GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
1:250 000 GEOLOGICAL SERIES — EXPLANATORY NOTES

NEWMAN

WESTERN AUSTRALIA

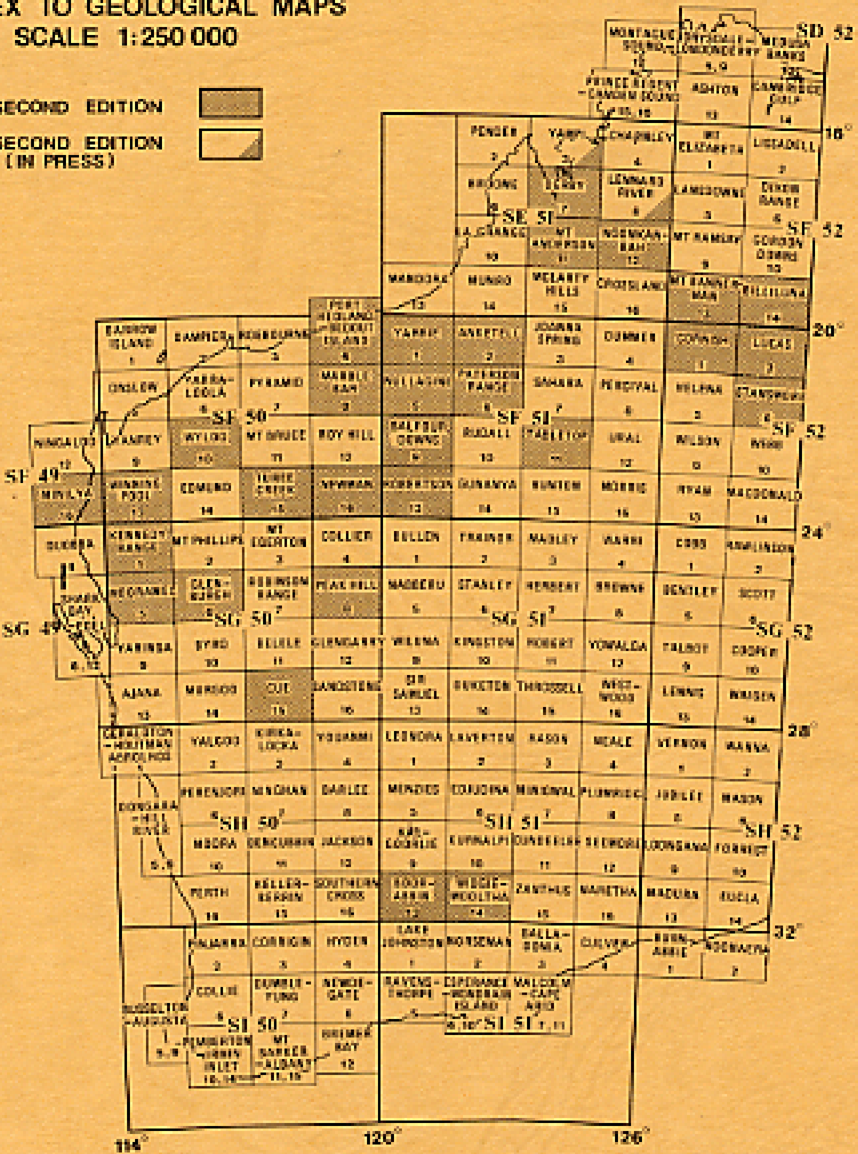
SECOND EDITION

SHEET SF50 – 16 INTERNATIONAL INDEX

WESTERN AUSTRALIA
INDEX TO GEOLOGICAL MAPS
SCALE 1:250 000

SECOND EDITION

SECOND EDITION
(IN PRESS)



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
1:250 000 GEOLOGICAL SERIES — EXPLANATORY NOTES

NEWMAN

WESTERN AUSTRALIA

SECOND EDITION

SHEET SF50 - 16 INTERNATIONAL INDEX

BY

I. M. TYLER, W. M. HUNTER, and I. R. WILLIAMS

PERTH, WESTERN AUSTRALIA 1991

MINISTER FOR MINES
The Hon. Gordon Hill, J.P., M.L.A.

DIRECTOR GENERAL OF MINES
D. R. Kelly

DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
Phillip E. Playford

ISSN 0729 - 3720
National Library of Australia Card Number and ISBN 0 7309 1115 2

Copies available from:
The Director
Geological Survey of Western Australia
100 Plain Street
EAST PERTH WESTERN AUSTRALIA 6004
Ph. (09) 222 3168

CONTENTS

Page

Page

FIGURES

TABLES

Explanatory Notes on the Newman Geological Sheet, Western Australia (Second Edition)

by I. M. Tyler, W. M. Hunter, and I. R. Williams

INTRODUCTION

The NEWMAN* 1:250 000 geological sheet (SF50 – 16 of the International Series) is bounded by latitudes 23°00′ and 24°00′ S, and by longitudes 118°30′ and 120°00′ E. The only town in the sheet area is Newman (population 5466 in 1981), established in the early 1970s to provide accommodation for workers at the Mount Whaleback iron-ore mine. The town is reached from the south via the sealed Great Northern Highway. Northwards from Newman to Port Hedland, the highway is graded. A new highway to the north via Wonmunna and Mount Robinson has been constructed. A standard-gauge single track railway line connects the Mount Whaleback iron-ore mine with the deep-water port at Port Hedland. The Ophthalmia Dam, built across the Fortescue River and Warrawanda Creek, ensures the Newman water supply by providing recharge for underground aquifers. Exploration camps are maintained at Rhodes Ridge, Giles Mini, and West Angelas.

Much of the southern and central part of NEWMAN is pastoral lease used for grazing cattle, and access is via graded roads and station tracks. Homesteads on Prairie Downs and Turee Creek Stations are occupied. Other leases which extend on to NEWMAN are Marillana, Roy Hill, Ethel Creek, Sylvania, Weelarrana, and Bulloo Downs.

The northern part of NEWMAN is mostly vacant Crown land, however extensive exploration for iron ore in the 1960s and 1970s has provided access into many areas. Only the main access roads to the exploration camps are maintained, and extreme care should be taken when negotiating other roads and tracks, particularly drill tracks, which are often steep and badly washed out. The southeast corner of the Hamersley Range National Park occupies a small area in the northwest of NEWMAN.

Geological investigations prior to 1965 are summarized in the first edition explanatory notes (Daniels and MacLeod, 1965). Subsequent studies are referred to in the appropriate sections of this publication.

PHYSIOGRAPHY, VEGETATION, AND CLIMATE

NEWMAN lies on the divide between three major drainages; the Fortescue flowing to the north, the Ashburton flowing to the southwest, and the Savory flowing to the east. The main physiographic units on NEWMAN are the Hamersley Plateau, the Fortescue Valley, and the Kumerina Hills (Beard, 1975, Fig. 3).

---

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

The Hamersley Plateau occupies the northern half of NEWMAN and comprises rugged hill country in the Ophthalmia and Hamersley Ranges. These ranges are characterized by long strike ridges rising over 300 m above the intervening valley floors. Prominent hills are Mount Newman (1055 m), Pamelia Hill (874 m), Mount Robinson (1142 m), and The Governor (1051 m). The highest point, in excess of 1200 m, is at the extreme northwest edge of NEWMAN. Valley floors may contain extensive flats of Cainozoic sediments deposited on the less resistant units of the lower Hamersley Group. In the northeast, the high plateau country is dissected by deep gorges.

The Fortescue Valley occupies the northeast corner of NEWMAN and comprises extensive alluvial flats and sand plain which form the flood plain of the Fortescue River.

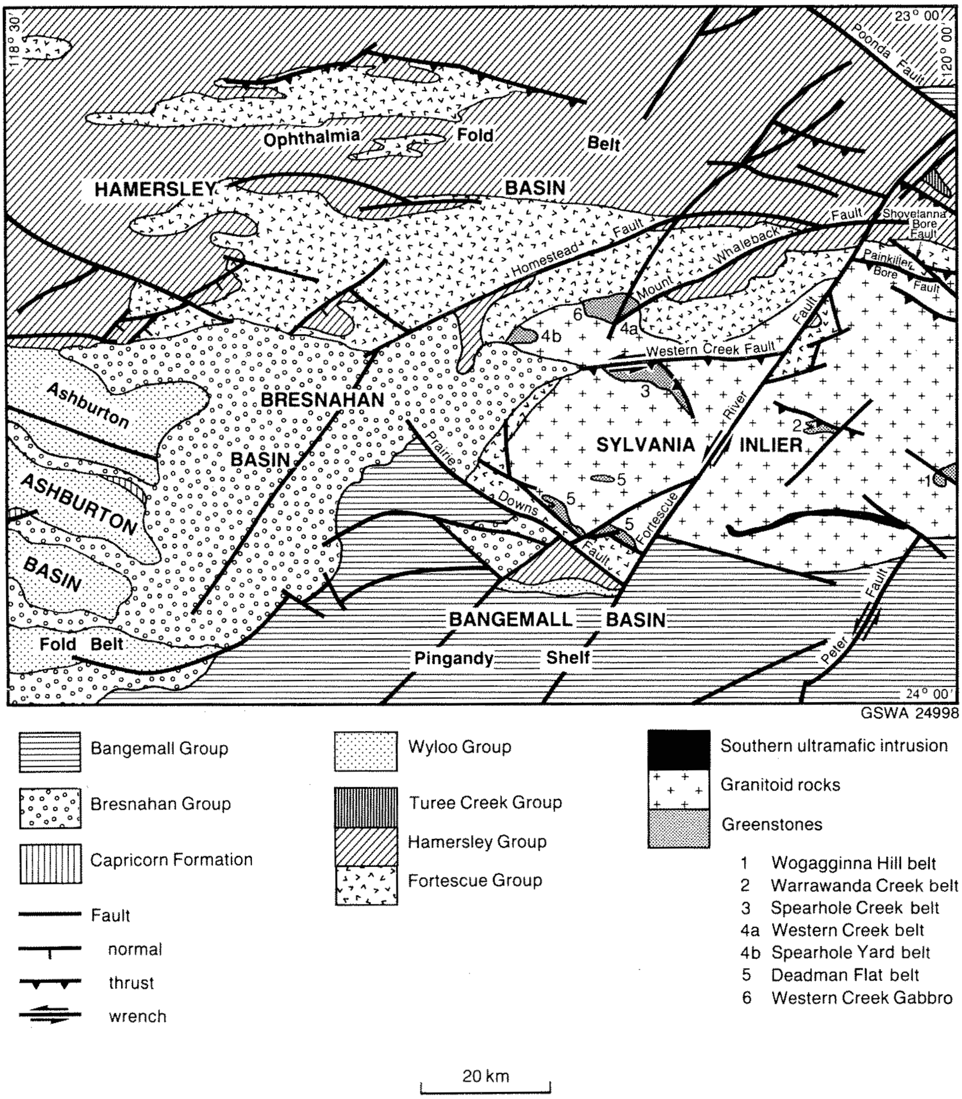


Figure 1. Simplified geological map of NEWMAN showing the principal tectonic and structural units.

The Kumerina Hills comprise gently undulating plain country broken by low rocky hills. Prominent landmarks include Deadman Hill (731 m) and the Kunderong Range. The area underlain by Archaean rocks of the Sylvania Inlier consists mainly of a stony, poorly vegetated plain scattered with low granite tors.

Vegetation in the area has been described by Beard (1975). The Hamersley Plateau consists of tree steppe comprising buck spinifex (*Triodia wiseana*) and snappy gum (*Eucalyptus brevifolia*). Valleys are filled with low mulga woodland. The Fortescue Valley consists of low woodland dominated by shrub steppe (*E. gamophylla and spinifex*) on sandplain. The Kumerina Hills are covered by low mulga woodland and scrub.

Climate is arid with hot summers and mild to warm winters. Winter minimum temperatures may drop below freezing. The long-term average annual rainfall is 300 – 350 mm which derives mainly from intense cyclones in late summer. The area may also be affected by winter rains from the southwest. Watercourses are intermittent, only flowing after prolonged heavy rain, however permanent pools are found in some gorges.

REGIONAL SETTING

The main tectonic features of NEWMAN are shown in Figure 1. NEWMAN is situated at the southeast corner of the Pilbara Craton. From geophysical data, Drummond (1981) interpreted the southern margin of the craton, against the east-trending early Proterozoic (2200 – 1600 Ma) Capricorn Orogen, as lying on COLLIER, 75 km south of Newman.

Archaean granite – greenstone terrane (older than 2750 Ma), which represents cratonic basement, is exposed in the Sylvania Inlier. This is unconformably overlain by the late Archaean to early Proterozoic (2750 – 2300 Ma) Hamersley Basin, which represents a passive continental margin. An initial rift in the relatively cold and brittle continental crust evolved to produce a stable shelf or platform environment. During the Capricorn Orogeny (2200 – 1600 Ma) the southern margin of the Pilbara Craton acted as a foreland and the Hamersley Basin on NEWMAN was deformed to form the southeast part of the Ophthalmia Fold Belt, which is interpreted as a foreland fold and thrust belt. The Ashburton Basin, a foreland basin, developed during the orogeny. The Ashburton Basin is unconformably overlain by the Blair Basin. Both the Ashburton and Blair Basins were deformed to form the Ashburton Fold Belt at a late stage of the orogeny.

Rocks that were involved in the Capricorn Orogeny are unconformably overlain by the Middle Proterozoic Bresnahan Basin (c. 1600 Ma). This basin consists of a series of large alluvial fans, prograding to the southeast, which are related to an extensive extensional fault system. The Bresnahan Basin is unconformably overlain by the northern margin of the Bangemall Basin (1500 – 1100 Ma). Both basins have been interpreted as developing in an intracratonic setting. The Bangemall Basin rocks on NEWMAN were deposited on the Pingandy Shelf, a stable marine shelf developed on the southern margin of the Pilbara Craton.

Extensive faulting post-dates the Bangemall Basin sedimentation and may have taken place periodically throughout the Phanerozoic.

The geological history of NEWMAN is summarized in Table 1.

ARCHAEAN GRANITE - GREENSTONE TERRANE — THE SYLVANIA INLIER

Archaean granite – greenstone terrane (unconformably overlain by 2750 Ma Fortescue Group) outcrops within the Sylvania Inlier (Fig. 1), which extends eastwards onto ROBERTSON (Williams and Tyler, 1989). Daniels and MacLeod (1965) initially referred to the inlier as the "Sylvania Dome", analogous to outcrops of granite – greenstone terrane in the southwest Hamersley Basin. Tyler (1991) has shown that the structural controls on its outcrop are complex and the term "inlier" is preferred.

Small areas of greenstone belt are scattered throughout the inlier (Fig. 1). Elements of the stratigraphy seen in the Jimblebar greenstone belt on ROBERTSON (Williams and Tyler, 1989) can be recognized. Low- to medium-grade metamorphosed and deformed mafic and ultramafic volcanic rocks, clastic metasedimentary rocks, cherts, and banded iron-formations (BIF) are present together with mafic to ultramafic intrusions. All these lithologies show evidence of at least two, and probably three, phases of deformation.

The greenstones are intruded by granitoid rocks. Two granitoid phases are seen: an early banded and/or foliated phase, best developed near Round Hill Bore; and a later, typically undeformed phase. Both the granitoids and the greenstones are intruded by numerous mafic dykes.

GREENSTONE BELTS

Warrawanda Creek greenstone belt (*im, ba, us*)

The Warrawanda Creek greenstone belt outcrops 16 km south of the Capricorn Roadhouse and consists of east-trending quartz – magnetite BIF (*im*), schistose amphibolite (*ba*) and a serpentinite sill (*us*), all extensively intruded by granitoid.

Spearhole Creek greenstone belt (*ih, bg, us, ua*)

The Spearhole Creek greenstone belt outcrops along the southern side of Spearhole Creek, 7 km southwest of Outcamp Well. It is dominated by quartz – hematite – magnetite BIF (*ih*), together with lithologies which represent a layered mafic sill (*bg*) younging to the northeast. Along the southern margin of the belt, serpentinite (*us*) and ultramafic schist (*ua*) is associated with minor weakly foliated amphibolite, containing relict amygdales.

