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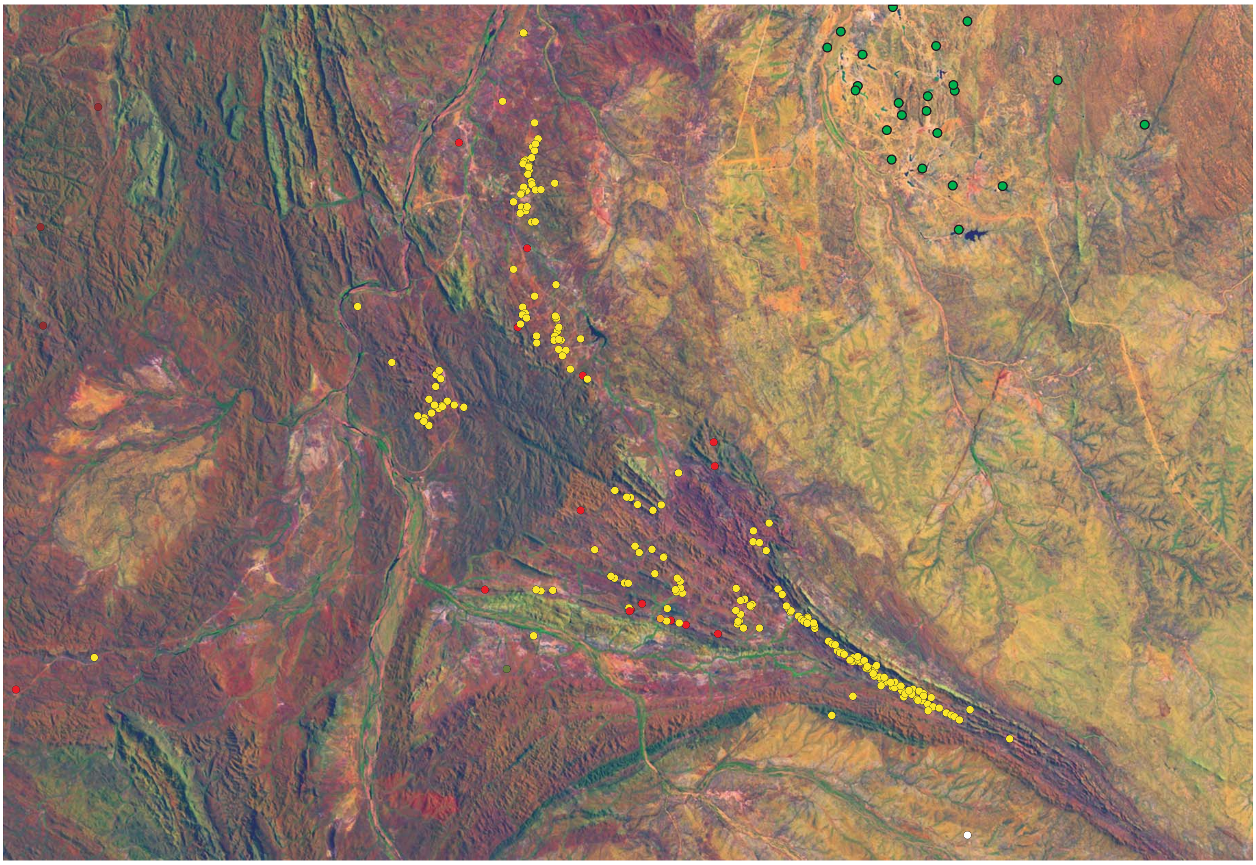
REPORT
81

MINERAL OCCURRENCES AND EXPLORATION POTENTIAL OF THE EAST PILBARA

by K. M. Ferguson and I. Ruddock



Geological Survey of Western Australia

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

REPORT 81

MINERAL OCCURRENCES AND EXPLORATION POTENTIAL OF THE EAST PILBARA

by
K. M. Ferguson and I. Ruddock

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Cover photograph: Landsat image of the Marble Bar – Warrawoona area showing the distribution of mineral occurrence sites (yellow — predominantly vein and hydrothermal gold; red — vein copper–lead; orange — vein nickel; green — alluvial and pegmatitic tin and tantalum; white — kimberlitic diamond). See Plate 1A and Figure 20 for details of geology and structure of the area shown.

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Mineral occurrences and exploration potential of the east Pilbara

by

K. M. Ferguson and I. Ruddock

Abstract

The east Pilbara area is an important contributor to the State's economy with major input from the iron ore export facilities and the hot briquetted iron (HBI) plant, located at Port Hedland, and the iron ore mining operation at Yarrie. The area is also a significant producer of tantalum and manganese, and until 1998 it was also a producer of gold. Geologically, the area includes mainly the northeastern part of the Archaean–Palaeoproterozoic Pilbara Craton that consists of an older granite–greenstone basement and an unconformably overlying sequence of volcanic and sedimentary rocks of the Hamersley Basin. In the north the craton is overlain by Mesozoic sedimentary rocks of the Northern Carnarvon Basin. In the east the area includes sedimentary rocks of the western edge of the Phanerozoic Canning Basin and the northern parts of the Neoproterozoic Officer Basin, the Mesoproterozoic Paterson Orogen, and the Collier Basin.

The long history of mining and mineral exploration in the area was triggered by the discovery of payable amounts of gold at Nullagine in 1888. Further discoveries of gold, tin, and base metals were made elsewhere in the area throughout the 1890s, and diamonds were found at Nullagine in 1895. In the early 1900s discoveries of tantalum and asbestos were made. Early mining production of gold and tin reached a peak at the beginning of the 20th century but this declined by 1910; although there was an increase in production from the mid-1930s to early 1940s. For short periods in the 1920s and 1950s there was moderate production from the lead–zinc–silver deposits of the Gregory Range. In the early 1950s the discovery of numerous manganese deposits in the Oakover River valley led to the area becoming Australia's main producing district until 1960.

The most significant boost to the area's prosperity was the iron ore exploration boom of the early 1960s and the subsequent development of major mines at Mount Goldsworthy, Shay Gap, Nimingarra, and Yarrie. During the 'base metals and nickel boom' of the late 1960s and early 1970s, the Archaean greenstone belts were a major focus for copper–zinc and nickel–copper exploration. This led to the discovery of small volcanogenic massive sulfide deposits at Big Stubby and Lennons Find in felsic volcanic rocks of the Warrawoona Group, and small deposits of nickel–copper sulfides in layered ultramafic sills at Soanesville and at Cookes Creek. In the early 1990s further VMS deposits were delineated in the Panorama area in felsic volcanic rocks of the Sulphur Springs Group. Further base metal potential was highlighted in the 1980s by the discovery of stratabound (clastic-hosted) sedimentary deposits of copper and lead in the Throssell Range.

From the mid-1980s there was renewed interest in gold at old mining centres, as a result of new developments in openpit mining methods and metallurgical processing of lower grade ores. Mine production was revived at Bamboo Creek, North Pole, Warrawoona, and Marble Bar, and continued until 1995. After this, gold production came from reopened mines in the Pilgangoora area between 1995 and 1998. Although gold mining is presently stalled, there is potential for further development of gold deposits in the east Pilbara, which may follow from recent advances in the understanding of the regional and local controls on gold mineralization, based on the results of the National Geoscience Mapping Accord in the north Pilbara.

In the most recent developments in the area, there has been increased production of tantalum from deposits at Wodgina, manganese production has recommenced at Woodie Woodie, and there are plans to restart barite production at North Pole. Interest in diamonds has also received a boost with recent discoveries in the Brockman kimberlite dyke, east of Warrawoona.

KEYWORDS: mineral exploration, mineral occurrences, mining, mineralization, Pilbara Craton, granite–greenstone terranes, Hamersley Basin, Paterson Orogen, Canning Basin, Officer Basin, Northern Carnarvon Basin, Collier Basin, regolith, iron ore, gold, base metals, manganese, tin, tantalum, lithium, barite, antimony, silver, asbestos, nickel, tungsten, chromium, molybdenum, fluorite, beryl, diamond

Introduction

Present study

This study of the east Pilbara area aims to promote and enhance the mineral prospectivity of the region by presenting an up-to-date review of its geological setting, exploration history, mineral occurrences, and mineralization controls. The study collates information from all available published sources and, in particular, it incorporates the vast amount of information held in Geological Survey of Western Australia (GSWA) databases covering mineral exploration activity, mineral occurrences, and mineral resources. It also includes some of the results from recent 1:100 000-scale geological mapping of the region.

Details of mineral exploration, mineral occurrences, and other geoscientific information for the study have been compiled from the following sources:

- the large dataset of open-file statutory mineral exploration reports held in the Western Australian mineral exploration (WAMEX) database at the former Department of Minerals and Energy (DME), now Department of Mineral and Petroleum Resources (MPR);
- the database of Western Australia's mines and mineral deposits information (MINEDEX) held at MPR;
- books, journals, and industry publications and datasets;
- regional geological surveys, and airborne geophysical and remote sensing datasets.

This mineral prospectivity study of the east Pilbara has three main parts: this report, Plates 1 and 1A of this report, and a digital dataset on CD-ROM. The report reviews the regional geology of the area, the history of mining and mineral exploration, the main mineral occurrences, the mineralization controls, and the potential for further mineralization. Plates 1 and 1A show the mineral occurrences, indicating commodity and mineralization style, on a geological map (a simplified interpretation of the solid geology and regolith) at 1:500 000 scale. The key to the mineral occurrences on Plates 1 and 1A is provided in Appendix 1. Where mineral occurrences are referred to in the report they are also identified by the WAMIN 'deposit name' and the WAMIN 'deposit number' shown thus: Iron Stirrup Au (**2808**).

Appendix 2 defines the terms used in the GSWA Western Australian mineral occurrences database (WAMIN) and mineral exploration activity spatial index database (EXACT). Appendix 3 gives a brief description of the digital datasets included on the CD-ROM. Appendix 4 provides a summary table of all mineral production as well as total production figures for the main commodities produced in the east Pilbara area (iron ore, manganese, tantalum, tin, gold, lead, copper, tungsten, beryl, and barite).

The accompanying CD-ROM includes all the data used to compile the Report and the plates, and it also includes files of geophysical, remote sensing, topographic, and mining tenement position data. The CD-ROM contains the files necessary for viewing the data in the ArcView GIS environment plus a self-loading version of the ArcExplorer software package modified to suit this particular dataset. Metadata statements on the geological, geophysical, and topographic datasets are also provided.

Location, physiography, climate, and access

This report covers the east Pilbara area that includes the four 1:250 000-scale map sheets – PORT HEDLAND – BEDOUT ISLAND, YARRIE, MARBLE BAR, and NULLAGINE (Fig. 1).

The area is broadly divided into the following physiographic units based on the criteria used by Hickman (1983), see Figure 2:

- Coastal and/or tidal flats
- Alluvial plains and valley floors
- Strike ridges and low hills
- Dissected plateau

The coastal flats include tidal mangrove swamps, samphire flats, extensive silt and mud flats, and areas of coastal dunes. Inland from this marine environment, the alluvial plains form areas of low relief that include broad river floodplains, valley floors, and adjacent gently dipping pediment plains that abut the higher relief areas of ridges, hills, and dissected plateaus.

The physiographic division of strike ridges and low hills is generally underlain by Archaean granite–greenstone rocks, but the division is also present over some areas of exposed Archaean granitoids, Permian Paterson Formation clastic sedimentary rocks, and Cainozoic calcareous sandstones of the Oakover Formation.

The dissected plateau comprises a scenic region of hills and deeply incised narrow valleys of the partly eroded surface of a Cainozoic peneplain, the Hamersley Surface (Twidale et al., 1985). This is predominantly underlain by volcanic and sedimentary rocks of the Fortescue Group of the Hamersley Basin.

The area has a semi-arid steppe-type tropical climate, with an average annual rainfall of about 300 mm, most of which reflects the tropical thunderstorms and cyclones of the January to March 'monsoon' season. Short periods of heavy rain can also occur in winter when cold fronts extend far enough north to interact with moist tropical upper-air streams. Summer temperatures range between daytime maxima of 36° to 43°C and night-time minima of 27° to 30°C. Corresponding winter ranges are between 26° and 30°C, and 7° and 12°C.

The sealed North West Coastal Highway and the mostly sealed Great Northern Highway provide the main road access to the area, linking with a network of partially sealed and unsealed graded shire and pastoral roads and tracks, which provide reasonable access through the low relief and hilly terrain. Access in the dissected plateau areas is more limited with single tracks of variable quality depending on the topography, drainage, and season.

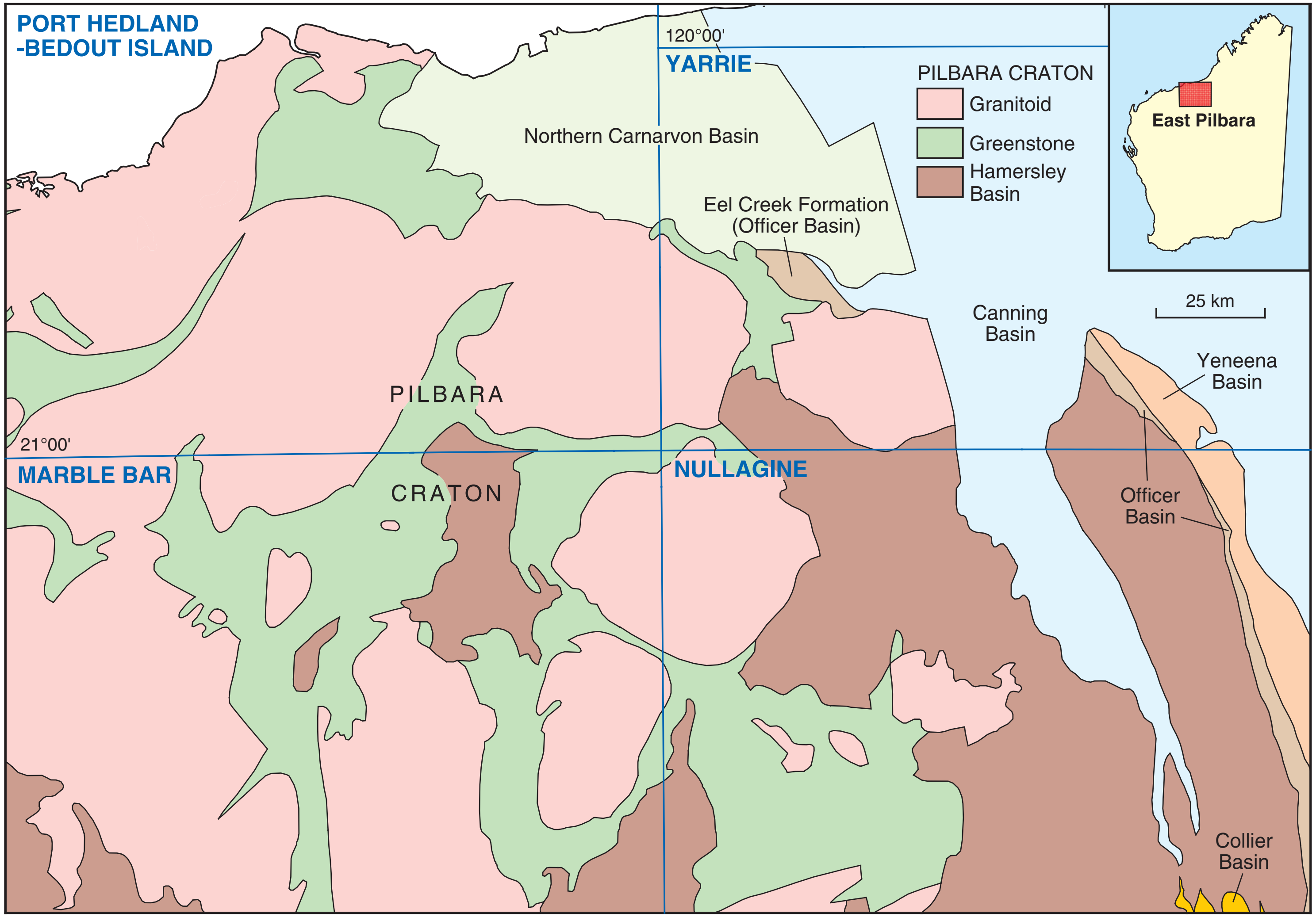


Figure 1. Tectonic units of the east Pilbara. Boundaries of the four 1: 250 000 geological maps included in the area are shown in blue

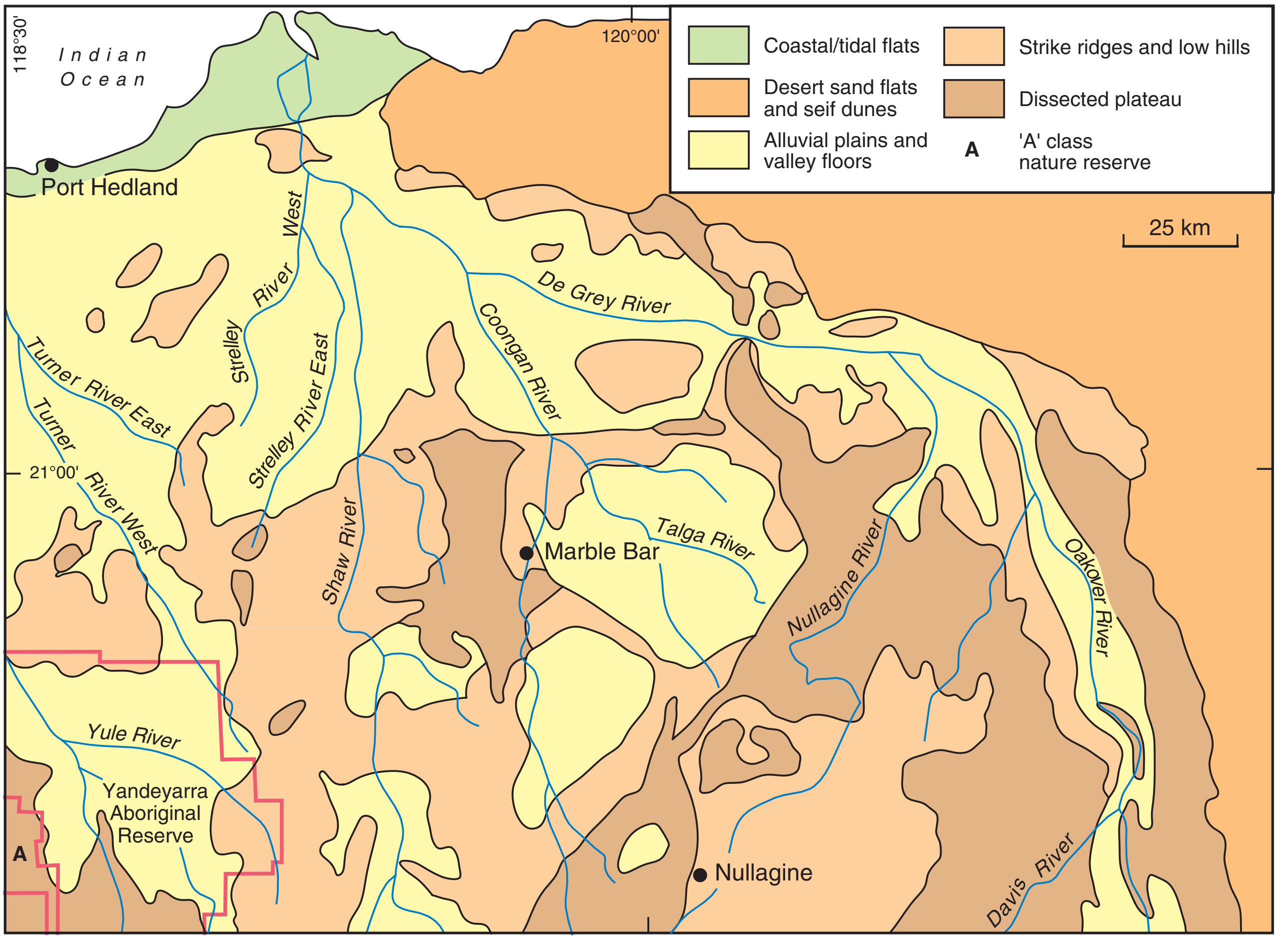


Figure 2. Location map of the east Pilbara, showing physiographic units, towns, and boundaries of the Yandeyarra Aboriginal Reserve and 'A' Class Nature Reserve

Previous work

The first to comment on the geology of the east Pilbara area was the surveyor H. T. Gregory (1884) during his 1861 expedition to establish the suitability of the area for pastoral development. The east Pilbara was later visited by the new Government Geologist, Harry Woodward, in 1890, and he provided brief details of mining and prospecting activities and geological features in the Coongan and Nullagine areas (Woodward, 1891, 1895). Further descriptions of mining activity were made by Becher (1896, 1897). More detailed geological investigations were carried out by the GSWA from 1904 to 1909, in 1912, and in 1921 (Maitland, 1904, 1905, 1906, 1908, 1909; Montgomery, 1907; Simpson and Gibson, 1907; Woodward, 1911; Blatchford, 1913; Talbot, 1920; Wilson, 1922).

Between 1935 and 1939 the Aerial Geological and Geophysical Survey of Northern Australia (AGGSNA) undertook field investigations at numerous mining centres in the east Pilbara. This was part of a joint program (Commonwealth government and State governments of Western Australia and Queensland) to investigate mineral development possibilities in the less accessible parts of Australia, lying to the north of latitude 22°S. AGGSNA issued 34 reports for the east Pilbara area on gold, tin, tantalite, iron, antimony, and chrysotile deposits (Finucane, 1935a,b; 1936a–f; 1937a,b; 1938a–g; 1939a–e; Finucane and Sullivan, 1939; Finucane et al., 1939; Finucane and Telford, 1939a–c; Jones, 1938a,b; 1939; O'Halloran, 1936; Sullivan, 1939a,b). A geophysical report on the Bamboo Creek area was also issued (Blazey et al., 1938).

The first systematic regional geological mapping in the east Pilbara was carried out during the late 1950s at a scale of 4 miles to the inch (1:253 440 scale). The YARRIE 4-mile sheet (Wells, 1959) was mapped by the Bureau of Mineral Resources (BMR, now Australian Geological Survey Organisation (AGSO)), and the 4-mile sheets of MARBLE BAR and NULLAGINE were mapped by the GSWA and published as part of a bulletin (Noldart and Wyatt, 1962). The PORT HEDLAND sheet was completed later as a 1:250 000 scale map by the GSWA (Low, 1965). Following on from this BMR and GSWA work in the east Pilbara, an initial appraisal was made of the geology and mineral resources of the area (Ryan, 1964).

During the 1970s the GSWA remapped the four sheets of the east Pilbara area at 1:250 000 scale (Hickman, 1978; Hickman and Lipple, 1978; Hickman and Gibson, 1982; Hickman et al., 1983). In 1976–77 the area around Port Hedland was mapped at 1:50 000 scale during the

GSWA urban geology mapping program (Archer, 1977a,b). During the mid-1990s the easternmost part of the area was mapped at 1:100 000 scale (Williams and Trendall, 1998a–c).

The first comprehensive regional synthesis of the geology and mineral resources of the northern Pilbara Craton was produced by Hickman (1981, 1983), which incorporated all the results that were available up to 1981 from GSWA regional mapping, mineral exploration, and various researchers.

Since 1945 the GSWA has published a number of commodity-specific studies of the State, and these include details of mineral occurrences in the east Pilbara: tantalum and niobium (Miles et al., 1945); iron ore (Connolly, 1959; MacLeod, 1966); lead–zinc–silver (Blockley, 1971a); copper (Low, 1963; Marston, 1979); manganese (de la Hunty, 1963); molybdenum, tungsten, and chromium, (Baxter, 1978); tin (Blockley, 1980); nickel (Marston, 1984); talc, pyrophyllite and magnesite (Abeysinghe, 1996); barite and fluorite (Abeysinghe and Fetherston, 1997); and limestone (Abeysinghe, 1998). An updated lead–zinc–silver study has recently been completed (Ferguson, 1999).

Since the mid-1970s there have been numerous important research papers and articles on the geology and mineralization of the east Pilbara (other than studies by the GSWA and AGSO), and references to these are provided in other parts of this report where appropriate.

In addition there is a GSWA study of the Fortescue Group, Pilbara Craton (Thorne and Trendall, 2001) that includes the area of the east Pilbara. Two project maps, which include the east Pilbara area, have been produced as part of GSWA's regional syntheses: north Pilbara Craton 1:1 000 000 scale (Hickman, 1983) and Fortescue Group, Pilbara Craton 1:500 000 scale (Thorne and Hickman, 1998).

Since 1994, the GSWA has been remapping the northern part of the Pilbara Craton at 1:100 000 and 1:250 000 scales as part of the National Geoscience Mapping Accord* (NGMA) project in conjunction with AGSO (Bagas and Van Kranendonk, in prep.; Bagas and Farrell, in prep.; Blewett et al., 2001; Farrell, in prep.; Smithies, in prep.; Smithies et al., 2001; Van Kranendonk, 2000, in prep.; Williams, 1999a,b, 2000, in prep.; Williams and Bagas, in prep.).

An important part of the NGMA project has been the major program of airborne geophysical data acquisition. Airborne surveys commenced in 1995 and a number of products covering the east Pilbara have been released by AGSO, including high-resolution aeromagnetic data and radiometric data. Remote sensing data for the project has also been obtained from Landsat-5TM, SPOT, and Airborne Multispectral Scanner Geoscan (AMSS) imagery.

* The National Geoscience Mapping Accord (NGMA) concluded in June 2000. A new agreement has been negotiated — the National Geoscience Agreement (NGA). For this report, however, the project will be referred to as the NGMA, as the geological studies were undertaken under that Accord

Company names

Company names used throughout this report have been abbreviated. This lists the full name of the company and the abbreviation used.

Alcoa	Alcoa of Australia Ltd
Amax	Amax Exploration Australia Inc.
Anglo American	Anglo American PLC
Anglo Westralian	Anglo Westralian Pty Ltd
Aquitaine	Aquitaine Australia Minerals Pty Ltd
Ashling	Ashling Resources NL
Associated Minerals	Associated Minerals Pty Ltd
Australia and New Zealand Exploration	Australia and New Zealand Exploration Company
Australian Ores and Minerals	Australian Ores and Minerals Ltd
Aztec	Aztec Mining Company Ltd *and* Aztec Exploration Ltd
Bell Basic Industries	Bell Basic Industries Ltd
BHP	The Broken Hill Proprietary Co. Ltd
BP *or* BP Minerals	BP Minerals Australia Pty Ltd
CEC	Carpentaria Exploration Company Pty Ltd (Mount Isa Mines Ltd)
Centenary	Centenary International Mining Ltd
Clackline	Clackline Ltd
Cominco	Cominco Exploration Pty Ltd
Consolidated Minerals	Consolidated Minerals Limited
Conwest	Conwest (Aust) NL
CRA	CRAE Conzinc Riotinto of Australia Pty Ltd *and* CRA Exploration Pty Ltd
D. F. D. Rhodes	D. F. D. Rhodes Pty Ltd
Day Dawn	Day Dawn Mines
De Grey	De Grey Mining Ltd
Dome Hill Mining	Dome Hill Mining (NT) Ltd
Duval	Duval Mining (Australia) Ltd
Esso	Esso Australia Ltd *and* Esso Exploration and Production Australia Inc.
Falconbridge	Falconbridge (Australia) Pty Ltd
General Mining	General Mining Corporation Ltd
Golden Eagle	Golden Eagle NL
Goldsworthy	Goldsworthy Mining Limited
Hancock & Wright	Hancock & Wright Prospecting Pty Ltd
Hancock Mining	Hancock Mining Pty Ltd
Haoma	Haoma Mining NL
Hawkstone	Hawkstone Investments Ltd *and* Hawkstone Minerals Ltd
Herald Resources	Herald Resources Ltd
HiTec	HiTec Energy NL
Hunter Resources	Hunter Resources Ltd
Jennings Mining	Jennings Mining Ltd
King Mining	King Mining Corporation Ltd
Kingsway Minerals	Kingsway Minerals NL
Kismet	Kismet Gold Mining NL
Leopold Minerals	Leopold Minerals NL
Longreach Metals	Longreach Metals NL
Lynas	Lynas Gold NL *and* Lynas Corporation Ltd
Mines Administration	Mines Administration Pty Ltd
Miralga Mining	Miralga Mining NL
Mount Newman	Mount Newman Mining Company Pty Ltd
Mount Sydney Manganese	Mount Sydney Manganese Pty Ltd
Narla Minerals	Narla Minerals NL
Newmont	Newmont Pty Ltd
Noranda	Noranda Inc. *and* Noranda Australia Ltd
Outokumpu	Outokumpu Exploration Australia Pty Ltd *and* Outokumpu Zinc Australia Pty Ltd
Pennant Resources	Pennant Resources Ltd
Pennzoil	Pennzoil of Australia Pty Ltd
Pindan	Pindan Pty Ltd
Placer	Placer Prospecting Pty Ltd *and* Placer Exploration Ltd
Portman Mining	Portman Mining Ltd
Preussag	Preussag Australia Pty Ltd
Project Mining	Project Mining Corporation Ltd
Resolute	Resolute Ltd *and* Resolute Resources Ltd
Sentinel Mining	Sentinel Mining Pty Ltd
Serem	Serem (Australia) Pty Ltd

Sipa	Sipa Resources Ltd *and* Sipa Resources International NL
SOG	Sons of Gwalia Ltd
Sovereign Resources	Sovereign Resources Pty Ltd *and* Sovereign Resources (Australia) NL
Stockdale	Stockdale Prospecting Ltd
Valiant Consolidated	Valiant Consolidated Ltd
Welcome Stranger	Welcome Stranger NL
Westfield	Westfield Minerals (WA) NL
Westralian Ores	Westralian Ores Pty Ltd
WMC	Western Mining Corporation Ltd
Woodsreef	Woodsreef Mines Ltd
Zenith	Zenith Mining NL

Regional geology

The east Pilbara area includes predominantly the eastern part of the Archaean–Proterozoic Pilbara Craton. It also includes the northwestern part of the Proterozoic Paterson Orogen, the northeastern part of the Proterozoic Collier Basin, the northernmost tip of the Proterozoic–Phanerozoic Officer Basin, the southeastern part (Lambert Shelf) of the Phanerozoic Northern Carnarvon Basin, and the northwestern part (Wallal Embayment and Platform and Samphire Graben) of the Phanerozoic Canning Basin (Fig. 1). The 1:500 000-scale map showing the regional geology and mineralization (Plate 1) and the digital geological data on the CD-ROM, accompanying this report, are based on the AGSO lithological digital compilation of the east Pilbara (derived from the GSWA 1:250 000 geological maps that were published between 1978 and 1983) and on the recent 1:100 000 geological maps (those published, in press, and in preparation; see **Introduction**). The 1:500 000 geological map Plate 1A of Bulletin 144 (Thorne and Hickman, 1998) has also been used as a source of data. The solid geology interpretation has also been facilitated using aeromagnetic images for the area. The regolith* units were obtained from published GSWA 1:250 000 geological maps (see **Introduction**) and the 1:500 000 map of Thorne and Hickman (1998).

Pilbara Craton

The Pilbara Craton consists of two different tectonic components: an older Archaean granite–greenstone basement, formed between 3.6 and 2.8 Ga, and an unconformably overlying Archaean–Proterozoic volcano-sedimentary supracrustal cover sequence called the Mount Bruce Supergroup, occupying the Hamersley Basin and deposited between c. 2770 Ma and c. 2400 Ma (Trendall, 1990a,b; Griffin, 1990).

Archaean granite–greenstones

The basement of Archaean granite–greenstones in the north Pilbara is characterized by linear to curvilinear greenstone sequences that envelop elongate to ovoid granitoid complexes. Evidence from recent NGMA investigations has shown that the granite–greenstone basement may be divided into five distinct litho-tectonic units, four of which are exposed in the east Pilbara (Fig. 3). From northwest to southeast across the area, these four units are as follows: the Mallina Basin, the East Pilbara Granite–Greenstone Terrane (EPGGT), the Mosquito Creek Basin, and the Kurrana Terrane (KT) (Van Kranendonk et al., in prep.).

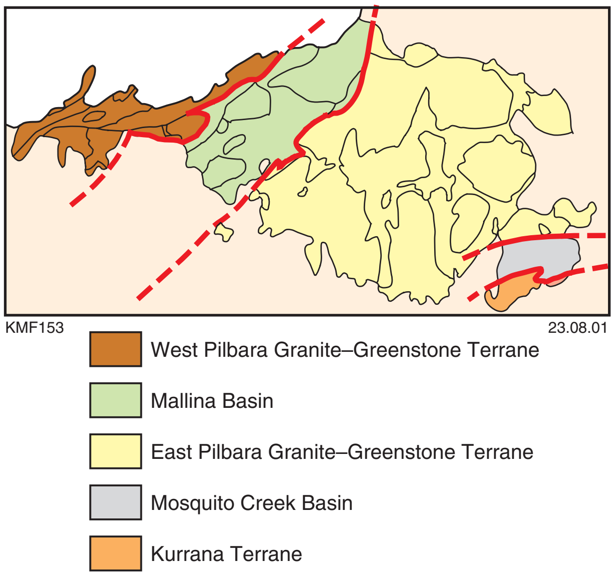


Figure 3. Five main litho-tectonic elements of the granite–greenstone terranes in the north Pilbara Craton

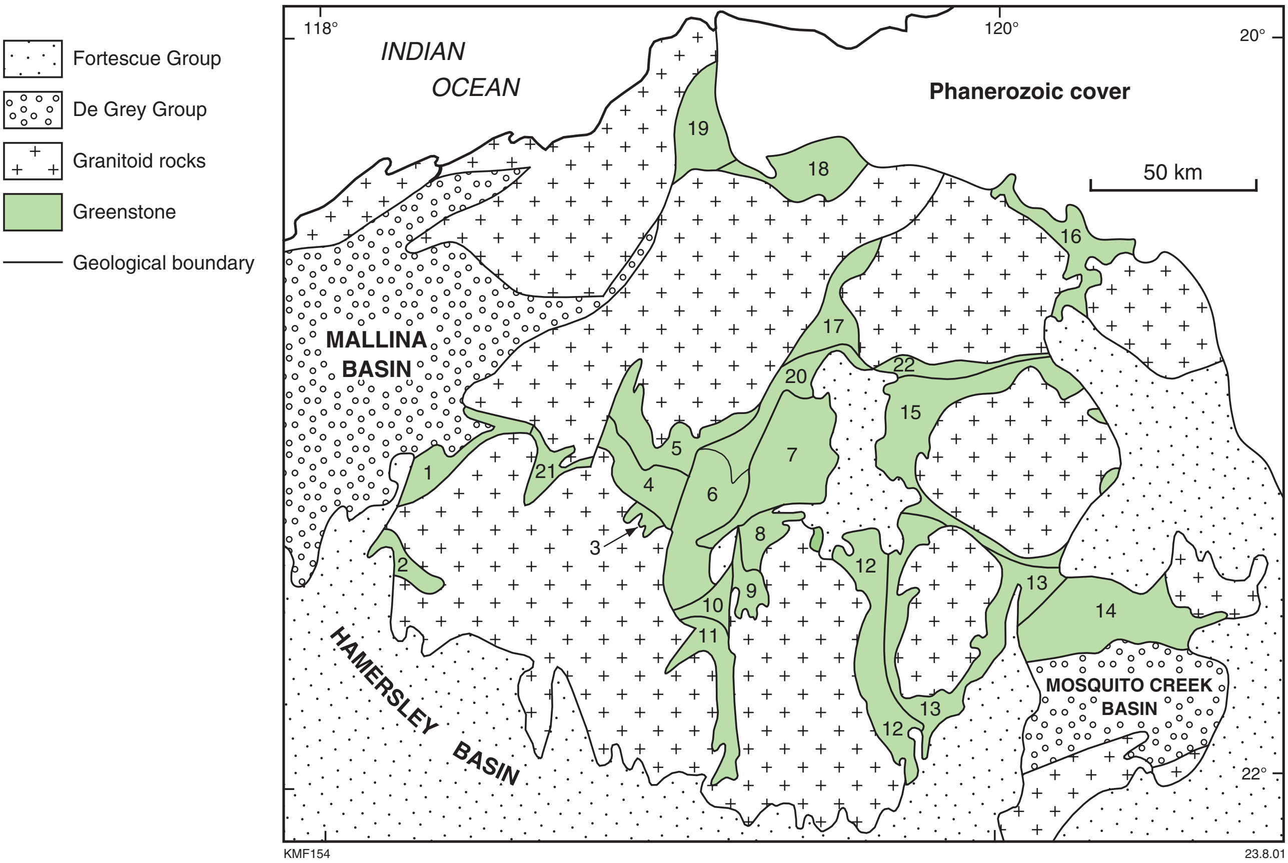
Greenstone sequences

The greenstones are assigned to the Pilbara Supergroup (Hickman, 1983) and include metamorphosed mafic to ultramafic volcanic rocks, felsic to intermediate volcanic rocks, clastic sedimentary rocks, chert, banded iron-formation, and sills of mafic to ultramafic intrusive rocks. The distribution of greenstone sequences and the names of the greenstone belts are shown on Figure 4. The stratigraphy of the Archaean greenstone sequences of the area is shown in Table 1*.

In the Mallina Basin the Archaean sequence consists of clastic sedimentary rocks assigned to one group within the Pilbara Supergroup: the De Grey Group. In the East Pilbara Granite–Greenstone Terrane (EPGGT) the Pilbara Supergroup is divided into five volcano-sedimentary groups and two formations (Van Kranendonk, et al., in prep.). In order of oldest to youngest these are: the Coonterunah Group, the Warrawoona Group, the Wyman Formation, the Sulphur Springs Group, the Gorge Creek Group, and the De Grey Group; the undated Golden Cockatoo Formation occurs in greenstone enclaves within the Yule Granitoid Complex. In the two litho-tectonic elements to the southeast of the EPGGT, results from the NGMA program are incomplete and there is uncertainty

* Regolith components on the 1:500 000-scale map (Plate 1) are shown only as three types of overprint: depositional regolith, relict regolith, and ‘Poondano Formation’ pisolite, whereas on the CD-ROM the regolith components are the several Cainozoic units shown on the 1:500 000-scale geological map of Thorne and Hickman (1998)

* Table 1 shows stratigraphic units and map codes as they appear on the 1:100 000-scale maps used to compile Plate 1, but on the 1:500 000-scale map (Plate 1) and on the solid geology in the digital dataset these stratigraphic units and map codes have been modified to provide an abbreviated map legend that is appropriate for the smaller map scale



1. Pilbara greenstone belt
2. Cheeara greenstone belt
3. Abydos greenstone belt
4. Pincunah greenstone belt
5. East Strelley greenstone belt
6. Soanesville greenstone belt
7. Panorama greenstone belt
8. North Shaw greenstone belt
9. Emerald mine complex
10. Tambina complex
11. Western Shaw greenstone belt
12. Coongan greenstone belt
13. Kelly greenstone belt
14. McPhee–Elsie greenstone belt
15. Marble Bar greenstone belt
16. Shay Gap greenstone belt
17. Warralong greenstone belt
18. Goldsworthy greenstone belt
19. Ord Range greenstone belt
20. Lalla Rookh greenstone belt
21. Wodgina greenstone belt
22. Doolena Gap greenstone belt

Figure 4. Distribution of Archaean greenstone belts in the east Pilbara (after Van Kranendonk et al., in prep.)

about the ages of the greenstone units. The Mosquito Creek Basin contains clastic sedimentary rocks assigned to the undated Mosquito Creek Formation. Southeast of this basin the Kurrana Terrane consists mainly of granitoid rocks that contain xenoliths of metamorphosed sedimentary, mafic, and ultramafic rocks.

