EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

MOUNT BRUCE
1:250 000 SHEET
WESTERN AUSTRALIA

SECOND EDITION

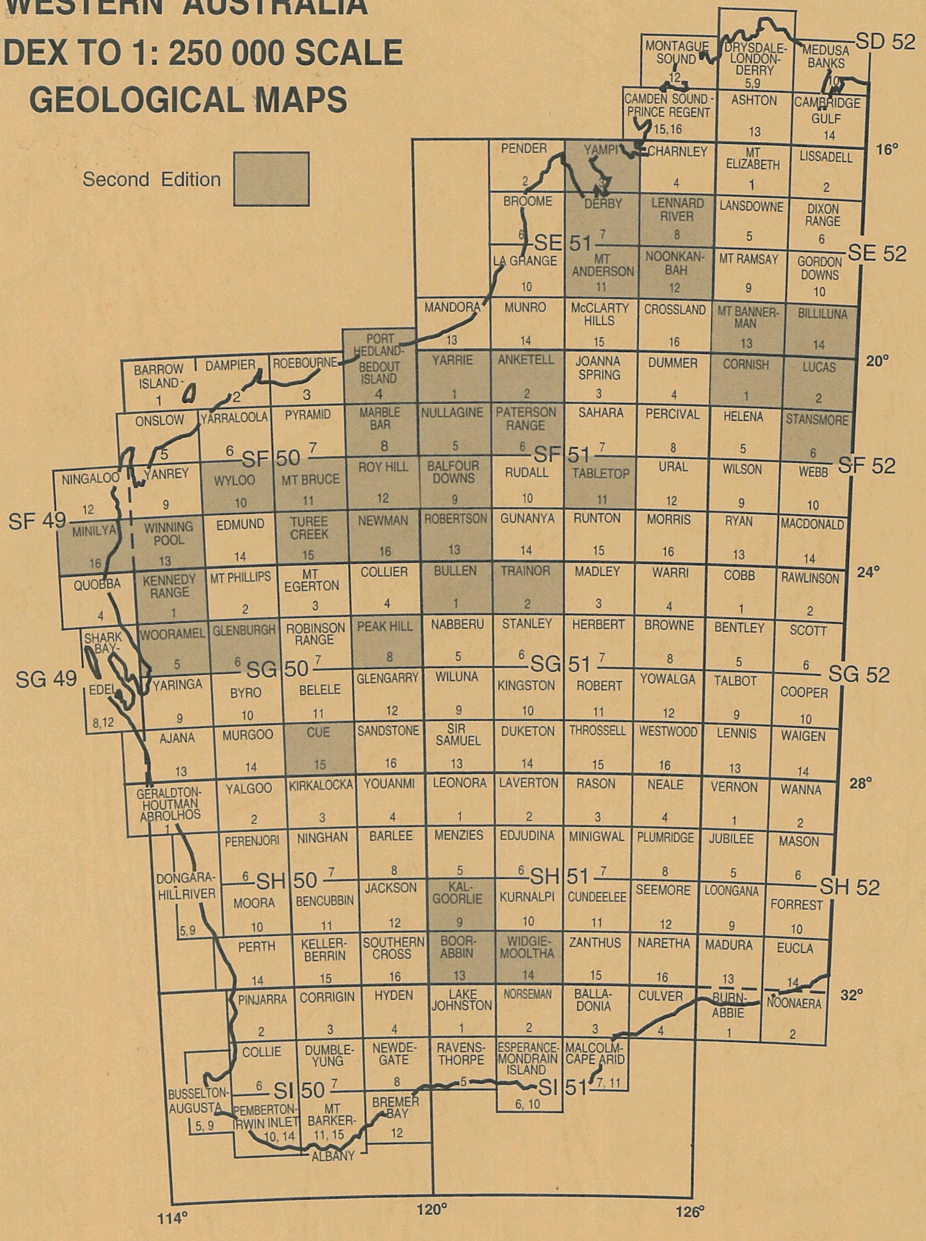
SHEET SF 50-11 INTERNATIONAL INDEX

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

WESTERN AUSTRALIA
INDEX TO 1: 250 000 SCALE GEOLOGICAL MAPS

Second Edition



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

MOUNT BRUCE

WESTERN AUSTRALIA

SECOND EDITION

SHEET SF50–11 INTERNATIONAL INDEX

by

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Perth, Western Australia 1997

MINISTER FOR MINES

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by A. M. Thorne and I. M. Tyler

INTRODUCTION

The MOUNT BRUCE* 1:250 000 map sheet (SF50–11) is bounded by latitudes 22°00'S and 23°00'S and longitudes 117°00'E and 118°30'E. It contains the town of Tom Price (pop. 3630) and the abandoned town of Wittenoom, as well as Hamersley, Mulga Downs, and Rocklea Stations. The sealed Nanutarra–Paraburdoo–Tom Price road crosses the extreme southwestern and central southern part of the map sheet, and joins an unsealed road which links the southwestern part of MOUNT BRUCE to Wittenoom and the nearby Karijini National Park.

The climate is arid: annual rainfall is between 200 and 300 mm. Most rain falls from January to June. Summers are very hot: January maxima range from 36 to 44°C, minima from 24 to 28°C. Winters are mild: July maxima range from 20 to 25°C, minima from 6 to 11°C. Evaporation from a free water surface is about 3600 mm per year.

Most of MOUNT BRUCE, except for the southwestern corner, forms part of the Fortescue Botanical District (Beard, 1975). Granitic rocks in the core of the Rocklea and Milli Milli Domes are colonized by sparse shrubs, mainly mulga (*Acacia aneura*) and snakewood (*A. xiphophylla*), and buck spinifex (*Triodia wiseana*). Elsewhere, outcrops of basaltic rock are characterized by a mosaic of *A. aneura, A. pyrifolia,* and *Triodia*, with *Eucalyptus brevifolia* on the steepest, rockiest areas. Iron formations of the Hamersley and Chichester Ranges are covered by the snappy gum (*E. brevifolia*)–*T. wiseana* association, and *E. gamophylla* is present locally. Most of the valley plains carry *A. aneura*; *E. camaldulensis* occurs along the major watercourses. Colluvium and sheetwash plains along the northern margin of the Hamersley Range are colonized by *T. basedowii, Hakea suberea,* and *E. gamophylla.* This association gives way to *A. aneura* woodland along much of the Fortescue River valley.

The remainder of MOUNT BRUCE forms part of the Ashburton Botanical District (Beard, 1975). Mudstone and sandstone of the Ashburton Formation are colonized by species of *Senna, Eremophilia,* and stunted *Acacia*. Other rock units, colluvium and Cainozoic gravel are characterized by *A. aneura, A. xiphophylla,* and *A. victoriae;* they may be associated with small shrubs such as *Eremophila cuneifolia, Sclerolaena divaricata* and *Atriplex inflata*.

MOUNT BRUCE can be divided into four main physiographic zones corresponding broadly to the areas of granite–greenstone basement, Hamersley Basin, Ashburton Basin rocks, and Cainozoic sediments.

* Names of 1:100 000 and 1:250 000 scale map sheets are printed in capitals

Granite–greenstone basement rocks form areas of low, rounded hills and ridges, and sandy valleys in southwestern and southeastern MOUNT BRUCE. Maximum elevation in this region is about 500 m and local relief is less than 100 m. Hamersley Basin rocks underlie most of the remaining map sheet area and give rise to a varied topography of high, rounded hills, plateaus, and strike ridges. The most extensive upland areas are associated with the iron formations of the Hamersley Group, especially the Brockman Iron Formation. Mount Bruce (22°36'26"S, 118°08'22"E), the highest point on the map sheet area, is an erosional remnant of the main banded iron-formation scarp on east-central MOUNT BRUCE. Here, local relief ranges up to 550 m and steep-sided gorges characterize the Hamersley Group outcrop, particularly along its northern margin. Ashburton Basin rocks are confined to the southwestern part of MOUNT BRUCE. In this area, folded sandstone, basalt, and dolomite give rise to a strike-ridge topography of low to moderate relief. Gently undulating hills of low to moderate relief occur where folds are open, or where the proportion of basalt or mudstone is high. Extensive areas of Cainozoic deposits form gently sloping plains, and broad valleys between the main outcrop areas. The largest of these is the Fortescue River valley, which transects the northeastern part of the map sheet area and separates Hamersley Basin rocks in the Chichester Range from those in the Hamersley Range.

Early geological investigations in the area are summarized in the first edition explanatory notes for the MOUNT BRUCE 1:250 000 geological sheet (de la Hunty, 1965). More recent accounts are discussed in the following text.

TECTONIC SETTING

The granite–greenstone basement of the Pilbara Craton (older than 2800 Ma) outcrops in the Rocklea and Milli Milli Domes in southern MOUNT BRUCE. These rocks are unconformably overlain by 2765–2470 Ma supracrustal deposits of the Hamersley Basin that outcrop in the northern part of the map sheet. Hamersley Basin rocks are unconformably overlain by the c. 2000 to 1800 Ma rocks of the Ashburton Basin, which was initiated during the early stages of the Capricorn Orogeny. Subsequent deformation of the Ashburton Basin took place during the final stages of the Capricorn Orogeny, at about 1800 Ma.

TERMINOLOGY

Rocks of the Hamersley and Ashburton Basins have been subjected to lower greenschist facies metamorphism, but for the sake of brevity, the prefix 'meta' is not used in the following descriptions when discussing the rocks that make up these basins.

PILBARA CRATON GRANITE–GREENSTONE ROCKS

Pilbara Craton granite–greenstone rocks are confined to the Rocklea and Milli Milli Domes and comprise quartzofeldspathic and quartz–chlorite schist, and metamorphosed basalt and pyroxene spinifex-textured basalt, chert, siliciclastic sedimentary rocks, biotite monzogranite, dolerite dykes, and minor pegmatite dykes. On MOUNT BRUCE, the minimum age of these rocks is fixed by the 2765 Ma age of the overlying lower Fortescue Group. Their maximum age is unknown, although comparison with similar granite–greenstone assemblages on the northern Pilbara Craton (Hickman, 1990) indicates that they formed between 3500 and 2800 Ma.

Granite–greenstone rocks on MOUNT BRUCE have been subject to lower greenschist facies metamorphism (Blight, 1985)

METAMORPHOSED BASALT (*Ab*) AND PYROXENE SPINIFEX-TEXTURED BASALT (*Abm*)

Metamorphosed basalt and pyroxene spinifex-textured basalt occur in small, irregularly shaped outcrops in the central, southern, and southeastern Rocklea Dome, and a small area in northeastern Milli Milli Dome. Contact relationships show that these rocks have been intruded by the main body of biotite monzogranite, and also by pegmatite and dolerite dykes.

Metabasalt forms massive, generally non-vesicular flows associated with minor metabasaltic breccia. This generalized unit has been subdivided where significant interbeds of metamorphosed pyroxene spinifex-textured basalt have been recognized. Most metabasalt is aphyric and consists of a felted mass of tremolite, epidote–clinozoisite, plagioclase, and chlorite, together with subordinate white mica and quartz. Plagioclase-phyric varieties, with porphyroblasts up to 1 mm long, are also recorded. The mineralogy of these rocks is thought to reflect mainly tholeiitic original compositions.

Metamorphosed spinifex-textured basalts are non-vesicular, and consist predominantly of randomly oriented, acicular relict pyroxene, interlayered with thin seams in which the pyroxene needles are aligned normal to the flow boundaries. The mineralogy of these rocks reflects their original high-Mg basalt composition and the lower greenschist facies metamorphism, and consists of recrystallized acicular tremolite and actinolite, in a finer grained matrix of chlorite, epidote–clinozoisite, talc, and sphene.

SCHIST DERIVED FROM IGNEOUS ROCK (*Al*)

Quartzofeldspathic schist, quartz–chlorite schist, and talc–carbonate schist outcrop in the northern part of the Rocklea Dome, and are separated from less deformed metamorphosed monzogranite and metabasaltic rocks to the south by an easterly trending belt of strongly foliated monzogranite and quartz–feldspar mylonite. Within this northern belt, contacts between the different schist types are generally subparallel to the strong foliation, although several quartz–chlorite schist bodies that show sharp contacts are strongly discordant to this trend.

Relict textures preserved within quartzofeldspathic schist indicate these rocks are formed from two separate protoliths: biotite monzogranite and felsic volcanic rock. The former consists of equant to flattened porphyroclasts of potassic feldspar and quartz aggregate in a fine-grained, sericitic quartzofeldspathic matrix. Schist derived from felsic volcanic rock is fine to medium grained and shows rounded to angular beta quartz, sericitized feldspar phenocrysts, and rhyolite or dacite lithic fragments, in a sericitized quartzofeldspathic matrix.

Quartz–chlorite schist is generally fine to medium grained and contains lenticular, or ribbon-like, porphyroclasts of recrystallized quartz set in a matrix of strongly aligned chlorite and leucoxenized opaques. Many quartz–chlorite schists are strongly carbonated. The mineralogy of this rock suggests that it originated as mafic igneous rock, while the strongly discordant relationships shown by some quartz–chlorite schist bodies suggest that they represent former dolerite dykes.

Friable talc–carbonate schist is the least abundant type of schist. It is generally very fine grained, and is probably derived from former ultramafic rock.