Western Creek and Spearhole Yard greenstone belts (*lq, ih, ba*)

Two areas of greenstone belt outcrop in the northwest part of the inlier, one on Western Creek and the other north of Spearhole Yard. Both are dominated by clastic metasedimentary rocks (*lq*) and BIF (*ih*). Minor amphibolite derived from metabasalt (*ba*) is also present, together with a calcareous schist representing recrystallized tuff.

Clastic metasedimentary rocks (*lq*) comprise well-foliated, fuchsitic metaquartzite and metasandstone. North of Spearhole Yard a fuchsitic metaconglomerate overlies metasandstone in the core of a major synform. The conglomerate contains matrix-supported, recrystallized quartz pebbles (2 – 3 cm long).

TABLE 1. SUMMARY OF THE GEOLOGICAL HISTORY OF NEWMAN

(1) Deposition of greenstones probably equivalent to the Gorge Creek Group (3000 – 2800 Ma) of the northern Pilbara greenstones. Intrusion of mafic – ultramafic sills.

(2) Intrusion of precursor to banded and/or foliated granitoid (*gm*).

(3) Deformation and metamorphism of greenstones and early granitoid (D_{1g}, M_g, D_{2g}, D_{3g}).

(4) Intrusion of Western Creek Gabbro, and a layered sill southeast of Bubbacurry Well.

(5) Intrusion of "main granitoid" (*ge, gv*), metasomatism of part of Western Creek Gabbro.

(6) Intrusion of north-northeast mafic dykes (d_1).

(7) Intrusion of east – west mafic and ultramafic dykes (d_2, us_2).

(8) Period of uplift and erosion followed by rifting and initiation of the Hamersley Basin with eruption of basic and acid volcanics of the Fortescue Group (c. 2750 Ma).

(9) Stable shelf conditions, deposition of the Hamersley Group dominated by banded iron-formations (c. 2500 Ma).

(10) Deposition of the clastic metasediment-dominated Turee Creek Group. Evidence of static metamorphism (M_h) under greenschist facies and epidote – albite amphibolite facies conditions preserved in granitoid rocks and d_1 mafic dykes.

(11) Uplift and erosion along craton margin, establishment of Ashburton Basin (c. 2000 Ma). Deposition of lower Wyloo Group.

(12) Formation of Ophthalmia Fold Belt (D_{1c}, D_{2c}) and uplift of Sylvania Inlier during collision between the Pilbara and Yilgarn Cratons. Metamorphism (M_c) of Hamersley Basin rocks under pumpellyite – actinolite facies and greenschist facies conditions. Grade reaches albite – epidote amphibolite facies in Sylvania Inlier.

(13) Intrusion of west-southwest and west-northwest mafic dykes (d_3 and d_4).

(14) Deposition of middle and upper Wyloo Group.

(15) Uplift and erosion during early stages of the Ashburton Fold Belt, followed by deposition of the Capricorn Formation.

(16) Main deformation in Ashburton Fold Belt (D_{2a}) driven by dextral wrench faulting on craton margin.

(17) Uplift and erosion, formation of Bresnahan Basin (c. 1600 Ma). Mount Whaleback Fault forms as part of associated fault system. Formation of main hematite ore bodies.

(18) Intrusion of northwest mafic dykes (d_5).

(19) Uplift and erosion, establishment of the Bangemall Basin (1500 – 1100 Ma). Prairie Downs and Poonda Faults active.

(20) Intrusion of east – west mafic dyke (d_6). Intrusion of mafic sills into Bangemall Group.

(21) Intrusion of north-northeast (d_7) and west-northwest (d_8) mafic dykes.

(22) Late sinistral faulting (?Phanerozoic) on northwest Shovelanna Bore Fault and northeast Fortescue River and Peter Faults.

(23) Formation of Hamersley Surface in late Mesozoic/early Tertiary. Formation of Marra Mamba Iron Formation orebodies. Hamersley Surface is uplifted and dissected.

Deadman Flat greenstone belt (*bg, us, ba, ua, ic, la*)

The Deadman Flat greenstone belt is exposed as a series of discontinuous xenoliths in granitoid at the southwest margin of the inlier, north of Deadman Hill. It consists of deformed remnants of a layered mafic intrusion (*bg, us*) together with an interlayered sequence of amygdaloidal metabasalt (*ba*), ultramafic schist (*ua*), chert (*ic*) and quartz – muscovite schist (*la*) which may represent a crystal – lithic tuff.

Rocks that formed the layered intrusion are now thoroughly recrystallized; metagabbro is typically foliated and lineated, and comprises medium- to coarse-grained amphibole (actinolite or grunerite), epidote, albite, sericite and sphene. Locally, small- and medium-scale layering can be recognized and the presence of grunerite suggests primary Fe-rich, Al-poor layers.

Higher-grade amphibolite comprising hornblende, plagioclase, and quartz crops out near Curly Bore. A discontinuous ridge of serpentinite (*us*) is associated with metagabbro west of Jillary Well.

MAFIC INTRUSIONS

Western Creek Gabbro (*bg, go*)

Fine- to coarse-grained, undeformed metagabbro (*bg*) intrudes into the Western Creek greenstone belt. It is itself intruded by the later granitoid, and granitoid veins are common.

Typically the rock is massive and homogeneous comprising actinolite, epidote, albite and quartz, with minor amounts of biotite and sphene. Grunerite is present in some specimens. Primary ophitic textures can be recognized.

Where the Newman – Prairie Downs road crosses Western Creek, a petrographically unusual suite of mafic to felsic coarse-grained rocks (*go*) outcrops. Their field relationships are similar to those of the metagabbro. Leucocratic and melanocratic varieties are present, with subhedral megacrysts of albite, up to 3 cm long, in a matrix of medium-grained albite, green biotite, and quartz. Sphene, apatite, and allanite occur with minor carbonate and chlorite.

Igneous features typical of layered mafic intrusions are common (cumulus textures, rhythmic layering) within this unusual suite of rocks. Tyler (1991) has speculated that the unusual composition (monzodioritic to quartz diorite) is the result of metasomatism, probably during granitoid intrusion. The rocks were recrystallized during a later low-grade burial metamorphism.

Other intrusions

Medium- to coarse-grained, foliated or banded amphibolite (*bg*) is exposed to the southeast of Bubbacurry Well. The amphibolite has been intruded by granitoid, and represents the metamorphosed and deformed remnants of a layered mafic intrusion. The rock is thoroughly recrystallized, and is composed of hornblende, plagioclase (oligoclase – andesine), epidote, clinozoisite, quartz, and rare biotite with minor sphene, apatite, and opaques.

GRANITOID ROCKS

Granitoid rocks form the most extensively exposed units within the inlier. Two types are recognized: an early foliated and/or banded granitoid; and a later, generally undeformed granitoid. The later granitoid is the most extensive and will be referred to as the "main granitoid".

Samples collected near Round Hill Bore give Rb – Sr dates of 2755 ± 200 Ma (Ri = 0.7032) for the foliated and/or banded granitoid, and 2800 ± 240 Ma (Ri = 0.7007) for the main granitoid (Tyler et al., in prep.). An isochron combining both sample suites gives a date of 2755 ± 105 Ma (Ri = 0.7028). Tyler et al. (in prep.) have interpreted the dates as the result of resetting due to burial under the Hamersley Basin. Sm – Nd model ages of T_{DM} = 3155 Ma and T_{DM} = 3092 Ma for the foliated and/or banded granitoid, and T_{DM} = 3315 Ma for the main granitoid have been also obtained from the vicinity of Round Hill Bore (Tyler et al., in prep.)

Foliated and/or banded granitoid (*gm*)

Foliated and/or banded granitoid is most extensively exposed west of Round Hill Bore and Jillary Well. It is also well exposed near Bubbacurry Well. It is typically intruded, and extensively veined, by the "main granitoid".

The unit ranges from monzogranite to granodiorite in composition and varies considerably in grain size. Fine-grained varieties are typically more mafic and schistose than coarser varieties. The foliation may be folded, as are associated pegmatite veins.

The rock is thoroughly recrystallized; mineral assemblages are metamorphic and comprise greenish-brown biotite, epidote, albite or oligoclase – andesine, microcline (usually perthitic), muscovite and quartz, with minor amounts of sphene, apatite, fluorite, and opaques. Albite is characteristically sieved by fine, unoriented grains of epidote. The foliation is picked out by strings of randomly oriented biotite flakes intergrown with rounded epidote.

The "main granitoid" (*ge, gv*)

The main granitoid consists of a medium to coarse, even-grained (*ge*) to sparsely porphyritic (*gv*) monzogranite to granodiorite. The porphyritic variety contains microcline and plagioclase megacrysts which can reach 2 cm in length. A true porphyritic rock is usually not developed and megacrysts rarely exceed 10 – 15% of the rock. Even-grained varieties grade into sparsely porphyritic varieties. Medium, even-grained syenogranite to monzogranite occurs as widespread dykes, veins, and patches in the main granitoid.

The rock is recrystallized and mineral assemblages are similar to those of the early granitoid with the addition of rare garnet. Albite is sieved by fine epidote and muscovite.

STRUCTURE

Structures in greenstones

Williams and Tyler (1989) identified three periods of deformation within the Jimblebar greenstone belt on ROBERTSON (D_{1g} – D_{3g}). Structures that can be related to these three deformatons have been identified on NEWMAN.

As on ROBERTSON the occurrence of D_{1g} is inferred mainly from the presence of a layer-parallel foliation deformed by D_{2g}. Small-scale isoclinal D_{1g} folds are locally preserved.

A major D_{2g} fold closure occurs in the Spearhole Yard greenstone belt. The fold is isoclinal, and from the plunge of small-scale folds is regarded as a west-plunging synform. Facing evidence is not available.

Open D_{3g} fold closures are recognized in the Spearhole Creek, Western Creek, and Spearhole Yard belts. These form a conjugate set plunging to the southwest and southeast; a crenulation cleavage is developed. The D_{2g} fold at Spearhole Yard is refolded by a D_{3g} structure.

Structures in granitoid rocks

Foliated and/or banded granitoid (*gm*) is not seen in contact with greenstone belts. Folding is generally tight, and affects associated pegmatites, which may also show pinch-and-swell structures. It is probable that establishment of the foliation and the banding corresponds to D_{1g} structures in greenstone belts with folding of the banding being D_{2g} in age.

METAMORPHISM

Metamorphism of the greenstone belts, M_g, and the early foliated and/or banded granitoid (*gm*) generally occurred under greenschist facies conditions during the D_{1g} deformation event. Foliated amphibolite (*ba*) near Curly Bore appears to record higher-grade conditions, transitional between greenschist facies and amphibolite facies.

POST-GRANITOID MINOR INTRUSIONS

Tyler (1991) has divided into three groups the mafic dykes outcropping within the Sylvania Inlier: those predating greenstone belt deformation; those which predate the Capricorn Orogeny; and those which were intruded after deformation associated with the Capricorn Orogeny.

On NEWMAN the first group is not seen, and the earliest dykes (d_1) trend north-northeast and intrude both greenstones and granitoids. They are not seen to intrude the overlying Fortescue Group and are presumed to predate the unconformity in this area. Based on their orientation and field relations they are correlated with the Black Range dyke swarm of the northern Pilbara Craton (Hickman and Lipple, 1975).

The dykes in the western part of the Sylvania Inlier show little evidence of deformation. In the eastern part, reorientation of the dykes, together with associated foliation development, is seen. Individual dykes range from a few metres to more than 200 m in width. Intrusion has been complex; several dykes may coalesce, while later dykes cut earlier formed ones. *En echelon* intrusion patterns are common with dyke sections offset up to 100 m.

Near Round Hill Bore dykes are numerous with about two occurring every kilometre. Tyler (1991) has calculated that they represent a local extension of 14%.

Mineral assemblages in the dykes comprise amphibole, plagioclase (albite or oligoclase-andesine replacing relict laths of labradorite) and quartz with minor amounts of sphene, apatite, iron oxides, chlorite, epidote, and biotite. Primary igneous textures are commonly preserved.

A major east-trending dyke-like intrusion of serpentinite (us_2), which truncates d_1 dykes, occurs towards the southern margin of the inlier. For most of its outcrop it is capped by massive opaline silica (uz_2). In places, east-trending metadolerite dykes (d_2) are also present.

HAMERSLEY BASIN

The Hamersley Basin is a late Archaean to early Proterozoic (2750 - 2300 Ma) depositional basin occupying most of the southern part of the Pilbara Craton (Trendall, 1983). Three stratigraphic groups are recognized (Table 2): the mafic volcanic-dominated Fortescue Group, whose base has been dated elsewhere at c. 2750 Ma (Pidgeon, 1984; Richards and Blockley, 1984); the banded iron-formation dominated Hamersley Group dated at c. 2500 Ma (Compston et al., 1981); and the more restricted, clastic dominated Turee Creek Group.

On NEWMAN, Hamersley Group rocks occur principally in the northern half of NEWMAN but are also present to the south of the Sylvania Inlier, around Deadman Hill.

FORTESCUE GROUP

Fortescue Group rocks outcrop throughout NEWMAN (Fig. 1), however the mafic volcanic-dominated lower part of the group is restricted to the margins of the Sylvania Inlier. Daniels and MacLeod (1965) did not recognize any mafic units, and mapped the Jeerinah Formation as overlying a basal clastic sedimentary unit, which was correlated with the Hardey Sandstone. Where it is not faulted, the contact between the inlier and Fortescue Group is unconformable.

Two successions can be identified in the lower Fortescue Group exposed adjacent to the Sylvania Inlier (Fig. 2): a southwestern succession described by Tyler (1986) who correlated units directly with the southwest Hamersley Basin succession; and a northern succession described by Horwitz (1976) and Tyler (1991). Horwitz correlated the northern succession with the Pillingini Tuff and the Maddina Volcanics of the northern Pilbara Craton. In this publication it is felt that correlations between successions recognized on NEWMAN and those described from the northern Pilbara Craton and the southwest Hamersley Basin are not well enough established to allow formal naming of units below the Jeerinah Formation. Informal names are preferred, based on those used by Tyler (1986).

Blake and Groves (1987) have interpreted the mafic volcanic-dominated lower part of the group as developing in a continental rift environment established on relatively cold, cratonized Archaean crust.

Basal metasedimentary unit (*Fs*)

The basal metasedimentary units recognized at the base of the southwestern and the northern successions of the Fortescue Group are not regarded as time equivalents. It is more likely that their relationship is diachronous, with the Fortescue Group lapping onto a basement palaeohigh to the north and east. The existence of such a palaeohigh has been suggested by several authors (Horwitz and Smith, 1978; Blake, 1984; Blight, 1985).

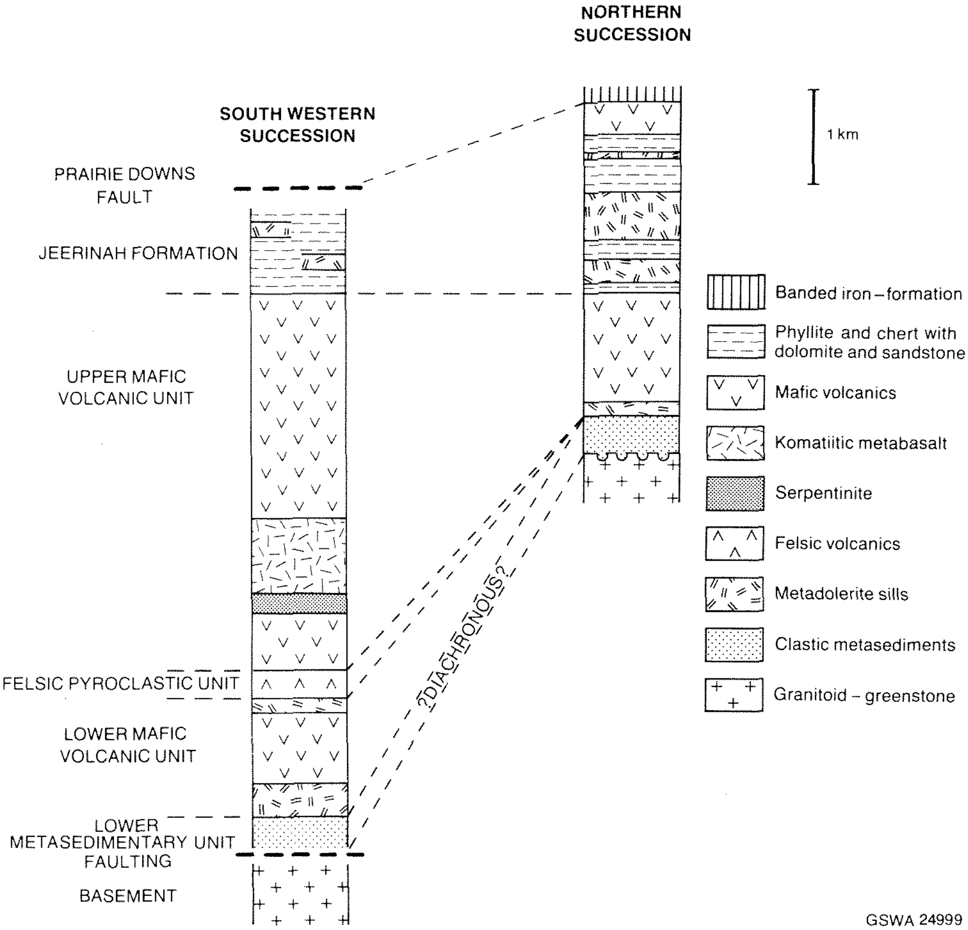


Figure 2. Stratigraphy of Fortescue Group rocks adjacent to the Sylvania Inlier.