The Archaean sequences of the various greenstone belts in the east Pilbara are described in Geological Survey publications by Hickman (1978, 1983), Griffin (1990), Hickman and Lipple (1978), Hickman and Gibson (1982), Hickman et al. (1983), Williams (1999a,b, in prep.), Van Kranendonk (2000, in prep.). A review of the most recent data on the greenstone sequences is provided by Van Kranendonk et al. (in prep.).

The greenstone sequences have also been the subject of numerous research publications relating to their stratigraphy, sedimentology, petrology, structure, geochemistry, and geochronology. Stratigraphy, sedimentology, petrology, and structure have been discussed by Barley (1993, 1997), Barley et al. (1979), Buick and Dunlop (1990), Buick and Barnes (1984), DiMarco and Lowe (1989a,b,c), Eriksson (1981), Eriksson et al. (1994), Hofmann et al. (1999), Horwitz (1987, 1990a), Krapez (1984, 1993), Wilhelmij and Dunlop (1984), Zegers et al. (1996, 1998, 1999), Nijman et al. (1998a,b). Geochemistry of the greenstones has been investigated by Cullers et al. (1993), Glikson and Hickman (1981a,b), Glikson et al. (1986, 1991). Geochronological studies have been carried out by McNaughton et al. (1993), Nelson (1998, 1999, 2000, in press), Pidgeon (1978, 1984), Richards et al. (1981), Collins and Gray (1990), Williams and Collins (1990), and Thorpe et al. (1992a,b). In addition, there have been a number of publications relating to mineralization in the greenstone sequences and these are referred to later in the section on **Mineralization**.

Granitoid complexes and other granitoid bodies

The granitoid complexes in the east Pilbara area are large, domal, composite bodies that consist of syntectonic granitoid intrusions, gneissic granitoid, and migmatite;

Table 1. Stratigraphy of Archaean Pilbara Supergroup in the east Pilbara

Group/Formation	*Rock code*[(a)]	*General thickness (m)*	*Lithology and relationships*
De Grey Group (<3048–2941 Ma)[(b)]			
Cooragoora Formation	*ADa*	2 000	Interbedded red-purple and red-brown coarse- to medium-grained sandstone, conglomerate, shale, siltstone, and grey-brown wacke
Cattle Well Formation	*ADo*	2 500	Thinly bedded medium- to coarse-grained sandstone, feldspathic sandstone, and wacke; interbeds of siltstone and shale; minor carbonate and calcareous shale
Lalla Rookh Sandstone	*ADl*	0–5 000	Conglomerate, sandstone, minor shale
Mosquito Creek Formation	*ADq*	>5 000	Psammitic, psammopelitic, and pelitic rocks with minor conglomerate
Mallina Formation	*ADm*	>5 000	Interbedded shale, siltstone, and medium- to fine-grained wacke, minor chert; minor basalt and high-Mg basalt interflows; minor interbeds of quartz–feldspar porphyry
Constantine Sandstone	*ADc*	1 300–3 500	Poorly sorted coarse- to fine-grained subarkose and wacke, ferruginous clastic sedimentary rocks
Whim Creek Group	(*AC*)		Felsic volcanic and sedimentary rocks (interpreted from aeromagnetic data). Age c. 3009 Ma
Dalton Suite	*AaL*	0–200	Layered mafic and ultramafic sills intruding Gorge Creek and Sulphur Springs Groups and the Strelley Granite. Age c. 3070 Ma
Gorge Creek Group (interpreted date c. 3235–3000 Ma)[(b)]			
Coonieena Basalt	*AGo*	1 500	Massive and pillowed tholeiitic basalt, silicified basaltic andesite, with minor high-Mg basalt
Cundaline Formation	*AGu*	1 000	Shale, siltstone, sandstone, immature pebbly sandstone and conglomerate, and wacke
Nimingarra Iron Formation	*AGn*	400–1 000	BIF, banded and ferruginous chert, black (pyritic) shale, mudstone
Pyramid Hill Formation	*AGy*	1 000	Shale and BIF
Honeyeater Basalt	*AGh*	0–1 000	Pillowed tholeiitic basalt and minor high-Mg basalt. Intruded by dolerite and gabbro sills
Cleaverville Formation	*AGl*	1 000	Banded iron-formation, chert, fine-grained clastic sedimentary rocks
Unassigned formation			
Charteris Basalt[(c)]		0–1 000	Pillow basalt and minor high-Mg basalt. Intruded by dolerite and gabbro sills
Soanesville Subgroup			
Paddy Market Formation	*AGp*	500–1 000	Banded chert, iron formation, ferruginous clastic sedimentary rocks, quartzite, felsic volcanic rocks
Corboy Formation	*AGc*	500–1 000	Banded chert, iron formation, ferruginous clastic sedimentary rocks, quartzite, felsic volcanic rocks
Pincunah Hill Formation	*AGi*	0–1 200	Banded chert, iron formation, ferruginous clastic sedimentary rocks, quartzite, felsic volcanic rocks
Sulphur Springs Group (c. 3255–3235 Ma)			
Kangaroo Caves Formation	*Asc*	1 700	Differentiated volcanic–volcaniclastic pile of a mainly tholeiitic sequence of basalt to rhyolite, with comagmatic granitoid. Local chert, polymictic megabreccia, and iron formation
Kunagunarinna Formation	*Ask*	3 000	Pillow basalt, komatiite, high Mg basalt, and chert
Leilira Formation	*Asl*	200–3 900	Wacke and intercalated rhyolite, sandstone, mudstone, chert
Unassigned formations			
Golden Cockatoo Formation	*Aj*	2 000	Cherty silicate-facies iron formation, rhyolite, quartzite, and interbedded pelite
Wyman Formation	*Aw*	1 000	Rhyolite, felsic pyroclastic rocks and debris-flow deposits; local chert and basalt. Age c. 3325 Ma

Table 1. (continued)

Group/Formation	*Rock code[(a)]*	*General thickness (m)*	*Lithology and relationships*
Warrawoona Group (c. 3480– 3340 Ma)			
Salgash Subgroup			
Euro Basalt	*Awe*	2 000–8 000	Pillow basalt, tholeiitic basalt, chert, with peridotitic komatiite and high-Mg basalt. Intruded by sills of dolerite and gabbro
Strelley Pool Chert	*Aws*	0–100	Laminated chert; silicified siliciclastic and chemical sedimentary rocks; stromatolites
Panorama Formation	*Awp*	0–1 000	Felsic lavas, tuffs, agglomerate, chert, and tuffaceous sedimentary rocks
Apex Basalt	*Awa*	2 000	Tholeiitic pillow basalt, high-Mg basalt, peridotitic komatiite, grey and white layered chert. Intruded by sills of dolerite, gabbro, and rare ultramafic rocks
Talga Talga Subgroup			
Duffer Formation	*Awd*	0–8 000	Dacitic tuff, lava, and agglomerate, with subordinate rhyolite, basalt, and chert, intruded by felsic porphyry
Dresser Formation	*Awr*	0–1 500	Blue, black, and white layered chert, barite, carbonate, and mafic volcanic rocks; stromatolites
Mount Ada Basalt	*Awm*	2 000–2 500	Massive basalt, pillow basalt, and chert. Intruded by dolerite sills
McPhee Formation	*Awh*	50–200	Talc–chlorite schist and talc–carbonate schist, chert, BIF, basalt, pelite
North Star Basalt	*Awn*	2 000	Massive basalt and pillow basalt. Intruded by numerous sills of dolerite and gabbro
Coonterunah Group (c. 3515 Ma)			
Double Bar Formation	*Aod*	2 000	Basalts and volcanogenic sedimentary rocks
Coucal Formation	*Aoc*	1 000	Mafic and felsic volcanic rocks, chert, carbonate rocks, BIF
Table Top Formation	*Aot*	2 500	Basalt, local komatiitic basalt
~~ *?Terrane boundary or ?tectonic boundary* ~~~~~~~~~~			
?Granitoid crustal basement to Pilbara greenstone sequences			

NOTES: (a) Table 1 shows stratigraphic units and rock codes as they appear on 1:100 000-scale geological maps, but on the 1:500 000-scale map (Plate 1) and on the solid geology in the digital dataset these stratigraphic units and rock codes have been modified to provide an abbreviated map legend that is appropriate for the smaller map scale
(b) Final stratigraphic positions of various formations within the De Grey and Gorge Creek Groups are yet to be determined
(c) Stratigraphic position of Charteris Basalt uncertain; no longer assigned to Soanesville Subgroup. Rock code not yet assigned

SOURCE: modified from Van Kranendonk et al. (in prep.)

some complexes contain enclaves of metamorphosed greenstones or layered mafic–ultramafic bodies (Fig. 5). The various components of the complexes are of different ages and they have been interpreted to explain the gradual development of the complexes during the evolution of the Pilbara Craton (Van Kranendonk et al., in prep.). Other granitoid bodies occur as discrete intrusions within greenstone belts: North Pole Monzogranite, Strelley Granite, and Keep It Dark Monzogranite. The granitoid complexes and granitoid bodies are listed in Table 2, in the order of decreasing isotopic age of the oldest granitoid component (also listed are the map codes shown on Plate 1 and in the digital dataset).

Data from geochronological and field studies show that, within the complexes, the older components are generally distributed along the margins while successively younger components occupy the cores of progressively dilating domes (Van Kranendonk et al., in prep.). Other studies show that plutonic phases in some of the complexes coincide with episodes of felsic volcanism in nearby greenstone sequences (Williams and Collins, 1990; Thorpe et al., 1992a; Barley and Pickard, 1999; Brauhart, 1999).

Over the last 25 years, a number of detailed geochemical–petrological studies and structural–metamorphic studies have been undertaken on selected granitoid complexes and plutons in the east Pilbara (Bettenay et al., 1981; Bickle et al., 1983, 1985, 1989, 1993; Champion and Smithies, 2000; Collins, 1983, 1989; Collins and Gray, 1990; Davy and Lewis, 1986; Davy, 1988; Oversby, 1976). Mineralization studies related to a number of granitoid bodies were carried out by Blockley (1980); Barley (1982); and Jones (1990). Hickman (1983) and Griffin (1990) have also provided accounts of the complexes and plutons. As part of the NGMA program, geochronological studies are being undertaken on almost

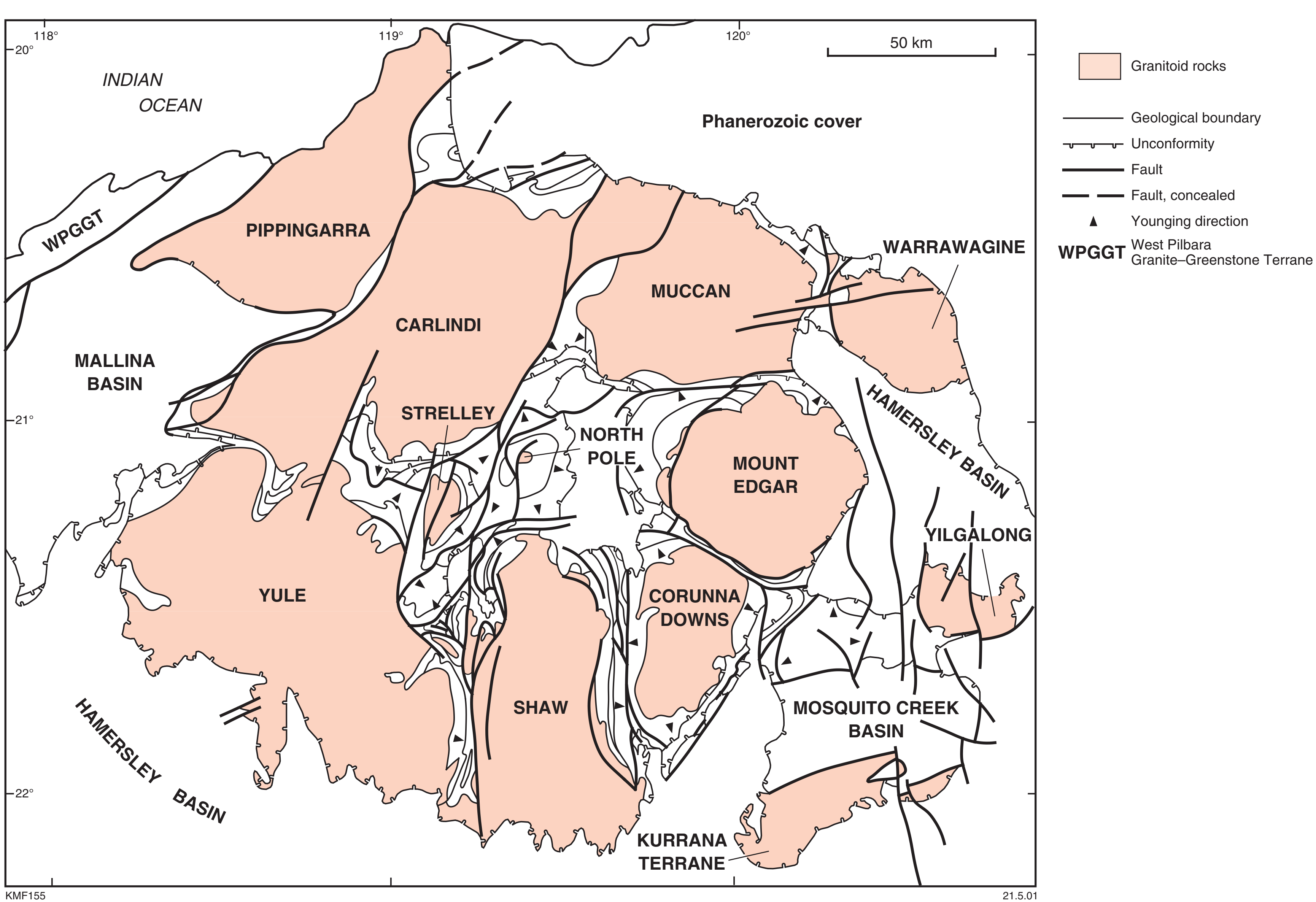


Figure 5. Distribution of Archaean granitoid complexes and granitoid plutons in the east Pilbara (after Van Kranendonk et al., in prep.)

Table 2. Archaean granitoid complexes and granitoids of the east Pilbara area, showing relationships of younger (2950–2830 Ma) granitoids associated with tin–tantalum mineralization

Granitoid Complex or granitoid (rock code)	*Granitoid associated with tin–tantalum mineralization (rock code)*	*Age (reference)*
Cookes Creek Granite (*Agco*)		no data
Pippingarra Granitoid Complex (*AgI*)	General code (*AgIsn*[a]) includes:	2955–2928 Ma
	Myanna Leucogranite (*AgImy*[b])	no data
	Thelman Monzogranite (*AgIth*[b])	no data
	Tabba Tabba Leucogranite (*AgItt*[b])	no data
Keep It Dark Monzogranite (*Agki*)		2936 ± 5 Ma (Van Kranendonk, 2000)
Strelley Granite (*Agst*)		3238 ± 2 Ma (Brauhart, 1999)
Corunna Downs Granitoid Complex (*AgO*)		3317–3307 Ma
Gobbos Granodiorite (*Aggo*)		3314 ± 4 Ma
Yilgalong Granitoid Complex (*AgA*)		no data
Kurrana Granitoid Complex (*AgK*)		c. 3300 Ma (unpublished)
Yule Granitoid Complex (*AgY*)	General code (*AgYsn*[a]) includes:	3470–2927 Ma
	Numbana Monzogranite (*AgYnu*[b])	post-2930 Ma (Blewett et al., 2001)
Mount Edgar Granitoid Complex (*AgE*)	General code (*AgEsn*) includes:	3466–2830 Ma
	Moolyella Monzogranite (*AgEmo*[b])	2830 ± 30 Ma (Pidgeon, 1978)
Tambina Granitoid Complex (*AgT*)		no data
Muccan Granitoid Complex (*AgM*)		3470–3244 Ma
North Pole Monzogranite (*Agno*)		3459 ± 18 Ma (Thorpe et al., 1992a)
Shaw Granitoid Complex (*AgS*)	General code (*AgSsn*[a]) includes:	3493–2851 Ma
	Cooglegong Monzogranite (*AgScg*[b])	2851 ± 2 Ma (Nelson, 1998)
	Spear Hill Monzogranite (*AgSsh*[b])	2851 ± 2 Ma (Nelson, 1998)
	Coondina Monzogranite (*AgSco*[b])	no data
Carlindi Granitoid Complex (*AgL*)	General code (*AgLsn*[a]) includes:	3484–2941 Ma
	Kadgewarrina Monzogranite (*AgLkd*[b])	no data
	Poocatche Monzogranite (*AgLpo*[b])	no data
	Minnamonica Monzogranite (*AgLmq*[b])	no data
Warrawagine Granitoid Complex (*AgW*)		3655–3242 Ma

NOTES: (a) General code is used on Plates 1 and 1A accompanying this report
(b) Rock codes for individual granitoids, as shown on Geological Survey of Western Australia Geological Series maps

all of the granitoid units in the north Pilbara (Nelson, 1996, 1997, 1998, 1999, 2000, in press).

Structure and tectonic evolution

A complete new regional synthesis for all of the granite–greenstone basement in the north Pilbara will not be available until the former NGMA has been finalized. However, results obtained to date from the current GSWA–AGSO detailed 1:100 000 geological mapping and geochronological studies in the granite–greenstones have enabled the GSWA to make new correlations of rock units and to propose new interpretations of the stratigraphy, structure, and tectonic evolution (Hickman, 1997; Smithies, 1996, 1997; Smithies et al., 1999; Nelson, 1996, 1997, 1998, 1999, 2000; Van Kranendonk, 1998; Van Kranendonk and Morant, 1998; Van Kranendonk et al., in prep; Hickman et al., 2000).

In the EPGGT the most conspicuous structures are broad domal granitoid complexes separated by narrow synformal greenstone belts (Figs 4 and 5). Hickman (1983) and Hickman et al. (1990) proposed a model of continuous lithostratigraphy in the greenstones, with lateral continuity across the north Pilbara, in which the dominant structures were produced by multi-stage granitoid diapirism. Hickman (1983) also postulated that the diapirism was due to gravity deformation in the upper crust, as a response to a thick layer of high density mafic rocks (the basal sequences of the Pilbara Supergroup) accumulating over a low density layer of granitic crust.

However, alternative models have challenged Hickman's concept of lateral stratigraphic continuity and proposed that the granite–greenstones may instead represent separate tectono-stratigraphic domains formed in different geotectonic settings with each of the domains being separated by northeasterly trending lineaments (Krapez and Barley, 1987; Krapez, 1993; Krapez and Eisenlohr, 1998; Horwitz, 1990b; Barley et al., 1992; Barley, 1997; Eriksson et al., 1994). These alternative models assume that modern plate-tectonic processes (subduction, arc-accretion and strike-slip pull-apart extensional processes) have operated in the evolution of the granite–greenstone basement from c. 3500 Ma and that the major lineaments (faults) represented large-scale crustal features with a long history of development and reactivation.

Detailed mapping and geochronology results from the NGMA program have provided a large amount of new information that does not support these alternative models to granitoid diapirism (Smithies et al., 1999; Van Kranendonk et al., in prep.). In the most recent interpretation, using NGMA results, Van Kranendonk et al. (in prep.) suggested that in the EPGGT the most persuasive evidence supporting the granitoid diapirism model is the regional map pattern and the field relationships of greenstone sequences and granitoid complexes, which show domal granitoid complexes being flanked by circular tracts of greenstones that have been affected by contact metamorphism. This map pattern is also emphasized by the distribution of the Fortescue Group, which forms in synclinal outliers preserved over older synclines in greenstone belts between the granitoid domes. These authors also suggested that the diapir hypothesis is supported by the autochthonous nature of successive greenstone groups that formed in progressively deepening synclines and by the repeated intrusion of successively younger phases of granitoids into the cores of progressively evolving granitoid domes.

Van Kranendonk et al. (in prep.) proposed that the dome-and-basin (or dome-and-keel) architecture in the east Pilbara developed during periods of coeval granitoid plutonism and felsic volcanism in adjacent greenstone belts, at punctuated intervals during the evolution of the EPGGT. The intervals proposed are the distinct episodes recognized by Collins et al. (1998) at c. 3450 Ma, 3310 Ma, 3240 Ma, and 2930 Ma in the EPGGT, and a further episode in the Fortescue Group at c. 2760 Ma. The proposed mechanism for driving this diapiric process is partial convective overturn between relatively dense upper crustal mafic greenstone sequences and a buoyant, partially melted, mid-crustal felsic sill complex of synvolcanic sodic granitoids (Collins et al., 1998; Van Kranendonk et al., in prep.): this is a similar mechanism to that proposed by Hickman (1983).

It is proposed that the diapiric process was initiated after c. 3400 Ma when the gravitationally stable crustal configuration of the lower part of the Warrawoona Group was destabilized. This was caused by the eruption of enormous volumes of mafic magma that produced up to 9 km stratigraphic thickness of basaltic rocks of the Euro Basalt. As a consequence, there was partial remelting of a mid-crustal tonalite–trondhjemite–granodiorite (TTG) sill complex, augmented by the probable addition of conductive heat from below (?from underplated magmas). The resulting granitic melts then ascended through the upper crust via pre-existing positive perturbations in the TTG sill complex. These perturbations are proposed to have been initiated, prior to c. 3400 Ma, as point sources of felsic magma generation between c. 3510 Ma and 3430 Ma that produced felsic volcanism and subvolcanic laccoliths and domes in the upper crust (Collins et al., 1998; Van Kranendonk et al., in prep.).

Deformation events reflect the punctuated intervals of dome-and-basin evolution proposed above. The earliest recognized structures (representing a period of development prior to the main diapiric events) occurred at c. 3490–3410 Ma and are broadly grouped together as D_1. They are associated with the development of the initial subvolcanic laccoliths and domes, and include synvolcanic listric growth faults, tilting of sequences away from the cores of domes, and local folds formed by gravitational sliding off rising domes. Other D_1 structures include the earliest gneissic fabrics and isoclinal folding seen in zones of protoliths in granitoid complexes: e.g. in migmatites, banded gneisses, and greenstone xenoliths.

In the EPGGT there are two main deformation episodes, D_2 and D_3, which are related to periods of major diapiric emplacement of granitoid material in the dilating granitoid complexes. D_2 occurred in the eastern part of the EPGGT and accompanied deposition of the felsic volcanic Wyman Formation and intrusions of related granitoid plutonism at c. 3325–3308 Ma, particularly in the Mount Edgar and Corunna Downs Granitoid complexes. Collins (1989), Collins et al. (1998), and Van Kranendonk et al. (in prep.) described and discussed a number of D_2 structures that demonstrate deformation due to diapirism.

D_3 occurred in the western part of the EPGGT during eruption of the Sulphur Springs Group and widespread granitoid intrusion at c. 3240 Ma, in particular the Strelley Granite (in the Soanesville belt) and granite intrusion in the northeastern part of the Yule Granitoid Complex with similar deformation structures to those of D_2 (Van Kranendonk et al., in prep.).

There is new geochronological evidence to indicate that the EPGGT and the WPGGT were juxtaposed and 'stitched together' at c. 3020 Ma, when the Cleaverville Formation of the Gorge Creek Group was deposited across the EPGGT and the WPGGT, and that the two terranes acted as a coherent unit thereafter (Smithies et al., 2001).

Deformation in the EPGGT during D_4 is related to a period of major northwest–southeast compression at c. 2940 Ma. This produced the northerly to north-northeasterly trending Lalla Rookh – Western Shaw Structural Corridor, with accompanying deposition of coarse clastic sedimentary rocks of the De Grey Group, and a northeasterly trending foliation in the Yule and Shaw Granitoid Complexes (Van Kranendonk and Collins, 1998; Van Kranendonk et al., in prep.).

D_5 deformation affected the northwestern part of the EPGGT at c. 2890 Ma and produced sinistral shearing along north-northeasterly striking zones (Neumayer et al., 1993).

Deformation of the EPGGT was largely completed by c. 2850 Ma when the undeformed tin-bearing granitoids were emplaced into the cores of a number of granitoid complexes (Hickman, 1983; Nelson, 1998; Kinny, P. D., 2001, written communication). However, Van Kranendonk et al. (in prep.) proposed that there was a later component of granitoid doming (D_6) at c. 2750 Ma that is recorded in the deposition of the lower part of the Fortescue Group.

The Mallina Basin is considered to have developed at c. 3010–2940 Ma during a period of intracontinental extension located at the boundary between the EPGGT and the WPGGT. Supracrustal rocks of the basin include a volcanic rift–margin succession of the Whim Creek greenstone belt in the northwestern part of the basin that developed at c. 3010–2975 Ma (Van Kranendonk et al., in prep.). This succession is in the west Pilbara area (Ruddock, 1999). Siliciclastic and turbiditic rocks of the De Grey Group predominate in the eastern two thirds of the basin and were deposited at c. 2970–2940 Ma (Van Kranendonk et al., in prep.). The eastern extension of this turbiditic sequence is in the western part of the east Pilbara project area.

During the evolution of the basin, deformation took place in response to three contractional events, with a period of extension separating the second and third events (Van Kranendonk et al., in prep.). This period of extension is thought to reflect reactivation of early basin-developing faults within the basement (Smithies et al., 1999) to produce numerous east-northeasterly trending shear zones. The largest of these shears is the Mallina Shear Zone, which extends into the east Pilbara area as the Tabba Tabba Shear Zone (Van Kranendonk et al., in prep.).

The Mosquito Creek Basin is preserved as an easterly striking, linear fold–thrust belt of turbiditic metasedimentary rocks with thrust contacts on both its northern and southern edges. This deformation geometry is quite different to that of the dome-and-basin geometry of the EPGGT and it appears that the basin developed after c. 3020 Ma (Van Kranendonk et al., in prep.). Along the northern margin of the basin, the metasedimentary rocks are intruded by an ultramafic sill that may be of similar age (c. 2925 Ma) to the layered intrusions of the west Pilbara.

The Kurrana Terrane consists predominantly of granitoid bodies and appears to represent a separate crustal fragment that is distinct from the EPGGT (Tyler et al., 1992).

Hamersley Basin (late Archaean – Palaeoproterozoic)

The volcanic and sedimentary rocks of the Hamersley Basin unconformably overlie the basement of granite–greenstone terranes. The rocks in the basin are assigned to three groups, in ascending order, the Fortescue, Hamersley, and Turee Creek Groups, which are collectively known as the Mount Bruce Supergroup (Trendall, 1990b). The Turee Creek Group is not present in the east Pilbara area. Included within the Mount Bruce Supergroup is the Gregory Granitic Complex, now known to be the same age as the lower part of the Hardey Formation in the Fortescue Group (Trendall, 1991; Williams and Trendall, 1998a).

Geochronological data indicate that basin development occurred between the late Archaean and the Palaeoproterozoic, with the arbitrary boundary between the two eras, at 2500 Ma, located in the lower part of the Brockman Iron Formation of the Hamersley Group (Trendall, 1990b). Blake (1993) proposed a sequence stratigraphy for the Mount Bruce Supergroup and used this in a discussion of a crustal extension model for the Pilbara Craton.

Gregory Granitic Complex (Archaean)

In the east of the area the Gregory Granitic Complex and the Fortescue Group form the Gregory Range Inlier (Trendall, 1991; Williams and Trendall, 1998a,b,c; Thorne and Trendall, 2001). In addition, banded iron-formation (BIF) assigned to the Gorge Creek Group is exposed in a small area around Mount Cecelia in the northwestern part of the inlier (Williams and Trendall, 1998a,b). The inlier marks the eastern margin of the Pilbara Craton and occurs as a north-northwesterly trending belt about 160 km long and 30 km wide.

The Gregory Granitic Complex occupies much of the eastern side of the inlier and has four major components. These components are: medium- to coarse-grained syenogranite or alkali granite (ranging from leucocratic to mafic-rich varieties); granophyre; porphyritic to seriate syenogranite; and equigranular, fine-grained to microporphyritic granitoid rock. Enclaves of schistose metasedimentary rocks occur within the complex. These may be remnants of older Archaean greenstone belts of the Pilbara Craton (Williams and Trendall, 1998a,b,c).

From the evidence of geochemical and geochronological data, the Gregory Granitic Complex is considered to be comagmatic with the felsic rocks of the Koongaling Volcanic Member of the Hardey Formation of the Fortescue Group (Trendall, 1991; Williams and Trendall, 1998a,b,c; Thorne and Trendall, 2001). It is coeval with felsic volcanic rocks of the Bamboo Creek Member, east of Bamboo Creek (Williams, 1999a).

Fortescue Group (late Archaean)

The Fortescue Group forms outliers over substantial parts of the south-central and eastern parts of the area. The group consists of mafic lavas (flood basalts and basaltic andesites) and subordinate intermediate to felsic lavas and tuffs, mafic intrusive rocks, and siliciclastic and carbonate sedimentary rocks. Trendall (1990b) and Thorne and Trendall (2001) have proposed a six-fold subdivision of the succession into lower, middle, and upper volcanic and sedimentary units. These are listed below, in ascending order, together with map symbols that appear on Plate 1 and in the digital dataset. The proposed sequence stratigraphy of Blake (1993) is also listed for comparison.

Symbol	*Formation/unit (Thorne and Trendall, 2001)*	*Sequence stratigraphy (Blake, 1993)*
AFr	Mount Roe Basalt (c. 2770 Ma)	Nullagine Supersequence
AFh	Hardey Formation	Nullagine Supersequence
AFk	Kylena Formation	Mount Jope Supersequence
AFt	Tumbiana Formation	Mount Jope Supersequence
AFm	Maddina Formation	Mount Jope Supersequence
AFj	Jeerinah Formation (c. 2680–2630 Ma)	Marra Mamba Supersequence

The lower Fortescue Group rocks (Mount Roe Basalt and Hardey Formation) were deposited on the basement of granite–greenstone terranes within three north-northeasterly trending sedimentary basins, known as the west Pilbara, the Marble Bar, and the east Pilbara basins (Blake, 1984). The basins were initiated under a regional tensional regime that produced north-northeasterly trending tensional fractures. In the east Pilbara area Blake (1984) recognized the Marble Bar Basin and the East Pilbara Basin; the latter basin he subdivided into the Bamboo Creek, Meentheena, and Nullagine Sub-basins. Blake (1993) further proposed a sequence stratigraphic framework for the Fortescue Group, in which the Mount Roe Basalt and Hardey Formation are included in the Nullagine Supersequence and the Kylena, Tumbiana, and Maddina Formations are included in the Mount Jope Supersequence. The Jeerinah Formation was included in the Marra Mamba Supersequence with the lower part of the Hamersley Group.

Fortescue Group rocks occur in the east in the Gregory Range Inlier, where they are cut by numerous faults subparallel to the north-northwesterly trend of its long axis. Trendall (1991) identified a number of these as main faults that divided Fortescue Group rocks into tectonically discrete elongate belts or 'slices'.

Hamersley Group (late Archaean – Palaeoproterozoic)

The Hamersley Group overlies the Fortescue Group in the east of the area, along the broad valley of the Oakover River, where it is represented solely by the Carawine Dolomite (*AHc*).

Carawine Dolomite (*AHc*)

This carbonate unit rests disconformably on the Jeerinah Formation. Recent research indicates that the dolomite formed in a shallow-water platform environment in the eastern part of the Hamersley Basin (Simonson et al., 1993). The unit is characterized by the development of abundant stromatolites, oncolites, and wave ripples, with local evaporitic crystal pseudomorphs and oolitic to pisolitic textures. Correlation of this dolomite with the Wittenoom Dolomite to the southwest of the region (central part of the Hamersley Basin) has been discussed by Williams and Trendall (1998a) who concluded from isotopic age evidence that there was very little difference between the ages of the two dolomite units: Pb–Pb age of 2541 ± 32 Ma for the Carawine Dolomite (Jahn and Simonson, 1995) and SHRIMP zircon age of 2560 ± 5 Ma for part of the Wittenoom Dolomite (Williams and Trendall, 1998a).

Pinjian Chert Breccia (*Ᵽcb*)

The Pinjian Chert Breccia (Noldart and Wyatt, 1962) unconformably overlies (and replaces) the Carawine Dolomite and forms extensive outcrops in the valleys of the Oakover River and Davis River. The breccia is included as the uppermost unit in the Mount Bruce Supergroup (Williams and Trendall, 1998a,b,c) and it consists of randomly mixed angular fragments of chert and banded chert that are chaotically or poorly bedded. In places the siliceous matrix is enriched in manganese and iron oxides.

The formation of the chert breccia is related to karst processes, probably occurring first in the early Palaeoproterozoic, with further modifications in the middle Cainozoic. Its origin is discussed in detail by Williams (1989) and Williams and Trendall (1998a,b).

Mafic dyke swarms

Archaean to Neoproterozoic mafic dyke swarms intrude rocks of the Pilbara Craton, and Tyler (1990) has recognized three main groups: those that pre-date deformation of the greenstone belts; those that post-date deformation of the greenstone belts, but pre-date development of the Hamersley Basin (e.g. Black Range Suite); and those that developed during and after the Capricorn Orogeny (c. 1830 to 1780 Ma). At least ten separate swarms may be distinguished.

Felsic and mafic intrusions

Hickman (1983) recognized a number of small plutons and dykes of hornblende monzogranite and hornblende porphyry that intrude Archaean granite–greenstones and the Fortescue Group. The intrusions lie along a north-northwesterly trending belt about 140 km long and 25 km wide in the eastern part of the EPGGT. The largest of these is the Bridget Adamellite (Hickman, 1978) in the Mosquito Creek Basin. Small plutons and dykes in the Bamboo Creek area are described by Williams (1999a). The rocks have also been studied by Rock and Barley (1988), who referred to them as monzonites, quartz monzonites, and calc-alkaline lamprophyres, and suggested an approximate age for the rocks as 1700–1800 Ma. These authors also considered that the rocks represent a widespread intrusive phase in the Pilbara (see **Kimberlite and lamprophyre dykes**).

Kimberlite and lamprophyre dykes

A relatively prominent airphoto feature, known as the Brockman Dyke (cutting the Mount Edgar Granitoid Complex and Corunna Downs Granitoid Complex), has recently been identified as kimberlitic and found to be diamondiferous (Haoma Mining NL, 1999). The dyke trends east-northeasterly and offsets dykes belonging to the northeasterly trending Black Range suite. Other possible kimberlite intrusions were previously identified in Fortescue Group rocks just to the west of Nullagine (Blake and Chalmers, 1994).

Occurrences of lamprophyre dykes associated with granitoids in the east Pilbara were reappraised by Rock and Barley (1988) and Bettenay et al. (1990) who suggested that these were more widespread than previously understood (many minor intrusives had previously been recorded as other types of mafic or intermediate igneous rocks). They proposed that the lamprophyre suites may represent a significant phase of magmatism during the evolution of the Pilbara Craton that may have influenced episodes of mineralization.

Collier Basin

The northernmost tip of the eastern part of the Collier Basin occupies a very small area in the far southeast of the region, where it is represented by rocks of the Manganese Group of the Bangemall Supergroup. The Manganese Group is probably equivalent to the c. 1200–1070 Ma Collier Group (Grey et al., in prep.).

Manganese Group (Mesoproterozoic)(ᵽMN)

Woblegun Formation

This formation consists mainly of fine-grained clastic units: shale, mudstone, and fine-grained sandstone. These units are locally interbedded with minor coarse-grained sandstone and conglomerate units; chert beds with possible gypsum casts also occur. In one locality there is a stratiform sedimentary-hosted barite unit interbedded with thin beds of mudstone and dolomite. At another locality there is a thick unit of stromatolitic dolomite characterized by large columnar and domical stromatolites (Williams and Trendall, 1998c).

Davis Dolerite

The Davis Dolerite (*ᵽdd*) intrudes the Woblegun Formation and has a high titano-magnetite content, which produces a strong aeromagnetic signature.

Paterson Orogen

The Paterson Orogen forms a belt of folded and metamorphosed Palaeoproterozoic and Neoproterozoic sedimentary and igneous rocks that have a common tectonic history (Williams and Myers, 1990). The belt is highlighted by the Warri gravity ridge that extends 2000 km from the east Pilbara to central Australia, and probably formed during the Paterson and Petermann Ranges Orogenies around 550 Ma. In the east Pilbara area, the orogen is represented by rocks of the Yeneena Supergroup and the Tarcunyah Group that have been thrust against the eastern margin of the Pilbara Craton during multiple episodes of tectonic activity until the c. 550 Ma Paterson Orogeny.

The Tarcunyah Group (deposited in the Officer Basin) unconformably overlies the Hamersley Basin and Collier Basin in the western part of the Paterson Orogen. The group is itself unconformably overlain by later Neoproterozoic rocks (or Supersequences 3 and 4) of the Officer Basin (Williams and Bagas, 1999). To the east, the rocks of the Paterson Orogen are also unconformably overlain by Phanerozoic rocks of the Canning Basin (Bagas, 2000).

Yeneena Supergroup (Neoproterozoic)

The ‘Yeneena Group’ was first defined and assigned to the tectonic unit called the Paterson Province (Chin et al., 1980), and was later assigned to the renamed Paterson Orogen (Williams and Myers, 1990; Williams, 1990). More recently the ‘Yeneena Group’ has been redefined as the Yeneena Supergroup, which includes the Throssell and Lamil Groups (Bagas, et al., 1995; Williams and Bagas, 1999). The maximum age of the groups has now been constrained to c. 1070 Ma, and they may correlate with units in the Neoproterozoic Amadeus Basin in central Australia (Bagas et al., in prep.).

Throssell Group (ᵽT)

Coolbro Sandstone (ᵽTC)

The Coolbro Sandstone is exposed in the northern part of the Paterson Orogen and is a fine- to coarse-grained sandstone with local interbeds of conglomerate and shale (Williams and Trendall, 1998b). The Coolbro Sandstone is considered to have been deposited in a fluviatile–deltaic environment (Hickman and Clarke, 1994; Hickman and Bagas, 1998).

Broadhurst Formation (ᵽTb)

The Broadhurst Formation is rather poorly exposed, forming scattered outcrops and a few low hills. Lithologies in the formation include shale, carbonaceous siltstone, black pyritic shale (with local copper and lead sulfides); and subordinate dolomite and sandstone. The Broadhurst Formation is considered to be a shallow-marine sequence that developed in a euxinic (?barred basin) environment (Williams and Trendall, 1998a; Bagas and Smithies, 1998).

Lamil Group (ᵽL)

The Lamil Group is exposed in the Muttarbarty Hill area where the group is represented by a sequence of siliciclastic rocks overlain by dolomitic rocks (Williams and Trendall, 1998a). Elsewhere in the east, where there are no exposures, rocks of the group have been intersected in mineral exploration drillholes. The mixed clastic–carbonate succession is considered to represent a deep-water marine-shelf or slope environment that was subjected to turbidite activity (Williams and Trendall, 1998a; Bagas and Smithies, 1998).

