GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

YAMPI

WESTERN AUSTRALIA

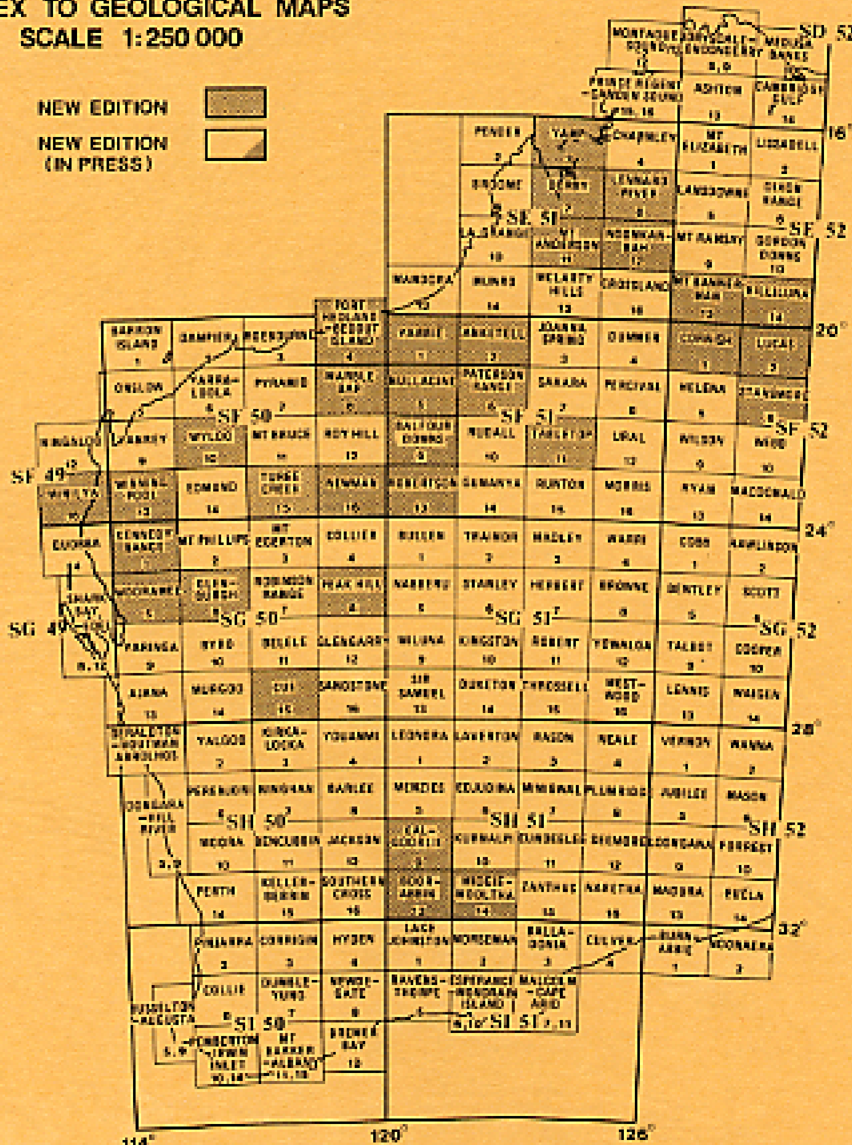
SECOND EDITION

SHEET SE51-3 INTERNATIONAL INDEX

WESTERN AUSTRALIA
INDEX TO GEOLOGICAL MAPS
SCALE 1:250 000

NEW EDITION

NEW EDITION (IN PRESS)



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by

I. M. TYLER, AND T. J. GRIFFIN
(WITH A CONTRIBUTION FROM P. E. PLAYFORD)

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DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Explanatory notes on the Yampi 1:250 000 Geological Sheet, Western Australia (Second edition)

by I. M. Tyler and T. J. Griffin

INTRODUCTION

The YAMPI* 1:250 000 geological sheet (SE51–3) is bounded by latitudes 16°00'S and 17°00'S, and longitudes 123°00'E and 124°30'E. Iron-ore mining has been carried out on Cockatoo and Koolan Islands by subsidiaries of BHP Pty Ltd since 1951, and a company town on Koolan Island provides accommodation for employees. The mine on Cockatoo Island has been worked out, and the former company town there is now a tourist resort. Both Cockatoo and Koolan Islands are serviced by air from Derby.

The northern part of the mainland east of King Sound is within the Larinyuwar Aboriginal Reserve (which includes Cone Bay). West of King Sound, the mainland is within the Beagle Bay and Lombadina Aboriginal Reserves, and there is a settlement at One Arm Point. Sunday Island and East Sunday Island are also Aboriginal reserves. A permit, issued through the Aboriginal Affairs Planning Authority, is required to enter these reserves.

East of King Sound, much of the southern part of the mainland is taken up by a Defence Reserve made up of the former Kimbolton and Oobagooma pastoral leases. A caretaker occupies Kimbolton Homestead and permission to enter the reserve must be obtained from the Officer Commanding the Seventh Military District, based in Darwin. The Meda and Napier Downs pastoral leases occupy the southeastern part of YAMPI.

Access within the Beagle Bay and Lombadina Aboriginal Reserves, the Defence Reserve, and the pastoral leases is via graded roads and station tracks. Access into the Larinyuwar Aboriginal Reserve, and the islands of the Buccaneer Archipelago, is possible only by boat or helicopter.

Geological investigations prior to 1973 are summarized in the first edition explanatory notes (Gellatly and Sofoulis, 1973). Subsequent studies are referred to as appropriate in the following notes.

The remapping of the Proterozoic rocks for this second edition was carried out between 1986 and 1988. Only limited helicopter time was available and therefore helicopter work was concentrated on areas, inaccessible by vehicle, where the relationships between units were well exposed. As a consequence, many other areas were not visited and data collected during the first edition mapping has been incorporated into the second edition map.

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

PHYSIOGRAPHY, VEGETATION, AND CLIMATE

YAMPI lies on the boundary between two major physiographic divisions: North Kimberley, and Fitzroyland (Jutson, 1950). The vegetation in the area has been described in detail by Beard (1979).

The North Kimberley Division on YAMPI can be separated into two provinces (Wright, 1964). The Kimberley Plateau is an irregular dissected plateau, which on YAMPI is present between Secure Bay and Doubtful Bay. It is covered by high-grass savanna woodland. The Kimberley Foreland is a region of high, almost vertical scarps facing outwards from the plateau, coincident with folded and faulted rocks at the southwestern margin of the Kimberley Basin. The highest point on YAMPI, at 339 m, occurs in the High Range, within this province. Vegetation consists of high-grass and tall bunch-grass savanna woodland, together with spinifex low-tree savanna.

The Fitzroyland Division can be divided into three provinces (Wright, 1964). The Fitzroy Uplands comprise rugged hill country in front of the scarps of the Kimberley Foreland. Topography is varied, ranging from low, sinuous ridges of metasedimentary rocks, to tors and whalebacks of granitic rocks. Black-soil plains, and tall bunch-grass savanna woodland fringe the hill country.

The Fitzroy Plains in the southeastern part of YAMPI comprise lower lying country with very subdued relief, underlain by Phanerozoic rocks. Vegetation consists of tall bunch-grass tree savanna and low-tree savanna, together with pindan woodland. The Sand Plain Province on the Dampier Peninsula, west of King Sound, is also covered by pindan woodland.

The irregular nature of the shoreline within YAMPI, consisting of numerous rocky headlands separated by rias, is consistent with a drowned coast. Mangroves fringe much of the coastline.

The climate is semi-arid monsoonal, and two seasons are apparent: ‘wet’ and ‘dry’. Almost all rainfall, for which the annual average is between 800 and 1200 mm, is derived from monsoonal rains and thunderstorms between November and April. During the dry season days are warm to hot and the humidity low. In the wet season temperatures are high to very high, frequently in excess of 40°C, and humidities are high.

Watercourses are intermittent, only flowing after prolonged heavy rain. Permanent pools occur in some of the rivers. Springs occur at the base of the scarps forming the Kimberley Foreland, and are also associated with Phanerozoic rocks in the Fitzroy Plains.

REGIONAL GEOLOGICAL SETTING

The main tectonic features of YAMPI are shown in Figure 1, and the geological history of rocks within the sheet area is summarized in Table 1. Three tectonic units are present: the Hooper Complex, the Kimberley Basin, and the Canning Basin. Rocks of the Hooper Complex and folded rocks of the Kimberley Basin together form the King Leopold Orogen.

The Hooper Complex on YAMPI consists of Lower Proterozoic (c. 1900 Ma to 1840 Ma) metasedimentary rocks, basic sills, felsic volcanic rocks and granitic rocks. The metasedimentary rocks and basic sills represent an extensional environment. The felsic volcanic rocks and the granitic rocks were generated during the Hooper Orogeny, caused

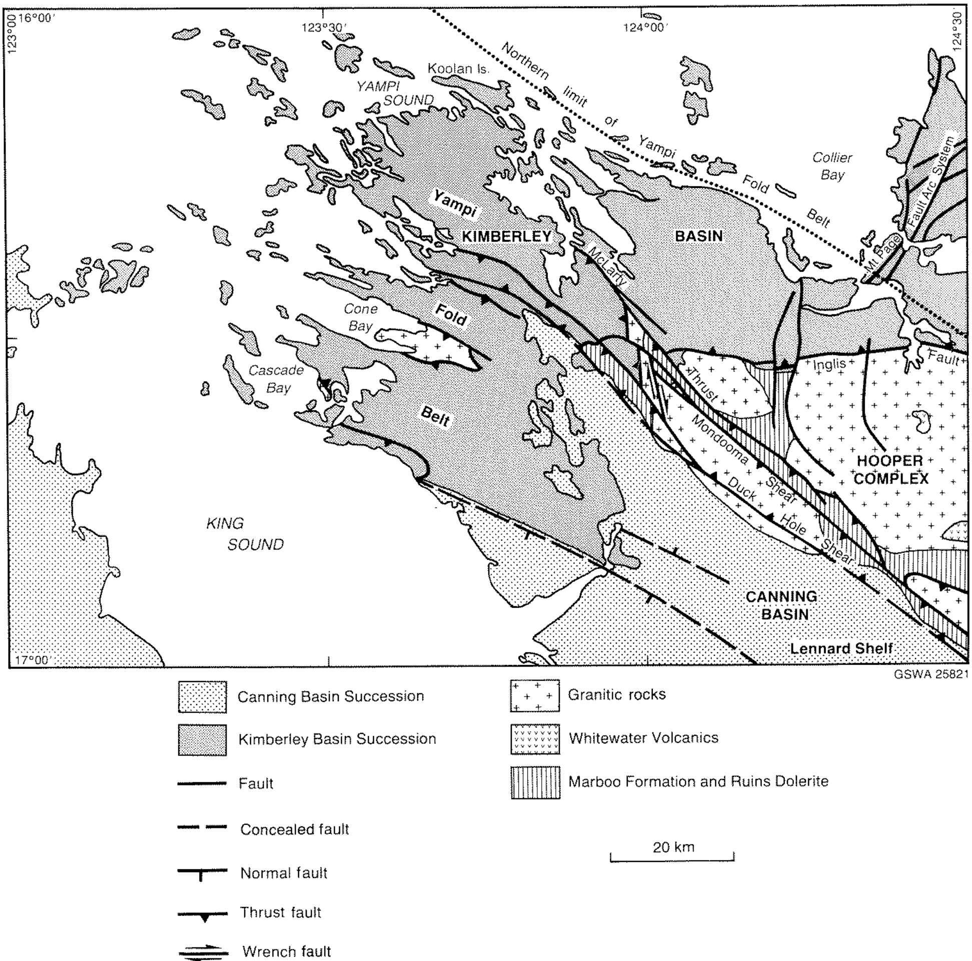

Figure 1. Simplified geological map of YAMPI showing the principal tectonic and structural units

by collision or convergence between fragments of Archaean or earliest Proterozoic cratonic crust that now underlie the Kimberley Basin and the Canning Basin.

The Hooper Complex is overlain by the shallow marine-shelf deposits of the Early Proterozoic (c. 1840 Ma to c. 1800 Ma) Kimberley Basin. Contacts between the Hooper Complex and the Kimberley Basin are now tectonized, but were originally unconformable.

The Hooper Complex and the Kimberley Basin were deformed and metamorphosed during two subsequent orogenic events. The Middle Proterozoic Yampi Orogeny produced northeast-directed folding and thrusting. The Late Proterozoic to Early Palaeozoic King Leopold Orogeny caused sinistral strike-slip faulting and related southwest-directed thrusting, together with refolding of Yampi Orogeny structures.

The Canning Basin began to form during the Ordovician. On YAMPI the earliest Phanerozoic rocks are the Upper Devonian reef complex, which unconformably overlies the Proterozoic basement. These deposits represent a barrier reef deposited on the Lennard Shelf, fringing a landmass of Proterozoic rocks to the northeast. To the southwest of YAMPI

Table 1. Summary of the geological history of YAMPI

(1) Deposition of the turbiditic Marboo Formation (c. 1900–1850 Ma). Intrusion of the Ruins Dolerite.

HOOPER OROGENY

(2) Early deformation (D_1), principally restricted to zones of high strain.