In the southwestern succession, the lower metasedimentary unit is 200 m thick and consists of interbedded phyllite, quartz – muscovite schist, cross-laminated medium- to coarse-grained metasandstones, and peloidal carbonate. Local conglomeratic units, containing vein quartz and lithic fragments in a shaly matrix, are also present.

In the northern succession, the basal metasedimentary unit is 400 – 500 m thick and consists of interbedded parallel-laminated polymict conglomerate, coarse-grained sandstone, and shale. Conglomerate, which ranges from a few centimetres to several metres thick, is poorly sorted with sub-angular to sub-rounded clasts. It varies from clast-supported, with a coarse matrix, to matrix-supported, with a fine shaly matrix. Clasts are locally derived, and consist of vein quartz together with greenstone lithologies.

Lower mafic volcanic unit (*Fbo*)

The lower mafic volcanic unit is exposed in the southwestern succession overlying the basal metasedimentary unit. It is 750 m thick and comprises interlayered fine- to medium-grained mafic tuff and metabasalt with individual layers being 2 – 3 m thick. The rocks typically contain actinolite, chlorite, albite and epidote, with minor amounts of sphene and iron oxides.

TABLE 2. STRATIGRAPHY OF THE HAMERSLEY, ASHBURTON, AND BLAIR BASINS

Basin	*Group*	*Formation*	*Member*
Blair Basin		Capricorn Formation	
		unconformity	
Ashburton Basin	Wyloo Group	unassigned dolomite	
		Ashburton Formation	
		Mount McGrath Formation	
		unconformity	
		Beasley River Quartzite	
		unconformity	
Hamersley Basin	Turee Creek Group		
	Hamersley Group	Boolgeeda Formation	
		Woongarra Volcanics	
		Weeli Wolli Formation	
		Brockman Iron Formation	Yandicoogina Shale Member Joffre Member Whaleback Shale Member Dales Gorge Member
		Mount McRae Shale	
		Mount Sylvia Formation	
		Wittenoom Dolomite	West Angelas Shale Member
		Marra Mamba Iron Formation	Mount Newman Member MacLeod Member Nammuldi Member
	Fortescue Group	Jeerinah Formation	
		Upper mafic volcanic unit	
		Felsic pyroclastic unit	
		Lower mafic volcanic unit	
		Basal metasedimentary unit	
		unconformity	
		granite – greenstone terrane	

Thin, Ca-rich fine-grained metasedimentary units are also present, now forming quartz-actinolite – epidote schists.

Felsic pyroclastic unit (*Fbp*)

A felsic pyroclastic unit overlies the lower mafic volcanic unit in the southwestern succession. It is 300 m thick and comprises felsic tuff, locally laminated, overlain by a 5 – 10 m thick banded chert. Much of the tuff is massive and recrystallized, and consists of quartz, biotite, muscovite and, less commonly, feldspar. Iron oxides replace sulphides. Shards and subhedral feldspar crystals occur in some samples.

Upper mafic volcanic unit (*Fbu*)

The upper mafic volcanic unit occurs in both the southwestern and the northern successions. In the southwestern succession it is a 4-km thick monotonous sequence of fine- to medium-grained, locally feldspar-phyric, metabasalt containing epidote, chlorite, and actinolite with some relict feldspar. Igneous textures can be recognized; epidote, sericite, and albite intergrowths pseudomorph feldspar laths which were up to 1 cm in length.

A thick (1 km) unit of komatiitic metabasalt (*Fbk*) interbedded with thin ultramafic tuff occurs near Nirran Nirry Bore. A serpentinite sill (*Fus*) is present at the base of the unit. The komatiitic metabasalt shows good spinifex textures with tremolite – actinolite replacing pyroxene needles up to 3 cm long in a matrix of epidote, amphibole and chlorite with minor sphene, quartz, and albite. Locally the unit is variolitic. The serpentinite probably represents a high-level feeder to the volcanics rather than the differentiated base of a single flow as suggested by Tyler (1986).

In the northern succession, a single mafic volcanic unit, 1.2 km thick, overlies the lower metasedimentary unit, and, as it passes conformably up into the Jeerinah Formation, it is probably a lateral equivalent of the upper unit in the southwestern succession. In the northern succession it consists of both massive and amygdaloidal metabasalt, and mafic tuff. Flows may develop spinifex-type textures, however the rocks are quite felsic and do not have high-Mg compositions. The textures are interpreted as the result of rapid cooling.

Jeerinah Formation (*Fj*)

In the southwestern succession, the Jeerinah Formation is dominated by phyllite interbedded with 2 – 3 m thick silicified mudstone and chert units. The formation is 900 m thick, including mafic sills.

Similar lithologies occur in the northern succession where the formation is 2 km thick. Mafic sills make up 850 m of this succession. At the base of the formation, Horwitz (1976) records 100 m of "chertified current-bedded sediment" overlain by "125 m of sandy and gritty, ferruginized quartzitic sandstone and some shales". Later he correlates this with the Woodiana Sandstone Member, a unit well developed in the northern Pilbara Craton (Horwitz, 1987). East of Western Creek, the lower part of the Jeerinah Formation consists of interbedded shaly mudstone and laminated siltstone; no sandstone or cross-laminations have been recognized in this area.

Felsic tuffs and thin dolomite occur extensively in the upper part of the Jeerinah Formation and are well exposed in the Wonmunna Anticline.

Near Mount Whaleback a metabasalt unit (*Fjb*) containing well-developed pillows (Blockley et al., 1980) occurs beneath the Marra Mamba Iron Formation. This unit can be traced westwards, south of Western Ridge, and is also present in the Wonmunna and Alligator Anticlines.

MAFIC SILLS (*Fd*)

Mafic sills are intruded throughout the Fortescue Group. They are best developed within the Jeerinah Formation where they can make up over 50% of the exposed section. However, sills are absent from Jeerinah Formation at the eastern end of NEWMAN.

The sills consist of fine- to coarse-grained metadolerites which have preserved ophitic to poikilitic igneous textures. Clinopyroxene may be preserved as plates up to 7 mm across which show alteration to chlorite and/or actinolite. Plagioclase laths are invariably albitized; some have been replaced by intergrowths of sericite and epidote – clinozoisite. Iron oxides are leucoxenized. Pumpellyite is present in some samples. Large-scale primary igneous layering occurs with the development of metapyroxenite at the base of several sills.

HAMERSLEY GROUP

The Hamersley Group on NEWMAN is part of the well-known stratigraphic sequence (Table 1) which is seen throughout the Hamersley Basin (MacLeod et al., 1963; MacLeod, 1966; Trendall and Blockley, 1970).

Due to the lack of modern analogues there has been considerable speculation concerning the environment of deposition of the BIF units within the Hamersley Group. Models range from a restricted barred basin, closed to the south (Trendall and Blockley, 1970; Trendall, 1975a); through a shelf environment open to the ocean to the north-west (Horwitz and Smith, 1978; Ewers and Morris, 1981); to a platform or bank isolated from adjacent landmasses (Morris and Horwitz, 1983; McConchie, 1984). These authors have also discussed the possible mechanisms of BIF deposition.

Marra Mamba Iron Formation (*Hm*)

The Marra Mamba Iron Formation can be divided into three units (Trendall and Blockley, 1970) and these have been formally established as members (Kneeshaw, 1984; Blockley et al., in prep.). In the Newman area the units have been described in detail by Slepecki (1981), and the formation here is 145 m thick. Good sections are present in gorges in the Wonmunna area.

The lowest unit is the Nammuldi Member, which consists of 70 m of yellow-weathering chert and cherty BIF with some shale bands. Towards the top of the unit, chert podding is common with the development of a marker band known as the "potatoes". The middle unit is the MacLeod Member, which comprises 25 m of shale with relatively thin BIFs. The upper unit is the Mount Newman Member consisting of 50 m of BIF with 18 thin shale bands.

Wittenoom Dolomite (*Hd*)

The Wittenoom Dolomite is generally poorly exposed, particularly in the eastern part of NEWMAN. However, good exposures are present in the headwaters of Weeli Wolli Creek and in the vicinity of The Governor.

Slepecki (1981) described a 36 m thick Mn-rich shale unit, with minor BIF and chert, overlying the Mount Newman Member of the Marra Mamba Iron Formation. It was included within a four-fold subdivision of that formation. Subsequently the shale unit has been named the West Angelas Shale Member (Blockley et al., in prep.) and has been placed at the base of the Wittenoom Dolomite. It is absent from the western part of the basin prompting suggestions that it results from leaching during ore formation. However, its presence above unmineralized Marra Mamba Iron Formation in the eastern part of the basin has been proved by drilling (Slepecki, 1981).

Above the basal shale the Wittenoom Dolomite can be divided into two, the lower part comprising massive crystalline dolomite that passes into an upper part comprising interbedded thin shales, cherts, dolomites and minor BIF. Daniels and MacLeod (1965) estimated the unit was 152 m (500 feet) thick.

Mount Sylvia Formation and Mount McRae Shale (*Hs*)

The Mount Sylvia Formation consists of shale, dolomite, and three BIF bands. A BIF band marks the top and the bottom of the unit, the uppermost being the distinctive "Brunos Band". Kneeshaw (1975) records the presence of a 21 m thick feldspathic sandstone between the central and the upper BIF bands. Total thickness of the unit is 45 m at Mount Whaleback.

The Mount McRae Shale consists of black graphitic and chloritic shales, with interbedded BIF and shale forming the upper part. At Mount Whaleback the BIFs are mineralized. In the middle of the formation several zones carry abundant pyrite nodules up to 5 cm across. Minor chert bands are also present. Where the formation is unenriched, it is up to 30 m thick.

Brockman Iron Formation (*Hb*)

The Brockman Iron Formation is the thickest and economically the most important iron formation unit within the Hamersley Group. On NEWMAN it forms prominent strike ridges which rise 200 – 400 m above the surrounding country. It has been divided into four members (Trendall and Blockley, 1970).

The basal unit is the Dales Gorge Member which has been described in detail by Trendall and Blockley (1968, 1970) and Ewers and Morris (1981). It comprises an alternating sequence of 17 BIF and 16 shale "macrobands". At Mount Whaleback the upper member of the Mount McRae Shale is mineralized and is included within the local definition of the Dales Gorge Member (Kneeshaw, 1975). Trendall and Blockley (1970) recorded thicknesses of 119 m at Mount Newman and 107 m at Giles Point for the Dales Gorge Member. The thickness of the member increases towards the north and the west. The Whaleback Shale Member consists of 30 m of shale interbedded with chert and BIF. Kneeshaw (1975) divided the unit into three zones: a basal shale zone, a central chert band, and an upper shale zone. McConchie (1984) identifies the lower shale as dominated by pyritic black shale, while the upper unit is dominated by carbonate-rich material. A prominent BIF outcrops at the base of the central chert band. The Whaleback Shale

Member forms a strike gully and provides a marker useful in unravelling local structure. The Joffre Member consists dominantly of BIF with minor shale bands. The unit is 340 m thick at Mount Whaleback (Kneeshaw, 1975). The uppermost unit is the Yandicoogina Shale Member which is poorly exposed, and in the Newman area consists of 30 m of shale and BIF. The total thickness of the Brockman Iron Formation at Mount Whaleback is approximately 520 m.

Weeli Wolli Formation (*Hj*)

Weeli Wolli Formation consists of interbedded BIF, chert, and shale intruded by several metadolerite sills (*Hjd*). BIF is commonly jaspilitic. Daniels and MacLeod (1965) measured a 366 m (1200 feet) section near Kalgan Creek, over half of which was metadolerite.

The metadolerite is fine to medium grained with subophitic igneous textures preserved. Relict pyroxene is common and may be altered to chlorite, or more rarely stilpnomelane and/or actinolite. Feldspar is albitized. Chlorite, epidote, pumpellyite, and prehnite are also present. Iron oxides are typically leucoxenized.

The metadolerite is generally regarded as being in sills; chilled margins and transgressive relationships can be seen. A.F. Trendall (personal communication, 1987) has reported pillows in outcrops at Coondiner Creek, 3 km north of Eagle Pool. From their morphology the pillows are thought to indicate intrusion into wet sediment.

Woongarra Volcanics (*Hw*)

The Woongarra Volcanics are well exposed in the northeast corner of NEWMAN. The unit comprises quartz-phyric and K-feldspar-phyric rhyodacite and rhyolite. Albitized plagioclase and secondary chlorite are present in a devitrified, commonly spherulitic-textured, quartzo-feldspathic groundmass. In some rocks, the preserved textures are consistent with a fragmental, tuffaceous origin. Daniels and MacLeod (1965) reported a 294 m (965 feet) measured section of Woongarra Volcanics near Kalgan Creek.

A distinctive rock that has the appearance of a welded tuff is present at the top of the formation. It contains blocks of jaspilitic BIF up to 20 cm across. A discontinuous jaspilitic BIF band in the central section of the Woongarra Volcanics has been noted as a distinctive feature of the formation in the northeast corner of NEWMAN.

Boolgeeda Iron Formation (*Ho*)

The Boolgeeda Iron Formation is the uppermost unit of the Hamersley Group. Trendall and Blockley (1970) suggested that it can be subdivided into an upper and lower iron-formation separated by a poorly exposed median shale unit. The lower BIF is typically a dense, black to dark-brownish, well-laminated rock which has a flaggy appearance. The upper BIF is typically finer grained, and is finely laminated and rather shaly in appearance. The formation is 220 m thick.

TUREE CREEK GROUP (*TU*)

Finely laminated dark-brown shale outcrops in the core of a syncline 10.5 km south-east of Kalgan. This apparently lies conformably on the Boolgeeda Iron Formation and is correlated with the Turee Creek Group.

METAMORPHISM

Granitoid rocks and d_l mafic dykes exposed in the Sylvania Inlier west of the Fortescue River Fault (Fig. 1) preserve evidence of a static metamorphic event under greenschist facies and albite – epidote amphibolite facies conditions. Tyler (1991) has interpreted this event as equivalent to the burial metamorphism (M_h) recognized by Smith et al. (1982) in the overlying Hamersley Basin rocks.

ASHBURTON BASIN

WYLOO GROUP

Rocks that were deposited in the Lower Proterozoic (c. 2000 Ma) Ashburton Basin (Thorne and Seymour, 1991) are restricted to relatively small areas of outcrop at the western edge of NEWMAN and to the south of Deadman Hill. The stratigraphy is shown on Table 2.

Units of the lower Wyloo Group are seen to unconformably overlie Hamersley and Turee Creek Group rocks on WYLOO and TUREE CREEK (Trendall, 1979; Seymour et al., 1988; Thorne and Tyler, in press). Beasley River Quartzite unconformably overlies Weeli Wolli Formation south of Deadman Hill.

