SH 50-14 AND PART OF SH 50-13

PRELIMINARY PRINTING, 1974

SUBJECT TO AMENDMENT