GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

TUREE CREEK

WESTERN AUSTRALIA

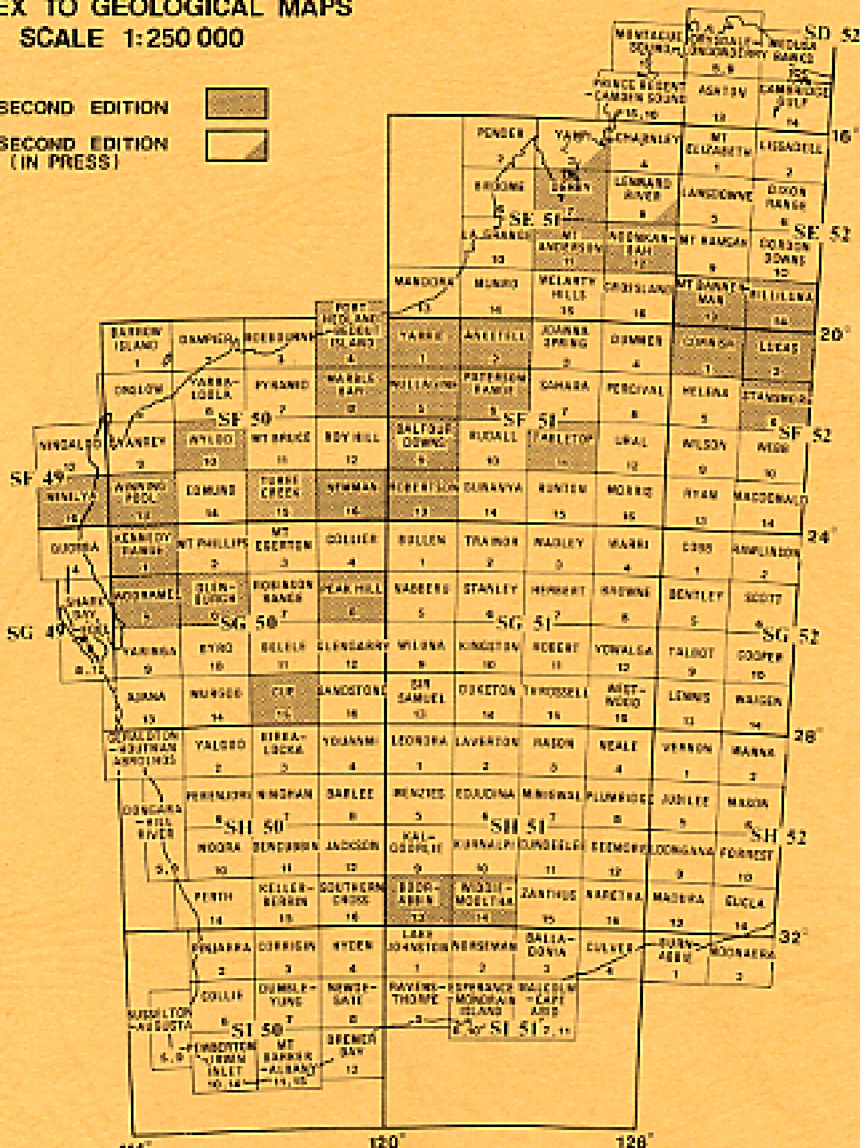
SECOND EDITION

SHEET SF50-15 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

TUREE CREEK

WESTERN AUSTRALIA

SECOND EDITION

SHEET SF50–15 INTERNATIONAL INDEX

by

A. M. THORNE, I. M. TYLER, AND W. M. HUNTER

Perth, Western Australia 1991

04083-1

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 07309 1107 1

Copies available from:

Director
Geological Survey of Western Australia
100 Plain Street
EAST PERTH, WESTERN AUSTRALIA 6004
Telephone (09) 222 3222

CONTENTS

04083-2

MAP

FIGURE

Explanatory Notes on the Turee Creek 1:250 000 Geological Sheet, Western Australia (Second Edition)

by A. M. Thorne, I. M. Tyler, and W. M. Hunter

INTRODUCTION

The TUREE CREEK*1:250 000 geological sheet (SF50–15 of the International Series) is bounded by latitudes 23° and 24°S and longitudes 117° and 118°30'E. The name is derived from the Turee Creek which drains the northeastern part of the sheet area.

The mining town of Paraburdoo (pop. 2000) is the largest settlement on TUREE CREEK. Sealed roads link the town to nearby Tom Price, and to the North West Coastal Highway, 270 km to the west. The Mount Vernon–Nanutarra gravel road crosses the southern and western part of TUREE CREEK. The pastoral stations of Ashburton Downs, Mininer, and Pingandy Creek occur in the southern part of TUREE CREEK; they are linked to each other, and to neighbouring stations, by a network of tracks which provide reasonable access to much of the area.

CLIMATE, VEGETATION, AND PHYSIOGRAPHY

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.

The country north of a line from 23°00'S, 117°12'E to 23°30'S, 118°30'E forms part of the Fortescue Botanical District (Beard, 1975). Outcrops of basaltic rock are characterized by a mosaic of *Acacia aneura, A. pyrifolia, and Triodia sp.*, with *Eucalyptus brevifolia* on the steepest, rockiest areas. Iron formations of the Hamersley Range are covered by the *E. brevifolia–Triodia wiseana* association, and *E. gamophylla* is present locally. Most of the valley plains carry *Acacia aneura*; *Eucalyptus camaldulensis* occurs along the major watercourses.

The remainder of TUREE CREEK forms part of the Ashburton Botanical District (Beard, 1975). Mudstone and sandstone of the Ashburton Formation are colonized by species of *Cassia, Eremophila,* and stunted *Acacia.* Other rock units, colluvium and Cainozoic gravel are characterized by *Acacia aneura, A. xiphophylla,* and *A. victoriae;* they may be associated with small shrubs such as *Eremophila cuneifolia, Bassia divarica* and *Atriplex inflata.* In addition, *Acacia citrinoviridis, A. grasbyi, A. wanyu,* and *A. bivenosa* occur along many drainage lines. Main river channels are lined with *Eucalyptus camaldulensis* and *Melaleuca leucodendron.*

* Map sheet names are printed in capitals.

TUREE CREEK can be divided into four main physiographic zones corresponding broadly to the areas of Hamersley, Ashburton, Bresnahan and Bangemall Basin rocks.

Hamersley Basin rocks are confined to the northeastern part of TUREE CREEK and are characterized by a rugged topography of high, rounded hills and strike ridges. The highest point on TUREE CREEK (900 m) is in this area, and local relief ranges up to 450 m.

Ashburton Basin rocks form a broad west-northwest-trending belt in the central part of TUREE CREEK. Areas of tightly folded mudstone and sandstone give rise to a strike-ridge topography of low to moderate relief. Gently undulating hills of low relief occur where folds are open and the proportion of mudstone high.

Bresnahan Basin rocks form an arc of moderately high ground (maximum elevation 683 m) in the southeastern part of TUREE CREEK. Weathering of Bresnahan Group sandstone has given rise to areas of sand dune country in the far east of TUREE CREEK.

Bangemall Basin rocks occur in a triangular area in the southwestern corner of TUREE CREEK. Gently dipping Bangemall Group strata form rugged cuestas with a relief of up to 150 m. The northern margin of the Bangemall Basin is a prominent, often precipitous escarpment, cut by deeply incised creeks.

Rivers and creeks flow only after heavy rain, but there are permanent water holes in many of the larger drainage lines. The Ashburton River flows from southeast to northwest, parallel to the principal structural trend in the underlying bedrock. Superimposed drainage patterns occur near the headwaters of Cherrybooka and Kennedy creeks, close to the Bresnahan Group–Ashburton Formation unconformity.

PREVIOUS INVESTIGATIONS

The earliest descriptions of the region were made by the explorer Frank Gregory, who visited the area in 1861 (Gregory and Gregory, 1884; Favenc, 1888). The first geological account, a description of the Top Camp gold mining centre, was given by Woodward (1891). Subsequent investigations were carried out by Maitland (1909, 1919) and Talbot (1926).

Maitland's and Talbot's stratigraphic framework provided the basis for geological description until the early 1960s. During this time attention was focussed mainly on mining activity (Simpson, 1926, 1951; Jones and Telford, 1939; Ellis, 1951; Low, 1963). The first systematic geological mapping of TUREE CREEK was undertaken in 1963 (Daniels et al., 1967; Daniels, 1968). More recent accounts of the area are discussed in the text.

TECTONIC SETTING

The main tectonic features of TUREE CREEK are shown in Figure 1. The map sheet area forms part of the northern margin of the Capricorn Orogen, a major zone of deformed, low- to high-grade metamorphic rocks and granitoid intrusions lying between the Pilbara and Yilgarn Cratons (Gee, 1979; Myers, 1990). Pilbara Craton granite–greenstone basement (older than 2800 Ma) is not exposed on TUREE CREEK but crops out in the Rocklea and Milli Milli domes, 20 km north of the northern TUREE CREEK boundary. These rocks are unconformably overlain by 2765–2470 Ma supracrustal deposits of the Hamersley Basin which crop out in the northern part of TUREE CREEK.

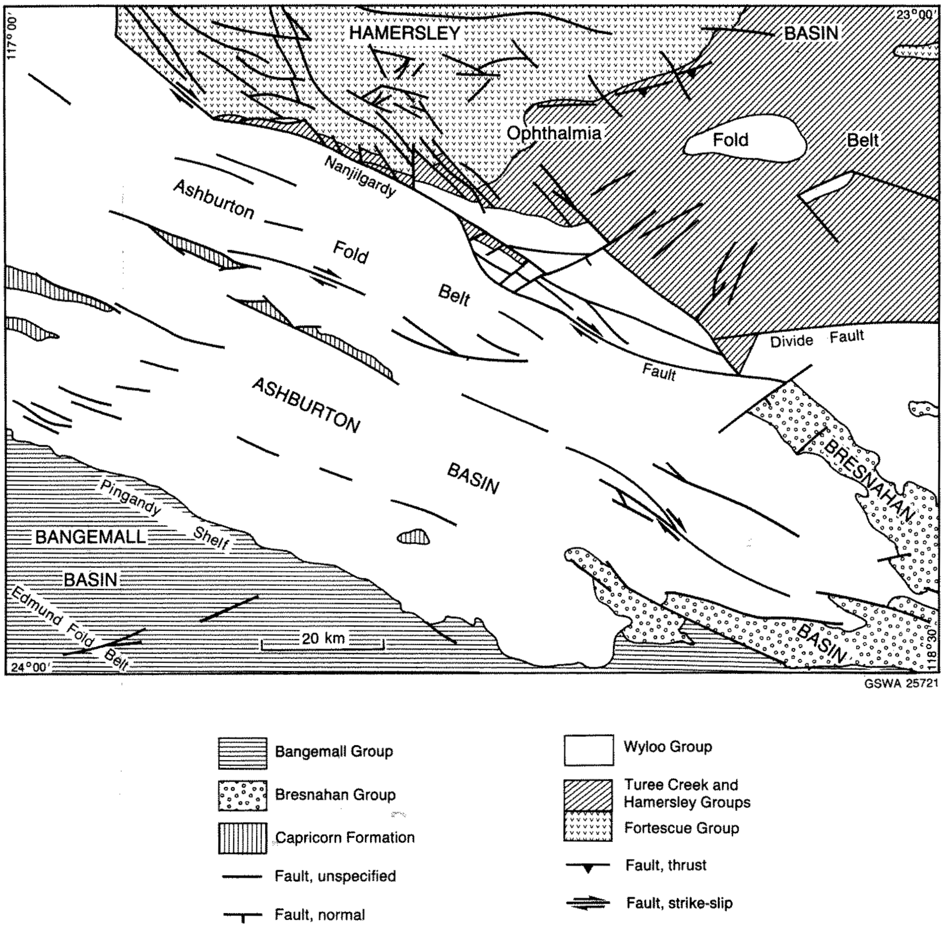


Figure 1. Tectonic sketch map of TUREE CREEK

Hamersley Basin rocks are unconformably overlain by the Ashburton Basin (c. 2000 Ma), which was initiated during the early stages of the Capricorn Orogen. Subsequent deformation of the Ashburton Basin, and of the unconformably overlying Blair Basin, took place during the final stages of the Capricorn Orogen, at about 1700 Ma.