Beasley River Quartzite (*Wq*)

Beasley River Quartzite outcrops 21 km northwest of Turee Creek Homestead and to the south of Deadman Hill. It consists of fine- to coarse-grained sandstones that may show extensive cross-lamination. The unit can be extensively silicified. Characteristics of the formation throughout the Ashburton Basin have been described by Thorne and Seymour (1986; 1991) who interpreted it as a tide-influenced fan-delta system developed at the edge of the Pilbara Craton.

Mount McGrath Formation (*Wm*)

The Mount McGrath Formation forms isolated outcrops of massive coarse sandstone containing abundant BIF fragments, 15 km northwest of Turee Creek Homestead. Its relationship to other units has not been observed.

Ashburton Formation (*Wa*)

Ashburton Formation, which comprises green and black mudstones interbedded with sandstone and dolomite, is exposed in the southwest corner of NEWMAN. It is intruded by dolerite sills.

Undifferentiated Wyloo Group (*Wo*)

The Wyloo Group on NEWMAN includes several outcrops of stromatolitic dolomite (*Wo*). Where way-up features are present near Saltwater Pool, the dolomite appears to overlie the Ashburton Formation.

Two forms of stromatolite are present (K. Grey, personal communication, 1989), and these are quite distinct from taxa previously recorded from the Duck Creek Dolomite exposed on WYLOO (Grey, 1985).

Two small hills, 15 km north-northwest of Turee Creek Homestead, consist of domical bioherms of yellow-weathering dolomite containing a columnar stromatolite (Grey, 1981a) that resembles *Patomia* f. indet. Walter 1972. This form also occurs 8 km southwest of Turee Creek Homestead. The bioherms are formed by tall, narrow, widely spaced columns, which are characterized by smooth, steeply convex laminae. The stromatolites probably developed sub-aqueously in a shallow lagoon. Assignment of this form to *Patomia* may be incorrect (Grey, 1981a) but detailed systematic studies are required to resolve problems of identification.

An unidentified stromatolite form of pseudogymnosolenid type occurs 9 km west-southwest and 8 km southwest of Turee Creek Homestead (in the outcrop referred to above). It is also present 4 km west of Indabiddy Pool, and at the western end of the Kunderong Range on TUREE CREEK (Grey, 1981b). The stromatolite forms planar biostromes of millimetre-sized digitate columns and pseudocolumns, which are finely laminated and in which identical laminae are found in contiguous columns. It probably grew in shallow water conditions with intermittent subaerial exposure.

BLAIR BASIN

CAPRICORN FORMATION (*R*)

Capricorn Formation (*R*) rocks occur in a series of small outcrops along the southern margin of the Kunderong Range. They lie unconformably on the Ashburton Formation (*Wa*) and on the unnamned Wyloo Group dolomite (*Wo*). The Capricorn Formation is overlain with marked angular unconformity by conglomerate and sandstone of the Bresnahan Group. Maximum exposed thickness of the formation is about 20 m.

These outcrops consist of thinly bedded to laminar, quartz-rich, mica-bearing fine-grained sandstone to siltstone. Scattered quartz-pebble conglomerate occurs, and the top few metres of the formation contain massive and blocky quartzite.

Flaggy partings are common on a centimetre scale. Fine parallel laminations within these rocks may be bedding laminations or shallow planar cross-bedding. Tool marks are ubiquitous and provide excellent current direction indicators. Trough cross-bedding and ripple marks are common.

CAPRICORN OROGENY

Structures which post-date the intrusion of d_2 mafic dykes and pre-date the Bresnahan Group unconformity are regarded as having formed during the Capricorn Orogeny of Gee (1979). In the Sylvania Inlier such structures take the form of faults and shear zones. In the Hamersley Basin and Ashburton Basin, large-scale, generally east-trending, folds are present. The Ophthalmia Fold Belt developed in rocks of the Hamersley Basin, while the Ashburton Fold Belt developed in rocks of the Ashburton Basin (Gee, 1979).

Deformation in the Hamersley Basin has previously been interpreted as a passive response of cover to vertical movements of basement blocks (MacLeod, 1966; Gee, 1979) with folding on NEWMAN being attributed to large-scale slumping of units off a rising Sylvania "Dome" (Kneeshaw, 1975; Gee, 1979). Tyler (1991), however, suggests that deformation in both basement and cover is linked, and interprets the observed shear zones and north-facing folds in the inlier and Ophthalmia Fold Belt as forming part of a northerly directed foreland fold and thrust system. Within the Ashburton Fold Belt, deformation has been interpreted in terms of a later, regional-scale dextral strike-slip system (Thorne and Seymour, 1991; Tyler, 1991).

Deformation has been interpreted as the result of a collision between the Pilbara and Yilgarn Cratons (Tyler, 1991; Thorne and Seymour, 1991; Tyler and Thorne, 1990). An anomalous Rb – Sr isochron of 2235 ± 54 Ma has been reported from an Archaean granite inlier in Fortescue Group rocks near Newman (Blockley et al., 1980). It was interpreted as the result of equilibration of Sr isotopes with Proterozoic water from the Hamersley Basin during uplift, and may provide a maximum age for deformation.

DEFORMATION IN THE SYLVANIA INLIER

Deformation within the Sylvania Inlier is less intense than that seen on ROBERTSON (Williams and Tyler, 1989). The inlier can be divided into two parts separated by the Fortescue River Fault (Fig. 1). In the east, intense shear-zone development is seen southeast of Bubbacurry Well, and shear zones are folded about east-trending axes. Shear zones are also well developed at the margins of the Warrawanda Creek greenstone belt. Between the shears, granitoid rocks are foliated. Shear zones and the foliation trend east to west-northwest and generally dip to the south, although steep northerly dips occur southeast of Bubbacurry Well. A pronounced stretching lineation may be present on foliation surfaces and this maintains a northerly orientation.

Although not exposed, the Painkiller Bore Fault is interpreted as extending onto NEWMAN to form the basement – cover contact east of the Fortescue River. This structure has been interpreted as a south-dipping thrust (Tyler, 1991).

In the western part of the inlier, deformation is much less intense and the granitoid is generally not foliated. The Western Creek Fault (Fig. 1) is interpreted along the line of Western Creek and Spearhole Creek. A high strain zone, which forms the northwest margin of the Spearhole Creek greenstone belt, is a splay fault from this structure. A sinistral offset on the Western Creek Fault is apparent at the west end of the inlier. A shear zone is developed in granitoid 7 km east of Jillary Well.

OPHTHALMIA FOLD BELT

Deformation within Hamersley Basin rocks forms the southeastern part of the Ophthalmia Fold Belt and consists of two phases: an early event which produced infrequent, layer-parallel folds; and a later regional-scale fold event.

Folds related to the early deformation phase (D_{1c}) have been recognized at several localities and are restricted to particular stratigraphic horizons. Folds are tight to isoclinal, layer-parallel, and small-scale. They have a well-developed tectonic cleavage and may be associated with mylonites. Good examples occur at the base of the Boolgeeda Iron Formation, near the radio transmitter 30 km north-northeast of Newman and at Eagle Pool; and at the top of the Jeerinah Formation, 9 km northwest of Newman and 12.5 km southeast of Mount Robinson. Mylonitic metasedimentary rocks are well developed at the base of the Fortescue Group 7.5 km south-southwest of the Capricorn Roadhouse.

Large-scale fold structures of this age are not developed and deformation is restricted to zones a few metres thick. Tyler (1991) has interpreted the structures as developing within bedding-plane controlled shear zones. Movement directions are not known but the shears probably represent an early stage of regional thrusting.

The second fold phase (D_{2c}) corresponds to a major regional fold event. Folds from this phase occur on all scales, and refold D_{1c} structures. The folds have an easterly trend in the western part of NEWMAN and this swings more to west-northwest in the eastern area. Folds range from upright to near recumbent. They are generally north-facing, close to tight, and are often conjugate in form. They are of buckle-type and are non-cylindrical with sub-horizontal axes. They are impersistent, dying out both laterally and vertically along their axial planes. Fold profiles on all scales vary from parallel to flattened parallel, near-similar forms.

At Mount Whaleback the relationship of smaller scale folds to larger scale folds is well exposed. Folding here is asymmetrical and overturned with smaller scale folds fanning around larger structures. Folds with steeply inclined axial surfaces occur on long, shallow-dipping limbs, while folds with gently inclined axial surfaces occur on short, steep, overturned limbs. Variations in the tightness of folds is controlled by the thickness of each bed and its competency relative to adjacent lithologies (Tyler, 1991).

The most intense deformation occurs north of the Sylvania Inlier, here two structural zones are recognized: a zone of overturned north-facing folds, with a zone of reverse faulting to its north. In general, the folds become progressively tighter and more overturned as the contact with the inlier is approached. Reverse faulting takes the form of steep, southerly dipping faults with throws varying from a few metres to several hundred metres. These reverse faults are believed to root into a flat-lying sole thrust that underlies most of the Ophthalmia Fold Belt on NEWMAN. The position of the thrust is controlled by the relatively less competent Fortescue Group. Folding continues to the north of the reverse faults and shortening is thought to be taken up by movement on a blind extension of the sole thrust. Folding to the northwest and west of the Sylvania Inlier is much less intense with folds having steeply inclined to upright axial surfaces.

An axial-plane cleavage is well developed, with slaty cleavage in shale passing into a spaced cleavage in adjacent BIF and chert. Cleavage becomes less intense towards the western margin of NEWMAN.

ASHBURTON FOLD BELT

The Ashburton Fold Belt extends onto the southwest corner of NEWMAN. Exposure is poor and large-scale structures are not recognized. Medium- and small-scale folds are tight to isoclinal with a well-developed west-northwest-trending axial-plane cleavage. Structures belong to the second fold period (D_{2a}) recognized by Seymour et al. (1988) in Ashburton Basin rocks on WYLOO. Tyler (1991) has related D_{2a} structures to large-scale dextral wrench faulting along the Pilbara Craton margin.

METAMORPHISM

Smith et al. (1982) interpreted the regional recrystallization of Hamersley Basin rocks under prehnite – pumpellyite to lower greenschist facies conditions as the result of burial metamorphism (M_h). The occurrence of a well-developed axial-plane cleavage in Hamersley Basin rocks exposed on NEWMAN indicates that recrystallization under pumpellyite – actinolite facies and lower greenschist facies conditions (M_c) in the southeast Hamersley Basin actually occurred during the deformation that formed the Ophthalmia

Fold Belt (Capricorn Orogeny). Metamorphic conditions were probably similar to those established during the earlier burial event (cf. Tyler, 1991). In the Sylvania Inlier east of the Fortescue River, granitoid rocks, d_1 mafic dykes, and remnants of a layered intrusion near Woggaginna Hill are foliated and recrystallized under albite – epidote amphibolite facies conditions.

Metamorphism during the Capricorn Orogeny has also affected Wyloo Group rocks in the Ashburton Basin. Grade ranges from pumpellyite – actinolite facies adjacent to the Hamersley Basin to upper greenschist facies adjacent to the Bangemall Basin (Thorne and Seymour, 1991).

BRESNAHAN BASIN

BRESNAHAN GROUP

The Bresnahan Group was deposited within the Bresnahan Basin and unconformably overlies the eastern end of the Ashburton Fold Belt. It forms an alluvial-fan style deposit comprising conglomerate and sandstone with minor siltstone and mudstone. The group lies with marked angular unconformity on the Hamersley Basin succession, Wyloo Group, and Capricorn Formation. It is unconformably overlain by the Bangemall Group. Outcrop is confined to the southwest of NEWMAN.

The two-fold division of the Bresnahan Group into "Cherrybooka Conglomerate" and "Kunderong Sandstone", proposed by Daniels and MacLeod (1965), has not been used in this revision. There is no distinct boundary between the two lithologies, rather there are gradational lithofacies changes both laterally and vertically. Further, the two divisions are not distinct mappable units.

The age of the Bresnahan Group (c. 1600 Ma) is constrained by the general age limits of the Capricorn Orogeny (2200 – 1600 Ma) and the age of the lower part of the Bangemall Basin (c. 1500 Ma).

ROCK TYPES

Conglomerate and sandstone, with minor amounts of siltstone and mudstone, were deposited on an irregular erosional surface which had local relief of at least 30 m. The basal deposits are dominated by massive beds of cobble conglomerate, 1 – 10 m thick. These are succeeded by lenticular-bedded conglomerate and sandy conglomerate (< 12 cm thick).

The conglomerate is poorly sorted and is both matrix and clast supported. Maximum clast size ranges up to 0.5 m with clasts of all sizes being well rounded and subspherical. Dominant clast types are sandstone, pebbly sandstone, chert, and vein quartz (generally tourmaline-bearing). Dolomite, mudstone, and jaspilite clasts occur locally. The matrix is a purple, poorly sorted, micaceous granule sandstone with no apparent vertical or lateral variation. Very thickly bedded conglomerate may incorporate lenticular horizons of very coarse-grained sandstone, up to several metres thick.

Conglomerate is locally underlain by, or interbedded with, purple mudstone, siltstone, sandstone, and conglomerate containing purple mudstone clasts. The mudstone is thinly bedded and parallel laminated whereas siltstone and fine-grained sandstone are thin to medium bedded and may be parallel laminated or ripple cross-laminated. Coarse-grained sandstone forms erosively based, lenticular beds which generally lack internal stratification.

Purple-mudstone conglomerate is thin to thick bedded, massive, and both matrix and clast supported.

A transition zone up to 20 m thick exists between the lower conglomerate and the stratigraphically dominant upper sandstone in which thin cobble bands and pebble – cobble lags are common within broad, deep-channelled pebbly sandstone.

The upper sandstone resembles the matrix of the basal conglomerate but appears more mature. It consists of medium- to very coarse-grained granule and pebble sandstone with sparse cobble sandstone and mudstone. Quartz-lithic sandstone is dominant and contains various amounts of feldspar and mica. Pebble clasts are well rounded and sub-spherical; they are predominantly composed of sandstone and vein quartz with minor chert, but jaspilite and cleaved mudstone are locally abundant. Medium-grained sandstone is generally mica-rich. Accumulations of heavy minerals (including iron oxides, titanium oxides, tourmaline, and apatite) occur throughout the sandstone, and are commonly present along the asymptotes and bases of trough cross-bedding. They also form lamellar bands up 10 cm thick in parallel-laminated sandstone.

Lenses, up to 200 m thick, of mudstone and siltstone interbedded with sandstone occur within the medium- to coarse-grained sandstone. The mudstone and siltstone are generally parallel laminated whereas micaceous fine- to medium-grained sandstone occurs in tabular to lenticular beds. Thicker sandstone beds display trough cross-bedding and thinner beds are generally parallel laminated. Current lineations, ripples, flute marks, and ball-and-pillow structures are abundant.

The Bresnahan Group is dominated by channel sequences; individual channels range in size from 2 – 20 m across. Palaeocurrent data indicate a single source with unidirectional transport from the west.

DISTRIBUTION AND INTERPRETATION

The lowermost beds of the Bresnahan Group are discontinuous and of variable thickness; they appear to have been derived from nearby basement rocks and to have filled the depressions in the irregular erosion surface upon which the Bresnahan Group was deposited.

Boulder conglomerate, 50 m thick in the central Kunderong Range, and 500 m of cobble to boulder conglomerate 22 km northeast of Turee Creek Homestead, both contain well-rounded, subspherical clasts. These deposits are interpreted as massive debris flows, proximal to an elevated fluvial source.

The remainder of the Bresnahan Group succession on NEWMAN consists of interbedded conglomerate, conglomeratic sandstone, and coarse- to medium-grained sandstone in lenticular stacked-channel sequences. It is interpreted as a stream-dominated alluvial-fan facies with braided channels of low sinuosity.

Close to the northern boundary of the Bresnahan Group (between the Angelo River and Tunnel Creek), a conglomerate, containing rounded cobbles and boulders of quartz sandstone, is overlain by coarse-grained pebbly sandstone, typical of the upper Bresnahan Group. The pebbly sandstone contains angular blocks of quartz sandstone up to 10 m across and 2 – 3 m thick. The angular blocks are interpreted as a rockfall of Beasley River Quartzite fragments.

East of the Kunderong Range, there lies a group of north-northeast-trending low hills consisting of mudstone and siltstone interbedded with medium-grained sandstone. The deposits are discontinuous and are overlain, east of Tunnel Creek, by coarse-grained sandstone and pebbly sandstone. A similar association occurs 28 km southeast of Prairie Downs Homestead.