METASEDIMENTARY ROCKS (*As*)

Strongly foliated metasedimentary rocks, derived from argillite, lithic sandstone, chert, and minor conglomerate, outcrop in the northern part of the Rocklea Dome, and in the northern and southwestern Milli Milli Dome. In the latter area they were interbedded with minor basalt.

Pelite, derived from argillaceous rocks, is strongly foliated and often silicified and ferruginous; in southwestern Milli Milli Dome it grades into quartz–muscovite schist. Pelitic rocks are commonly interlayered with 0.02–1.0 m thick beds of metamorphosed, fine- to very coarse-grained sandstone; pebbly sandstone and pebble-conglomerate interbeds are present locally. Thin-bedded metasandstone is structureless or normally graded; thicker beds of metamorphosed sandstone, pebbly sandstone and conglomerate are massive. Compositionally, the metasandstones are quartz wackes and contain abundant polycrystalline quartz fragments and subordinate lithic clasts, comprising chert, pelite, and possible felsic volcanic rock.

Metamorphosed grey and white banded, fine-grained chert (*Ac*) outcrops within the sedimentary rock succession on the Milli Milli Dome, and also forms a laterally persistent marker unit within quartzofeldspathic schist and quartz–chlorite schist in the northern part of the granite–greenstone outcrop of the Rocklea Dome. In the latter, centimetre-scale banding within the chert reflects variations in quartz crystal grain size, the darker layers being composed mostly of 10–20 μm crystals, whereas grains in the coarser layers are generally 50–100 μm across. Isoclinal folds, with hinge lines and axial surfaces parallel to the bounding surfaces of the chert, are observed in some areas and deformation of cross-cutting quartz veins points to considerable flattening of this chert locally.

Field relationships suggest that many discontinuous chert outcrops represent highly silicified pelite or *Al* rocks. Other chert bodies, which are strongly foliated and lineated, and appear to contain relicts of porphyroclasts, may represent recrystallized mylonite.

METAMORPHOSED BIOTITE MONZOGRANITE (*Agm*)

Although affected by low-grade metamorphism, biotite monzogranite has the mineralogy and texture typical of intrusive granitoid.

Homogeneous, biotite monzogranite forms the dominant rock type in the south-central Rocklea Dome and central Milli Milli Dome. Contact relationships in both areas show that these rocks have intruded the metabasalt and spinifex-textured metabasalt. Monzogranites typically show a mineralogy comprising quartz, plagioclase (now albitic), microcline, minor biotite, and secondary sericite, epidote, and chlorite. Adjacent to the mylonitic contacts with *As* and *Al* on Milli Milli and northern Rocklea Domes, the monzogranite develops a blastomylonitic texture in which porphyroclasts of plagioclase and microcline lie in a fine-grained matrix of quartz, feldspar, biotite, and secondary white mica.

METAMORPHOSED MAFIC DYKES (d_1) AND PEGMATITE DYKES

North-trending metamorphosed mafic dykes, including the prominent intrusion extending northward from (22°53'05"S, 117°17'08"E), cut all granite–greenstone rocks in the core of the Rocklea Dome. These dykes are unconformably overlain by the lower Fortescue Group and are correlated with the earliest suite (d_1) of dykes in the Sylvania Inlier (Tyler, 1991). They appear to pre-date the north- to northeast-trending Black Range Dyke Suite on ROY HILL, which is coeval with lower Fortescue Group deposition (Wingate, 1994).

Small, discontinuous pegmatite dykes, up to 4 m thick, intrude basaltic greenstones in the southeastern part of the Rocklea Dome. These show no systematic trend and are not shown on the accompanying map sheet. Their relationship to both the d_1 dolerite dykes and the Fortescue Group is unknown.

GRANITE–GREENSTONE STRUCTURE

In the northern part of the Rocklea Dome, a pervasive, broadly easterly trending, northerly dipping foliation is developed in the biotite monzogranite and adjacent quartzofeldspathic schist and quartz–chlorite schist. The foliation grades into the easterly trending Mithgoondy Shear Zone, within which highly sheared rocks show a range of blastomylonitic to ultramylonitic textures. A prominent stretching lineation plunges 300/25–45 and sense-of-shear criteria indicate oblique dextral movement. The foliation and associated lineation within both the monzogranite and schistose rocks are deformed locally by small- to large-scale open folds of variable orientation (e.g. at 22°48'52"S, 117°16'22"E and 22°47'13"S, 117°25'08"E). These open folds are cut by the northward-trending dyke-suite (d_1) which is in turn displaced by an easterly trending pre-Fortescue Group dextral strike-slip fault located at 22°46'41"S, 117°17'22"E. Localized dextral C–S fabrics, observed within schistose rocks in this area, are probably related to this structure. A northwest-trending set of near vertical fractures, with centimetre-scale dextral offsets, cuts the prominent chert unit at 22°45'52"S, 117°20'55"E. These fractures are parallel to, and show the same shear sense as the main fault system in the nearby cover rocks, and were probably formed during the D_{2a} event of the Capricorn Orogeny (see below).

In the northeastern Milli Milli Dome the contact between sedimentary rocks (*As*) and the combined monzogranite (*Agm*) and basalt (*Ab*) units is marked by an east-northeasterly trending, mylonitic shear zone which generally dips steeply (70–90°) to the south and predates the Fortescue Group. Granitic rocks close to this zone show a strong, eastward-trending, steeply southward-dipping foliation (S_1), marked locally by a southwesterly plunging stretching lineation. Rotated feldspar porphyroclasts within these rocks show a consistent dextral sense-of-shear. A similar shear sense was also obtained from C–S fabrics within sedimentary rocks adjacent to the mylonite zone. In the western Milli Milli Dome, the mylonite zone and sedimentary rocks are folded into an upright, megascopic, synform–antiform combination, with a moderate (30°) west-northwesterly plunge. These folds also pre-date the basal Fortescue Group. Throughout the central Milli Milli Dome the S_1 foliation is cut locally by a second, steeply southward dipping, west-northwesterly trending foliation. It is not known if this second foliation is related to the pre-Fortescue Group macroscopic folds, or is associated instead with the D_{2a} event of the Capricorn Orogeny.

HAMERSLEY BASIN

The Hamersley Basin is a late Archaean to early Proterozoic (2765–2470 Ma) depositional basin which is exposed over most of the southern part of the Pilbara Craton. Three major stratigraphic units (collectively referred to as the Mount Bruce Supergroup) are recognized within the basin; these are, in ascending order, the Fortescue, Hamersley and Turee Creek Groups.

FORTESCUE GROUP

The Fortescue Group is the lowermost stratigraphic unit of the Hamersley Basin and rests with angular unconformity upon granite–greenstone basement. It is exposed over a large part of central and southern MOUNT BRUCE where it consists of about 6.4 km of low-grade volcanic and sedimentary rocks. The Fortescue Group was deposited between 2765 and 2687 Ma (Arndt et al., 1991). Six major stratigraphic units are recognized on MOUNT BRUCE. They are, in ascending order, the Mount Roe Basalt, Hardey Formation, Boongal Formation, Pyradie Formation, Bunjinah Formation, and Jeerinah Formation. In the Chichester Range, in the extreme northeast of MOUNT BRUCE, the Maddina Basalt is the lateral equivalent of the Bunjinah Formation.

Mount Roe Basalt (*AFr*)

The Mount Roe Basalt is confined to the southeastern limb of the Rocklea Dome and has a maximum thickness of about 100 m. It consists of basalt flows interbedded with thin beds of basaltic breccia. A thin feldspathic sandstone, coarsening upward into pebbly sandstone and conglomerate, occurs locally at the base of the formation.

Basalt flows range in thickness from 3–30 m. Most are massive in lower to middle parts of the flow but display strongly vesicular or amygdaloidal flow tops. The basalt consists of altered plagioclase phenocrysts in a carbonated and chloritized matrix; amygdules are infilled by carbonate, quartz and feldspar. Thin beds of flow-top breccia separate the basalt flows locally.

Hardey Formation (*AFh*)

The Hardey Formation unconformably overlies the granite–greenstone basement over most of MOUNT BRUCE, except for the eastern limb of Rocklea Dome where it disconformably overlies the Mount Roe Basalt. The Hardey Formation has a maximum thickness of about 1.8 km, and up to 500 m of the stratigraphy consists of dolerite and layered sills. The non-intrusive component consists of sandstone, siltstone, mudstone, conglomerate, volcaniclastic rock, basalt, and chert.

Trough cross-stratified feldspathic quartz sandstone and minor quartz pebble conglomerate (*AFhs*) dominate the lowermost 250–300 m of the Hardey Formation. Troughed sets range from 0.1 to 1.3 m thick, and trough axes indicate a general palaeoflow toward the southwest and west. Mudstone and siltstone occur interbedded with upward-coarsening feldspathic sandstone units in middle to upper parts of the stratigraphy.

Clast-supported, polymictic, pebble to boulder conglomerate (*AFhc*) forms lenticular bodies near the base of the Hardey Formation along the eastern and northern limbs of Rocklea Dome and in central Milli Milli Dome. In the eastern Rocklea Dome, the basal conglomerate contains a high proportion of Mount Roe Basalt fragments in addition to clasts of monzogranite, vein quartz, and chert. Conglomerate exposed on the northern margin of the Rocklea Dome is dominated by clasts of quartz–chlorite schist, chert, and quartzofeldspathic schist from the underlying greenstone succession, whereas in the Milli Milli Dome the clasts are composed mostly of vein quartz and metasedimentary rock.

Fine- to coarse-grained mafic volcaniclastic rock and basalt flows occur locally in the Hardey Formation, but are most abundant in middle to upper parts of the stratigraphy. Volcaniclastic layers contain lithic and vitric fragments of basaltic and andesitic composition, mixed with xenocrystic quartz and K-feldspar. The quartz and feldspar are generally well rounded and probably represent detritus from a pre-existing granitoid source. Volcaniclastic units display a variety of internal structures including trough cross-stratification, parallel stratification, current and wave-ripple cross-lamination, convolute lamination, and small slump folds. Basalt flows are generally 2–5 m thick, and have irregular, vesicular flow tops.

Boongal Formation (*AFo*)

The Boongal Formation conformably overlies the Hardey Formation in central southern MOUNT BRUCE. The formation has a maximum thickness of about 1 km and consists of submarine mafic volcanic rocks comprising massive mafic lava and tube- or sack-like pillow lava. Fine- to very coarse-grained hyaloclastite breccia, and mafic volcaniclastic rock are abundant locally. The altered mafic lavas are fine to medium grained, and may contain phenocrysts of plagioclase and tremolite. The matrix consists of chlorite, epidote, altered feldspar and actinolite. Beds of sand- to silt-sized volcaniclastic rock exhibit parallel lamination or ripple cross-lamination and many fine upwards.

Pyradie Formation (*AFp*)

The Pyradie Formation conformably overlies the Boongal Formation and is up to 1 km thick. It is characterized by a suite of submarine pyroxene spinifex-textured flows and pillow lavas, interbedded with hyaloclastite breccia, sand- to silt-sized volcaniclastic rock, mudstone, and minor chert. A prominent serpentinized komatiite flow (*AFpk*) occurs in the middle of the Pyradie Formation around the southeastern and northwestern limbs of Rocklea Dome.

Pyroxene spinifex-textured basalt flows range in thickness from 2–50 m. Many of the thicker flows show a structured zonation in which random blades and needles of former pyroxene occur in the lower part of the flow and pass up into a unit containing vertically aligned pyroxene sheaves interlayered with random pyroxene blades and needles. Flow bases are sharp and planar; flow tops are brecciated and in some cases, vesicular, and are often transitional upwards into hyaloclastite breccia. Columnar jointing is present in several flows.

Komatiite is restricted to Pyradie Formation outcrops to the south and southwest of Rocklea homestead (22°53'10"S, 117°26'51"E) and west of the Beasley River (22°43'26"S, 117°19'17"E). The komatiite flow is 100 m thick and shows a sharp, planar base and an irregular flow top, which is transitional into the overlying bed of hyaloclastite breccia. The internal structure of the flow comprises a lower unit of massive pyroxene cumulate, overlain successively by porphyritic and massive olivine orthocumulate, pyroxene spinifex-textured rock, and finally by fine-grained flow-top material. Komatiite mineralogy has been modified by low-grade metamorphism: olivine is replaced by antigorite, chlorite, and magnetite, whereas pyroxene has altered to tremolite. Interstitial material in the pyroxene-rich units consists largely of various combinations of tremolite–actinolite, leucoxene, saussuritized and albitized plagioclase, and quartz.

Sand- to silt-sized volcanic sandstone, argillite, and minor chert outcrop in the southeast corner of Rocklea Dome and north of the Mount Turner Syncline at 22°31'00"S, 117°41'30"E. Most beds of sand- to silt-sized volcaniclastic rock range in thickness from 0.1–0.4 m and exhibit parallel lamination or ripple cross-lamination. Thin- to medium-bedded chert units are generally less than 2 m thick and show fine to coarse, parallel planar to undulatory lamination.

Bunjinah Formation (*AFu*) and Maddina Basalt (*AFm*)

The Bunjinah Formation conformably overlies the Pyradie Formation. It has a maximum thickness of about 0.9 km and is very similar lithologically to the Boongal Formation, except that upper parts of the formation are represented by highly vesicular basalt flows interbedded with hyaloclastite breccia. Thick accumulations of hyaloclastite breccia and sand- to silt-sized volcaniclastic rock (*AFub*) characterize the formation in southwest MOUNT BRUCE.