The Bresnahan Basin and the overlying Bangemall Basin are the youngest Precambrian tectonic units on TUREE CREEK and post-date all Capricorn Orogen structures.

TERMINOLOGY

Rocks of the Hamersley and Ashburton Basins have been subjected to lower greenschist facies metamorphism; however, for the sake of brevity, the prefix 'meta' will not be used in the following descriptions.

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 in the central northern part of TUREE CREEK and consists of about 6.4 km of low-grade metavolcanic and metasedimentary rocks. The Fortescue Group was deposited between 2765 Ma and 2687 Ma (Arndt et al., 1991). Seven major stratigraphic units are recognized on TUREE CREEK—they are, in ascending order, the Bellary Formation, Mount Roe Basalt, Hardey Formation, Boongal Formation, Pyradie Formation, Bunjinah Formation, and Jeerinah Formation.

The Hardey Formation is equivalent to the Hardey Sandstone of Blight (1985); the change in terminology is considered appropriate in view of the high proportion of non-arenaceous rocks within this part of the stratigraphy. The Boongal, Pyradie, and Bunjinah Formations are equivalent to the Boongal Pillow Lava Member, the Pyradie Pyroclastic Member, and the Bunjinah Pillow Lava Member, respectively, of the Mount Jope Volcanics (de la Hunty, 1965; Daniels, 1968). They are elevated to formation status because they form major lithological units which can be recognized throughout the southern Hamersley Basin.

Bellary Formation (*Fb*)

The Bellary Formation is the lowermost stratigraphic unit of the Fortescue Group and is exposed in the core of the Bellary Dome, immediately north of Paraburdoo. The formation has a minimum thickness of 400 m, and is conformably overlain by the Mount Roe Basalt. The base of the Bellary Formation is not exposed, but is thought to be unconformable upon granite–greenstone rocks.

Bellary Formation rocks have previously been assigned to the Hardey Formation (Daniels et al., 1967), and subsequently to a basement greenstone succession (Blight, 1985). The first interpretation is rejected on the grounds that the Bellary Formation is clearly overlain by the Mount Roe Basalt, while the second view is considered unlikely as there is a gradational, conformable contact between the Bellary Formation and the Mount Roe Basalt.

The Bellary Formation consists of mudstone, siltstone, and sandstone, interbedded with smaller amounts of conglomerate, basalt, basaltic breccia, and tuff.

Sericitic mudstone and siltstone are generally parallel laminated and are interlayered with thin to very thick beds of lithic quartz sandstone, feldspathic quartz sandstone and conglomerate. Thin-bedded sandstones fine upwards and may display incomplete Bouma sequences (generally $T_{b\text{-}d}$). Thick-bedded sandstones are either massive or trough cross-stratified. Conglomerates are generally clast-supported and occur in lenticular, erosively based units; most are either massive or parallel stratified. Clasts range in size up to 0.6 m and generally consist of vein quartz, monzogranite, sandstone, argillite, chert, and mafic volcanic rock.

Basaltic lava flows and pillow lava occur in lower and upper parts of the Bellary Formation. Flows are 2–25 m thick and may be massive or moderately vesicular; pillows are sparsely vesicular. Interflow material comprises fine- to coarse-grained hyaloclastite breccia, and laminated tuff.

Mount Roe Basalt (*Fr*)

Rocks belonging to Mount Roe Basalt were formerly mapped as an unnamed basalt unit within the Hardey Formation (Daniels et al., 1967), but were elevated to their present status by Blight (1985). The Mount Roe Basalt crops out in the Bellary Dome and has a maximum thickness of about 950 m; it consists of basalt flows interbedded with minor tuff and hyaloclastite breccia.

Basalt flows range in thickness from 3 to 30 m. Most are massive in the lower to middle parts of the flow but display strongly vesicular or amygdaloidal flow tops. The basalts consist of altered plagioclase phenocrysts in a carbonated and chloritized matrix; amygdales are infilled by carbonate, quartz and feldspar.

Basalts are locally interbedded with reworked vitric tuff, accretionary lapilli tuff, and crystal-lithic tuff. These rocks are generally cross stratified or parallel stratified. Hyaloclastite breccia is locally an important lithology in lower parts of the Mount Roe Basalt.

Hardey Formation (*Fh*)

The Hardey Formation conformably overlies the Mount Roe Basalt. It crops out on the flanks of the Bellary Dome; in addition, upper parts of the formation are exposed to the east and west of Bellary Creek at 23°05'S, 117°52'E. The Hardey Formation has a maximum thickness of 1300 m on TUREE CREEK; however, up to 500 m of the stratigraphy consists of ultramafic and mafic sills. The non-intrusive component consists of sandstone, siltstone, mudstone, tuff, basalt, and chert.

Trough cross-stratified feldspathic quartz sandstone and minor quartz pebble conglomerate 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. Thin-bedded, upward-fining feldspathic sandstone occurs interbedded with mudstone and siltstone in middle to upper parts of the stratigraphy.

Fine- to coarse-grained tuff and lapilli tuff (*Fhb*) occur throughout the Hardey Formation, but are most abundant in the middle part of the stratigraphy. Many tuff 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. Tuffaceous units display a variety of internal structures ranging from trough cross-stratification, parallel stratification, current- and wave-ripple cross-lamination, convolute lamination, and small slump folds.

Basalt flows occur locally in the middle to upper parts of the formation; most are 2–10 m thick, and have irregular, vesicular flow tops.

Boongal Formation (*Fo*)

The Boongal Formation conformably overlies the Hardey Formation in the northern part of TUREE CREEK. The formation has a maximum thickness of about 1000 m and consists of massive mafic lava, tube- or sack-like pillow lava, fine- to very coarse-grained hyaloclastite breccia, and mafic tuff. 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. Tuffaceous beds exhibit parallel lamination or ripple cross-lamination; many fine upwards from a sand-sized base.

Pyradie Formation (*Fp*)

The Pyradie Formation conformably overlies the Boongal Formation and is up to 600 m thick on TUREE CREEK. It is characterized by a suite of pyroxene spinifex-textured basalt flows and pillow lavas, interbedded with tuff and minor chert. A massive, serpentinized komatiite flow occurs locally within the lower part of the Pyradie Formation. Pyroxene spinifex-textured basalt flows range in thickness from 2 to 50 m and may 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 tops may be vesicular.

Bunjinah Formation (*Fu*)

The Bunjinah Formation conformably overlies the Pyradie Formation. It has a maximum thickness of 900 m and is very similar lithologically to the Boongal Formation, except that upper parts of the formation may contain highly vesicular mafic lava flows interbedded with hyaloclastite breccia.

Jeerinah Formation (*Fj*)

The Jeerinah Formation conformably overlies the Bunjinah Formation and is confined to the north central part of TUREE CREEK. It has a maximum thickness of 1200 m, but up to 50% of the formation may consist of coarse-grained dolerite and gabbro sills. The remainder of the stratigraphy consists of mafic lava, pillow lava, and breccia; mudstone and siltstone; chert; and sandstone. The Jeerinah Formation is conformably overlain by the Marra Mamba Iron Formation of the Hamersley Group.

Mafic lava and pillow lava makes up about half of the non-intrusive Jeerinah Formation stratigraphy on TUREE CREEK. Lava units occur throughout the formation and may either be lenticular or laterally persistent over tens of kilometres; units range in thickness up to 100 m. Lenticular beds of hyaloclastite breccia are often associated with the lava flows.

Most of the remaining thickness of the Jeerinah Formation consists of carbonaceous or ferruginous mudstone and siltstone, interbedded with finely laminated chert. Near the top of the formation an impersistent sandstone unit, up to 8 m thick, is interbedded with argillaceous deposits and dolerite sills. Individual sandstone beds are up to 1.5 m thick, and contain abundant fragments of felsic volcanic rock. Zircon crystals recovered from this unit give a $^{207}Pb/^{206}Pb$ age of 2690 ± 16 Ma (Arndt et al., 1991).

MAFIC (*Fd*) AND LAYERED (*Fl*) SILLS IN THE FORTESCUE GROUP

Mafic and layered sills are an important component of the Fortescue Group, particularly in the Hardey and Jeerinah Formations. Mafic sills have a relic sub-ophitic to poikilitic texture, and a mineralogy of actinolite, chlorite, epidote, altered plagioclase, and subordinate interstitial quartz, opaques, and apatite.

Layered sills have a medium- to coarse-grained cumulate texture and a mineralogy of tremolite–chlorite pseudomorphs after pyroxene, in a matrix of chlorite, tremolite, talc, serpentine and sphene. Locally, a serpentinite layer forms the lowest part of the intrusion. In many sills the ultramafic component is confined to lower and middle levels and is gradational upwards into leucocratic gabbro or dolerite.

HAMERSLEY GROUP

The Hamersley Group crops out in the northeast corner of TUREE CREEK forming the limbs of the Turee Creek Syncline and extending west-northwest to form the southern limb of the Bellary Anticline (Fig. 1). A strip of upper Hamersley Group rocks occurs to the south of Turee Creek, extending 12 km east-southeast from Mount Maguire.

The stratigraphy of the Hamersley Group is well established (MacLeod et al., 1963; MacLeod, 1966; Trendall and Blockley, 1970) and all units are present on TUREE CREEK. Hamersley Group rocks conformably overlie the Fortescue Group and are dominated by deposition of banded iron-formation (BIF). The environment of deposition has been variously suggested as a barred basin (Trendall and Blockley, 1970; Trendall, 1975); a shelf (Horwitz and Smith, 1978; Ewers and Morris, 1981); and a platform or bank (Morris and Horwitz, 1983; McConchie, 1984). A detailed study of the main iron-formation, the Brockman Iron Formation, has been carried out by Trendall and Blockley (1970).

Marra Mamba Iron Formation (*Hm*)

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., in press).

The Nammuldi Member is the lowest unit and is estimated to be 115 m thick in the Paraburdoo area (Bourn and Jackson, 1979). It consists of alternating yellow to yellow-brown chert and brown to black iron-formation mesobands. Podding of the banding is common. The overlying MacLeod Member is 30 m thick, comprising interlayered thin shales, chert and BIF. The contact between the Nammuldi Member and the MacLeod Member lies a short distance above a distinctive chert pod layer known as 'the potatoes'. The uppermost division, the Mount Newman Member, is 60 m thick and consists dominantly of BIF with thin shale intervals.

Wittenoom Dolomite (*Hd*)

The Wittenoom Dolomite can be divided into two units: a lower sequence of massive crystalline dolomite with minor chert; and an upper sequence of interlayered thin cherts, dolomite and shale. On TUREE CREEK the lower unit is exposed in the deep valley south of Radio Hill where the contact with the Marra Mamba Iron Formation is seen. A section has been measured at this locality (Simonson, written communication, 1986). The basal 17 m is marked by interbedded shale and chert, passing into interbedded dolomite and chert. This is overlain by 246 m of thin- to thick-bedded dolomite in which infrequent small-scale cross-stratification may be present. The section is incomplete, but the total thickness of Wittenoom Dolomite is in excess of 340 m.

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

The Mount Sylvia Formation conformably overlies the Wittenoom Dolomite and consists of shale, dolomitic shale and three prominent BIFs. A BIF marks both the top and the bottom of the unit. The upper BIF is the distinctive 'Bruno's Band'. Bourn and Jackson (1979) estimate the thickness of the unit as 30 m.