The fine-grained sediments are interpreted as being deposited in a series of ephemeral lakes marginal to an eastward-building alluvial fan. The presence of glauconite in some samples southeast of Prairie Downs suggests at least some deposition was in a marine environment. Lenticular trough cross-stratified sandstone is interpreted as a distal fluvial deposit, while tabular, parallel-laminated sandstone is interpreted as a flash-flood deposit in lake-margin shallows.

PROVENANCE

The high degree of rounding of most clasts implies a polycyclic history. Daniels (1975) and Goode (1981) have assigned the sedimentary clasts to the Beasley River Quartzite and the granitic mineralogy to the Sylvania Inlier. However, palaeocurrent data clearly indicate a source region in the west.

The clasts in the Bresnahan Group consist of rock types which are more abundant in the Capricorn Formation than in the Beasley River Quartzite. Where basal conglomerate overlies Capricorn Formation, it shows unequivocal evidence of derivation from that formation. The Capricorn Formation has been recognized as far east as the eastern Kunderong Range. The only known occurrences of Beasley River Quartzite are the rockfall deposits between the Angelo River and Tunnel Creek, and in outcrop south of Deadman Hill.

The combination of transport direction, indicated by palaeocurrent data, and the distinctive nature of clasts, which are tourmaline-rich, suggests that the granitic detritus was derived from the Gascoyne Complex rather than the Sylvania Inlier.

STRUCTURE

A well-developed extensional fault system (Fig. 1) forms the northern margin of the Bresnahan Basin and was active during deposition of the Bresnahan Group.

The fault system consists of a series of northeast-oriented normal faults, the most prominent of which is the Mount Whaleback Fault which extends for 45 km. The normal faults are offset by a series of sinistral, west-northwest-oriented transfer faults (Gibbs, 1984) that are consistent with an overall southeast-directed extension.

The Mount Whaleback Fault is complex, with the single fault present at Western Ridge splitting into two at Mount Whaleback itself. The main throw is transferred by a series of splay and subsidiary faults to a parallel fault 1 km to the south. Kneeshaw (1975) records dip values of 65 – 75° on this fault. In the hanging wall of the main fault, two flat-lying normal faults, the East Pit Footwall Fault and the Central Fault (Swindells et al., in prep.), form the floor to the hematite ore body. Both faults root into the main fault. Numerous smaller scale faults occur throughout the mine area.

Faults of this age also occur within the Sylvania Inlier and affect Hamersley Basin rocks in the Deadman Hill area.

Large-scale open folding of the Bresnahan Group about west-northwest-trending axes probably resulted from reactivation of fault structures in the underlying Ashburton Fold Belt. Deformation pre-dates formation of the Bangemall Basin.

BANGEMALL BASIN

BANGEMALL GROUP

Sedimentary rocks belonging to the Middle Proterozoic Bangemall Group occur along the southern margin of NEWMAN. They define the northern edge of the Bangemall Basin (Muhling and Brakel, 1985) which unconformably overlies rocks of the Sylvania Inlier and the Hamersley, Ashburton, and Bresnahan Basins. Contacts between the Bangemall Basin and older units are extensively faulted.

Of the nine defined formations described from the Bangemall Group on NEWMAN, six belong to the older (c. 1500 Ma) Edmund Subgroup which occupies the southern margin of NEWMAN, and three belong to the younger (c. 1100 Ma) Collier Subgroup in the southeast corner of NEWMAN. Recent exploratory drilling for hydrocarbons, carried out 35 km northeast of Newman, intersected sub-surface sedimentary rocks which are tentatively assigned to the Manganese Subgroup, a northerly correlate of the Collier Subgroup (Williams, 1990).

Table 3 shows changes in stratigraphy between the first edition of NEWMAN (Daniels and MacLeod, 1965) and the present survey.

TABLE 3. COMPARISON OF BANGEMALL GROUP STRATIGRAPHY ON NEWMAN

Daniels and MacLeod (1965) (1st Edition)	*This publication*
	Collier Subgroup
?Kurabuka Formation	Ilgarari Formation
	Calyie Formation
? Fords Creek Shale	Backdoor Formation
	Edmund Subgroup
	Devil Creek Formation
	Jillawarra Formation
	Kiangi Creek Formation
	Cheyne Springs Formation
"Prairie Downs Beds"	Prairie Downs Formation
"Top Camp Dolomite"	Irregully Formation

Edmund Subgroup

The stratigraphic units of the Edmund Subgroup which are mapped on NEWMAN are largely as defined by Muhling and Brakel (1985) and Chuck (1984) with some modifications based on the present survey.

Irregully Formation (Mi)

The lowest unit, the Irregully Formation (following the definition of Chuck, 1984) mainly occurs southwest of the old Turee Creek – Bulloo Downs track. It rests unconformably on the Bresnahan Group, a good exposure being 9 km south of Yindabiddy Pool. At this locality, thin beds of sandstone interbedded with dolomitic breccia are overlain by brown-weathering, pink and grey dolomite and laminated dolomite with microbial banding and probably oncolites. The sequence is about 15 m thick and is capped by silcrete. This sequence wedges out eastwards near the Turee Creek – Bulloo Downs track where it is disconformably overlain by the arenaceous Prairie Downs Formation. A small exposure, 11 km north of the Carbuna Rock Hole and resting unconformably on the Bresnahan Group, is the only other occurrence of Irregully Formation on NEWMAN. This exposure is also overlain by the Prairie Downs Formation.

The Irregully Formation has been interpreted as a near-shore, tidal flat and lagoonal sequence (Chuck, 1984; Muhling and Brakel, 1985).

Prairie Downs Formation (Mpd)

The Prairie Downs Formation is restricted to NEWMAN and the northern boundary of COLLIER. The formation disconformably overlies eroded Irregully Formation and transgresses the Irregully Formation to rest unconformably on the Bresnahan Group. The eastern boundary of the Prairie Downs Formation is the Prairie Downs Fault which separates it from the Fortescue Group of the Hamersley Basin. The formation appears to be conformably overlain by the Cheyne Springs Formation or, where this is absent, disconformably by the Jillawarra Formation.

The Prairie Downs Formation was previously called the "Prairie Downs Member" of the Top Camp Formation of Muhling and Brakel (1985), which Chuck (1984) correlated with the Gooragoora Sandstone. However, the present survey has shown that the Prairie Downs Formation occupies a discrete and definable area on NEWMAN and adjacent COLLIER. Its stratigraphic relationships, thickness, and wedge-shaped distribution suggest that it is not a direct correlative of the Gooragoora Sandstone.

The formation shows a lateral variation in its component lithologies from north to south. A thick 300 m sequence of boulder and cobble conglomerate interbedded with coarse-grained sandstone and wacke (*Mpd(c)*) lies 9 km south of Prairie Downs Homestead. A lens of sandy dolomite and calcareous sandstone (*Mpd(d)*) occurs in this sequence 6 km south of Nirran Nirry Bore. The basal conglomerate beds are structureless, matrix-supported debris flows. These rest unconformably on the Bresnahan Group. Southwards this sequence is overlain by a thick sequence (< 600 m) of graded-bedded conglomerate, wacke, cross-bedded sandstone and minor siltstone (*Mpd*). Clasts in all the conglomerate beds are predominantly jaspilite, banded chert, and banded iron-formation, with minor amounts of acid volcanic rocks, vein quartz, and a little hematite iron ore. Hamersley Basin rocks are the undoubted provenance for the conglomerates.

To the southwest, adjacent to the Turee Creek – Bulloo Downs track, the conglomerate – sandstone sequence intertongues with a white, coarse- to medium-grained sandstone which overlies eroded Irregully Formation. The sandstone consists of well-rounded quartz grains, detrital muscovite, and abundant tourmaline. A granitic provenance, possibly the Sylvania Inlier, is envisaged for this sandstone.

Both this sandstone and the interbedded conglomerate – sandstone sequence are overlain southwards by dark-red to purple, ferruginous and glauconitic sandstone, wacke, siltstone, and shale (*Mpd(g)*). This widespread unit extends onto COLLIER. The total thickness of the Prairie Downs Formation probably exceeds 1200 m.

The Prairie Downs Formation is interpreted as a localized, high-energy fan-delta deposit, which was generated by basin-margin faulting (the Prairie Downs Fault?). The alluvial-fan delta deposits are intertongued and transgressed in part by marginal shallow-marine deposits. Cross-bedding indicates that the current direction was from north to south.

Cheyne Springs Formation (Mp)

On NEWMAN the Cheyne Springs Formation (Chuck, 1984) is interpreted as being present as a sequence of interbedded dolomite, shaly dolomite, dolomite breccia, chert and minor white shale which is exposed in scattered outcrops 1 km southwest of Perry Spring, 11 km north of Georges Camp Bore, and 10 km north of Carbuna Rock Hole. The latter exposure appears to conformably overlie the Prairie Downs Formation. Elsewhere the carbonate sequence appears to intertongue with dark-coloured shales of the Jillawarra Formation.

Kiangi Creek Formation (Mk)

The Kiangi Creek Formation (Muhling and Brakel, 1985) forms mesa cappings and bold strike ridges of white quartz sandstone with minor pebble beds and siltstone and shale interbeds which occur 10 km west of Perry Crossing Bore and 5 km north of Carbuna Rock Hole. At the latter locality the sequence appears to conformably overlie the Cheyne Springs Formation. On NEWMAN the Kiangi Creek Formation appears to be discontinuous and intertongued with dark-coloured shale of the Jillawarra Formation.

The sandstone is graded and cross-bedded, and contains many shale and siltstone intra-clasts. Stylolites are also present.

Both the Kiangi Creek and Cheyne Springs Formations are restricted to the area west of the Fortescue River Fault.

Jillawarra Formation (Mj)

The Jillawarra Formation (Brakel and Muhling, 1976) is the most widespread unit of the Edmund Subgroup on NEWMAN. It appears to transgress the Prairie Downs Formation and Cheyne Spring Formation east of Perry Fault. Although bedrock is not exposed, it is inferred that the Jillawarra Formation unconformably overlies the Sylvania Inlier in the area between the Fortescue River Fault and Peter Fault. The Peter Fault separates the Edmund Subgroup from the stratigraphically younger Collier Subgroup.

The Jillawarra Formation comprises interbedded, purplish-red, brown, yellow and grey-white laminated and thin-bedded shales, flaggy siltstone, chert, and minor thin-bedded, fine-grained sandstone. The shales are commonly silicified, and the flaggy siltstone and sandstone show flute and load casts. The grey cherty shale contains limonite balls (after marcasite or pyrite).

Black, banded chert unit (Md)

A synclinal structure, east of Georges Camp Bore contains a thick, black, banded chert (*Md*). This unit is a possible correlative of the Discovery Chert (Muhling and Brakel, 1985). It conformably overlies the Jillawarra Formation.

Devil Creek Formation (Mv)

A thick sequence of interbedded pink, cream, green-grey, purple, yellow, and brown dolomite, dolomitic breccia, black and green shale, siltstone, and minor chert has been assigned to the Devil Creek Formation. It is exposed in the headwaters of the Ashburton River, between the Fortescue River Fault and the Great Northern Highway. The dolomite ranges from laminated to thick-bedded. Although microbial lamination is present, columnar and domical stromatolites have not been found. Very large, internally laminated, cigar-shaped structures, up to 5 m wide and 50 m long, are present in several localities between the Great Northern Highway and Bulloo Downs Homestead and are restricted to a single dolomitic horizon. The structures may be parallel, *en echelon,* or bifurcate at low angles. They may be stromatolitic, or, more probably, a type of tepee structure.

The shale component (*Mv(s)*) increases towards the top of the formation. The Devil Creek Formation conformably overlies the Jillawarra Formation.

Collier Subgroup

Backdoor Formation (Mb)

The Backdoor Formation (Muhling and Brakel, 1985), the basal unit of the Collier Subgroup in this region, is restricted to the Six Mile Syncline in the southeast corner of NEWMAN. The regional trend of this structure suggests that the formation may be unconformable on the underlying Devil Creek Formation but the contact between the two formations is intruded by dolerite.

The Backdoor Formation is a mixed sequence of thin-bedded, red-brown to greenish, micaceous shale, mudstone, siltstone, and thin lenses of purple to yellow dolomite. An unusual, cliff-forming unit, 2 to 3 m high, consisting of brecciated silica rock annealed by jasper and agate-bearing chalcedonic silica (*Mb(t)*)*, forms a prominent marker bed half-way up the formation. This marker bed is traceable for over 16 km around the Six Mile Syncline. The unit consistently overlies a silicified green mudstone and is, in turn, overlain by thin lenses of dolomite interbedded with shale. More shale, coarsening to silty sandstone, overlies the dolomite. The marker bed may represent a silicified evaporite unit.

The Backdoor Formation coarsens upwards into the overlying arenaceous Calyie Formation.

Calyie Formation (My)

The Calyie Formation (Muhling and Brakel, 1985) occupies most of the southeast corner of NEWMAN including the Six Mile Syncline. It conformably overlies the Backdoor Formation. In the Six Mile Syncline area the formation consists of cream to white, medium- to coarse-grained quartz sandstone with scattered pebbles. It is interbedded with pebble conglomerate and siltstone. The sandstone contains cross-beds, current ripple marks, and current striae. Interbedded fine-grained glauconitic sandstone, siltstone, and shale occur 6 km north of Cundlebar Well. This sequence is similar to units described from the Stag Arrow Formation of the Manganese Subgroup on ROBERTSON with which it is correlated. Bottom structures, such as load casts, flutes and tool marks, are also prominent in the fine-grained sandstone.

---

* The marker horizon *Mb(t)* shown on the coloured tectonic sketch map should refer to the marker horizon in the Collier Subgroup only.

Ilgarari Formation (Mz)

Small areas of Ilgarari Formation (Muhling and Brakel, 1985) occur in the core of the Six Mile Syncline and eastwards along the southern margin of NEWMAN. The formation is predominantly a grey-green shale carrying traces of manganese in the basal shales. Minor amounts of black chert, siltstone, and fine-grained sandstone are also present.

The formation conformably overlies the Calyie Formation. It is correlated with the Balfour Formation of the Manganese Subgroup on ROBERTSON.

Manganese Subgroup

Dolomite, siltstone, sandstone and glauconitic sandstone were intersected in two hydrocarbon exploratory holes drilled in the Fortescue River floodplain 9 km and 11 km northeast of Kalgan Siding (on the Newman – Port Hedland railway line). The sequence, which lies north of the Poonda Fault, is thought to be part of the Manganese Subgroup (Williams and Tyler, 1989). A narrow trough, possibly related to movement along the Poonda Fault, is interpreted as extending northwest from the Limestone Well area on ROBERTSON (Williams and Tyler, 1989).

MAFIC INTRUSIONS

The Bangemall Group contains numerous large dolerite intrusions throughout the entire sequence. Most intrusions are sills but transgressive contacts are also evident. Individual bodies reach 100 m in thickness and may be up to 20 km long. The larger bodies sometimes show faint layering in places. The dolerite (*do*) is medium- to fine-grained with some porphyritic varieties.

An unusual exposure of fine-grained, trachytic-textured and porphyritic, ocellar basalt occurs 1 km southeast of Four Mile Bore (Bulloo Downs). This rock appears to be the chilled margin of a large dolerite sill which has intruded wet, unconsolidated muds of the Devil Creek Formation. Similar rocks have been found adjacent to the Prairie Downs Fault in the Prairie Downs Formation. The dolerite sills predate the folding of the Bangemall Group.

STRUCTURE

Muhling and Brakel (1985) subdivided the Bangemall Basin into three tectonic units, based on variations in fold style and intensity. The Bangemall Group on NEWMAN lies within the Pingandy Shelf. The unit is characterized by continuous, simple sedimentary units (relatively undeformed), which lie marginal to the Pilbara Craton.

Remapping of NEWMAN has shown that the Bangemall sequence is gently folded. Folds are open and are characterized by short, curvilinear axes, which trend generally east to southeast. Exceptions occur adjacent to the Prairie Downs Fault where north-trending fold axes are truncated by the fault. The fold patterns in the area have been attributed to basement block faulting (Muhling and Brakel, 1985).