In the Chichester Range, in the extreme northeast of MOUNT BRUCE, the Maddina Basalt is the lateral equivalent of the Bunjinah Formation. It consists largely of 5–50 m-thick, subaerial to shallow marine, amygdaloidal basalt flows and flow top breccia. The Maddina Basalt stratigraphy is not fully exposed on MOUNT BRUCE; on adjacent parts of ROY HILL the formation has a maximum thickness of about 350 m.

Jeerinah Formation (*AFj*)

The Jeerinah Formation conformably overlies the Bunjinah Formation and Maddina Basalt and is conformably overlain by the Marra Mamba Iron Formation of the Hamersley Group. Its present maximum thickness of 1.8 km is recorded in the southern part of MOUNT BRUCE where there has been extensive intrusion by dolerite and gabbro sills. Here, the depositional thickness is about 0.9 km and the formation consists of submarine massive and pillowed basaltic lava flows and basaltic breccia; mudstone and siltstone; chert; sandstone; and felsic volcanic rock. Mafic volcanic and intrusive rocks become less abundant, and the stratigraphy becomes thinner as the Jeerinah Formation is traced northeastward across MOUNT BRUCE. In the Chichester Range, for example, the formation is only about 150 m thick and comprises a basal quartz sandstone (Woodiana Member (*AFjo*)) overlain by carbonaceous pelite, chert, and minor thin-bedded sandstone.

Massive and pillowed basaltic lava flows make up most of the non-intrusive Jeerinah Formation stratigraphy in southern parts of MOUNT BRUCE. They form thin, lenticular units interlayered with dolerite and sedimentary rocks and also form thicker, laterally persistent units (*AFjl*) in the middle of the formation. Discontinuous beds of hyaloclastite breccia are commonly associated with the lava flows. Most of the remaining thickness of the Jeerinah Formation consists of parallel laminated, carbonaceous or ferruginous mudstone and siltstone, interbedded with finely laminated chert. In the northern Jeerinah Anticline, the upper part of the Jeerinah Formation contains a prominent, thinly bedded unit of fine-grained felsic volcaniclastic rock.

In the Chichester Range, the Woodiana Member has a maximum thickness of about 50 m and comprises cross-stratified quartz sandstone, with minor pelite and chert. It is interpreted as a transgressive shoreline deposit (Thorne and Trendall, in prep.).

Mafic (*AFd*) and layered mafic to ultramafic (*AFl*) sills in the Fortescue Group

Mafic and layered sills are an important component of the Fortescue Group, particularly in the Hardey and Jeerinah Formations. Massive, mafic sills range from discontinuous bodies only a few metres thick, to laterally persistent intrusions with a thickness of several hundred metres. Most are doleritic to gabbroic and have a relict subophitic to poikilitic texture. Their present mineralogy of actinolite, chlorite, epidote, altered plagioclase, and subordinate interstitial quartz, opaques, and apatite reflects the superimposed regional lower greenschist facies metamorphism.

Layered sills are generally 50–200 m thick and show an upward gradation from pyroxenite to leucocratic gabbro or dolerite. Lower levels of the sill have a medium- to coarse-grained cumulate texture and a mineralogy of tremolite–chlorite pseudomorphs after orthopyroxene in a matrix of chlorite, tremolite, talc, serpentine, and sphene. Locally, a thin serpentinite occurs at the base of the intrusion.

HAMERSLEY GROUP

Marra Mamba Iron Formation (*AHm*)

The Marra Mamba Iron Formation is the lowest unit of the Hamersley Group, and conformably overlies the Jeerinah Formation. It has been divided into three members (Kneeshaw, 1984; Blockley et al., 1993), but because of their limited thickness and the often poor quality of exposure of these units on MOUNT BRUCE this subdivision is not shown on the map.

The Nummuldi Member is the lowest unit and is estimated to be about 100 m thick in the Rocklea area. It consists of alternating yellow to yellow-brown chert and brown to black iron-formation mesobands. Podding of the banding is commonly seen. The overlying MacLeod Member is about 45 m thick and comprises interlayered thin shale, chert and banded iron-formation (BIF). The contact between the Nammuldi Member and the MacLeod Member is marked by a distinctive, podded chert layer known as the 'potato bed' (Blockley et al., 1993). The uppermost division, the Mount Newman Member, is estimated to be 60 m thick and consists dominantly of BIF with thin shale intervals.

Wittenoom Formation (*AHd*)

The Wittenoom Formation (formerly Wittenoom Dolomite) is one of the most heterolithic units of the Hamersley Group, and is estimated to be between 275 and 700 m thick on MOUNT BRUCE. It is subdivided into 3 members: a lower West Angela Member, a middle Paraburdoo Member, and an upper Bee Gorge Member (Simonson et al., 1993; Blockley et al., 1993). This subdivision is not shown on the map.

The West Angela Member has a maximum thickness of about 100 m and consists primarily of dolomite and dolomitic argillite. Chert is abundant in lower parts of the member but forms only a minor component towards the top. Sedimentary structures within the argillaceous beds include reverse graded-bedding and flame structures. Pyrite occurs in argillite beds as blebs and bedding-parallel stringers, and as fracture fillings (Blockley et al., 1993).

The Paraburdoo Member (Simonson et al., 1993) is probably between 175 and 450 m thick on MOUNT BRUCE. It consists of thin- to thick-bedded dolomite with minor amounts of chert and argillite, and almost everywhere displays even, tabular bedding. Most dolomite beds are a few centimetres to several decimetres thick; argillite layers are thinner on average, occurring in the form of submillimetre partings to thin beds up to a few centimetres thick.

The Bee Gorge Member (Simonson et al., 1993) is estimated to be between 75 and 230 m thick in the map sheet area. Thinly laminated graphitic argillite is the main lithology, together with subordinate thicknesses of carbonate, chert, volcaniclastic rock, and iron-formation. Many of the non-argillite rock-types display clastic textures and current-formed structures, and Kargel et al. (1996) recorded subaerial desiccation features. Simonson (1992) and Simonson et al. (1993) interpreted a layer of sand-sized potassium feldspar spherules that occurs within the Bee Gorge Member as melt droplets that were generated by a major bolide impact.

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

The Mount Sylvia Formation is about 30 m thick on MOUNT BRUCE, and conformably overlies the Wittenoom Formation. It consists of shale, dolomitic shale and three prominent BIFs, two of which mark the top and the bottom of the unit. The upper BIF, known as Bruno's Band, is the thickest, and forms a prominent marker bed throughout the Hamersley Range.

The Mount McRae Shale is about 70 m thick and comprises interlayered shale, dolomitic shale, chert, and minor BIF.

Brockman Iron Formation (*ℙHb*)

The Brockman Iron Formation is the main iron-formation within the Hamersley Group and has been described in detail by Trendall and Blockley (1970). It has an estimated maximum thickness of about 550 m and consists of four members: the Dales Gorge Member, the Whaleback Shale Member, the Joffre Member, and the Yandicoogina Shale Member.

The Dales Gorge Member consists of an alternating sequence of 17 BIF and 16 argillite macrobands (Trendall and Blockley, 1970). Where it is unmineralized the member is about 150 m thick. Compston et al. (1981) reported a U–Pb zircon age of 2490 ± 20 Ma from the S13 macroband of Dales Gorge Member.

The Whaleback Shale Member overlies the Dales Gorge Member and is composed predominantly of interlayered chert and shale with two BIF bands near the base. The member's thickness on MOUNT BRUCE is about 75 m. The Joffre Member overlies the Whaleback Shale and consists of 280 m of BIF with minor thin shale horizons. A prominent dolerite sill (*ℙHt*) intrudes the upper part of the Joffre Member in the northwestern part of the map sheet area. On MOUNT BRUCE the Yandicoogina Shale Member is about 40 m thick and overlies the Joffre Member. It comprises alternating chert and thin shale, intruded by dolerite sills.

Weeli Wolli Formation (*ℙHj*)

The Weeli Wolli Formation (500 m thick on MOUNT BRUCE) conformably overlies the Brockman Iron Formation and is conformably overlain by the Woongarra Rhyolite. It consists of 5–10 m-thick, typically jaspilitic, iron-formation, together with shale and chert. The formation has been intruded by several dolerite sills giving a distinctive, broadly striped appearance to the outcrops.

Woongarra Rhyolite (*ℙHw*)

The Woongarra Rhyolite (formerly Woongarra Volcanics) is 800 m thick at Woongarra Pool (22°52'59"S, 117°06'08"E) and is generally divisible into 3 units: a lower massive rhyolite; a median raft of BIF, shale, and dolerite; and an upper massive rhyolite (Trendall, 1995). The upper and lower units consist of massive, medium-grained quartz- and/or feldspar-phyric rhyolitic to rhyodacitic igneous rocks. The top of the upper unit is generally marked by a tuffaceous horizon that displays features consistent with the margin of a sill intruded into wet sediment (Trendall, 1995).

Trendall (1995) argued that both the upper and lower units of the Woongarra Rhyolite were emplaced as sills, having been injected via a comparatively small feeder pipe in the central part of the Hamersley Basin.

Reported multi-grain U–Pb zircon ages of 2470 ± 30 Ma (Compston et al., 1981) and 2439 ± 10 Ma (Pidgeon and Horwitz, 1991) — the latter includes single-grain analyses — provide the best estimate for the age of the Woongarra Rhyolite (Trendall, 1995).

Boolgeeda Iron Formation (*PHo*)

The Boolgeeda Iron Formation is the uppermost formation of the Hamersley Group and has a maximum thickness of 250 m. It conformably overlies the Woongarra Rhyolite and is itself conformably overlain by the Turee Creek Group. The Boolgeeda Iron Formation is subdivided into a lower unit comprising massive black to dark yellow-brown BIF, a poorly exposed central shaly unit, and an upper unit characterized by purple-black, thinly bedded and fissile BIF.

TUREE CREEK GROUP

The Turee Creek Group conformably overlies the Boolgeeda Iron Formation in the Hardey and Mount Brockman Synclines. It has an estimated maximum thickness of about 4 km in the Hardey Syncline, and here it is overlain unconformably by the Wyloo Group (Seymour et al., 1988; Powell and Li, 1991). Middle levels of the Turee Creek Group in the Hardey Syncline are intruded by medium- to coarse-grained dolerite sills (*PTUd*). The depositional setting of the Turee Creek Group is interpreted as offshore to deltaic (Krapez, 1996).

Trendall (1979) defined and described the Turee Creek Group in the Hardey Syncline and adjacent parts of WYLOO. He included within it the thick basal Kungarra Formation and a number of unnamed overlying units. Trendall's (1979) nomenclature for the lower Turee Creek Group is adopted for these notes and, in addition, the middle and upper part of the stratigraphy is subdivided into two newly named formations: the Koolbye Formation, which conformably overlies the Kungarra Formation, and the Kazput Formation, which conformably overlies the Koolbye Formation, and forms the uppermost part of the Turee Creek Group.

Kungarra Formation (*PTUk*)

The Kungarra Formation is about 2.8 km thick and its base is marked by a gradational, conformable contact with the underlying Boolgeeda Iron Formation. Above this contact the remainder of the formation comprises mudstone, siltstone, and thin-bedded sandstone. Mudstone and fine-grained siltstone are parallel laminated, whereas coarse-grained siltstone and fine-grained sandstone are either parallel laminated or ripple cross-laminated. Coarser grained sandstone forms tabular to lenticular beds. These are either structureless or normally graded, while some are parallel laminated with current ripple-laminated tops.

The Meteorite Bore Member (*PTUkm*) is a distinctive pebble to cobble argillite and sandstone unit that crops out in the upper part of the Kungarra Formation, on the southern side of the Hardey Syncline (22°55'13"S, 117°01'31"E) (Trendall, 1976). Most of the unit is massive, apart from local thick lithic sandstone beds. Pebbles and cobbles of sandstone and felsic volcanic rock are the dominant clast type, together with minor chert, carbonate rock, and vein quartz. A small proportion of these cobbles are faceted and striated; a feature which prompted Trendall (1976) to suggest that this deposit may be glacial in origin.

Koolbye Formation (*PTUo*)

The 130 m-thick Koolbye Formation (named after Koolbye Well, 22°59'49"S, 117°04'44"E) is confined to the Hardey Syncline where it is equivalent to the unnamed 'quartzite unit 1' of Trendall (1979). It apparently conformably overlies the Kungarra Formation and consists largely of fine- to coarse-grained quartz sandstone, and minor argillite and conglomerate.

Topographically, the formation forms a prominent strike-ridge within the outcrop area of middle Turee Creek Group argillaceous rocks.

The type section for the Koolbye Formation occurs at 22°54'27"S, 117°02'03"E. Here, the base of the formation is marked by a thin, discontinuous pebbly sandstone which is overlain by thin- to thick-bedded coarse-grained quartz sandstone. The remainder of the unit is dominated by tabular to lenticular beds of fine- to medium-grained quartz sandstone with thin argillite interbeds. Internal structure of the sandstones is varied and includes small- to medium-scale trough cross-strata, parallel planar to undulatory lamination, and ripple cross-lamination. Straight-crested symmetrical ripples are preserved on many bedding surfaces. The depositional environment of the Koolbye Formation is interpreted as coastal to shallow marine.