(3) Uplift and erosion. Deposition of Whitewater Volcanics (c. 1850 Ma). Intrusion of associated sub-volcanic granitoids.

(4) Formation of upright, steeply plunging folds (D_2) associated with possible sinistral strike–slip movement on steep shear zones. Greenschist facies metamorphism (M_1).

(5) Intrusion of major granitoid plutons (c. 1840 Ma). Contact metamorphism.

KIMBERLEY BASIN

(6) Uplift and erosion. Deposition of the Speewah and Kimberley Groups (c. 1840–1800 Ma) in a fluvial and shallow-marine environment.

(7) Intrusion of the Hart Dolerite and Wotjulum Porphyry (c. 1800 Ma).

YAMPI OROGENY

(8) Formation of the ?Middle Proterozoic (c. 1800–670 Ma) north-northeast-facing Yampi Fold Belt deforming the Kimberley Basin succession (D_{3a} and D_{3b}). Thrusting on large-scale shear zones in the Hooper Complex (D_3). Amphibolite facies low-P–high-T metamorphism (M_2).

KING LEOPOLD OROGENY

(9) Late Proterozoic to Ordovician (c. 670–510 Ma) south-southwest-directed thrusting on Kimberley Basin unconformity (D_4). Refolding of D_3. Formation of 'Mount Page Fault Arc System'.

CANNING BASIN

(10) Uplift and erosion. Deposition of the Upper Devonian Napier Range Reef Complex on the Lennard Shelf, marginal to the Fitzroy Sub-basin.

(11) Deposition of the Upper Devonian to Lower Carboniferous Lillybooroora Conglomerate, associated with west-northwest-trending normal faulting. Deposition of the Fairfield Group. Formation of Oobagooma uranium mineralization.

(12) Uplift and erosion. Deposition of the glacigenic Upper Carboniferous to Lower Permian Grant Group.

(13) Uplift and erosion during the Early Mesozoic. Deposition of shallow marine, fluvial, and continental deposits during Late Mesozoic, Tertiary, and Quaternary.

the basin deepened into the Fitzroy Trough. Subsequent deposition of shallow-marine and fluvial sediments has occurred on the Lennard Shelf intermittently throughout the upper Palaeozoic, Mesozoic, and Cainozoic.

PROTEROZOIC GEOLOGY

HOOPER COMPLEX

In the southeastern corner of YAMPI, Lower Proterozoic (1900–1840 Ma) igneous and low- to medium-grade metamorphic rocks are exposed (Bennett and Gellatly, 1970; Page, 1976, 1988; Page et al., 1984). Turbiditic metasedimentary rocks are intruded by thick metadolerite sills, and, with felsic tuff and lava, are intruded by granitoid rock.

Sofoulis et al. (1971) and Gellatly and Sofoulis (1973) described the igneous components as part of the Lamboo Complex, originally identified in the Halls Creek Orogen at the eastern margin of the Kimberley Craton (Dow and Gemuts, 1969). While there are many similarities between the rocks described here and those in the Lamboo Complex, to avoid confusion the term Hooper Complex (Griffin and Grey, 1990) is preferred. The metasedimentary rocks formerly thought to be Archaean are included within the complex.

Marboo Formation (Ꝑm)

Sofoulis et al. (1971) and Gellatly and Sofoulis (1973) tentatively correlated the metamorphosed turbidites, which constitute the oldest rocks on YAMPI, with the Olympio Formation of the Halls Creek Group, defined in the Halls Creek Orogen (Dow and Gemuts, 1969). Although the lithologies in both units are similar (i.e. they both consist of metamorphosed turbidites), there is not continuous outcrop between them. Units of the Halls Creek Group seen to underlie the Olympio Formation in the Halls Creek Orogen are not recognized on YAMPI, nor on CHARNLEY nor on LENNARD RIVER to the east and southeast (Gellatly and Halligan, 1971; Derrick and Playford, 1973; Griffin et al., in press). Therefore, it is not felt appropriate to formally ascribe these metasedimentary rocks to the Olympio Formation of the Halls Creek Group, and they are here named the Marboo Formation (*Ꝑm, Ꝑma, Ꝑmh*). The top of the unit is not seen, and no base or basement has been recognized.

The type area of the Marboo Formation is in the vicinity of Marboo Pool on the Townshend River. The unit consists of thinly bedded metamorphosed turbidite rocks that also outcrop in the headwaters of the Little Tarraji River and Mangrove Creek, as well as in the southeastern corner of YAMPI. The formation outcrops in the Cone Bay Inlier.

The rocks are intruded by granitoids that give a Rb–Sr date of c. 1840 Ma (Bennett and Gellatly, 1970; Page, 1976; Page et al., 1984). This is consistent with U–Pb dates on zircons of c. 1880 Ma from Halls Creek Group rocks in the Halls Creek Orogen reported by Page (1988). An Archaean age has been suggested for the metasedimentary rocks (e.g. Gellatly, 1971) based on a Rb–Sr date of c. 2700 Ma from a pegmatite intruding the Halls Creek Group (Bofinger, 1967). Another pegmatite with the same field relationships gave a Rb–Sr model age of 2250 Ma. Page (1976) concluded that this large discrepancy, together with an isochron age of 1755 Ma from highly radiogenic muscovite from the first pegmatite, made the data very difficult to interpret. The available geochronological evidence pointed to an Early Proterozoic, rather than an Archaean, age for the Halls Creek Group.

The Marboo Formation originally consisted of interbedded mudstone, siltstone and quartz wacke. It was metamorphosed under greenschist facies conditions, with grade reaching the amphibolite facies near Alexander Creek. Sandstone beds are generally 10–30 cm thick and, before metamorphism, typically consisted of fine- to medium-grained, subangular quartz clasts in a clay matrix. Detrital tourmaline grains are abundant, with lesser amounts of apatite, allanite, rutile, zircon and Fe-oxides. Locally, thicker beds (up to 1 m) of very coarse sandstone occur. The sandstone typically has a sharp base and grades upwards into siltstone and mudstone.

The sedimentary rocks are parallel laminated and display many features consistent with deposition by turbidity currents (Walker, 1984). Outcrop is dominated by units showing the BDE Bouma sequence (Bouma, 1962), and the rocks probably represent the lower, more distal part of a submarine fan. Sole marks on the base of sandstone occur sporadically and, although Sofoulis et al. (1971) reported current bedding in sandstone in the Mondooma area, the direction of sediment transport is not known.

Ruins Dolerite (Ꝑdr)

The Ruins Dolerite was defined on LENNARD RIVER (Griffin et al., 1993) and here refers to rocks previously mapped as Woodward Dolerite (Sofoulis et al., 1971; Gellatly and Sofoulis, 1973). The Ruins Dolerite is poorly exposed and consists of steeply dipping metamorphosed basic sills. They outcrop mainly on the southeast corner of YAMPI but also in the headwaters of the Little Tarraji River, Townshend River and Sandy Creek, and in the Cone Bay Inlier, south of Cone Hill. The sills are indistinctly layered and are up to several hundred metres thick (Sofoulis et al., 1971). They intrude phyllites of the Marboo Formation and have been deformed, although this is not well defined due to the poor outcrop and later faulting which has dismembered the units. The Ruins Dolerite is intruded by granitoid.

Textures in the dolerite (although obscured by recrystallization to amphibolite) are medium to coarse grained, and even grained to porphyritic. Coarse porphyritic plagioclase (up to 3 cm long) is distinctive and porphyritic gabbro forms layers up to 20 m thick (Sofoulis et al., 1971). Similar, very coarse glomeroporphyritic gabbro outcrops on CHARNLEY. One sharp hornfels contact was identified by Sofoulis et al. (1971) whereas most contacts are defined by chloritic schist. Shears within coarse dolerite contain plagioclase augen, and thin epidote veins are widespread.

Whitewater Volcanics (Ꝑw)

Acid volcanic rocks of the Whitewater Volcanics are restricted to the southeastern part of YAMPI where they outcrop south of Secure Bay, and in the headwaters of the Pardaboora River. They occupy a total area of less than 20 km^2. Some of the rocks previously mapped as Whitewater Volcanics (Sofoulis et al., 1971; Gellatly and Sofoulis, 1973) are now included in the Mondooma Granite, which is a porphyritic micromonzonite regarded as subvolcanic to the Whitewater Volcanics. Sheared granitic material in ductile fault zones can resemble acid volcanic rocks. Page and Hancock (1988) obtained a U–Pb zircon age of 1850 ± 5 Ma from the Whitewater Volcanics in the Halls Creek Orogen.

The main rock type is a foliated crystal tuff which dominates the southern outcrops. South of Secure Bay there is flow-banded rhyodacite lava and crystal tuff, as well as graded units that may represent volcaniclastic sedimentary units.

All contacts of the Whitewater Volcanics are with granitoid and are either intrusive or sheared. The rock types and relationships are consistent with the more extensive outcrop on LENNARD RIVER.

Granitoids

Granitoid rocks make up a major component of the Hooper Complex on YAMPI and include a large number of porphyritic varieties which are considered, along with the same units on LENNARD RIVER, to be subvolcanic, and chemically related to the Whitewater Volcanics (Griffin et al., 1993). Rb–Sr data obtained by Bennett and Gellatly (1970) give a pooled 'age' for granitic magmatism at 1840 ± 50 Ma (Page, 1988). Detailed petrographic descriptions of most of the units described here are provided by Sofoulis et al. (1971). Two new granitoid units are recognized. We have found no basis for the threefold division of the felsic igneous rocks by Sofoulis et al. (1971) and Gellatly and Sofoulis (1973).

The boundaries of the various granitoid bodies are based on aerial photograph patterns supported by ground observations. Many boundaries are poorly constrained because of the development of a strong, pervasive north-northwest-trending tectonic fabric during regional deformation and metamorphism (see 'Yampi Orogeny'). There are many closely spaced, north-northwest-trending shear zones and associated quartz veins which break up the pattern of individual units and are evident on the aerial photographs.

Mondooma Granite (Ꝑgm)

Several large bodies of the Mondooma Granite form steep, rugged, bouldery hills within the Hooper Complex. Much of the outcrop is characterized by prominent jointing. The Mondooma Granite (Sofoulis et al., 1971) comprises light-grey, foliated, quartz-phyric, biotite monzogranite, as well as a less extensive even-grained phase. Fine-grained syenogranite and granodiorite are minor phases. Many outcrops of deformed Mondooma Granite resemble crystal-rich, ash-flow tuff of the Whitewater Volcanics, but the micrgranitic texture is distinguishable where a strong tectonic fabric is absent. The Mondooma Granite is interpreted to be closely related to the Whitewater Volcanics and intrudes them as well as the Marboo Formation.

Mount Disaster Porphyry (Ꝑgdp)

The Mount Disaster Porphyry (Sofoulis et al., 1971) is a distinctive, foliated, coarsely porphyritic, biotite micromonzogranite which outcrops as rugged high ground south of Secure Bay. It also occupies extensive areas on LENNARD RIVER (Griffin et al., 1993). Phenocrysts, up to 4 mm across, of white K-feldspar, green or cream plagioclase, and blue-grey quartz, are set in a fine-grained groundmass of quartz, feldspar and streaky biotite.

The Mount Disaster Porphyry intrudes Whitewater Volcanics. Its contacts with the Mondooma Granite are faulted or obscured by scree. However, all three units are considered to be closely related chemically, and were probably intruded over a short time period.

Tarraji Microgranite (Ꝑgt)

The Tarraji Microgranite (Sofoulis et al., 1971) is a foliated, porphyritic, biotite micromonzogranite which outcrops to form strongly jointed, rugged rocky hills southwest and southeast of Secure Bay. Components of the unit are also recognized on LENNARD RIVER (Griffin et al., 1993).

K-feldspar, biotite and quartz are present as phenocrysts in a fine-grained, granitic-textured groundmass dominated by K-feldspar, quartz, plagioclase, and biotite. The Tarraji Microgranite intrudes the Whitewater Volcanics and is intruded by the Lennard Granite.

Lennard Granite (Pgl)

The Lennard Granite (Sofoulis et al., 1971; Gellatly et al., 1974; Derrick and Playford, 1973; Griffin et al., 1993) is the most extensive granitoid unit on YAMPI. It forms whalebacks and tors scattered throughout sandy plains northeast of the Robinson River and passes into low bouldery hills in the higher country further to the northwest, and also west of Secure Bay.

The Lennard Granite is predominantly a leucocratic, foliated, coarse-grained, porphyritic, biotite monzogranite. It is locally heterogeneous, and minor syenogranite, granodiorite and non-porphyritic phases are important. It is characterized by coarse K-feldspar phenocrysts (up to 5 mm) in a coarse- to medium-grained groundmass dominated by K-feldspar, plagioclase, myrmekite, recrystallized quartz, and minor biotite which is also recrystallized and associated with secondary sphene. Details of intrusive relationships are described by Sofoulis et al. (1971). The subdivision of the Lennnard Granite into xenolith-rich granite, muscovite granite and biotite granite by Gellatly and Sofoulis (1973) was not found to be justified over significant areas, with local variations in granite composition being too small to put on the map.