The margin of the Bangemall Group on NEWMAN shows significant fault control. A confirmed unconformity occurs between the Bangemall and Bresnahan Groups southwest of Prairie Downs Homestead. An inferred unconformity lies 10 km south of Deadman Hill between the Wyloo and Bangemall Groups. The remaining boundaries between the Bangemall Group and the Sylvania Inlier and the Fortescue, Hamersley, and Bresnahan Groups are faulted.

The largest marginal fault is the mineralized west-northwest-trending Prairie Downs Fault. Steep north- and south-dipping fault planes have been recorded with a north-block-up movement. This, together with adjacent oblique fold axes, suggests that the fault has had a complex movement history. The fault was probably active during deposition of the fan-deltaic Prairie Downs Formation.

The dip of the Poonda Fault is not known but its history is complex. Initial north-block-up movement juxtaposed the Wittenoom Dolomite, which underlies much of the Fortescue Valley, against upper Hamersley Group. Later movement, probably contemporaneous with Bangemall Group deposition, was north-block-down. A fault northwest of Turee Creek Homestead shows evidence both of north-block-down and sinistral movement, and represents reactivation of the Bresnahan Basin transfer faults.

POST-BANGEMALL BASIN FAULTING

The Shovelanna Bore Fault, a northwest-trending sinistral fault (Williams and Tyler, 1989) occurs at the eastern margin of NEWMAN offsetting the Painkiller Bore Fault. It degenerates into a series of conjugate folds and kinks which refold D_{2c} structures near the Ophthalmia Dam. Minor kink bands, faults and chevron folds, which post-date the Mount Whaleback Fault, affect rocks at Mount Whaleback.

The youngest set of faults are northeast-trending and have a sinistral sense of movement. They are best developed in the eastern half of NEWMAN with the most prominent being the Fortescue River Fault. This structure offsets both the Prairie Downs Fault and the Poonda Fault. The Ethel Lineament, identified within Cainozoic sediments on BALFOUR DOWNS by Williams (1989), lies along the trend of this fault.

The Peter Fault, which limits the westward extent of the younger Collier Subgroup of the Bangemall Group, and separates it from the older Edmund Subgroup, is of a similar trend and sense of movement. It is along strike from the Neds Gap Fault on COLLIER. Both the Fortescue River Fault and the Peter Fault are parallel to the Tangadee Lineament (Muhling and Brakel, 1985).

MINOR INTRUSIONS

Mafic dykes which post-date the development of the Hamersley Basin occur extensively throughout NEWMAN. Tyler (1991) has identified six separate swarms within the Sylvania Inlier.

Dykes are typically thin (1 – 10 m) and mineral assemblages are fresh except for minor very low-grade alteration. All dykes are doleritic, consisting of clinopyroxene and feldspar with minor amounts of quartz, hornblende and biotite. Orthopyroxene and olivine occur in some of the youngest dyke swarms.

The oldest swarm (d_3) consists of west-southwest-trending dykes exposed near Deadman Flat. These are cut by major west-northwest- (d_4) and northwest-trending (d_5) swarms. The west-northwest swarm is consistently cross-cut by the northwest swarm and is restricted to the southwest of the Sylvania Inlier and the southern part of the Hamersley Basin outcrop. It post-dates D_{2c} folding, and from relationships on TUREE CREEK (Thorne and Tyler, in press) it is regarded as of early Wyloo Group age. The northwest swarm extends further to the northeast. Tyler (1990) regards it as post-dating the Capricorn Orogeny. In the Hamersley Group iron-formations, these dykes are poorly exposed: their presence indicated by deep gullies, previously interpreted as faults (Daniels and MacLeod, 1965) whose floors are filled with cemented scree. Dykes are well exposed in adjacent Fortescue Group and can be traced directly into the gullies.

In the Sylvania Inlier the northwest swarm is cut by an east-trending dyke (d_6). This occurs *en echelon* and comprises several segments individually up to 7 km long and collectively 17 km long. The dykes of this swarm are characterized by olivine micro-phenocrysts and a distinctive dusting of fine magnetite. These features are also seen in the Murramunda Dolerite on ROBERTSON and the Davis Dolerite, a suite of sills and associated dykes intruded into the Manganese Group, on BALFOUR DOWNS and ROBERTSON (Williams, 1989; Williams and Tyler, 1989).

The youngest major swarm (d_7) trends northeast to north-northeast and may be found intruding along faults. Individual dykes may be up to 12 km long, and cut Bangemall Group rocks.

The north-northeast swarm is cut by west-northwest-trending dykes (d_8) at the southern margin of the Sylvania Inlier. Dykes of this swarm also intrude the Bangemall Group.

CAINOZOIC GEOLOGY

A prominent feature of the Cainozoic geology on NEWMAN is the Hamersley Surface (MacLeod et al., 1963; Campana et al., 1964; Twidale et al., 1985), an uplifted and dissected peneplanation surface of probable late Mesozoic or early Tertiary age.

Residual deposits (*Czr*) which formed as part of this surface are lateritic and may be ferruginous. On banded iron-formation, surficial iron enrichment produces thin deposits of hematite – goethite ore (Morris, 1980; Kneeshaw, 1984). The surface is best developed in the northeast part of NEWMAN in the headwaters of Coondiner Creek. Ridges of Brockman Iron Formation rise above the surface and are cloaked by the residual deposits. Massive and pisolitic laterite (*Czl*) occurs in the southern part of NEWMAN with silcrete (*Czb*) developing on sandstones of the Bresnahan and Bangemall Groups.

An early stage of dissection of the Hamersley Surface produced extensive valley-fill deposits. These typically take the form of partly consolidated and cemented colluvium (*Czc*). Colluvium may also be deposited on the residual Hamersley Surface. Pisolitic limonite deposits (*Czp*) occur in the headwaters of the Angelo River, 20 km north of Turee Creek Homestead. These are correlated with the Robe Pisolite (MacLeod, 1966).

Calcrete (*Czk*) occurs extensively along the main drainages, particularly where they cross the Wittenoom Dolomite. Also found along drainages are ridges of massive opaline silica (*Czo*).

Extensive areas of sheetwash plain (*Qw*) occur throughout NEWMAN but are best developed east of Prairie Downs, along Tunnel Creek, and around Turee Creek. The unit consists of alluvium and colluvium and has a distinctive striped aerial-photograph pattern produced by regularly spaced stands of mulga oriented normal to sheet-flow direction. An extensive area of eolian sand (*Qs*), occurring as dunes and sheets, is present in the southwest corner of NEWMAN, south of the Kunderong Range. Colluvium (*Qc*) forms recent talus slopes. These occur adjacent to bedrock outcrop, and also form adjacent to Tertiary deposits. Swelling clay soils (*Qb*) are associated with mafic intrusions.

Alluvium (*Qa*) comprising unconsolidated silt, sand, and gravel is deposited along present drainage channels. Small areas of lacustrine deposits (*Ql* and *Qd*) and clay hardpan (*Qe*) occur towards the southern margin of NEWMAN.

ECONOMIC GEOLOGY

GOLD

Alluvial gold has been found at Deadman Flat associated with greenstone belt fragments at the southern margin of the Sylvania Inlier. There has been no recorded production.

BASE METALS

Copper occurs within uppermost Jeerinah Formation shale in the Wonmunna area in the north of NEWMAN. The geology of the prospects has been summarized by Marston (1979).

Typically, mineralization takes the form of scattered veinlets and stainings of cuprite, malachite, and chrysocolla associated with limonite, which may occur over a width of 25 m and a strike length up to 700 m. There is little continuity of mineralization along strike. Mineralization is apparently derived from oxidation of sulphides, principally pyrite with subordinate pyrrhotite and minor chalcopyrite and sphalerite, which occur as thin laminae, lenses and small nodules within the shale.

In 1953 production of 13.53 t of copper ore (25.6% Cu) and 5.96 t of cupreous ore (23.75% Cu) came from the Wonmunna prospect (Low, 1963). Subsequent drilling of this prospect and others in the area has failed to find intersections of greater than 3.43% Cu (Marston, 1979).

Several small copper prospects lie 2.5 km and 5 km east-southeast of Junction Well on Bulloo Downs. The copper mineralization is restricted to sheared margins of east-northeast-trending dolerite dykes which have intruded shale of the Devil Creek Formation. Blebs and stringers of malachite and chrysocolla, together with copper-stained clay, are visible in the old workings. No production has been recorded.

Galena and cerussite, together with copper minerals, occur in a gangue of barite and ferruginous quartz discontinuously along a 2.4 km length of the Prairie Downs Fault. The prospect has been described by Blockley (1971).

Mineralization occurs *en echelon* in veins ranging up to 2 m wide, which occur in zones up to 60 m long. Assays are up to 32.4% Pb, 11.3% Zn, and 2.69% Cu.

URANIUM

Uranium mineralization has been discovered in arkose of the Bresnahan Group, 16 km north-northwest of Turee Creek Homestead. Uranyl phosphates and silicates occur above 200 m above the base of the Bresnahan Group in a 500 000 t body grading slightly less than 0.05% U_3O_8 (Battey et al., 1987).

Most exploration for uranium has been concentrated on the basal unconformity of the Bresnahan Group (Ewers and Ferguson, 1985) but only minor uranium occurrences in the Wyloo Group basement rocks have been identified on NEWMAN. A small uranium occurrence is associated with basal Fortescue Group rocks near Jillary Well.

IRON

Hamersley Group rocks on NEWMAN lie within the Hamersley Iron Province of MacLeod et al. (1963) and extensive exploration for iron ore has taken place. At present BHP Iron Ore Ltd (formerly Mount Newman Mining Co. Pty Ltd) is producing ore from its Mount Whaleback mine and the nearby Marra Mamba mine. A brief history of the discovery and development of the Mount Whaleback deposit is given by Kneeshaw (1975) and of the Marra Mamba deposit by Slepecki (1981). Other major deposits occur at Orebody 24 and Eastern Ridge (near Newman), and at Rhodes Ridge, Giles Mini, Parallel Ridge, Wonmunna, Angelo River, and West Angelas. Numerous small deposits occur throughout the northern half of NEWMAN. Iron-ore deposits within the Hamersley Iron Province and their genesis have been discussed by MacLeod (1966), Trendall (1975b) and Morris (1980, 1985). According to Morris (1980, 1985) ore formation took place during the early Proterozoic (c. 1800 Ma). Tyler (1991) has speculated that ore formation in the southeast Hamersley Basin is younger than that in the west (e.g. Paraburdoo and Tom Price), and was being controlled by faulting during the formation of the Bresnahan Basin.

The Mount Whaleback orebody has been described by Kneeshaw (1975). It is developed predominantly in the Dales Gorge Member of the Brockman Iron Formation and the upper part of the Mount McRae Shale. Ore occurs in two large-scale, west-plunging synclines truncated by the Mount Whaleback Fault and its subsidiary structures. The ore is massive, hard martite – hematite (Kneeshaw, 1975, 1984) grading to 69% Fe. Primary banding can be recognized but mineralization has reduced the section to 65 m (54% of its original thickness). Reserves of low phosphorus, high-grade ore ($Fe > 64\%$, $P < 0.05\%$) are in excess of 1400 Mt. Ore is present 325 m below the water table. In general, other orebodies developed in the Brockman Iron Formation are of the higher phosphorus "martite – (hematite) – goethite" ore type (Kneeshaw, 1984), and are not currently economic.

Initial exploration concentrated on the Brockman Iron Formation. Later efforts were directed towards the Marra Mamba Iron Formation where the Mount Newman Member is significantly enriched in places. Ore formation is concentrated in synclinal structures and the orebodies are commonly buried beneath alluvial and colluvial deposits adjacent to outcropping Nammuldi Member (Neale, 1975). Ore formation occurred in the Mesozoic to early Tertiary (Morris, 1985). Ore is of the martite – limonite type and is generally soft (Kneeshaw, 1984). Limited production of ore from BHP's Marra Mamba mine, developed on Orebody 29 to the south of Mount Whaleback, began in 1978 for test purposes (Slepecki, 1981).

Significant enrichment has not been found associated with either Weeli Wolli Formation or Boolgeeda Iron Formation BIFs.

OCHRE

Between 1938 and 1941, 1651 t of red ochre were mined from Boolgeeda Iron Formation 29 km north-northeast of Mount Newman (Matheson, 1945). A further 8 t was produced from Weeli Wolli Formation 7 km north of Mount Newman Homestead. This deposit was not relocated during the present survey.

CROCIDOLITE

Trendall and Blockley (1970) reported the occurrence of a seam of crocidolite up to 8 cm (3 inches) thick in a tributary gorge to Coondiner Creek. The seam occurs in upper Dales Gorge Member of the Brockman Iron Formation which forms the core of a medium-scale anticline.

CHRYSOPRASE

Chrysoprase has been mined from the massive silica capping which has developed on the ultramafic intrusion at the southern margin of the Sylvania Inlier.

REFERENCES

BATTEY, G. C., MIEZITIS, Y., and McKAY, A. D., 1987, Australian uranium resources: Australia Bureau of Mineral Resources, Resource Report 1.

BEARD, J. S., 1975, Pilbara (Sheet 5), Vegetation Survey of Western Australia 1:1 000 000 Vegetation Series Map and Explanatory Notes: Perth, University of Western Australia Press.

BLAKE, T. S., 1984, The lower Fortescue Group of the northern Pilbara Craton — stratigraphy and palaeogeography, *in* Archaean and Proterozoic Basins of the Pilbara, Western Australia *edited by* J. R. MUHLING, D. I. GROVES, and T. S. BLAKE: University of Western Australia, Geology Department and University Extension, Publication, no. 9, p. 123 - 143.

BLAKE, T. S., and GROVES, D. I., 1987, Continental rifting and the Archaean - Proterozoic transition: Geology, v. 15, p. 229 - 232.

BLIGHT, D. F., 1985, Economic potential of the lower Fortescue Group and adjacent units in the southern Hamersley Basin: Western Australia Geological Survey, Report 13.

BLOCKLEY, J. G., 1971, The lead, zinc and silver deposits of Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 9.

BLOCKLEY, J. G., TEHANAS, I., MANDYCZEWSKY, A., and MORRIS, R. C., in prep., Proposed stratigraphic subdivision of the Marra Mamba Iron Formation and the lower Wittenoom Dolomite: Western Australia Geological Survey, Report, Professional Papers.

BLOCKLEY, J. G., TRENDALL, A. F., de LAETER, J. R., and LIBBY, W. G., 1980, Two anomalous isochrons from the vicinity of Newman: Western Australia Geological Survey, Annual Report 1979, p. 93 - 96.

BRAKEL, A. T., and MUHLING, P. C., 1976, Stratigraphy, sedimentation and structure in the Bangemall Basin, Western Australia: Western Australia Geological Survey, Annual Report 1975, p. 70 - 79.

CAMPANA, B., HUGHES, F. E., BURNS, W.G., WHICHER, I.G., and MUCENIEKAS, E., 1964, Discovery of the Hamersley iron deposits (Duck Creek — Mt Pyrton — Mt Turner areas): Australasian Institute of Mining and Metallurgy, Proceedings, no. 210, p. 1 - 30.

CHUCK, R. G., 1984, The sedimentary and tectonic evolution of the Bangemall Basin, Western Australia and implications for mineral exploration: Western Australian Mining and Petroleum Research Institute (WAMPRI), Report, no. 6.

COMPSTON, W., WILLIAMS, I. S., McCULLOCH, M. T., FOSTER, J., ARIENS, P. A., and TRENDALL, A. F., 1981, A revised age for the Hamersley Group, *in* Sediments through the Ages *edited by* D. I. GROVES et al.: Geological Society of Australia, Annual Convention, 5th, Perth, W.A., Abstracts; Abstract Series, no. 3, p. 40.

DANIELS, J. L., 1966, Revised stratigraphy, palaeocurrent system and palaeogeography of the Proterozoic Bangemall Group: Western Australia Geological Survey, Annual Report 1965, p. 48 - 56.

DANIELS, J. L., 1975, Bresnahan and Mount Minnie Basins, *in* The Geology of Western Australia: Western Australia Geological Survey, Memoir 2, p. 143 - 146.

DANIELS, J. L., and MacLEOD, W. N., 1965, Newman, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes.