The Mount McRae Shale is 55 m thick (Bourn and Jackson, 1979). The lower 43 m comprises interlayered cherts and shales, while the upper 12 m includes BIF.

Brockman Iron Formation (*Hb*)

The Brockman Iron Formation is the main iron-formation within the Hamersley Group and forms a prominent strike ridge. The unit has been described in detail by Trendall and Blockley (1970). It 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 macrobands (cf. Trendall and Blockley, 1970) and 16 shale horizons. Where it is not mineralized near Paraburdoo the member has a measured thickness of 135 m (Baldwin, 1975). Bourn and Jackson (1979) reported considerable differences between the thicknesses of BIF macrobands and shale bands measured at Paraburdoo and the same units measured at the Channar deposit, 20 km to the east. The member is about 140 m thick near Fish Pool (Trendall and Blockley, 1970, Plate 3).

The Whaleback Shale Member overlies the Dales Gorge Member and is composed predominantly of interlayered chert and shale with two BIF bands occurring near the base. The thickness of the member near Paraburdoo varies from 43 m to 81 m (Baldwin, 1975).

The Joffre Member overlies the Whaleback Shale and consists of 280 m of BIF with minor thin shale horizons (Bourn and Jackson, 1979). A dolerite sill intrudes the upper part of the Joffre Member. This is well exposed in the eastern closure of the Turee Creek syncline and to the north of the Channar deposit.

The Yandicoogina Shale Member overlies the Joffre Member and comprises alternating chert and thin shale. Near Paraburdoo it has a measured thickness of 45 m (Bourn and Jackson, 1979). It may be intruded by dolerite sills.

Weeli Wolli Formation (*Hj*)

The Weeli Wolli Formation consists of 5–10 m-thick, typically jaspilitic, iron-formations, together with shales and cherts, which have been intruded by several dolerite sills. This gives a distinctive striped appearance to the outcrops. On the northern limb of the Turee Creek syncline the unit is 600 m thick.

Woongarra Volcanics (*Hw*)

The Woongarra Volcanics consist of medium-grained quartz- and/or feldspar-phyric dacitic to rhyodacitic igneous rocks. Near Fish Pool on the north limb of the Turee Creek Syncline the unit is 800 m thick. The top of the unit is often marked by a tuffaceous horizon that displays features consistent with the margin of a sill intruded into wet sediment (A. F. Trendall, personal communication, 1989). Within the unit is a distinctive but discontinuous jaspilitic BIF horizon which may be up to 5 m thick. This central BIF is well developed on the southern limb of the Turee Creek Syncline.

Daniels (1968) referred to a thinning of the Woongarra Volcanics to only 15 m (50 feet) at the eastern end of the Turee Creek Syncline. However, it appears that this was measured from the central BIF, misidentified as the Weeli Wolli Formation. Actual thickness in the area is probably similar to that measured near Fish Pool.

Boolgeeda Iron Formation (*Ho*)

The Boolgeeda Iron Formation is the uppermost unit of the Hamersley Group. It conformably overlies the Woongarra Volcanics and 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. It passes conformably into shales of the Turee Creek Group. Near Fish Pool the unit is 260 m thick.

TUREE CREEK GROUP (*TU*)

The Turee Creek Group rests conformably upon the Boolgeeda Iron Formation in the Turee Creek Syncline and in the vicinity of Mount Maguire. The maximum thickness of the group on TUREE CREEK is estimated to be about 2.5 km.

Lower and middle levels of the Turee Creek Group are poorly exposed and consist of mudstone, siltstone, and fine-grained sandstone. Upper levels consist of mudstone and siltstone interbedded with quartz sandstone and carbonate. The upper sandstone units are fine- to coarse-grained and display small-scale trough cross-stratification, and both symmetrical and asymmetrical ripples. Carbonate units contain abundant stylolites; some dolomite is stromatolitic (Walter, 1983).

The Turee Creek Group is unconformably overlain by the Wyloo Group.

METAMORPHISM

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

On TUREE CREEK most Hamersley Basin rocks lie within the highest grade (prehnite)–epidote–actinolite zone, which represents lowermost greenschist facies conditions. A narrow strip along the southwest margin is in the lower grade prehnite–pumpellyite–epidote–actinolite zone representing the pumpellyite–actinolite facies. The overall pattern observed by Smith et al. (1982) showed grade increasing towards the southern margin of the Hamersley Basin. This is coincident with a general increase in stratigraphic thickness of Hamersley Basin sedimentary rocks, and the zonal pattern was interpreted as the product of regional burial metamorphism (M_h). The appearance of lower grade rocks at the southern margin of the basin was explained by local thickening of the Fortescue Group and thinning of the Hamersley Group.

In the present study pumpellyite has been identified in a dolerite sill in the Turee Creek Group within the Turee Creek Syncline. The isograds and zones identified by Smith et al. (1982) are based on assemblages in the Fortescue Group, which is at the base of the sequence. Stratigraphically higher units reached correspondingly lower grades (Smith et al., 1982, fig. 3). The isograd pattern produced when all units in the Hamersley Basin are considered is more complex than that interpreted by Smith et al. and tends 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 a broad west-northwest-trending belt in the central part of TUREE CREEK and comprises a 12 km-thick succession of low-grade, metasedimentary and metavolcanic rocks.

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). The age of the Wyloo Group is poorly constrained but is thought to be about 2000 Ma (Thorne and Seymour, 1991).

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

Beasley River Quartzite (*Wq*)

The Beasley River Quartzite is the lowermost formation of the Wyloo Group. On TUREE CREEK it is 150–200 m thick and rests disconformably upon the Mount Bruce Supergroup. Principal outcrops occur in the vicinity of Divide Well (23°28'30"S, 118°28'30"E), in the Turee Creek Syncline, southeast of Mount Maguire (23°20'S, 117°45'E), and west of the Paraburdoo minesite. Descriptions of the Beasley River Quartzite are given by Daniels (1968), Horwitz (1981), and Thorne and Seymour (1991).

The formation mainly consists of cream- or white-weathering fine- to coarse-grained quartz sandstone, intruded locally by dolerite sills. Minor coarse-grained ferruginous sandstone and granule- to pebble-conglomerate occur in the Turee Creek Syncline.

The internal structure of the sandstones is dominated by 0.05–1.5 m-thick sets of trough cross-strata, interlayered with parallel-stratified or ripple cross-laminated units. Locally, symmetrical ripples are preserved on bedding surfaces. Palaeocurrent data from the thickest troughed sets are directed towards 260°, smaller scale structures record flows to the west and east-northeast.

Thorne and Seymour (1991) interpret the Beasley River Quartzite on TUREE CREEK as a tide-influenced delta complex.

Cheela Springs Basalt (*Wb*)

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 TUREE CREEK, the Cheela Springs Basalt crops out in the Turee Creek Syncline and immediately southeast of Mount Maguire; in these areas it conformably overlies the Beasley River Quartzite.

The formation has a minimum thickness of 1.4 km and comprises basalt flows with subordinate fine- to coarse-grained tuff and lithic sandstone.

Basalt flows are generally vesicular and range from 2 to 30 m thick. Most basalts have undergone prehnite–pumpellyite to lower greenschist facies metamorphism and now consist of andesine and relic pyroxene (partly or completely replaced by actinolite and chlorite) phenocrysts set in a groundmass of andesine, actinolite, chlorite, sphene, epidote, pumpellyite, and iron oxide.

Fine-grained interflow tuffs are generally thin bedded and either parallel laminated or ripple cross-laminated. Coarse-grained tuffs and lithic sandstones are massive or graded, with local scour surfaces.

Mount McGrath Formation (*Wm*)

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 1200 m and occurs in discontinuous outcrops between 23°00'S, 117°10'E and 23°35'S, 118°14'E.

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

Conglomerates are generally clast supported and occur in lenticular or tabular beds up to 4 m thick. Most are parallel stratified and exhibit normal or inverse grading. The clasts are mainly of BIF (with hematite ore locally), vein quartz, chert, quartz amygdales, and felsic igneous rock.

Sandstone and pebbly sandstone crop out in lenticular units up to 20 m thick. They are either cross stratified or parallel stratified, or 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.

Thorne and Seymour (1991) interpret the Mount McGrath Formation as an abandoned delta complex which received sediment from the southern Hamersley Basin.

Duck Creek Dolomite (*Wd*)

The Duck Creek Dolomite rests conformably upon the Mount McGrath Formation and has a maximum thickness of 1000 m. It occurs in a series of discontinuous outcrops between 23°00'S, 117°07'E and 23°45'S, 118°23'E. The formation consists of thin- to thick-bedded, buff, grey, or mauve dolomite. Silicification is locally intense.

Low and upper levels of the Duck Creek Dolomite consist of thin-bedded dolomite and nodular dolomite interlayered with thin- to very thick-bedded dolomitic conglomerate.

Thin-bedded dolomites are planar to undulose laminated and often contain layers and nodules of red or black chert. Beds are generally interstratified with thin horizons 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-conglomerate 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.* 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.

Thorne and Seymour (1991) interpret the Duck Creek Dolomite as an assemblage of shelf and shelf-slope carbonates.

Ashburton Formation (*Wa*)

The Ashburton Formation, the uppermost stratigraphic unit of the Wyloo Group, conformably overlies the Duck Creek Dolomite. It crops out in a broad southeast-trending belt in the central part of TUREE CREEK and has an estimated thickness of 5 to 12 km (Thorne and Seymour, 1991). The formation is composed of mudstone, siltstone, and immature sandstone, interbedded with minor amounts of conglomerate, dolomite, mafic volcanic rock, and BIF.

Mudstone and siltstone (*Wam*) make up an estimated 65% of the Ashburton Formation and are most abundant in middle and upper parts of the stratigraphy. Chloritic and ferruginous mudstone occur as layers a few millimetres to several metres thick that are interbedded with sandstone, conglomerate, or chemical deposits; they also form units up to several hundreds of metres thick. Mudstones are either structureless or parallel laminated. Chloritic siltstones occur as beds within thick mudstone units, or as a capping to thin- to medium-bedded sandstone. Their internal structure consists of parallel lamination or climbing ripple cross-lamination. In many cases, primary structure is modified by soft-sediment deformation.

Feldspathic and lithic quartz (*Was*) sandstone make up approximately 30% of the Ashburton Formation. It is the most abundant rock type in the lower part of the stratigraphy. Two varieties of arenaceous deposit are recognized; thin- to medium-bedded sandstone and massive sandstone. Thin to medium thickness sandstone beds 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 sandstones suggests sediment transport was toward the west-northwest.

Clast- and matrix-supported conglomerates crop out in lenticular or tabular beds up to 40 m thick. Many beds are parallel stratified and may show either normal or reverse grading. Many coarse-grained conglomerates are structureless. Clasts consist of vein quartz, with smaller amounts of jaspilitic chert, felsic volcanic rock, and silicified sandstone.

Thin-bedded and stromatolitic dolomite occur in the upper part of the Ashburton Formation in the eastern part of TUREE CREEK. Thin-bedded dolomite occurs interlayered with mudstone and may display normal grading, slump folds, and boudinage structures; many contain irregular chert nodules. Stromatolitic dolomite containing the form *Pseudogymnosolen* f. indet. has been described from small outcrops near the western end of the Kunderong Range (Grey, 1981). Grey (1984a) recorded the occurrence of *Patomia* f. indet. from dolomite fragments in alluvium, northeast of Kennedy Creek (23°44'45"S, 118°19'30"E). If derived locally, their presence would suggest that nearby dolomite outcrops (23°45'S, 118°22'E) may be part of the Ashburton Formation and not the Duck Creek Dolomite as marked on TUREE CREEK.