Officer Basin

Tarcunyah Group (ꝒU) (Neoproterozoic)

The Neoproterozoic (c. 800 Ma) Tarcunyah Group is in faulted contact with the Throssell Group along the Vines, Southwestern, and McKay Faults. Rocks of the group were deposited in the Officer Basin and were later involved in the Paterson Orogeny. The Tarcunyah Group was initially placed in the 'Yeneena Basin' of the then-called 'Paterson Province' (Chin et al., 1980), but Bagas et al. (1995) suggested that the group should be regarded as part of the Officer Basin; this has recently been supported by detailed seismic interpretations (Perincek, 1996). In the east Pilbara, most rocks of the Tarcunyah Group occur in the southeast, but there are small outliers of the group (represented by the Eel Creek Formation) in the northeast in a small area around the Yarrie mine area (Williams, 1999a).

In the southeast the group consists mainly of clastic sedimentary rocks, divided into four units:

Googhenama Formation (*ꝒUg*)

Woroongunyah Formation (*ꝒUw*)

Brownrigg Sandstone (*ꝒUr*)

Yardanunyah Formation (*ꝒUy*)

There is also a fifth unit of mixed clastic and carbonate rocks, in which carbonate rocks predominate, called the Waltha Woora Formation (*ꝒUa*). The carbonate rocks are characterized by the widespread occurrence of stromatolites (Williams and Trendall, 1998a,c).

In the northeast on MUCCAN the Eel Creek Formation *(ꝒUe)* is a succession of clastic sedimentary rocks and minor tuffaceous volcanic rocks. These rocks have been correlated with the Tarcunyah Group on the eastern margin of the Pilbara Craton (Williams and Trendall, 1998a). The basal unit of the formation is a discontinuous, unique conglomerate, rich in hematite clasts, up to 12 m thick, which is the source of iron ore at Yarrie 10 mine (Waters, 1998).

Canning Basin

The northwesterly trending southern marginal shelf of the Canning Basin, known as the Anketell Shelf, occurs in the east of the area where Palaeozoic–Mesozoic sequences lie unconformably on a Precambrian basement consisting of the Paterson Orogen and Hamersley Basin (Williams, in prep.). The structure of the shelf is complicated by the development of northwesterly trending horst-and-graben features: namely, the Samphire Embayment and Graben, the Wallal Platform and Embayment, and the Waukarlycarly Embayment (Hocking et al., 1994). The Wallal Platform is believed to correspond to a Proterozoic basement high (Williams and Trendall, 1998b).

Palaeozoic

Early Permian

Over much of the area the Permian rocks are obscured by widespread Quaternary sand cover; the main exposures are in the Oakover River valley, around the Mount Cecelia area, and near the Yarrie mine area. In areas lacking exposure, mineral exploration drilling has intersected up to 250 m of Early Permian rocks lying unconformably on Proterozoic rocks.

Paterson Formation (Pa)

The rocks of the Paterson Formation are predominantly diamictites, with interbedded sandstone, shale, and conglomerate. They are interpreted to be fluvioglacial in origin (Towner and Gibson, 1983).

Poole Sandstone (Pp)

The sandstone is mainly fine-grained sandstone, with interbeds of coarse-grained sandstone and mudstone. It is probably a shallow-marine deposit (Hickman et al., 1983).

Northern Carnarvon Basin

Lambert Shelf

The sequence is post-Permian and unconformably overlies Archaean granite–greenstone terrane in the north of the area (Hocking et al., 1994; Williams, in prep.). In the northeast of the area the shelf sequence extends further to the east where it lies unconformably on Permian rocks of the Canning Basin.

Mesozoic

Callawa Formation (JKc)

The formation is of Jurassic–Cretaceous age and consists of cross-bedded, fine- to coarse-grained sandstone and conglomerate, with minor siltstone. The rocks were probably deposited in a fluviatile environment (Hickman et al., 1983). The formation forms prominent mesas and buttes in the headwaters of Eel and Salt Creeks around Shay Gap and Callawa (Williams, 1999a). To the north and east of this, over much of the desert sandplains, the formation forms low rocky rises.

Parda Formation (Kp)

The formation is of Cretaceous age and consists of thin-bedded mudstone and minor fine-grained sandstone, which probably formed in a shallow-marine environment (Hickman et al., 1983). The Parda Formation shows distinctive white weathering where it is exposed on low rocky rises in the desert sandplain area, and it disconformably overlies the Callawa Formation.

Regolith

Cainozoic

Regolith materials form surficial cover over most of the northern and eastern parts of the area, and were developed in the Cainozoic and Quaternary as the products of weathering, mass wasting, erosion, and transport. On the accompanying 1:500 000-scale map (Plate 1) the regolith is divided into relict, exposed, and depositional units, shown as an overprint. The 'Poondano Formation' (*Czaf*) is presumed to be equivalent to the Robe Pisolite in the west Pilbara and is shown as a separate overprint. These regolith units are subdivided further on the digitized geology (on the accompanying CD-ROM) and described below (map codes are those shown on the CD-ROM).

Duricrust *(Czx)* — relict

The oldest units are residual ferruginous duricrust and related siliceous cap rocks that formed in the early Cainozoic, and are typically seen in upland areas over mafic volcanic rocks and BIF of the Hamersley Basin, and along strike ridges over some of the ultramafic and arenaceous rocks of the Archaean granite–greenstones.

Pisolite (*Czaf*)

Unique iron-rich alluvial deposits, referred to as the 'Poondano Formation' (Lindner and Drew, *in* McWhae et al., 1958; de la Hunty, 1961) developed in palaeochannels of ancient drainage systems with the iron derived from Precambrian iron formations. A few scattered remnants of these drainage systems occur as mesa cappings to the south and east of Port Hedland. The 'Poondano Formation' is probably the equivalent of the more extensive Robe Pisolite that is in the areas of the Robe River and Fortescue River in the southwestern part of the west Pilbara (Harms and Morgan, 1964). The palaeochannels were filled by limonitic and pisolitic goethite together with fragments of fossil wood and seams of clay during the Eocene (Backhouse, 1979).

Calcrete (included in *Qx* and *Qa*) — depositional

Calcrete forms deposits in valley floors and along old drainage channels in the broad coastal plains. The unit includes the extensive and thick calcrete deposits known as the Oakover Formation, which is confined to the Oakover River valley (Noldart and Wyatt, 1962; Williams and Trendall, 1998a,b,c).

Colluvium *(Qx)* — depositional

Older colluvium deposits, consisting of scree, gravel, sand, and silt, form dissected talus and sheetwash aprons that flank elevated areas of exposed rock. Younger colluvial and alluvial material form extensive areas of floodplain near the north coast.

Alluvium *(Qa)* — depositional

Alluvial deposits occupy the present drainage channels, and they have also formed on the floodplains and deltas of major rivers. They consist of unconsolidated or partly consolidated clay, silt, sand, and gravel. In many floodplain areas clayey silt forms an irregular rough surface called 'gilgai' (or crabhole) country characterized by numerous cracks and small sinkholes. Alluvial gravels and sands provide important sources of water for towns, mines, and pastoral stations. A large borefield in alluvium of the De Grey River supplies water for Port Hedland; the borefield is just north of the Great Northern Highway about 70 km east of the town (Davidson, 1974).

Eolian sand (*Qs*) — depositional

Eolian sand occurs in the northeast of the area, eastward from Pardoo Creek, where the unit forms an undulating sandplain with widely scattered, westerly trending, longitudinal (seif) and chain dunes. This sand-covered area is part of the southwest margin of the Great Sandy Desert.

Coastal deposits *(Qm)* — depositional

Coastal deposits include tidal, intertidal, and supratidal muds and silts (with mangroves) and shelly sand in coastal dunes and old beach lines.

Exploration and mining

Iron ore

The first investigation of iron ore potential in the east Pilbara area was undertaken in the late 1930s by AGGSNA at Ellarine Hills*, later known as Mount Goldsworthy (Finucane and Telford, 1939c). However, the Commonwealth Government's decision to impose an embargo on the export of iron ore in July 1938 stopped further work until 1960. Because of this embargo the Western Australian Government would not approve mining tenements for iron ore exploration and development under the Mining Act and, as a consequence, exploration for iron was stifled for 22 years (Blockley et al., 1990). Following the lifting of the embargo in December 1960, the State Government made tenements available to explorers for iron ore and a boom started in 1961. The main interest concentrated in the area of the Hamersley Basin, where enormous deposits of iron ore were quickly rediscovered.

However, Mount Goldsworthy may be considered an exception to other deposits in the Pilbara that were discovered and assessed during that time, because the deposit was known prior to the boom and its initial resource assessment was carried out by the Western Australian Department of Mines (now MPR) during a 1960 diamond drilling program as part of the State's effort to persuade the Commonwealth Government to lift the export embargo (Low, 1961; Blockley et al., 1990). During the exploration boom of the early 1960s two main types of ore were being targeted in the BIFs of the Hamersley

* Some authors have indicated that the first reference to Ellarine Hills was in an early report on the Pilbara by Woodward (1890), but this is not the case. Woodward makes only a rather general statement about iron ore throughout the Pilbara and is not specific about individual occurrences.

Basin: hematite and hematite–goethite enrichment ore (supergene-enriched BIF) and pisolitic ore (formed in palaeochannels of major drainage systems). In the granite–greenstone terrane of the east Pilbara area the supergene-enriched type was the main target for exploration at Mount Goldsworthy (where it is developed within Nimingarra Iron Formation) and in other areas of outcropping Archaean iron formation (Nimingarra Iron Formation and Cleaverville Formation).

Pisolitic iron ore deposits in the east Pilbara area were also assessed during mineral exploration in the 1960s, but were considered to be too small for development. The deposits form cappings to several small mesas of the Cainozoic 'Poondano Formation' to the south and east of Port Hedland (Plate 1). They were initially assessed (at the same time as Mount Goldsworthy) in 1960 by the GSWA (de la Hunty, 1961), but had been previously identified by the BMR (Traves et al., 1956; Veevers and Wells, 1959) and they were also mentioned by Harms and Morgan (1964). The pisolites are probably the scattered remnants of Cainozoic palaeochannels, representing drainage systems that would have drained large areas of the Nimingarra Iron Formation and Cleaverville Formation (the original sources of iron for the secondary accumulations of pisolitic ores).

In 1961, the State Government offered the Mount Goldsworthy deposit for tender, and the successful bidder was a joint venture (known as Mount Goldsworthy Mining Associates) consisting of Consolidated Goldfields (Aust.) Pty Ltd, Cyprus Mines Corporation, and Utah Construction and Mining Company, who were granted Temporary Reserves over the deposit in 1962. These companies were also granted additional Temporary Reserves to cover several other areas of BIF (interpreted by the company from aerial photographs and shown on BMR's YARRIE (Wells, 1959) to explore for supergene enrichment deposits and to cover areas of pisolite deposits in the Port Hedland hinterland (Matheson et al., 1965).

The joint venture carried out further detailed exploration and evaluation to outline five orebodies and five satellite bodies at Mount Goldsworthy that enabled development to start in early 1965. This development also involved the construction of a new townsite (Goldsworthy), the building of a rail link to Port Hedland and the establishment of deep-water port facilities for bulk iron ore carriers at Port Hedland (Finucane Island). The Mount Goldsworthy operation was the first iron ore producer to export from the Pilbara, shipping its first cargo from Port Hedland in June 1966. Goldsworthy Mining Limited was formed by the joint venture as the operating company*, and mining continued at Mount Goldsworthy until resources were exhausted at the end of 1982.

Exploration by Goldsworthy and other companies (Sentinel Mining Pty Ltd and D. F. D. Rhodes Pty Ltd) in the early 1960s elsewhere in the 'Goldsworthy greenstone belt' and the 'Shay Gap greenstone belt', identified further resources of supergene-enriched ore to the west of Mount Goldsworthy (in the Ord Ranges), to the east (in the Nimingarra – Shay Gap area and the Kennedy Gap – Yarrie area), and to the south (Strelley Gorge area); resources of pisolitic ore were also identified in the Ord Ranges, Poondano area, Lalla Rookh area, and Pincunah–Abydos areas.

A second major development took place further east in 1972–73, when Goldsworthy began to produce ore from the supergene-enriched BIF deposits at Shay Gap and Sunrise Hill to supplement (and eventually replace) production from the Mount Goldsworthy mine. These new developments also involved a 70-km extension to the rail link and the establishment of a new mining town at Shay Gap.

In a third development in 1989, known as the Goldsworthy Extension Project, the company extended mining operations to the nearby Nimingarra deposit. This development was further extended to include production from the Y10 deposit (formerly called Kennedy Gap) and the Yarrie deposits 25 km to the east.

Production from Yarrie commenced in late 1993 and production from Shay Gap and Sunrise Hill deposits ceased in 1995. The town of Goldsworthy was closed in 1992 and the town of Shay Gap was closed in 1993. Between 1966 and 2000 a total of 206 Mt of iron ore has been produced from deposits at Mount Goldsworthy, Nimingarra, Shay Gap, Sunrise Hill, Sunrise Hill West, and Yarrie (Table 4.2, Appendix 4).

Vanadium

Vanadium mineralization was discovered in 1913 in lead ores in the Braeside area; this was the first reported concentration of vanadium in an ore deposit in Western Australia (Blatchford, 1925; Finucane, 1938e; Simpson, 1952; Baxter, 1978). Finucane (1938e) considered that the small amounts of vanadium mineralization here were not of any economic importance.

Base metals

Exploration for base metals in the east Pilbara began through following up chance discoveries of copper and lead made during the first rush of gold exploration in the 1880s and 1890s. Gossans were known in the Big Stubby area at the turn of the century, but the only activity at that time was the excavation of a minor trench. Lennons Find in the Yandicoogina area was found in 1907 and worked intermittently from then until the 1950s. The Marble Bar and Marble Bar South copper–gold mines were in production in 1911 (Marston, 1979). Also in 1911, copper ore was mined from quartz vein stockworks at Breens in the North Pole area.

Early finds noted by Blatchford (1925), in the Braeside lead field area, included minor copper workings in three

* There have been a number of changes in company interests in Goldsworthy Mining Limited since its inception. The companies involved, at various times, have been Consolidated Goldfields (Aust.) Pty Ltd, Cyprus Mines Corporation, Utah Construction and Mining Company (later Utah Development Co), MIM Holdings Ltd, BHP, the Hanson Group, CI Minerals Australia Pty Ltd, and Mitsui Iron Ore Corporation. At present, BHP Iron Ore (Goldsworthy) Limited, part of BHP Iron Ore Division, manages the Mount Goldsworthy Joint Venture on behalf of BHP (85%), CI Minerals Australia Pty Ltd (8%), and Mitsui Iron Ore Corporation Pty Ltd (7%)

locations southeast of Barramine in the Isabella Range, where malachite, chalcocite, chalcopyrite, and cuprite were found in northwesterly striking quartz veins in shales, tuffs, and basalts of the Fortescue Group.

Further south, in the Ragged Hills area of the Gregory Range, the high grade of the vein-type lead–zinc mineralization ensured that it was recognized early. Interest was boosted by war-related higher metal prices. Production of lead, zinc, and silver from north-northwesterly trending quartz veins within the regional fault system is recorded for the period between 1925 and 1928.

In the Middle Creek area, copper associated with antimony in quartz veins was mined during the period from 1937 to 1949.

The era of modern exploration began in the 1950s and brought renewed minor scale production of copper in the Copper Hills and Marble Bar areas, at the Lionel mine in the McPhee Dome, and at Otways. The main lead and silver production from the Ragged Range area occurred during this period, once again related to war-influenced higher prices. A combination of the development of more sophisticated concepts of ore genesis, particularly for sedimentary and volcanogenic ores, and the development of new exploration techniques, saw a rejuvenation of exploration, particularly in the 1960s and 1970s. However, the small size of the Ragged Hills deposits in such a remote region has meant that these deposits have not been developed to production.

Exploration for volcanogenic targets in the east Pilbara began in the 1960s, with the recognition of the potential for deposits like those at Whim Creek and Mons Cupri in the west Pilbara. The companies Westfield, and later Cominco, Serem, and Centenary, reassessed Lennons Find, whilst Newmont and Narla looked at Big Stubby.

At Lennons Find, Westfield (and later Cominco) conducted IP surveys and diamond drilling of the main gossan in the late 1960s. The best intersection was 1.22 m at 1.37% Cu, 2.8% Pb, and 8.3% Zn. In 1973 Project Mining and Jennings Mining carried out grid mapping and geochemistry leading to a major diamond drilling program carried out by Serem in 1976–77. This work established a demonstrated resource of 1.2 Mt at 7.76% Zn, 0.43% Cu, 1.94% Pb, 100.42 g/t Ag, and 0.3 g/t Au in the Hammerhead deposit, calculated by Centenary who took over management of the project in 1983. They further defined an inferred resource of 4.2 Mt in extensions of Hammerhead and in other, on-strike, mineralized zones. With ore widths too thin to support an economic underground operation attempts were made to establish a resource in the oxidized zone suitable for openpit mining.

Extensive exploration for this type of target in the east Pilbara continued through the 1970s and 1980s in the Marble Bar belt, the Warrawoona Syncline, the McPhee Dome, the Coongan and Kelly belts, and the Shaw and Soanesville belts. Many of the prospects were interpreted as being hosted at a stratigraphic level corresponding with the Duffer Formation of the Warrawoona Group.

From the mid-1980s exploration for volcanogenic targets declined concomitant with base metal prices. However, a notable exception to this trend was the exploration carried out by the Sipa–Ashling joint venture in the Panorama area around the margins of the Strelley Granite. This led from an initial discovery of copper, lead, and zinc mineralization in the Strelley area in 1970, at the Cardinal gossan. In 1984 Horatius Wilhelmij discovered magnesium sulfate precipitates in Sulphur Springs Creek. In 1984, prospector Denis O'Meara followed up this find to discover the Sulphur Springs gossan. An extensive follow-up program of exploration by Sipa–Ashling, and subsequently (in joint venture) Outokumpu, between 1989 and 1992, located a related group of volcanogenic massive sulfide (VMS) deposits and occurrences in felsic volcanic rocks surrounding the Strelley Granite.

Porphyry-type base metals were also targeted in the 1960s and 1970s with work by companies such as Anglo American, Hawkstone, Newmont, and Cominco in the Copper Hills and Kellys areas and at other localities in the McPhee Dome. At Coppin Gap, Anglo American and then Esso and Amax recognized a multiple-phase stockwork of copper- and molybdenum-rich quartz–carbonate veins related to apophyses of the Coppin Creek Granodiorite. At Miralga Creek, CRA and Sipa identified epithermal stringer vein gold and base metal mineralization associated with quartz porphyry stocks in Warrawoona Group basalts.

In the 1980s and 1990s a number of companies investigated the potential of the Mesoproterozoic Yeneena Supergroup for Nifty-type stratabound base metals. Prior to this, gold was discovered during gossan sampling by Day Dawn and Newmont geologists, while they were exploring for Zambian-style copper in the Yeneena Supergroup; this led to the pegging of the Telfer gold deposit by Newmont in 1972. Subsequent exploration in the Yeneena Supergroup was directed mostly at gold, but WMC shifted its emphasis to copper following reappraisal of the geological environment in relation to sediment-hosted deposits. In 1980, as a result of a lag-sampling program, WMC discovered copper mineralization at Nifty.

The discoveries of stratiform–stratabound copper (lead–zinc) mineralization in the Broadhurst Formation at Nifty, and elsewhere, enhanced the prospectivity of the Yeneena Supergroup, particularly the graphitic–sulfidic, carbonate-rich facies of the Broadhurst Formation.

Nickel

During the nickel boom between 1968 and 1972, exploration focused on the nickel sulfide potential of ultramafic volcanic sequences and the mafic–ultramafic sills that intruded them in various greenstone belts of the east Pilbara. Although there were some encouraging results during the early stages of exploration at a number of localities, further detailed exploration did not locate any economic mineralization. The only nickel sulfides of any significance from this work, as reported by Marston (1984), were those delineated as small subeconomic deposits in an ultramafic sill at Soanesville (located by Kingsway in 1971) and in a body of altered ultramafic rocks (located by Woodsreef in 1969–70) in a fault zone in the Bamboo Creek – Pear Creek area. The Soanesville nickel deposits and host ultramafic sills have been reassessed during a recent detailed exploration program undertaken between 1994 and 1997 by the Sipa–Outokumpu joint venture (with the area referred to as Daltons nickel prospect). Drilling results from geochemically and geophysically anomalous zones were regarded as disappointing, although potential remains for nickel mineralization at greater depth (Doepel, M. J., 2001, written communication).

Another deposit of some significance, but not recorded by Marston (1984), is the Cookes Creek nickel deposit in an ultramafic sill to the northeast of Nullagine. The prospect was explored by Mines Administration and CEC between 1969 and 1973, Alcoa from 1975 to 1977, and CRA in 1977. Other ultramafic sills in the Mosquito Creek Basin to the east and southeast of Nullagine were examined by Falconbridge between 1971 and 1973, but with disappointing results.

An unusual (possibly hydrothermal) nickel occurrence was discovered in 1969 at the Otway prospect, north of Nullagine (Nickel et al., 1979; Marston, 1984). Drilling of the prospect by Conwest in 1969–70 did not intersect any significant mineralization. Nickel sulfides were located at Fieldings Gully (Warrawoona area) by Hawkstone in 1970 in ultramafic units interfingered with felsic and mafic volcanic units hosting massive sulfide mineralization.

Gold

The first gold found in the east Pilbara seems to have been that located by Mr N. W. Cook at Nullagine in 1886 (Plate 1; Maitland, 1905). But the rush to the Nullagine area did not occur until after the 1888 discoveries of gold at Mallina and Pilbara in the west Pilbara. Woodward (1891) described gold in conglomerate at Nullagine, and in ‘a very nice patch of auriferous country’ east of Nullagine (presumably he was referring to the supergene-enriched vein-hosted gold in the Mosquito Creek Formation). Becher (1898) described the gold diggings at Nullagine and he also lauded the ‘brilliant prospects’ of the Marble Bar field that had been discovered in 1890.

Official MPR (formerly DME) records show that gold production was under way in most of the presently defined ‘fields’ by between 1897 (early limit of records) and 1901. Only the Wymans Well, Eastern Creek, McPhees Creek, and Pilgangoora areas show production later than 1901. The gold being mined was mainly from high-grade supergene enrichments of primary vein and hydrothermal gold mineralization. Historically, a significant proportion of gold production in the east Pilbara has come from palaeo-placer deposits in Proterozoic conglomerates in the Marble Bar and Nullagine areas. As in the west Pilbara, much of the gold obtained went unreported in the early years of mining in the east Pilbara, and it is impossible to assess what the true early production may have been.

In the period between 1900 and 1910, annual gold production declined for the Pilbara region as a whole from 510 kg to about 170 kg and it remained at about this level throughout the 1920s (Fig. 6). The period from 1930 to 1954 saw production rise to a peak of 620 kg in 1942 and maintain average levels of about 300 kg. This reflected significant production from the Bamboo Creek and Marble Bar centres, the Warrawoona area (Trump and Copenhagen), the Nullagine area with significant contributions from the Middle Creek group (All Nations and Hopetoun), and from the Mosquito Creek line (Blue

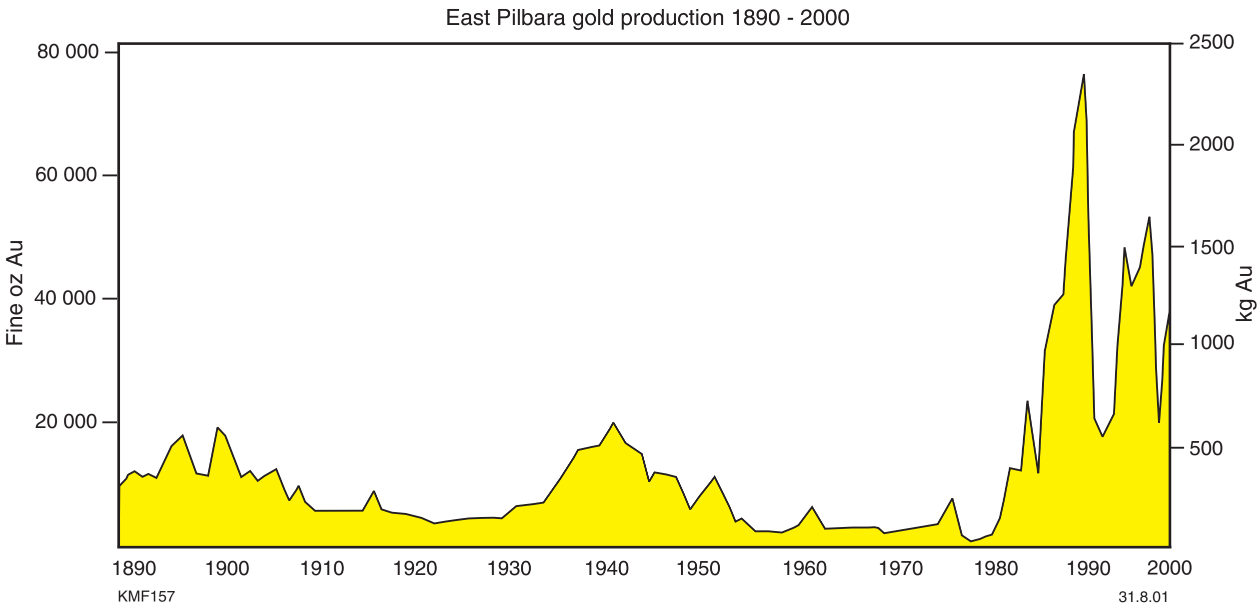


Figure 6. Graph showing production of gold in the east Pilbara between 1890 and 2000. Early figures understate actual production

Spec and Billjim). Production from the Normay mine in the North Pole area also contributed at this stage, as did mines in the Sharks area and in the Pilgangoora group.

From 1954 until 1962, levels of annual production ranged between 80 and 150 kg, with production at Blue Spec continuing. Production then slumped further to an annual average of about 45 kg until the early 1980s. A marked increase in production followed, reflecting the advances in modern mining methods (including the advent of large openpits) and metallurgical processing techniques allowing lower grade throughput. Up until 1995 the Bamboo Creek centre showed strong production, from the Mount Prophecy – Perseverance and Kitchener mines. In the Warrawoona area, smaller mines at Copenhagen and Charlie contributed to east Pilbara production. In the Marble Bar field, mining continued (on a smaller scale) at Just In Time, Coongan Star, Ironclad, Betty Boo, and Stray Shot. The Normay mine, at the North Pole centre, also contributed to production. The most recent production, from 1995 to 1998, has been from mines in the Pilgangoora area (McPhees, Birthday Gift, Lynas, Zakanaka, Main Hill, and Breccia Hill).

At the time of writing, the Bamboo Creek mines are on care and maintenance. Haoma, owner of the mines, is currently testing its new metallurgical process (Elazac Process) at its plant at Bamboo Creek, to extract gold from tailings and low-grade stockpiles from the Kitchener mine. The company also owns mines in the Marble Bar area and in parts of the Warrawoona, Wymans, North Pole, Talga Talga, Sharks Gully, and Lalla Rookh areas; it also plans to use its new process to treat ores from the Copenhagen, Warrawoona, Normay, and Comet mines (Haoma Mining NL, 1999).

Antimony

Antimony has been mined with gold from the shear-hosted quartz–stibnite veins in pelitic units of the Mosquito Creek Formation, northeast of Nullagine. The main production has been from the Blue Spec mine and from the Billjim group of workings.

Chromium and platinum group elements (PGE)

From the early 1980s onward, several companies have explored for chromium and PGE mineralization over areas of mafic–ultramafic intrusions, often in conjunction with exploration for nickel sulfides. Prior to this, General Mining located disseminated chromite in an ultramafic body at Pear Creek, during a nickel exploration program from 1970 to 1974. This was further drilled by Hancock & Wright between 1983 and 1985, but results were disappointing. At Nobb Well disseminated chromite was located by Hickman in an ultramafic unit during mapping of MARBLE BAR (Hickman and Lipple, 1978; Baxter, 1978). In 1986 Golden Fortune Mining reported up to 49.4% Cr in grab samples from chromite seams in an ultramafic body near the confluence of the Talga and Coongan rivers, but this was not followed up by the company. During a nickel exploration program from 1994 to 1997, the Sipa–Outokumpu joint venture also examined the PGE potential of the ultramafic sills at Soanesville (Doepel, M. J., 2001, written communication).

Silver

Silver has been encountered and mined from vein and hydrothermal deposits, as a byproduct of gold production and of copper–lead–zinc production,. The most significant source of silver has been the vein-hosted lead deposits of the Braeside lead field (see **Base metals**). The main production came during the periods 1925 to 1928 and 1947 to 1958, from the Mount Brockman group of mines and from mines at Ragged Hills, Ragged Hills East, and Devons Cut in this field.

Uranium

Minor uranium is present in the Hardey Formation of the Fortescue Group. Exploration in the late 1960s and early 1980s focused mainly on targets of Blind River type placer deposits in the Hardey Formation, but failed to locate any significant concentrations. Alcoa obtained a drill intersection of 0.3 m grading 1510 ppm U_3O_8 in a conglomerate above the Kylena Basalt.

Diamond

Diamonds were first discovered in Western Australia in 1895, near Nullagine (Groom, 1896). They were located in conglomerate of the Hardey Formation near Brooks Hill. Only three of the diamonds found at that time were considered marketable. One of these was bright yellow. Hickman (1983) noted that by 1973 at least 70 diamonds had been found, mostly in Cainozoic sediments that had been washed out of the weathered conglomerate. Carter (1974) provided descriptions of the diamonds from Cainozoic fluviatile sandstone.

In the early 1970s, CRA and others found diamonds in the Cainozoic Brooks Hill Formation at Banana Hill, and Stockdale found a micro-diamond in Fortescue Group sedimentary rocks in the Coondamar Creek area in 1990.

As mentioned above, possible kimberlite intrusions were identified in Fortescue Group rocks just west of Nullagine (Blake and Chalmers, 1994). However, in 1999 a definite kimberlitic dyke (the Brockman Dyke) was located by the Haoma–Stockdale joint venture in the Warrawoona area; this is a possible source for the detrital occurrences. Macrodiamonds (>0.4 mm) have been identified in bulk sampling of the Brockman Dyke, and this discovery has led to renewed exploration for further primary sources in the east Pilbara.

Manganese

Manganese was reported by Blatchford (1924) in the Barramine–Braeside region on the eastern edge of NULLAGINE, although this and other occurrences along the western side of the Gregory Range were probably discovered by prospectors in the early 1900s*. Finucane (1938e) later identified and mapped manganese outcrops to the west of the Braeside area. Encouraged by rising world prices for manganese in the early 1950s, prospecting syndicates and companies prospected in the area and discovered large deposits in the region of the Oakover River drainage basin. At that time, production of manganese for export was limited to quotas imposed by the Commonwealth Government, but sales for the domestic market were not restricted. During 1952 and between 1956 and 1958, joint Commonwealth–State assessments of manganese resources were made in the east Pilbara (Owen, 1953; de la Hunty, 1955, 1963; Casey and Wells, 1956). The main areas of manganese mineralization assessed were at Woodie Woodie, Mount Sydney, Ripon Hills, Mount Cooke, Sunday Hill, Skull Springs, and Ant Hill. At Woodie Woodie and Mount Sydney, diamond drilling and gravity surveys were carried out (de la Hunty, 1965a; Rowston, 1965). The manganese-rich region of the Oakover drainage basin was referred to as the 'Pilbara Manganese Province' by de la Hunty (1963, 1965b). Outside this province, other areas of manganese mineralization in the east Pilbara were also examined, at Nimingarra and Yarrie (de la Hunty, 1963).

Mining of manganese in the area commenced in 1954 and exploration peaked around 1956–57. Most of this early work in the 'Manganese Province' was undertaken by Westralian Ores, Northern Mineral Syndicate, Mount Sydney Syndicate, BHP, and D. F. D. Rhodes; with work at Nimingarra undertaken by Pindan. However, during the early 1960s, exploration interest declined in the east Pilbara, following the discovery of the very large low-grade manganese deposits at Groote Eylandt in the Northern Territory (de la Hunty, 1963; Williams and Trendall, 1998c).

Nevertheless, the relatively high-grade, but small, manganese orebodies in the area continued to attract sporadic mining and exploration activity in the 1960s and 1970s by Sentinel Mining, Mount Sydney Manganese, Bell Basic Industries, Longreach Metals, BHP, CRA, and Preussag. Mining and exploration languished in the 1980s because of the low demand for manganese during a recession in the steel industry. Following a large improvement in manganese prices in 1989, there was renewed interest in the early 1990s with the redevelopment of Woodie Woodie mine and a resurgence of regional exploration by Portman Mining. Other companies to join this resurgence were Hancock Mining, Pennant Resources, King Mining, and Sovereign Resources.

In 1993 Valiant Consolidated also became involved in exploration and this led to the discovery of the Mike deposit near Woodie Woodie. Portman Mining closed its operations at Woodie Woodie between 1994 and 1995. In 1996 Valiant Consolidated bought Portman Mining's manganese project and planned to continue production from Woodie Woodie in conjunction with production from its Mike mine. However, with another downturn in manganese prices and a crippling disruption to mining and exploration caused by record heavy rains in 1997, Valiant Consolidated closed its operations and went into receivership. In April 1998 the company underwent a capital reconstruction and changed its name to Consolidated Minerals Limited. Mining of high-grade ore restarted at Woodie Woodie in mid-1999 and exploration intensified for small high-grade manganese deposits in the vicinity, using gravity and magnetic surveys to identify target zones for drilling (Consolidated Minerals Limited, 2000).

During 1996–97 Sovereign Resources undertook metallurgical testing and feasibility studies to use the large resources of low-grade manganese ore at Ant Hill* as a source of manganese sulfate for agricultural fertilizer and animal feed. Further feasibility studies in 1998–99 showed that the ore could also be used to produce electrolytic manganese dioxide (EMD) for use in the battery industry. Under an agreement with Consolidated Minerals, additional low-grade ore would be obtained from the Woodie Woodie mine. In December 1999 Sovereign changed its name to HiTec Energy NL and announced plans to commence production of EMD in early 2002 at a plant in Port Hedland using a proprietary hydrometallurgical process; manganese sulfate would be a secondary product (HiTec Energy NL, 2000).

Manganese production for the area is shown in Appendix 4 (Table 4.3). Records for individual production sites are incomplete, because producers in the 1950s and 1960s reported combined figures from several sites throughout the 'Pilbara Manganese Province'.

Barite

Barite has been mined from the North Pole deposit, where it occurs in veins and beds within syngenetic chert–barite horizons interbedded within a mafic volcanic sequence in the North Pole Dome (Hickman, 1973, 1983). The chert–barite horizons were fed by a series of chert–barite dykes emplaced through syndepositional growth faults in the lower basaltic sequence (Williams et al., 1999). Barite was mined in 1970 and between 1976 and 1990 from the Dresser mine. An inferred resource of 0.5 Mt of $BaSO_4$ remains (Abeysinghe and Fetherston, 1997). Dome Hill Mining has plans to re-open the mine in the near future (Flint and Abeysinghe, 2001).

During the geological mapping of PORT HEDLAND (Hickman and Gibson, 1982), veins and beds of barite were discovered in a sandstone–chert–felsic lava sequence at Cooke Bluff Hill (Hickman, 1977). Barite also forms abundant gangue mineralization to copper–lead–zinc sulfide mineralization at Big Stubby (Hickman and Lipple, 1978; Brook, 1974).

Fluorite

Fluorite was recognized in veins during mineral exploration at Meentheena in 1970; the mineral was noted by station owners in the 1960s but was not then positively identified (Abeysinghe and Fetherston, 1997). Hickman

* Memorandum dated 20 March 1903 to the Under Secretary for Mines from the Acting Government Geologist referred to manganese samples received from the upper Oakover River (GSWA File 57/1900)

* Ant Hill is located on BALFOUR DOWNS south of the east Pilbara project area

was the first to describe the deposits (Hickman, 1974). Hickman also discovered disseminated fluorite in a porphyry intrusion at Ngarrin Creek (Hickman, 1976).

Tin–tantalum–lithium–niobium

Tin prospectors moved into the Pilbara area in 1888 (Blockley, 1980). Many discoveries of alluvial–eluvial tin were quickly made and production began in 1893 at Eleys. Tin production continued strongly for the next two decades, until the 1920s and 1930s when the easily accessed surface deposits became depleted. In the mid-1950s tin production recovered, accompanying the rise in tin prices and the introduction of powerful earth-moving equipment to alluvial mining sites.

Pegmatite-hosted occurrences

The main source areas for pegmatite-hosted tantalum and niobium (in tantalite–columbite minerals) are Wodgina, Tabba Tabba, Strelley, Cooglegong, Pilgangoora, and Eleys. Only in the Wodgina area has a significant quantity of tin been mined from primary sources.

In the Wodgina centre albite pegmatite and associated tourmaline lodes have been the main source of primary tin, tantalum, and lithium in the east Pilbara (Blockley, 1980; Hickman, 1983). The Wodgina, West Wodgina, Stannum, Mills Find, Numbana, and Mount Francisco mining areas are included within the Wodgina centre, but most of the production has come from the Mount Cassiterite underground mine (recently this has become an opencut operation for tantalite).

At Mount Cassiterite the ore is located within an up to 4 m-wide albite–quartz pegmatite containing cassiterite, tourmaline, beryl, tantalite, and lithium minerals with tin concentrated toward the margins of the pegmatite. Historical production (between 1904 and 1918) from this mine was 335 t of tin concentrate. This is the only significant source of primary tin ore in the east Pilbara.

Since 1989, the Wodgina area has been a main centre for tantalite production. Between 1989 and 1993 production was from the Wodgina Main Lode but, since 1995, production has come from Mount Cassiterite (Bester, 2000).

Tantalite production has also come from pegmatites on the western margin of the Pilgangoora belt. The mineralization is relatively low grade and much of the production has come from alluvium and colluvium material.

Alluvial occurrences

Most of the tin mined from the east Pilbara has come from alluvial and eluvial deposits. Blockley (1980) noted a relationship between these and ‘post-tectonic’ granitoid plutons and cassiterite-bearing pegmatites of similar age. The main areas of alluvial production are as follows: Moolyella (northeast of Marble Bar); the Shaw River area, which includes centres at Cooglegong, Eleys, Five Mile Creek, Tambourah Creek, Split Rock, Coomba Creek, and Hartigan Creek; and the Coondina area. Most of the recorded tin production is from the Moolyella, Cooglegong, and Eleys areas. The primary tin–tantalum deposits and occurrences in the Wodgina area are the sources for a number of alluvial and eluvial workings in that area.

Tungsten

Post-tectonic granitoids, intruded at about 2.6–2.7 Ga, are the source of wolframite-bearing pegmatites in the east Pilbara area. Tungsten production of this type has come mainly from late-stage differentiated pegmatite dykes in the Cookes Creek Granite, in the south of the area. Most of the production, totalling 17 583.2 kg, was during 1951–52 (Hickman, 1983). Both scheelite and wolframite have also been produced from a 1 m-wide pegmatite in mafic schist about 2 km southwest of the main mine at Cookes Creek.