The granite has a pervasive north-northwest-trending foliation which dips steeply southwest. In addition the granite contains shear zones with a similar trend, which are generally silicified and form prominent ridges. Weathered, steeply dipping joints are a feature of this unit on aerial photographs.

The Kongorow Granite, which is an important unit on LENNARD RIVER Griffin et al., 1993), was identified on YAMPI by Sofoulis et al. (1971) and Gellatly and Sofoulis (1973), but the rocks on YAMPI are now regarded as a compositionally banded phase of the Lennard Granite. This granite contains large xenoliths, including moderately abundant biotite-rich and banded amphibolite xenoliths, many of which are partially resorbed.

Secure Bay Monzogranite (Pgsb)

The Secure Bay Monzogranite replaces the name Secure Bay Adamellite of Sofoulis et al. (1971) and Gellatly and Sofoulis (1973). This unit is a foliated, medium- to fine-grained, generally non-porphyritic, biotite monzogranite, with minor syenogranite and granodiorite, which outcrops in rugged bouldery hills southwest of Secure Bay and 15 km further west. It contains abundant ridges of sheared rock and vein quartz which trend north-northwest to north. Also a prominent northeast-trending set of shear zones and quartz veins are present southwest of Secure Bay. The Secure Bay Monzogranite is considered to be closely related to the Lennard Granite (Sofoulis et al., 1971).

Nellie Tonalite (Pgn)

The Nellie Tonalite (Sofoulis et al., 1971) is confined to a narrow (<2 km-wide) northwest-trending, discontinuous belt 20 km long, located west and northwest of Mount Nellie, and east of the McLarty Range. It forms low hills between Mangrove Creek and cliffs of King Leopold Sandstone.

The Nellie Tonalite comprises foliated, medium-grained, hornblende–biotite tonalite, diorite, and granodiorite, with minor pegmatitic material. Alternating mesocratic and leucocratic bands (10–30 cm thick) are confined to the margin. Chloritic schist and quartz veins are abundant in small shear zones and along contacts with the Marboo Formation and the Ruins Dolerite.

Sofoulis et al. (1971) regarded the Nellie Tonalite as an early phase of the felsic igneous activity; however, there is no conclusive indication of this, and it appears that it is probably part of the widespread granitoid event that post-dated the Whitewater Volcanics. The Kongorow Granite, McSherrys Granodiorite and Richenda Microgranodiorite on LENNARD RIVER (Gellatly et al., 1974; Griffin et al.,1993) include components similar to the Nellie Tonalite.

Cone Hill Granite (Ᵽgc)

The Cone Hill Granite (Sofoulis et al., 1971; Gellatly and Sofoulis, 1973) is restricted to the rocky peninsula in Cone Bay and a few nearby islands. This granite, with the Square Top Microgranite and Ruins Dolerite to the east, outcrops within the Cone Bay Inlier (Fig. 1). At its eastern margin, the Cone Hill Granite is faulted against other units of the Hooper Complex.

The Cone Hill Granite mainly comprises foliated, coarsely porphyritic, biotite–muscovite monzogranite. It is similar to the Lennard Granite in containing coarse porphyritic K-feldspar, biotite, minor muscovite and aligned small amphibolite xenoliths. Small veins of tourmaline-bearing aplite and pegmatite intrude the monzogranite (Sofoulis et al., 1971).

Square Top Microgranite (Ᵽgq)

The Square Top Microgranite outcrops as steep rocky hills and was previously mapped as ?Whitewater Volcanics (Sofoulis et al., 1971; Gellatly and Sofoulis, 1973). The microgranite intrudes the Ruins Dolerite and the Marboo Formation east of Cone Bay. It has a metamorphic mineral assemblage of mainly quartz, kyanite, and chloritoid. The unmetamorphosed precursor was a quartz-phyric microgranite which is similar to the Tarraji Microgranite and the Mondooma Granite, and is therefore regarded as part of the regional felsic volcano-plutonic event in the Hooper Complex.

Cascade Bay Monzogranite (Ᵽgb)

The Cascade Bay Monzogranite is a foliated, coarsely porphyritic, biotite–muscovite monzogranite. It outcrops in small areas as low coastal cliffs beneath King Leopold Sandstone in Cascade Bay. These small exposures of the Hooper Complex have not previously been recognized. The contact with the overlying quartzite sequence is a thrust fault (Tyler and Griffin, 1990).

Coarse K-feldspar phenocrysts, and recrystallized biotite and quartz define a strong tectonic foliation and mineral elongation which shows a reverse movement on south-dipping foliations. This unit is similar to the Lennard Granite.

Felsic dykes

Randomly oriented aplite and pegmatite dykes, generally less than 1 m wide, intrude many granitoid outcrops. A coarse muscovite- and beryl-bearing pegmatite dyke intrudes the Ruins Dolerite 10 km northwest of Limestone Spring.

Structure

Rocks forming the Hooper Complex were affected by two periods of deformation (D_1 and D_2) prior to the intrusion of the granitoids (Tyler and Griffin, 1990).

First deformation

The oldest deformation (D_1) is only recognized in the Marboo Formation, mainly as a layer-parallel foliation (S_1). S_1 has not been recognized in the metasedimentary rocks exposed in the Cone Bay Inlier. D_1 folds are uncommon. Tight to isoclinal small-scale folds are present 7.5 km north of Boulder Hill, associated with a zone of high strain. A large-scale fold closure of D_1 age occurs 1 km southeast of Grants Find. This structure is a tight anticline plunging to the west, and S_1 can be seen cross-cutting bedding on the limbs of the fold.

Tyler and Griffin (1990) suggested that the restricted nature of D_1 folding is consistent with large-scale faulting and shearing. This could have taken place either as part of a thrust system or an extensional fault system. Thick dolerite sills (the Ruins Dolerite) are intruded into the Marboo Formation. In the Halls Creek Orogen similar intrusions have MORB chemistry (Sun et al., 1986). This suggests that D_1 may have formed in an extensional environment (Wickham and Oxburgh, 1985, 1987), within which the Marboo Formation was deposited.

Second deformation

The second deformation (D_2) produced upright, open to isoclinal folds at all scales that deform the Marboo Formation, the metadolerite sills of the Ruins Dolerite, and the Whitewater Volcanics. Deformation predates intrusion of the granitoid rocks.

An axial-plane cleavage (S_2) that crenulates S_1 has developed. A lineation (L_2) that results from the intersection of bedding and cleavage occurs parallel to the hinges of the crenulations. The folds trend west-northwest to northwest and plunge steeply either to the northwest or the southeast. A large-scale tight to isoclinal D_2 fold closure is present 5 km northeast of The Albert Waters. In the headwaters of the Little Tarraji River D_2 folding is quite open, with bedding trending east-northeast. D_2 folds here are seen to refold both large- and small-scale D_1 folds.

Open to tight D_2 folds are present in metasedimentary rocks in the Cone Bay Inlier. A weak axial-plane cleavage developed in the hinges of the folds.

Tyler and Griffin (1990) attributed D_2 folding to large-scale, possibly sinistral, strike-slip movements on steep west-northwesterly trending shear zones, prior to intrusion of the granitoids. The Early Proterozoic movements on the shear zones may have been extensively overprinted by later reactivation during D_3 (see below). The tectonic setting of the possible strike-slip movements is not known, but may reflect oblique convergence or collision between cratonic crust concealed beneath the Kimberley Basin and cratonic crust now underlying the Canning Basin.

Metamorphism

Regional metamorphism

Metamorphism within the Hooper Complex during D_1 and D_2 (M_1 of Griffin et al., 1993) was low grade (greenschist facies). In the headwaters of the Little Tarraji River the pelitic units are very fine- to fine-grained and mineral assemblages are dominated by quartz and muscovite. Chlorite is present in many samples. Both the S_1 and S_2 cleavages are defined by the alignment of phyllosilicate minerals. Fe-oxides are concentrated along the cleavage domains. The grain size increases to the south with medium-grained quartz–muscovite–chlorite schist occurring 6 km north-northeast of Lone Hill and 8 km north-northeast of Boulder Hill.

Contact metamorphism

High-grade psammitic and pelitic metasedimentary rocks (*PLmh*) outcrop 7.5 km north-northwest of Boulder Hill. The psammite is a thinly layered, medium-grained rock having the mineral assemblage quartz–plagioclase–K-feldspar–biotite–muscovite–garnet. Tourmaline and zircon are present as detrital grains. The more mafic minerals are concentrated into thin pelitic layers up to 1 mm thick. The more quartz-rich layers are up to 5 mm thick. The micas show a preferred orientation parallel to layering.

The psammite is interlayered with a dark, massive, medium-grained pelitic rock that contains the mineral assemblage quartz–K-feldspar–plagioclase–biotite–muscovite–sillimanite–andalusite(–cordierite). Again, tourmaline and zircon are present as detrital grains. Cordierite is replaced by pinite and forms large poikiloblastic crystals up to 5 mm across. K-feldspar is the dominant feldspar and is perthitic. Sillimanite occurs as felted masses 2–3 mm across. Andalusite occurs as irregular, relict crystals.

Due to the restricted occurrence of these rocks and their formation at low pressure and high temperature (andalusite replaced by sillimanite), they are interpreted as the product of contact metamorphism against the Lennard Granite, which is exposed 1.5 km to the south-southwest. Regional metamorphic assemblages in metasedimentary rocks 2.5 km to the east are in the greenschist facies.

KIMBERLEY BASIN

Rocks deposited within the Early Proterozoic Kimberley Basin are exposed on the northern and western parts of YAMPI. The succession is made up of two stratigraphic groups: the Speewah Group, and the conformably overlying Kimberley Group. The rocks were described in detail by Sofoulis et al. (1971) and those descriptions form the basis of the following summary, supplemented by information obtained during this survey.

Sofoulis et al. (1971) and Gellatly and Sofoulis (1973) stated that the Kimberley Basin succession on YAMPI unconformably overlies the Hooper Complex. Tyler and Griffin (1990) suggested that the contact was everywhere sheared, consistent with the identification by Griffin and Myers (1988), and Griffin (1989) of a thrust, the Inglis Fault, at the contact on LENNARD RIVER. As will be discussed below, evidence from the Cone Bay Inlier suggests that movement on the contact there must have been relatively minor and that the original relationship was unconformable. There is also little evidence of shearing on the contact between the Speewah Group and the Marboo Formation north of Grants Find.

Plumb et al. (1981) interpreted the Speewah Group as a transgressive–regressive cycle with fluvial sands passing into alternating or interfingering fluvial and shallow-marine facies and then back into fluvial sands. Sediment was derived from the elevated and tectonically active King Leopold and Halls Creek Orogens. The Kimberley Group was interpreted as being deposited within a broad semi-enclosed, shallow-marine basin. Shores to the west, and possibly the northeast, supplied sediment for dispersal by ?longshore currents flowing to the south-southeast.

The provenance of the Kimberley Group on YAMPI is more complex than in other parts of the Kimberley Basin, with local unconformities in the upper part of the succession suggesting proximity to a shoreline (Sofoulis et al., 1971).

The Kimberley Basin succession is intruded by thick basic and acid sills of the Hart Dolerite and the Wotjulum Porphyry. A Rb–Sr date of c. 1760 Ma has been obtained from the Hart Dolerite (Bofinger, 1967; Page et al., 1984). Deposition of the Kimberley Basin succession must have occurred between c. 1840 Ma (the age of the granitoids in the Hooper Complex) and c. 1800 Ma.

Speewah Group (ⱣS)

The Speewah Group on YAMPI is exposed at the contact between the Kimberley Basin succession and the Hooper Complex between Secure Bay and Mount Nellie, and around the Cone Bay Inlier. It consists of quartz sandstone, micaceous sandstone and quartzite, and is up to 360 m thick (Sofoulis et al., 1971). Although the complete sequence of stratigraphic units recognized in the type area on LANSDOWNE (Gellatly and Derrick, 1967) is not developed here, the unit can be traced eastwards into the Speewah Group on CHARNLEY (Gellatly and Halligan, 1971).

Rocktypes were described by Sofoulis et al. (1971), who reported cross-bedded white, pale purple-grey, buff, and pale red-brown, coarse-grained, poorly sorted, quartz sandstone exposed in the High Range and McLarty Range areas. Thin quartz-pebble conglomerate occurs near the base of the unit.

The Speewah Group around the Cone Bay Inlier comprises white to brown micaceous sandstone and massive grey quartzite. Immediately above the contact, at the southern margin of the inlier 5 km southeast of Square Top Hill, a conglomerate is exposed containing pebble- and cobble-sized clasts of a distinctive quartz–kyanite–chloritoid rock. This is identical to the Square Top Microgranite exposed immediately below the contact, and strongly suggests that the Speewah Group here is derived from the underlying Hooper Complex.

Kimberley Group

The Kimberley Group on YAMPI consists of six formations (Table 2). Sofoulis et al. (1971) originally identified five; however, the Yampi Member of the Pentecost Sandstone is here raised to formation status. The group consists of a sequence of conglomerate, arkose, quartz sandstone, feldspathic sandstone, siltstone, mudstone (locally iron-rich), and glauconitic sandstone, together with tholeiitic metabasalt, tuffaceous sandstone and agglomerate, that overlies the Speewah Group with apparent conformity.