Kazput Formation (*ȻTUa*)

The Kazput Formation (named after Kazput Pool, 22°58'37"S, 117°11'25"E) is confined to the Hardey Syncline, where it is about 1.1 km thick and conformably overlies the Koolbye Formation. Although this formation outcrops in the extreme southwest of MOUNT BRUCE, its stratigraphy is best developed on adjacent parts of WYLOO. There it is equivalent to the combined unnamed 'carbonate and shale unit', and 'quartzite units 2 and 3' of Trendall (1979). The Kazput Formation is conformable upon the Koolbye Formation, and is unconformably overlain by the Beasley River Quartzite.

The type area for the Kazput Formation occurs in the Hardey Syncline on southeast WYLOO near 22°53'45"S, 117°58'15"E. There the succession consists largely of fine- to coarse-grained quartz sandstone, argillite, conglomerate, dolomite, and minor basalt and banded iron-formation. Argillaceous rocks form areas of low topography in the core of the Hardey Syncline; sandstone and conglomerate are more resistant and give rise to rounded hills and ridges. The depositional environment for the Kazput Formation is interpreted as shallow marine shelf to deltaic.

On MOUNT BRUCE the Kazput Formation is exposed below the Wyloo Group unconformity at 22°53'52"S, 117°00'04"E. Here the succession comprises a lenticular body of grey, recrystallized dolomite, underlain by a thin unit of ferruginous argillite and iron formation. Little surface detail is present in the dolomite other than a diffuse, irregularly sinusoidal banding of light and dark layers.

METAMORPHISM

It was thought initially that rocks in the Hamersley Basin were little affected by regional metamorphism (Trendall and Blockley, 1970). A study by Smith et al. (1982), however, established a zonal pattern of very low- and low-grade metamorphism, based mainly on assemblages observed in mafic volcanics from the Fortescue Group.

On MOUNT BRUCE four metamorphic zones were identified (Fig. 1), with grade increasing from the prehnite–pumpellyite zone in the northeastern corner of the sheet, through the prehnite–pumpellyite–epidote zone and the prehnite–pumpellyite–epidote–actinolite zone, to the (prehnite)–epidote–actinolite zone in the southwestern part. A narrow strip along the southwest margin is in the prehnite–pumpellyite–epidote–actinolite zone also. The overall pattern observed by Smith et al. (1982) throughout the Hamersley Basin showed that grade increased towards its southern margin. This is co-incident with a general increase in stratigraphic thickness of Hamersley Basin sedimentary rocks, and the zonal pattern was interpreted as the product of a regional burial metamorphism (M_h). The appearance of lower

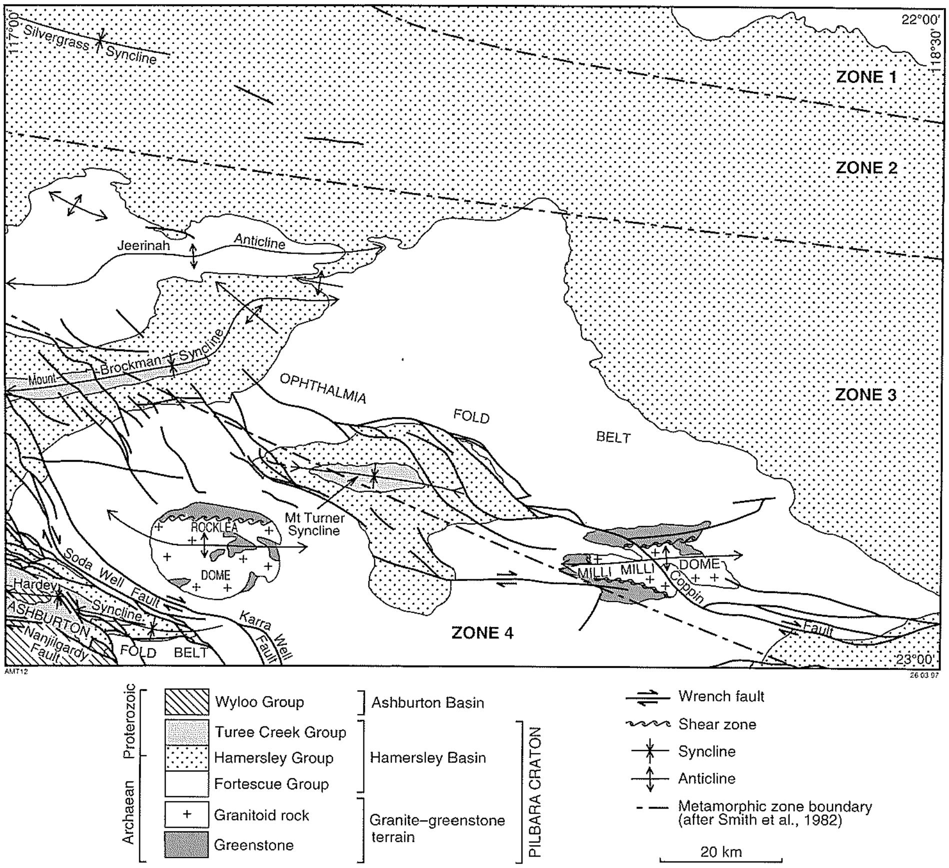

Figure1. Simplified geological map of MOUNT BRUCE showing the main tectonic units

grade rocks at the southern margin of the basin was explained by Smith et al. (1982) as the result of local thickening of the Fortescue Group and thinning of the Hamersley Group. However, Tyler (1991) considered their presence to be the result of later burial metamorphism beneath the Ashburton Basin.

The isograds and zones identified by Smith et al. (1982) are based on assemblages in the Fortescue Group, in the lower part of the Mount Bruce Supergroup. Stratigraphically higher units reached correspondingly lower grades (Smith et al., 1982, fig. 3). When all the units in the Hamersley Basin are considered, the isograd pattern is more complex than that interpreted by Smith et al. (1982) and appears to reflect the fold pattern, with lower grade rocks in the synclines and higher grade rocks in anticlines. Metamorphic conditions were between 300°C at 120 MPa and 470°C at 250 MPa (the interpreted maximum depth of observation, Smith et al., 1982).

ASHBURTON BASIN

The Ashburton Basin (Thorne, 1990; Thorne and Seymour, 1991) corresponds to the present day outcrop of the Wyloo Group. It is exposed in the extreme southwestern part of MOUNT

BRUCE and comprises a 12 km thick succession of sedimentary and volcanic rocks that have been metamorphosed at low grade.

WYLOO GROUP

The Wyloo Group was informally established and subdivided by MacLeod et al. (1963), and subsequently revised by Trendall (1979), Horwitz (1980), and Thorne and Seymour (1991). Felsic tuff in the upper part of the Wyloo Group on WYLOO gave a U–Pb zircon age of 1843 Ma (Pidgeon and Horwitz, 1991), whereas lead isotopes reported by Richards (1986) for galena in the Ashburton Formation on YARRALOOLA gave a model lead age of about 2.0 Ga.

On MOUNT BRUCE, the Wyloo Group is subdivided (in ascending order) into the following formations: Beasley River Quartzite, Cheela Springs Basalt, Mount McGrath Formation, Duck Creek Dolomite, and Ashburton Formation.

Beasley River Quartzite (*ЕWq*)

The Beasley River Quartzite is exposed along the axis and southern limb of the Hardey Syncline. It is 200–250 m thick and rests unconformably on the Turee Creek Group (Seymour et al., 1988; Powell and Li, 1991).

The formation consists mainly of cream- or white-weathering fine- to coarse-grained quartz sandstone, intruded locally by dolerite sills (*ЕWt*). The sandstone forms 0.05–1.5 m-thick tabular to lenticular beds showing a complex organization of internal stratification in which undulatory and planar parallel lamination pass vertically and laterally into sets showing trough or planar cross-stratification. Locally, symmetrical ripples are preserved on bedding surfaces. No reliable regional sediment transport directions were obtained from this unit which is characterized by palaeocurrent data of highly varied orientation (see Horwitz and Powell, 1992; figs 5, 8). In contrast, a more consistent, west-northwest directed palaeoflow was obtained from an assemblage of stacked sets of large-scale trough cross-stratification at 22°53'52"S, 117°01'45"E. Thorne and Seymour (1991) interpreted these quartz sandstones as shallow-marine, tidal-channel and sand-bar facies.

Up to 90 m of parallel-laminated and cross-laminated argillite, interbedded with subordinate amounts of ferruginous sandstone and jaspilitic BIF-derived conglomerate occur at the base of the Beasley River Quartzite along the axis of the Hardey Syncline. Horwitz and Powell (1992, fig 9a) recorded a broad northeastward palaeoflow from the jasper-bearing unit at one locality on the southeastern flank of the Hardey Syncline. However, this could not be confirmed by our observations at this locality.

Cheela Springs Basalt (*ЕWb*)

The Cheela Springs Basalt was initially regarded as a member within the Mount McGrath Formation (MacLeod et al., 1963), but was elevated to formation status by Horwitz (1980). On MOUNT BRUCE, the Cheela Springs Basalt outcrops in the area immediately southwest of the Hardey Syncline, where it conformably overlies the Beasley River Quartzite.

The formation has a thickness of about 1.7 km and comprises basalt flows interbedded with minor amounts of flow top breccia and parallel-laminated dolomite. Basalt flows are generally amygdaloidal and range from 5–20 m thick. All basalt has undergone prehnite–pumpellyite to lower greenschist facies metamorphism and now consists of andesine and relict pyroxene (partly or completely replaced by tremolite and chlorite) phenocrysts set in a groundmass of andesine, actinolite, chlorite, sphene, epidote, pumpellyite, and iron oxide.

Mount McGrath Formation (*ꞒWm*)

The Mount McGrath Formation was subdivided by de la Hunty (1965) and later redefined by Horwitz (1980) as 'the essentially clastic rocks that overlie disconformably the Cheela Springs Basalt and overlap unconformably onto older formations. It is conformably overlain by the Duck Creek Dolomite, which itself overlaps onto older units'. The Mount McGrath Formation has a maximum thickness of at least 1.2 km and occurs in discontinuous outcrops immediately south of the Hamersley Range.

The formation comprises ferruginous conglomerate and sandstone (often pebbly), quartz sandstone, argillite, dolomitic argillite, and dolomite. Ferruginous conglomerate and sandstone are most abundant in the middle part of the Mount McGrath Formation; the remaining rock types characterize lower and upper parts of the stratigraphy.

Conglomerate is generally clast-supported and occurs in lenticular or tabular beds up to 4 m thick. Most beds are parallel stratified and exhibit normal or inverse grading. The clasts are mainly of BIF, vein quartz, chert, quartz amygdules, and felsic igneous rock.

Sandstone and pebbly sandstone crops out in lenticular units up to 20 m thick. They are either cross-stratified or parallel stratified, or else are massive. Palaeocurrent data (axes of medium-size troughs) indicate that sediment transport was generally toward the south and southwest.

Quartz sandstone and siltstone are generally ripple cross-laminated or parallel laminated; mudstone is parallel laminated. Dolomite (including dolomitic mudstone) is generally parallel laminated, but may also contain soft-sediment folds and thin beds of intraformational breccia.

Approximately 100 m of parallel laminated ferruginous argillite and minor sandstone, conglomerate, and chert occur locally at the base of the Mount McGrath Formation. Lower levels of this unit may contain cobble- to boulder-sized clasts of dolomite, similar to the dolomite occurring at the top of the underlying Cheela Springs Basalt.

The upper part of the Mount McGrath Formation is characterized by a thick succession of dolomitic argillite, dolomite, and minor ferruginous sandstone (*ꞒWmd*). This unit is usually partly concealed beneath a Cainozoic silcrete caprock.

Duck Creek Dolomite (*ꞒWd*)

The Duck Creek Dolomite rests conformably upon the Mount McGrath Formation and has a maximum thickness of 1 km. The formation consists of thin- to thick-bedded, buff, grey, or mauve coloured dolomite. Silicification is locally intense.

Lower and upper levels of the Duck Creek Dolomite consist of thin-bedded dolomite and nodular dolomite interlayered with thin- to very thick-bedded dolorudite. Thin-bedded dolomite is planar to undulatory laminated and often contains layers and nodules of red or black chert. Beds are generally interstratified with thin layers of chloritic or ferruginous mudstone, and may contain synsedimentary folds. Thin-bedded dolomite is transitional into nodular dolomite. This fabric ranges from a gentle pinch-and-swell in the dolomite layers, to a complex network of interlocking nodules, which resembles a mechanical breccia. Thin to very thick beds of both clast- and matrix-supported, pebble- to boulder-dolorudite consist of a chaotic mixture of dolomite fragments set in a matrix of mudstone, coarsely crystalline dolomite or sparry quartz.

The middle part of the Duck Creek Dolomite consists of stromatolitic dolomite interbedded with dolomitic grainstone. Stromatolites recognized include *Pilbaria perplexa, Pilbaria* cf. *perplexa,* and *Asperia ashburtonia* (Grey, 1985). These forms are locally associated with planar laminated stromatolitic dolomite and isolated domical stromatolites. Intraclast grainstones are generally massive and poorly sorted, and often contain fragments of stromatolitic dolomite.

Ashburton Formation (*ȻWa*)

The Ashburton Formation, the uppermost stratigraphic unit of the Wyloo Group, conformably overlies the Duck Creek Dolomite in the extreme southwestern corner of MOUNT BRUCE. The formation has an estimated thickness of 5 to 12 km on neighbouring TUREE CREEK (Thorne and Seymour, 1991); only the lower part of this stratigraphy is exposed on MOUNT BRUCE.