Scheelite is associated with gold in the Ard Patrick mine in the Mosquito Creek area; scheelite also occurs in the Stray Shot gold mine at Marble Bar. Minor production (412.9 kg WO_3) in the 1950s is recorded from a wolframite deposit south of Burrows Well in the Split Rock area. The mineralization is in a quartz vein about 2 km from the margin of the Cooglegong Monzogranite.

Mineralization

A total of 1612 mineral occurrences have been recorded in WAMIN for the east Pilbara area, and these are shown on Plates 1 and 1A and on Figure 7. On Plates 1 and 1A the occurrences are grouped by commodity (colour) and mineralization style (symbol), as explained in Appendix 2. In the following sections the occurrences are grouped by mineralization style and then by commodity groups under various sub-headings. Mineral occurrences referred to below are identified by the WAMIN ‘deposit name’ and ‘deposit number’, shown thus: Edelweiss Au (**2798**).

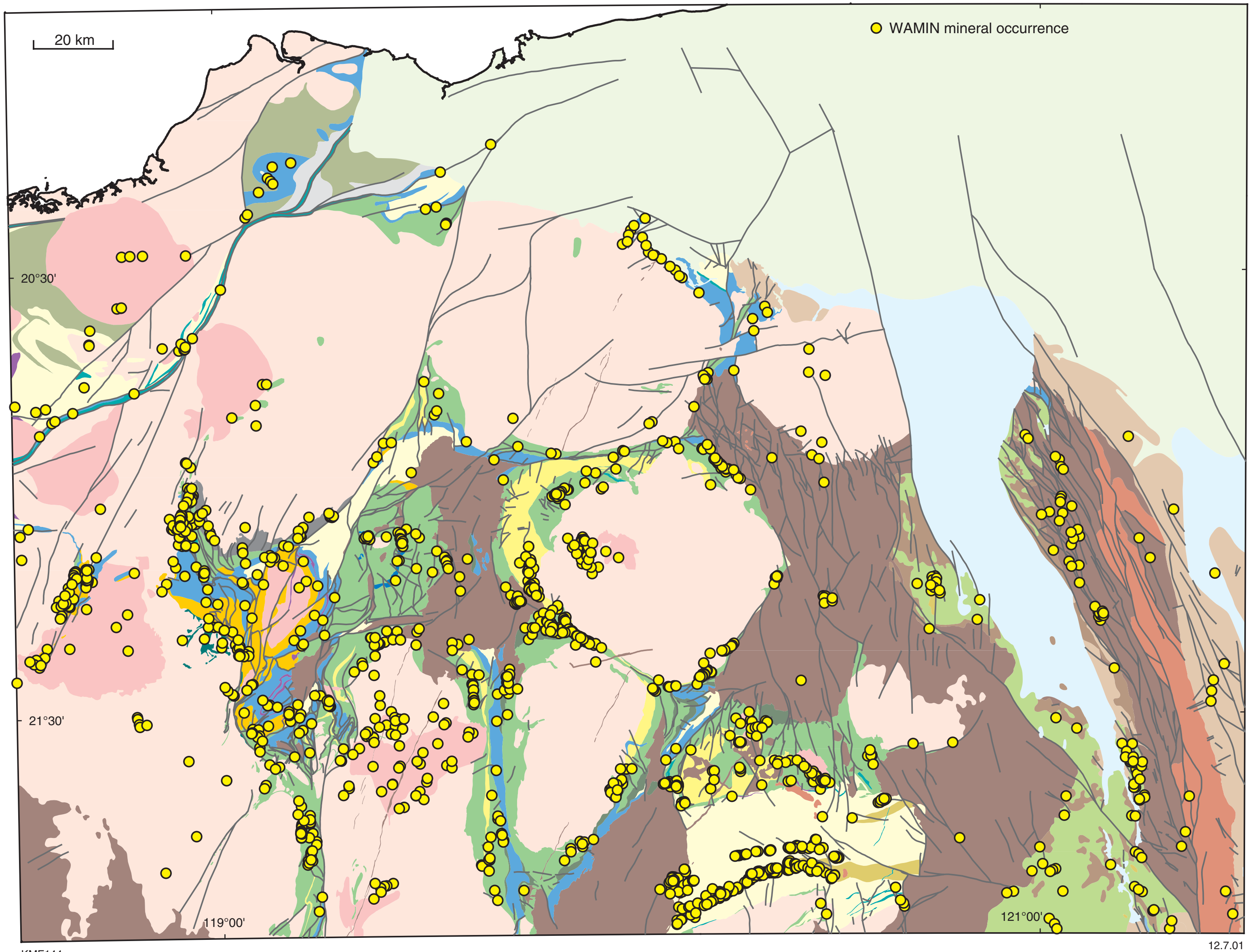
The nature of mineralization in the east Pilbara is discussed in terms of the major geological events that have shaped the area. The temporal relationship between geological evolution and mineralization has been summarized in Figure 8, and it is useful to refer to this figure while reading the following description and discussion.

Mineralization in kimberlite and lamproite intrusions

Precious mineral — diamond

There are 9 diamond occurrences in the east Pilbara, one of which is kimberlite hosted. The other 8 occurrences are in Cainozoic sedimentary rocks.

Since the discovery of diamonds in the Nullagine area at the turn of the century near Brooks Hill (**2916**), in Cainozoic sedimentary rocks derived from Fortescue Group sedimentary rocks, many prospectors and explorers have sought to locate the supposed kimberlitic source of



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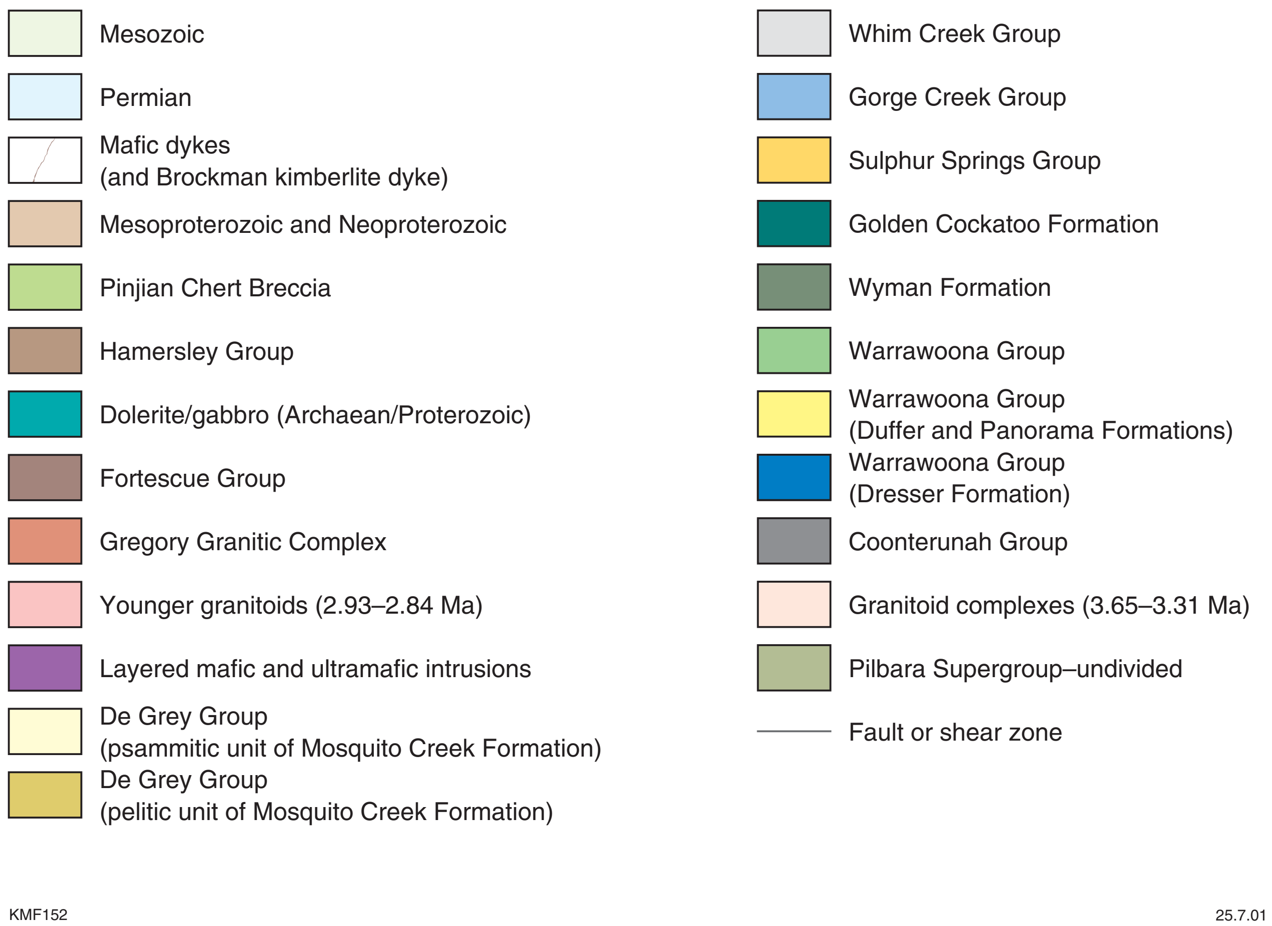

Figure 7. Distribution of 1612 WAMIN occurrences in the east Pilbara

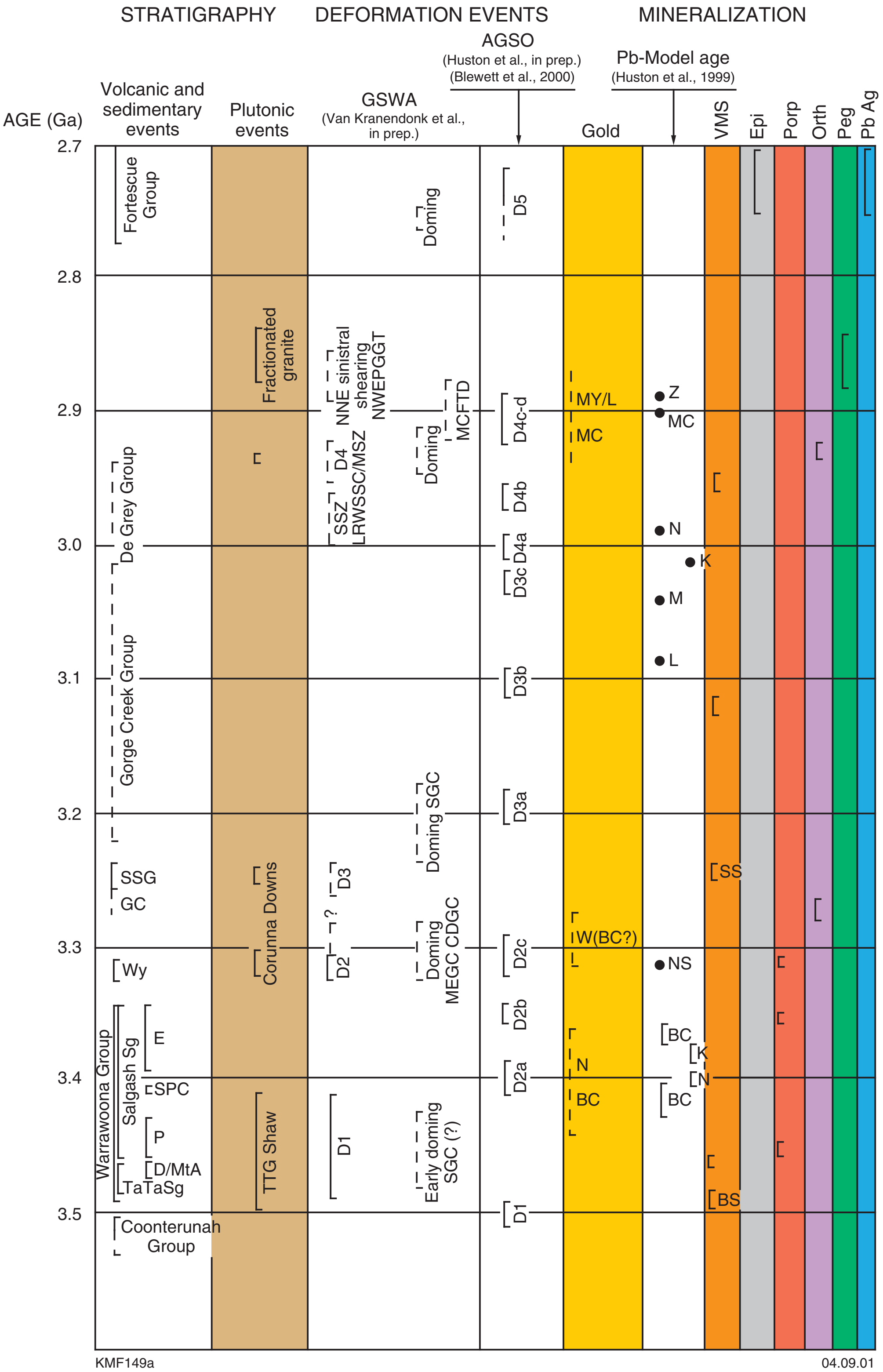

Figure 8. Geological evolution and mineralization in the east Pilbara. See legend opposite

KEY TO ABBREVIATIONS

SSG	Sulphur Springs Group	BC	Bamboo Creek
D/MtA	Duffer Formation/Mt Ada Basalt	W/P	Warrawoona/Pilgangoora
P	Panorama Formation	MC	Mosquito Creek
GC	Golden Cockatoo Formation	K	Klondyke
SPC	Strelley Pool Chert	SS	Sulphur Springs
E	Euro Basalt	NS	Talga Talga (North Star)
Wy	Wyman Formation	Z	Zakanaka
TTG	Tonalite–trondhjemite–granodiorite	L	Lalla Rookh
CDGC	Corunna Downs Granitoid Complex	M	McPhees
MEGC	Mount Edgar Granitoid Complex	N	North Shaw (Normay)
SGC	Shaw Granitoid Complex	BS	Big Stubby
MCFTD	Mosquito Creek Fold–Thrust deformation	VMS	Volcanogenic massive sulfide mineralization
LRWSSC	Lalla Rookh–Western Shaw Structural Corridor	Epi	Epithermal mineralization
NWEPGGT	Northwest East Pilbara Granite–Greenstone Terrane	Porp	Porphyry Cu–Mo mineralization
SSZ	Sholl Shear Zone	Orth	Orthomagmatic Ni–Cu mineralization
MSZ	Mallina Shear Zone	Peg	Pegmatite Sn–Ta mineralization
TaTaSg	Talga Talga Subgroup	Pb Ag	Lead–silver mineralization
MY/L	Mount York/Lynas		

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these diamonds. However, these endeavours met with little success. As a result, an opinion developed that the source dykes may have formed at levels higher than the present land surface, and had been largely eroded, leaving only root systems (Carter, 1974). However, interest in the potential of the east Pilbara has been revived, following the 1997–98 discovery of diamonds in a kimberlitic dyke system (Brockman Dyke) in the Warrawoona area (Plate 1A, Inset 6), where Haoma Ltd is in joint venture with Stockdale Prospecting; the joint venture has since reported dykes with possible kimberlitic affinities in the Coongan belt and at Hillside.

The Brockman Dyke (**6341**) contains macrodiamonds (>0.4 mm) and microdiamonds that have been located during drilling. The dyke intrudes a greenstone belt in the Warrawoona area and the granitoid complexes of Mount Edgar and Corunna Downs, which lie to the north and south of the greenstone belt. During 2000, Stockdale (in joint venture with Haoma) reported the recovery of 10 diamonds from four mini-bulk samples in the Brockman Dyke.

Orthomagmatic mafic and ultramafic mineralization

There are some 57 mineral occurrences in the east Pilbara in this style of mineralization (Fig. 9), represented by three commodity groups:

Steel-industry metal — nickel (copper, cobalt), chromium (24 occurrences)

Base metal — copper (12 occurrences)

Industrial mineral — asbestos (21 occurrences)

Steel-industry metal — nickel (copper, cobalt)

Subeconomic deposits of nickel–copper sulfides occur in ultramafic bodies in the Soanesville area (**3008**, **3247**, **6017–18**), the Bamboo Creek area (**4235**), and the Cookes Creek area, northeast of Nullagine (**6246–50**). At Soanesville (**3247**), nickel sulfides were intersected in 1971 during a diamond drilling program by Kingsway Minerals. The host rock is a serpentinized peridotite (?sill) of the Dalton Suite intruded into clastic sedimentary rocks of the Sulphur Springs Group. Low-grade disseminated mineralization is in a narrow zone (up to 0.53% Ni and 0.45% Cu over 3–4 m) near the lower contact of the peridotite. Higher grades (up to 2.55% Ni and 1.16% Cu over 3.5 m) were intersected in massive sulfides in two drillholes. In these higher grade intersections, up to 0.55% Co was reported.

At the Bamboo Creek mining centre (Plate 1A, Inset 4), nickel mineralization (**4235**) is disseminated gersdorffite in silicified, brecciated, and carbonated ultramafic rock of the Euro Basalt in the Warrawoona Group. It forms a concealed body located between the Mount Prophecy and Prince Charles gold mines (Hickman, 1983; Marston, 1984; Williams, 1999a). Drilling by Woodsreef in 1969 obtained up to 1.69% Ni averaged over an intersection of 5.09 m. Hickman (1983) suggested that the ultramafic unit was in an arcuate fault zone and that the nickel mineralization resulted from deformation and metasomatism of an initial magmatic accumulation of nickel sulfide in the ultramafic rock. It may be that the Bamboo Creek nickel mineralization is epithermal, similar to other epithermal occurrences in the Pilbara recognized by Marshall (2000).

In the Cookes Creek area at 'Anomaly Hill' (**6246–8**), nickel–copper mineralization is found as disseminated pentlandite with minor amounts of chalcopyrite in serpentinized dunite in the basal parts of an intrusive sill (Plate 1A, Inset 10). From drilling results in 1973, CEC estimated a small sulfide resource at Anomaly Hill of about 0.5 Mt grading 0.9% Ni. Later geophysical surveys and drilling by Alcoa and CRA in 1977 showed that sulfide mineralization in the sill complex extends for about 1200 m along strike in the area around Anomaly Hill. Minor occurrences of nickel sulfides were also located further east along the sill (**6249–50**). The age of the sill

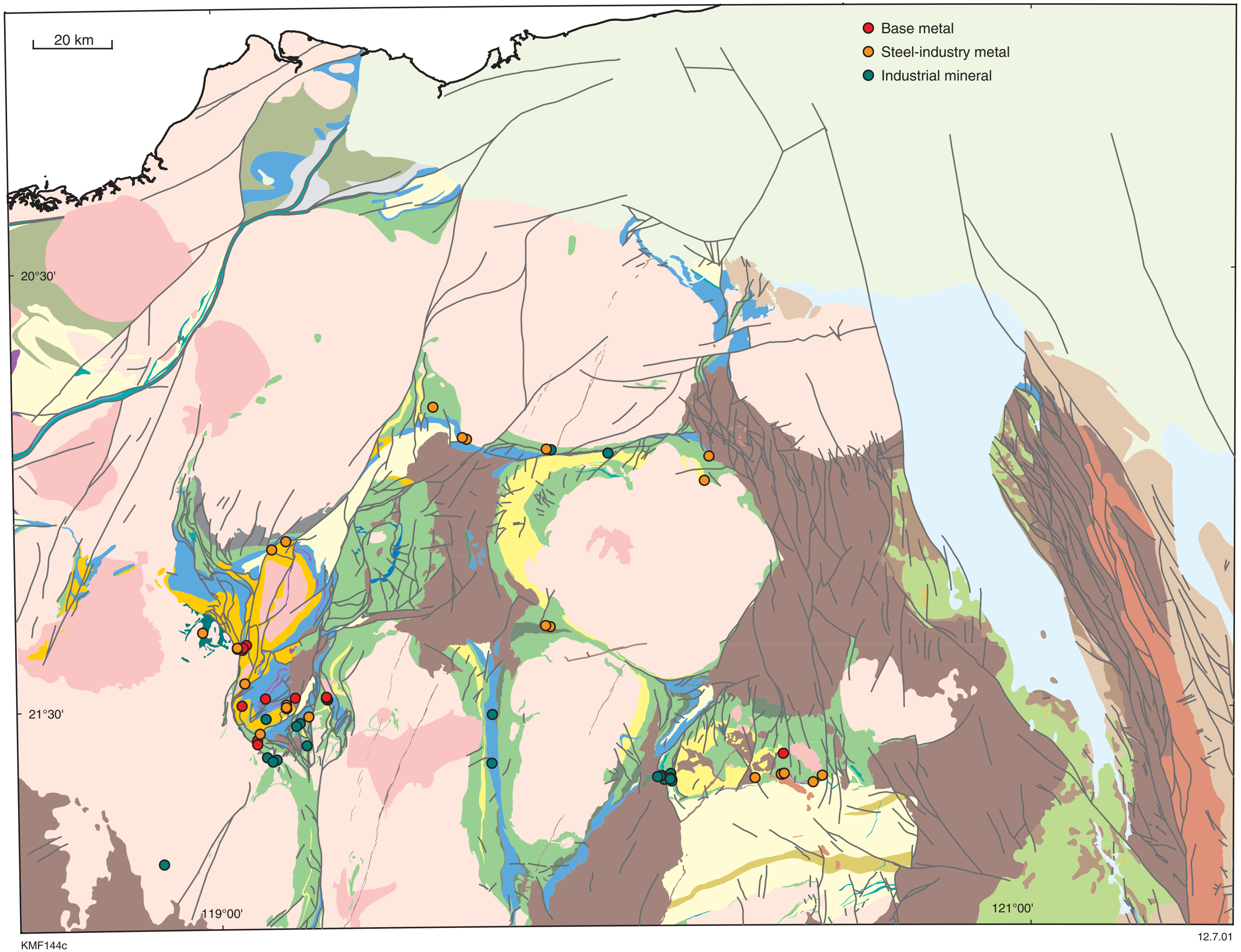

Figure 9. Distribution of orthomagmatic mafic and ultramafic mineral occurrences in the east Pilbara. See Figure 7 for geological legend

is somewhat uncertain at present, but this may soon be clarified by field mapping and geochronlogical work of the NGMA. Mapping and drilling by CEC, Alcoa, and CRA indicated that the ultramafic sill is a relatively late intrusion. Company results show that the sill intrudes a narrow belt of greenstones (felsic volcanic and sedimentary rocks, cherts, and minor mafic volcanic rocks) that is unconformable on Warrawoona Group (mafic volcanic rocks) and the Cookes Creek Granite. Also, parts of the sill 'interfinger' with clastic sedimentary rocks of the Mosquito Creek Group; similar ultramafic intrusions lie in the southern part of the Mosquito Creek Basin (Hickman, 1978). It may be that the 'Cookes Creek sill' and these other sills were intruded at the same time as the layered mafic intrusions of the west Pilbara (c. 2925 Ma).

Steel-industry metal — chromium

Chromite is disseminated in ultramafic bodies at Pear Creek prospect (**4981**) and Nobb Well prospect (**4232**) (Baxter, 1978; Hickman, 1983; Williams, 1999a). There is a chromite seam in an ultramafic body near the confluence of the Talga and Coongan rivers (**6032**, **7467**).

Industrial mineral — asbestos (chrysotile)

Hickman (1983) noted that chrysotile asbestos in the east Pilbara is mainly in serpentinized peridotite, predominantly at the Lionel centre (**5950**, **5980–81**, **6627–29**, **6631–33**; Plate 1A, Inset 9), and in the Soanesville area (**6019–22**). Chrysotile asbestos has also been mined near Mount Webber (**5997–98**, **6002**). In the Lionel centre peridotite sills intrude Archaean basalt and dolerite of the Warrawoona Group, and metasedimentary rocks of the Gorge Creek Group. The asbestos is in veinlets averaging 1 cm wide, but up to 10 cm wide. Hickman (1983) quoted production of about 4000 t. In the Soanesville area, in a similar setting, production was about 250 t.

Base metal — copper

Relatively minor copper occurrences (**8887–89**) are present in unassigned ultramafic units in the North Shaw area, southeast of the Strelley Granite (Van Kranendonk, 2000).

Stratabound volcanic and sedimentary mineralization

In the east Pilbara area, occurrences listed under this heading include deposits of volcanic-hosted sulfides (VMS) hosted by proximal felsic volcanic and volcaniclastic rocks, and exhalative base metal deposits in more distal volcaniclastic sedimentary rocks. Where the exact nature of the associations within the volcano-sedimentary sequence is unclear the occurrences have been grouped under 'undivided'.

There is a total of 74 occurrences in the stratabound volcanic and sedimentary grouping, 32 of which are within the subgroup volcanic-hosted sulfide, 10 in sedimentary-hosted sulfide, and 32 undivided (Fig. 10).

Volcanic-hosted sulfide

Base metal — copper, lead, zinc (silver, gold)

In the Panorama area a group of related Cu–Zn deposits and prospects lies within the predominantly felsic volcanic and volcaniclastic Kangaroo Caves Formation of the Sulphur Springs Group, within the Panorama greenstone belt (Van Kranendonk, 2000).

The following indicated and inferred resources have been identified by Sipa (Morant, 1998): Sulphur Springs — 2.8 Mt at 10.7% Zn and 0.6% Cu, and 2.5 Mt at 4.0% Cu and 1.1% Zn; Kangaroo Caves — 1.7 Mt at 9.8% Zn and 0.6% Cu; and Bernts — 0.6 Mt at 7.8 % Zn and 0.3% Cu.

The two main deposits — Sulphur Springs Zn–Cu (**2847**) and Kangaroo Caves Zn–Cu (**7730**) — and three prospects — Breakers Zn–Cu (**3235**), Anomaly 45 (**3237**), and Roadmaster Zn–Cu (**7732**) — lie near the top of the Sulphur Springs Group and are evenly distributed at about 6 km intervals around the Strelley Granite. The Bernts Zn–Pb (**2777**) prospect is at the same stratigraphic level but lies within the tectonically complex Bernts Deformation Zone in a slice of brecciated and contorted rocks between the Soanesville and Panorama greenstone belts (Van Kranendonk, 2000). However, Morant (1995) considered the Bernts prospect to be hosted by pumiceous rhyolitic breccias of the Gorge Creek Group.

A well-defined marker chert near the top of the Sulphur Springs Group has been used to relate the various prospects stratigraphically. At Sulphur Springs, the Zn–Cu mineralization lies within the chert and in a 200 m-thick dacite, immediately below the chert, and is Zn-rich at the top and Cu-rich, in a possible 'stringer zone', beneath the chert. Mineralization is within the marker chert at Kangaroo Caves.

At Sulphur Springs and Kangaroo Caves the sulfide assemblage is made up of pyrite, low-Fe sphalerite, chalcopyrite, and galena, with minor tennantite and arsenopyrite in some intersections. Vearncombe et al. (1994, 1995, and 1998) described well-preserved sulfide textures at both Sulphur Springs and Kangaroo Caves. These include dendritic, colloform, and botryoidal types that are similar to the open-space textures in the sulfide chimneys formed by black smokers at present-day submarine hydrothermal vents. There is also an abundance of sulfates, mostly barite, in the original hydrothermal deposition system, suggesting a close similarity to modern VMS deposits.

All five of the main deposits and prospects around the Strelley Granite have been shown to be spatially related to growth faults within, and emanating from, the granite (Vearncombe et al., 1998; Van Kranendonk, 2000). Granite-related hydrothermal circulation and deposition of the mineralization is suggested by this, and by evidence of zoned chlorite–quartz, sericite–quartz alteration facies surrounding the prospects, sulfide mineralization in veins with greisen-altered margins in the outer phase of the Strelley Granite, and molybdenum in greisen within the granite (Greisen Mo (**7739**) prospect) (Van Kranendonk, 2000).

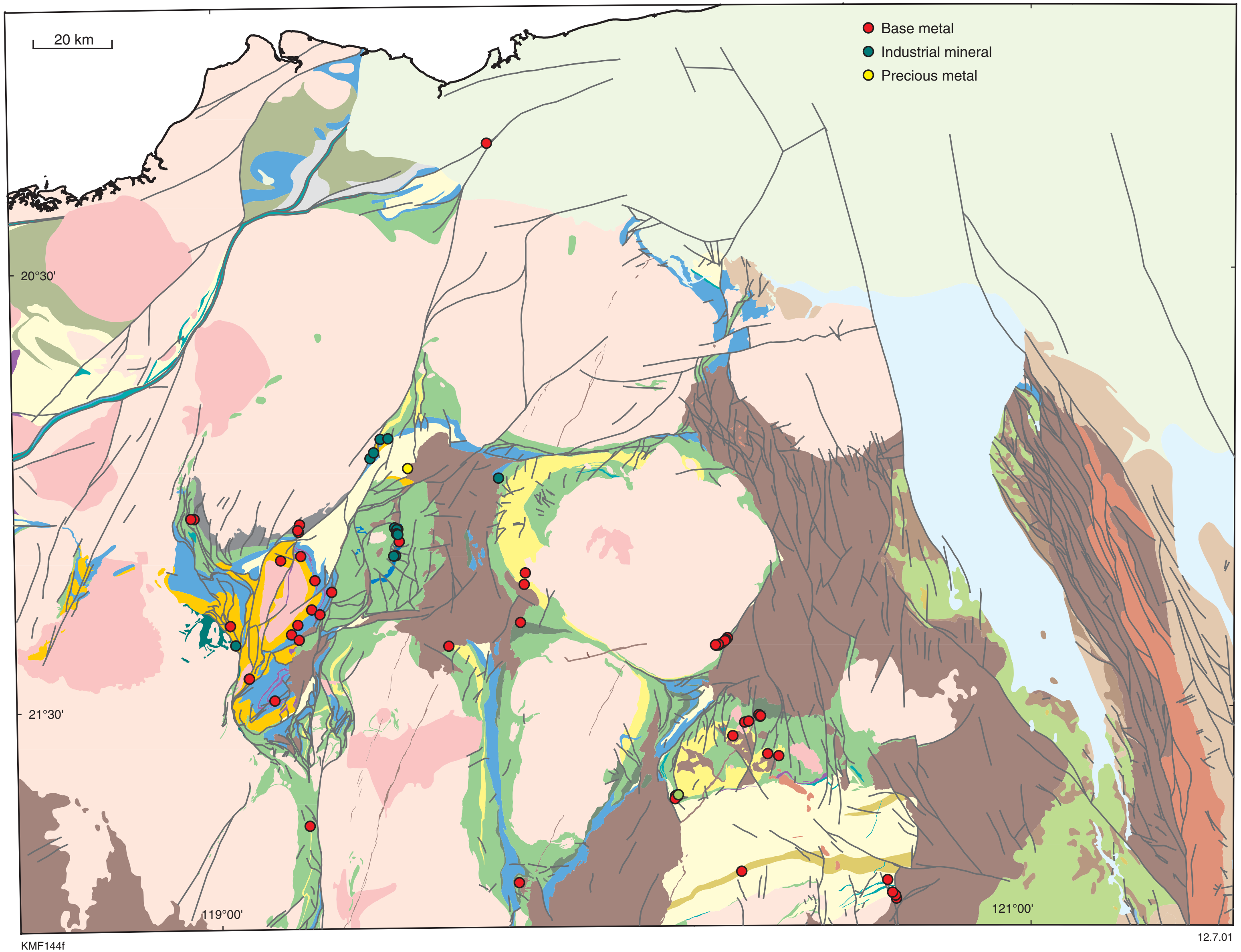

Figure 10. Distribution of stratabound volcanic and sedimentary mineral occurrences in the east Pilbara. See Figure 7 for geological legend

The Strelley Granite and the felsic volcanic rocks of the Kangaroo Caves Formation are geochemically similar. Van Kranendonk (2000) has interpreted the work of Vearncombe et al. (1998) and Brauhart (1999) as indicating that the outer phase of the Strelley Granite intruded a basic volcanic sequence containing felsic subvolcanic sills beneath a carapace of volcaniclastic and epiclastic sediments at the sea floor. The granite initiated hydrothermal circulation that leached metals from the volcanic sequence and created a silicified impermeable cap to the sequence. A second granitic intrusion, the inner phase of the granite, and comagmatic dolerite, caused asymmetric inflation of the granite sill, leading to the development of growth faults in the overlying volcanic sequence. These provided a pathway for convecting fluids in the volcanic rocks to precipitate sulfide minerals beneath the chert surface cap and in some cases onto the sea floor.

Gossans 6 km south of Marble Bar mark the Big Stubby deposit (**2778**), which is made up of seven massive subvertical lenses of Zn–Pb–Cu and Ba mineralization within felsic to intermediate (andesitic–rhyolitic) volcanic and volcaniclastic rocks near the top of the Duffer Formation (Plate 1A, Inset 6). The main gossan was first drill-tested in 1971 by Newmont and Narla Minerals. Subsequent exploration by a number of companies (including Aquitaine, BP, Alcoa, and Anglo American) established a deposit of limited size with a best intersection of 4.27 m at 14.1% Zn, 3.2% Pb, 840 g/t Ag, and 0.3% Cu (Ferguson, 1999).

Mineralization is associated with chert bands interlayered with turbiditic tuff and overlying a sequence of tuff breccias with minor intercalated volcaniclastic conglomerate and turbiditic tuff. Lenses of subaqueous pyroclastics are associated with the mineralization. Zinc–lead mineralization, including barite, lies stratigraphically above a copper-rich zone, whereas barite and gypsum are present in the lateral extensions of the lenses. Sphalerite, galena, pyrite, and barite are the main ore minerals, acanthite is the silver mineral (Ferguson, 1999).

Lead ages of 3500 Ma, obtained by Richards et al. (1981), are consistent with the c. 3470 Ma age of the Duffer Formation (Van Kranendonk et al., in prep.). Brook (1974) estimated reserves of 0.1 to 0.2 Mt at 13.8% Zn, 4.5% Pb, 305 g/t Ag, and 20% Ba.

At Lennons Find (Yandicoogina), a group of lenticular stratiform bodies (**4620**, **5085–87**, **5089–92**) bearing zinc, copper, lead, and silver lies in sheared sericite schists, calc-silicate rocks, and metamorphosed felsic volcanic rocks within the upper part of the Duffer Formation in the Warrawoona Group. The host rocks are felsic pyroclastic and pelitic to psammitic sedimentary rocks that have been overprinted by amphibolite-grade metamorphism. They are conformably overlain by mafic volcanic and minor ultramafic rocks (Hickman, 1983; Ferguson, 1999).

The main ore horizon extends about 4.3 km along strike, trending at about 055° and dipping at 40–60° southeast. Surface gossans contain malachite, chrysocolla, anglesite, cerussite, and hemimorphite. A chert beneath this zone is a useful marker horizon. Mineralization is massive (massive units are up to 4.4 m thick), thinly banded, and disseminated. It contains cobaltiferous pyrite, sphalerite, galena with silver (up to 180 g/t), minor chalcopyrite, and barite. Chlorite and carbonate alteration have been reported. The bodies are typically zinc, lead, and barium rich at the top, and zinc and copper rich at the base; the dimensions of the main Hammerhead lens are 400 × 300 × 2 m. A further five gossan anomalies have been defined along strike. Another three gossans are present in the stratigraphically lower Grey Nurse Zone.

Pb-model ages of between 3400 and 3500 Ma (Richards et al., 1981; Barley, 1992) are similar to the zircon U–Pb age for the Duffer Formation obtained by Thorpe et al. (1992a) of between 3471 ± 5 and 3465 ± 3 Ma.

In the late 1980s SIROTEM surveys gave some encouragement for the location of 'hidden' lodes; and possible 'stringer' zones to the stratiform mineralization were also being sought. Pilbara Mines acquired the property from SOG in 1997.

Sulfide mineralization is present at Copper Gorge (**4615**) in the Duffer Formation (cyclic mafic to felsic metavolcanic rocks) at the eastern end of the McPhee Dome. Three cycles of basalt, andesite, and felsic volcanic rocks capped by black chert, and dipping northwest at 20 to 25°, are present. The mineralization is in the top 30 m of felsic volcanic rocks of the lowermost cycle, within rhyolite and rhyodacite and coarse rhyolite breccia that accumulated between two growth faults, which may have acted as synvolcanic conduits. Mineralization occurs as pyrite, chalcopyrite, sphalerite, and quartz disseminations with minor galena. The development of mineralization appears erratic; it is accompanied by sericite, carbonate, and silica alteration.

The prospect was discovered by W. Mickle in 1964, and a small amount of copper ore was extracted in the following year. Cominco carried out 415 m of percussion drilling in 1966 and inferred a resource of 0.5 Mt at 0.5% Cu. Between 1969 and 1983, Australian Ores and Minerals undertook ground magnetic, IP, EM, and resistivity surveys, plus percussion and diamond drilling. The best drill intersection was 4.5 m at 2.25% Zn, 0.16% Cu, and 8 g/t Ag, and the mineralization was considered subeconomic. BHP included the prospect in a regional study carried out between 1977 and 1984 but considered the potential to be low.

At Middle Creek Au–Cu–Zn–Pb (**4628**) exploration by Aquitaine (1976–77) located small high-grade polymetallic gossans in volcaniclastic rocks and cherts of the Mosquito Creek Formation of the De Grey Group. The sequence has been extensively tectonized with upright isoclinal folding and axial-plane cleavage parallel to bedding. The gossans represent stratiform massive sulfide mineralization in exhalative chert and contain up to 21.5% Cu, 3.3% Pb, 7.25% Zn, 6.8% Sb, 35.5 g/t Au, and 380 g/t Ag. They are in the lower of two stratigraphic units representing distal volcanism. However, the zones of mineralization are very restricted. Small stringers, pods, and lenses up to 10 m long and 1.2 m wide extend over 200 m of strike. Other pods are found farther away.

Extensive supergene magnesite alteration may be related to the high base metal values in the gossans. More widespread prospecting in the area encountered only minor, but high-grade, occurrences in ironstone float. Two drillholes indicated that the mineralization in the gossans has very limited persistence with depth, although Aquitaine did not infer a supergene origin. Production of 7.5 t of oxide ore containing 5.3% Cu has been recorded for this prospect.

In the Fieldings Gully area of the Warrawoona Syncline, exploration was undertaken by Alcoa between 1978 and 1986 for base metals and gold in interfingering mafic and felsic volcanic rocks and felsic volcaniclastic rocks. Lead–copper–silver anomalism in rock chips (up to 4.2% Cu, 4.9% Pb, and 3800 g/t Ag) was located (e.g. Fieldings Gully Cu–Pb, **4634**). An inconclusive single percussion hole intersected malachite- and azurite-bearing stringers in siliceous sedimentary rocks with anomalous arsenic, antimony, and silver, but low base metals. This suggested that the base metal anomalism might be due to surface enrichment. Drilling of a gold anomaly 500 m to the west intersected quartzite, gossanous chert, sericite, and carbonate-rich rocks with zinc levels up to 0.56%.

At Abydos Zn (**4636**), between 1978 and 1982, Mount Newman examined base metal gossans for stratabound VMS, and located a subeconomic deposit in volcanic rocks of the Warrawoona Group. Three diamond drillholes intersected chalcopyrite, sphalerite, and galena with pyrite, pyrrhotite, minor barite, and rutile in felsic (andesitic–dacitic) fragmental rocks in contact with intrusive pyroxenite in a possible south-plunging complex mineralized zone. An approximate resource was estimated to contain about 2700 t Zn, 600 t Cu, 180 t Pb, and 2.4 t Ag. This was based on an average intersection of 4.5% Zn, 1.00% Cu, 0.3% Pb, and 40 g/t Ag, for a body with dimensions of 200 m × 100 m × 1 m. The best intersection was 1.35 m at 6.51% Zn, 0.56% Pb, and 0.99% Cu. Harris and MacDonald (1986) recommended follow-up of Mount Newman's drilling on the assumption that the company's drilled zone could lie in the marginal zone of a higher grade body.