King Leopold Sandstone (ⱣKl)

The King Leopold Sandstone is the basal unit of the Kimberley Group. It consists of fine- to coarse-grained, white or light grey, buff or pale brown, thick- to thin-bedded quartz sandstone. Trough cross-bedding is frequently observed. In the west, on Sunday Island, Mermaid Island, and around Cascade Bay, the sandstone is coarser grained and contains significant amounts of muscovite and tourmaline (up to 5%).

Sofoulis et al. (1971) reported a measured section of 1050 m of King Leopold Sandstone near Mount Nellie. They also reported an estimated thickness of 1800 m for the unit south of the Cone Bay Inlier; however, as will be discussed, the King Leopold Sandstone in this area is very probably tectonically thickened due to thrusting.

Table 2. Stratigraphy of the Early Proterozoic (c. 1840–1800 Ma) Kimberley Basin

Group	*Formation*	*Thickness (m)*	*Lithology*
KIMBERLEY GROUP	Yampi Formation (*EKy*)	>900	Quartz sandstone, hematitic sandstone, feldspathic sandstone, siltstone, quartz-pebble conglomerate
	Pentecost Sandstone (*EKp*)	1 375	Sandstone, siltstone, conglomerate
	Elgee Siltstone (*EKe*)	120–180	Siltstone, sandstone, conglomerate
	Warton Sandstone (*EKw*)	240–500	Quartz sandstone, feldspathic sandstone, siltstone
	Carson Volcanics (*EKc*)	360–1 140	Metabasalt, tuff, agglomerate, feldspathic sandstone, quartz sandstone, siltstone, mudstone
	King Leopold Sandstone (*EKl*)	1 050	Quartz sandstone
SPEEWAH GROUP (*ES*)		360	Quartz sandstone, micaceous siltstone, conglomerate

Sofoulis et al. (1971) identified heavy-mineral grains in the King Leopold Sandstone. Towards the base of the unit tourmaline was abundant. Higher in the unit tourmaline was virtually absent, with zircon predominant over rutile.

Carson Volcanics (EKc)

The Carson Volcanics conformably overlie the King Leopold Sandstone. The unit consists of interbedded basalt, tuff, agglomerate, feldspathic sandstone, quartz sandstone, siltstone, and mudstone, and ranges from 360 m thick in the Kimbolton Range, to 1140 m thick north of the McLarty Range (Sofoulis et al., 1971). The basic volcanic rocks and the sedimentary rocks have been metamorphosed under greenschist facies conditions.

In the southern central part of YAMPI, around Kimbolton and along the Stewart River, mudstone, siltstone and fine- to medium-grained quartz sandstone are the dominant rock types. Basalt, tuff, and agglomerate, and a prominent feldspathic sandstone unit, are present north of the McLarty Range. There, the basal part of the sequence consists of amygdaloidal metabasalt, with individual flows ranging from 6 m to more than 100 m thick. The occurrence of pillows indicates subaqueous eruption for at least some of the flows. Pyroclastic deposits dominate in the upper part of the succession. Basaltic bombs were recognized, together with blocks of chert and phyllite 25 cm long and 10 cm across, in a matrix of fine- to medium-grained tuffaceous greywacke. The coarseness of the pyroclastic material, and the increasing thickness of the sequence in the northern part of YAMPI, suggests proximity to an eruptive centre (Sofoulis et al., 1971).

Warton Sandstone (ƁKw)

The Warton Sandstone conformably overlies the Carson Volcanics and consists of a sequence of quartz sandstone, feldspathic sandstone, and siltstone. The thickness of the unit ranges from 500 m in the northeast and southwest of the sheet, to between 240 m and 330 m in the northwest (Sofoulis et al., 1971). North of the McLarty Range, the Warton Sandstone has been removed by erosion and the overlying Elgee Siltstone lies directly on the Carson Volcanics. On Koolan Island the unit has been subdivided into three members: the Blinker Hill Sandstone Member; the Jap Bay Member; and the Arbitration Cove Sandstone Member (Sofoulis et al., 1971). A broad division into two sandstone members separated by a thin siltstone member can be recognized throughout the unit on YAMPI.

The lower unit is a thick-bedded, massive, medium- to coarse-grained, cross-bedded, white to buff quartz sandstone. Layers of pebble conglomerate occur near Walcott Inlet. Grey, flaggy, laminated hematitic siltstone forms the central unit. It is associated with feldspathic sandstone and micaceous shale. The upper sandstone unit is made up predominantly of well-sorted quartz sandstone that is less massive and more thinly bedded than the lower sandstone unit. Feldspathic sandstone is an important component of the upper unit. Cross-bedding and asymmetrical or interference ripple markings occur abundantly throughout the Warton Sandstone, and indicate palaeocurrent directions predominantly from the northeast.

Elgee Siltstone (ƁKe)

The Elgee Siltstone generally overlies the Warton Sandstone. North of the McLarty Range it overlaps unconformably onto the Carson Volcanics. The unit consists of siltstone, sandstone and conglomerate. Thickness is between 120 m and 180 m, thinning from northwest to southeast across the sheet. On Koolan Island erosion before deposition of the overlying Yampi Formation has reduced the thickness to as little as 13 m. A thick sequence of rocks 6 km west of Oobagooma, attributed by Sofoulis et al. (1971) to the Elgee Siltstone, is here regarded as part of the Carson Volcanics.

The Elgee Siltstone is characterized by fine-grained, thin-bedded to laminated, grey and red-brown siltstone and mudstone. Cuspate, symmetrical ripple marks occur abundantly, as well as asymmetrical and interference ripples. Thin interbeds of fine- to coarse-grained, trough cross-bedded sandstone are present in most sections. Conglomerate, up to 75 m thick, occurs at the base of the unit north of the McLarty Range, and contains cobbles of quartz sandstone in a granule sandstone matrix.

Pentecost Sandstone (ƁKp)

The Pentecost Sandstone is a sequence of sandstone, siltstone, and minor conglomerate that conformably overlies the Elgee Siltstone, except between Walcott Inlet and Secure Bay where it unconformably overlies the Warton Sandstone. North of The Graveyard the unit is up to 1375 m thick (Sofoulis et al., 1971, fig. 20), but has been entirely removed by erosion on Koolan Island where the overlying Yampi Formation lies directly on Elgee Siltstone.

The unit is predominantly a white, grey or pale-brown, massive, thick-bedded, medium- to coarse-grained, strongly cross-bedded quartz sandstone. Infrequent thin beds of pebbly sandstone and pebble conglomerate are present, with beds of coarser conglomerate occurring between Secure Bay and Walcott Inlet.

North of The Graveyard the unit is dominated by thin-bedded to laminated micaceous siltstone and mudstone, together with minor glauconitic sandstone, and abundant thin, ripple-marked feldspathic and quartz sandstone interbeds.

Yampi Formation (ⱣKy)

Sofoulis et al. (1971) named the upper part of the Pentecost Sandstone on YAMPI, the Yampi Member. The unit is here raised to formation status. It consists of quartz sandstone, hematitic sandstone, feldspathic sandstone, siltstone, and quartz-pebble conglomerate. Where the unit overlies the Pentecost Sandstone, its base is defined by the first appearance of appreciable quantities of hematite. On Koolan Island the Yampi Formation lies unconformably on the Elgee Siltstone. The top of the unit is not seen, but the sequence on Koolan Island reaches 900 m thick.

Gellatly (1972) concluded that the sediments of the Yampi Formation were deposited near a shoreline. Fe-rich heavy minerals were concentrated on a beach or nearshore bar by prolonged reworking, and winnowing of quartz from the deposit. The southern limit of the outcrop of the Yampi Formation was thought to mark the position of the shoreline.

Hart Dolerite (*Ᵽdh*)

The Hart Dolerite is a massive, composite-sill complex which intrudes the Kimberley Basin succession, especially within and below the Warton Sandstone. It is exposed in valleys between the cliff-forming, quartz-rich sandstone units, and forms scattered, low rounded hills in places containing unvegetated outcrops of rounded black boulders. The dolerite is more difficult to distinguish adjacent to Carson Volcanics. Many of the more irregular valleys which Sofoulis et al. (1971) and Gellatly and Sofoulis (1973) thought contained Hart Dolerite, contain partially consolidated coarse valley-fill deposits (*Czc*).

The sills are stratigraphically controlled, and several sills may be present at different stratigraphic levels in any one section. For example, north of the western outcrop of the Secure Bay Monzogranite, one sill of Hart Dolerite was intruded beneath the Kimberley Basin succession. Further up the sequence to the north another sill was intruded above the Carson Volcanics. Sofoulis et al. (1971) gave details of a composite sill in the High Range which indicated a multiple intrusive history for the Hart Dolerite.

The Hart Dolerite is a massive subophitic-textured rock with a poorly developed flow foliation. Much of it is amphibolite with relict pyroxene. Plagioclase is highly saussuritized. Chloritization is generally intense. Locally, the Hart Dolerite is granophyric and contains large elongate feathery amphiboles (Sofoulis et al., 1971). Sofoulis et al. (1971) estimated composite thicknesses between 240 m and 820 m, which is similar to estimates further east (Gellatly et al., 1974; Griffin et al., 1993). U–Pb age data from zircons obtained from the Hart Dolerite on LENNARD RIVER indicate an intrusive age of 1800 Ma (Page, R.W., 1989, pers. comm.)

Wotjulum Porphyry (*Ᵽpw*)

The Wotjulum Porphyry (Sofoulis et al., 1971; Gellatly and Sofoulis, 1973) is an acid porphyry sill which outcrops on low rocky hills around broad folds in the Yampi Peninsula. It is a grey, quartz–feldspar porphyry containing abundant rose-pink quartz phenocrysts, with plagioclase and microcline phenocrysts (5 to 10 mm) set in a fine-grained quartz–feldspar–sericite matrix which contains patches and lenses of chloritized biotite. The quartz phenocrysts are rounded and embayed. Sericite and chlorite are abundant in sheared rocks and also define a foliation at some localities (Sofoulis et al., 1971).

The Wotjulum Porphyry intrudes the Elgee Siltstone at a variety of levels ranging from the contact with the Warton Sandstone to the contact with the Pentecost Sandstone. It is generally parallel to bedding but minor dyking does occur (Sofoulis et al., 1971) and contact hornfels is present. The thickness variations observed by Sofoulis et al. (1971) led them to interpret the Wotjulum Porphyry as a laccolith with a maximum thickness of about 600 m in the Copper Mine Creek area.

The Wotjulum Porphyry is apparently not directly associated with the Hart Dolerite as it occurs at a higher stratigraphic level.

Sofoulis et al. (1971) reported occurrences of andalusite 'granofels' on Gibbings Island, Dunvert Island, and also 6 km south of Wotjulum Mission. All these localities are in the Elgee Siltstone where it has been intruded extensively by the Wotjulum Porphyry. In the present study, samples taken from the Elgee Siltstone 7 km southwest of Wotjulum Mission contained porphyroblasts of biotite up to 3 mm across in a fine- to medium-grained matrix of quartz, muscovite, and biotite. Porphyroblasts were best developed adjacent to the porphyry, and, with the reported andalusite occurrences, are interpreted as the result of contact metamorphism. The biotite porphyroblasts are wrapped by a later foliation.

YAMPI OROGENY

Introduction

The Yampi Orogeny affects rocks in both the Hooper Complex and the Kimberley Basin. It corresponds to the D_3 event recognized by Tyler and Griffin (1990). Large-scale shear zones in the Hooper Complex cut into the Kimberley Basin succession and are oriented parallel to the axial surfaces of large-scale, generally northeast-facing, folds. Deformation was interpreted by Tyler and Griffin (1990) as the result of northeast-directed thrusting.

Deformation post-dates the intrusion of the Hart Dolerite (c. 1800 Ma). D_3 structures are deflected by, and therefore pre-date, movement on the contact between the Hooper Complex and the Kimberley Basin succession (D_4, see 'King Leopold Orogeny' below). On LENNARD RIVER, D_4 post-dates the Mount House Group, a sequence of Upper Proterozoic glacial deposits (c. 670 Ma; Coats and Preiss, 1980). The compressional event that produced D_3 probably also produced open warping of units throughout the Kimberley Basin. This event preceded deposition of the glacial sequence. Tyler and Griffin (1990) suggested that the D_3 event may be related to c. 1.3 Ma deformation and metamorphism of the Rudall Complex at the southwest margin of the North Australian Shield.

The Yampi Orogeny was essentially intracratonic, reactivating an early Proterozoic zone of weakness. Remoteness from a collision zone is indicated by the absence of any related igneous activity. The accompanying metamorphic event (M_2) is of a type characterized by the early growth of andalusite, typical of intracratonic, high-T–low-P, middle Proterozoic orogenies throughout central Australia (e.g. Clarke et al., 1987; Clarke et al., 1990).