Feldspathic and lithic quartz sandstone, interbedded with variable amounts of argillite and minor conglomerate make up most of the Ashburton Formation on MOUNT BRUCE. Two varieties of arenaceous deposit are recognized: thin- to medium-bedded sandstone, and massive sandstone. Sandstone beds of thin to medium thickness are laterally continuous, normally graded, and display a partial or complete development of the Bouma sequence of sedimentary structures. Massive sandstone is generally medium- to coarse-grained or pebbly, and occurs in tabular or lenticular beds up to 5 m thick. Palaeocurrent data from Ashburton Formation sandstone suggest sediment transport was toward the west-northwest.

Chloritic and ferruginous argillite forms layers that range in thickness from a few millimetres to several metres. Silt-sized layers are either parallel laminated or cross-laminated; mudstones are massive or parallel laminated.

CAPRICORN OROGEN STRUCTURE AND METAMORPHISM

STRUCTURE

The main tectonic features of MOUNT BRUCE are shown in Figure 1. The map sheet area forms part of the northern margin of the Capricorn Orogen (Fig. 2), a major zone of deformed, low- to high-grade metamorphic rocks and granitoid intrusions formed during continental crustal collision between the Pilbara and Yilgarn Cratons about 2000–1700 Ma (Gee, 1979; Myers, 1990a; Tyler and Thorne, 1990; Thorne and Seymour, 1991)

Available geochronological data, reviewed and summarized by Libby et al. (1986), suggest that the Orogen developed between 2200 and 1600 Ma, based on Sm–Nd and Rb–Sr data. A U–Pb zircon date of c. 1840 Ma for the June Hill Volcanics (Pidgeon and Horwitz, 1991) provides an age for the upper part of the Wyloo Group, regarded as synorogenic by Tyler and Thorne (1990, 1994). Early Proterozoic deformation is not restricted to the Ashburton Basin — it has also affected the Pilbara Craton rocks, producing large-scale folding and faulting. The timing of this folding and faulting, its relationship to the Capricorn Orogeny, and how many deformation events are represented, has been the subject of some debate, and is discussed below.

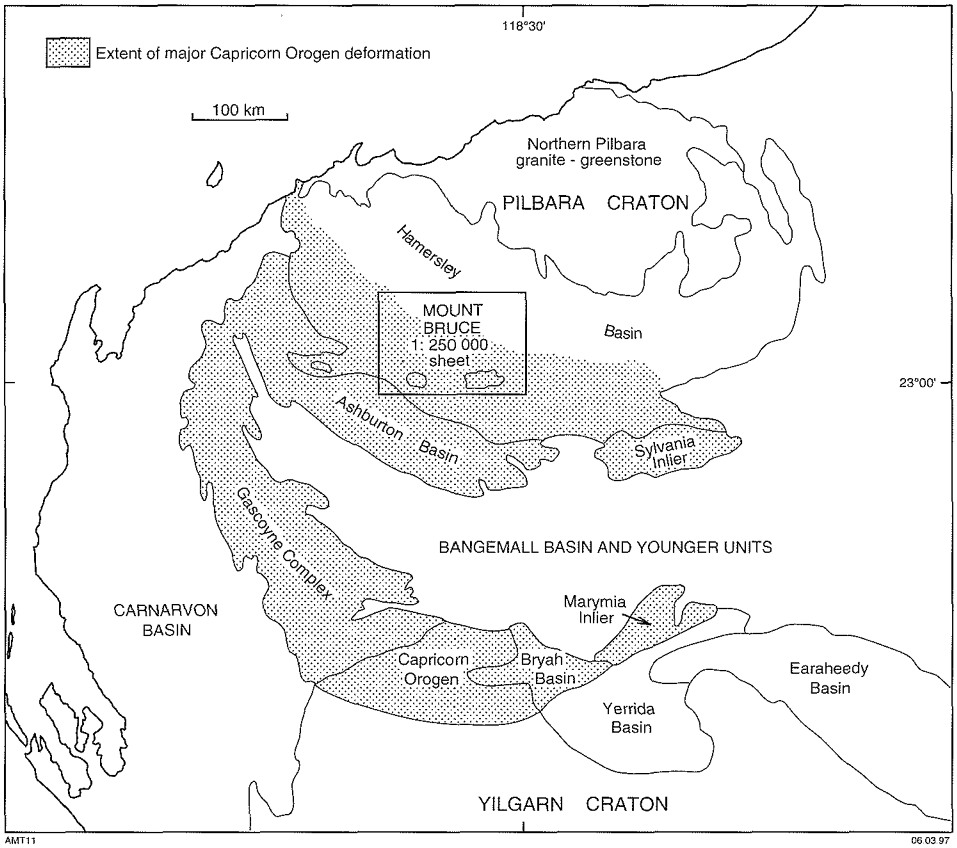

Figure 2. Map showing the main tectonic units of the Pilbara Craton, the northern Yilgarn Craton, and the Capricorn Orogen

Previous interpretations of structural development in the northern Capricorn Orogen have been based on the mapping of MacLeod et al. (1963), Halligan and Daniels (1964) and MacLeod (1966). In general, an increasing intensity of deformation was recognized from the Fortescue Valley southwards with two fold periods, the Ophthalmian and the Rocklean, inferred from the presence of large-scale dome-and-basin structures interpreted as fold interference patterns. Folding was regarded as passive, formed as a response to essentially vertical movements in the basement. Due to the absence of small-scale folds that could be attributed to the Rocklean fold period, Gee (1979) re-interpreted the fold pattern as a single set of folds with curvilinear axes. Trendall (1979) documented an unconformity between the Wyloo Group and the Mount Bruce Supergroup. This enabled Gee (1979) to separate structures into two fold belts: the Ophthalmia Fold Belt, and the younger Ashburton Fold Belt (Fig. 1).

Tyler and Thorne (1994) and Thorne and Trendall (in prep.) have recognized the occurrence of two major sets of west-northwest trending faults — the Jeerinah–Sylvania Fault system and the Nanjilgardy Fault system — that were initiated as normal faults and controlled regional variations in stratigraphy and sedimentation patterns during deposition of the Fortescue Group. These structures are regarded as having controlled later deformation, being periodically re-activated as extensional faults, strike-slip faults, and thrusts.

In the southwestern part of the Hamersley Basin, the Ophthalmia Fold Belt is characterized by broad-scale, open folds having a mainly northwesterly trend, which corresponds to the central structural zone of MacLeod et al. (1963). Tyler (1991) identified a regional-scale foreland fold-and-thrust belt in the southeastern Hamersley Basin characterized by easterly trending, close to tight folds with short wavelengths, corresponding to the southern structural zone of MacLeod et al. (1963). As will be discussed, structural and stratigraphic relationships along the margin between the Ophthalmia and Ashburton fold belts suggest that these two groups of folds represent different events. Deformation to produce the open folds was attributed by Tyler (1992) to dextral transpression along the southern Pilbara margin during the early stages of the Capricorn Orogeny of Gee (1979). Horwitz and Powell (1992) and Blake and Barley (1992), however, have suggested that this deformation was related to the development of the McGrath Trough (Horwitz, 1982) which was initiated either as a foreland basin or a backarc compressive cratonic basin during a collision between the Pilbara Craton and an unknown southern continent sometime after c. 2440 Ma but before 1840 Ma.

Tyler and Thorne (1990, 1994) interpreted the foreland fold-and-thrust belt in the southeastern Hamersley Basin as the result of an oblique collision between the Pilbara and Yilgarn Cratons at c. 1840 Ma, taking place in the east first and migrating westwards. Uplift of the Sylvania Inlier supplied granitic sediment to the Ashburton Formation in the Ashburton Basin. Initial deformation of the Ashburton Basin to form the Ashburton Fold Belt was attributed to thrusting. Associated uplift provided sediment to the Mount Minnie Group and the Capricorn Formation. Later deformation was related to a dextral wrench fault system produced by the extrusion of material westwards from between the two approaching craton margins.

In contrast, Horwitz and Powell (1992) regarded the widespread occurrence of northwesterly oriented mafic dykes as evidence of a period of extension during upper Wyloo Group time, marked by the occurrence of mafic volcanics. The formation of both the open fold structures and the foreland fold-and-thrust belt was thought to have occurred contemporaneously, prior to the deposition of the upper Wyloo Group.

Ophthalmia Fold Belt

The earliest deformation that affected Hamersley Basin rocks within the Ophthalmia Fold Belt produced small-scale layer-parallel folds. This deformation, referred to as D_{1c}, was first recognized by Tyler et al. (1990) on NEWMAN, where it is restricted to particular stratigraphic units. On MOUNT BRUCE, D_{1c} folds have been recognized within the lower part of the Boolgeeda Iron Formation at the eastern end of the Mount Brockman Syncline. Tight to isoclinal, layer-parallel small-scale folds with a sporadically developed axial planar cleavage, which have been described by Horwitz and Powell (1992, p. 54) from the Mount Sylvia Formation on Mount Nameless near Tom Price, are here regarded as D_{1c} structures also. Although they have a west-northwesterly trend and occur on the northeastern limb of the regional-scale Mount Turner Syncline, their fold geometry and layer-parallel orientation are not consistent with their formation parallel to the axial plane of this upright to steeply inclined, close to tight structure.

The origin of D_{1c} structures is problematical. Although they occur throughout the Hamersley Basin, any one occurrence appears to be limited in its extent. Deformation is restricted to bedding planes, and ramping, in which the deformation cuts up or down the stratigraphy, is not seen. Movement directions are unknown and they could represent either extensional or compressional features. Horwitz and Powell (1992) suggested that these structures may be related to the formation of extensional features which are widespread in banded iron-formations of the Hamersley Basin (the cross-pods of Trendall and Blockley, 1970).

Broad-scale, open dome-and-basin structures with curvilinear trends that vary from west-northwest to east-northeast are mapped as D_{2c} folds that belong to the Ophthalmia Fold Belt on MOUNT BRUCE. In general, folding becomes more intense from northeast to southwest across the sheet. The main structures are the Silver Grass Syncline, the Jeerinah Anticline, the Mount Brockman Syncline, the Mount Turner Syncline, the Rocklea Dome, the Milli Milli Dome, and the Hardey Syncline (Fig. 1). These fold structures tend to die out along their axes, a good example being the Mount Turner Syncline, which dies out towards the western margin of the sheet, between the Rocklea Dome and the Mount Brockman Syncline. A pervasive axial planar cleavage, similar to that developed in the southeastern Ophthalmia Fold Belt (Tyler et al., 1990; Tyler, 1991), is not developed on MOUNT BRUCE. However, steeply inclined to upright small- and medium-scale folds, with an associated slaty or spaced cleavage, are present locally. Within banded iron-formation units a spaced cleavage may form as a 'crenulation' of the microbanding. The 'regional rippling' described by Trendall and Blockley (1970) as occurring subparallel to the major fold axes, appears to represent a larger scale version of this cleavage, forming either as kink bands, or as asymmetrical extensional shear bands.

In the Hardey Syncline west-northwesterly trending, open, steeply inclined to upright structures deform the Turee Creek Group (Trendall, 1979; Seymour et al., 1988; Powell and Li, 1991). The Beasley River Quartzite of the lower Wyloo Group lies unconformably on the folded Turee Creek Group (Seymour et al., 1988; Powell and Li, 1991), and this relationship is well illustrated 2 km north-northwest of Meteorite Bore (22°55'36"S, 117°02'28"E). Similar relationships are seen at the eastern end of the Wyloo Dome farther to the west on WYLOO (Horwitz, 1982; Seymour et al., 1988).

Tyler and Thorne (1990) and Tyler (1991) used these relationships as evidence that folding in the western part of the Ophthalmia Fold Belt pre-dated the fold-and-thrust event in the southeast, which folds the lower Wyloo Group rocks that lie with apparent conformity on Turee Creek Group rocks in the core of the Turee Creek Syncline (Thorne et al., 1991). Powell and Li (1991), however, pointed out that there are two fold phases in the Hardey Syncline, with the second post-dating the lower Wyloo Group. Based on the occurrence of only one cleavage that occurs in both the Turee Creek Group rocks and the lower Wyloo Group rocks, they interpreted the two sets of essentially co-planar folds as actually representing one set of west-northwesterly trending folds that started to form during Turee Creek Group times and continued to form after the Beasley River Quartzite was deposited. They correlated this continuous folding event with the D_{2c} event of Tyler and Thorne (1990) and Tyler (1991), and regarded it as evidence that the main fold structures throughout the Ophthalmia Fold Belt all formed at this time.

To the southeast of MOUNT BRUCE on PARABURDOO and TUREE CREEK there is no evidence that folding took place between the deposition of the Turee Creek Group and the Beasley River Quartzite. The Beasley River Quartzite lies disconformably on the Weeli Wolli Formation of the Hamersley Group along the southwestern limb of the Bellary Dome, whereas in the Mount Maguire area and the core of the Turee Creek Syncline it rests with apparent conformity on the Turee Creek Group (Thorne et al., 1991; Thorne and Tyler, 1994). As has been discussed, palaeocurrent directions in the upper Turee Creek Group are consistent with uplift to the southwest, but reliable (non-marine) palaeocurrent directions in the Beasley River Quartzite indicate derivation from the northwest and northeast (Thorne and Seymour, 1991), not from the southwest as would be expected with the lower Wyloo Group foreland basin model.