Sedimentary-hosted sulfide

Base metal — copper, lead, zinc (silver, gold)

Exploration by CEC in the Coondamar Creek area in the 1970s outlined a number of prospects (Coondamar Creek CEC, **5828**; Coondamar Creek Mogul, **4614**; Coondamar Horse Creek Cu–Pb–Zn–Ag, **5830**).

Two gossans, 500 m apart, are present in metamorphosed sedimentary and felsic volcanic rocks in the Mosquito Creek Formation in the core of a tight north-northwesterly trending syncline between two northerly trending faults. The southern gossan (Coondamar Creek Mogul) covers an area of 3 m × 20 m and contains malachite, azurite, chrysocolla, cuprite, hydrozincite, smithsonite, and cerussite, with up to 27% Cu in surface samples. Primary mineralization consists of short intervals of pyrite, chalcopyrite, sphalerite, and galena in quartz–chlorite–sericite–feldspar schists in the southern gossan. Diamond drilling by CEC (1974–75) beneath the gossan gave intersections of 1.8 m at 1.1% Cu and 2.51% Zn; and 3.5 m at 3.9% Cu, 2.89% Pb, 3.12% Zn, and 189 g/t Ag.

The northern gossan (Coondamar Creek CEC) is largely pyritic at depth. Further north, Coondamar Horse Creek (**5830**) and Coondamar Creek Grit Cu (**5829**) appear to be in similar stratigraphic positions in the Mosquito Creek Formation. In the former, chips gave up to 18% Cu, 1.7% Pb, 19.5% Zn, 210 g/t Ag, and 1.75 g/t Au.

In the Tambourah belt at Tambourah Creek, exploration by Hawkstone between 1969 and 1973 in felsic volcanic–sedimentary chlorite–carbonate–quartz schists suggested potential for stratabound copper with up to 1.5 m at 5.1% Cu. Also, at Leilira Creek Cu–Zn–Au (**4551**), in the North Shaw area, Miralga Mining located a mineralized gossan 400 m long and 3 m thick in the core of a syncline in shales and sandstones of a turbidite sequence. Samples gave up to 1.05% Cu, 0.94% Pb, 1.12% Zn, and 1.5 g/t Au. At Supply Well Zn (**7460**), northeast of Goldsworthy, CRA located a narrow zone of high-grade zinc mineralization (0.85 m at 16.7% Zn, 0.38% Pb) in sulfidic cherts of the Cleaverville Formation.

Undivided mineralization (sulfates and sulfides)

Sulfate — barite

Several deposits of barite (Dresser Ba 1 and 2, **3171** and **3172**; North Pole Dresser Ba, **2834**; North Pole Ba 1–5, **3173–75**, **3187–88**) are present in the North Pole Dome within chert and silicified evaporite of the Dresser Formation, part of the Talga Talga Subgroup of the Warrawoona Group (Plate 1A, Inset 5). The main production of barite has been from the Dresser centre, at the southern end of an 8 km north–south trending zone of minor workings and occurrences. A total of 129 505 t of barite was mined, principally from the Dresser opencut, between 1970 and 1990. A total inferred resource of 500 000 t of barite has been estimated for the Dresser centre (Abeysinghe and Fetherston, 1997; Hickman, 1983).

Van Kranendonk (2000) has summarized the origins of these deposits within the recently refined context of volcanism within the Talga Talga Subgroup. The deposits formed as beds and mounds in the Dresser Formation, and within coarsely crystalline veins associated with black chert, which intrude the underlying Mount Ada Basalt. Features such as barite in basal diamictite layers, barite in fine laminations, and barite in coarsely crystalline mounds adjacent to synsedimentary growth faults (Nijman et al., 1998a), support a syngenetic, volcanogenic exhalative model for the origin of the deposits. The barite veins can be interpreted as part of a footwall vein-stockwork system. Nijman et al. (1998a) estimated a water depth of 50 m, probably within a restricted inshore-marine setting, which would be too shallow to allow boiling and the deposition of volcanogenic massive sulfides.

Large barite deposits, predominantly in sedimentary rocks of the Sulphur Springs Group, were discovered in the Miralga Creek and Cooke Bluff Hill areas during geological mapping by the GSWA (Hickman, 1977, 1983). In four locations (Miralga Creek Ba 1–4, **6039**, **6041–42**, **6044**), about 25 km north of North Pole, barite lies in veins within a sequence of tightly folded conglomerate, sandstone, and chert, and in barite sandstone, all overlying felsic volcanogenic rocks (Abeysinghe and Fetherston, 1997). As in the Dresser area, the associations and textures suggest the involvement of syngenetic volcanic exhalative processes in the formation of these deposits.

Sulfide — base metals

In the Bridget area, a number of base metal gossans with copper(–zinc–silver–gold–molybdenum) are in predominantly mafic volcanic rocks (**4983**, **6223–25**, **6229**). Maxima of 32% Cu, 19% Zn, 300 g/t Ag, 1.3 g/t Au, and 0.4% Mo were encountered in exploration by Anglo American in the mid-1970s. The gossans are both concordant and cross-cutting, and were presumed to be associated with fault zones.

In 1911, at a locality 2.5 km southeast of Marble Bar (**5096**), Cox and McDonald raised 4.83 t of copper ore containing 0.488 t Cu. This is possibly a VMS-style deposit. Production recorded in MINEDEX is 2.16 t Cu ore and 275.42 units of Cu as cupreous ore for fertilizer.

Stratabound sedimentary mineralization

There are 31 occurrences of stratabound sedimentary mineralization in the east Pilbara (Fig. 11). Of these, 28 are clastic-hosted (1 iron, 6 base metal, 18 gold, and 3 uranium), and there are 3 undivided, for industrial mineral.

Clastic-hosted mineralization

Precious metal — gold

About 2 km northwest of Nullagine there are palaeo-placer deposits of gold in the Beatons Creek Conglomerate Member of the Hardey Formation (basal Fortescue Group). These deposits include Grants Hill (**4465**), Freak of Nature (**4467**), and the Barneys Hill group of workings (**4471–72**, **4474**, **4483**, and **4485**). At this location, the Beatons Creek Member unconformably overlies Archaean metasedimentary rocks of the Mosquito Creek Formation and shows lithic content that indicates derivation from them. Hickman (1983) indicated that in this area the Hardey Formation was deposited on the southeastern side of a depositional basin, and that the placers probably formed in stream channels draining the area to the southeast.

Maitland (1905) and Hickman (1983) considered that the gold was detrital and derived from the Mosquito Creek Formation in the Nullagine to Middle Creek area. Maitland considered the gold to have entered the Proterozoic rocks in ‘percolating solutions’, but the form of the gold, partly as flakes and rounded particles, clearly indicates a detrital origin. The deposits show some similarities to the South African Witwatersrand placer deposits that formed in steep channels with no signs of reworking.

Base metal — copper, lead, zinc (silver)

The principal stratabound clastic-hosted mineral occurrences in the east Pilbara are in the far east of the area where Cu–Pb–Zn(–Ag) deposits and prospects lie in the Throssell Group (1100–850 Ma) of the Yeneena Supergroup, in the Paterson Orogen (see **Regional geology**). The Throssell Group is largely obscured by sand and lies to the east of the Vines Fault, on the eastern side of the Gregory Range. The base metal occurrences are all within the Broadhurst Formation, a transgressive shallow-marine deposit probably formed under euxinic conditions (Williams and Trendall, 1998a). One of its characteristic lithologies is a black to dark-grey carbonaceous siltstone and shale, which contains finely disseminated crystalline pyrite and framboidal pyrite.

Exploration by WMC in the Broadhurst Formation, within the east Pilbara area, led to the discovery of the Rainbow (**4692**), Rainbow South (**6114**), Warrabarty (**4694**), Hammerhead (**4696**), and Holly (**4693**) prospects (Williams and Trendall, 1998a; Ferguson, 1999).

At Rainbow (**4692**) and Rainbow South (**6114**) stratiform copper mineralization lies close to the western margin of the Yeneena Basin. It takes the form of a thin, sheet-like body of disseminated and massive chalcopyrite, with some bornite, in two layers within laminated chert and chloritic silty shale. This body is at the base of a thick sequence of carbonaceous sedimentary rocks above a pink quartz arenite, with disseminated sphalerite and rare galena. Separate lead–zinc mineralization is in carbonaceous shale and siltstone on the north limb of a northwesterly trending anticline. The combined thickness of the mineralized layers is 1 m or less, intersected in several drillholes over a distance of 4 km (Williams and Trendall, 1998a; Ferguson, 1999).

At Warrabarty (**4694**), fault-bound and stratabound, epigenetic zinc and lead mineralization is present in a sequence of massive crystalline dolomite, interbedded dolomite, and carbonaceous siltstone of the Broadhurst Formation. Mineralization is in a flat-lying sequence on the east limb of an anticline and in a north-northwesterly trending fault zone. The fault-bound mineralization is contained in a steeply dipping zone of intense solution breccia, dolomite vein-breccias, and dolomitization. The zinc mineral is sphalerite, on the margins of dolomite breccia-veinlets. Lead is present as galena in the vein breccia and in late-stage, steeply dipping dolomite veins. The stratabound mineralization is dominated by sphalerite, and lies in dolomite beds and shale units beneath crystalline dolomite. Minor disseminated to massive sulfide mineralization forms stratiform and crosscutting zones. Zinc contents are generally less than 4% and diminish to the northeast, downdip from the fault.

Three phases of dolomite formation are indicated, one as a replacement prior to mineralization, a void-filling phase probably synchronous with mineralization, and a post-sphalerite void-filling phase. Smith and Gemmell (1994) outlined a preliminary genetic model describing a complex sequence of epigenetic dolomitization of host

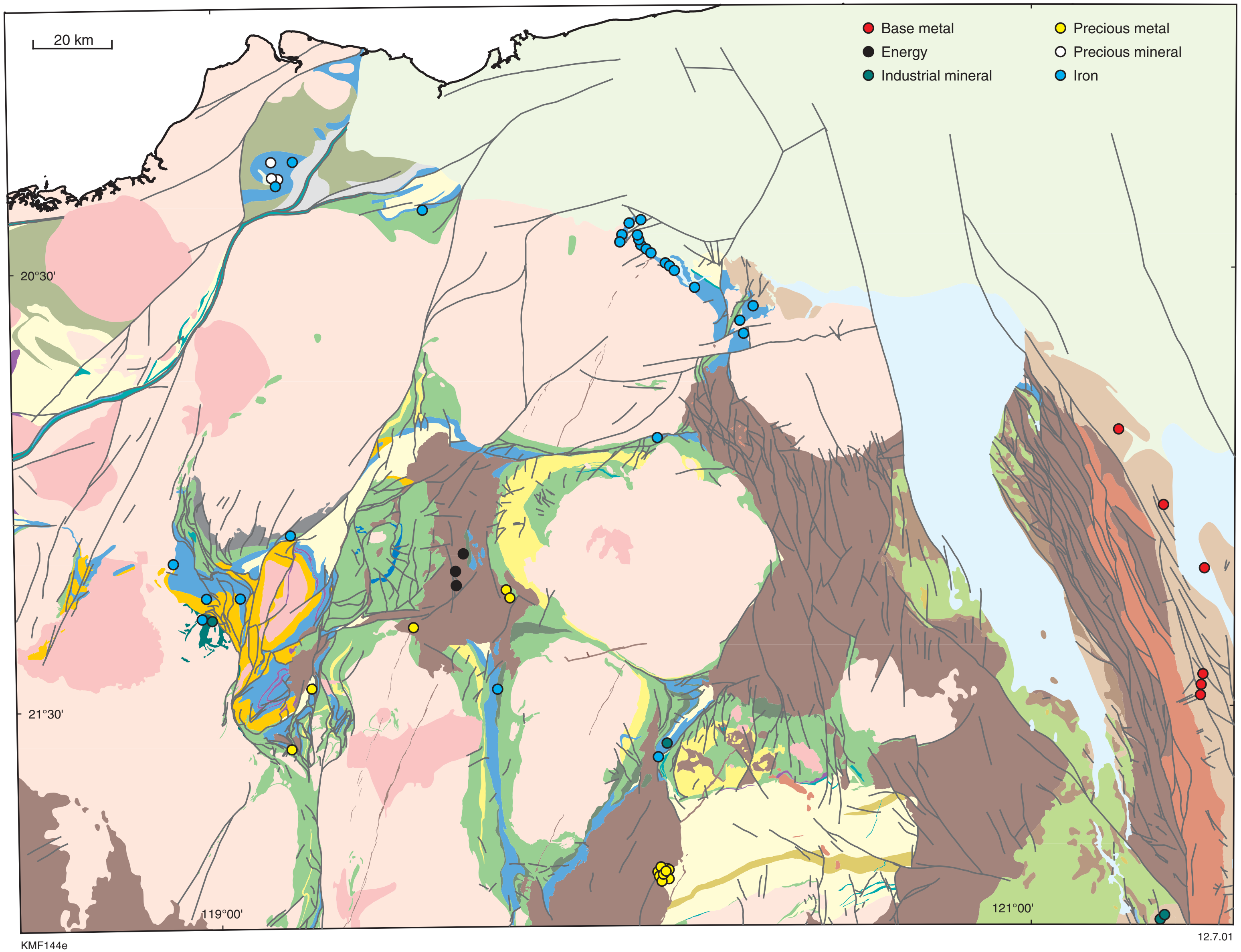

Figure 11. Distribution of stratabound sedimentary and sedimentary mineral occurrences in the east Pilbara. See Figure 7 for geological legend

rocks followed by carbonate dissolution, brecciation, mineralization, and hydrothermal dolomitization. The prospect is overlain by 80–150 m of Permian and Cainozoic rocks. Galena samples from the deposit record lead ages of about 900 Ma (Ferguson, 1999).

Warrabarty was discovered by WMC in 1984 during reconnaissance stratigraphic percussion drilling in an area defined by airborne magnetic and EM surveys, and anomalous surface geochemistry. The best intersection found up until 1991, in 114 percussion holes and 256 diamond holes, was 28 m at 3.67% Zn and 1.43% Pb. Other intersections include 14 m at 7.46% Zn and 1.3% Pb. Percussion drilling has defined an anomalous zone extending over an area of 4.5 km^2 (Ferguson, 1999).

In the Holly prospect (**4693**), discovered in 1983, disseminated zinc, lead, and copper mineralization is present in interbeded carbonaceous shale, dololutite, sandstone, and wacke on the south limb of a northwest-trending anticline. At the Grevillea prospect (**4695**), discovered in 1987, veins of sphalerite mineralization with anomalous lead and silver lie within a complexly faulted dolomite succession underlain by interbedded carbonaceous shale and carbonate. Drilling intersected a 66 m-thick zone of pyrite associated with an easterly trending fault. The Hammerhead lead, silver, and zinc prospect (**4696**), discovered in 1988 beneath 100 m of surficial cover, is in a thin crystalline dolomite in steeply dipping carbonaceous siltstones.

'Hematite-conglomerate iron ore'

The Yarrie 10 (Y10) deposit (**4137**), formerly known as the Kennedy Gap deposit, is in a unique iron-rich conglomerate unit of the Neoproterozoic Eel Creek Formation. The conglomerate consists of clasts of well-rounded pebbles and cobbles of hematite in a matrix of well-cemented, fine-grained hematite sand. It is presumed the conglomerate was sourced from the nearby supergene hematite-enrichment deposits at Yarrie known as Y2 and Y3, and that it formed in a marine near-shore environment in the Neoproterozoic (Waters, 1998; Centofanti, 2000). This conglomerate provides evidence that the period of supergene enrichment of iron at Y2 and Y3 (and by inference perhaps also in the Hamersley Basin) was at least pre-Neoproterozoic.

Hickman (1983) noted similar beds of ferruginous sandstone and conglomerate at the base of the Waltha Woora Formation (Tarcunyah Group) at Ripon Hills.

Energy mineral — uranium

As mentioned above (see **Exploration and mining**) minor amounts of uranium were located in the Hardey Formation of the Fortescue Group during exploration in the late 1960s and early 1980s. This exploration focused mainly on Blind River type placer deposits in the Hardey Formation and failed to locate any significant concentrations of uranium. WMC, Alcoa, Placer, Leopold Minerals, and others also explored for this style of mineralization, but obtained little encouragement. Alcoa intersected 0.3 m grading 1510 ppm U_3O_8 in a conglomerate above the Kylena Basalt.

Undivided mineralization

Minor occurrences of gypsum and barite are found in sedimentary rocks of the Manganese Group in the southeast corner of the study area (**4748–49**).

Sedimentary mineralization

There are 35 occurrences of sedimentary mineralization in the east Pilbara (Fig. 11). Of these, 34 are in banded iron-formation (28 of supergene-enriched iron, 2 of iron in taconite, and 4 of tiger eye in taconite), and there is 1 barite occurrence in chert.

Banded iron-formation (supergene enriched)

Iron

The supergene-enriched BIF ores are commercially the most important of the State's iron ore resources, and most of the iron production is from the Hamersley Basin from the Brockman Iron Formation and Marra Mamba Iron Formation of the Hamersley Group. The ores are referred to as supergene hematite and hematite–goethite ores, which have developed as a result of alteration and iron-enrichment processes involving supergene metasomatic replacement in BIFs (Morris, 1985; Blockley et al., 1990; Harmsworth et al., 1990). In the east Pilbara, supergene-enrichment ores form in BIFs of the Nimingarra Iron Formation and Cleaverville Formation (Fig. 12).

The iron ore deposits referred to by industry as 'detritals' are a category of iron-rich scree (talus) material that has developed adjacent to the supergene-enrichment bedrock source of hematite and hematite–goethite deposits (Preston, 1998). For the purposes of classification in WAMIN, these detrital ores are included with supergene-enrichment ores.

The main supergene-enrichment deposits in the east Pilbara are Mount Goldsworthy (**6058**, **7991**), Shay Gap (**4201**, **4206**, **4210**, **5413–14**), Sunrise Hill (**5406–07**), Nimingarra (**7879**), Yarrie (**4128**; Fig. 13), Cundaline Ridge (**5415**), Callawa (**5418**), and Ord Range (**7381**, **7990**). Descriptions of these and discussions of their ore genesis have been provided by Brandt (1964, 1966), Matheson et al. (1965), Neale (1975), Podmore (1990), and Waters (1998). In his account of ore deposits at Mount Goldsworthy, Brandt (1964) introduced the terms 'lode type', 'derived type', and 'crust type'. This terminology is exclusively used by Goldsworthy, but has not been adopted by other companies for supergene-enrichment ores in the Hamersley Basin. For comparison, the 'lode type' would equate to the typical major orebodies of the Hamersley Basin formed by the complex process of supergene metasomatic replacement and burial metamorphism (Morris, 1985; Waters, 1998); the 'derived type' would equate to detrital ores of the Hamersley Basin; and the 'crust-type' ores would equate to 'canga' ore formed as hardcaps by surficial alteration and duricrust formation during the Mesozoic and Cainozoic (Kneeshaw, 1984).

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Figure 12. Yarrie iron ore mine (Y2/3 pit), looking south

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Figure 13. Yarrie iron ore mine — basal unconformity of the (c. 3050 Ma) Nimingarra Iron Formation on the (c. 3440 Ma) Muccan Granitoid Complex. A thin basal sandstone on the angled contact with the granitoid is overlain by iron formation. Kimberley Gap and terminal loop of Yarrie – Port Hedland railway in centre; Callawa Plateau beyond this, to the south

Total iron production from the Goldsworthy operation is shown in Table 4.2 (Appendix 4).

Other supergene enrichment deposits and occurrences in the east Pilbara are at Strelley Gorge (**3250**), Pincunah (**2839–40**), Abydos North (**2775**), Lionel North (**5983**), and Kitty Gap (**7102**). Hickman (1983) noted there is possibly some potential in BIFs at Paddy Market Gorge.

Banded iron-formation (taconite)

Iron

There are small deposits of less-enriched taconite ores (30–40% Fe) at Pincunah (**7740**) and Blue Bar (**2930**).

Precious mineral

In the Ord Ranges (**8618**, **8620–21**, **8630**) the semi-precious mineral tiger eye has been worked from 30 to 40 m-wide seams within jaspilitic taconite ores in BIF. The tiger eye is golden-brown chatoyant material formed by oxidation and silicification of the asbestos mineral crocidolite (Blockley, 1976).

Undivided mineralization

Minor barite workings have been noted in chert in the Lionel area (**5982**).

Vein and hydrothermal mineralization

Undivided mineralization

There are 996 occurrences of vein and hydrothermal mineralization in the east Pilbara area. All have been classified as 'Vein and hydrothermal — undivided'. A total of 794 of these are of precious metal (predominantly gold), 170 of base metal, 15 of industrial mineral, 13 of steel industry mineral, 3 of speciality metal, and 1 of iron (Fig. 14).

Precious metal — gold (antimony)

Structurally (and lithologically) controlled vein and hydrothermal gold occurrences (also known as mesothermal or epithermal lode occurrences) are widely distributed throughout the east Pilbara, both spatially and stratigraphically. Since the late 1980s a very large number of research papers have considered this class of deposit, and there have been recent reviews by Groves (1993), Hodgson (1993), Solomon and Groves (1994), Pirajno (1994), Kerrich and Cassidy (1994), Groves et al. (1995), Witt and Vanderhor (1996), and McCuaig and Kerrich (1998). Common characteristics of the deposits, which also apply to those in the east Pilbara, are:

- They are late orogenic, and are found in metamorphic terranes;
- They are associated with major fault zones, or second or higher order splays, which have focused the flow of large volumes of metamorphic and igneous fluids;
- They are found in a wide range of brittle and brittle–ductile structures;
- They have developed in domains of lower strain where rock dilation has enabled mineralization to accumulate;
- The host rocks generally exhibit greenschist facies metamorphism.

In the east Pilbara these occurrences are predominantly hosted by mafic and ultramafic volcanic rocks, but are also found in metasedimentary lithologies, to a small extent in granitoid and porphyry, and are a source for alluvial and colluvial deposits in the regolith. Unlike vein and hydrothermal gold occurrences in the Yilgarn Craton, which predominantly formed at about 2640 Ma, recent data (Huston et al., 1999) indicate that those in the east Pilbara formed in at least two main periods: one at around 3500 Ma and the other at c. 2750 Ma (Fig. 7). For the East Pilbara Granite–Greenstone Terrane there are fewer recent detailed studies of gold mineralization than for the Yilgarn Craton. Most studies have been concerned with the Bamboo Creek group (Zegers, 1996; Zegers, et al. 1996, 1998, 1999) and the recently mined Mount York group (Neumayer et al., 1993, 1998). Also, a significant amount of recent exploration has been carried out in four specific areas. These are the Warrawoona area — exploration by Aztec–BP Minerals (Aztec Exploration Ltd, 1987, 1988, 1990); Lynas–CRA (Blewett and Huston, 1999); in the Bamboo Creek area (Atkinson and Partners, 1979); in the Pilgangoora area by Lynas (confidential reports); and in the Mosquito Creek area — exploration by Aztec (Bell, 1987), Kismet (Baxter, 1992), and Golden Eagle NL (Yates, 1990).

Comparative studies of many of the east Pilbara centres, with an emphasis on structural control and timing of mineralization, have been carried out by Huston et al. (1999), Blewett and Huston (1999), Huston et al. (in prep.), and Blewett et al. (in prep.). Van Kranendonk and Collins (1998) and Van Kranendonk et al. (in prep.) have conducted a detailed structural analysis of the Warrawoona Syncline. Finally, recent 1:100 000-scale mapping (Hickman, 2001a, in prep.) has enabled further refinement of the structural setting in this area.

The gold mineralization in the east Pilbara is decribed below under the headings of the various mining centres and groups of mines. Centres in the EPGGT (3270–3440 Ma) are described first, followed by those in the Mosquito Creek Basin and the Mallina Basin (c. 2900 Ma).

East Pilbara Granite–Greenstone Terrane

Bamboo Creek

The Bamboo Creek Mining Centre has produced a total of 6512.489 kg of gold from 799 350 t of ore (averaging 8.15 g/t as a recovered grade) between 1897 and 1995 (60% of the total production has been since 1986). The mineralization is hosted by the Euro Basalt in the upper Warrawoona Group, which contains a high proportion of ultramafic and metasedimentary rocks within massive tholeiitic and high-Mg basalts. The main control for mineralization is the bedding-parallel Bamboo

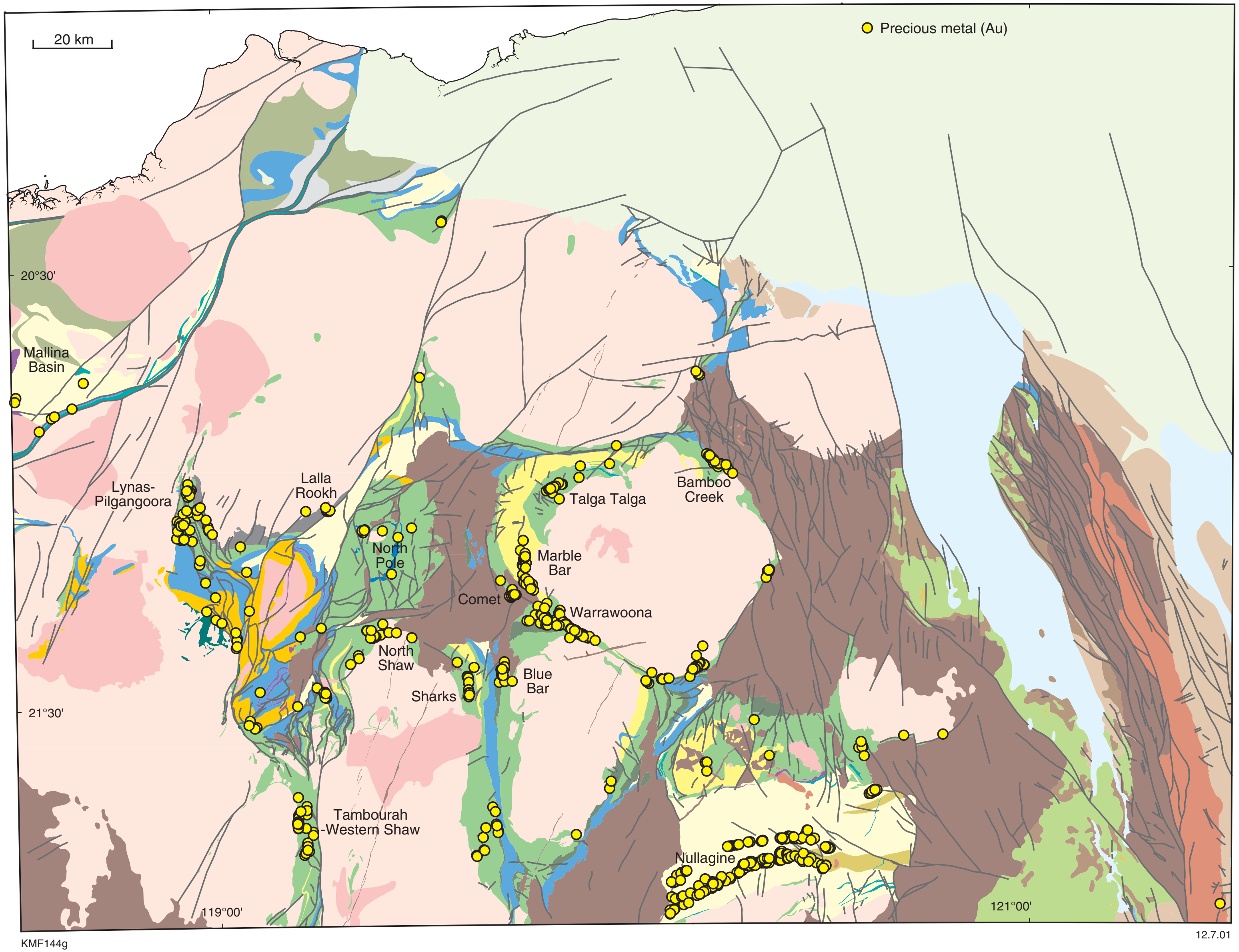

Figure 14. Distribution of vein and hydrothermal — precious metal (gold) mineral occurrences in the east Pilbara. See Figure 7 for geological legend

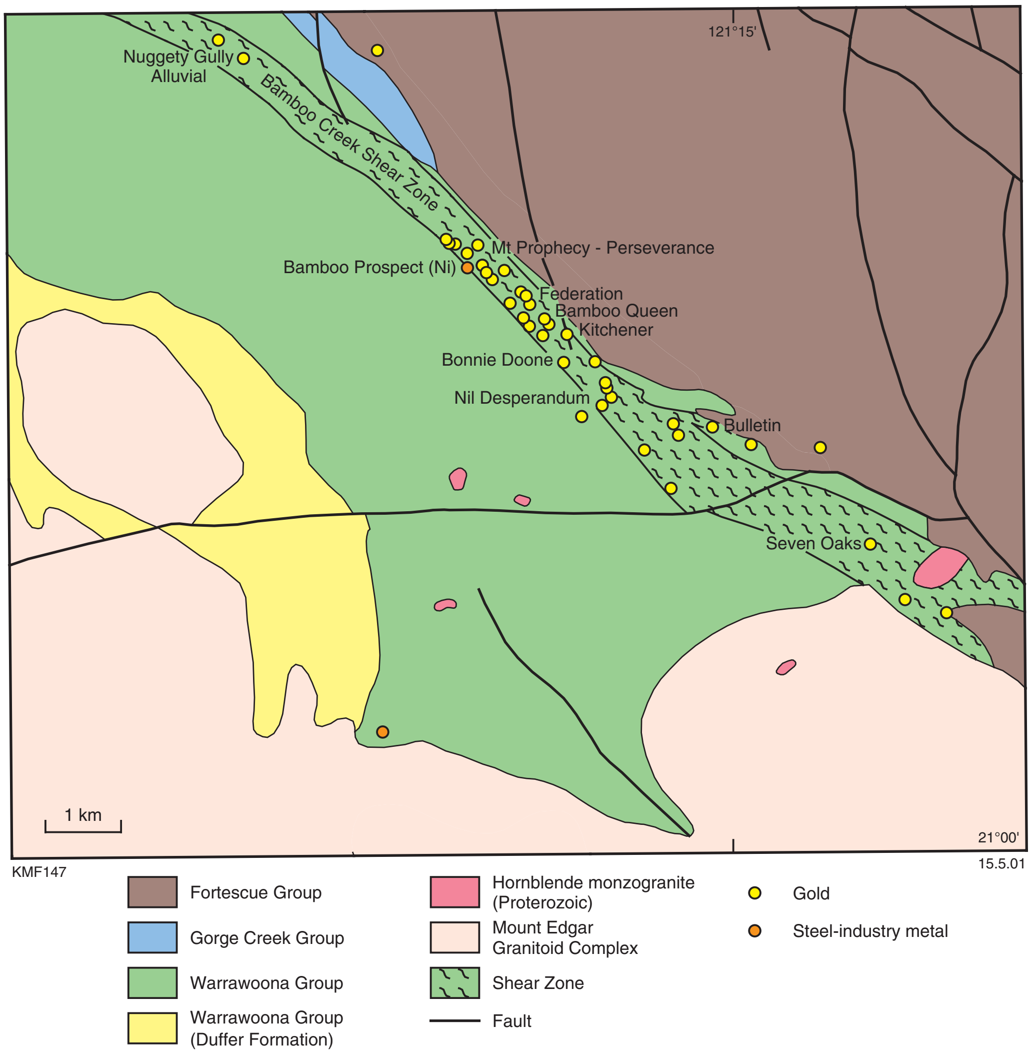

Figure 15. Bamboo Creek area – mineralization and structure

Creek Shear Zone (Fig. 15) that contains serpentine-rich and talc-rich ultramafic rocks (Williams, 1999a; Zegers et al., 1996). The shear zone is arcuate and about 30 km long and appears as a zone of talc–chlorite mylonite schist with pods and boudins of carbonate- and silica-altered komatiite. Some 33 occurrences, ranging from underground mines to pits and minor old workings, are present in the main mineralized zone over a strike length of 5 km.

The gold is concentrated in quartz- and carbonate-veined ductile shears in boudins, which are related to a sinistral/northeast-up kinematic framework (Zegers et al., 1996). In the Kitchener underground mine (**4014**) the boudin contains three gold lodes that are offset by later northerly trending dextral faults. Elsewhere, in the Prophecy–Perseverance line (**4047**, **4049**, **4057**, **4065**, **7466**) mineralized zones are similar. They contain sulfides (galena, tetrahedrite, pyrite, sphalerite, and gersdorffite), and gold is within laminated and micro-brecciated quartz–carbonate veins up to 3 m wide. Most of the recent production has come from the Kitchener mine, Prophecy–Perseverance mines, and from Bamboo Queen (**4029**) (Plate 1A, Inset 4; Fig. 16).

The Bulletin mine and opencut (**4004**) lie on a crosscutting, dextral strike-slip fault that offsets part of the Bamboo Creek Shear Zone. Carbonate–talc–chlorite–fuchsite rock and talc–chlorite schist are common, in a similar host suite to that at Prophecy–Perseverance and Bamboo Queen.

A Pb–Pb model age of 3400 ± 40 Ma (Zegers, 1996) is probably close to the age of mineralization at Bamboo Creek, in view of the close association of galena with the mineralization.

Warrawoona

In the Warrawoona area gold mineralization is concentrated in a narrow zone of parallel shears on the northern limb of the Warrawoona Syncline. Here, mafic and ultramafic units of the Warrawoona Group (along with felsic volcanic rocks of the Duffer Formation) and the younger Wyman Formation, become attenuated and are faulted out by shearing to the east-southeast between the Mount Edgar and Corunna Downs Granitoid Complexes (Plate 1A, Inset 6; Fig. 17). Historical production from the Warrawoona area totals 935.105 kg

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Figure 16. The Bamboo Queen pit and adit (looking northwest) within the Bamboo Creek Shear Zone, in komatiitic schists of the Euro Basalt

Au from 21 924 t ore recorded between 1898 and 1983.

A total of 122 occurrences of vein and shear-hosted gold are present over 19 km of strike in this area (Fig. 18). Most of these are relatively small old workings that reported high grades of gold related to surface enrichment. The majority lie within, or close to, the Klondyke–Salgash Shear Zone, and are hosted by steeply dipping ultramafic carbonate schists. Relatively large production was reported over about 1500 m of strike, from mines that lie parallel to, and about 50 m north of, the main shear zone. The mines include Gauntlet (**3431**, produced 141 kg), Klondyke Queen (**2814**, **3442**, produced 40.5 kg), and Klondyke – Klondyke Boulder (**3450**, produced 438 kg).

In the western part of the Warrawoona area, the bulk of the occurrences appear to lie south of the western extension of the Klondyke Shear Zone, at the Wyman centre, which includes the Salgash–Apex area and the Copenhagen mine (**2792–93**). This area appears to be dominated by a number of sub-parallel shear zones, expressed as highly silicified zones of shear-parallel felsic and ultramafic volcanic and volcaniclastic rocks expressed as cherty ridges (see **Fieldings Gully**, **other base metal occurrences**, below). These shear zones appear to coalesce towards the Klondyke–Salgash Shear Zone, and are probably truncated by it. Within this western zone the Copenhagen mine has been a significant producer, with 7.1 kg Au brought out between 1938 and 1968. Several shafts were sunk here to access copper–gold mineralization in quartz veins that are parallel to the west-northwesterly trending foliation, bedding, and shear trends. The mineralization lies within carbonatized ultramafic rocks and mylonite that occupy a 12 m-wide belt flanked by chert horizons, proximal to one of the shear zones.

Other related sub-parallel lines of gold prospects include the Crystal Tuff line of minor workings, the Coronation Ridge line of prospects (**3968–69**, **5569**, **5627–28**, **5633**) in iron-rich chert, the Euro mine (**3381**), and the Salgash–Apex (**3073**, **3386**) line northwest of Copenhagen. These linear groups of workings lie within the northern limb of the Warrawoona Syncline, and are truncated by the north-northeast trending Salgash Fault.

Recently, updated models have been proposed for the tectonic development of the Warrawoona Syncline and the associated shear zones that appear to control the gold mineralization in the Warrawoona centre. Collins and Van Kranendonk (1999) and Van Kranendonk et al. (in prep.) proposed a model based on a diapiric, 'dome and keel' granite–greenstone evolution of the east Pilbara (see **Regional geology**). In this model, partial convective overturn in the crust, due to doming of the Mount Edgar and Corunna Downs Granitoid Complexes, produced the Warrawoona Syncline and subsequent diapirism led to downwarping, to produce a deep 'keel' of greenstones. The vertical stress caused by the tilting of the Mount Edgar Granitoid Complex during this process is considered to have been taken up in part by the Klondyke–Salgash Shear Zone. This led to the juxtaposition of high-grade, kyanite-bearing greenstones north of the fault against low-grade equivalents to the south.