An extensive outcrop of mafic volcanic rock (*Wab*) occurs near Mount Boggola at (23°45'30"S, 117°41'00"E). It comprises approximately 600 m of pillow lava and pillow breccia, coarse-grained volcaniclastics, and laminated tuff. The lowermost volcanics are interbedded with mudstone, and the top of the unit is overlain by BIF and chert (*Wai*) or mudstone.

Thorne and Seymour (1991) interpret the Ashburton Formation as a linear submarine-fan system.

BLAIR BASIN

CAPRICORN FORMATION (*R*)

The 800 m-thick Capricorn Formation is the only stratigraphic unit within the Blair Basin (Thorne and Seymour, 1991). It rests with angular unconformity upon the Ashburton Formation and occurs in the eastern Capricorn Range, in linear inliers to the west-northwest of Mount Elephant, on the summit of Mount Boggola, and in scattered outcrops beneath the Bresnahan Group unconformity. The Capricorn Formation was deposited in the interval between two episodes (D_1 and D_2) of post-Wyloo Group – pre-Bresnahan Group deformation; it has a maximum age of about 2000 Ma and a minimum age of about 1680 Ma (Thorne and Seymour, 1991).

The formation consists of sandstone, siltstone, and mudstone, and small amounts of conglomerate, dolomite, and felsic volcanic rock.

Fine- to coarse-grained quartz sandstone and lithic sandstone are commonly ferruginous and micaceous. They display a range of sedimentary structures that include parallel stratification, trough and tabular cross-stratification, ripple cross-lamination, sole markings and ball-and-pillow structures.

Mudstone and siltstone are generally ferruginous and micaceous. Mudstones are either structureless or parallel laminated; siltstones are parallel laminated or else display a variety of ripple profiles and bedforms.

Matrix-supported conglomerate occurs in units up to 40 m thick. Most are structureless and very poorly sorted with clast diameters generally in the range 5–200 mm. Clasts are composed of dolomite, sandstone, chert, vein quartz, and mudstone.

Beds of stromatolitic dolomite and thin-bedded dolomite occur locally within the Capricorn Formation. The former are often characterized by small, laterally linked columns with convex lamination. Grey (1984b) described a small, branching columnar stromatolite from Mount Elephant, but was unable to assign it to any previously described form.

A 4.5–15 m-thick rhyodacitic tuff unit occurs in the middle part of the formation in the eastern Capricorn Range. The unit comprises tabular beds of structureless tuff and parallel-stratified lapilli tuff. Some lapilli tuff layers show normal grading; in others the coarsest fragments are in the middle of the bed.

CAPRICORN OROGEN—STRUCTURE AND METAMORPHISM

STRUCTURE

Previous interpretations of structural development in the southern Pilbara have been based on first edition mapping and are summarized in 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. Two fold periods, the Ophthalmian and the Rocklean, were 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 (1991) identified a regional-scale foreland fold-and-thrust belt in the southeast Hamersley Basin. Deformation was attributed to the Capricorn Orogeny of Gee (1979), which developed as the result of a collision between the Yilgarn and Pilbara Cratons between 2.2 Ga and 1.6 Ga (Tyler and Thorne, 1990). The Ophthalmia Fold Belt on TUREE CREEK (Fig. 1) represents the western limit of this fold and thrust belt.

Tyler and Thorne (1990) regarded the collision between the Pilbara and Yilgarn Cratons as oblique, 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. The orientation of the fault system along the Pilbara Craton margin was controlled by pre-existing lines established during rifting in Fortescue Group times.

Ophthalmia Fold Belt

Structures that form part of the Ophthalmia Fold Belt affect Hamersley Basin and lowermost Wyloo Group rocks. Tyler and Thorne (1990) have noted that folds in the belt form two distinct groups: those in the southwest Hamersley Basin, which form broad scale, open dome-and-basin structures having a mainly northwest trend (the central structural zone of MacLeod et al., 1963); and those in the southeast, which have an easterly trend, are close to tight, and have short wavelengths (the southern structural zone of MacLeod et al., 1963).

The first group of structures pre-date the basal unconformity of the Wyloo Group, with Beasley River Quartzite unconformably overlying folded Hamersley Group and Turee Creek Group rocks that form the Hardey Syncline on WYLOO (Trendall, 1979; Seymour et al., 1988). Pre-Wyloo Group uplift on TUREE CREEK is indicated by Beasley River Quartzite disconformably overlying Marra Mamba Iron Formation, Brockman Iron Formation, Weeli Wolli Formation, and Woongarra Volcanics. The earliest deformation of the Hamersley Basin succession appears to have occurred as a result of block faulting in the basement, with only minor tilting of strata.

The main Ophthalmia Fold Belt structures on TUREE CREEK formed following eruption of the Cheela Springs Basalt, which outcrops in the core of the Turee Creek syncline. The age of folding is further restricted by the occurrence of pebbles of hematite ore in Mount McGrath Formation, 8 km west-southwest of Paraburdoo. As folds are cut by west-northwest-trending mafic dykes which pre-date ore formation (Morris, 1980), folding must have taken place before ore formation and therefore before deposition of the Mount McGrath Formation. Post-Cheela Springs Basalt, pre-Mount McGrath Formation uplift is also indicated by the occurrence of Mount McGrath Formation unconformably overlying Weeli Wolli Formation, 11 km southeast of Snowy Mountain.

The earliest structures (D_{1c}) are localized tight to isoclinal, layer-parallel, small-scale folds (Tyler, 1991). On TUREE CREEK these folds have been found within the central BIF in the Woongarra Volcanics where it outcrops along the southern limb of the Turee Creek syncline, southeast of Kooinano Pool. Folds typically have a tectonic cleavage, and may be associated with mylonitic fabrics.

The main fold structures (D_{2c}) form upright to steeply inclined, generally north-facing, close to tight folds which are often conjugate in form. They are of buckle-type with parallel to flattened-parallel profiles, and are non-cylindrical and impersistent, dying out both laterally and vertically. An axial-plane cleavage may be present near the eastern edge of TUREE CREEK, becoming weak to absent further west. Fold trends are dominantly west-northwest to northwest, with easterly trends being restricted to the core of the Turee Creek Syncline and some folds at the eastern edge of the sheet.

Ashburton Fold Belt

The Ashburton Fold Belt generally affects the Wyloo Group and Capricorn Formation, and also affects some Hamersley Basin rocks. Deformation takes the form of open to isoclinal folds, and normal, reverse, and strike-slip faults. The belt has been described by Thorne and Seymour (1991) and the structural sequence on TUREE CREEK is similar to that recognized on WYLOO (Seymour et al., 1988). The earliest fold event (D_{1a}) took place after deposition of the Ashburton Formation. The second fold event (D_{2a}) is separated from the D_{1a} phase by deposition of the Capricorn Formation.

Low-angle normal faults are preserved within the Paraburdoo orebody (Morris, 1985). These pre-date ore formation, but post-date the formation of folds belonging to the Ophthalmia Fold Belt.

D_{1a} fold structures are best preserved along the southern edge of the fold belt, south of the Ashburton River. In general, the first fold event (D_{1a}) is marked by a strong local foliation (S_{1a}) dipping in the same direction as, but more steeply than, bedding. A horizontal to gently plunging bedding/S_{1a} intersection lineation (L_{1a}) is also present. With increasing metamorphic grade the foliation passes into a metamorphic schistosity, subparallel to bedding.

Bedding and the S_{1a} cleavage are folded by open to tight, locally isoclinal, D_{2a} folds. Where an S_{1a} cleavage is present the cleavage formed during D_{2a} (S_{2a}) is a crenulation cleavage. A second (cleavage/cleavage) intersection lineation (L_{2a}) is also developed. The two fold phases are generally coaxial.

The Ashburton Fold Belt on TUREE CREEK can be divided into three zones (Fig. 1). The northern zone is dominated by large-scale, open to tight D_{2a} folds. The separation of Ashburton Fold Belt from Ophthalmia Fold Belt structures in this marginal zone can be difficult with the later deformation tightening up pre-existing folds and reactivating earlier-formed faults. In the central zone strain is high and folds are tight to isoclinal. Medium-scale and large-scale folds are often truncated by reverse faults which develop parallel to axial surfaces. Faults and axial surfaces have steep, southwesterly dips. In the southern zone, strain during D_{2a} was relatively low and D_{1a} structures are preserved, with large-scale refolded fold patterns present. D_{2a} folds are open to tight and are generally upright. Downward-facing D_{2a} structures occur near the head of Fords Creek. These indicate that D_{1a} folds were overturned in this area. The flat-lying nature of the S_{1a} cleavage is consistent with the presence of gently inclined to recumbent folds.

D_{1a} and D_{2a} structures are generally coaxial, however D_{1a} folds near Mount Boggola plunge to the southwest, while D_{2a} folds there plunge west-northwest.

The northeast margin of the Ashburton Fold Belt is marked by a set of west-northwest to northwest-oriented faults of D_{2a} age (Fig. 1). These extend from Bukardi Creek to Cairn Hill Well. Dextral offsets on individual faults may be as great as 7.5 km. In the southern limb of the Bellary Anticline faulting has taken place parallel to the regional strike of bedding, removing the Wittenoom Dolomite as well as parts of the overlying lower Wyloo Group. The contact between Beasley River Quartzite and the Hamersley Group, exposed 3.5 km west of the Paraburdoo mine, is a fault, and a resilicified fault breccia occurs in quartzite at the contact. Further faulting is indicated by the juxtaposition of Beasley River Quartzite and Duck Creek Dolomite, 9 km west-northwest of Ratty Spring, and by the truncation of fold structures immediately south of the mine. Despite the deformed nature of much of the contact, an unconformity is preserved between the Beasley River Quartzite and Hamersley Group rocks 1 km south-southwest of Ratty Spring. Dips on fault surfaces range from vertical to moderate and are to the northeast (Bourn and Jackson, 1979).

The north-trending, east-dipping fault which truncates the Marra Mamba and Brockman Iron Formations near Radio Hill has a sinistral offset, and is here regarded as antithetic (cf. Wilcox et al., 1973) to the main dextral system. This differs from the interpretation of Bourn and Jackson (1979), who regarded movement as having occurred prior to the deposition of the Wyloo Group. Other north-trending faults, which are well developed west of the mine and in the vicinity of Mount Maguire, have a normal sense of movement with minimal lateral offsets. These correspond to the 'antithetic-normal' faults described from model wrench systems by Wilcox et al. (1973).

Several folds in the lower Wyloo Group southeast of Mount Maguire have an easterly trend and are arranged en echelon to a west-northwest-trending fault, the Nanjilgardy Fault (Fig. 1). This relationship is consistent with these folds developing as part of the dextral wrench-fault system. An axial-plane cleavage is well developed in Boolgeeda Iron Formation and Turee Creek Group shale south of Nanjilgardy Pool, a feature not seen associated with Ophthalmia Fold Belt D_{2c} folds in the Turee Creek Syncline.

The Hamersley and Turee Creek Group rocks that crop out at Mount Maguire are separated from the main Hamersley Basin outcrop by the Nanjilgardy Fault. Locally, faulting is complex, and thrusting, which involves Mount McGrath Formation and Beasley River Quartzite, is well developed, repeating the upper Hamersley Group – Turee Creek Group – lower Wyloo Group sequence 2.5 km and 4 km south of Nanjilgardy Pool. Faulting is interpreted to have developed within an extensional fault jog (cf. Sibson, 1987) as part of the dextral wrench-fault system. The jog occurred as the result of en echelon segmentation of the Nanjilgardy Fault.

Medium-scale, north-facing chevron-type folds developed in association with D_{2a} age faulting of the Hamersley Group in Doggers Gorge. Elsewhere D_{2a} folding of the Hamersley Group takes the form of medium- and small-scale conjugate folds.