Although Powell and Li (1991) and Horwitz and Powell (1992) correlated the post-Beasley River Quartzite folding in the core of the Hardey Syncline with the fold-and-thrust event in the southeast of the Ophthalmia Fold Belt, there is no evidence in the Wyloo Group succession on MOUNT BRUCE that substantial folding or tilting of strata took place between the deposition of the Cheela Springs Basalt and deposition of the Mount McGrath Formation. Further to the west, the Mount McGrath Formation lies unconformably on Hamersley Basin rocks around the southwestern and western margins of the Wyloo Dome (Horwitz, 1982; Seymour et al., 1988) indicating that uplift did occur locally during D_{2c}. To the southeast, the Mount McGrath Formation lies unconformably on Hamersley Basin rocks along the southern limb of the D_{2c} Turee Creek Syncline (Thorne et al., 1991).

Ashburton Fold Belt

The Ashburton Fold Belt has been described by Thorne and Seymour (1991) and affects Wyloo Group and Hamersley Basin rocks in the southwestern corner of MOUNT BRUCE, which lie within the northern structural zone, dominated by large-scale, open to tight D_{2a} folds. Early, recumbent D_{1a} folds are restricted to the southern and central zones of the fold belt and are not recognized on MOUNT BRUCE. The separation of Ashburton Fold Belt from Ophthalmia Fold Belt structures in this marginal zone can be difficult as folding is essentially co-planar, with the later deformation tightening pre-existing folds and reactivating previous faults. On MOUNT BRUCE the northeastern margin of the Ashburton Fold Belt is represented by the Nanjilgardy and Soda Well faults (Fig. 1) and associated quartz veins (*q*) in the southwest of the sheet.

Along the northeastern limb of the Hardey Syncline, faulting has taken place parallel to the regional strike of bedding, and units including the Wittenoom Dolomite, the Marra Mamba Iron Formation, and parts of the Jeerinah Formation, have been removed. Horwitz and Ramanaidou (1993) attributed this to syndepositional slumping. However, the faults can be traced out into northwesterly trending structures that cut across the nose of the fold, and are linked to faults with similar relationships, but which cut Wyloo Group rocks and show dextral offsets of up to 7.5 km, along the southern limb of the Bellary Dome on PARABURDOO and TUREE CREEK (Tyler, 1991; Thorne et al., 1991; Thorne and Tyler, 1994). These fractures are linked also to prominent dextral strike-slip faults along the eastern margin of the Wyloo Dome to the west (Seymour et al., 1988).

Throughout the southwestern limb of the Hardey Syncline, a prominent cleavage is developed within Wyloo Group rocks, including Cheela Springs Basalt and adjacent Mount McGrath Formation. This fabric is therefore regarded as D_{2a} in age and, as there is no evidence of the development of a crenulation cleavage, is regarded as the same fabric that occurs in Turee Creek Group and Beasley River Quartzite in the core of the syncline. Horwitz and Powell (1992, fig. 3a) regarded a northwesterly trending fold structure as younger, refolding the core of the Hardey Syncline. This structure is parallel to a fault, and to the west of Meteorite Bore the S_{2a} fabric becomes more intense towards it, with tails developed on pebbles in diamictite. Again, there is no evidence of the development of a crenulation cleavage. The relationship between northwesterly trending folds and faults and west-northwesterly trending folds (Fig. 1) is consistent with dextral strike-slip faulting (Wilcox et al., 1973) controlled by reactivation of the Nanjilgardy Fault system during D_{2a} (Tyler and Thorne, 1994). Similar relationships between folding and faulting occur in Wyloo Group rocks to the southeast of Mount Maguire on PARABURDOO and TUREE CREEK (Thorne et al., 1991; Thorne and Tyler, 1994).

Within the Ophthalmia Fold Belt, a zone of west-northwesterly to northwesterly oriented faults and associated folds is well developed along the northwestern limb of the Turee Creek Syncline (22°28'S,118°15'E), along the southern and eastern limb of the Mount Turner Syncline, and through the northeastern end of the Mount Brockman Syncline and the Jeerinah Anticline. This has been interpreted as the result of reactivation of the Jeerinah–Sylvania Fault system as a dextral strike-slip fault system during D_{2a} (Tyler and Thorne, 1994). Along the northwestern margin of the Turee Creek Syncline the Coppin Fault is oriented east to east-southeast, either parallel to, or slightly oblique to the strike of Fortescue Group bedding. The steeply dipping, south-side down fault geometry has resulted in considerable attenuation of the Fortescue Group outcrop, largely through the down-faulting of the Boongal and Pyradie Formations. The surface expression of the Coppin Fault can be traced as far west as 22°54'13"S, 118°07'03"E in the central southern Milli Milli Dome. Here it joins a second D_{2a} structure (Fig. 1) before trending northwestward through the basement core of the dome and cutting the southeastern closure of the Mount Turner Syncline. Although the line of the fault through the centre of the Milli Milli Dome is concealed by Cainozoic deposits, the marked northwesterly deflection of the easterly trending foliation in metasedimentary rocks at 22°47'43"S, 117°59'27"E supports the interpretation of a major northwest-trending fault in this area.

Upright, northwesterly plunging, small- to large-scale folds are developed along the eastern limb of the Mount Turner Syncline and are associated with a series of D_{2a} dextral strike-slip faults — the Tom Price Fault system. Twelve kilometres southeast of Tom Price, faulting occurs subparallel to the strike of the Jeerinah Formation, with the main fault surface stepping up the stratigraphy as it is traced toward the west. At 22°46'41"S, 117°49'06"E this fault truncates the lower part of the Marra Mamba Formation and continues northwestward as the Batter Fault, a southwesterly dipping, southwest-side down structure, which can be traced through the Tom Price orebody as far as 22°42'49"S, 117°43'28"E. A major northwesterly trending fault cuts through the Jeerinah Formation and lower Hamersley Group stratigraphy between 22°46'34"S, 117°51'27"E and 22°39'01"S, 117°43'13"E, before linking up with another set of strike-slip faults which cut the northeastern margin of the Mount Turner Syncline (Fig. 1).

The eastern end of the Mount Brockman Syncline, and the Jeerinah Anticline to the north, have both been refolded about west-northwesterly trending axes to produce regional-scale type 1 and type 2 fold interference patterns (Ramsay and Huber, 1987). Open to isoclinal small- and medium-scale folds, with steeply south-southwesterly dipping axial surfaces and gentle to moderate west-northwesterly, or, less frequently, east-southeasterly plunges, are locally developed. A spaced cleavage may be present axial planar to these folds. Medium-scale type 2 interference patterns occur along the southeastern limb of the Mount Brockman Syncline, with larger scale interference patterns occurring within Brockman Iron Formation to the east of Mount Brockman. This is consistent with a north-northeast–south-southwest compression, as would be expected as part of a northwesterly oriented dextral transpression during D_{2a}. The curvilinear trend of the major folds within the Ophthalmia Fold Belt on MOUNT BRUCE can be attributed to clockwise rotation of the fold axes during D_{2a} dextral strike-slip faulting, similar to the interpreted rotation of the D_{2c} Turee Creek Syncline (Tyler and Thorne, 1990; Tyler, 1991). To the northeast of the Jeerinah Anticline, D_{2a} deformation is restricted to narrow zones and takes the form of large-scale box folds and monoclines associated with minor thrusts. Good examples are seen from the approach road to Mount Sheila (22°13'18"S, 117°36'02"E), and in a railway cutting 12 km north of Hamersley homestead (22°16'39"S, 117°40'32"E).

Horwitz and Powell (1992) noted that the fold pattern in the western Ophthalmia Fold Belt was the result of interference between west-northwesterly trending folds and northwesterly trending folds, but they regarded dextral strike-slip faulting as a younger event.

METAMORPHISM

Throughout the Ashburton Basin on MOUNT BRUCE the metamorphic grade is low, with the quartz–chlorite–sericite assemblage being typical of much of the fold belt.

In terms of the known stratigraphic and structural sequence, metamorphism in the Ashburton Fold Belt is a separate event (M_a) from the burial metamorphism recognized in the Hamersley Basin. Tyler and Thorne (1990) regarded peak metamorphism in the Wyloo Group as the product of overthrusting during the D_{1a} deformation, with retrogression taking place during the later, higher level D_{2a} event.

MAFIC DYKES

Four mafic dyke swarms, trending north (d_1), west-northwest (d_4), northwest (d_5), and northeast (d_7), occur on MOUNT BRUCE (Fig. 3). All the dykes are dolerite and consist of pyroxene and feldspar with minor quartz, hornblende and biotite.

The d_1 swarm is the oldest dyke suite; it cuts Pilbara Craton granite–greenstone rocks in the core of the Rocklea Dome but is overlain by the basal Fortescue Group. It appears to pre-date the north- to northeast-trending Black Range Dyke Suite (d_1) on ROY HILL, which is coeval with lower Fortescue Group deposition (Wingate, 1994).

West-northwesterly (d_4) and northwesterly (d_5) trending mafic dykes (Tyler, 1990) are seen to cut Hamersley Basin rocks, with the northwesterly set, equivalent to the Round Hummock Suite of Hickman and Lipple (1978), also cutting the Beasley River Quartzite in the core of the Hardey Syncline. On PARABURDOO, mafic dykes that post-date D_{2c} folding (Tyler, 1991; Thorne et al., 1991; Thorne and Tyler, 1994) are thought to pre-date the major period of iron-ore formation (Morris, 1980).

The west-northwesterly trending dykes are restricted to the southern margin of the Pilbara Craton (Tyler, 1990) and are older than the northwesterly trending swarm, being cut by them in the Sylvania Inlier (Tyler, 1991). The northwesterly trending dykes are more extensive, occurring throughout the Pilbara Craton. Northwesterly trending dykes are particularly well developed in the southern part of MOUNT BRUCE. Both sets typically infill pre-existing joints and faults (Baldwin, 1975; Bourn and Jackson, 1979). Horwitz and Powell (1992) noted that northwesterly trending small- and medium-scale folds around the Mount Turner Syncline, here regarded as D_{2a} in age, were localized along the margins of the northwesterly trending dykes, suggesting that dyke emplacement occurred pre- to syn-D_{2a}.

The northeast-trending (d_7) swarm is equivalent to the Mundine Well Suite of Hickman and Lipple (1978) and the Mundine dyke swarm of Myers (1990b). Dykes are continuous over long distances, and their intrusion post-dates deformation of the Bangemall Basin on southern TUREE CREEK (Thorne et al., 1991). A dyke belonging to this suite caused recrystallization of hematite ore at Channar on PARABURDOO (Bourn and Jackson, 1979).

CAINOZOIC GEOLOGY

A prominent feature of the Cainozoic geology of the Pilbara region is the Hamersley Surface (MacLeod et al., 1963; Campana et al., 1964; Twidale et al., 1985), an elevated and dissected peneplanation surface, probably of late Mesozoic to early Tertiary age. Residual deposits (*Czr* and *Czl*) that formed as part of this surface are lateritic and may be ferruginous. Surficial iron enrichment produced deposits of hematite–goethite ore over banded iron-formation locally (Morris, 1980, 1985; Kneeshaw, 1984).

An early stage in the dissection of the Hamersley Surface produced extensive valley-fill deposits. These take the form of partly consolidated and cemented colluvium (*Czc*), and

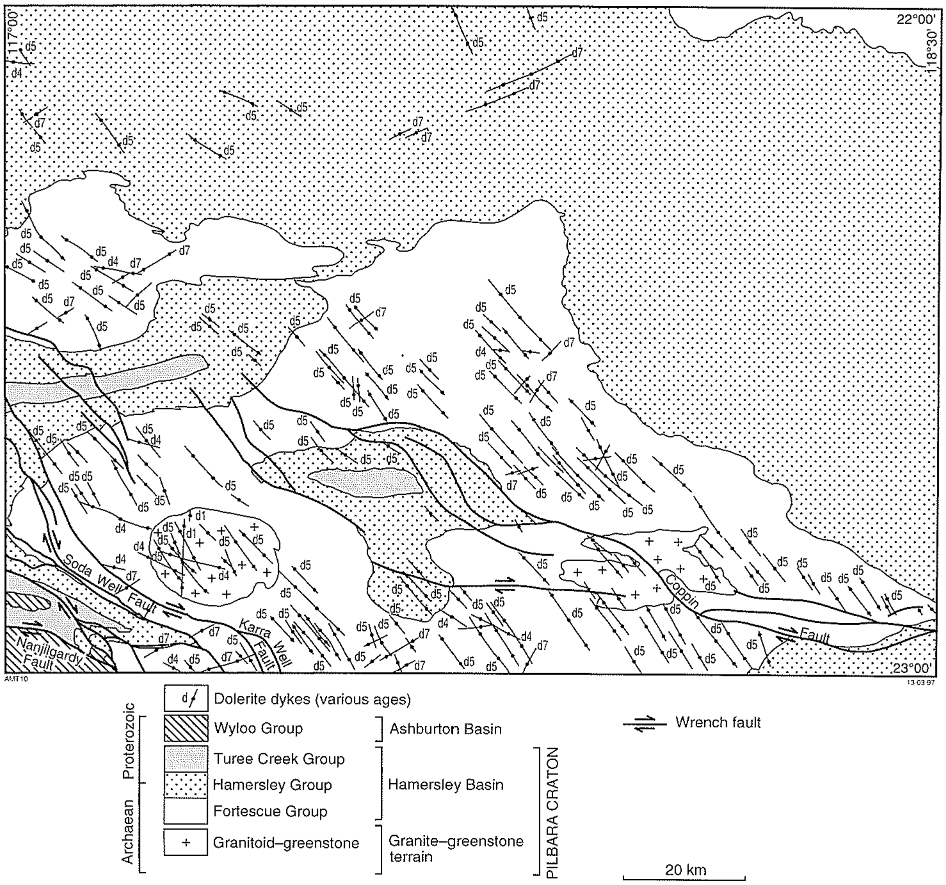

Figure 3. Simplified geological map of MOUNT BRUCE showing the trends of the major dolerite dyke swarms

alluvium (*Cza*), and calcrete (*Czk*). The Robe Pisolite (*Czp*) is 15–45 m thick, forms elevated terraces and mesas above the valley fill, and contains limonite and hematite pisoliths, generally small amounts of terrigenous detritus, and scattered fragments of fossil wood. Hocking et al. (1987) suggested a Late Eocene age for the Robe Pisolite.