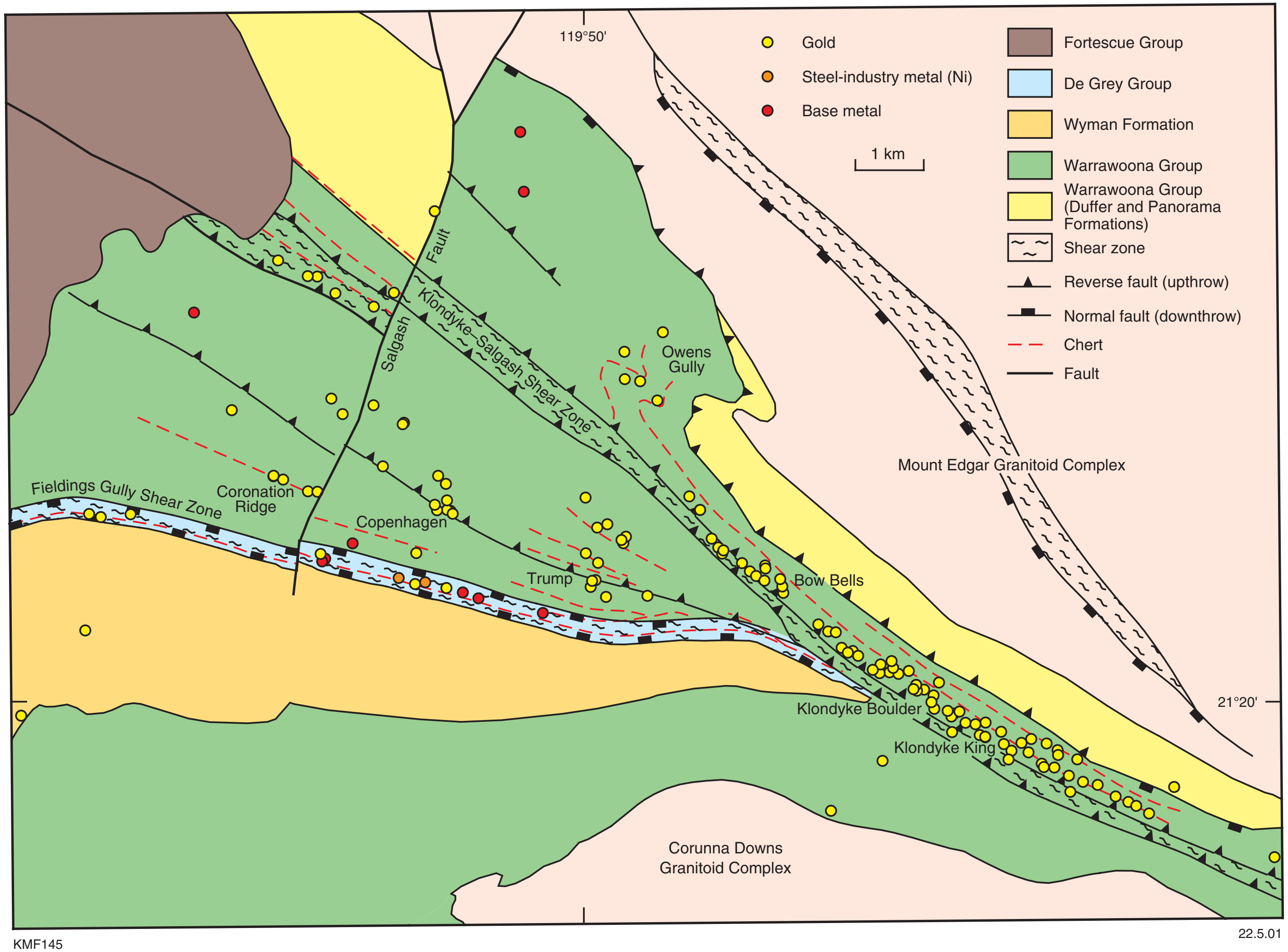

Figure 17. Warrawoona area — mineralization and structure

Figure 18. The Warrawoona Syncline, in the vicinity of the Klondyke Shear Zone, looking west from the Klondyke King mine area toward the Klondyke Boulder mine

Recent mapping by the GSWA in the Warrawoona Syncline has enabled Hickman (2001a, in prep.) to further refine the model for this downwarping process. He suggested that two types of shear zone have developed within these narrow keels of greenstone belts lying between the granitoid domes. Marginal shear zones are developed at, or close to, the contact between the granitoid dome and the greenstone sequences, as a consequence of differential movement during diapirism. During the same process, major axial faults have developed within many greenstone keels, in response to the considerable downward, graben-style differential displacement within synclinal cores. The Klondyke Shear Zone belongs to a third type of fault formed by layer-parallel shearing during the doming process (Hickman, 2001a).

The Fieldings Gully Shear Zone and a number of lesser shears (Fig. 17) appear to be truncated by the Klondyke–Salgash Shear Zone. It may be significant that the main cluster of gold occurrences and deposits in the area lies adjacent to, and just north of, that intersection, suggesting that ore-bearing fluids in both shears contributed to the Klondyke group. During the course of Hickman's recent mapping (Hickman, in prep.) he has noted that the metasedimentary rocks in this highly mineralized zone are less competent than the other units, and that they may thus have contributed to the degree of vertical slippage and provided a focus for the concentration of gold (Fig. 19).

Blewett and Huston (1999) noted that the pervasive subvertical lineation prominent in this zone, has been produced by two orthogonal foliations. They described sheared and boudinaged sulfide-bearing veins that have developed with long axes plunging gently in a steeply dipping fabric. They also quoted Vearncombe (Vearncombe, 1995, *in* Blewett and Huston, 1999) as having identified four phases of deformation, with the main schistosity associated with mineralization.

These considerations would suggest a mineralization age of about 3.3 Ga, which is consistent with the timing of the D_2 structural regime related to the doming of the granitoid complexes. Huston et al. (in prep.) have obtained a scatter of Pb-model ages from deposits in the Warrawoona area (3.05, 3.37, and 3.385 Ma). They suggested three possible reasons for this, including a genuine scatter of mineralizing events, the sourcing of Pb from regions with heterogeneous Pb isotope characteristics, or the mixing of Pb from more than one hydrothermal event. They proposed a broad range between 3430 and 3370 Ma for all gold mineralization in

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Figure 19. Panorama (looking toward northwest) of the old shaft and pits at the Klondyke Boulder mine in the Warrawoona area. The ridge in the background is a highly tectonized zone of quartz–carbonate veining, showing a vertically plunging intersection lineation, possibly associated with late remobilization of the gold

the Warrawoona Group. However, the Fieldings Gully Shear Zone (Fig. 17) clearly post-dates deposition of the c. 3325 Ma Wyman Formation, and the shear zone was probably active after deposition of the c. 2950 Ma De Grey Group (Hickman, 2001a).

It seems, however, that the clear close association of the gold mineralization with D_2 structures in the Warrawoona gold centre would favour an age between 3300 and 3325 Ma. If the Klondyke–Salgash and Bamboo Creek Shear Zones can be regarded as related structures, then a similar age may also apply for part of the gold mineralization at the Bamboo Creek centre.

Comet

The Comet group contains 17 occurrences (**2786**, **3368–73**, **5989**, **7600–01**, **7615**, **7617**, **7622**, **7626–29**), and is located about 7 km south of Marble Bar (Plate 1A, Inset 6). This group was a significant producer, with production of about 3818 kg Au, mainly in the 1930s to early 1950s. The gold is in a 2 m-wide zone of pyritic chlorite–fuchsite–carbonate rock with a thin veining of quartz and carbonate minerals. Before mining, the mineralized zone was about 40 m long and dipped to the south at about 70°. The main ore shoot plunges east-southeasterly at 40°, controlled by the intersection of a zone of fracturing and the regional schistosity (Hickman, 1983).

As a result of recent mapping, Hickman has suggested that there may be a structural connection between the Warrawoona and Comet mineralized centres (Hickman, in prep.). Figure 20 is the satellite image of the Warrawoona–Comet area and shows a fault in the Mount Roe Basalt of the Fortescue Group. The fault is in line with the trend of the Klondyke–Salgash Shear Zone to the south. Hickman suggested that this fault is related to an earlier shear structure that connects the two mineralized centres beneath rocks of the Fortescue Group (Hickman, in prep.).

Marble Bar

There are 29 gold occurrences in the Marble Bar group, extending in a 3.7 km north–south line, about 1 km east of the town (Plate 1A, Inset 6). The group is within carbonatized mafic schist of the Warrawoona Group, overlain to the west by felsic volcanic rocks of the Duffer Formation and underlain to the east by granitoid. The mineralized zones, which strike northerly and north-westerly and dip at 10 to 20° to the west, consist of thin auriferous quartz veins within, and marginal to, sills of metadolerite (Hickman, 1983).

Recent GSWA mapping (Hickman, in prep.) suggested that this mineralization is controlled by a doming-related layer-parallel shear in the Duffer Formation — a shear related to the upward movement of the granitoid body, rather than the later sinking of the syncline. Shearing and alteration occurred preferentially within the dolerite and other mafic rocks, whereas the felsic volcanic rocks of the Duffer Formation were much less deformed.

Much of the total production of 1298 kg came from the Homeward Bound (**2807**, **3349**), and Stray Shot (**3352–55**, **3357**) groups in the late 19th century and from about 1935 to 1950.

Sharks

At the Sharks Mining Centre a number of mines operated at the end of the 19th century and in the 1930s to early 1950s. The main producer was the Mount Ada mine (**3363**, **3367**, **5573–74**, **5576–77**) where gold occurs in folded quartz veins in carbonate–chlorite schist of the Warrawoona Group. The carbonate–chlorite schist and the immediately underlying felsic schist have been deformed by a layer-parallel shear zone.

The main operations were on the eastern limb of an anticline trending 330°. The main shoots are in parasitic drag folds on the main structure, which pitch north-northwesterly at 70° (Finucane, 1939a; Hickman, 1983). Gold grades were up to 100 g/t over 0.5 m in some areas. The workings are about 50 m deep. Recorded production between 1898 and 1981 for the group of mines (including Mount Florence) was 1935 t of ore (averaging 36.28 g/t) to produce 70.2 kg of gold.

Talga Talga

In the Talga Talga centre, narrow stratabound quartz veins in quartz–carbonate–chlorite schist of the McPhee Formation (Warrawoona Group), were mined between the 1890s and 1940 for a total of 1902 t of ore (averaging 30.84 g/t) to produce 60.6 kg of gold. A similar amount may also have been won from alluvial material (Hickman, 1983). The major producer, the McPhee Reward mine, targeted lenticular quartz bodies and stringer zones over a 400 m strike length.

Hickman (1983) considered that mineralization at Sharks and Talga Talga occupies the same stratigraphic level and is broadly similar in style. Subsequent SHRIMP U–Pb zircon geochronology (Nelson, 2000, in press) has confirmed that the host rocks at the two centres are the same age — c. 3477–3470 Ma.

Yandicoogina

The historic line of gold workings at Yandicoogina, worked predominantly at the turn of the 19th–20th centuries, may be an eastern extension of the Warrawoona line, though the setting, as Hickman (1983) noted, is rather different, being at the margin of the greenstones. This group of workings produced 3304 t of ore (averaging 60.76 g/t) to produce 201 kg of gold.

Mineralized quartz veins are present in a zone of intense shearing along the southern margin of the Mount Edgar Granitoid Complex. Veining is present in felsic schist (metamorphosed sedimentary and felsic volcanic units of the Duffer Formation in the Warrawoona Group) and in sheared granitoid. In the largest mine of the group, Uncle Tom (**4318**), the main mineralized shear zone is flanked by granitoid.

North Pole

The Normay mine (**2833**) is located in sheared mafic schists (metabasalt) of the Talga Talga Subgroup of the

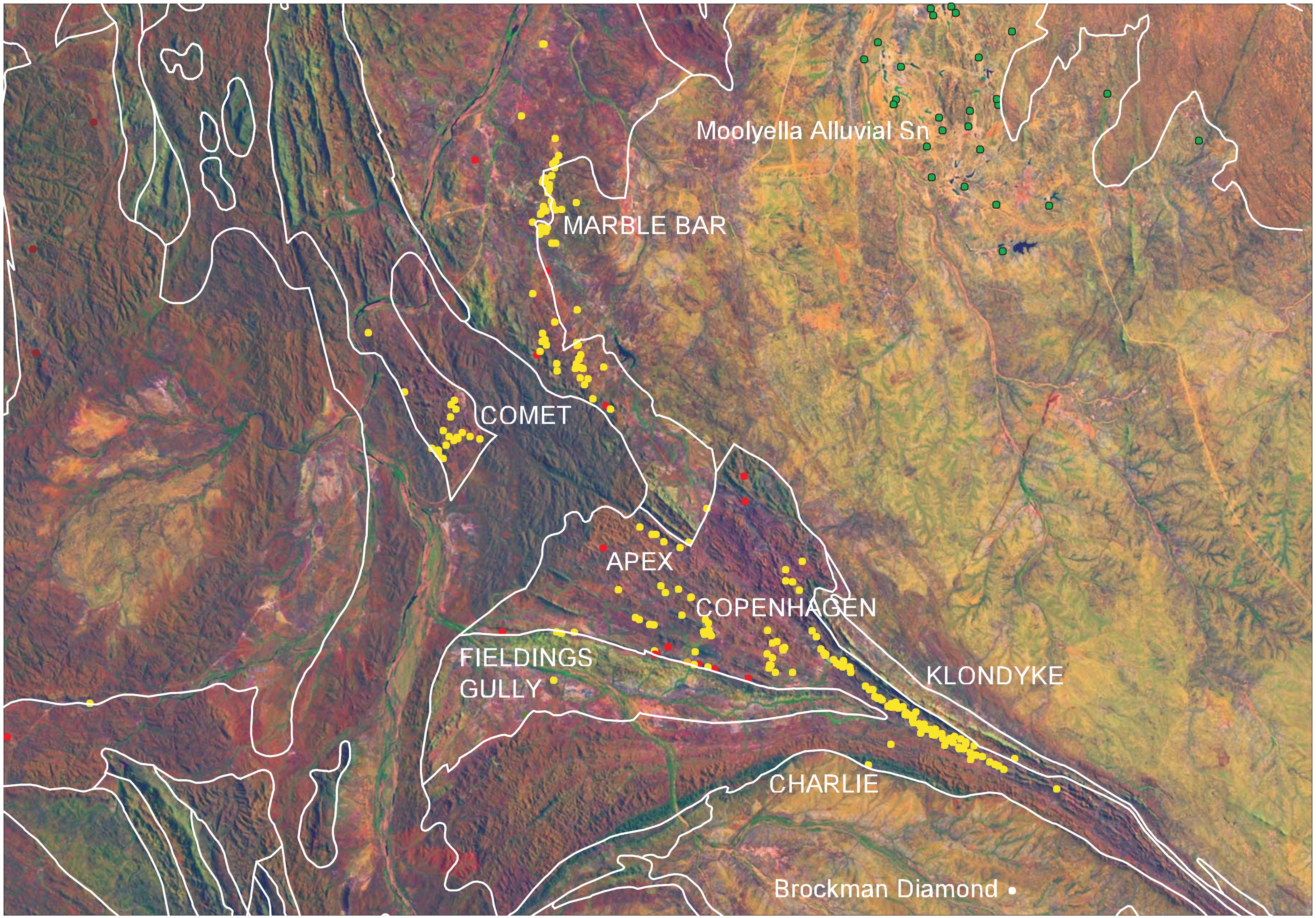

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Figure 20. **Landsat image of the Marble Bar – Warrawoona area. Mineral occurrences are marked as coloured circles as follows: yellow — vein and hydrothermal gold; red — vein copper–lead; orange — vein nickel; green — alluvial and pegmatitic tin and tantalum; white — kimberlitic diamond. See Plates 1 and 1A for geological units**

Warrawoona Group, close to the northern contact of the North Pole Monzogranite in the North Pole Dome (Plate 1A, Inset 5). Much of the early production was recorded between 1949 and 1957, but recorded production continued until 1972, giving a total of 6243.31 t of ore mined (averaging 15.5 g/t) to produce 96.77 kg of gold. More recent production in the period between 1988 and 1994 yielded 1052.7 kg of gold.

The gold is in a 1.3 m-wide quartz vein striking approximately easterly over about 1 km and dipping at about 80° to the north. It has been worked as an opencut over a length of 400 m, and to a depth of 10 m. Hickman (1983) considered the mineralization to be related to the 3459 Ma intrusion of the monzogranite. The Breens (**3157**, **3160**, **3163**), Try Again (**4544**), and Democrat (**3161**) mines, with a couple of other smaller workings on the northwestern side of the monzogranite, were mined between 1899 and 1912 for about 11 kg of gold, and accessory copper. The veins appear to be of a stockwork type that intrude felsic porphyry (Hickman, 1983). The gold mineralization at the Normay mine gives a Pb-model age of 3406–3392 Ma (Thorpe et al., 1992b; Huston et al., in prep.).

Lalla Rookh

The Lalla Rookh gold mineralization (**2815**, **2817**, **2912–13**, **7569**) is hosted by chlorite–carbonate schist in relatively undeformed mafic volcanic rocks of the Tabletop Formation in the Coonterunah Group (Van Kranendonk, 2000). The mineralized quartz–carbonate material forms saddle reefs in the fold hinges of tight easterly trending upright folds, and subconcordant veins in the fold limbs. Mining took place between 1920 and 1940, with recorded production of 3631 t of ore yielding 80.6 kg of gold (Fig. 21). The current holders, Haoma, re-evaluated the resources in 1996–97, estimating 22 000 t of ore at 2.5 g/t at North Reef, 199 000 t at 1.9 g/t at South Reef, and 47 000 t at 2.81 g/t at South Reef Shoot. This gives a total of 268 000 t of ore at 2.11 g/t for 565.5 kg of contained gold, with further potential at depth in the shallow plunging South Reef (Van Kranendonk, 2000).

Huston et al. (1999) described the mineralized quartz lodes as being within an easterly trending, vertically dipping shear zone, which is sub-parallel to the foliation but transects it. Thorpe et al. (1992b) dated galena from Lalla Rookh at c. 3188 Ma.

Tambourah – Western Shaw

In the Tambourah centre (**2967–73**, **5455–56**, **7783–85**), gold was mined mainly in the l890s and sporadically in the 1920s, and 1940s to 1950s. Gold is in strike-parallel northerly trending mineralized quartz veins, up to 0.6 m wide, within amphibolitic schists and metasedimentary rocks of the Warrawoona Group (Plate 1A, Inset 3). The richest deposits lie in a 1 km-long reef, 300 m east of the margin of the Yule Granitoid Complex (Hickman, 1983). A total of 2062.8 t of ore (averaging 31.61 g/t Au) has yielded 65.2 kg of gold from the centre.

The Western Shaw centre is broadly similar in style, host rock, and structural orientation to Tambourah (Hickman, 1983). Mining took place predominantly

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Figure 21. Headframe at the old Lalla Rookh gold mine (North Reef), looking to the north

before 1900, with recorded production totalling 1111 t of ore to produce 26.1 kg of gold.

North Shaw – Daltons

Patchy, low-grade gold was obtained from Big Bertha (**3135**) and other shallow workings in the late 1800s and in the1920s and 1930s. Mineralization is in northerly and easterly trending veins in metamafic rocks of the Mount Ada Basalt, in the Talga Talga Subgroup of the Warrawoona Group.

About 20 km to the southwest is the Daltons group of mines, which include McLeods Reward (**3084**) and Eclipse (**3090**). Production, mostly in the 1920s, came from a north-northwesterly striking line of quartz and quartz–carbonate veins in interleaved mafic and ultramafic schists (possibly sheared layered-mafic intrusions of the Dalton Suite). A total of 26.3 kg of gold was produced from 1163 t of ore between 1897 and 1975. Thorpe et al. (1992a) dated galena from the Big Bertha mine at c. 2988 Ma.

Mercury Hill

At the Mercury Hill prospect (**3240**), Lynas Gold NL has estimated a shallow inferred resource of 60 000 t of ore averaging 3 g/t Au. Mineralization is in highly sheared and altered fuchsite schists in the Numerous Scrapes Shear Zone, along a contact between unassigned ultramafic rocks and felsic volcanic rocks of the Sulphur Springs Group. Grades of up to 7.6 g/t Au were identified in exposures of dark-grey quartz veins (Van Kranendonk, 2000).

Lynas–Pilgangoora

Gold mineralization within the Pilgangoora greenstone belt lies within mafic and ultramafic rocks of the Warrawoona Group (Fig. 22 and Plate 1A, Inset 2). The only exception is the Mount York group of deposits that are hosted by BIF of the Gorge Creek Group.

Production in the area began in the 1930s in the McPhees group (**3575–76**, **6280–82**, **6286**, **6677**) and at Birthday Gift (**5469**). Birthday Gift had a second period of production between 1964 and 1981, and Iron Stirrup (**2808**) also operated in the 1960s. Total production for the McPhees group for the period 1932 to 1981 is 3057 t of ore for 21 kg of gold.

Recent production from 1994 to 1998 by Lynas Gold came from the McPhees North (**2826**) and South (**5468**) pits, and from the Main Hill (**2823**), Breccia Hill (**2782**), and Zakanaka mines (**2865**, **7883**) in the Mount York area. A total of 3822.9 kg of gold was produced.

AGSO has undertaken preliminary studies of gold mineralization in the Pilgangoora belt (Huston et al., 1999), and these suggest four generations of structures in the area. A major northerly trending, bifurcating, D_1 thrust–shear zone is considered to control and host the mineralization at the McPhees, Iron Stirrup, and Old Faithful (**6676**) mines, as well as other minor deposits and prospects (Fig. 22). Within the shear zone, boudins of mafic and ultramafic country rocks lie in a 50 to 500 m-wide zone in highly strained talc–chlorite schists that formed by the shearing of komatiite and serpentinized peridotite units.

Most of the deposits in this zone show evidence of mineralization being concentrated by competency contrasts between the sheared talc–chlorite schist and the more resistant mafic boudins, indicating a flow of mineralizing hyrothermal fluids. Alteration at boudin margins also suggests that the mineralizing fluid was in chemical disequilibrium with the mafic lithologies, and that this enhanced the mineralization process.

At Iron Stirrup, mineralization is along the eastern, sheared margin of a large serpentinite boudin (Figs 23 and 24), whereas at McPhees the mineralization is in elongated orebodies in large mafic boudins that trend parallel to the D_1 foliation (Huston et al., 1999).

Mineralization has also been recently studied at the Main Hill, Breccia Hill, and Gossan Hill (**5467**) deposits. These deposits are within easterly to northwesterly trending amphibolite and BIF of the Gorge Creek Group. The rocks are metamorphosed to talc–carbonate–chlorite schist interbedded with quartzite containing up to 20% magnetite (Neumayer et al., 1998). The gold is hosted by mineralized breccias with angular to boudinaged quartzite clasts in a sulfide-rich matrix and in wall rocks marginal to quartz–biotite veins (Huston et al., 1999). Immediately south of the mineralized horizon this zone is in contact with a hanging wall of mica schist within the Corboy Formation of the Gorge Creek Group.

The Zakanaka North and South deposits are along a northwesterly trending sheared contact between mafic and ultramafic schists. At Zakanaka South the mineralized lens occurs as an irregular stockwork of sulfidic quartz–calcite veins within quartz–biotite amphibolite schist. These deposits have been dated at 2888 ± 6 Ma using a Pb–Pb isochron of alteration minerals (Neumayer et al., 1998).

The small working at Birthday Gift (Fig. 22) illustrates another deposit type in the Pilgangoora area. The mineralization is in saccharoidal quartz veins within strongly foliated metabasalt, which is in contact with foliated granitoid of the Carlindi Granitoid Complex. The foliation in the basalt in this area is folded into a shallow south-southwest plunging anticlinorium, interpreted as D_4, whereas the workings follow a mesoscale ?D_5 antiform (Huston et al., 1999).

Mosquito Creek Basin

In this area gold is hosted by structurally controlled zones of quartz veining along shear zones within metamorphosed turbiditic psammitic and pelitic sedimentary rocks of the Mosquito Creek Formation in the De Grey Group (c. 2950–2900 Ma), deposited within the Mosquito Creek Basin (Plates 1 and 1A, Inset 8; Fig. 25).

The predominantly low metamorphic grade Mosquito Creek Formation has an unconformable contact with the Warrawoona Group to the north and has been subjected to a complex multiple-deformation history (Blewett et al., 2000, in prep.). The earliest D_4 deformation (D_4a) has imparted a strong east-northeasterly slaty

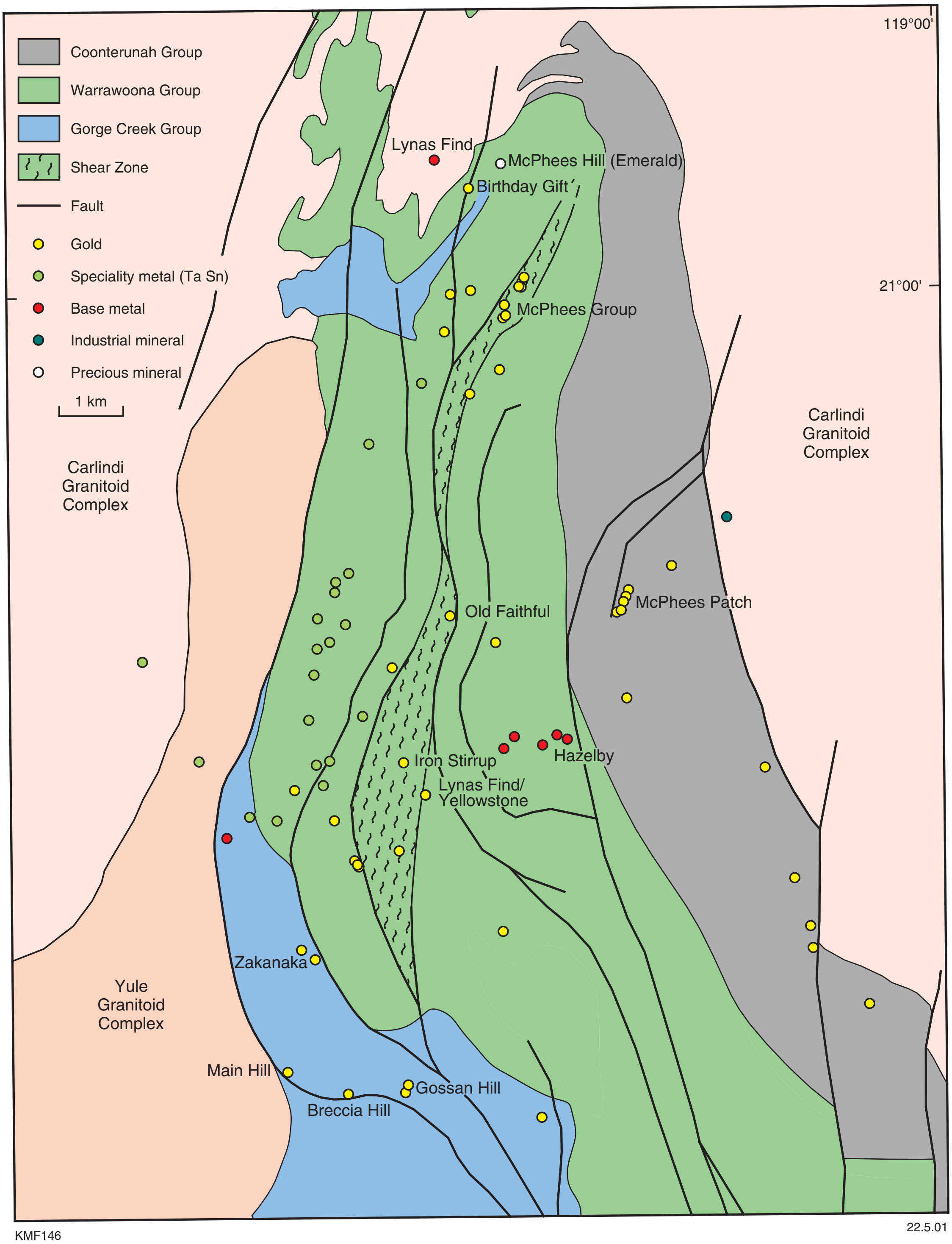

Figure 22. Pilgangoora–Lynas area — mineralization and structure

cleavage. Deformation is more intense in the pelitic lithologies and in zones of silicification that form prominent topographic ridges. Following a fine crenulation (D_4b) that overprints D_4a, shear zones have formed parallel to the D_4a cleavage, in response to northwesterly thrusting. This deformation has formed well-defined east-northeasterly trending 'belts' of particularly intense shearing, mapped on NULLAGINE (Thom et al., 1979) as *Amp* (pelitic schist and phyllite).

Two well-defined lines of gold occurrences, including historic mines and more recently explored prospects, stand out in the regional distribution, coinciding with the D_4c shear zones (Fig. 25). The southern line, known as the Middle Creek line, is about 45 km long, and includes the Five Mile Creek and Middle Creek Mining Centres (Fig. 25). Mineralization also extends to the southwest, passing through the Golden Eagle group; and to the east, passing through the Little Wonder and Galtee More

KMF165 23.07.01

Figure 23. The recently abandoned Iron Stirrup pit. The main shear (in the centre of the picture) lies between a large competent serpentinite boudin to the right, and weathered carbonate schists to the left. Mineralization is in the pale zone to the right of the shear, which was presumably controlled by the competency contrast

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Figure 24. Iron Stirrup pit — a fractured chert boudin with mineralized margins

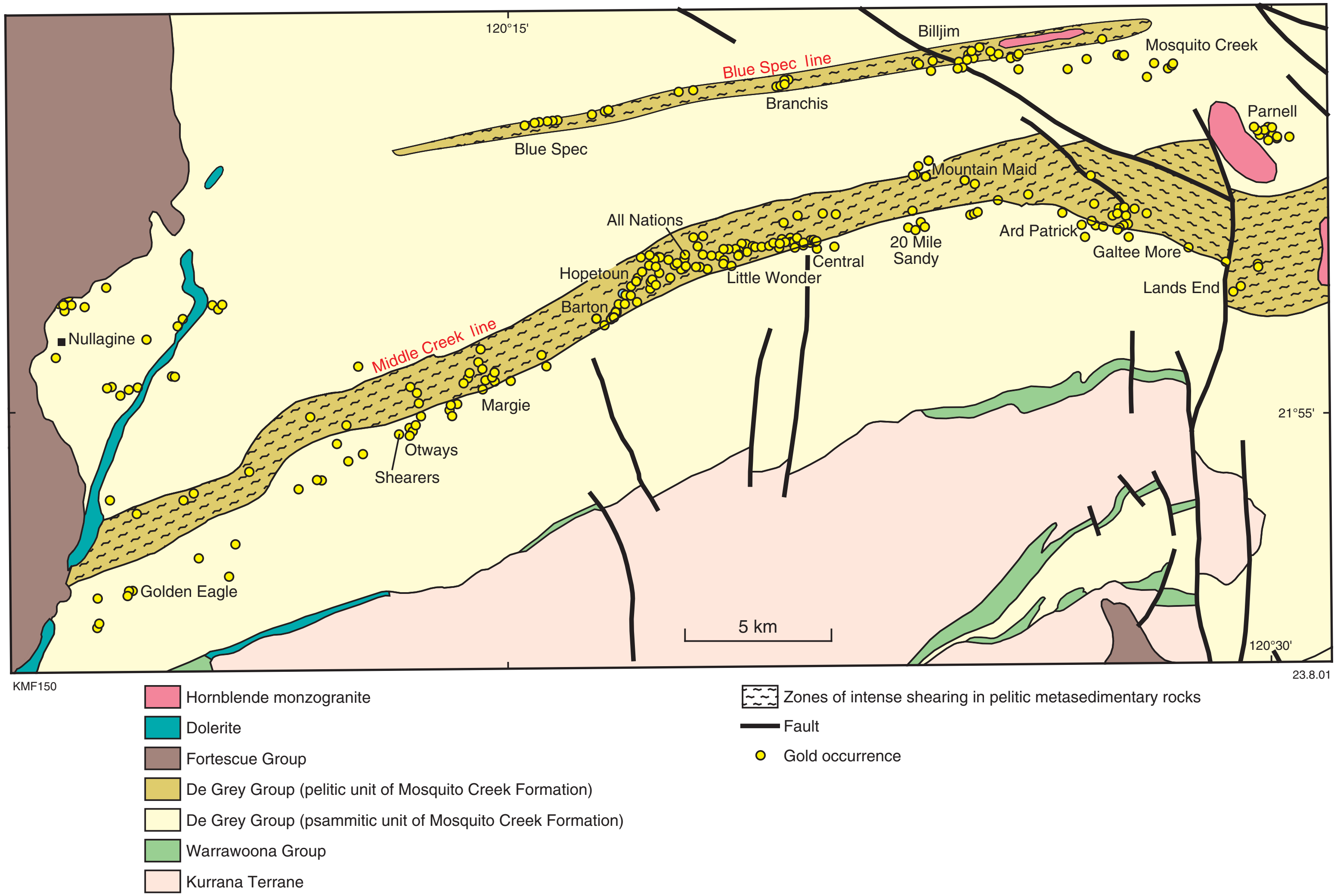

Figure 25. Nullagine – Mosquito Creek area — gold mineralization and structure

groups. The northern line, known as the Blue Spec line, hosts deposits that contain both antimony and gold in veins and sheeted veins. The occurrences lie along a strike line of about 30 km and include the Blue Spec mine and Golden Spec deposit, and also the Branchis, Billjim, Golden Gate, and Mosquito Creek groups of deposits.

Nullagine — Middle Creek line

The Middle Creek Mining Centre was in production from the late 1800s through to the 1960s. This group of deposits has produced a total of 717.81 kg of gold from 31 408 t of ore (averaging 22.85 g/t Au), and it includes the All Nations (**4268**, **5661–64**), Hopetoun (**4263**, **4266**), and Barton (**4253**, **4255–57**) groups of mines (Plate 1A, Inset 8).

The Middle Creek line of gold mineralization shows a clear spatial relationship with the southern east-northeasterly trending line of shearing that occurs over a strike length of about 45 km. In detail the distribution of mineralization within this stratigraphic–structural zone is more complex (Huston et al.,1999; Blewett et al., in prep.). Although the groups of occurrences and deposits lie parallel to the east-northeasterly trend, within each of the groups there are cross-cutting relationships, even on a macro scale (Fig. 25). This is particularly obvious in the Five Mile Creek and Middle Creek areas, where groups of deposits and occurrences, such as Margie, Barton–Hopetoun, and All Nations, follow northerly to north-easterly trends. Blewett et al. (in prep.) indicated that within the Middle Creek line the deposits show a diversity of styles.

Golden Eagle: The Golden Eagle group of old workings and prospects (**4550**, **6640–46**) include a new deposit, Golden Eagle 2 Au (**5654**), which has recently been defined by Welcome Stranger at the southwestern end of the Middle Creek line. Golden Eagle 2 Au has a resource estimated to contain 10.1 t of gold, and it lies on the northern upright limb of a major inclined east-plunging D_2 fold in low-grade metapelitic and meta-psammitic rocks. The ore is associated with abundant pyrite, both in veins and disseminations, and rutile, magnetite, chalcopyrite, sphalerite, and galena are also present. Quartz veining and mineralization tends to be broadly stratiform and more concentrated in psammitic units, or in mixed psammitic–pelitic units, which have presumably been more inclined to brittle fracturing. The deposit, in its lack of carbonate, resembles lode gold deposits in the Yilgarn (Blewett et al., in prep.).

The gold mineralization is interpreted as being relatively late, controlled by fractures and faults intersecting a pre-existing D_2 structural geometry. The original Golden Eagle workings are associated with narrow ferruginous quartz veins dipping easterly to southeasterly in highly cleaved siltstone; the veins were very high grade (up to 145 g/t Au).

Shearers and Otways: At the Shearers prospect (**5655**), 10 km east-northeast of Golden Eagle, mineralization is hosted in two fault-controlled discontinuous quartz veins trending at 20°. These intrude coarser lithologies (conglomerate, psammite, and grit) at a high angle to the main east-northeasterly trend of the Middle Creek line. These steep dextral faults offset the bedding by 80 m and also offset the Middle Creek line. The faults may be reactivated syn-sedimentary growth faults (Huston et al., 1999; Blewett et al., in prep.).

In the Otways deposit (**5656**) and prospect area, deep shafts have exploited a 200 m-long zone (trending 55°) in boudinaged quartz veins in foliated metapelites and meta-psammites. About 50 m south of these old workings, east-northeasterly trending, subvertical, mineralized quartz veins are found in a conglomerate bed, and appear to be controlled by it (Huston et al., 1999; Blewett et al., in prep.).

Barton–Hopetoun: The related Barton and Hopetoun deposits have a complex structural history of folding and refolding, and several generations of shearing are recognized by Huston et al. (1999) and Blewett et al. (in prep.).

The Barton deposit was the biggest producer (between 1898 and 1926) in the Middle Creek group, with 6521.34 t of ore (averaging 36.53 g/t Au) to produce 238.25 kg of gold. The mineralization lies within pelitic schists, and is hosted by northeasterly to north-northeasterly striking quartz reefs that dip to the southeast initially at about 60°, but become shallower at depth within the mine (Hickman, 1983; Huston et al., 1999). The four ore ‘shoots’ of the main reef are described as plunging to the northeast at about 40°. This orientation coincides with the intersection of the quartz veins and the cleavage of the pelitic schists (Hickman, 1983). Blewett et al. (in prep.) described the mineralized, anastomosing quartz veins as being associated with D_4 shearing at c. 2900 Ma.

The Hopetoun line of deposits, northeast of Bartons, has a similarly complex structural history involving folding and refolding, with several generations of shearing (Blewett et al., in prep.). The main fabric is a cleavage to schistosity, which has been extensively reworked by later shearing, with quartz veins deformed into boudins parallel to the fabric. The main shear sense suggests a northwest-directed thrusting event. The shear zone is a north-northeasterly trending extension of the Barton reef and it lies parallel to the surface expression of the mineralized quartz reef (Fig. 25).

Nullagine — Blue Spec line

Gold and antimony mineralization in the Blue Spec line of workings is developed in metaturbidites within an east-northeasterly trending arcuate shear zone that is 15 to 20 m wide. The Blue Spec mine (**4345**) is a major producer in the east Pilbara, with a total of 995.59 kg of gold produced from 54 245.67 t of ore (averaging 18.35 g/t Au). Other occurrences and old workings include the Golden Spec deposit (**4348**), a similar but smaller occurrence that lies 1 km to the west of Blue Spec. The Branchis (**4354**, **6206–08**) and Billjim (**4355**) groups of old workings lie to the east of Blue Spec, and the Golden Gate mine (**4357**) is at the eastern end of the 20 km structure (Plate 1A, Inset 8; Fig. 25).

Mineralization is found toward the north and south margins of the shear zone. The mineralized centres coincide, in similar fashion to the Middle Creek line, with a high incidence of east-northeasterly to easterly trending zones defined by D_4a schistosity and D_4c shearing in pelitic lithologies (Huston et al., in prep.).

The mineralized bodies dip vertically to steeply south and contain stibnite, aurostibnite, and native gold associated with pyrite, pyrrhotite, and carbonate, plus minor scheelite, arsenopyrite, marcasite, sphalerite, chalcopyrite, magnetite, mackinawite, calaverite, rickardite, and gudmundite (Hickman, 1983; Gifford, 1990).

Shearing appears to be synchronous with the mineralization, and shearing has controlled the size and shape of mineralized bodies, as pods or lenses, and deformed stibnite crystals (Hickman, 1983). Gifford (1990) considered that the Blue Spec mine is located at a flexure in the Blue Spec shear zone, a broader zone where more shear planes exist. Irregular mineralized reefs, up to 30 m long and 5 m thick, have developed on some of the shear planes, within intensely brecciated rock.

At the Golden Spec mine, mineralization is in a single tabular body (only 1 m thick) in a narrow, but essentially similar, extension of the shear zone (Gifford, 1990).

Mallina Basin

The other main area of De Grey Group rocks in the east Pilbara is to the northwest of the Tabba Tabba Shear Zone, at the western margin of the project area, where sedimentary rocks of the Mallina Formation and Constantine Sandstone lie adjacent to the shear zone. The rocks are bisected by the eastern extension of the Mallina Shear Zone, known to host c. 2900 Ma turbidite-hosted gold mineralization in the Indee project area (of Resolute) in the west Pilbara (Ruddock, 1999).

De Grey has recently released information on gold occurrences discovered during a joint venture with CRA. These are in the Tabba Tabba Shear Zone (Fig. 14; Winter, 2000) where shallow ?RAB drilling intersected 8 m at 5.62 g/t Au and 28 m at 1.13 g/t Au (**8363**, **8365–66**). Resolute has also located gold near Mount Berghaus (**4622**), just north of the Mallina Shear Zone, with aircore drilling giving a best intercept of 3 m at 12.8 g/t Au (from 33–36 m).

Base metal — copper, lead, zinc (silver, gold)

Vein and hydrothermal base metal occurrences are scattered throughout the Archaean greenstone belts of the east Pilbara (Fig. 26), but there are some notable groups: in the McPhee Dome, in the North Pole Dome, and in the Kelly greenstone belt. The other significant grouping of occurrences is in the Gregory Range, in the faulted sedimentary and felsic volcanic rocks of the Fortescue Group.