Anticlines, with axial surfaces trending east-northeast, developed locally in Brockman Iron Formation on the northwest limb of the Turee Creek Syncline. Thrusts developed beneath these structures, and décollement occurred in the Wittenoom Dolomite. Movement was to the northwest, placing Brockman Iron Formation directly on top of the Marra Mamba Iron Formation.

METAMORPHISM

Throughout most of the Ashburton Basin the metamorphic grade is low; however, a general increase in grade is seen from northeast to southwest. The typical assemblage recorded throughout much of the fold belt is quartz–chlorite–sericite. However, at the head of Fords Creek the metamorphic grade reaches middle to upper greenschist facies with the occurrence of chlorite–muscovite–biotite–quartz assemblages. Textures indicate that porphyroblastic biotite grew both during and after D_{1a}, over a groundmass of quartz–muscovite–chlorite. Lower grade metamorphism during D_2 accompanied the formation of an S_{2a} cleavage wrapping porphyroblasts and retrograding biotite to chlorite.

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. Burial metamorphism reached a peak at the end of Turee Creek Group times, after which uplift and erosion took place along the southern margin of the 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.

BRESNAHAN BASIN

BRESNAHAN GROUP (*B*)

The Bresnahan Group is the only stratigraphic unit of the Bresnahan Basin and lies with marked angular unconformity upon the Wyloo Group and Capricorn Formation in the southeastern part of TUREE CREEK. The Bresnahan Group has a maximum measured thickness of 4 km and comprises conglomerate, sandstone, siltstone, and mudstone. The two-fold division of the stratigraphy into Cherrybooka Conglomerate and Kunderong Sandstone, proposed by Daniels and MacLeod (1965), is not employed here as there is no distinct horizon marking the boundary between the formations; rather there is a gradual vertical and lateral transition from conglomerate- to sandstone-dominated lithofacies. As a result, the two divisions are not clearly mappable units.

At the base of the Bresnahan Group, localized accumulations of conglomerate, with minor siltstone and mudstone, fill small palaeovalleys and hollows in the underlying surface. This buried topography has a relief of at least 30 m. The conglomerates are generally thick bedded, very poorly sorted, and unstratified; most show a mixture of clast and matrix support. Clasts are well rounded and subspherical, and have a maximum diameter of 1.5 m; they include sandstone, pebbly sandstone, chert, vein quartz (often tourmaline-bearing) and jaspilite. The conglomerate matrix consists of micaceous granule sandstone.

Conglomerate units are transitional, both laterally and vertically, into very coarse-grained sandstone and pebbly sandstone. The arenaceous deposits form a lenticular bedded sequence that makes up the remainder of the Bresnahan Group on TUREE CREEK. Individual beds are generally up to 2 m thick, and may include a pebble or cobble lag above the basal scour surface. Internal structure is dominated by single or stacked sets of medium- to large-scale trough cross-stratification. Palaeocurrent data record a consistent easterly directed palaeoflow.

Sandstones are composed of quartz and lithic fragments with various amounts of feldspar and mica. Accumulations of heavy minerals (including iron and titanium oxides, tourmaline, and apatite) are present locally.

The Bresnahan Group is interpreted as a fluvial-dominated alluvial fan deposit (Hunter, 1990; Thorne and Seymour, 1991).

STRUCTURE OF THE BRESNAHAN BASIN

Northeast-trending normal faults, offset by east- to northwest-trending transfer faults (cf. Gibbs, 1984), developed contemporaneously with the deposition of the Bresnahan Group. Normal faulting is best developed southeast and east of Mount Channar, and at Horrigan Pool. Near Kooinano Pool (23°17'05"S, 118°16'20"E), Beasley River Quartzite is repeated by normal faulting. Kink folds are well developed in rocks adjacent to the associated northwest-trending transfer faults, and refold small-scale D_{1c} folds 6.5 km southeast of Kooinano Pool. The east-trending Divide Fault forms the northern limit of the currently exposed Bresnahan Basin. The normal faults cut both Ophthalmia and Ashburton Fold Belt structures and offset strike-slip faults. The fault system is the product of a southeast-directed extension and belongs to the Mount Whaleback fault set of Tyler et al. (1991).

Deposition of the Bresnahan Group, and contemporaneous faulting, post-dates the D_{1a} and D_{2a} deformations in the Ashburton Fold Belt. The group is itself unconformably overlain by the Bangemall Group, and prior to this, gentle to open, upright folding took place about southeast and east-southeast-plunging axes. A cleavage is not developed. These folds parallel trends in the underlying Ashburton Fold Belt, and correspond to the Newmanian fold period of Halligan and Daniels (1964).

Large-scale steeply dipping to vertical faults occur parallel to the main fold trends, and have truncated folds to produce a distinctive cuesta topography. Faulting probably accompanied folding and was controlled by reactivation of pre-existing basement structures.

BANGEMALL BASIN

BANGEMALL GROUP

The Bangemall Group is the only stratigraphic unit within the Bangemall Basin and it unconformably overlies rocks of the Ashburton and Bresnahan Basins in the southwestern part of TUREE CREEK. The group has a maximum thickness of 3.5 km and is subdivided into seven formations. In ascending order these are: Irregully Formation, Cheyne Springs Formation, Kiangi Creek Formation, Jillawarra Formation, Devil Creek Formation, Ullawarra Formation, and Mount Vernon Sandstone. The six lower formations, up to and including the Ullawarra Formation, form the Edmund Subgroup; the Mount Vernon Sandstone belongs to the conformably overlying Mucalana Subgroup (Williams, 1990).

The age of the Bangemall Group is poorly constrained; Williams (1990) suggested an age range of 1.6–1.2 Ga for the Edmund Subgroup, and 1.2–1.0 Ga for the Mucalana Subgroup.

Edmund Subgroup

Irregully Formation (Mi)

The 500 m-thick Irregully Formation rests unconformably upon the Ashburton Formation and the Bresnahan Group, and is conformably overlain by either the Cheyne Springs Formation or the Jillawarra Formation. The Irregully Formation is dominated by dolarenite and dololutite, but also contains interbeds of pebble conglomerate, quartz sandstone, siltstone, mudstone, and chert. Domical stromatolites are abundant throughout the stratigraphy and occur interbedded with crinkle-laminated dolomite, tepee structures, intraclast grainstone and conglomerate, and ripple-laminated quartz sandstone. The conical stromatolite *Conophyton garganicum australe* Walter 1972 has been recorded from scree material in Fords Creek (Walter, 1972). Other forms occurring in the Fords Creek section include an unnamed variably oriented conical stromatolite with pronounced lateral linkage, and a large domical (*Paniscollenia*-like) stromatolite (K. Grey, personal communication, 1990).

The depositional setting for the Irregully Formation is interpreted as a coastal lagoon system, with associated tidal flats, shoals, and washover fans (Chuck, 1984; Muhling and Brakel, 1985).

Cheyne Springs Formation (Mp)

The Cheyne Springs Formation (Chuck, 1984) has a maximum thickness of about 250 m on TUREE CREEK. It is a lenticular unit which conformably overlies either the Irregully Formation or the Jillawarra Formation, and is itself conformably overlain by the Kiangi Creek Formation. The Cheyne Springs Formation is dominated by stromatolitic dolomite, dolorudite, dolarenite, and dololutite. Many of these carbonates contain variable amounts of siliciclastic detritus. Dolarenite beds are often graded and may display truncated Bouma sequences; dolorudite beds are massive and show a mixture of clast- and matrix-support.

The Cheyne Springs Formation is interpreted as a shallow-water shelf, shelf slope, and basin deposit (Chuck, 1984).

Kiangi Creek Formation (Mk)

The Kiangi Creek Formation (Chuck, 1984; Muhling and Brakel, 1985) is a lenticular unit which is generally less than 50 m thick on TUREE CREEK. It is conformably overlain by the Jillawarra Formation and consists of massive sandstone, cross-stratified sandstone, and thin- to medium-bedded sandstone and argillite.

Massive sandstone is the most abundant rock type in the Kiangi Creek Formation. It occurs in beds which range in thickness from 0.2 to 2 m, and is interbedded with variable amounts of mudstone, siltstone, and thin-bedded sandstone. Sedimentary structures include dewatering tubes and graded bedding; flute casts, tool markings, and current lineations are present on the bases of some beds (Chuck, 1984).

The proportion of argillite increases towards the top of the Kiangi Creek Formation, and there is a transitional contact with the overlying Jillawarra Formation.

The Kiangi Creek Formation is interpreted as a submarine fan and marine-shelf deposit (Chuck, 1984).

Jillawarra Formation (Mj)

The Jillawarra Formation (Chuck, 1984) includes all the dominantly argillaceous units which occur above the Irregully Formation, and below the Devil Creek Formation. On TUREE CREEK these rocks crop out below the Cheyne Springs Formation, where they are intruded by a major dolerite sill, and above the Kiangi Creek Formation.

The formation has a total thickness of about 150 m, excluding dolerite. It consists of parallel-laminated mudstone and siltstone interlayered locally with thin- to thick-bedded sandstone. The sandstone beds generally have sharp bases, with local flute marks and load structures; most are either massive or show the AB divisions of the Bouma sequence.

The top of the Jillawarra Formation is marked by a thin (5–20 m) siliceous unit, the Discovery Chert (Chuck, 1984; Muhling and Brakel, 1985). It consists of grey to black, thin-bedded chert and cherty mudstone; internal lamination is generally weak.

The depositional setting for the Jillawarra Formation is believed to be a restricted or open-marine shelf (Muhling and Brakel, 1985).

Devil Creek Formation (Mv)

The 650 m-thick Devil Creek Formation conformably overlies the Jillawarra Formation and is itself conformably overlain by the Ullawarra Formation. The formation consists of stromatolitic dolomite, dolorudite, and interbedded thin- to medium-bedded dolarenite and dolomitic argillite.

Stromatolitic dolomites are characterized by planar to irregularly undulating lamination, which is locally transitional into small domical stromatolites. Dolorudites occur in lenticular beds throughout the Devil Creek Formation and consist of subangular to rounded, tabular clasts of dolomite (up to 1 m across) in a dololutite matrix. Thin-bedded dolarenites are normally graded, and display parallel lamination and/or ripple cross-lamination. Medium-bedded dolarenites are either massive or parallel laminated. All the above-mentioned rocktypes are interbedded with parallel-laminated dololutite, argillaceous dololutite, and dolomitic mudstone.

The Devil Creek Formation represents a variety of depositional environments ranging from shallow subtidal shelf, through shelf slope, to basin plain (Chuck, 1984).

Ullawarra Formation (Mu)

The 1000 m-thick Ullawarra Formation is the uppermost stratigraphic unit of the Edmund Subgroup. It consists of mudstone, siltstone, and thin-bedded turbidite sandstone, interlayered with dolerite sills. The upper part of the Ullawarra Formation is probably equivalent to the Fords Creek Shale of Chuck (1984); however, the strong lithological similarity between these units has prevented them being mapped as separate formations.

The Ullawarra Formation is interpreted as a relatively deep-water, submarine-fan deposit (Chuck, 1984).

Mucalana Subgroup

Mount Vernon Sandstone (Mm)

The 200 m-thick Mount Vernon Sandstone is the only representative of the Mucalana Subgroup on TUREE CREEK. It conformably overlies units mapped as Ullawarra Formation, and consists of massive and cross-stratified quartz sandstone, interbedded with minor argillite.

Massive, medium-grained to very coarse-grained sandstone forms medium- to thick-bedded units. These are either structureless, or display weak parallel stratification, flute markings, dewatering pipes and dish structures, and symmetrical ripples.

Cross-stratified sandstone also occurs in medium- to thick-bedded units and includes a variety of stratification types including trough cross-stratification, low- and high-angle planar cross-stratification, and hummocky cross-stratification. Fine-grained interbeds are often graded and may be ripple cross-laminated.