A Rb–Sr whole rock isochron of 1517 ± 100 Ma was obtained by Bennett and Gellatly (1970) from three samples of Pentecost Sandstone collected between Dugong Bay and Yampi Sound. However, three samples of siltstone from the same area, one collected from the Carson Volcanics and two from the Elgee Siltstone, gave a Rb–Sr whole rock isochron of 617 ± 90 Ma. Apart from the lithological differences, there appears little geological justification for separating the six samples onto two isochrons. The sample sets overlap spatially, and have undergone the same geological history of deformation and metamorphism. It is therefore difficult to explain the large difference in the dates obtained, or to ascribe them to particular events. The reliability and significance of these dates (if any) must be held in question until they can be substantiated by other geochronological methods.

Deformation in the Hooper Complex

Deformation in the Hooper Complex takes the form of a number of large-scale northwest-trending shear zones. These are linked by north-northwest-trending shear zones (Fig. 1). The principal structures are concentrated into a 10–15 km-wide zone extending from Clara Hill to the Table Range.

The shear zones are marked by foliated and lineated mylonitic granitoid rocks, amphibolite, and metasedimentary rocks. Dips on the foliation are generally moderate to steep to the southwest, with lineations generally plunging to the south or southwest. In granitoid rocks a lineation which plunges 40° to 70° to the south and southeast is defined by mineral elongations (biotite recrystallization and quartz rodding). The more northeasterly of the shears display shear criteria (e.g. c- and s- surfaces and asymmetrical tails on feldspar porphyroclasts (Berthe et al, 1979; Simpson and Schmid, 1983), consistent with northeast-directed thrust movements.

A prominent ridge of mylonitic granitoid extends for 11 km southeast from the Robinson River. At Duck Hole the shear zone is vertical but c- and s-surfaces are present, indicating upward movement of the northeast side of the shear zone. This is interpreted as a backthrust (Fig. 1).

North-northwest-trending shear zones are well developed between Mangrove Creek and Mount Nellie. These typically display dextral movement. Tyler and Griffin (1990) interpreted them as oblique ramps linking the main shear zones.

In the Marboo Formation, tight to isoclinal small-scale D_3 folds developed in shear zones, with axial surfaces parallel to the shear zones, and axes that plunge steeply down dip. Small-scale open to tight D_3 folds are generally well developed adjacent to the shear zones, together with an associated crenulation cleavage (S_3) and a lineation parallel to the crenulation hinges (L_3). They are particularly well developed in rocks east of The Albert Waters. Axial surfaces dip moderately to the northeast, while fold axes plunge at gentle to moderate angles to the northwest or southeast. Small-scale interference folding of D_2 by D_3 (usually type-3 'hooks'; Ramsay and Huber, 1987) is locally developed.

Tyler and Griffin (1990) suggested that D_3 shear zones represented reactivation of steep D_2 structures. Strain during D_3 was strongly partitioned into the shear zones with large areas of rock between them showing little or no evidence of deformation during D_3. D_3 structures are absent from metasedimentary rocks in the headwaters of the Little Tarraji River.

Yampi Fold Belt

Rocks of the Kimberley Basin succession were affected by two phases of folding and thrusting during the Yampi Orogeny. The structures form part of the Yampi Fold Belt (Tyler and Griffin, 1990).

The first fold phase (D_{3a}) produced large-scale near-isoclinal folds with gently inclined to recumbent axial surfaces. Folding is particularly well-developed on Lachlan Island in Cascade Bay. An axial-plane cleavage (S_{3a}) is present. At the eastern end of Cascade Bay a thrust contact is exposed between granitoid rocks and the King Leopold Sandstone. Four kilometres northeast of Sanderson Point, granitoid rocks below this contact display c- and s-surfaces with shear criteria showing a consistent south-to-north movement. Small- and medium-scale layer-parallel isoclinal folds are developed in metasedimentary rocks above the thrust. A flat-lying D_{3a} thrust is recognized within the King Leopold Sandstone 18.5 km west-southwest of Kimbolton. D_{3a} structures have only been recognized to the south of Cone Bay. Considerable thickening of the King Leopold Sandstone is apparent in the southern limb of the Cone Bay Anticline. This is attributed to an imbricate fan (Boyer and Elliot, 1982) marking the front of the D_{3a} thrusting.

The second fold phase (D_{3b}) consists of large-scale, northeast-facing folds with moderately to steeply southwest-dipping axial surfaces, and is responsible for the major map-scale fold structures seen on YAMPI (Fig. 1). An axial-plane cleavage (S_{3b}) locally crenulates S_{3a} in the core of the Kimbolton Syncline. D_{3a} structures are refolded by D_{3b}. Few small-scale D_{3b} fold structures are seen due to the massive nature of the quartzites that make up the majority of the Kimberley Basin succession.

Basement shear zones pass up into the Kimberley Basin succession in the area south of the McLarty Range. Typically the structures form southwest-dipping thrusts (Fig. 1). Basement rocks are thrust over Kimberley Basin succession rocks at Mount Nellie and along the southern edge of the Table Range. The back-thrust recognized at Duck Hole passes into the northeast-dipping thrust outcropping between the Townshend River and the Kammargoorh River. Southwest-facing folds occur beneath this structure.

In the Table Range a sill of Hart Dolerite was initially deformed by folding before failing along dextral (northeast limb) and sinistral (southwest limb) strike-slip faults.

In the Cone Bay Inlier rocks of the Hooper Complex are exposed in the core of an asymmetrical D_{3b} anticline whose northern limb is overturned. C- and s-surfaces in a shear zone along the southern side of Cone Hill show south-to-north movement consistent with the development of a thrust at this contact. The thrust dies out into an anticline to the southeast.

As has been discussed above, the occurrence of pebbles of the distinctive Square Top Microgranite in the Speewah Group, above the sheared southern contact of the inlier, implies that there has been only local movement here, possibly reflecting flexural-slip during folding (Tyler and Griffin, 1990).

D_{3a} folds and thrusts are interpreted as early-formed, deeper level structures carried on the later D_{3b} thrusts and deformed by them (Boyer and Elliott, 1982). Tyler and Griffin (1990) noted the abrupt curtailment of folding north of Koolan Island. This was attributed to the reactivation of the steep D_2 shear zones in the Hooper Complex, with these structures controlling ramping of the D_{3b} thrusts (Wiltschko and Eastman, 1983).

Metamorphism

Deformation in the Hooper Complex during the Yampi Orogeny was accompanied by a low- to medium-grade metamorphic event (M_2). The highest grade rocks occur in the southeast corner of YAMPI. Medium-grade (amphibolite facies) metasedimentary rocks are also present in the Cone Bay Inlier. Low-grade (greenschist facies) metamorphism accompanied formation of the S_3 crenulation cleavage east of The Albert Waters. Elsewhere M_1 assemblages are preserved.

Between Clara Hill and Limestone Spring medium-grained, schistose pelitic metasedimentary rocks have the assemblage quartz–muscovite–biotite(–garnet–staurolite)–chlorite. Tourmaline, zircon, and Fe-oxides are present as accessory minerals. The main foliation in the area, S_3, developed as a crenulation of S_2, and is picked out by the preferred orientation of muscovite and biotite. Small, irregular staurolites are associated with the foliation. Garnet porphyroblasts occur as small rounded crystals up to 1.5 mm across, which are typically wrapped by S_3. They may show cores rich in fine, randomly oriented inclusions. Chlorite forms large, randomly oriented porphyroblasts up to 2 mm long, which overgrow, and therefore post-date, the S_3 fabric. Hornblende–plagioclase–quartz assemblages in the Ruins Dolerite are consistent with amphibolite facies metamorphism.

Further to the northwest, 6.5 km west of Mondooma Yard, crenulated pelitic schists have the assemblage quartz–muscovite–garnet–chloritoid–chlorite. Garnet porphyroblasts occur as euhedral crystals up to 5 mm across that are partially replaced by symplectic intergrowths of chlorite, muscovite, and Fe-oxides. Chloritoid occurs as 1–2 mm-long needles that are oriented parallel to the S_3 fabric.

Metasedimentary rocks east of The Albert Waters are lower grade, comprising quartz–muscovite(–chlorite–biotite). Sofoulis et al. (1971) reported the occurrence of chloritoid phyllites in this area.

Randomly oriented, euhedral porphyroblasts of chloritoid are present in a medium-grained, schistose semi-pelitic rock, 5 km west-southwest of Mount Nellie. Porphyroblasts are up to 4 mm long and are wrapped by an S_3 foliation, implying pre-D_3 growth. Many of the crystals are fractured and have been rotated, apparently during D_3.

Randomly oriented chloritoid crystals up to 1 cm long are present in a medium-grained groundmass of quartz, chlorite and muscovite in metasedimentary rocks in the Cone Bay Inlier. Symplectic intergrowths of muscovite and staurolite are interpreted as replacing andalusite porphyroblasts. Poikiloblastic biotite porphyroblasts up to 2 mm across were found, but in some places were replaced by finer biotite–muscovite–quartz aggregates.

Biotite porphyroblasts up to 0.5 mm across, occur in a fine- to medium-grained schist south of the Table Range. The porphyroblasts are wrapped by S_3 and are partially replaced by nonoriented chlorite and muscovite. Staurolite has been reported by Sofoulis et al. (1971) from near Quiana Pool.

Metamorphic grade in the Kimberley Basin succession varies from medium grade (amphibolite facies) in Cascade Bay, to low grade (lower greenschist facies) northeast of Talbot Bay. Quartz–muscovite–chlorite is the typical assemblage in metasedimentary rocks. Tourmaline, zircon, and Fe-oxides occur as accessory minerals. Mafic rocks in the Carson Volcanics are characterized by actinolite–epidote–chlorite–sericite–quartz assemblages.

Kyanite and staurolite occur with quartz and muscovite in a quartzite overlying the thrust contact between granitoid and the King Leopold Sandstone in Cascade Bay. Kyanite is also present with chloritoid in recrystallized Square Top Microgranite underlying the Speewah Group at the southern margin of the Cone Bay Inlier.

The assemblage kyanite–chloritoid–quartz represents an alkali-poor rock which was derived by weathering and leaching of the microgranite during exposure at the Earth's surface. The same mineral assemblage is seen in pebbles of the microgranite sampled from conglomerate in the overlying Speewah Group. This might suggest that metamorphism predated deposition of the conglomerate; however, the assemblage kyanite–chloritoid–quartz is also present in the recrystallized matrix of the conglomerate, consistent with metamorphism taking place after deposition of the rock.

The sequence of mineral growth is consistent with an early, pre-S_3, period of high-T–low-P metamorphism characterized by porphyroblasts of randomly oriented andalusite, and poikiloblastic biotite. Staurolite, kyanite, garnet and chloritoid grew during the main D_3 shearing event, indicating evolution of the orogen to higher pressures. Gellatly and Halligan (1971) and Griffin et al. (1993) reported kyanite, muscovite, and staurolite replacing early andalusite on the adjacent parts of CHARNLEY and LENNARD RIVER. Growth of chlorite, either as primary porphyroblasts or as a replacement of biotite and garnet, was post-tectonic.

KING LEOPOLD OROGENY

The King Leopold Orogeny corresponds to the D_4 event recognized by Tyler and Griffin (1990). On LENNARD RIVER the D_4-age Precipice Fold Belt deforms rocks of the late Proterozoic (c. 670 Ma) Mount House Group. An upper limit on the age of folding is set by the Ordovician age of rocks at the base of the Canning Basin succession (Yeates et al., 1984). The Precipice Fold Belt extends onto CHARNLEY but folding dies out in the vicinity of Mount Hart. On YAMPI D_4 consists of shearing at the contact between the Hooper Complex and the Kimberley Basin succession, sinistral strike-slip faulting, and associated refolding of D_3 structures. Tyler and Griffin (1990) interpreted the deformation as the result of southwestward movement of the cratonic basement underlying the Kimberley Basin, accompanying major strike-slip movements on faults in the Halls Creek Orogen.

Shearing at the contact between the Hooper Complex and the Kimberley Basin succession is well developed between Secure Bay and Mount Nellie. Along much of this contact Hart Dolerite is in direct contact with the Hooper Complex. D_3 fabrics in the Hooper Complex may be deflected to give a north-to-south sense of movement on the shear zone (Tyler and Griffin, 1990, fig. 5c). The D_3 Duck Hole back-thrust may have been reactivated during this event.

A complex zone of faulting is developed in the northeast corner of YAMPI between Doubtful Bay and Secure Bay. These faults belong to the 'Mount Page Fault Arc System' of Sofoulis et al. (1971), and have an arcuate trend from north-northeast, north of Secure Bay, to south-southeast further south. Faults in the Kimberley Basin succession pass directly into shear zones in the Hooper Complex and show either vertical movements, or sinistral offsets (e.g. 5 km northeast of Grants Find).

Refolding of D_3 folds has taken place about east- and northeast-trending axes. Large-scale 'hook'-style, type-3 fold interference patterns (Ramsay and Huber, 1987) occur south-southeast of Koolan Island; on Irvine Island; and between the Stewart and Keightly Rivers, north-northeast of Mount Heytesbury. Dome-and-basin style, type-2 fold interference patterns (Ramsay and Huber, 1987) occur in Cascade Bay; at the northwest end of the Kimbolton Range; between the Wotjulum Mission and Yampi Sound; and between Talbot Bay and Shoal Bay.

The restricted, non-pervasive nature of the refolding, and the variation in style, suggests that it has developed above pre-existing structures in the Hooper Complex. Fold orientations are consistent with the sinistral movement on the Mount Page Fault Arc System, producing an overall northeast to southwest compression in the area.