Areas of sheetwash plain (*Qw*) occur within the Hardey and Mount Brockman Synclines. Alluvium (*Qa*), comprising unconsolidated silt, sand and gravel, was deposited along the present drainage channels, and colluvium (*Qc*) forms recent talus slopes, adjacent to outcropping bedrock. Small areas of wind-blown sand (*Qs*) occur in the Hardey Syncline and Rocklea Dome.

ECONOMIC GEOLOGY

GOLD

Small amounts of gold have been recovered from Cainozoic deposits overlying granite–greenstone and Fortescue Group rocks on MOUNT BRUCE. Total production reported to the

Department of Minerals and Energy until the end of 1994 amounted to 2.2 kg, most of this having been obtained from alluvial workings on the northern limb of the Rocklea Dome. Here, the source of this alluvial gold is thought to be either sheared quartz–chlorite schist (*Al*) or basal Hardey Formation conglomerate (*AFhc*). In the northern Milli Milli Dome, abandoned alluvial workings overlie silicified metasedimentary rocks (*As*).

IRON

Hamersley Group rocks on MOUNT BRUCE lie within the Hamersley Iron Province of MacLeod et al. (1963). The presence of major hematite ore bodies on MOUNT BRUCE was recognized during the 1960s (de la Hunty and Jones, 1964), the principal associations being with BIF in the Brockman and Marra Mamba Iron Formations, and Cainozoic valley floor deposits, particularly the Robe Pisolite (*Czp*) and some ferruginous gravels (*Czr*). Iron ore is currently being mined at Tom Price, Marandoo, and the Brockman No. 2 Detritals deposit.

The formation of hematite ore bodies in BIF has been discussed by Morris (1980, 1985). The occurrence of hematite pebbles containing microplaty hematite, a form of hematite characteristic of the major ore bodies, in the Mount McGrath Formation near Paraburdoo restricts the age of ore formation to early Proterozoic (c. 2000 Ma, the age of the Wyloo Group). The close association of high-grade hematite deposits with areas of structural complexity suggests hydrothermal fluid flow along large-scale Capricorn Orogen (D_{2a}) faults (Sibson, 1987) was an important element in the iron-ore enrichment process. The principal ore types are martite–hematite and martite–(hematite)–goethite (Baldwin, 1975; Kneeshaw, 1984).

Demonstrated resources of high-grade (>60% Fe), low- and medium-phosphorus ore from the Brockman Iron Formation on MOUNT BRUCE stand at 825 Mt, whereas the equivalent figure for the Marra Mamba Iron Formation is 1348 Mt. In addition, the MOUNT BRUCE area has demonstrated resources of 400 Mt of high-grade pisolitic ore (>55% Fe) associated with the Robe Pisolite, and an additional 459 Mt of detrital ore (>55% Fe) occurring as part of the Cainozoic scree cover.

ASBESTOS

Numerous occurrences of crocidolite have been recorded from the Brockman and Marra Mamba Iron Formations of the Hamersley Group. The main concentrations occur within the Brockman Iron Formation around Wittenoom and Yampire Gorges (22°19'49"S, 118°19'49"E and 22°23'37"S, 118°18'41"E respectively) where the mineral occurs within the Dales Gorge Member. Mining of these deposits began in 1933 and continued spasmodically until 1966, by which time the Wittenoom and Yampire mines had produced about 20 kt and 1 kt of crocidolite fibre respectively (Blockley, 1976).

The principal crocidolite deposits in the Marra Mamba Iron Formation are associated with medium-scale D_{2a} folds on the northern limb of the Jeerinah Anticline, near Mount Brockman homestead (22°17'58"S, 117°17'28"E). Recorded production from this area is almost 60 t of fibre (Blockley, 1976).

Minor occurrences of fibrous chrysotile asbestos occur locally within the Fortescue Group on MOUNT BRUCE (Blight, 1985). In all cases this material fills fractures in layered sills and ultramafic flows within the Hardey and Pyradie Formations.

COPPER

Most exploration for copper on Mount Bruce has focused attention on carbonaceous and sulfidic shales in the upper part of the Jeerinah Formation, with some attention also having been given to the Hardey Formation (Marston, 1979). The most prospective areas are centred on old workings on the Milli Milli Dome and the northern limb of the Jeerinah Anticline.

Minthicoondunna (Mindi) prospect (22°44'40"S, 118°15'40"E) is on the northeastern flank of the Milli Milli Dome and occurs within the Jeerinah Formation, close to the contact with the Marra Mamba Iron Formation (Marston, 1979). A 110 m vertical drillhole sunk by Western Mining Corporation encountered pyrite and pyrrhotite-bearing graphitic shale assaying a maximum of 2080 ppm Cu. Most assays were, however, considerably less than 1000 ppm.

The adjacent Brockman and Edneys prospects (22°20'59"S, 117°18'00"E) occur in Jeerinah Formation argillite and interbedded chert on the north-dipping limb of the Jeerinah Anticline (Marston, 1979). Five vertical drillholes bored by Western Mining Corporation encountered a maximum of 1.62 m of 0.4% Cu. Low-grade oxidized copper mineralization over an average width of 8 m (3 Mt averaging 0.4% Cu) was indicated by 67 percussion drillholes, of 30 m average depth, put down at the Brockman Prospect in 1968. The best intersection was 1.6 m assaying 0.7% Cu. Further shallow drilling in 1971 yielded a peak value of 4.6 m of 0.61% Cu.

Minor anomalous copper values are reported from the Hardey Formation in the western Rocklea Dome (Marston, 1979). The anomalies occur at the Beasley River prospect (22°47'57"S, 117°11'56"E) in carbonate-bearing, weakly pyritic, feldspathic sandstone, and graphitic shale. Surface mineralization occurs in a north trending 60 x 30 m area. Two diamond drillholes (total length 280 m) intersected 1.6 m assaying 0.13% Cu and 2.4 m assaying 0.19% Cu.

LEAD AND MERCURY

Blight (1985) recorded that lead and mercury mineralization are associated with quartz veins on the southern side of the Milli Milli Dome, immediately west of Coppin Pool (22°52'58"S, 118°08'30"E). Galena and cerrusite, and traces of cinnibar occur in an east-trending quartz vein which is totally contained within a dolerite sill in the Hardey Formation. J. R. Richards (quoted in Blight, 1985) dated the lead at 2.4 Ga.

MANGANESE

Small deposits of manganese dioxide have been reported from Mount Bruce, although none has proved to be economic. Most enrichment is associated with the Marra Mamba Iron Formation of the Hamersley Group.

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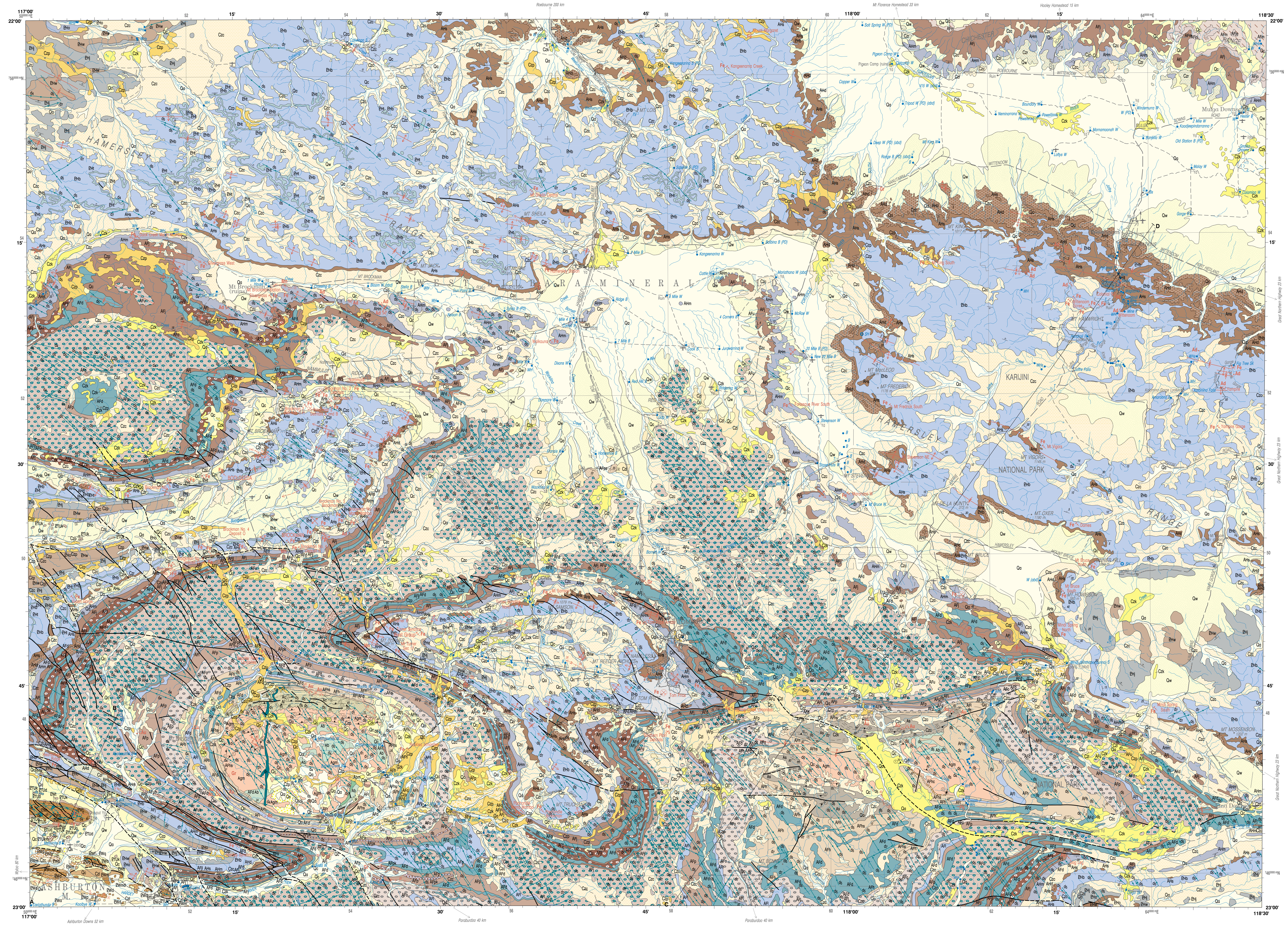
MOUNT BRUCE

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SF 50-11



SYMBOLS

Geological boundary
- exposed

Fault
- exposed
- concealed
- reverse
- mylonite zone

Major fold, showing trend and plunge direction
- anticline; exposed
- syncline; exposed, concealed
- overturned anticline; exposed
- monocline; exposed
- superposed

Minor fold, showing strike and dip of axial surface, trend and plunge direction, and nature of vergence (Z, M, or S profile)
- Capricorn Orogeny
  - Ashburton Fold Belt, D_{2a}
    - inclined
    - vertical
  - Ophthalmia Fold Belt
    - inclined
- Pre-Fortescue Group
  - inclined

Bedding, showing strike and dip
- inclined
- horizontal
- overturned
- strike and dip estimated from aerial photographs
  - 0—15°
  - 16—45°
  - 46—90°
  - trend

Way-up indicator
- sedimentary structure

Foliation, showing strike and dip
- Pre-Fortescue Group
  - inclined
  - interpreted from aerial photographs
    - inclined
    - vertical
    - trend

Cleavage, showing strike and dip
- Capricorn Orogeny
  - Ashburton Fold Belt, D_{2a}
    - inclined
    - vertical
    - strike coincident with bedding
    - C-S fabric; inclined
  - Ophthalmia Fold Belt
    - inclined
    - vertical
- Pre-Fortescue Group
  - inclined

Lineation, showing trend and direction of plunge
- axis of crenulation
- bedding-cleavage intersection

- Major road
- Formed road
- Track
- Railway with siding
- Powerline
- Airfield; landing ground
- Townsite, population 1000—10 000 — TOM PRICE
- Homestead — Juna Downs
- Building
- Yard
- Locality — Boolgeeda
- National Park boundary
- Microwave repeater station
- Horizontal control, minor

- Watercourse, ephemeral
- Pool, spring, waterhole, soak, sinkhole — P S WH Sk SH
- Bore, well — B W
- Windpump
- Dam, tank — D T
- Abandoned, position doubtful — (abd) (PD)