Massive and cross-stratified units of the Mount Vernon Sandstone are interpreted as subaqueous mass-flow and reworked mass-flow deposits respectively (Chuck, 1984).

STRUCTURE OF THE BANGEMALL BASIN

The structure of rocks deposited in the Bangemall Basin has been discussed by Muhling and Brakel (1985). On TUREE CREEK they identified two tectonic units: The Pingandy Shelf, and the Edmund Fold Belt (Fig. 1).

The Pingandy Shelf was described as a relatively undeformed apron of sediments flanking and overlying the Ashburton Fold Belt. Sedimentary rocks dip gently to the west and south.

The Edmund Fold Belt consists of open to tight folds with steeply dipping axial surfaces. Folds are elongate and are non-cylindrical, with axes plunging less than 30°. On TUREE CREEK folds are tight and axes trend west-northwest, parallel to structural trends in the Ashburton Fold Belt. A cleavage is developed axial planar to the tight folds.

Muhling and Brakel (1985) interpreted folding in the Edmund Fold Belt as initially formed during a period of extension, with drape folds over basement blocks that moved on normal faults. Subsequent shortening of the basement produced shortening of the cover by squeezing the fold belt against the Pingandy Shelf.

Winsor (1987) carried out a study of deformation in the Bangemall Group at Irregully Gorge. Three phases of open folding were identified which followed trends in the underlying Ashburton Formation. Folding was attributed to the reactivation of the basement structures.

MAFIC DYKES

Four mafic dyke swarms trending west-northwest, northwest, north-northeast, and east-northeast occur on TUREE CREEK. The first two sets are the oldest and are seen to cut Hamersley Basin rocks and the Beasley River Quartzite. Intrusion of the last two sets post-dates deformation of the Bangemall Basin. All the dykes are dolerite and consist of pyroxene and feldspar with minor quartz, hornblende, and biotite.

West-northwest-trending dykes outcrop along the southern margin of the Pilbara Craton (Tyler, 1991; Tyler et al., 1991). They are older than the northwest-trending swarm, being cross-cut by them in the Sylvania Inlier (Tyler, 1991). This is supported by the relationship of the dykes to hematite ore. At Paraburdoo the west-northwest dykes post-date folding and are pre-ore in age (Morris, 1980). Northwest-trending dykes are more extensive, occurring throughout the Pilbara Craton, and are equivalent to the Round Hummock Suite of Hickman and Lipple (1978). Dykes which cut iron-ore deposits in the Brockman Syncline on MOUNT BRUCE produced massive recrystallization of adjacent hematite (Evans and Clint, 1975), and therefore post-date ore formation. Northwest-trending dykes are particularly well developed in the northeast part of TUREE CREEK. Both sets typically infill pre-existing joint and fault systems (Baldwin, 1975; Bourn and Jackson, 1979).

The north-northeast-trending swarm is equivalent to the Mundine Well Suite of Hickman and Lipple (1978). Dykes are continuous over long distances and can typically be traced across the width of the sheet (110 km). Perhaps the best example is the Channar dyke, which caused recrystallization of hematite ore 20 km west-southwest of Paraburdoo (Bourn and Jackson, 1979). The age of this swarm relative to the east-northeast trending swarm is not known.

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 peneplained surface of probably late Mesozoic to early Tertiary age.

Residual deposits (*Czr*) that 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, 1985; Kneeshaw, 1984). Remnants of the Hamersley Surface are best preserved around the Turee Creek Syncline.

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*).

Extensive areas of sheetwash plain (*Qw*) occur within the Turee Creek Syncline. They consist of alluvium and colluvium. Alluvium (*Qa*), comprising unconsolidated silt, sand, and gravel, was deposited along the present drainage channels. Colluvium (*Qc*) forms recent talus slopes, adjacent to outcropping bedrock.

ECONOMIC GEOLOGY

GOLD

Gold was first recorded from TUREE CREEK in 1890 (Woodward, 1891) and is associated with quartz veins and shears in the Fortescue and Wyloo Groups, and with Cainozoic deposits overlying the Wyloo Group.

A small gold prospect within the Bellary Formation of the Fortescue Group occurs approximately 4 km north of Paraburdoo (Zeelanberg, 1976; Blight, 1985). Gold values of 0.2–0.7 g/t (22 g/t maximum) have been reported from a pyrite-bearing, sheared conglomerate in the upper part of the formation.

Most gold recovered from TUREE CREEK has come from Cainozoic gravels overlying Ashburton Formation, or from quartz veins and shears within the Ashburton Formation. Two localities have been worked intermittently since the 1890s: Top Camp and Soldiers Secret.

In the Top Camp area (23°44'40"S, 117°16'30"E) many workings follow the margins of a northwest-trending dolerite dyke. Most auriferous veins dip steeply, and strike between southwest and northwest. Mudstone and siltstone host rocks dip steeply to the north-northeast or south-southwest. Simpson (1926) reported that a 2.36 kg nugget was found in 1893.

Soldiers Secret is located east of Wandarry Creek, at 23°36'S, 117°05'E. Although much alluvial gold has been found, most quartz veins are barren.

COPPER

Small amounts of copper have been extracted from veins and shears in the Ashburton Formation in the southwestern part of TUREE CREEK.

Windy Ridge (Tropic) Mine is located at 23°27'10"S, 117°15'10"E. Malachite, chrysocolla, chalcocite, and cuprite occur in impersistent limonitic quartz veins and pods. A ferruginous gossan was reported to have capped the deposit (Low, 1963), but has since been removed.

The Soldiers Secret Northeast (Donnelly) copper–gold occurrences (23°35'30"S, 117°07'00"E) comprise veins carrying malachite, chrysocolla, limonite, and gold emplaced along bedding, cleavage and fracture planes. This and other smaller deposits occurring at Goobaroo Pool (23°29'00"S, 117°17'36"E), Mount Blair South (23°29'S, 117°08'E), and Station Creek (23°26'12"S, 117°01'48"E) were described by Blockley (1971) and Marston (1979).

LEAD AND SILVER

A small amount of lead and silver has been recorded from the Station Creek prospect (Blockley, 1971). Minor galena mineralization has also been reported from the Irregully Formation at 23°57'S, 118°07'E (Chuck, 1984).

IRON

Hamersley Group rocks on TUREE CREEK lie within the Hamersley Iron Province of MacLeod et al. (1963). The presence of major hematite ore bodies along the southern limb of the Bellary anticline was recognized during the 1960s (Daniels, 1968). 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). Large-scale faulting controlling the fluid flow (cf. Sibson, 1987) is an important element in the supergene-enrichment model proposed for ore formation by Morris (1980, 1985). Examples of normal faulting (which controls mineralization) are preserved within the orebody (Morris, 1985). The complexity of faulting at Paraburdoo reflects its position at the termination of the Nanjilgardy Fault (Fig. 1), which locally forms the boundary between the Hamersley Basin and the Ashburton Basin.

Deposits at Paraburdoo, currently being mined by Hamersley Iron Pty Ltd, have measured and indicated resources of about 330 million tonnes of high-grade ore (>64% Fe, <0.076% P). Total potential for high-grade ore in the region is about 1100 million tonnes, and deposits at Channar, 21 km to the east, are being developed. The deposits have been described by Baldwin (1975) and Bourn and Jackson (1979). Most mineralization occurs in the Brockman Iron Formation, where the greatest resources are associated with the Joffre and Dales Gorge Members (Bourn and Jackson, 1979). In addition, minor amounts of ore occur in the Marra Mamba Iron Formation (18E deposit) and the Weeli Wolli Formation.

In general the ore bodies have moderate dips to the southeast. The principal ore types are martite–hematite and martite(–hematite)–goethite (Kneeshaw, 1984). Increasing amounts of goethite result in higher phosphorus contents; there is also a marked increase in phosphorus content with increasing depth.

Minor detrital and surficial ore deposits are also present throughout the region.

ASBESTOS

Crocidolite has been reported from the eastern side of the gorge where Turee Creek cuts through the northwestern limb of the Turee Creek Syncline (Trendall and Blockley, 1970). It occurs 9.7 m (32 feet) above the base of the Dales Gorge Member of the Brockman Iron Formation. The fibre was regarded as having no economic interest.

URANIUM

Most arenaceous rock units of the Ashburton, Blair, and Bresnahan Basins have been examined for sandstone-hosted uranium, but results have not been encouraging (Carter, 1981). Many radioactive anomalies in the Capricorn Formation were found to be thorium-based. In Bresnahan Group sandstone localized radiometric anomalies are associated with heavy-mineral layers containing uraniferous monazite, zircon and ilmenite; no significant mineralization has been reported.

Turee Creek (Angelo River) uranium prospect (23°34'30"S, 118°14'00"E) is associated with a northeast-trending normal fault, which separates Mount McGrath Formation from Bresnahan Group (Ewers and Ferguson, 1985). Host rocks in the fault zone are brecciated hematitic and carbonaceous shale, sandstone breccia, chert breccia, dolomitic shale, and clay.

REFERENCES

ARNDT, N.T., NELSON, D. R., COMPSTON, W., TRENDALL, A. F., and THORNE, A. M., 1991, The age of the Fortescue Group, Hamersley Basin, Western Australia, from ion microprobe zircon U-Pb results: Australian Journal of Earth Sciences, v. 38(3), p. 261–281.

BALDWIN, J. T., 1975, Paraburdoo and Koodaideri iron ore deposits, and comparisons with Tom Price iron ore deposits, 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. 898–905.

BEARD, J. S., 1975, The vegetation of the Pilbara area: Explanatory Notes to Sheet 5, Vegetation Survey of Western Australia: Nedlands, University of Western Australia Press.

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, p. 234.

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

BOURN, R., and JACKSON, D. G., 1979, A generalised account of the Paraburdoo iron orebodies: Australasian Institute of Mining and Metallurgy, Annual Conference, Perth, W.A., 1979, Papers; Conference Series, no. 8, p. 187–201.

CAMPANA, B., HUGHES, F. E., BURNS, W. G., WHITCHER, 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.

CARTER, J. D., 1981, Uranium exploration in Western Australia: Western Australia Geological Survey, Record 1981/6.

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 Institute (WAMPRI now MERIWA), Report no. 6.

DANIELS, J. L., 1968, Turee Creek, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes.

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

DANIELS, J. D., HALLIGAN, R., and JONES, W. R., 1967, Turee Creek (first edition): Western Australia Geological Survey, 1:250 000 Geological Series, Map.

de la HUNTY, L. E., 1965, Mount Bruce, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes.

ELLIS, H. A., 1951, Report on a reconnaissance examination of the Kooline lead field: Western Australia Geological Survey, Annual Report 1949, p. 9–15.

EVANS, W. J., and CLINT, P., 1975, Iron deposits of the Brockman Syncline, 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. 906–910.

EWERS, G. R., and FERGUSON, J., 1985, Unconformity-related uranium deposits—Turee Creek uranium prospect, Western Australia: Australia Bureau of Mineral Resources, Annual Report, 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(7), p. 1929–1953.

FAVENC, E., 1888, The history of Australian exploration from 1788 to 1888: Sydney, Turner and Henderson, 474 p.

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 in extensional basin margins: Geological Society of London, Journal, v. 141, p. 711–732.

GREGORY, A. C., and GREGORY, F. T., 1884, Journal of Australian Explorations: Brisbane, 184 p.

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

GREY, K., 1984a, Stromatolitic limestone from the Duck Creek Dolomite, near Kennedy Creek (Turee Creek Sheet), and a re-assessment of the occurrence of *Patomia* f. indet. at the same locality: Western Australia Geological Survey, Palaeontology Report 8/84 (unpublished).