Mafic dykes

Mafic dykes having a northwesterly trend intrude granitoid rocks at Boulder Hill, and granitoid rocks and Whitewater Volcanics 10 km north-northeast of Mount Disaster. A dyke 10 km east-southeast of Mount Disaster trends northeast and extends on to CHARNLEY. The two orientations may be part of a conjugate set and are similar to the orientations of Late Proterozoic to early Palaeozoic dykes (post-King Leopold Orogeny) on LENNARD RIVER (Griffin et al., 1993).

The rocks are medium grained and show good ophitic textures of intergrown pyroxene and plagioclase, with minor amounts of biotite. Accessory apatite and iron oxide are present. A dyke at Boulder Hill contains relic olivine surrounded by aggregates of granular clinopyroxene. The dykes are typically fresh, but the primary minerals can show alteration to amphibole, chlorite and sericite.

CANNING BASIN

PALAEOZOIC

Devonian — Napier Range Reef Complex

(by P. E. Playford)

Introduction

Devonian limestone and dolomite forming part of the Devonian 'Great Barrier Reef' of the Canning Basin are exposed in the narrow, rugged, Napier Range in the extreme southeast of YAMPI, and are believed to continue in the subsurface to the northwest. The exposed carbonates of the reef complex are probably not more than 200 m thick, but about 800 m of subsurface Devonian strata were penetrated in the Napier 4 well (Lennard Oil N.L., 1970).

Earlier references to the Devonian geology are detailed in Playford and Lowry (1966), and Playford (1980). The principal contributions since then of relevance to YAMPI are by Playford (1981, 1984), Playford et al. (1989), Hurley and Lohman (1989), Kerans (1985), and Kerans et al. (1986). The regional geology of the Canning Basin is described by Towner and Gibson (1983), and much relevant information is contained in the Canning Basin Symposium volume edited by Purcell (1984).

The Napier Range reef complex began growth on adjoining LENNARD RIVER in the early Frasnian (Late Devonian), or possibly a little earlier, and continued through to the late Famennian. However, on YAMPI the exposed reefal limestone platforms are entirely of Famennian age, consisting of the Windjana Limestone and Nullara Limestone, which constitute the Nullara Cycle of reef development (Playford, 1980).

The Napier Range Famennian reef complex grew as a reef-rimmed limestone platform flanked by steep marginal slopes which descended to depths of as much as several hundred metres in the adjoining basin. Depositional dips in the marginal-slope deposits were commonly up to 35° to 40° in loose debris, and near-vertical where cyanobacterial binding was involved. Water depths on the platforms were generally less than 5 m, and some areas were intertidal. Early submarine cementation was very important in developing and maintaining the high-relief reef margins and very steep reefal slopes (Playford, 1980; Kerans et al., 1986).

Three basic facies are recognized in the reef complexes — platform, marginal-slope, and basin facies — although there are no exposures of the basin facies on YAMPI. The platform facies is subdivided into reef-margin, reef-flat, back-reef, and bank subfacies; and the marginal-slope facies into reefal-slope, fore-reef, and fore-bank subfacies.

The reef-margin deposits are massive limestones, whereas the reef-flat deposits are bedded. Both were subjected to strong early cementation, and were constructed during the Famennian by frame-building cyanobacteria, with minor contributions by stromatoporoids in some areas.

Contemporary fracturing of the strongly cemented limestones around the platform margins and upper marginal slopes caused periodic submarine landsliding of large sections of reef, giving rise to debris flows and large allochthonous reef blocks in the marginal-slope deposits. Where the fractured limestone remained in place, fissures were variously filled at an early stage with cement, detrital sediment, and organic growths, to form extensive networks of neptunian dykes (Playford, 1984; Playford et al., 1989; Kerans et al., 1986).

Contemporary faulting is believed to have led to mountainous topography in the adjoining landmass of the King Leopold Orogen and Kimberley Basin, which was the source of the enormous masses of terrigenous boulder conglomerate that interfinger with the Napier Range reef complex and elsewhere (Playford and Lowry, 1966; Playford, 1984; Botten, 1984). These fanglomerate complexes reflect environments ranging from proximal alluvial fans through fan deltas to submarine fans.

Extinction of reef growth in the late Famennian and initiation of the mixed siliciclastic-carbonate depositional sequence of the succeeding Fairfield Group probably resulted from a sudden rise in sea level.

Napier Formation (Dn)

The Napier Formation on YAMPI consists of crudely bedded to well-bedded limestone, with some dolomite, and interbeds of terrigenous clastics. It constitutes the marginal-slope facies (reefal-slope and fore-reef subfacies) of the Napier Range reef complex.

The fore-reef subfacies consists largely of debris derived by contemporary erosion of the Windjana–Nullara platforms during the Famennian. The reefal-slope subfacies was deposited at the top of the marginal slopes, immediately adjoining the limestone platforms. Depositional dips were up to near vertical and resulted from the growth of layers of cyanobacteria and sponges, which formed the reefal frameworks and trapped and bound platform-derived sediments.

Windjana Limestone (Dw)

The Windjana Limestone consists of massive to crudely bedded reef limestone and minor dolomite, of Famennian age. The reefs were built primarily by cyanobacteria, principally Renalcis and Sphaerocodium, although some stromatoporoids also occur in the reefs exposed on YAMPI. There was contemporaneous deposition of large volumes of microcrystalline calcite in the reefs (Kerans, 1985; Kerans et al., 1986; Hurley and Lohman, 1989), to form rigid, wave-resistant structures.

The Windjana Limestone reefs grew outwards, at low angles, over the equivalent marginal-slope deposits of the Napier Formation, with interfingering and gradational contacts. Passing into the platform interior in the other direction, the Windjana Limestone also interfingers and grades into back-reef deposits of the Nullara Limestone.

Nullara Limestone (Dl)

The Nullara Limestone on YAMPI consists of fenestral limestone of Famennian age, which has been dolomitized in some areas. The Nullara Limestone is the back-reef equivalent of the Windjana Limestone. The original total thickness of the unit in this area is estimated to have been about 400 m.

Late Devonian–Early Carboniferous

Lillybooroora Conglomerate (DCl)

The Lillybooroora Conglomerate forms a discontinuous belt from the vicinity of Dugong Bay to the Robinson River; scattered outcrops extend southwest to Saddle Hill. The geology of the conglomerate has been described by Sofoulis et al., (1971) and, with an overlying sandstone unit (which is only seen in the subsurface), by Botten (1984), who regarded the deposits as a large alluvial fan, overlain by a delta.

The conglomerate is up to 60 m thick, and consists of large boulders (up to 1.2 m across), pebbles, and cobbles of quartzite, directly derived from the Lower Proterozoic King Leopold Sandstone, in a matrix of ferruginous sandstone. The unit was deposited in a system of valleys or stream lines, with breccia and conglomerate developed adjacent to angular and irregular contacts.

Fairfield Group (DCf)

The Lillybooroora Conglomerate is overlain by a sandstone unit which reaches 116 m in thickness. It consists of interbedded, well-cemented sandstone and silty claystone. Botten (1984) referred to this unit as the 'Yampi Sandstone'; however, this name is invalid, 'Yampi' having already been used by Sofoulis et al. (1971) for the Yampi Member of the Lower Proterozoic Pentecost Sandstone. A typical Early Carboniferous Tournaisian palynological assemblage was reported from the unit by Botten (1984), who regarded it as equivalent to the Yellow Drum Formation of the Fairfield Group. The unit was also intersected in Napier 4 where it has been correlated directly with the Yellow Drum Formation (Druce and Radke, 1979).

The Fairfield Group is poorly exposed in front of the Napier Range, and consists of limestone interbedded with calcareous shale and siltstone (Gellatly and Sofoulis, 1973). Druce and Radke (1979) regarded the group as a shallow-marine deposit, laid down after drowning of the reef complexes.

Gellatly and Sofoulis (1973) suggested that the exposed Fairfield Group on YAMPI, which is 130 m thick, is probably entirely Late Devonian (Famennian) in age. As such it would be equivalent to the Gumhole Formation of Druce and Radke (1979). In Napier 4 the Gumhole Formation is only 4 m thick and is underlain by the Luluigui Formation (Druce and Radke, 1979).

Late Carboniferous to Early Permian

Grant Group (CPg)

The Grant Group is exposed in the extreme southwest of YAMPI, near Limestone Spring. Low-lying outcrops of probable Grant Group are present about 30 km southeast of

Oobagooma, where they display large-scale trough cross-bedding (with a source from the east) discernible on aerial photographs (Sofoulis et al., 1971). The unit is at least 70 m thick on YAMPI (Botten, 1984, fig. 8) where it unconformably overlies the Fairfield Group (Druce and Radke, 1979).

Throughout the Canning Basin the Grant Group comprises dominantly marine deposits (Yeates et al., 1984). Diamictites and laminated clastic sedimentary rocks with dropstones are widespread, and the unit has been interpreted as glacial in origin.

Mesozoic

Rocks of Devonian to Jurassic age are present in most parts of the Canning Basin to the south and southeast of YAMPI. In the northwest part of the basin, however, Cretaceous rocks overlap the Palaeozoic and earlier Mesozoic rocks to lie unconformably on Precambrian rocks. Gellatly and Sofoulis (1973) suggested that the Blina Shale and Erskine Sandstone (both Triassic) are probably present in the subsurface under King Sound. Also, formations such as the Broome Sandstone (Cretaceous), and the Jarlemai Siltstone, Alexander Formation, and Wallal Sandstone (Jurassic), encountered in Fraser River 1, Puratte 1 and Padilpa 1, may be present in the extreme southwest of YAMPI.

Late Jurassic to Cretaceous

Jowlaenga Formation (JKw)

The Jowlaenga Formation is exposed on the Dampier Peninsula, and consists of 75–120 m of fine- to medium-grained silty sandstone. It is thought to be equivalent to the Broome Sandstone (Yeates et al., 1984). The unit contains a fauna, consisting mainly of belemnites and ammonites, considered to be either Tithonian (Stevens, 1965; Skwarko, 1970) or Valanginian (Gellatly and Sofoulis, 1973) in age.

Melligo Sandstone (Km)

The Melligo Sandstone forms the resistant Lombardina Plateau. The unit is Aptian in age, and consists of a beach deposit of well-sorted, thin-bedded sandstone (Yeates et al., 1984). Large-scale trough cross-bedding is discernible in places on aerial photographs.

TERTIARY

Pender Bay Conglomerate (Tp)

The Pender Bay Conglomerate is a ferruginous boulder conglomerate of fluviatile origin probably deposited by a large Tertiary river system flowing into an ancient Pender Bay (Gellatly and Sofoulis, 1973). The Borda Sandstone disconformably overlies the Pender Bay Conglomerate on Apex Island and at Cunningham Point, but is too small to be shown on the map (Gellatly and Sofoulis, 1973).

STRUCTURE

The Lennard Shelf occurs along the northeastern margin of the Canning Basin and is separated from the Fitzroy Graben by a series of northwesterly trending normal faults, such as the Pender Bay Fault and the Beagle Bay Fault, which are downthrown to the southwest (Yeates et al., 1984). These faults occur to the southwest of YAMPI, and Phanerozoic rocks within the sheet area were deposited entirely on the Lennard Shelf.

Movement on northwesterly trending normal faults took place on YAMPI during the Late Devonian and Early Carboniferous. This is apparent from drilling of the Lillybooroora Conglomerate and the overlying Yellow Drum Formation (Botten, 1984). From Figure 1 it is also apparent that the outcrop pattern of the Phanerozoic rocks has been controlled by the pre-existing Proterozoic shear zones, such as the Duck Hole Shear Zone, strongly suggesting that reactivation of these structures controlled the development of the Canning Basin in this area.

There is little evidence for extensive tectonic activity on YAMPI after the Early Carboniferous. Later fault movements (Mesozoic in age) were concentrated on the structures separating the Lennard Shelf from the Fitzroy Graben (Drummond et al., 1988).

SUPERFICIAL DEPOSITS

Cainozoic (undifferentiated)

Colluvial and alluvial deposits (*Czs*) consisting of partly consolidated silt, sand and gravel occur as valley-fill deposits. They are typically exposed in the upper reaches of the present drainage system. Extensive sand plain on the Dampier Peninsula is included in this unit. Low, easterly trending longitudinal sand dunes, formed during the Riss arid cycle, extend onto YAMPI from the west (Gellatly and Sofoulis, 1973).

Cobble and boulder conglomerates (*Czc*), formed as scree and valley-fill deposits, occur extensively within the rugged hill country of the Kimberley Plateau and the Kimberley Foreland. Typically they fill narrow valleys within the quartzite ridges.

Ferruginous duricrust and associated colluvial sand and gravel deposits (*Czd*) occur extensively in the southern part of YAMPI. The unit is usually developed on the Lillybooroora Conglomerate and the Grant Group.

Quaternary

Alluvium (*Qa*), comprising unconsolidated silt, sand, and gravel, is found along present-day drainage channels. Extensive areas of black-soil plain (*Qb*) cover the broad flood plains adjacent to the major rivers. These hummocky treeless plains consist of black and dark grey-brown soils, and cracking clays.