McPhee Dome

Quartz Circle

Lead–zinc mineralization was located at Quartz Circle (**4640**) by Alcoa in the 1970s during exploration for copper–zinc in calc-alkaline, intermediate to felsic volcanic and volcaniclastic rocks of the Duffer Formation. Both massive and vein-type base metal mineralization appear to be present. Marshall (2000) considered that mineralization at this prospect may have epithermal affinities.

Percussion and diamond drilling by Alcoa between 1976 and 1980 intersected 15% pyrite, with traces of galena and sphalerite. Particular intersections of 7.2 m at 22.5% Zn, and 14.14 m of massive sphalerite with 28.5% Zn, 0.33% Cu, 0.51% Pb, 0.145% Cd, 68 g/t Ag, and 0.5 g/t Au were located in coarse agglomerate and breccia. Sphalerite is found in cerussite- and gypsum-lined veins, with traces of pyrite and galena. The mineralization is in the Quartz Circle Member (uppermost Duffer Formation) within dacitic pyroclastic rocks (coarse- to fine-grained subaerial tuff) that are subhorizontal and dip gently to the south. Follow-up work in the vicinity by BHP between 1977 and 1984 tested for gold mineralization in quartz–sulfide stockwork veins within the same unit. Clackline (now Herald Resources) acquired the prospect in 1983 and explored it in joint venture with Pancontinental Mining.

North Pole Dome

The North Pole Dome is 35 km in diameter and consists of a granitoid core that is surrounded by mafic to felsic volcanic and metasedimentary rocks (including cherts) of the Warrawoona Group. Barite mineralization occurs in the chert horizons within tabular, stratigraphically controlled, chert bodies and in fracture-controlled chert boxworks (see also **Stratabound volcanic and sedimentary — undivided**).

Miralga Creek

Gold, zinc, lead, and copper mineralization at Miralga Creek (**2950–51**, **4648**, **7033–37**) has been interpreted as transitional between epithermal style and porphyry copper styles (Goellnicht et al., 1988), and it is associated with a felsic porphyry stock in subaqueous to subaerial basalt, dolerite, and minor chert of the Warrawoona Group. Disseminated, stringer, vein, and hydrothermal breccia-hosted mineralization occurs around the marginal intrusive breccia of the stock and in association with porphyry dykes. An early phase of pyrite–chalcopyrite mineralization is followed by a later phase with a sphalerite–galena–tetrahedrite–silver–gold assemblage that is characterized by vertical zoning. The associated alteration mineral assemblage reflects potassium metasomatism.

Fluid-inclusion studies (Goellnicht et al., 1988) indicated that the main alteration and mineralization is partly due to a dominantly magmatic, high-temperature, high-salinity fluid. Later, a fluid of lower temperature and salinity, dominated by seawater, was also involved. The complex zoning and alteration are interpreted to be related to the mixing of these fluids, and the metals are considered to have been transported as chloride complexes. The age of the porphyritic host rocks has been established as 3449 Ma by zircon U–Pb dating (Thorpe et al., 1992a). A Pb-model age obtained from galena at Miralga Creek gives a range of 3447 to 3451 Ma (Groves, 1987).

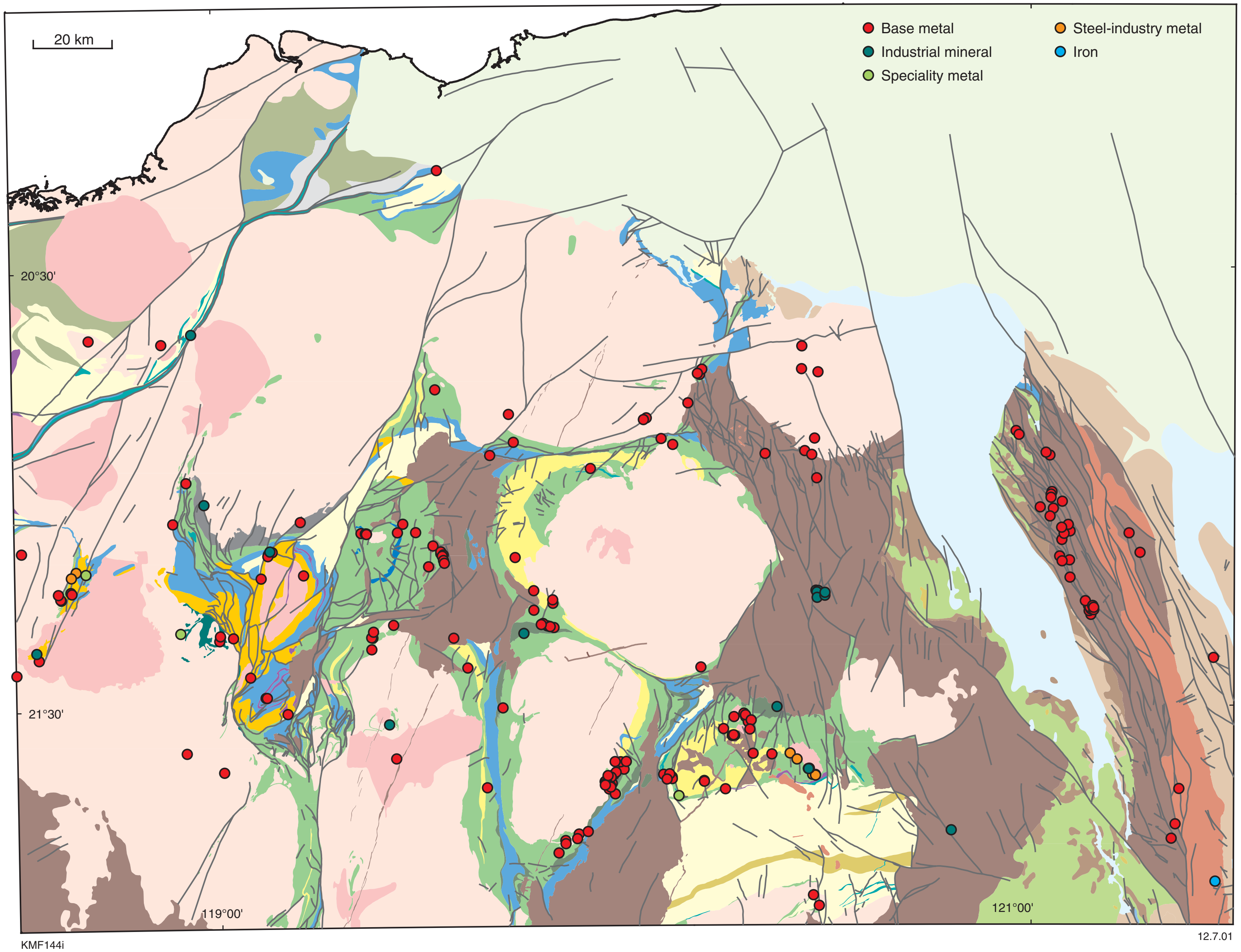

Figure 26. Distribution of vein and hydrothermal — undivided mineral occurrences for commodity groups other than gold, in the east Pilbara. See Figure 7 for geological legend

Marshall (2000) has pointed out that the cockscomb, comb, and crustiform textures, the sphalerite–galena–tetrahedrite–Ag mineral assemblage, and the association Pb–Zn–Cu–Ag–Au–As–Sb(–Hg–Bi–Ti–Se) are typical of low-sulfidation epithermal systems. The mineralization appears to reflect a poorly mineralized felsic porphyry hydrothermal system that has been overprinted by later vein, stringer, and breccia-hosted epithermal mineralization.

The prospect was explored by Sipa–Ashling following earlier work by Miralga Mining. In an area 2–5 km west of the main prospect, exploration by Noranda between 1984 and 1988 located minor quartz–barite–galena–cinnabar veining, with up to 6.6% Pb and 0.2% Zn, in felsic dykes and pyroclastic rocks.

Breens

A number of base metal and precious metal deposits and occurrences are present within the North Pole Dome. These appear to have formed at low temperatures, near the palaeosurface (Marshall, 2000). The Normay gold deposit is described above (**Vein and hydrothermal mineralization**).

The Breens copper deposit (**3157**, **3160**, **3163**) is a complex, northeasterly striking belt of stratabound mineralization, 500 m wide, consisting of stockworks and silicified breccia zones within mafic to felsic volcanic and volcaniclastic rocks of the Duffer Formation (Marston, 1979; Marshall, 2000). Drilling of an easterly dipping breccia zone within this belt yielded massive sulfides, including pyrite, chalcopyrite, chalcocite, covellite, neodigenite, and native copper. Between 1973 and 1985, CEC tested a stratiform zinc anomaly in felsic and intermediate volcanic rocks (1700 ppm Zn and 980 ppm Pb in rock chips) in an area surrounding the Breens copper mine (Marston, 1979). Drilling intersected up to 2 m at 0.12% Cu, 0.51% Zn, and 10.5 g/t Ag.

In this general area, Blockley (1971a) reported a vein containing galena associated with quartz, cerussite, malachite, and barite, which was worked in 1949 for about 0.6 t lead. Concentrates assayed 50–80% Pb and 180–500 g/t Ag.

Kelly greenstone belt

Copper Hills – Kellys

Two groups of copper mines and prospects lie in the Kelly greensone belt, west of the McPhee Dome (Plate 1A, Inset 7): the Copper Hills group (**2896**, **3074**, **4633**, **5050**, **5948**, **5988**, **6979**, **6981**) and the Kellys group (**2953**, **3098**, **3143**). Mineralization is within felsic volcanic rocks of the c. 3325 Ma Wyman Formation and related high-level felsic intrusive rocks (Marshall, 2000; Bagas and Van Kranendonk, in prep.).

The Copper Hills mine is the only significant producer of copper in the east Pilbara area, producing 1960 t Cu from 1952 to 1963, and 15 456 t of cupreous ore between 1954 and 1963. Primary mineralization (pyrite and chalcopyrite) is disseminated in a felsic porphyry and along fractures. However, there is no quartz-vein stockwork and no association with molybdenum. Other prospects in the belt, including the Kellys mine, are considered by Marston (1979) to be related to shears, breccias, veinlets, and stockworks. Witt et al. (1998) considered the mineralization to be epithermal-style at Copper Hills, Miralga Creek, and Breens.

Gregory Range group

The Braeside lead field occupies an elongate mineralized area within the central part of the Gregory Range along the eastern margin of the east Pilbara area (Fig. 26). Lead production was about 3000 t between 1925 and 1951. The basinal Fortescue Group succession of the Gregory Range is divided into five north-northwesterly trending 'slices' by regional-scale 'growth faults' that may have undergone later reactivation (Trendall, 1991). Galena is associated with (intra-slice) faults that transect the Tumbiana Formation felsic tuff and rhyolitic lava, and the underlying Kylena Formation. These faults are subparallel to the main 'slice' faults and the strike of the sedimentary rocks but dip at a steep angle to the east in contrast to the sedimentary rocks. Ages in the range 2700 to 2740 Ma for lead samples from these veins are only marginally younger than the model age of 2760 ± 300 Ma for the Kylena Formation (Richards et al., 1981). Mineralization is therefore presumably related to the same tectonic events that initiated basin development and early volcanism, although the area has been overprinted by Neoproterozoic deformation related to the Paterson Orogen.

Only minor exploration has been carried out since the early 1970s, generally limited to surface sampling in the vicinity of known vein-type lead–zinc occurrences. In the Ragged Hills area, some exploration has focused on two types of target: relatively wide, high-grade mineralized veins; and disseminated mineralization.

Barker Well – Gossan Hill

At the northern end of the Braeside lead field a group of quartz veins trending between 320° and 340° in basalt of the Fortescue Group contains argentiferous galena and sphalerite. Examples of these veins are at Barker Well and Gossan Hill (**4660**, **4682**, **5157**, **6115**, **6117**). The lodes are up to 64 m long and 1 m wide, and grab samples contain up to 43.7% Pb, 0.9% Zn, and 47.4 g/t Ag. Government-sponsored drilling in 1928 gave a best intersection of 2.25 m at 48.6% Pb, 5.5% Zn, and 40.43 g/t Ag.

Ragged Hills

Ragged Hills (**4663**, **6118**, **6120**, **6122–23**) is the largest of the deposits in the Braeside field. Two quartz-filled faults striking 340° and dipping 80° east (the regional trend of mineralized veins) follow a 30-m long ridge in sheared basalt, tuff, and carbonate rocks of the Fortescue Group (Kylena Formation). The volcanic rocks also strike north-northwesterly, but dip at shallow angles to the west-southwest. Lead is found over a strike length of 300 m, in a lode up to 4.2 m wide that is developed in a cymoid loop split on the western fault. The mineralization forms massive lenses or disseminations in quartz and quartz-filled breccia and consists mainly of galena with small amounts of sphalerite, chalcopyrite, bornite, and pyrite.

Cerussite, anglesite, and malachite are present in the oxidized zone. An average of 22 ore samples yielded 27.2% Pb and 110.72 g/t Ag (Finucane, 1938e; Ferguson, 1999). A best drill intersection gives 1.8 m at 8.1% Pb, 4.6% Zn, and 6.2 g/t Ag. Copper is present in the southern shoot and is enriched at the surface; sampling by Associated Minerals (1970–71) gave a highest assay of 6.1% Cu, 2.0% Pb, and 1.9% Zn.

The deposit was worked between 1925 and 1928, and from 1950 to 1959, over 150 m along strike and to 46 m depth. Total production was 2927.16 t of lead, 24.44 t of zinc, and 87.09 kg of silver. Anglo Westralian, who conducted the bulk of the underground mining in the 1950s, also drilled three diamond holes (see intersection quoted above). Associated Minerals (1970–71) examined the influence of country rock lithologies on ore development in the fault-parallel veins and on the potential of geochemically anomalous felsic porphyry horizons. WMC (from 1969 to 1972) carried out stream-sediment and rock-chip sampling in the area, and recorded up to 64% Pb in veins and up to 2.0% Zn in small veins. Hancock & Wright (between 1974 and 1982) carried out geological mapping, and ground magnetic and geochemical surveys in the area. At Ragged Hills they considered the high assays to be due to supergene enrichment. Esso (from 1980 to 1982) examined the Lewin Shale for sediment-hosted, stratiform targets with discouraging results. Newmont (1988) explored the gold and platinum potential of the volcanic–sedimentary sequence, using stream-sediment and rock-chip sampling, but obtained poor results.

Ragged Hills East

A line of en echelon faults, lying to the north-northeast of the Ragged Hills mine, contains mineralization at Ragged Hills East (**4670**, **4702**, **5142**, **6124**). Mineralization is within north-northwesterly trending, steep easterly dipping quartz veins in coarse-grained dolerite. Six separate shoots are described by Blockley (1971a). A sample taken from the No. 3 shoot opencut in 1968 assayed 50.6% Pb, 0.22% Zn, and 223.94 g/t Ag. Between 1949 and 1958, production from this group was 68.1 t of lead, 0.63 t of zinc, and 8.962 kg of silver from 106.49 t of ore.

Devons Cut

Anglesite, cerussite, and oxidized zinc and copper minerals are seen in the workings at Devons Cut (**4671**) over 30 m of a quartz reef, striking at 325° and dipping 80–85° east in basalt and andesite of the Maddina Formation of the Fortescue Group. The reef has been worked to 18.2 m depth and samples indicate up to 30.59% Pb, 12.6% Zn, and 102 g/t Ag. Total production, recorded for the periods from 1926 to 1928, and 1955–56, is 34.5 t lead and 7464.7 kg silver (Finucane, 1938e; Ferguson, 1999).

Mount Brockman

Three small mines in the group (**4672**) are located on three veins striking at 320–330° and dipping at 75–80° east in basalt and andesite of the Maddina Formation. Assay results are up to 54.8% Pb and 108.23 g/t Ag (separate samples). Production from the group between 1947 and 1955 was 52.8 t of lead and 17.604 kg silver (Finucane, 1938e; Ferguson, 1999).

Lightning Ridge (Moxom Well)

These mines (**4673**, **5932–33**) follow a quartz-filled subvertical fault over 1.07 km striking at 290° in basalt and andesite of the Kylena Formation. Mining has been restricted to a few richer patches at the western end of the reef and extends over an area of 30 × 6 m. Galena, chalcopyrite, bornite, covellite, and malachite are present in mine dumps. Separate samples gave up to 33.8% Pb, 1.32% Zn, and 49.8 g/t Ag. Production between 1949 and 1954 was 19.3 t of lead and 2.6747 kg silver (Finucane, 1938e; Ferguson, 1999).

Koongalin Hill

This mine (**4674**) is on a 0.3 m-wide quartz vein striking at 300° that links two barren veins trending 340° in basalt and andesite of the Kylena Formation. The deposit has been worked in two shafts and several opencuts, along a strike length of 180 m. The average of 11 samples is 31.7% Pb and 118.18 g/t Ag. Production in the periods from 1925 to 1927, and in 1949 was 34.5 t of lead and 0.2799 kg of silver (Finucane, 1938e; Ferguson, 1999).

Barramine

At Barramine (**4661**, **4679**, **4796–97**), a 1.2 m-wide quartz vein striking 320° and dipping steeply east lies in mafic volcanic rocks of the Fortescue Group (Maddina Formation) in a northern extension of the Braeside field. Only malachite, cuprite, and chalcocite are present in dump material. The workings extend 30 m along the vein and include a 10.7 m shaft, but no lead production is recorded (Finucane, 1938e; Ferguson, 1999). Two to three tonnes of copper ore have been extracted from the workings. Between 1972 and 1974 Australian Minerals explored for VMS-style mineralization in the general area north of the main Barramine – Ragged Hills mining locality, but drilling of target areas intersected only pyritic, graphitic shales.

Other base metal occurrences

Fieldings Gully

In the Fieldings Gully area (**3044–45**, **3047–48**, **5607–08**, **5630–31**, **5646**, **5721**) of the Warrawoona Syncline, exploration was carried out by Hawkstone (1970–71), Alcoa (between 1978 and 1986), and Aztec–BP (from 1983 to 1989), for base metals and gold. Anomalous Cu–Zn–Pb–Ni–Au–Ag was encountered in interfingering ultramafic, mafic, and felsic volcanic and volcaniclastic rocks. Rock chip sampling by Hawkstone gave up to 4.2% Cu, 4.9% Pb, and 3800 g/t Ag, and an inconclusive single percussion hole intersected malachite- and azurite-bearing stringers in siliceous sedimentary rocks that also contained anomalous arsenic, antimony, and silver, but low values for base metals. Hawkstone suggested that the base metal anomalism might be due to surface enrichment.

The mineralization follows a well-defined siliceous ironstone ridge and Alcoa considered that there was potential for a multi-element VMS style deposit; the company also concluded that narrow zones with massive Ni–Cu sulfide lenses were associated with intrusive ultramafic lens-shaped bodies. Also, gold was considered to have an association with komatiitic volcanism and subsequent structural control within the Fieldings Gully Shear Zone. Alcoa also recognized the presence of semi-stratiform quartz veining in the volcanic and sedimentary rocks.

Aztec–BP considered that the stratiform quartz veining in silicic ridges represented easterly trending mylonite zones, or strike-parallel shear zones, which coalesce to the east in the narrower part of the Warrawoona Syncline. These zones have a close association with both gold and base metal mineralization, and may have been a focus for vein and hydrothermal gold and for the redistribution of earlier magmatic Ni–Cu sulfides and exhalative Cu–Pb–Zn sulfides.

Recent mapping by the GSWA indicates that the main mineralized silicic ridge is a highly sheared zone related to the severe downfaulting of the central ‘axial graben’ of the Warrawoona Syncline as a result of crustal overturn between the Mount Edgar and Corunna Downs Granitoid Complexes (Hickman, 2001a). It may be that at least one of the nickel occurrences is a remnant of orthomagmatic mineralization that formed prior to shearing.

Coongan Siding (Dooleena Gap)

Stratabound massive galena has been mined at Coongan Siding (**4642**, **5218**) from a silicified shear zone between serpentinite to the east and felsic volcanogenic metasedimentary and intrusive ultramafic rocks of the Salgash Subgroup to the west. The mineralized zone strikes at 038°, dips 55° east, and is up to 9 m wide at the workings, and consists of sheared country rock, quartz veins, and stockwork veins. A vein on the hanging wall has been worked out over 60 m along strike. Ore material contains up to 40.1% Pb. Production in 1955 was 5.1 t of lead and 1.3996 kg of silver (Ferguson, 1999).

Richards et al. (1981) obtained a lead date of 3339 Ma from the galena. This has been recalculated by Thorpe et al. (1992a) to be 3329 Ma. The latter date is consistent with an association between the epigenetic mineralization and a felsic volcanic intrusive episode between 3300 and 3330 Ma, represented by rhyolite of the Wyman Formation and plutons in the area (Thorpe et al., 1992a).

Murphy Well

The occurrence of base metal mineralization at Murphy Well (**4646**) is associated with narrow quartz veins in a granitoid that is related to felsic intrusive stocks intruding the Duffer Formation. The veins are locally anomalous in base metals at Murphy Well and 7 km east-southeast of this, near Jenkins Well. Surface samples gave up to 3.4% Zn, 2.7% Cu, and 0.149% Pb (Alston, 1984). The veins are narrow, steeply dipping, and have an easterly strike. Mineralization occurs as traces of pyrite and chalcopyrite, but shows little potential for large-tonnage mineralization.

Esso (between 1972 and 1975) initially explored in this area for VMS-style mineralization in andesitic and dacitic volcanic rocks that contain graphitic and pyritic horizons. Sampling of two gossans gave assays up to 210 g/t Ag, but with only up to 1750 ppm Cu and 3756 ppm Pb. Drilling results were negative in pyritic and graphitic horizons. Duval (1981–82) was primarily exploring for porphyry-style copper–molybdenum targets in the Cundaline Gap and Talga Peak areas, but found little evidence of hydrothermal systems.

Yarrie South

At Yarrie South (**4647**, **5020**), on the eastern side of the Muccan Batholith, quartz veins cut foliated ultramafic rocks of the Gorge Creek Group in the Shay Gap Syncline. The southernmost of two limonitic veins assayed 2.56% Zn, 0.14% Cu, 2.4 g/t Au, and 83 g/t Ag.

Between 1969 and 1973 Australian Anglo American carried out exploration, including drilling, for porphyry-style copper–molybdenum in the general area. Quartz-vein systems related to granodiorite intrusives contained pyrite, molybdenite, chalcopyrite, and pyrrhotite. Results for zinc were negative. Pennzoil (1981) explored for similar mineralization in the same general area, but obtained discouraging results from grab sampling.

Hillside (Hillside Station, Cooglegong)

Two pods of coarse galena are located alongside a quartz vein in granitoid gneiss at Hillside (**4650**), about 61 km southwest of Marble Bar. Some tantalum, tin, and beryllium are present along strike in the same vein and these are related to the nearby Cooglegong Monzogranite (Blockley, 1971a). Richards et al. (1981) reported a lead age of 2400 to 2500 Ma for the mineralization and a Rb–Sr date of 2550 ± 130 Ma for the monzogranite.

Abydos

A narrow quartz vein in the Abydos area (**4652**), 4.3 km northwest of Woodstock outstation, contains galena, cerussite, and anglesite disseminated in small bunches. The vein is vertical and trends 150° in granitoid gneiss of the Yule Granitoid Complex, and has been worked over a strike length of 30 m in a trench up to 2.4 m deep (Blockley, 1971a).

Soanesville

Galena is present in a quartz vein within mafic volcanic rocks of the Gorge Creek Group at Soanesville (**4653**) on the western margin of a northerly extension of the Tambourah greenstone belt (Ferguson, 1999). Thorpe et al. (1992a) have calculated a lead age of 3132 Ma for the mineralization.

Lynas Find

A quartz vein at Lynas Find (**4654**), striking at 150° and dipping 80° east, in granitoid gneiss of the Carlindi Granitoid Complex, contains galena and cerussite over a strike length of 15 m. The granitoid gneiss intrudes sedimentary rocks of the Warrawoona Group and the vein is younger than the deformation of the Gorge Creek Group. Minor workings, 7.6 m long by 1.5 m deep, yielded a small amount of hand-picked ore, but only low-grade material remains (Blockley, 1971a). A lead-model age of 2742 Ma has been calculated for this occurrence (Thorpe et al., 1992a). Richards et al. (1981) suggested that the mineralization may be related to a pervasive event, at 2700–2900 Ma, that affected the granitoid domes of the region.

Wodgina

Finely granular galena with associated sphalerite is present in a 1.5 m-wide quartz vein at Wodgina (**4658**) in granitoid of the Yule Granitoid Complex. Anglesite, cerussite, smithsonite, and hemimorphite are present in outcrops. In a separate occurrence, a few kilometres southeast of Wodgina, a sample of coarsely crystalline galena yielded 74.6% Pb, 65.94 g/t Ag, and 0.82 g/t Au (Blockley, 1971b).

Coppin Gap (lead, zinc, copper, silver)

A quartz vein containing galena and sphalerite, with lesser amounts and traces of chalcopyrite and silver (**4159**), cuts basalt, dolerite, shale, and ?metasedimentary quartz–carbonate rock of the Apex Basalt. A lead-model age of 3326 Ma has been calculated by Thorpe et al. (1992a), and is consistent with the same felsic volcanic intrusive episode as that at Coongan Siding, between 3300 and 3330 Ma. The Coppin Gap Granodiorite shows an ion microprobe age of 3314 ± 26 Ma (Williams and Collins, 1990), and this would support a genetic relationship between the intrusion and the vein mineralization.

Mercury Hill (gold, copper, lead, zinc, mercury)

At this site (**3240**), about 15 km northeast of Abydos Homestead, gossans in fuchsitic chert (?exhalites) are found within ultramafic and felsic volcanic rocks. The gossans yield anomalous gold, base metals, and mercury, possibly indicating high-level, low-temperature epithermal activity (Hancock & Wright Prospecting, 1984; Marshall, 2000).

Steel-industry metal — nickel

At the Otways prospect (**5924**) Nickel et al. (1979) investigated an unusual style of nickel mineralization occurring along shear zones in a fault-bounded serpentinite body. Nickel et al. (1979) suggested that the mineralization was possibly the result of hydrothermal activity, but they were uncertain about the age of this event. Other vein-hosted nickel occurrences have been reported at Fieldings Gully (**5646**) and at Talga Talga in the Marble Bar area (Travis et al., 1976; Marston, 1984). These are recorded as nickel arsenides (with chalcopyrite) in narrow carbonate veins in a sequence of ultramafic fragmental rocks (up to 150 m thick). Recent work by Marshall (2000) has highlighted a number of hitherto unrecognized epithermal vein occurrences in the Pilbara, including a nickel occurrence at Sullam in the west Pilbara area (Ruddock, 1999). The mineral occurrences at Otways, Fieldings Gully, and Talga Talga may have a similar epithermal origin.

Steel-industry metal — vanadium

Vanadinite occurs in association with pyromorphite in veins at Braeside (**4673**) (Simpson, 1952; Blatchford, 1925).

Industrial mineral — fluorite

The deposits at Meentheena (**3911**, **4769–73**), 75 km east of Marble Bar, were located by station owners in the 1960s, but fluorite was not identified in the deposits until the 1970s when exploration was undertaken; a resource was later estimated (Hickman, 1974; Abeysinghe and Fetherston, 1997).

There are two main deposits located in a 60° and 235° trending conjugate system of fluorite-bearing fissure quartz veins within a fault-controlled structural high in the Mount Roe Basalt of the Fortescue Group. In this location the underlying granite–greenstone Archaean basement is considered to be only about 200 m below the surface. The location of the conjugate fluorite vein sets and the structural high are controlled by the north-trending Meentheena Fault and related splays.

The veins show many textures typical of epithermal systems including vein-parallel zone banding and brecciation of the vein walls. The veins also contain minor secondary and primary galena, malachite, brochantite, and atacamite, again consistent with an epithermal origin (Hickman, 1974; Abeysinghe and Fetherston, 1997; Marshall, 2000).

At Cookes Creek (**4776**) fluorite occurs with scheelite and wolframite in veins in the Cookes Creek Granite (Hickman, 1978; Abeysinghe and Fetherston, 1997).

Speciality metal — mercury

Near the Lionel mining centre there are two cinnabar occurrences (**4984–85**) that were identified during Cu–Zn exploration by Noranda within a sequence of felsic volcanic rocks, banded pyritic cherts, and sedimentary rocks (Duffer Formation). These occurrences may indicate potential for epithermal base metal mineralization in this area (Marshall, 2000).

Epithermal mineralization (a discussion)

In a recent study of low-temperature, low-pressure ('epithermal') base metal vein deposits in the Pilbara, Marshall (2000) has included the following deposits in this style of mineralization: the Miralga Creek vein and hydrothermal deposit; many of the deposits in the North Pole and McPhee Domes; veins in the Kelly greenstone belt; and the vein systems of the Gregory Range. Marshall (2000) concluded that in Precambrian rocks the prospectivity for economically significant epithermal deposits is limited to areas where high-level, largely subaerial volcanic sequences have been preserved.

In the east Pilbara area, potential for epithermal mineralization is suggested by the extensive areas of well-exposed, low-metamorphic grade greenstones, but only two deposits that conform to this mineralization style have been well documented: the Miralga Creek gold and base metal deposits (**2950–51**, **4648**, **7033–37**); and the Meentheena fluorite deposits (**3911**, **4769–73**). However, potential is also considered to be present for this deposit type in the North Pole Dome, the McPhee Dome, and in the Kelly greenstone belt (Marshall, 2000).

Epithermal deposits can be divided into two subtypes: high- and low-sulfidation types. High-sulfidation types are within, and proximal to, areas of active volcanism and involve the action of magmatic fluids. They could be considered as the distal parts of porphyry copper systems. Disseminated ore is common, whereas stockwork veining is rare. Zinc and gold–silver values are low in this high-sulfidation type. The low-sulfidation type deposits form in active geothermal systems where groundwaters dominate. Stockwork veining is common in open-space veins. Base metals dominate the deeper zones of this type, whereas precious metals are more common at higher levels.

Disseminated and stockwork mineralization in plutonic intrusions

There are 15 occurrences of this mineralization style in the east Pilbara area (Fig. 27). Of these, 11 are of base metal, 2 are of steel-industry metal, 1 is of speciality metal, and 1 is of industrial mineral.

Base metal — porphyry copper, molybdenum; tungsten

McPhee Dome

A number of vein-type copper, molybdenum, tungsten, and fluorite deposits and occurrences in the McPhee Dome are hosted by mafic and felsic volcanic rocks of the Warrawoona Group. Most of these are of the Cu–Mo(–W) porphyry type and were explored by Hunter Resources in the late 1980s. The occurrences include prospects at Lightning Ridge (**5932–33**), Gobbos (**4962–63**, **5923**), and Cookes Creek (**5540**) and, possibly, Wallabirdie Ridge (**5283–84**).

At Wallabirdie Ridge Cu–Mo mineralization is associated with granodiorite and felsic porphyry intrusions into the Warrawoona Group (Hickman, 1983). Chalcopyrite and molybdenite are in fractures toward the margins of the intrusions, but the grade of mineralization is too low to be considered for mining.

The Gobbos prospect (**4962–63**, **5923**) lies on the northern flank of the McPhee Dome and is well-exposed within basalt, andesite, and dacite of the Warrawoona Group. Mineralization lies within a zone of multiple-phase quartz veining related to a small intrusion of quartz–plagioclase porphyry at the northeastern corner of the Gobbos Granodiorite (Barley, 1982). The present level of exposure appears to be close to the top of the granodiorite, and chalcopyrite, molybdenite, and pyrite are accessory minerals within it.

At the notheastern corner of the granodiorite, there is a small, strongly silicified, sericitized, quartz–plagioclase porphyry intrusion that is the focus of a zone of multiple-phase fracturing and quartz–carbonate veining. This zone hosts the Fe–Cu–Mo mineralization and is about 1 km² in area. The veins contain up to 2% chalcopyrite and 1% molybdenite with scheelite, pyrite, and rare galena, and these minerals can also be seen on fracture surfaces. Basalt and felsic tuff in the veined area are silicified and show propylitic and sericitic alteration (Barley, 1982).

Mineralization is also present in an intrusive breccia along the northeastern contact of the granodiorite where it intrudes the basaltic sequence. Breccia fragments contain up to 3% chalcopyrite, molybdenite and pyrite.

Coppin Gap

The Coppin Gap copper–molybdenum deposit (**4155**) is located in a multi-phase stockwork of quartz–carbonate veins along the silicified contact zone of the intrusive porphyritic dacite and rhyodacite (Williams, 1999a; Marston,1979). The porphyry body intrudes high-Mg pillow basalt, sheared serpentinized peridotite, and talc–chlorite schist of the Euro Basalt. Resources have been estimated at 102 Mt of 0.152% Cu and 0.105% Mo (Jones, 1990). The stockwork of veins contains chalcopyrite, molybdenite, pyrite, pyrrhotite, scheelite, and rare sphalerite. Jones (1990) considered the porphyry bodies to be apophyses of the Coppin Gap Granodiorite, which lies about 1 km to the south.

Industrial mineral — fluorite

Ngarrin Creek

At Ngarrin Creek (**3944**) Hickman (1976) discovered disseminated fluorite in a series of northeasterly trending dacitic porphyry stocks and dykes that intrude the Warrawagine Granitoid Complex (Williams, 1999).

Pegmatitic mineralization

There are 114 occurrences of pegmatitic mineralization in the east Pilbara area. Of these, 87 are of speciality metal, 19 of steel-industry metal, 6 of precious mineral (emerald), 1 of industrial mineral, and 1 of base metal (Fig. 27).

Speciality metal — tin, tantalum, lithium, niobium, beryllium

Pegmatite forms veins, dykes, and pods (ranging in width up to tens of metres) in all the multicomponent domal granitoid complexes of the east Pilbara (Blockley, 1980; Hickman, 1983; Van Kranendonk et al., in prep.; Sweetapple, 2000). They are, by definition, coarsely crystalline (crystals from 5 mm to >1 m in diameter) and are mainly composed of quartz, K-feldspar, plagioclase,

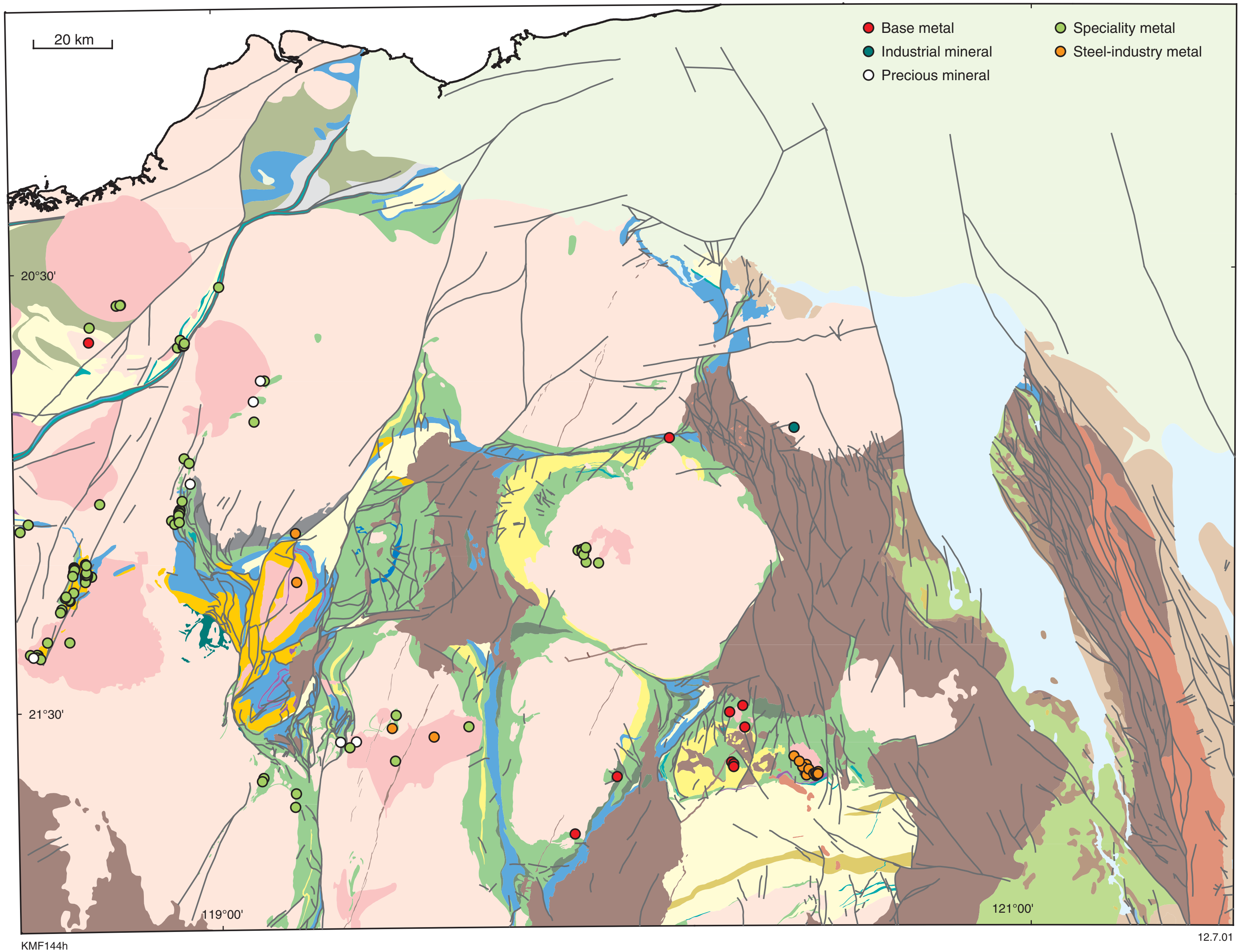

Figure 27. Distribution of occurrences of pegmatitic mineralization and disseminated and stockwork mineralization in plutonic intrusions in the east Pilbara. See Figure 7 for geological legend

and mica. Pegmatites associated with phases of the older components of the granitoid complexes, with ages in the range 3500–3300 Ma, are quite simple mineralogically and are lacking in economic minerals such as cassiterite, tantalite–columbite, beryl, lepidolite, and radioactive compounds (Hickman, 1983). Early investigations of pegmatitic mineralization in the east Pilbara were made by Simpson (1928), Finucane and Telford (1939a), Miles et al. (1945), and Ellis (1950).

The pegmatites that contain economic mineralization in the east Pilbara are those associated with the 'younger' post-tectonic granitoids, with ages in the range 2950–2830 Ma. Three types of tin–tantalum–lithium–beryllium pegmatites have been defined (Blockley, 1980; Hickman, 1983):

Simple pegmatite: containing quartz, albite, and muscovite, lesser amounts of cassiterite, tantalite–columbite minerals, and rarer lithium and beryllium compounds;

Layered albite pegmatite: bands of fine-grained quartz–albite aplite alternating with coarser quartz–microcline–albite–muscovite. These contain cassiterite, tantalite and columbite, lepidolite, zinnwaldite, beryl, gadolinite, and monazite, with lesser, non-commercial amounts of spessartine, tourmaline, magnetite, topaz, zircon, fluorite, simpsonite, and wodginite. Cassiterite is mostly in the finer albitic phase at vein margins;

Complex rare earth pegmatite: cassiterite, commonly subordinate to tantalite, columbite, beryl, and lithium minerals. These pegmatites mainly intrude greenstone belts, except at Numbana.