GREY, K., 1984b, A new stromatolite from the Proterozoic Capricorn Formation, near Mount Elephant, Turee Creek 1:250 000 Sheet area: Western Australia Geological Survey, Palaeontology Report 10/84 (unpublished).

HALLIGAN, R., and DANIELS J. L., 1964, Precambrian geology of the Ashburton Valley region, North West division: Western Australia Geological Survey, Annual Report 1963, p. 38–46.

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

HORWITZ, R. C., 1980, The Lower Proterozoic succession south of the Hamersley Iron Province between the Angelo and Beasley Rivers: Australia Commonwealth Scientific and Industrial Research Organization, Minerals Research Laboratories, Division of Mineralogy, Report FP22.

HORWITZ, R. C., 1981, Large scale slumping in the Ashburton Trough of Western Australia: Precambrian Research, v. 14. p. 389–401.

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

HUNTER, W. M., 1990, Bresnahan Basin, *in* Geology and Mineral Resources of Western Australia: Western Australia Geological Survey, Memoir 3.

JONES, F. H., and TELFORD, R. J., 1939, The Dead Finish, Mount Mortimer, Top Camp and Soldiers Secret mining centres, Ashburton Goldfield: Aerial Geological and Geophysical Survey Northern Australia, Western Australia Report no. 61, p. 11–16.

KNEESHAW, M., 1984, Pilbara iron ore classification: Australasian Institute of Mining and Metallurgy, Proceedings, no. 289, p. 157–162.

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

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

MacLEOD, W. N., de la HUNTY, L. E., JONES, W. R., and HALLIGAN, R., 1963, A preliminary report on the Hamersley Iron province, North-West Division: Western Australia Geological Survey, Annual Report 1962, p. 44–54.

MAITLAND, A. G., 1909, Geological investigations in the country lying between 21°30' and 25°30'S lat. and 113°30' and 118°30'E long., embracing parts of the Gascoyne, Ashburton and West Pilbara Goldfields: Western Australia Geological Survey, Bulletin 33.

MAITLAND, A. G., 1919, Chapter 1. A summary of the geology of Western Australia, *in* The Mining Handbook of Western Australia: Western Australia Geological Survey, Memoir 1, p. 1–55.

MARSTON, R. J., 1979, Copper mineralization in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 13, p. 208.

McCONCHIE, D. M., 1984, The geology and geochemistry of the Joffre and Whaleback Shale Members of the Brockman Iron Formation, Western Australia: University of Western Australia, Ph.D. thesis (unpublished).

MORRIS, R. C., 1980, A textural and mineralogical study of the relationship 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, Iron ore: Australia Commonwealth Scientific and Industrial Research Organization, Division of Mineralogy, Research Review, 1983, p. 36–39.

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 Basin—the evolution of an intracratonic Proterozoic basin: Western Australia Geological Survey, Bulletin 128.

MYERS, J. S., 1990, Precambrian tectonic evolution of part of Gondwana, southwestern Australia: Geology, v.18, p. 640–643.

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

SIBSON, R. H., 1987, Earthquake rupturing as a mineralizing agent in hydrothermal systems: Geology, v. 15, p. 701–704.

SIMPSON, E. S., 1926, Minerals of the Ashburton and Gascoyne valleys: Western Australia Geological Survey, Bulletin 85 (Appendix).

SIMPSON, E. S., 1951, Minerals of Western Australia, Volume 2: Perth, Western Australia, Government Printer.

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.

TALBOT, H. W. B., 1926, A geological reconnaissance of part of the Ashburton drainage basin: Western Australia Geological Survey, Bulletin 95.

THORNE, A. M., 1990, Ashburton Basin, *in* Geology and Mineral Resources of Western Australia: Western Australia Geological Survey, Memoir 3.

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

TRENDALL, A. F., 1975, 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., and BLOCKLEY, J. G., 1970, The iron formations of the Precambrian Hamersley Group, Western Australia, with special reference to the associated crocidolite: Western Australia Geological Survey, Bulletin 119, p. 174–254.

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, fasc. 3, p. 173–186.

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

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.

TYLER, I. M., HUNTER, W. M., and WILLIAMS, I. R., 1991, Newman, Western Australia (second edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes.

WALTER, M. R., 1972, Stromatolites and the biostratigraphy of the Australian Precambrian and Cambrian: Palaeontological Association (London), Special Papers in Palaeontology, no. 11.

WALTER, M. R., 1983, Archean stromatolites: evidence of the earth's earliest benthos, *in* Earth's Earliest Biosphere *edited by* J. W. SCHOPF: Princeton, N.J., Princeton University Press, p. 187–213.

WILCOX, R. E., HARDING, T. P., and SEELY, D. R., 1973, Basic wrench tectonics: American Association of Petroleum Geologists, Bulletin, v. 57, p. 74–96.

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

WINSOR, C. N., 1987, An example of the use of veins to establish cover fold history—Irregully Formation, Western Australia: Journal of Structural Geology, v. 9, p. 429–440.

WOODWARD, H. P., 1891, Annual general report of the Government Geologist, 1890: Western Australia Geological Survey, p. 20–22.

ZEELANBERG, D., 1976, Terminal report, Paraburdoo prospect (MC 47/3414–47/3417: Western Mining Corporation (Western Australia Geological Survey, M-series Open File, Roll 122, Item 248) (unpublished).

04083/10/91-1500-L/5551

GARRY L. DUFFIELD, Government Printer, Western Australia

TUREE CREEK

AUSTRALIAN 1:250 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SF 50-15

SYMBOLS

Geological boundary
Fault
- position accurate
- reverse
- concealed
- shear zone

Major folds, showing plunge where known
- anticline
- syncline
- overturned syncline

Minor folds
- Post-Capricorn Orogen, with direction and plunge; dip and strike of axial surface M, S, or Z profile
  - inclined
  - vertical
- Ashburton Fold Belt, with direction and plunge; M, S, and Z profile
  - D2a
    - anticline
    - syncline
    - M profile
    - S profile
    - Z profile
  - D1a
    - anticline
- Ophthalmia Fold Belt, with direction and plunge; dip and strike of axial surface; M, S, or Z profile
  - D2c
    - inclined
    - vertical
  - D1c
    - inclined
    - vertical

Bedding, showing dip and strike
- inclined
- vertical
- horizontal
- overturned
- dip estimated from aerial photographs
  - 0-15°
  - 16-45°
  - 46-89°
  - vertical
- general trend of bedding

Way-up indicator
- top of bed

Cleavage, showing dip and strike
- Ashburton Fold Belt D2a
  - inclined
  - vertical
  - strike coincident with bedding
- Ashburton Fold Belt D1a
  - inclined

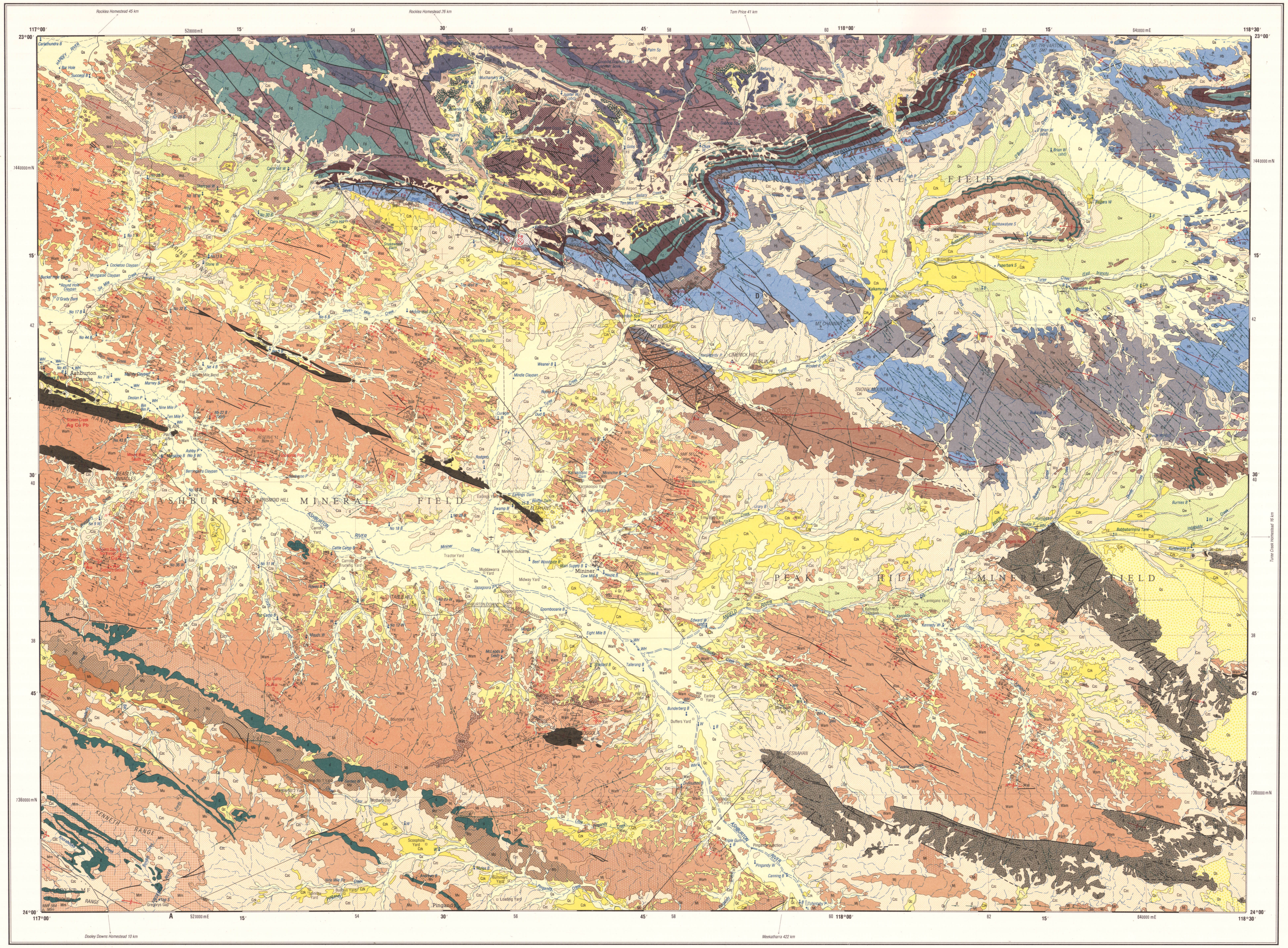
Stromatolite locality

Mineral field boundary
Formed road
Track
Railway
Townsite, population 1000-10000 — PARABURDOO
Homestead — Mininer
Building
Yard — Yd
Airfield
Landing ground
Horizontal control; major, minor

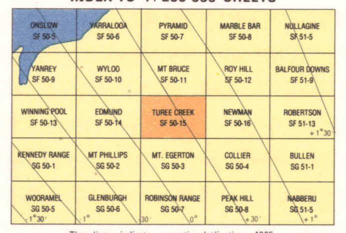
Watercourse, intermittent
Pool — P
Well — W
Bore — B
Windpump
Rockhole — RH
Waterhole — WH
Spring — S
Abandoned — (abd)
Position doubtful — (PD)

Mining
- opencut mine (major)
- mine, abandoned
- alluvial workings
- prospect
- made ground and mining area

Mineral occurrence
- Gold — Au
- Copper — Cu
- Crocidolite — Ad
- Iron — Fe
- Lead — Pb
- Silver — Ag
- Uranium — U



INDEX TO 1:250 000 SHEETS



REFERENCE

PHANEROZOIC — CAINOZOIC — QUATERNARY

- Qa — Alluvium — unconsolidated silt, sand, and gravel
- Qc — Colluvium — unconsolidated quartz and rock fragments in soil
- Qs — Eolian sand forming dunes and sheets
- Qw — Alluvium and colluvium — red-brown sandy and clayey soil