Beach and dune sands (*Qcb*) are confined to small sheltered bays, and consist of quartz sand with subordinate shell and coral fragments (Gellatly and Sofoulis, 1973). Tidal mudflats and mangrove swamps (*Qci*) border most of the bays and estuaries, particularly on the southern side of the Yampi Peninsula. Supratidal mudflats (*Qcs*) consist of mud and salt and are only inundated by the highest tides. Tidal channels contain coarse-grained sands, which commonly form cross-bedded tidal megaripples (Gellatly, 1970).

Coral reefs are common around the coast of the Yampi peninsula and adjacent islands (Gellatly and Sofoulis, 1973). Calcareous beach rocks are present on some islands, and consist of well-cemented fragmental limestone containing coral and shell fragments, together with detrital material derived from the Kimberley Basin rocks.

ECONOMIC GEOLOGY

IRON

Hematite iron ore is currently being mined by BHP Minerals Limited from a major high-grade orebody on Koolan Island. A similar deposit on Cockatoo Island has been mined out. Several smaller and lower grade deposits are known, and one on Koolan Island is being mined. Deposits on Irvine Island have yet to be developed. The deposits have been described by several authors (Canavan and Edwards, 1938; Reid, 1958; Sofoulis et al., 1971; BHP Staff, 1975). Ore shipments totalled 29 880 116 t from Cockatoo Island and 61 441 000 t from Koolan Island to the end of 1991. Demonstrated resources on Koolan Island (1991) are 6 Mt at 65.5% Fe and 0.04% P.

The orebodies outcrop at the base of the Yampi Formation, where it unconformably overlies the Elgee Siltstone. On Koolan Island the orebodies occur around an overturned syncline and an adjacent overturned anticline. The main orebody originally extended up to 180 m above sea level and is known to extend for at least 190 m below sea level. The ore consists predominantly of hematite (grading 66–67% Fe). Small amounts of magnetite are present as relict cores enclosed by secondary hematite (Gellatly, 1972). Minor quartz-pebble conglomerate with a hematite matrix is present. The ore grades laterally into hematitic conglomerate or hematitic sandstone. Local upgrading of the deposit has resulted from leaching of quartz pebbles from the conglomerate. The boundary of the leaching is usually sharp.

The ore bodies have been interpreted as heavy-mineral concentrations in clastic sediments (Gellatly, 1972). Iron minerals were deposited in the Warton Sandstone and were then eroded and redeposited near a beach or offshore bar. Concentration was the result of prolonged reworking during which quartz and tourmaline were removed to leave a deposit essentially consisting of hematite or magnetite sand. The minor element chemistry of hematite from the orebodies suggests primary derivation from a 'jaspilitic' (i.e. a banded iron-formation) source (Gellatly, 1972).

COPPER

Copper ore has been produced on YAMPI from the Monarch workings (13.4 t of ore containing 2.8 t of copper) and Coppermine Creek (94.35 t of ore containing 23.17 t of copper) (Marston, 1979). Numerous small deposits have also been described in summary by Marston (1979). They may occur associated with the Marboo Formation and the Ruins Dolerite; with the Kimberley Basin succession; or, less commonly, with granitoid.

The Chianti prospect is located within the Marboo Formation, 23 km north-northeast of Oobagooma Homestead. It is regarded as a stratiform deposit with small copper gossans occurring discontinuously in a zone 150 m long (Marston, 1979). A diamond drillhole put down by Australian Consolidated Minerals NL in 1972 cut massive and breccia ore containing iron sulfides, with minor chalcopyrite, sphalerite, and galena, in graphitic phyllite. The best intersection was 6.63 m of 1.06% Cu, 0.93% Pb, 2.85% Zn, and 29 g/t Ag.

The Limestone Spring prospect consists of two small limonite gossans containing malachite, azurite, and chalcocite, developed on Marboo Formation that is intruded by the Ruins Dolerite. A narrow zone within the metadolerite contains disseminated pyrrhotite and chalcopyrite. A diamond drillhole intersected disseminated sulfides in metadolerite, which assayed 0.39% Ni and 0.20% Cu over a drilled width of 7.6 m.

Other copper prospects in the Marboo Formation are in quartz veins and shear zones (Marston, 1979). At the surface malachite and chalcanthite are typically present in vein quartz, and as veinlets, layers, and disseminations with goethite in bleached and silicified phyllite. At Grants Find the base of the oxidized zone was 9 to 15 m below the surface and diamond drillholes put down by Western Mining Corporation Ltd encountered quartz and chalcopyrite. Mineralized intersections from 1.46 m to 8.53 m assayed between 1.29% and 2.6% Cu. At Wilsons Reward diamond drilling encountered disseminated pyrite and pyrrhotite with subordinate chalcopyrite in quartz. The best assay was 1.4% Cu over 3.8 m.

Blebs of chalcopyrite have been reported from a north-northeasterly trending quartz vein in the Lennard Granite near Secure Bay (Marston, 1979).

In the Kimberley Basin succession minor copper occurrences have been noted in the Carson Volcanics, the Warton Sandstone, the Elgee Siltstone, and the Pentecost Sandstone, as well as the Hart Dolerite (Sofoulis et al., 1971; Marston, 1979). At Coppermine Creek chalcocite, malachite, cuprite, atacamite, and brochantite occur in quartz veins emplaced into sheared, sericitized and carbonated Wotjulum Porphyry.

MICA AND BERYL

Mica and beryl have been produced from the Stuarts mine, 9 km north-northwest of Limestone Spring. Reported production was 14.18 kg of mica, and 3.56 t of beryl.

The deposit occurs in a composite quartz pegmatite dyke intruded into Marboo Formation and a sill of Ruins Dolerite. It has been described in detail by Sofoulis et al. (1971), who recorded books of muscovite mica up to 60 cm by 30 cm. Beryl crystals up to 15 cm across have also been reported (Harms, 1959).

PETROLEUM

Only one petroleum exploration well (Napier 4) has been drilled on YAMPI. The well did not encounter hydrocarbons, and intersected Precambrian basement at 852 m below sea level. Palaeozoic petroleum source rocks and reservoir sediments occur in the southern part of YAMPI, and some potential for discovery exists in this part of the sheet (Lehmann, 1986). Oil has, however, been discovered in wells to the southeast and south of YAMPI, and is being produced from Blina, Sundown, West Terrace and Lloyd oilfields located on LENNARD RIVER and DERBY.

HEAVY MINERAL SANDS

Baxter (1977) reported two occurrences of heavy mineral sands from YAMPI. On Gibbings Island, heavy mineral concentrates containing hematite, ilmenite, and rutile, formed 2.5% of beach sediment (Farrand, 1965). Deposits at the mouth of the Robinson River, south of Robinson Landing, contain 26% heavy minerals, consisting mainly of ilmenite and zircon.

URANIUM

Uranium mineralization was encountered in drillholes intersecting a sandstone unit overlying the Lillybooroora Conglomerate near Oobagooma Homestead (Botten, 1984). The sandstone is Late Devonian–Early Carboniferous in age, equivalent to the Yellow Drum Formation of the Fairfield Group. Deposition was interpreted as taking place on a large delta plain influenced by tidal and fluvial processes. Uranium mineralization was concentrated in areas of fluvial-dominated delta sedimentation where the greatest concentrations of organic matter occurred, and the greatest mixing of vadose and marine waters took place. The uranium was believed to have been derived mainly from the Hooper Complex during a major denudation phase between the Early Devonian and the Early Permian.

AFMECO (unpublished M-series open file report, Item No. 2781) identified two zones of mineralization at Oobagooma with an indicated geological resource of 3.867 Mt at 1.415 kg/t U_3O_8, and inferred reserves of 1.133 Mt at 2.748 kg/t.

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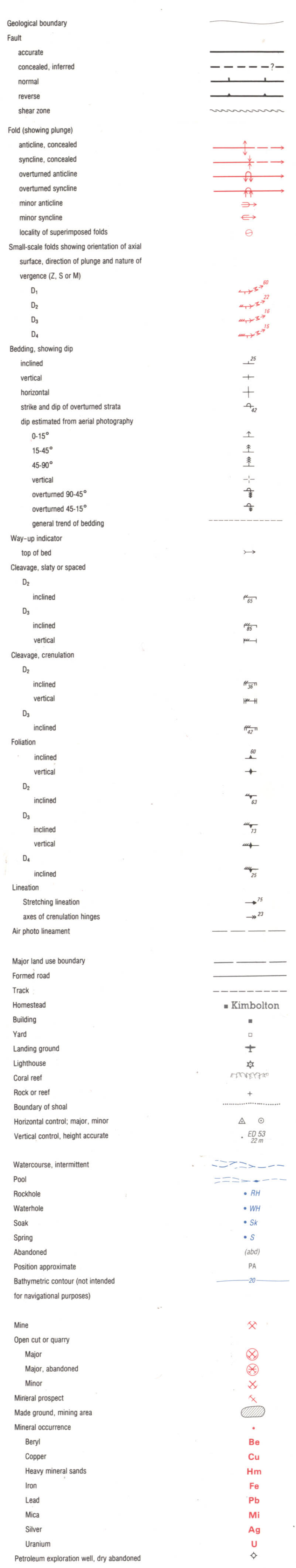
YAMPI

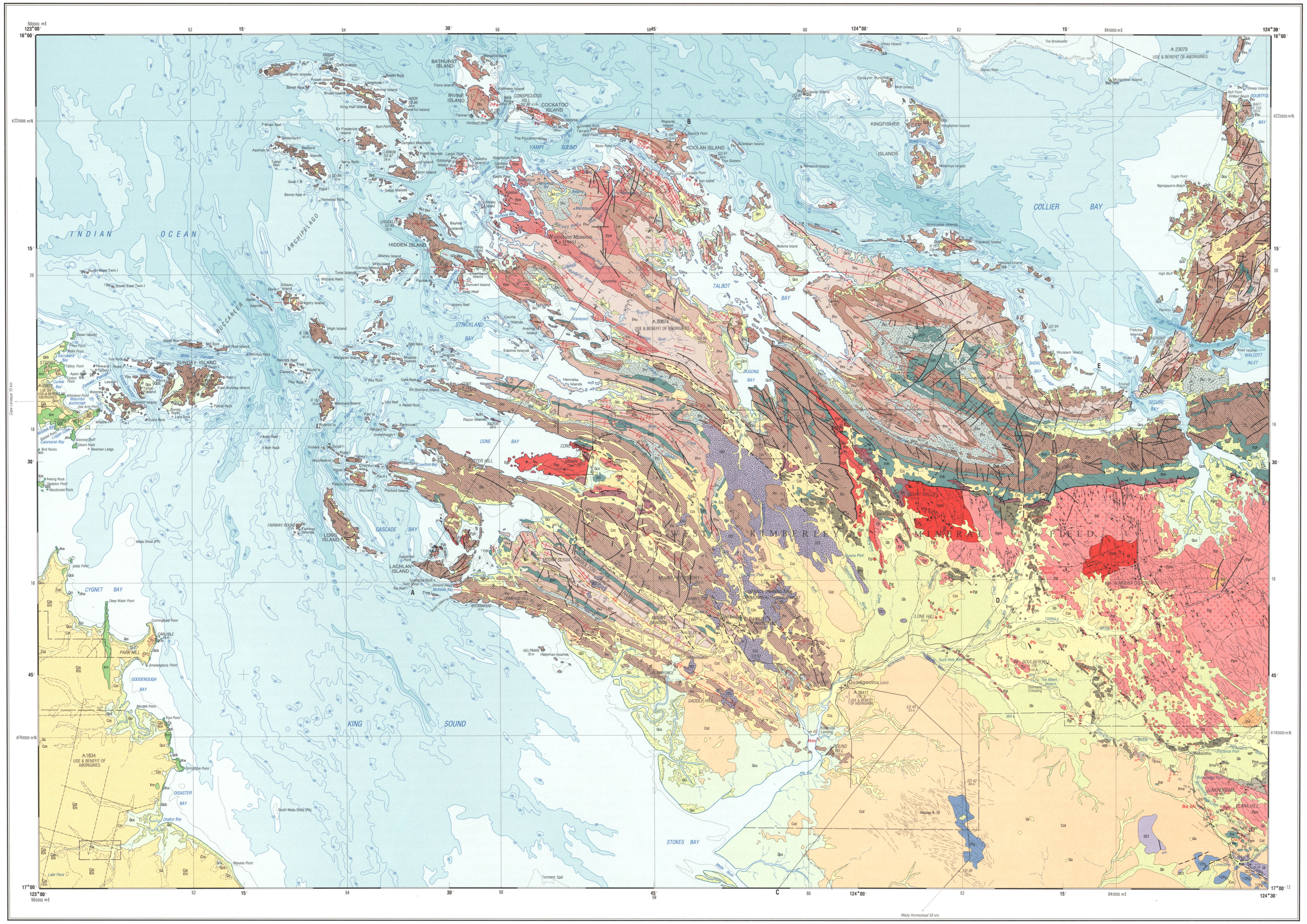
AUSTRALIA 1:250 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SE 51-3