DRUMMOND, B. J., 1981, Crustal structure of the Precambrian terrains of northwest Australia from seismic refraction data: Australia Bureau Mineral Resources Journal of Australian Geology and Geophysics, v. 6, p. 123 - 135.

EWERS, G. R., and FERGUSON, J., 1985, Unconformity related uranium deposits (W.A.), *in* BMR 85: Australia Bureau Mineral Resources, Yearbook, 1985, p. 35 - 37.

EWERS, W. E., and MORRIS, R. C., 1981, Studies on the Dales Gorge Member of the Brockman Iron Formation: Economic Geology, v. 76, p. 1929 - 1953.

GEE, R. D., 1979, Structure and tectonic style of the Western Australian Shield: Tectonophysics, v. 58, p. 327 - 369.

GIBBS, A. D., 1984, Structural evolution of extensional basin margins: Journal of the Geological Society, London, v. 141, p. 711 - 732.

GOODE, A. D. T., 1981, Proterozoic geology of Western Australia, *in* Precambrian of the Southern Hemisphere *edited by* D. R. HUNTER: Amsterdam, Elsevier, p. 105 – 203.

GREY, K., 1981a, *Patomia* f. indet. from an un-named carbonate unit (early Proterozoic), Newman 1:250 000 sheet: Western Australia Geological Survey, Palaeontological Report 51/81 (unpublished).

GREY, K., 1981b, A new digitate stromatolite from Kunderong Range, Turee Creek 1:250 000 sheet: Western Australia Geological Survey, Palaeontological Report 53/81 (unpublished).

GREY, K., 1985, Stromatolites in the Proterozoic Duck Creek Dolomite, Western Australia: Western Australia Geological Survey, Report 14, Professional Papers for 1983, p. 94 – 103.

HICKMAN, A. H., 1983, Geology of the Pilbara Block and its environs: Western Australia Geological Survey, Bulletin 127.

HICKMAN, A. H., and LIPPLE, S. L., 1975, Explanatory notes on the Marble Bar 1:250 000 geological sheet, W.A.: Western Australia Geological Survey, Record 1974/20.

HICKMAN, A. H., and LIPPLE, S. L., 1978, Marble Bar, Western Australia: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes.

HORWITZ, R. C., 1976, Two unrecorded basal sections in older Proterozoic rocks of Western Australia: Australia CSIRO, Mineral Research Laboratories, Division of Mineralogy, Report FP17.

HORWITZ, R. C., 1987, Structural trends of the Archaean to lower Proterozoic Hamersley Province, Western Australian Shield: Australia CSIRO, Division of Minerals and Geochemistry, Report MG31.

HORWITZ, R. C., and SMITH, R. E., 1978, Bridging the Pilbara and Yilgarn Blocks, Western Australia: Precambrian Research, v. 6, p. 293 – 322.

KNEESHAW, M., 1975, Mt. Whaleback iron orebody, Hamersley Iron Province, *in* Economic Geology of Australia and Papua New Guinea, Volume 1. Metals *edited by* C. L. KNIGHT: Australasian Institute of Mining and Metallurgy, Monograph 5, p. 910 – 916.

KNEESHAW, M., 1984, Pilbara iron ore classification — a proposal for a common classification for BIF-derived supergene iron ore: Australasian Institute of Mining and Metallurgy, Proceedings, no. 289, p. 157 – 162.

LIBBY, W. G., de LAETER, J. R., and MYERS, J. S., 1986, Geochronology of the Gascoyne Province: Western Australia, Geological Survey, Report 20.

LOW, G. H., 1963, Copper deposits of Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 8, p. 82 – 83.

MacLEOD, W. N., 1966, The geology and iron deposits of the Hamersley Range area: Western Australia Geological Survey, Bulletin 117.

MacLEOD, W.N., de la Hunty, L. E., Jones, W. R., and Halligan, R., 1963, Preliminary report on the Hamersley Iron Province, North West Division: Western Australia Geological Survey, Annual Report 1962, p. 44 – 54.

McCONCHIE, D., 1984, A depositional environment for the Hamersley Group — palaeogeography and geochemistry, *in* Archaean and Proterozoic Basins of the Pilbara, Western Australia — Evolution and Mineralization Potential *edited by* J. R. MUHLING, D. I. GROVES, and T. S. BLAKE, University of Western Australia, Geology Department and University Extension, Publication, no. 9, p. 144 – 190.

MARSTON, R. J., 1979, Copper mineralization in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 13.

MATHESON, R. S., 1945, Report on red ochre deposits, ML370H, Ophthalmia Range: Western Australia Geological Survey, Annual Report 1944, p. 92 – 95.

MORRIS, R. C., 1980, A textural and mineralogical study of the relationships of iron ore to banded iron formation in the Hamersley Iron Province of Western Australia: Economic Geology, v. 75, p. 184 – 209.

MORRIS, R. C., 1985, Genesis of iron ore in banded iron-formation by supergene and supergene-metamorphic processes — a conceptual model, *in* Handbook of Strata-Bound and Stratiform Ore Deposits, Volume 13 *edited by* K. H. WOLF: Elsevier, Amsterdam, p. 73 – 235.

MORRIS, R. C., and HORWITZ, R. C., 1983, The origin of the iron-formation-rich Hamersley Group of Western Australia — deposition on a platform: Precambrian Research, v. 21, p. 273 – 297.

MUHLING, P. C., and BRAKEL, A. T., 1985, Geology of the Bangemall Group — the evolution of an intracratonic Proterozoic basin: Western Australia Geological Survey, Bulletin 128.

NEALE, J., 1975, Iron ore deposits in the Marra Mamba Formation at Mining Area "C", Hamersley Iron Province, *in* Economic Geology of Australia and Papua New Guinea, Volume 1. Metals *edited by* C. L. KNIGHT: Australasian Institute of Mining and Metallurgy, Monograph 5, p. 924 - 932.

PIDGEON, R. T., 1984, Geochronological constraints on early volcanic evolution of the Pilbara Block, Western Australia: Australian Journal of Earth Sciences, v. 31, p. 237 - 242.

RICHARDS, J. R., and BLOCKLEY, J. G., 1984, The base of the Fortescue Group, Western Australia — further galena lead isotope evidence on its age: Australian Journal of Earth Sciences, v. 31, p. 257 - 268

SEYMOUR, D. B., THORNE, A. M., and BLIGHT, D.F., 1988, Wyloo, W.A. (second edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes.

SLEPECKI, S., 1981, Marra Mamba iron ore — a case history in exploration and development of a new ore type: Australasian Institute of Mining and Metallurgy, Annual Conference, 1981 Sydney, N.S.W., p. 195 - 207.

SMITH, R. E., PERDRIX, J. L., and PARKS, T. C., 1982, Burial metamorphism in the Hamersley Basin, Western Australia: Journal of Petrology, v. 23, p. 75 - 102.

SWINDELLS, C. E., TYLER, I. M., RANSOM, D. B., and JAMES, T., in prep., Low-angle normal faulting at Mount Whaleback, Western Australia.

THORNE, A. M., and SEYMOUR, D. B., 1986, The sedimentology of a tide-influenced fan-delta system in the early Proterozoic Wyloo Group on the southern margin of the Pilbara Craton, Western Australia: Western Australia Geological Survey, Report 19, Professional Papers for 1984, p. 70 - 82.

THORNE, A. M., and SEYMOUR, D. B., 1991, The geology of the Ashburton Basin: Western Australia Geological Survey, Bulletin 139.

THORNE, A. M., and TYLER, I. M., in press, Turee Creek, W.A. (second edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes.

TRENDALL, A. F., 1975a, Hamersley Basin, *in* The Geology of Western Australia: Western Australia Geological Survey, Memoir 2, p. 118 - 141.

TRENDALL, A. F., 1975b, Geology of Western Australian iron ore, *in* Economic Geology of Australia and Papua New Guinea, Volume 1. Metals *edited by* C. L. KNIGHT: Australasian Institute of Mining and Metallurgy, Monograph 5, p. 883 - 892.

TRENDALL, A. F., 1979, A revision of the Mount Bruce Supergroup: Western Australia Geological Survey, Annual Report 1978, p. 63 - 71.

TRENDALL, A. F., 1983, The Hamersley Basin, *in* Iron Formations — Facts and Problems *edited by* A. F. TRENDALL and R. C. MORRIS: Amsterdam, Elsevier, p. 69 - 129.

TRENDALL, A. F., and BLOCKLEY, J. G., 1968, Stratigraphy of the Dales Gorge Member of the Brockman Iron Formation in the Precambrian Hamersley Group of Western Australia: Western Australia Geological Survey, Annual Report 1967, p. 48 - 53.

TRENDALL, A. F., and BLOCKLEY, J. G., 1970, The iron formations of the Precambrian Hamersley Group, Western Australia: Western Australia Geological Survey, Bulletin 119.

TWIDALE, C. R., HORWITZ, R. C., and CAMPBELL, E. M., 1985, Hamersley landscapes of the northwest of Western Australia: Revue de Geologie Dynamique et de Geographie Physique, v. 26, p. 173 - 186.

TYLER, I. M., 1986, Age and stratigraphy of a sequence of metavolcanic and metasedimentary rocks in the Prairie Downs - Deadman Hill area, southwestern margin of the Sylvania Dome: Western Australia Geological Survey, Report 19, Professional Papers for 1984, p. 83 - 87.

TYLER, I. M., 1990, Mafic dyke swarms, *in* The Geology and Mineral Resources of Western Australia: Western Australia Geological Survey, Memoir 3.

TYLER, I. M., 1991, The geology of the Sylvania Inlier and the southeastern Hamersley Basin: Western Australia Geological Survey, Bulletin 138.

TYLER, I. M., FLETCHER, I. R., de LAETER, J. R., WILLIAMS, I. R., and LIBBY, W. G., in prep., REE, Sm – Nd and Rb – Sr patterns from granitoid rocks in the southeastern Pilbara Craton, Western Australia — evidence for a Late Archaean terrane boundary: Precambrian Research.

TYLER, I. M., HUNTER, W. M., and WILLIAMS, I. R., 1990, Explanatory notes on the Newman 1:250 000 geological sheet Western Australia (second edition): Western Australia Geological Survey, Record 1989/6.

TYLER, I. M., and THORNE, A. M., 1990, The northern margin of the Capricorn Orogen, Western Australia — an example of an early Proterozoic collision zone: Journal of Structural Geology, v. 12, no. 5 – 6. p. 685 – 701.

WELLMAN, P., 1976, The gravity field of the Australian Basement: Australia Bureau Mineral Resources, Journal of Australian Geology and Geophysics, v. 1, p. 287 – 290.

WILLIAMS, I. R., 1989, Balfour Downs, W.A. (second edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes.

WILLIAMS, I. R., 1990, The Bangemall Basin, *in* The Geology and Mineral Resources of Western Australia: Western Australia Geological Survey, Memoir 3.

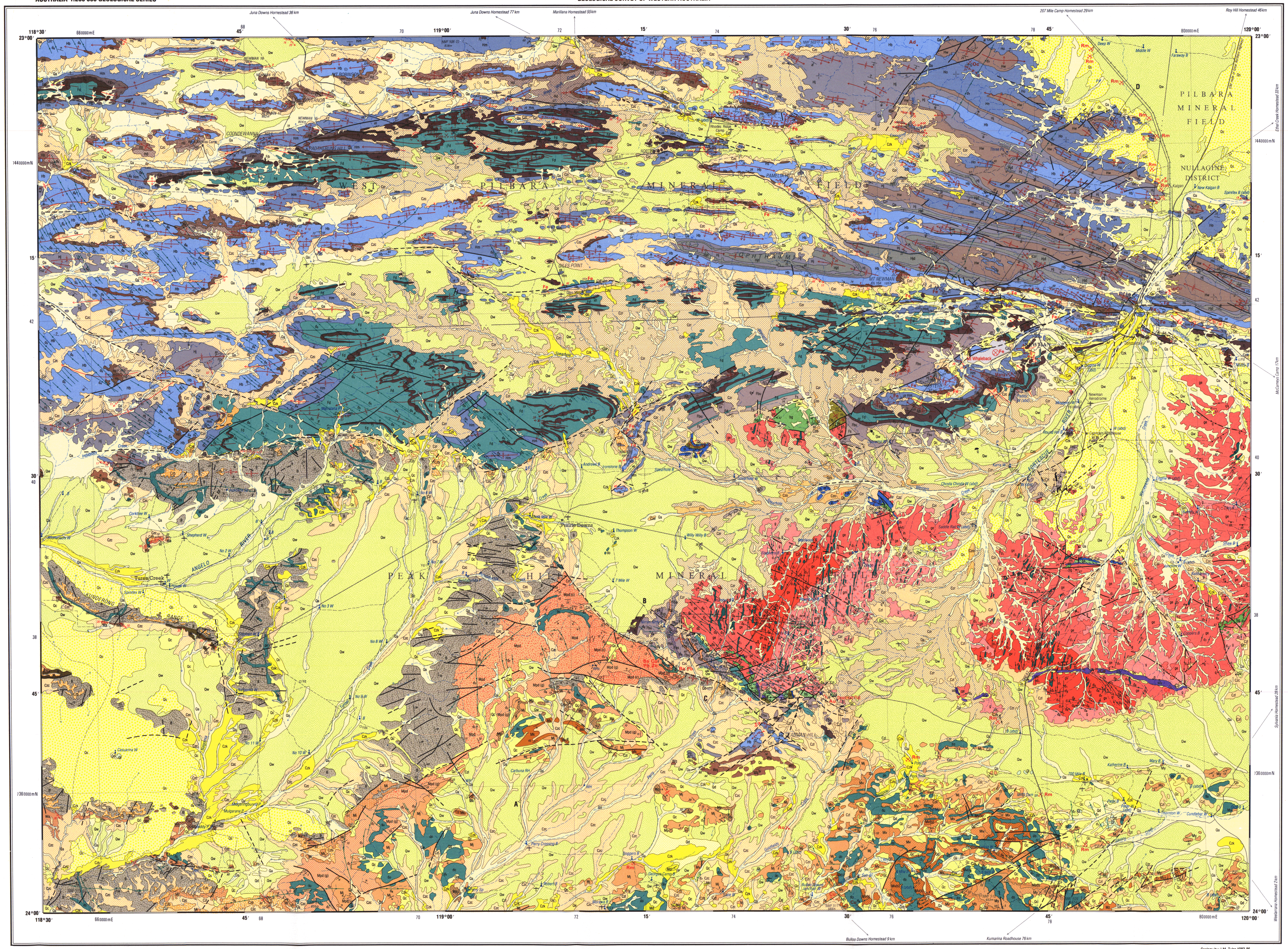
WILLIAMS, I. R., and TYLER, I. M., 1989, Explanatory notes on the Robertson 1:250 000 geological sheet Western Australia (second edition): Western Australia Geological Survey, Record 1989/5.