- Czb — Silcrete — siliceous duricrust
- Czc — Colluvium — partly consolidated valley-fill deposits
- Czk — Calcrete — sheet carbonate, found along major drainage lines
- Czl — Laterite — massive and pisolitic ferruginous duricrust
- Cza — Alluvium — partly consolidated silt, sand, and gravel
- Czr — Surficial hematite-goethite deposits and laterite on Hamersley Group rocks
- Czp — **ROBE PISOLITE** — pisolitic limonite deposits developed along river channels

- q — Quartz veins
- d — Dolerite dykes, sills, and small intrusions

PROTEROZOIC

c. 1100 Ma

BANGEMALL BASIN — Bangemall Group

Mucalana Subgroup
- Mm — **MOUNT VERNON SANDSTONE:** fine- to medium-grained quartz sandstone, siltstone, and mudstone; minor glauconitic sandstone and conglomerate

Edmund Subgroup
- Mu — **ULLAWARRA FORMATION:** mudstone, siltstone, and thin-bedded turbidite sandstone
- Mv — **DEVIL CREEK FORMATION:** dololutite, dolarenite, dolorudite, and local stromatolitic dolomite
- Mj — **JILLAWARRA FORMATION:** mudstone, siltstone, and minor turbidite sandstone; top of unit marked by thin-bedded DISCOVERY CHERT
- Mk — **KIANGI CREEK FORMATION:** quartz sandstone, siltstone, mudstone, dolomite, and minor conglomerate
- Mp — **CHEYNE SPRINGS FORMATION:** stromatolitic dolomite, dololutite, dolarenite, and dolorudite; lithologies are locally quartzitic
- Mi — **IRREGULLY FORMATION:** stromatolitic dolomite, dololutite, dolorudite, and minor quartz sandstone, conglomerate and chert

BRESNAHAN BASIN — Bresnahan Group
- B — Pebble to boulder conglomerate, pebbly coarse-grained sandstone

BLAIR BASIN
- R — **CAPRICORN FORMATION:** ferruginous and quartzitic sandstone, mudstone, siltstone, conglomerate, dolomite, and felsic volcanic rock

ASHBURTON BASIN — Wyloo Group
- **ASHBURTON FORMATION:**
  - Wam — Pelite, thin-bedded metasandstone; minor medium- to thick-bedded metasandstone, metaconglomerate, and metadolomite
  - Was — Thin- to thick-bedded metasandstone; pelite and local metaconglomerate
  - Wai — Banded iron-formation, chert, and ferruginous pelite
  - Wab — Metabasaltic pillow lava and pillow breccia
  - Was — Thin- to thick-bedded metasandstone and pelite; local metaconglomerate and metadolomite

c. 1840 Ma

- Wd — **DUCK CREEK DOLOMITE:** thin- to thick-bedded, locally stromatolitic, metadolomite; metadolorudite, and minor chert and pelite
- Wm — **MOUNT McGRATH FORMATION:** ferruginous metasandstone and metaconglomerate, pelite, and metadolomite
- Wb — **CHEELA SPRINGS BASALT:** vesicular and amygdaloidal metabasalt, metatuff, and metasandstone
- Wq — **BEASLEY RIVER QUARTZITE:** fine- to coarse-grained quartzitic metasandstone, and pelite; minor metadolerite sills

HAMERSLEY BASIN

Turee Creek Group
- TU — Pelite, metasandstone, local stromatolitic metadolomite

Hamersley Group
- Hb — **BOOLGEEDA IRON FORMATION:** fine-grained, finely laminated iron-formation; pelite and chert
- Hw — **WOONGARRA VOLCANICS:** meta-rhyolite, meta-rhyodacite, metatuff, and banded iron-formation (2470 ± 30 Ma, U-Pb; 2370 Ma, Rb-Sr)
- Hj — **WEELI WOLLI FORMATION:** banded iron-formation (often jaspilitic), pelite, and numerous metadolerite sills
- Hb — **BROCKMAN IRON FORMATION:** banded iron-formation, chert, and pelite (2690 ± 16 Ma, U-Pb)
- Hs — **MOUNT McRAE SHALE and MOUNT SYLVIA FORMATION:** pelite, chert, and banded iron-formation
- Hd — **WITTENOOM DOLOMITE:** thin- to medium-bedded metadolomite, dolomitic pelite, and metatuff
- Hm — **MARRA MAMBA IRON FORMATION:** chert, banded iron-formation, and pelite

2500 Ma

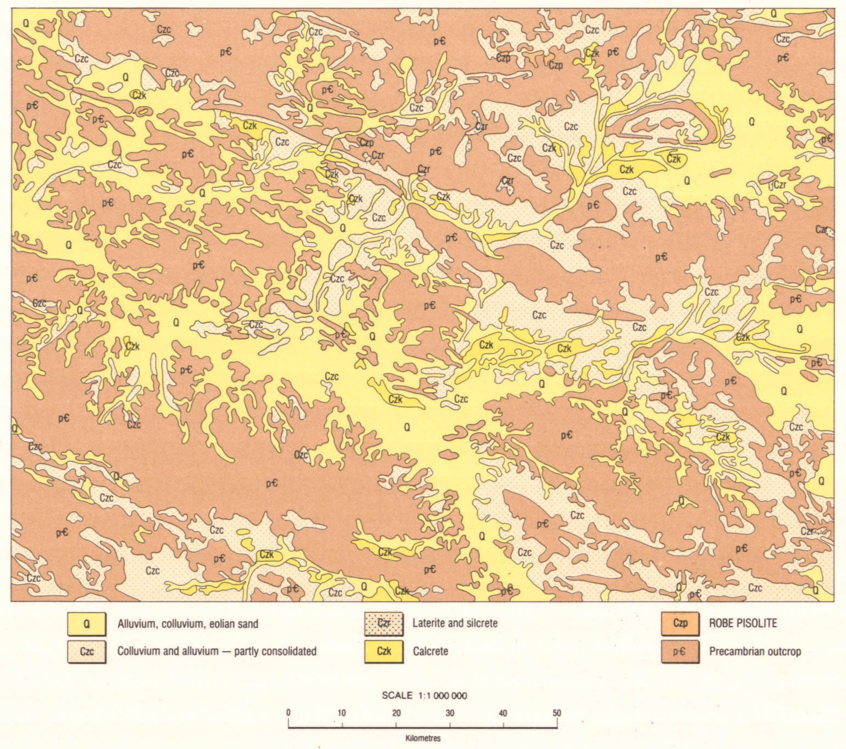
ARCHAEAN

- Fd — Metadolerite sills intruded into Fortescue Group; medium- to coarse-grained
- Fi — Layered mafic sills intruded into Fortescue Group; medium- to coarse-grained, sill tops may comprise coarse-grained leucocratic metadolerite

Fortescue Group
- Fj — **JEERINAH FORMATION:** pelite, metasandstone, chert, and metabasaltic pillow lava and breccia (2490 ± 20 Ma, U-Pb)
- Fu — **BUNJINAH FORMATION:** metabasaltic pillow lava and breccia; metatuff and minor chert
- Fp — **PYRADIE FORMATION:** pyroxene spinifex-textured metabasalt flows and pillow lava; metatuff, and minor chert; contains komatiite locally
- Fo — **BOONGAL FORMATION:** metabasaltic pillow lava and breccia; metatuff and minor chert
- Fh — **HARDEY FORMATION:** feldspathic metasandstone, pebbly metasandstone, and metaconglomerate
- Fhb — Metabasaltic tuff and breccia, and vesicular metabasalt flows
- Fr — **MOUNT ROE BASALT:** vesicular and amygdaloidal metabasalt, and metabasaltic breccia and tuff
- Fb — **BELLARY FORMATION:** pelite, feldspathic metasandstone and metaconglomerate, metabasaltic lava and pillow lava, and metatuff

c. 2765 Ma

CAINOZOIC GEOLOGY



HON. GORDON HILL, J.P., M.L.A.
MINISTER FOR MINES
D.R. KELLY, DIRECTOR GENERAL OF MINES

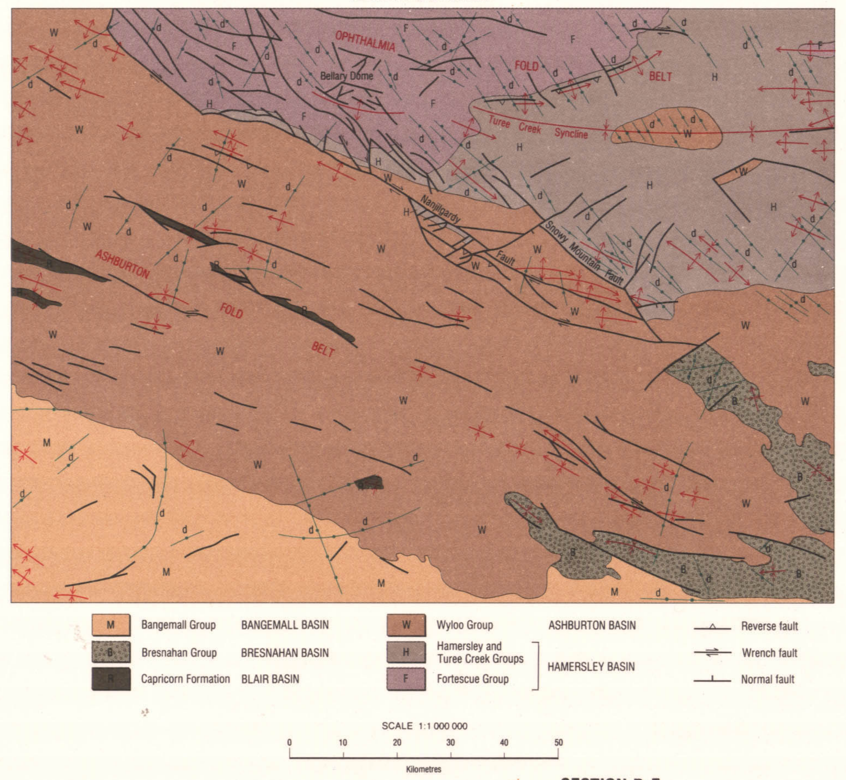
P.E. PLAYFORD
DIRECTOR, GEOLOGICAL SURVEY
OF WESTERN AUSTRALIA

SCALE 1:250 000

5000 Metres — 0 — 5 — 10 — 15 — 20 — 25 — 30 Kilometres

TRANSVERSE MERCATOR PROJECTION
ZONE 50 AUSTRALIAN MAP GRID

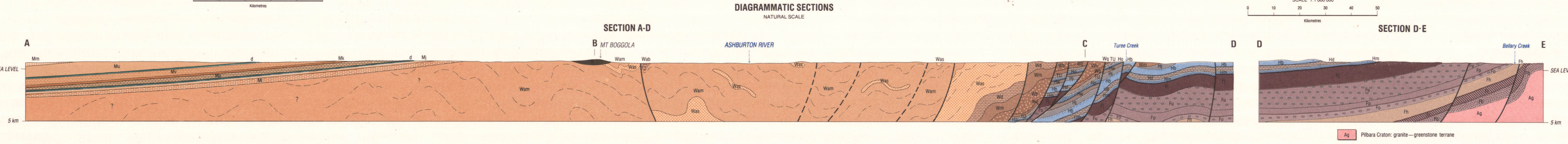
TECTONIC SKETCH MAP



DIAGRAMMATIC SECTIONS

NATURAL SCALE

SECTION A-D — SECTION D-E



Geology by: A.M. Thorne 1983-1989
D.B. Seymour 1983-1984
I.M. Tyler 1986
W.M. Hunter 1986

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

Topographic information 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 Print, Department of Services, Western Australia.

TUREE CREEK
SHEET SF 50-15

SECOND EDITION 1991