- Mineral field boundary
- Mining locality — BOOLGEEDA
- Mine, abandoned — Wittenoom
- Major opencut
- Opencut
- Alluvial workings; abandoned
- Prospect
- Processing plant
- Mining area
- Quarry
- Mineral occurrence
  - Asbestos (chrysotile) — Ac
  - Asbestos (crocidolite) — Ad
  - Copper — Cu
  - Gold — Au
  - Gravel — Gr
  - Iron — Fe
  - Lead — Pb
  - Manganese — Mn

REFERENCE

PHANEROZOIC — CAINOZOIC — QUATERNARY

- Qa — Alluvium—unconsolidated silt, sand, and gravel; in drainage channels and adjacent floodplains
- Qc — Colluvium—unconsolidated quartz and rock fragments in soil
- Qs — Eolian deposit—sand; in sheets and dunes
- Qw — Alluvium and colluvium—red-brown sandy and clayey soil; on low slope and sheetwash areas

- Cza — Alluvium—partly consolidated silt, sand, and gravel; old alluvium dissected by present-day drainage
- Czc — Colluvium—partly consolidated quartz and rock fragments in silt and sand matrix; old valley-fill deposits, locally derived
- Czk — Calcrete—sheet carbonate, found along major drainage lines
- Czl — Lateritic deposits—massive and pisolitic ferruginous duricrust
- Czr — Hematite-goethite deposits on banded iron-formation and adjacent scree deposits
- Czp — **ROBE PISOLITE** : pisolitic limonite deposits developed along river channels

- q — Quartz veins
- d_5, d_7 — Dolerite dykes, sills, and small intrusions; numbers identify different suites, lowest numbers earliest

PROTEROZOIC

Wyloo Group (Ashburton Basin) — *c.* 1840 Ma

- ƤWa — **ASHBURTON FORMATION** : thin- to thick-bedded metasandstone, pelite, and local metaconglomerate
- ƤWd — **DUCK CREEK DOLOMITE** : thin- to thick-bedded, locally metamorphosed stromatolitic dolomite; metadolorudite; minor chert and pelite
- ƤWmd — Dolomitic pelite, metadolomite, pelite, and metasandstone
- ƤWm — **MOUNT McGRATH FORMATION** : metamorphosed ferruginous sandstone and conglomerate, pelite, and metadolomite
- d_4 — Metadolerite dyke
- ƤWt — Fine- to medium-grained metadolerite sills and small intrusions
- ƤWb — **CHEELA SPRINGS BASALT** : metamorphosed amygdaloidal basalt flows and metabasaltic breccia, pelite, metasandstone, and metadolomite
- ƤWq — **BEAZLEY RIVER QUARTZITE** : fine- to coarse-grained metamorphosed quartzitic sandstone, metamorphosed ferruginous sandstone and conglomerate, and pelite; intruded by metadolerite sills

Mount Bruce Supergroup — Turee Creek Group

- ƤTUd — Medium- to coarse-grained metadolerite sills intruded into Turee Creek Group
- ƤTUa — **KAZPUT FORMATION** : pelite, metasandstone, metaconglomerate, metadolomite, and banded iron-formation
- ƤTUo — **KOOLBYE FORMATION** : fine- to coarse-grained metamorphosed quartzitic sandstone; minor pelite and metaconglomerate
- ƤTUk — **KUNGARRA FORMATION** : pelite and subordinate thin- to thick-bedded metasandstone
- ƤTUkm — **Meteorite Bore Member** : metadiamictite; clasts comprise metamorphosed felsic volcanic rock, chert, and sandstone

Hamersley Group (Hamersley Basin) — *c.* 2490 Ma

- ƤHt — Medium- to coarse-grained metadolerite sills in Hamersley Group
- ƤHo — **BOOLGEEDA IRON FORMATION** : fine-grained, finely laminated iron-formation; pelite and chert
- ƤHw — **WOONGARRA RHYOLITE** : metamorphosed rhyolite, rhyodacite, rhyolitic breccia, and banded iron-formation
- ƤHj — **WEELI WOLLI FORMATION** : banded iron-formation (commonly jaspilitic), pelite, and numerous metadolerite sills
- ƤHb — **BROCKMAN IRON FORMATION** : banded iron-formation, chert, and pelite

ARCHAEAN — 2500 Ma

- AHs — **MOUNT McRAE SHALE and MOUNT SYLVIA FORMATION** : pelite, chert, and banded iron-formation
- AHd — **WITTENOOM FORMATION** : metamorphosed thin- to medium-bedded dolomite, dolomitic pelite, chert, and volcanic sandstone
- AHm — **MARRA MAMBA IRON FORMATION** : chert, banded iron-formation, and pelite

Fortescue Group — *c.* 2690 Ma

- AFd — Medium- to coarse-grained metadolerite sills intruded into Fortescue Group
- AFl — Layered sills intruded into Fortescue Group; sills generally consist of a coarse-grained metapyroxenite base, overlain by leucocratic metagabbro or metadolerite; serpentinite occurs locally at the base of some sills
- AFj — **JEERINAH FORMATION** : pelite, metasandstone, chert, metabasaltic pillow lava and breccia, and metamorphosed felsic volcanic rock; intruded by numerous metadolerite sills
- AFjl — Pillowed and massive metabasaltic flows and metabasaltic breccia
- AFu — **BUNJINAH FORMATION** : pillowed and massive metabasaltic flows, metabasaltic breccia, metamorphosed volcanic sandstone, and minor chert; amygdaloidal metabasaltic flows occur in upper parts of the formation
- AFub — Metabasaltic breccia
- AFp — **PYRADIE FORMATION** : metamorphosed pyroxene spinifex-textured basaltic flows and pillow lava; metamorphosed volcanic sandstone and minor chert
- AFps — Metamorphosed lithic sandstone and pelite
- AFpk — Metakomatiite flow
- AFo — **BOONGAL FORMATION** : pillowed and massive metabasaltic flows, metabasaltic breccia, pelite, and minor chert
- AFh — **HARDEY FORMATION** : pelite, metasandstone, metaconglomerate, metabasalt, metamorphosed volcanic sandstone, and metabasaltic breccia
- AFhc — Metamorphosed conglomerate and pebbly sandstone
- AFhs — Metamorphosed feldspathic sandstone, pebbly sandstone, conglomerate, and minor pelite
- AFr — **MOUNT ROE BASALT** : metamorphosed amygdaloidal basaltic flows and breccia — *c.* 2765 Ma

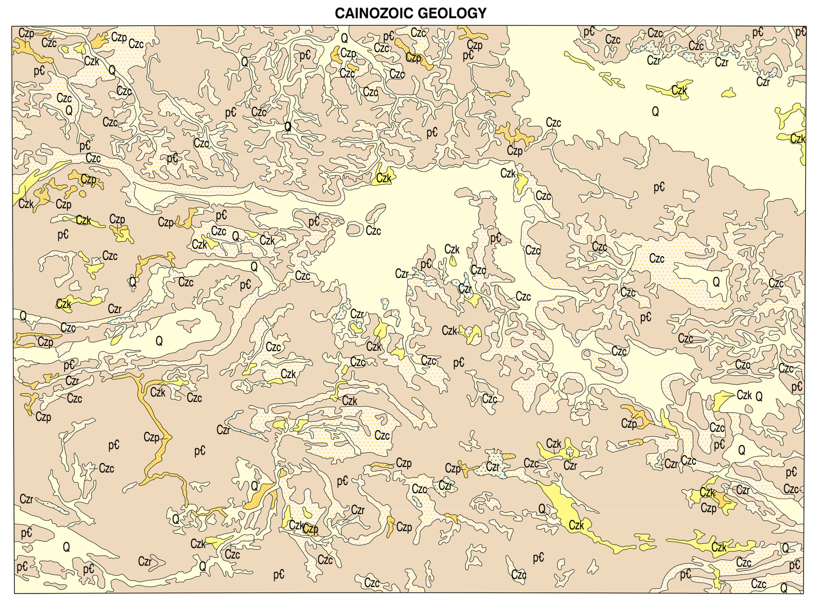
CHICHESTER RANGE AREA

- AFj — **JEERINAH FORMATION** : carbonaceous pelite, chert, and minor metamorphosed thin-bedded sandstone
- AFjo — **Woodiana Member** : metamorphosed quartzitic sandstone, pelite, and chert
- AFm — **MADDINA BASALT** : amygdaloidal metabasaltic flows and breccia

Granite—greenstone terrain (PILBARA CRATON)

- d_1 — Metadolerite dykes
- Agm — Metamorphosed biotite monzogranite; weakly to strongly foliated
- As — Pelite, metasandstone, metaconglomerate, chert, and minor metabasalt; locally mylonitic
- Ac — Chert, banded grey and white
- Al — Quartzofeldspathic schist, talc-carbonate schist, quartz-chlorite schist, quartzitic mylonite, and foliated felsic volcanic rock
- Ab — Metabasalt and metamorphosed pyroxene spinifex-textured basalt
- Abm — Metamorphosed pyroxene spinifex-textured basalt

CAINOZOIC GEOLOGY



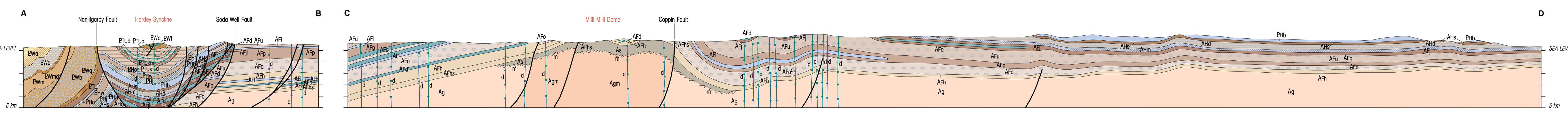
- Q — Quaternary alluvium, colluvium, eolian sand, and mixed alluvium and colluvium
- Czc — Cainozoic colluvium and alluvium
- Czk — Cainozoic calcrete
- Czr — Cainozoic hematite-goethite deposits and laterite
- Czp — Robe Pisolite
- p€ — Precambrian rock outcrop

SCALE 1:1 000 000

0 10 20 30 40 50 Kilometres

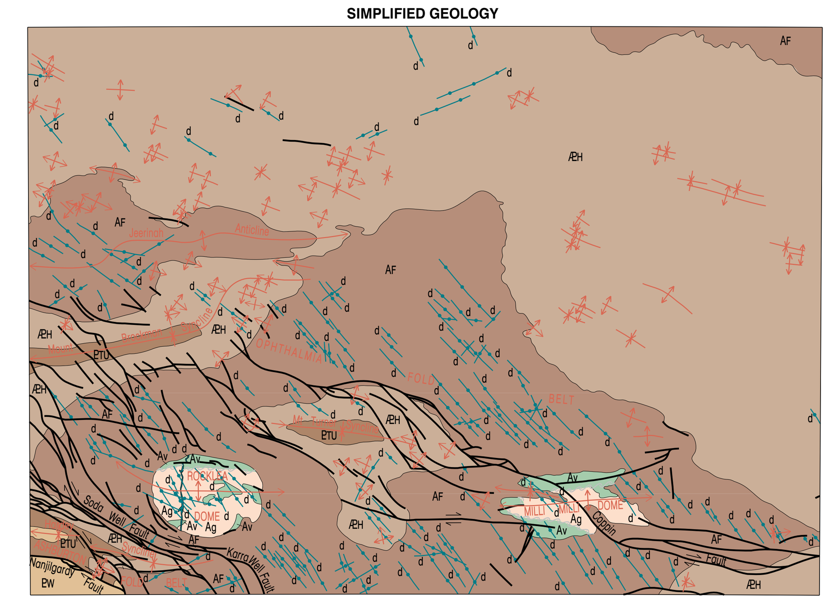
DIAGRAMMATIC SECTIONS

NATURAL SCALE



Ag — Undivided Archaean granitoid rock

SIMPLIFIED GEOLOGY



- d — Dolerite dykes (various ages)
- Proterozoic: ƤW — Wyloo Group — Ashburton Basin
- ƤTU — Turee Creek Group — Hamersley Basin — PILBARA CRATON
- ÆH — Hamersley Group — Hamersley Basin
- Archaean: AF — Fortescue Group — Hamersley Basin
- Ag — Granitoid rock — Granite—greenstone terrain
- Av — Greenstone — Granite—greenstone terrain
- Wrench fault

SCALE 1:1 000 000

0 10 20 30 40 50 Kilometres

Geology by D.F. Blight 1981, A.M. Thorne 1989-92, J.G. Blockley 1990, and I.M. Tyler 1992

Edited by D. Ferdinando and G. Loan

Cartography by C. Bartlett and P. Taylor

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5000 Metres 0 5 10 15 20 25 30 Kilometres

TRANSVERSE MERCATOR PROJECTION

Grid lines indicate 20 000 metre interval of the Australian Map Grid Zone 50

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KENNEDY RANGE SG 50-1 -0° 30′	MOUNT PHILLIPS SG 50-2 0°	MOUNT EGERTON SG 50-3 +0° 30′	COLLIER SG 50-4 +1°	BULLEN SG 51-1 +1° 30′

The lines indicate magnetic declination, 1990
+ 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′ easterly

MOUNT BRUCE

SHEET SF 50-11
SECOND EDITION 1996