SYMBOLS





REFERENCE

PHANEROZOIC	CAINOZOIC	QUATERNARY			Qa, Qci, Qcs, Qcb, Qb
		TERTIARY			Tp
	MESOZOIC	CRETACEOUS			Km
		LATE JURASSIC TO EARLY CRETACEOUS			JKw
	PALAEOZOIC	LATE CARBONIFEROUS TO EARLY PERMIAN		Grant Group	CPg
		LATE DEVONIAN TO EARLY CARBONIFEROUS	FAMENNIAN—TOURNAISIAN	Fairfield Group	DCf
					DCl
		LATE DEVONIAN	FAMENNIAN	Reef Complex	Dl, Dw, Dn

Qa Alluvium — unconsolidated silt, sand, and gravel
Qci Tidal flat and mangrove swamp deposit — silty clay, black organic clay; minor salt and beach ridge deposits
Qcs Supratidal mudflat deposit — clay, silt, sand; minor salt
Qcb Beach ridge deposit — quartzose sand, shelly in places
Qb Black soil — clay and silt

Czs Colluvium and alluvium — partly consolidated silt, sand, and gravel
Czc Colluvium — partly consolidated scree and valley-fill deposits; cobble and boulder conglomerate
Czd Colluvium and ferruginous duricrust — partly consolidated sand and gravel; usually developed on CPg

Tp **PENDER BAY CONGLOMERATE:** dark-grey boulder to pebble conglomerate

Km **MELLIGO SANDSTONE:** white to pale-grey, medium- to coarse-grained, silicified quartz sandstone; local large-scale cross-bedding

JKw **JOWLAENGA FORMATION:** fine- to medium-grained silty sandstone; poorly sorted, commonly ferruginous

CPg Undivided: massive aqueoglacial, unsorted silty sandstone, conglomeratic sandstone, conglomerate, siltstone, and shale

DCf Undivided: silty limestone and calcarenite; calcareous shale and siltstone

DCl **LILLYBOOROORA CONGLOMERATE:** boulder and cobble conglomerate

Dl **NULLARA LIMESTONE:** back-reef to reef-flat subfacies; bedded limestone and dolomite

Dw **WINDJANA LIMESTONE:** reef-margin subfacies; massive limestone

Dn **NAPIER FORMATION:** reefal-slope to fore-reef subfacies; bedded limestone, in part dolomitic

CANNING BASIN

PROTEROZOIC

q Quartz vein
d Dolerite dyke

c. 1800 Ma

Ꝑdh **HART DOLERITE:** dark-grey dolerite
Ꝑpw **WOTJULUM PORPHYRY:** grey quartz-feldspar porphyry

c. 1800 – 1840 Ma

Kimberley Group

ꝐKy **YAMPI FORMATION:** pink-brown arkose and feldspathic sandstone; minor siltstone, hematitic quartz sandstone, glauconitic sandstone

ꝐKp **PENTECOST SANDSTONE:** white, well-sorted quartz sandstone; grey siltstone

ꝐKe **ELGEE SILTSTONE:** red-brown and grey siltstone and minor phyllite; thin sandstone interbeds; boulder to pebble conglomerate

ꝐKw **WARTON SANDSTONE:** white, well-sorted quartz sandstone and feldspathic sandstone; siltstone interbeds

ꝐKc **CARSON VOLCANICS:** basaltic lava, tuff, agglomerate; quartz sandstone, feldspathic sandstone, laminated siltstone, and mudstone

ꝐKcs Feldspathic sandstone

ꝐKl **KING LEOPOLD SANDSTONE:** white to pale-brown, coarse-grained, well-sorted quartz sandstone

Speewah Group

ꝐS Undivided: pale purple-grey to buff quartz sandstone; micaceous in places, minor phyllite; pebble to cobble conglomerate

KIMBERLEY BASIN

p Muscovite pegmatite dyke

c. 1840 Ma

Ꝑgm **MONDOOMA GRANITE:** foliated, quartz-phyric biotite micromonzogranite; minor syenogranite and granodiorite
Ꝑgl **LENNARD GRANITE:** foliated, coarse porphyritic biotite monzogranite; minor syenogranite, granodiorite and non-porphyritic varieties
Ꝑgc **CONE HILL GRANITE:** foliated, coarse porphyritic biotite monzogranite
Ꝑgb **CASCADE BAY MONZOGRANITE:** foliated, coarse porphyritic biotite-muscovite monzogranite
Ꝑgsb **SECURE BAY MONZOGRANITE:** foliated, medium- to fine-grained biotite monzogranite; sparsely porphyritic
Ꝑgn **NELLIE TONALITE:** foliated hornblende–biotite tonalite and granodiorite
Ꝑgq **SQUARE TOP MICROGRANITE:** metamorphosed altered quartz-phyric microgranite; quartz-kyanite-chloritoid rock
Ꝑgt **TARRAJI MICROGRANITE:** foliated, porphyritic biotite micromonzogranite
Ꝑgdp **MOUNT DISASTER PORPHYRY:** foliated, coarse porphyritic biotite micromonzogranite

c. 1850 Ma

Ꝑw **WHITEWATER VOLCANICS:** foliated rhyodacite lava, tuff, and minor volcaniclastic sedimentary rocks; commonly crystal-rich

c. 1880 Ma

Ꝑdr **RUINS DOLERITE:** medium- to fine-grained metadolerite, and minor coarsely porphyritic varieties

c. 1900 Ma

Ꝑm **MARBOO FORMATION:** predominantly low-grade, thin turbiditic metasandstone and quartz-chlorite-muscovite(-biotite-chloritoid) phyllite
Ꝑma Medium-grade quartz-muscovite-biotite(-chlorite) metapsammite and quartz-muscovite-biotite(-chlorite-andalusite-staurolite-garnet-chloritoid) pelitic schist
Ꝑmh Hornfels: quartz-feldspar-muscovite-biotite-garnet metapsammite interlayered with quartz-K-feldspar-muscovite-biotite-sillimanite(-andalusite)-cordierite metapelite

HOOPER COMPLEX

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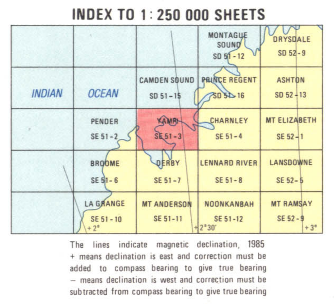
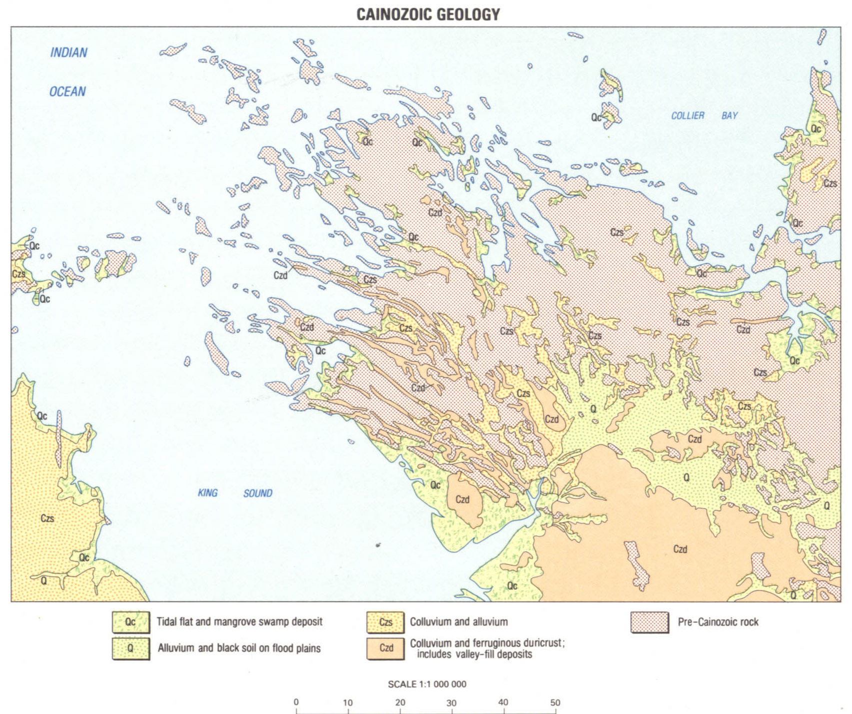


CAINOZOIC GEOLOGY



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ACTING DIRECTOR, GEOLOGICAL SURVEY
OF WESTERN AUSTRALIA

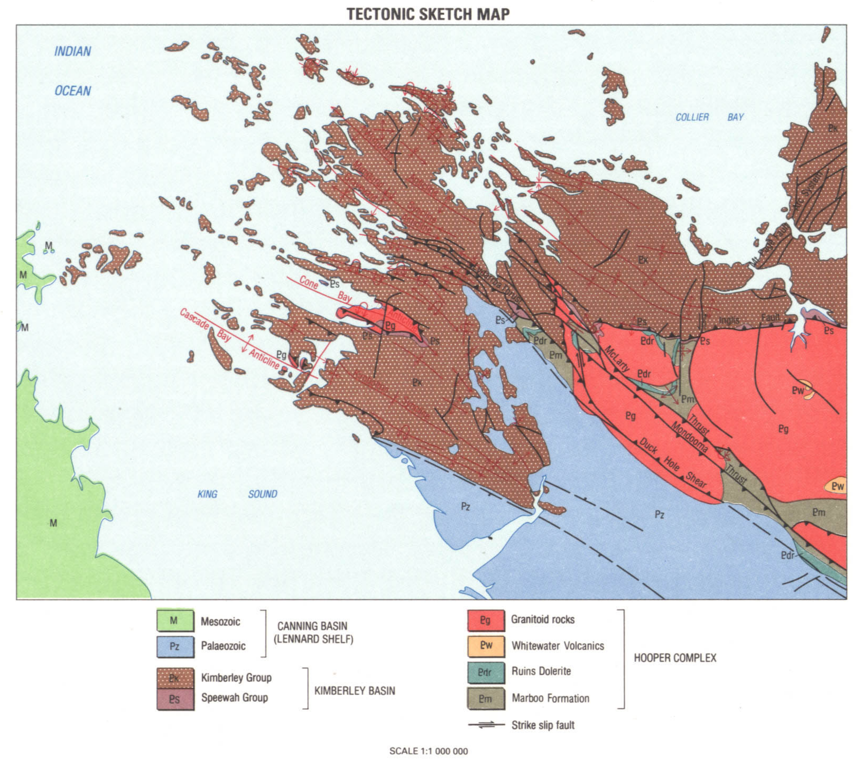
SCALE 1:250 000

5000 Metres 0 5 10 15 20 25 30 Kilometres

TRANSVERSE MERCATOR PROJECTION

ZONE 51 AUSTRALIAN MAP GRID

TECTONIC SKETCH MAP



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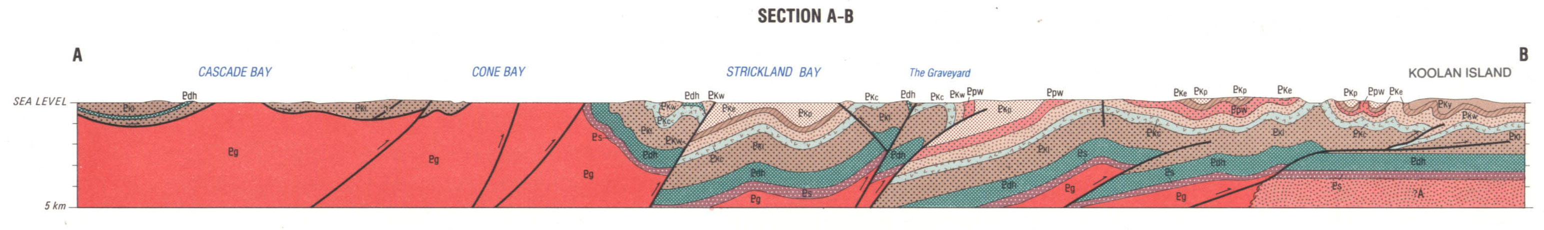
DIAGRAMMATIC SECTIONS

NATURAL SCALE

SECTION A-B



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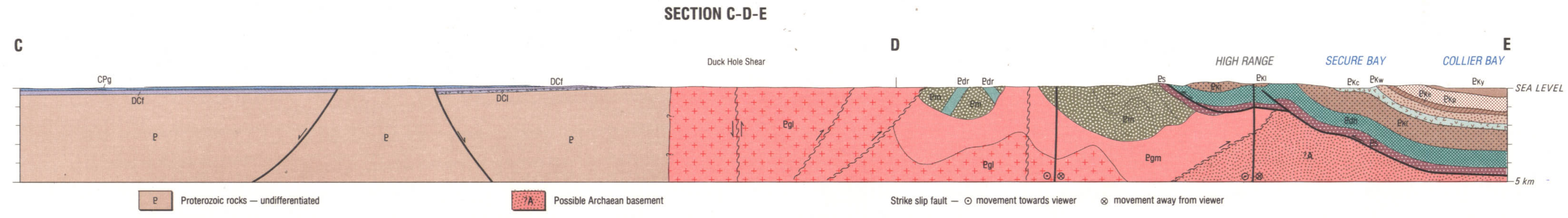

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SHEET SE 51-3

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