NEWMAN

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SF 50-16



Geology by: I.M. Tyler 1983-86
I.R. Williams 1986
W.M. Hunter 1986

SYMBOLS

Geological boundary	
Fault	
accurate	
normal	
reverse	
concealed	
shear zone	
Folds, showing direction of plunge	
anticline	
syncline	
overturned anticline	
overturned syncline	
minor anticline	30
minor syncline	25
locality of superimposed folds	
pre-Capricorn Orogeny	
trend and plunge of small-scale folds	38
Capricorn Orogeny	
Ophthalmia Fold Belt	
small-scale folds showing orientation of axial surface, direction of plunge and nature of vergence (Z, S or M)	
D1c	
inclined	52 60
D2c	
inclined	62 10
vertical	
plunge of D2c fold axis	
Ashburton Fold Belt	
plunge of minor anticline	
plunge of minor syncline	
Late, post-orogenic folds, usually associated with faulting	
inclined	19
vertical	
Bedding	
inclined	85
vertical	
strike and dip of overturned strata	60
dip estimated from aerial photographs	
horizontal	
0°-15°	
15°-45°	
45°-90°	
vertical	
general trend of bedding	
Younging	
top of bed	
pillow lava	
Foliation, gneissic banding	
inclined	70
Foliation, metamorphic	
pre-Capricorn Orogeny	
inclined	43
vertical	
Capricorn Orogeny	
inclined	46
vertical	
general trend of foliation	
Cleavage, slaty or spaced	
Capricorn Orogeny	
Ophthalmia Fold Belt	
inclined	67
vertical	
showing trend and plunge of bedding-cleavage intersection	68 9
Ashburton Fold Belt	
inclined	80
Lineation	
Capricorn Orogeny	
Ashburton Fold Belt	
trend and plunge	
Stromatolite locality	
Isotopic age determination site	
Mineral field boundary	
Highway with national route marker	95
Formed road	
Track	
Railway with siding	Kalgan
Townsite, pop 1 000-10 000	NEWMAN
Homestead	Prairie Downs
Building	
Yard	Yd
Airfield	
Landing ground	
Horizontal control; major, minor	
Watercourse, intermittent	
Pool	P
Well	W
Bore	B
Windpump	
Rockhole	RH
Waterhole	WH
Spring	Sp
Abandoned	(abd)
Position doubtful	(PD)
Mine, opencut or quarry	
major	
minor	
Alluvial workings	
Prospect	
Made ground, mining area	
Petroleum exploration well, dry, abandoned	
Mineral occurrence	
Barite	Ba
Copper	Cu
Crocidolite	Ad
Chrysoprase	Ce
Gold	Au
Iron	Fe
Lead	Pb
Ochre	Oc
Uranium	U
Zinc	Zn
Road metal	Rm

INDEX TO 1:250 000 SHEETS

YARRALOOLA SF 50-6	PYRAMID SF 50-7	MARBLE BAR SF 50-8	NULLAGINE SF 51-5	PATERSON RANGE SF 51-6
WYLOO SF 50-10	MT BRUCE SF 50-11	ROY HILL SF 50-12	BALFOUR DOWNS SF 51-9	RUDALL SF 51-10
EDMUND SF 50-14	TUREE CREEK SF 50-15	NEWMAN SF 50-16	ROBERTSON SF 51-13	GUNANYA SF 51-14
MT PHILLIPS SG 50-2	MT EGERTON SG 50-3	COLLIER SG 50-4	BULLEN SG 51-1	TRAINOR SG 51-2
GLENBURGH SG 50-6	ROBINSON RANGE SG 50-7	PEAK HILL SG 50-8	NABBERU SG 51-5	STANLEY SG 51-6

−30′ 0° +30′ +1° +1°30′ +2°

The lines indicate magnetic declination, 1985
+ means declination is east and correction must be added to compass bearing to give true bearing
− means declination is west and correction must be subtracted from compass bearing to give true bearing

Annual change is −1′ westerly

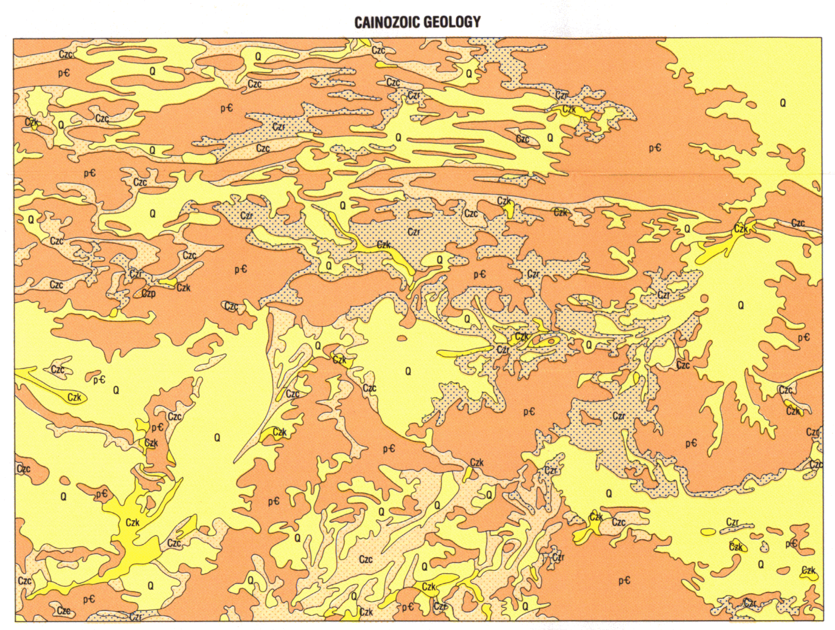
Cartography by the Surveys and Mapping Division, Department of Mines, Western Australia.

Topographic base supplied by the Department of Land Administration, Western Australia.

Published by and available from the Geological Survey of Western Australia, Department of Mines, 100 Plain Street, East Perth, WA 6004

Printed by the State Printing Division, Department of Services, Western Australia.

CAINOZOIC GEOLOGY



Q	Alluvium and colluvium, lacustrine deposits, eolian sand
Czc	Colluvium — partly consolidated
Czr	Laterite, silcrete, opaline silica
Czk	Calcrete
Czp	ROBE PISOLITE
p€	Rock outcrop

SCALE 1:1 000 000
0 10 20 30 40 50
Kilometres

HON. JEFF CARR, M.L.A.
MINISTER FOR MINES
D.R. KELLY, DIRECTOR GENERAL OF MINES

P.E. PLAYFORD
DIRECTOR, GEOLOGICAL SURVEY
OF WESTERN AUSTRALIA

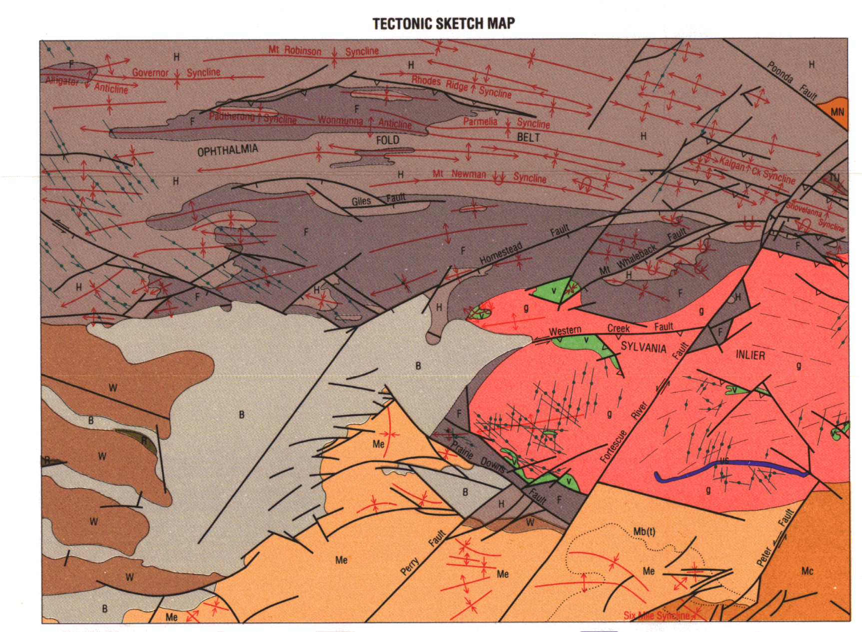
SCALE 1:250 000

5000 0 5 10 15 20 25 30
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION

ZONE 50 AUSTRALIAN MAP GRID

TECTONIC SKETCH MAP



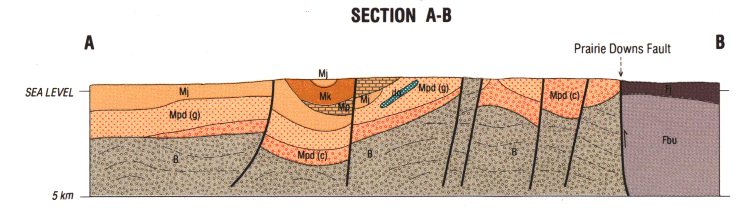
Mc, MN	Collier-Manganese Subgroups	BANGEMALL BASIN
Me	Edmund Subgroup	BANGEMALL BASIN
B	BRESNAHAN BASIN	
R	BLAIR BASIN	
W	ASHBURTON BASIN	
TU	Turee Creek Group	HAMERSLEY BASIN
H	Hamersley Group	HAMERSLEY BASIN
F	Fortescue Group	HAMERSLEY BASIN
us	Southern ultramafic intrusion	SYLVANIA INLIER
g	Granitoid	SYLVANIA INLIER
v	Greenstone belt	SYLVANIA INLIER
	Wrench fault	
	Marker horizon	

SCALE 1:1 000 000
0 10 20 30 40 50
Kilometres

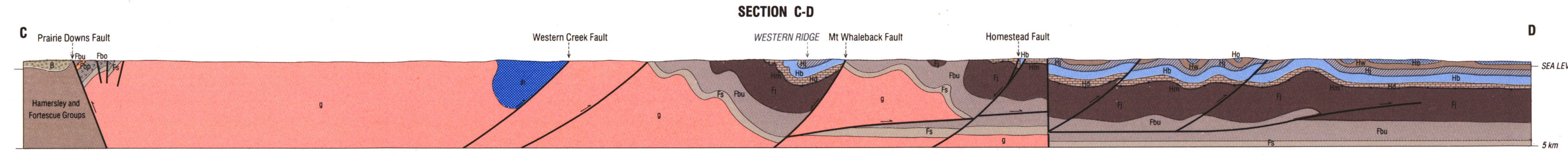
DIAGRAMMATIC SECTIONS

NATURAL SCALE

SECTION A-B



SECTION C-D



REFERENCE

PHANEROZOIC — CAINOZOIC — QUATERNARY

Qa	Alluvium — unconsolidated silt, sand and gravel
Ql	Lacustrine deposits — clay, silt; saline in part
Qd	Mixed lacustrine and eolian deposits — clay, silt, sand
Qs	Eolian sand — in sheets and dunes
Qb	Eluvium — gilgai; swelling clay soils
Qw	Alluvium and colluvium — red-brown sandy and clayey soil
Qc	Colluvium — unconsolidated quartz and rock fragments in soil
Qe	Colluvium and eluvium — clay hardpan
Czc	Colluvium — partly consolidated valley-fill deposits
Czb	Silcrete — siliceous duricrust
Czl	Laterite — massive and pisolitic ferruginous duricrust
Czr	Laterite, includes surficial hematite-goethite deposits on banded iron-formation; forms Hamersley Surface
Czp	**ROBE PISOLITE** — pisolitic limonite deposits developed along old river channels
Czk	Calcrete — sheet carbonate usually formed in major drainage lines
Czo	Opaline silica — vuggy white opaline silica developed within calcrete and on partially consolidated valley-fill

PROTEROZOIC

q	Quartz veins
d_{3-8}	Dolerite and metadolerite dykes; numbers identify different swarms, lowest number oldest
do	Dolerite — in sills and small intrusions

BANGEMALL BASIN — Bangemall Group — Collier Subgroup

Mz	**ILGARARI FORMATION:** shale, some manganiferous; siltstone, claystone, fine-grained sandstone; minor chert
My	**CALYIE FORMATION:** quartz arenite; flaggy to massive pebbly sandstone, minor conglomerate, siltstone and shale
Mb	**BACKDOOR FORMATION:** shale, siltstone, minor fine-grained sandstone, dolomite and chert
Mb(t)	Silicified marker horizon

c. 1100 Ma

Edmund Subgroup

Mv	**DEVIL CREEK FORMATION:** laminated and massive dolomite, interbedded shale, dolomitic breccia, chert and siltstone
Mv(s)	Shale, siltstone
Md	Black chert, banded chert; may be a correlate of DISCOVERY CHERT
Mj	**JILLAWARRA FORMATION:** shale, siltstone, minor sandstone, chert, claystone
Mk	**KIANGI CREEK FORMATION:** quartz arenite, pebbly sandstone, minor conglomerate, siltstone
Mp	**CHEYNE SPRINGS FORMATION:** dolomite, dololutite, dolomitic breccia
Mpd	**PRAIRIE DOWNS FORMATION:** quartz arenite, quartz wacke, pebbly sandstone, interbedded conglomerate
Mpd(c)	Boulder conglomerate interbedded coarse-grained sandstone
Mpd(d)	Dolomite
Mpd(g)	Medium-grained glauconitic sandstone, siltstone, shale
Mi	**IRREGULLY FORMATION:** dolomite, dololutite, chert

c. 1500 Ma

BRESNAHAN BASIN — Bresnahan Group

B	Boulder conglomerate, conglomeratic sandstone, pebbly sandstone, interbedded fine sandstone and mudstone

BLAIR BASIN

R	**CAPRICORN FORMATION:** fine- to medium-grained sandstone, siltstone and mudstone

ASHBURTON BASIN — Wyloo Group

c. 2000 Ma

Wo	Unassigned; dolomite, usually stromatolitic
Wa	**ASHBURTON FORMATION:** mudstone interbedded with sandstone and dolomite; intruded by dolerite sills
Wm	**MOUNT McGRATH FORMATION:** coarse sandstone
Wq	**BEASLEY RIVER QUARTZITE:** fine- to coarse-grained sandstone; may be silicified

HAMERSLEY BASIN — Turee Creek Group

TU	Undifferentiated; mudstone

Hamersley Group

Ho	**BOOLGEEDA IRON FORMATION:** fine-grained, finely laminated, dark grey-brown to black, flaggy iron-formation; minor chert, jaspilite and shale
Hw	**WOONGARRA VOLCANICS:** quartz- or feldspar-phyric rhyolite and rhyodacite as sills or flows; tuff and minor jaspilitic banded iron-formation (2470 ± 30 Ma, U-Pb; 2370 Ma, Rb-Sr)
Hj	**WEELI WOLLI FORMATION:** interlayered banded iron-formation and metadoleritic sills, minor shale
Hjd	Medium- to coarse-grained massive grey-green metadolerite sills, usually foliated
Hb	**BROCKMAN IRON FORMATION:** banded iron-formation, chert and minor shale (2490 ± 20 Ma, U-Pb)
Hs	**MOUNT McRAE SHALE** and **MOUNT SYLVIA FORMATION:** interbedded shale, chert and banded iron-formation
Hd	**WITTENOOM DOLOMITE:** dolomite; interbedded thin chert, shale and dolomite in upper part
Hm	**MARRA MAMBA IRON FORMATION:** chert, ferruginous chert and banded iron-formation with minor shale

2500 Ma

Fd	Metadolerite sills intruded into Fortescue Group; medium- to coarse-grained, massive grey-green rock, usually foliated

Fortescue Group

Fj	**JEERINAH FORMATION:** interbedded mudstone, siltstone and chert with minor felsic tuff, dolomite and sandstone
Fjb	Metabasalt; pillows locally well developed
Fbu	Upper mafic volcanic unit; metabasalt with minor metadolerite sills
Fbk	Spinifex-textured komatiitic metabasalt, ultramafic schist
Fus	Serpentinite
Fbp	Felsic pyroclastic unit; felsic metatuff with minor banded chert
Fbo	Lower mafic volcanic unit; interbedded metabasalt and mafic metatuff
Fs	Basal metasedimentary unit; phyllite, quartz-muscovite schist, metasandstone and metaconglomerate, minor carbonate

c. 2750 Ma

ARCHAEAN — SYLVANIA INLIER

us_2	Serpentinite forming southern ultramafic intrusion
uz_2	Chalcedonic and opaline silica developed on us_2
d_{1-2}	Metadolerite and amphibolite dykes
g	Granitoid rocks, undifferentiated, deeply weathered
ge	Medium, even-grained, metagranite to metagranodiorite
gv	Medium-grained, metagranite to metagranodiorite with sparse feldspar phenocrysts
go	Mesocratic to melanocratic metamonzodiorite to metaquartz-diorite; coarse cumulate phase locally present
gm	Mixed granitoid unit; extensive veins and patches of ge and gv intrude into a strongly foliated or banded metagranite to metagranodiorite
la	Quartz-muscovite schist
lq	Interbedded chert, fuchsitic metaquartzite, minor pelitic and semi-pelitic schist
i	Chert and banded iron-formation, undifferentiated
ic	Grey and white banded chert
ih	Hematite-magnetite-quartz banded iron-formation
im	Magnetite-quartz banded iron-formation; recrystallized, higher grade equivalent of ih
ba	Amphibolite; fine-, medium- and coarse-grained varieties derived from extrusive and intrusive rocks
bg	Metagabbro; medium- to coarse-grained
us	Serpentinite; cumulate textures may be preserved
ua	Tremolite-chlorite-talc schist

> 2750 Ma

NEWMAN
SHEET SF 50-16

SECOND EDITION 1990