There are, however, a small number of exceptions to the above in the east Pilbara. Somewhat older mineralized pegmatites, at about 2900 Ma, have been found in the Wodgina and Pilgangoora areas. Also, in the McPhee Dome, tungsten in the form of wolframite has been mined from late-stage differentiated pegmatites that intrude the Cookes Creek Granite and Warrawoona mafic volcanic rocks.

Moolyella

At Moolyella, about 15 km east of Marble Bar, tin mineralization is in layered albite pegmatites that occupy northerly trending tension fractures in older granitoids of the Mount Edgar Granitoid Complex, close to the younger, post-tectonic Moolyella Monzogranite. These pegmatite dykes have been worked for lode cassiterite at eight sites (**4845**, **4848–50**, **7382**, **7416**, **7424**, **8172**), just west and south of the two southwesterly trending, western arms of the Moolyella Monzogranite (Plate 1A, Inset 5). Some of the mines have been covered by subsequent alluvial diggings (Blockley, 1980), but they are reported to have been predominantly within a swarm on the western side of the monzogranite. In workings examined by Blockley (1980) most of the cassiterite was concentrated toward the margins of individual pegmatite dykes. Blockley (1980) also pointed out that the cassiterite content of the pegmatite dykes varied considerably, and in only a few places was it high enough to encourage mining.

Shaw River

In the Shaw River tin field, there are two post-tectonic younger granites that intrude the Shaw Granitoid Complex, the large Cooglegong Monzogranite and the small Spear Hill ?Adamellite. The only lode mining in the area was 1.8 km southeast of Spear Hill at Stutz's P. A. (**4854**), as noted by Hickman (1983).

The layered albite pegmatites predominantly intrude the older granitoid within a 2-km zone around the younger intrusions. Layering is seen as alternating coarse-grained, microcline-rich, and fine-grained, albite-rich, bands, and the pegmatites contain spessartine and green muscovite in addition to cassiterite (Blockley, 1980).

Wodgina

Pegmatites in the Wodgina area (Plate 1A, Inset 1) are the main producers of tin, tantalum, lithium, and beryllium, and they contain significant resources of niobium. In contrast with other areas of the east Pilbara described above, where pegmatites intrude granitoids, most of the mineralized pegmatites of the Wodgina area intrude greenstone lithologies of the Wodgina greenstone belt (Finucane and Telford, 1939a; Miles et al., 1945; Blockley, 1971b; Hickman, 1983; Sweetapple, 2000). Mining areas within the Wodgina tin field include Wodgina (**2858**, **2861**, **4810**, **4827**), West Wodgina (**2863**, **4825–26**, **4828**, **5269–70**, **6322**), Stannum (**4883–84**, **4888**, **4891**), Mills Find (**4899**), Numbana (**4913**), and Mount Francisco (**8008–09**).

The main production of tin in the Wodgina area has come from the Mount Cassiterite mine (**4806–08**). This was originally the largest underground tin mine in Western Australia. Mineralization is in an albite–quartz pegmatite up to 4.2 m wide (averaging 1.5 m) that intrudes ferruginous chert and contains cassiterite, tourmaline, beryl, tantalite, and lithium minerals. Between 1904 and 1918 a total of 344.11 t of tin concentrate was mined from Mount Cassiterite, far exceeding the output from adjacent workings such as Tinstone (**4809**), Anchorite (**4821**), and other minor workings south to Mount Francisco (Hickman, 1983).

The main early tantalite production from the Wodgina area was from the Wodgina Main Lode (or Tantalite Lode) (**2861**) on MC 107. This is a northerly striking pegmatite vein from 3 to 10 m wide that dips 40° east over a length of about 700 m. The pegmatite has a granitoid-textured core with marginal and cross-cutting veins of almost pure albite, and contains irregularly distributed bunches of quartz, microcline, lepidolite, and mica. Manganotantalite is present throughout the pegmatite but is most concentrated in the feldspathic portions (Hickman, 1983).

The Main Lode has also been the principal source of beryl in the east Pilbara, with more than half the total recorded production. Production came from one concentration within the lode. Historical production from the Main Lode is not recorded, but Hickman (1983) made an estimate of 140 t for tantalite–columbite concentrate for the whole Wodgina field; this estimate was based on prices obtained for concentrate and on assays over a period of years.

More recently, SOG has revitalized tantalum production from the Wodgina area. It is now the world's second largest hard-rock tantalum producing area (after the company's Greenbushes operation). From 1989 to 1993 the company mined tantalite from an openpit on the Main Lode. Since then, the focus of openpit production has shifted to Mount Cassiterite where the pegmatites (originally mined for tin) are a series of stacked, flat-lying bodies, with a shallow dip to the northwest (Bester, 2000). Production in the period from 1995 to 1998 totalled 275.33 t of tantalite and 39.6 t of tin. Current production levels are around 227 t (0.5 Mlb) and in July 2000 the company announced plans to double this to around 456 t (1.0 Mlb) over the next three years (Bester, 2000).

Sons of Gwalia recently made an important find in the Wodgina area. A mineralized pegmatite body approximately 50 m thick was intersected during drilling in 1996. The pegmatite body is in the vicinity of old tin workings at Mount Cassiterite East (**4816**), about 1 km south-southwest of the Wodgina Main Lode. The pegmatite dips to the south at a shallow angle, and mineralization is open in all directions, with drill intersections of up to 59 m at 525 ppm Ta_2O_5. A preliminary resource estimate of the mineralization is 28 Mt at 415 g/t Ta_2O_5 (Louthean, 1998).

At West Wodgina, on the western margin of the belt, simple and zoned pegmatite veins contain cassiterite and lepidolite, together with garnet and tourmaline. Only a few tonnes of tin were mined. At the Stannum group further south, veins less than 1 m wide contain cassiterite with columbite, lepidolite, blue tourmaline, and topaz (Hickman, 1983). At Siffleetes Reward (**4895**, **4897**), in the Mills Find area, about 4 t of tin concentrate was obtained from a pegmatite in amphibolite. Pegmatites in ultramafic schist and metasedimentary rocks in the Mount Francisco area contain cassiterite, tantalite, and beryl, and these have also been mined.

Tabba Tabba

At Tabba Tabba (18 km north-northeast of the homestead), a narrow body of amphibolitic schists and metasedimentery rocks is preserved between two portions of the Carlindi Granitoid Complex. The main mineralized body is a northwesterly trending pegmatite (600 m long by 10–50 m wide) consisting of coarsely crystalline albite, quartz, beryl, manganotantalite, maganocolumbite, cassiterite, simpsonite, and microlite. This body is part of an open, V-shaped outcrop of two pegmatites, that dip towards each other at about 30°. Mineralization (**2887**, **4939**, **4941**, **4944**, **4948**) is located in narrow layered zones of the aplitic albite pegmatite on the margins of large masses of sheeted quartz (Blockley, 1980; Hickman, 1983).

About 15–20 t of Ta_2O_5 has been produced from the pegmatite. Tin production is recorded in more detail, and this shows that 131.92 t of tin concentrate were recovered in the periods from 1916 to 1928, from 1935 to 1956, and in 1960. About 47 t of beryl concentrate was also obtained from the main tantalite lode.

Strelley

About 18 km north-northeast of Tabba Tabba, along the same line of amphibolite, serpentinite, chert, and pelitic schist, there is a broadly stratiform pegmatite dyke, about 700 m long and up to 200 m wide (**3100**). This contains greisen lenses and albitic stockworks that host tin, tantalum, and beryl mineralization. Scattered shallow workings (now largely filled-in) are located in concentrations of manganotantalite, lepidolite, and beryl, with lesser cassiterite, microlite, tapiolite, and lithiophyllite (Hickman, 1983)

Pilgangoora

Large pegmatite bodies intrude mafic and ultramafic schists near the western margin of the Pilgangoora greenstone belt in a northerly trending zone that is about 5 km long (Plate 1A, Inset 2). Individual bodies are up to 600 m long and 300 m wide. Small areas of these pegmatites are mineralized where quartz–microcline–biotite pegmatite has been altered to quartz, albite, and spessartine, with varying amounts of lepidolite, spodumene, tantalite, columbite, and cassiterite, together with traces of microlite, tapiolite, and beryl (Hickman, 1983). Mineralization (**6273–75**) is concentrated at the margins of the veins, and five groups of shallow pits have been sunk on these, principally for tantalum and niobium but also to a minor degree for tin. However, most of the production in this area was from surficial material.

Steel-industry metal — tungsten

Tungsten in the east Pilbara area is associated with pegmatite derived from post-tectonic granites (2.95–2.83 Ga). However, wolframite is not associated with the tin mineralization of major granitoid complexes. At Burrows Well (**4978**) wolframite has been mined from a small deposit associated with a northerly trending quartz vein that lies 2 km west of the eastern margin of the Cooglegong Monzogranite in the Shaw Granitoid Complex (Hickman, 1983).

Wolframite production has also been recorded from an unknown source in the Talga Talga area, and scheelite has been noted at Coppin Gap (Marston, 1979).

Cookes Creek

The margins of the Cookes Creek Granite and surrounding mafic volcanic rocks in the Warrawoona Group are intruded by late-stage, tungsten-bearing, differentiated pegmatites (Plate 1A, Inset 10). Small-scale workings (**4977**, **5711**, **6294–97**, **6392**, **6395–98**, **6401–02**, **6408**, **6410–14**, **6417–18**) operated in the early 1950s and produced a total of 17 583 kg of WO_3, mostly from dykes within the granite (Baxter, 1978; Hickman, 1983).

The largest workings are on a 0.3 m-wide quartz pegmatite vein that lies 400 m east of Cookes Creek. These, and most of the other workings, are close to the southwestern margin of the granite. Wolframite is the main ore mineral, with accessory scheelite, fluorite, and muscovite. Between 1975 and 1984 the Australian and New Zealand Exploration Company located 28 minor occurrences of scheelite around the margins of the granite.

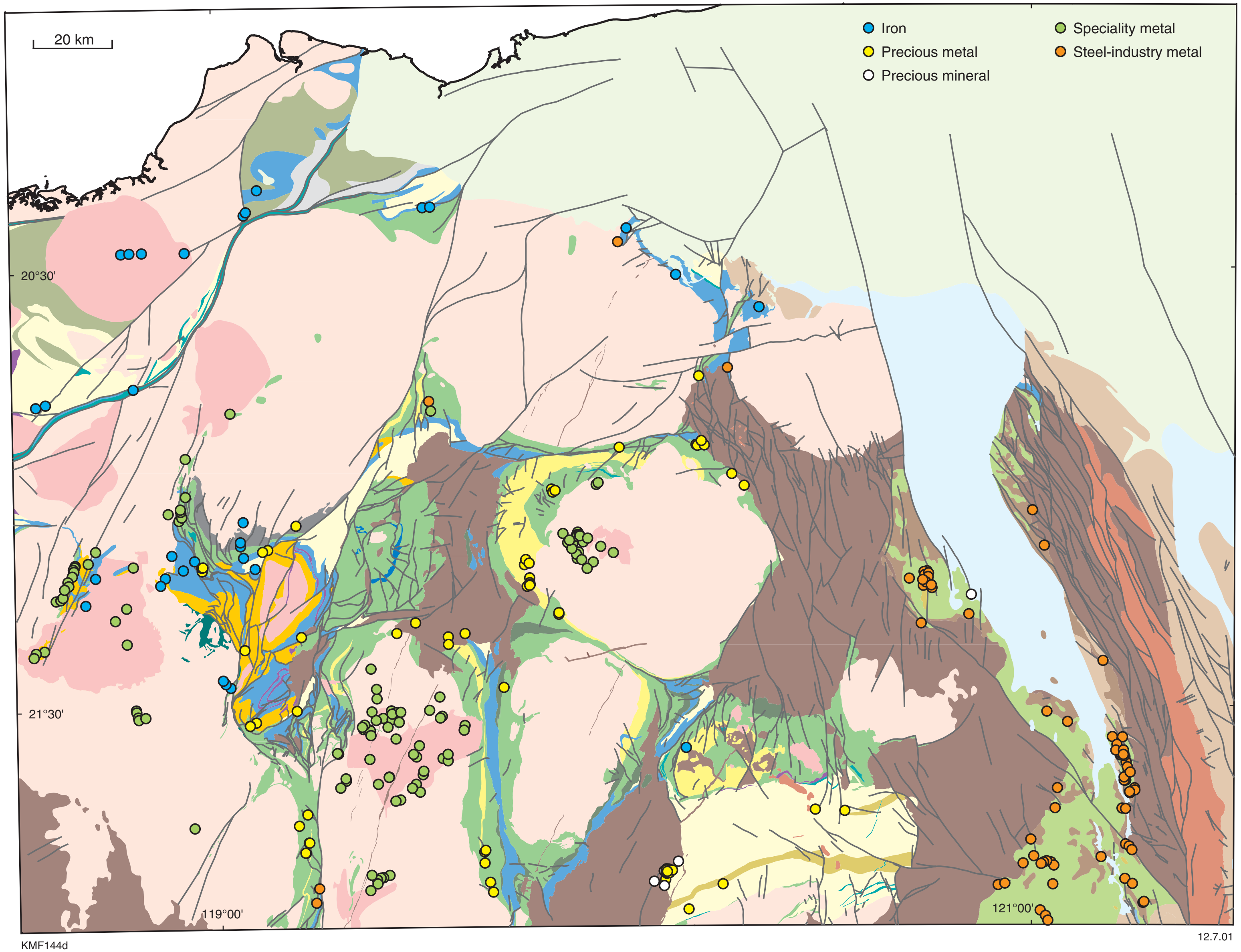

Figure 28. Distribution of mineral occurrences classified as regolith mineralization in the east Pilbara. See Figure 7 for geological legend

Precious mineral — beryl (emerald)

Emeralds have been found in pegmatite in the McPhees Hill area (**3101, 4986**), at Calverts White Quartz Hill (**2796, 4987**) in the Emerald mine complex (Fig. 4), and as minor pegmatite occurrences in the Mount Francisco area (**6048, 8009**). The only production recorded is 8.68 carats (cut) from McPhees Hill (Hickman, 1983).

Regolith mineralization

There are 206 occurrences of this type of mineralization in the east Pilbara area (Fig. 28). Of these, 118 are of speciality metal (mainly tin, tantalum), 52 are of precious metal (gold), 8 are of precious mineral (diamond, or emerald, or beryl), and 28 are of iron.

Alluvial to beach placer mineralization

Pisolitic iron ore

For the purposes of classification in WAMIN these pisolitic deposits are considered as a unique style of alluvial mineralization, in which the processes of physical and chemical weathering, transport, deposition, chemical concentration, and chemical precipitation have been involved. It would be misleading to refer to them as a supergene-mineralization style, because they have not developed by secondary processes 'in situ' over primary ore zones, or — as in the case of supergene hematite and hematite–goethite ores of the Hamersley Basin — by enrichment processes in BIFs (Ruddock, 1999).

The pisolitic ores of the 'Poondano Formation' (and other areas of Cainozoic pisolitic limonite in the east Pilbara) are riverine palaeochannel deposits similar to those of the Robe Pisolite in the west Pilbara. They consist of a mixture of hydrated oxides of iron and hematite (with some maghemite) forming cemented masses of concretionary spherulites. Deposits in the east Pilbara are described by de la Hunty (1961), and there are further useful discussions that relate to the Robe Pisolite by MacLeod et al. (1963), Harms and Morgan (1964), MacLeod (1966), and Butler (1976). The size of the spherulites (generally less than 2 mm) indicates that strictly they should be classified as ooliths, but MacLeod (1966) recommended use of the term 'pisolitic iron ore' to avoid confusion with 'oolitic iron ores of marine origin', and this became the accepted term until recently. As a result of recent industry-sponsored research it has been proposed that pisolitic iron ores should be called 'channel iron deposits' with the acronym 'CIDs' (Ramanaidou et al., 1991; Morris, 1994; Cudahy and Ramanaidou, 1997). However, all members of the iron ore industry have not yet accepted this proposed nomenclature.

It is generally agreed that the original source of the iron was the BIFs of the Pilbara: the Nimingarra Iron Formation and Cleaverville Formation in the East Pilbara Granite–Greenstone Terrane, and the Marra Mamba Iron Formation and Brockman Iron Formation in the Hamersley Basin. However, there is some contention over details of the mechanisms involved in the concentration of iron in the palaeochannels (Harms and Morgan, 1964; MacLeod, 1966; Butler, 1976; Hall and Kneeshaw, 1990). Notwithstanding these details, a simplified view is that the iron deposits formed in a forested mature landscape in swampy channels of broad meandering rivers. In the beds of the rivers there were accumulations of iron-rich fragments derived from BIFs (in the Gorge Creek Group and Hamersley Group) and overlying iron-rich laterite. These fragments acted as nuclei for the reprecipitation of dissolved iron (leached by acidic water from source rocks and laterite) so that alluvial muds and sands were gradually replaced to form thick channel-wide sheets of pisolitic iron ore.

In the east Pilbara, small deposits of pisolitic ore (Fig. 28) now exist as scattered remnants of Cainozoic palaeodrainage systems that developed in the following areas: east of Port Hedland (**6059–62** and **7988–89**); south of Port Hedland (**8000–02**); in the Pincunyah area (**2841**, **2881–83**, **7787**, **7999**); in the Strelley – Lalla Rookh area (**2885–86**, **3254–56**); in the Abydos area (**3245**, **3277–78**, **3281**); in the Wodgina area (**8746–47**); and at McPhee Creek (**7191**). There has been no production from these small deposits.

Residual to eluvial, and alluvial to beach placer mineralization

Precious metal — gold

Concentrations of detrital gold are found in alluvial and eluvial deposits around most of the vein and hydrothermal gold mining centres in the east Pilbara. The mineralization is in sheetwash and channel deposits, where gold has tended, due to its high density, to be concentrated in relatively elevated areas that are proximal to the epigenetic source deposits, and to be concentrated near the base of individual channels, as a consequence of winnowing processes.

In official production records, the source areas for this type of detrital gold rarely have accurate localities for production sites. However, records suggest that most of the detrital gold has been obtained from the Marble Bar and Nullagine Mining Centres.

In the WAMIN database, the number of sites for alluvial gold workings (46) is a significant underestimate of the total number of alluvial–eluvial deposits present in the east Pilbara area; this is a reflection of the small number of sites recorded in open-file exploration reports in WAMEX.

Precious mineral — diamond, emerald, beryl

As mentioned above, diamonds were first discovered in the east Pilbara in conglomerate of the Fortescue Group Hardey Sandstone at Brooks Hill and nearby. At most, a few hundred diamonds have been found, mainly in Cainozoic alluvial sediments washed from the Tertiary Brooks Hill Formation near Nullagine (**2916, 5239, 5972, 6168**), and at Banana Hill (**5974, 6170, 6197**). A single dodecahedral macrodiamond has been found in creek loam in the Carawine area by CRA (**6110**). It was considered to derive from remnant fluvioglacial deposits.

Speciality metal — tin, tantalum, lithium, niobium, beryllium

Areas of alluvial and eluvial deposits of tin, tantalum, lithium, niobium, and beryllium, at various mining centres, are distributed in broad haloes that lie around the primary pegmatite sources of this group of metals. There are 118 sites recorded in WAMIN.

The main centres of production from surficial deposits of the tantalite–columbite group of minerals, and for tin, are all located within the boundaries of the Shaw, Yule, and Carlindi Granitoid Complexes. The Cooglegong and Eley centres, within the Shaw Granitoid Complex, have hosted approximately 60% of the approximately 940 t of tantalite and tantalite–columbite concentrate that was produced from all primary and secondary sources in the east Pilbara. Similarly for tin, approximately 90% of production has come from surficial material in the Moolyella and Shaw River Mining Centres.

At Moolyella the main workings for cassiterite (**2829**, **4836**, **4843–45**, **7372–77**) are in buried alluvial channels that fan out from the basal slopes of low hills (Plate 1A, Inset 6). Cassiterite is contained within coarse gravel about 1 m thick that is bounded by green, or greenish-yellow puggy clay (Hickman, 1983). The gravel is overlain by finer material that has a lower cassiterite content, and this material has often been discarded. In general, early mining of these types of deposits was selective, whereas modern methods are more effective at extracting and treating bulk material to obtain concentrates.

In the Shaw River Granitoid Complex, most of the production has come from the Cooglegong and Eley centres. The largest diggings at Cooglegong are in Two Mile Creek (**4867**) extending for 5.5 km along the creek and with mining widths of between 20 m and 60 m.

Steel-industry metal — vanadium

Vanadinite occurs in concentrates from gold ore obtained at Talga Talga and Western Shaw (Simpson, 1952).

Residual and supergene mineralization

There are 83 occurrences of residual and supergene mineralization. Some 72 of these are of steel-industry metal (predominantly Mn), 6 are of precious metal (predominantly Au), and 5 are of iron (Fig. 28).

Steel-industry metal — manganese

The manganese occurrences in the east Pilbara area include those in the ‘Pilbara Manganese Province’ (de la Hunty, 1963) and those in the Nimingarra–Yarrie area. These occurrences have largely been formed by the supergene enrichment of underlying manganese-rich sedimentary rocks of Archaean to Neoproterozoic age. There are three main manganiferous sedimentary-source rocks and these are listed below in order of age:

a) BIF in the Gorge Creek Group (Nimingarra Iron Formation and Cleaverville Formation);
b) karsted dolomite in the Hamersley Group (Carawine Dolomite) and the associated overlying Pinjian Chert Breccia; and
c) shale in the Manganese Group (Woblegun Formation).

Supergene enrichment of manganese in the east Pilbara is considered to have been a multi-stage process with a number of phases of deposition, dissolution, replacement, and diagenetic reprecipitation (de la Hunty, 1963; Blockley, 1975; Denholm, 1977; Hickman, 1983; Fetherston, 1990; Ostwald, 1992a,b, 1993; Dammer et al., 1999). From these discussions, particularly those in Ostwald (1993) and Dammer et al. (1999), the main phases may be summarized as follows: initial deposition of manganese in BIFs and dolomites in the lower part of the Hamersley Group; first phase of manganese enrichment during deep weathering that followed initial uplift of the northeastern part of the Hamersley Basin (in the ?Palaeoproterozoic); second period of sedimentary manganese formation in rocks of the Manganese Group (with manganese sourced from manganiferous Hamersley Group rocks and their enriched derivatives); second major phase of enrichment during the Cainozoic to produce manganiferous duricrust.

‘Pilbara Manganese Province’

The province contains the main supergene manganese deposits of the east Pilbara and these have formed in karsted dolomite of the Hamersley Group (Carawine Dolomite) and in the associated overlying Pinjian Chert Breccia; other main deposits occur as supergene enrichment of shales in the Manganese Group (Woblegun Formation). The main ore minerals are cryptomelane, pyrolusite, and braunite (de la Hunty, 1963, 1965b).

Two types of ore have been recognized in the area (Denholm, 1977; Ostwald, 1993): metallurgical-grade manganese ore (containing a minimum of 48% Mn, a maximum of 8% Fe, and a maximum of 8% SiO_2); and ferruginous manganese ore* (containing a minimum of 28% Mn, a minimum of 16% Fe, and a maximum of 15% combined SiO_2 and Al_2O_3).

Deposits of higher grade material are associated with Carawine Dolomite and Pinjian Chert Breccia at Woodie Woodie (**4705**), Mount Sydney (**4683**), Skull Springs (**4707**, **4735**, **7192**, **7526**), and the Mike mine (**4709**). Large tonnages of lower grade ferruginous manganese deposits are associated with manganiferous shale in the Woblegun Formation at Ripon Hills (**3503**, **5219–28**, **5231–32**).

Shay Gap greenstone belt

Small deposits of manganese are developed in Cainozoic duricrust over BIF in the Gorge Creek Group to the east and east-southeast of Port Hedland. Deposits have been worked at Nimingarra Mn (**8478**) and Six Mile Well Mn (**4240**) (de la Hunty, 1963). The mineralization is pisolitic

* Ferruginous manganese ore has been referred to by some authors as ‘ferromanganese ore’, but this term is best avoided because it may be confused with the name of a particular metallurgically processed product called ferromanganese

and colloform pyrolusite (Hickman and Gibson, 1982; Hickman, 1983).

Iron

One of the ores recognized in the Goldsworthy mining operations in the east Pilbara is called crust-type ore (or 'crustals'). This type of mineralization was formed by weathering processes in the Mesozoic to Cainozoic as near-surface replacements of BIF (Brandt, 1964, 1966; Podmore, 1990). Crust-type ore consists of irregular-shaped masses of platy, fissile hematite that forms quite extensive tabular deposits at Mount Goldsworthy (**7991**, **9138**), Nimingarra (**9139**), Cattle Gorge (**4210**), and Yarrie (**7914**).

Mineralization controls and exploration potential

Most of the mineralization in the east Pilbara, as shown on Plates 1 and 1A, lies predominantly within the greenstone belts that surround the large ovoid granitoid complexes. In terms of the total number of occurrences, most are Archaean, epigenetic vein and hydrothermal gold, but they also include syngenetic, felsic volcanic-related base metal mineralization, deposits of steel-industry metals in ultramafic intrusives, supergene haematite–goethite iron deposits in BIF of the Gorge Creek Group, and pegmatite-hosted tantalum deposits in the Wodgina area. Figure 8 summarizes the relationship between geological evolution and mineralization.

Within the granitoid complexes, only the relatively minor pegmatitic, tin-dominant occurrrences, related to late-stage granites and their alluvial–eluvial derivatives, are in significant numbers.

Vein and hydrothermal lead–silver mineralization of Archaean age, but outside the granite–greenstone basement, is found in the c. 2700 Ma Braeside field, within the Fortescue Group. Neoproterozoic (c. 1070 Ma) sedimentary-hosted stratabound base metal mineralization is present in the Throssell Group.

Manganese deposits, formed by Cainozoic supergene enrichment of Palaeoproterozoic, Hamersley Group manganiferous sediments, lie in the eastern part of the east Pilbara area.

Mineralization in kimberlite and lamproite intrusions

Precious mineral — diamond

It is too early to be able to clearly assess the potential of the microdiamond and macrodiamond discoveries in the Warrawoona and other areas, following the discovery of the Brockman kimberlite dyke. However, indications of other possibly kimberlitic systems in the Coongan, Hillside, and other areas, suggest that current diamond exploration programs are achieving successful results in areas where earlier exploration failed to locate viable intrusive sources for the detrital diamonds in the Fortescue Group.

Orthomagmatic mafic and ultramafic mineralization

Nickel–copper

The main host rocks showing this style of mineralization, in the east Pilbara, are mafic–ultramafic sills. For the purposes of discussion in this report, these are referred to as 'older intrusions' and 'younger intrusions'. The 'older intrusions' intrude greenstone volcanic and sedimentary sequences in the Warrawoona Group, Sulphur Springs Group, and Gorge Creek Group. These sills are presumed to be comagmatic with mafic–ultramafic volcanic rocks in these sequences and are not related to the much younger (c. 2925 Ma) layered-mafic intrusions of the west Pilbara. Exploration to date has located only small nickel–copper deposits in the 'older intrusions', and it appears that the potential for larger deposits is fairly low. The 'younger intrusions' intrude rocks in the Mosquito Creek Basin, particularly along the northern margin of the basin, and they may be similar in age to layered-mafic intrusions of the west Pilbara. Although only a small sulfide deposit was located during exploration in a 'younger intrusion' at Cookes Creek, exploration also showed that sulfide mineralization in the intrusion extends 1200 m to the east of the small deposit. However, there has been no intensive exploration since 1977 to fully test the potential of this sulfide zone, nor has there been any exploration to investigate the potential of other parts of the layered-mafic intrusion that are shown on NULLAGINE (Hickman, 1978).

There is also some potential for nickel–copper mineralization to be hosted in komatiitic volcanic rocks in the east Pilbara, in areas where these rocks show their thickest development. Witt et al. (1998) highlighted the thick komatiitic units around Camel Creek (in the Warrawoona area) and in the North Shaw greenstone belt and Tambina Complex. However, these authors were also of the opinion that the komatiites in Pilbara greenstone sequences probably have a low potential for this style of mineralization because deep, mantle-tapping rifts were rare or absent during the period 3500 to 3100 Ma when the komatiites were erupted.

Stratabound volcanic and sedimentary mineralization

Base metals

As outlined above, VMS deposits and prospects, hosted by proximal felsic volcanic and volcaniclastic rocks, are present within the 3470 Ma Duffer Formation of the Warrawoona Group, and in the 3238 Ma Kangaroo Caves Formation of the Sulphur Springs Group.

Deposits and prospects so far located in the Warrawoona Group as a result of extensive exploration in the 1970s and 1980s — such as those at Yandicoogina – Lennons Find, Big Stubby, and Copper Gorge — have proved to be subeconomic.

The deposits and occurrences in the Sulphur Springs Group are genetically, and therefore spatially, related to the Strelley Granite. The overlying host suite has been extensively mapped and explored in detail by Sipa Resources and a number of prospects outlined. It might seem, therefore, that little potential exists for further discoveries around the Strelley Granite.

However, in the light of the technical success of exploration by Sipa Resources and its joint venture partners in the Sulphur Springs Group, and the detailed understanding of the mineralizing processes gained in these relatively weakly metamorphosed, and spectacularly exposed, rocks, continuing exploration is clearly warranted in this group, in the Warrawoona Group, and in other felsic-volcanic suites in the east Pilbara. With more-refined models (and given a more economically favourable climate) this may well be rewarded with significant discoveries.

Changes to the stratigraphy of the Warrawoona Group, based on recent 1:100 000-scale geological mapping by the Geological Survey (Van Kranendonk et al., in prep.), and the reassignment of the Duffer Formation as part of the Talga Talga Subgroup, may allow better targeted exploration for further VMS discoveries. An important result of recent mapping is that cherts previously correlated with the Towers Formation are now recognized as three separate, compositionally distinct units (Van Kranendonk, 2000). These cherts may be useful target zones for exploration, given that major chert horizons are related to hydrothermal activity at the close of major felsic magmatic events, e.g. the Marble Bar Chert representing the last remnant activity of Duffer felsic volcanism (Van Kranendonk et al., in prep.).

In the North Pole Dome area, there are two chert horizons that may be targets for further exploration. These are the Strelley Pool Chert (correlatable over 130 km) that conformably overlies the Panorama Formation, and the chert–barite horizon of the Dresser Formation.

Stratabound (clastic-hosted) mineralization

Base metals

The prospectivity of the Yeneena Group has been enhanced by the discoveries of stratiform–stratabound copper(–lead–zinc) mineralization in the Broadhurst Formation at Nifty, and elsewhere. This is particularly so in the graphitic–sulfidic, carbonate-rich facies of the Broadhurst Formation, where recent exploration suggests that the best potential for economic discoveries lies. However, Nifty's relatively remote location and depth of overburden remain limiting factors in development of the deposits and prospects thus far defined.

Iron ore (Eel Creek Formation)

There is further potential in the Yarrie area and to the north of this, where the conglomerate (shown as *Eue* on Plate 1) is unconformably overlain by Mesozoic sequences of the Lambert Shelf of the Northern Carnarvon Basin.

Sedimentary — banded iron-formation (supergene-enriched)

The potential for supergene-enriched iron deposits was extensively assessed during the iron ore boom of the 1960s in areas of exposed BIFs in the Cleaverville Formation and Nimingarra Iron Formation in the northern part of the area. The largest deposits were delineated in the Goldsworthy and Shay Gap greenstone belts at Mount Goldsworthy, Shay Gap, Nimingarra, Sunrise Hill, and Yarrie. With the exception of Yarrie, most of the high-grade material has been extracted. Also, iron deposits in the Ord Ranges and Cundaline Ridge have yet to be developed. Apart from these exposed areas of BIF, there could be further supergene-enriched deposits in concealed parts of these greenstone belts, in particular in an area of Mesozoic cover rocks to the north of the Ord Ranges where there is a large magnetic anomaly that may be due to iron deposits in the underlying Cleaverville Formation.

Smaller deposits of supergene-enriched material that were also identified in the 1960s in the Cleaverville Formation (at Strelley Gorge, Lalla Rookh, Pincunah, and Abydos) have yet to be developed. There may also be potential for other small deposits in Cleaverville Formation in the Paddy Market area (Hickman, 1983).

Sedimentary — banded iron-formation (taconite)

There is potential for possible future development of unenriched (taconite) material in the BIFs of the Cleaverville Formation and Nimingarra Iron Formation in greenstone sequences in the northern part of the east Pilbara.

Vein and hydrothermal mineralization

Gold

Although there is a large number of historical to present-day centres for epigenetic gold mining in the east Pilbara area, the total production from these centres is small when compared to the gold output from an area of similar size in the goldfields of the Yilgarn Craton. For example, the total production from the east Pilbara is approximately 22.5 t compared to 256 t for the northeast Yilgarn, an area of comparable size and ratio of granitoids to greenstones (Ferguson, 1998).

Attempts to explain this significant variation (Solomon and Groves, 1994; Witt et al., 1998; Huston et al., 1999) have focused on differences in lithologies and differences in structural geometry observed in the two cratons, as these reflect differences in geological evolution. In recent years, three broad schools of opinion have developed on the evolution of the Pilbara Craton. In one interpretation the east Pilbara is seen as being dominated by vertical tectonics, driven by diapiric emplacement of granitoid bodies, as a result of crustal overturn processes (Van Kranendonk et al. (in prep.). This interpretation is a significantly modified interpretation of earlier proposals by Hickman (1983).

Another interpretation is reflected in the work of Krapez (1993), Zegers et al. (1996), and Barley (1997), and it proposes an Archaean evolution of the Pilbara granite–greenstones in terms of horizontal tectonic models for early crust formation, associated with thrust-accretionary complexes and convergent margins.

Blewett and Huston (1999) referred to intraplate (extensional and compressional) tectonism with changes in far-field horizontal stresses controlling the system. These authors also suggested that all three of these models may have been involved in the evolution of the Pilbara granite–greenstones over about 800 million years.

As summarized in **Regional geology**, recent work by the GSWA has recognized that there are five litho-tectonic elements (Van Kranendonk et al., in prep.) for the granite–greenstones of the North Pilbara as a whole. Four of these are present in the east Pilbara area: the c. 3520–2850 Ma East Pilbara Granite–Greenstone Terrane, the c. 3010–2940 Ma Mallina Basin, the c. 2920–2850 Ma Mosquito Creek Basin, and the Kurrana Terrane (age uncertain).

Five of the six main gold producing centres (Bamboo Creek, Marble Bar, Warrawoona, North Pole, and Pilgangoora) in the east Pilbara lie within shear zones in mafic and ultramafic lithologies of the Warrawoona Group in the EPGGT. The other main centre is in the Mosquito Creek Basin (at Nullagine), where mineralization is in shear zones in fine-grained clastic metasedimentary rocks of the Mosquito Creek Formation. A reassessment of Pb-isotope data for gold mining centres in the Pilbara acknowledges that definitive ages for gold deposits are difficult to interpret because there is a broad spread of model ages (Huston et al., in prep.). The only definitive age obtained was for the Zakanaka deposit in the Pilgangoora area (2888 ± 6 Ma).

Huston et al. (in prep.) interpreted the regional data to suggest that two broad lode-gold mineralizing events occurred in the Pilbara. An older event at c. 3430–3370 Ma is suggested for mineralization in the Warrawoona, Bamboo Creek, and North Pole centres, and a younger event at c. 2950–2890 Ma is suggested for mineralization in De Grey Group metasedimentary rocks in the Mallina and Mosquito Creek Basins, and for mineralization in greenstones of the Pilgangoora area.

In the Bamboo Creek and Warrawoona centres, the trends of gold mines and prospects that can be seen in Plates 1 and 1A are proximal and parallel to the major shear zones; the shears presumably focused mineralizing fluids into these areas. In the Warrawoona centre, the D_2 Klondyke Shear Zone (some 20 km long and at least 200 m wide) is interpreted by Collins et al., (1998) and Collins and Van Kranendonk (1999), to be a ring fault in greenstones that flank the Mount Edgar Granitoid Complex, which accomodated their sinking, and later exhumation. A more recent reinterpretation of the Warrawoona Syncline (Hickman, 2001a) suggested that the Klondyke Shear Zone is close to, and may be related to, the tight graben-like structure that occupies the centre of the syncline and is post-Wyman Formation. Field relationships indicate that layer-parallel shear zones north of the graben-like structure are the main controlling structures for the gold mineralization at Warrawoona. This interpretation implies that the Pb-isotope dates obtained for gold mineralization at Warrawoona do not provide a reliable guide to the age of gold mineralization, due to the mobilization of older crustal lead. The formation of the D_2 Klondyke Shear Zone and related doming occurred between 3325 and 3308 Ma (Van Kranendonk et al., in prep.).

The Bamboo Creek Shear Zone (26 km long and about 300 m wide) on the northeastern flank of the Mount Edgar Granitoid Complex appears to have been the main focus and control for mineralizing fluids that formed deposits in the Bamboo Creek centre. If this shear zone is interpreted to be similar in style and age to the Klondyke Shear Zone, then (as for Warrrawoona) this also conflicts with the Pb-isotope dates for gold mineralization at Bamboo Creek (Hickman, in prep.). His recent structural reinterpretation for the Bamboo Creek Shear Zone is that it is not a syncline-axial structure (Fig. 15). Rather, it is a doming-related structure that formed by layer-parallel slip along an ultramafic member of the Euro Basalt (Fig. 29).

The mineralization at North Pole does not appear to be associated with major shear zones. It may be that gold in this centre is related to granitoid intrusion. The nearby 3459 ± 18 Ma North Pole Monzogranite lies immediately beneath the Normay mine, and the gold–copper deposits in the Breens–Democrat area are considered by Hickman (1983) to be of a stockwork type related to a 3432 ± 7 Ma felsic porphyry, possibly a late phase of the synvolcanic monzogranite. The Pb-isotope age for the Normay gold, within the range 3430 to 3370 Ma (Huston et al., in prep.), appears to support the geological evidence in this case.

The Marble Bar and Talga Talga deposits lie close to the western margin of the Mount Edgar Granitoid Complex and are connected with doming-related structures within the greenstones (Hickman, 2001a). Differing interpretations have been given for the Talga Talga Shear Zone (Collins, 1989; Van Haaften and White, 1998; Van Kranendonk et al., in prep.), but isotopic evidence indicates that there was a disturbance event at 3300 Ma (McNaughton et al., 1993). This age closely coincides with intrusion of voluminous granitoid rocks in the Mount Edgar Granitoid Complex.

Epigenetic gold occurs in metasedimentary rocks (ranging from c. 2920 to 2850 Ma) of the De Grey Group in the Mosquito Creek Basin. The two lines of gold (–antimony) mineralization (Blue Spec line and Middle Creek line) show the regional control of two easterly to east-northeasterly trending shear zones, about 20 km long, within the basin. The linear, fold–thrust geometry of this basin is distinctly different from the arcuate dome-and-basin geometry of the EPGGT (Van Kranendonk at al., in prep.). The fold–thrust style of deformation suggests that it may have occurred during the period of tectonic accretion of the Kurrana Terrane onto the EPGGT.

Recent exploration by Welcome Stranger (Huston et al., 1999; Blewett et al., in prep.), in the vicinity of the Golden Eagle deposit at the southeastern end of the

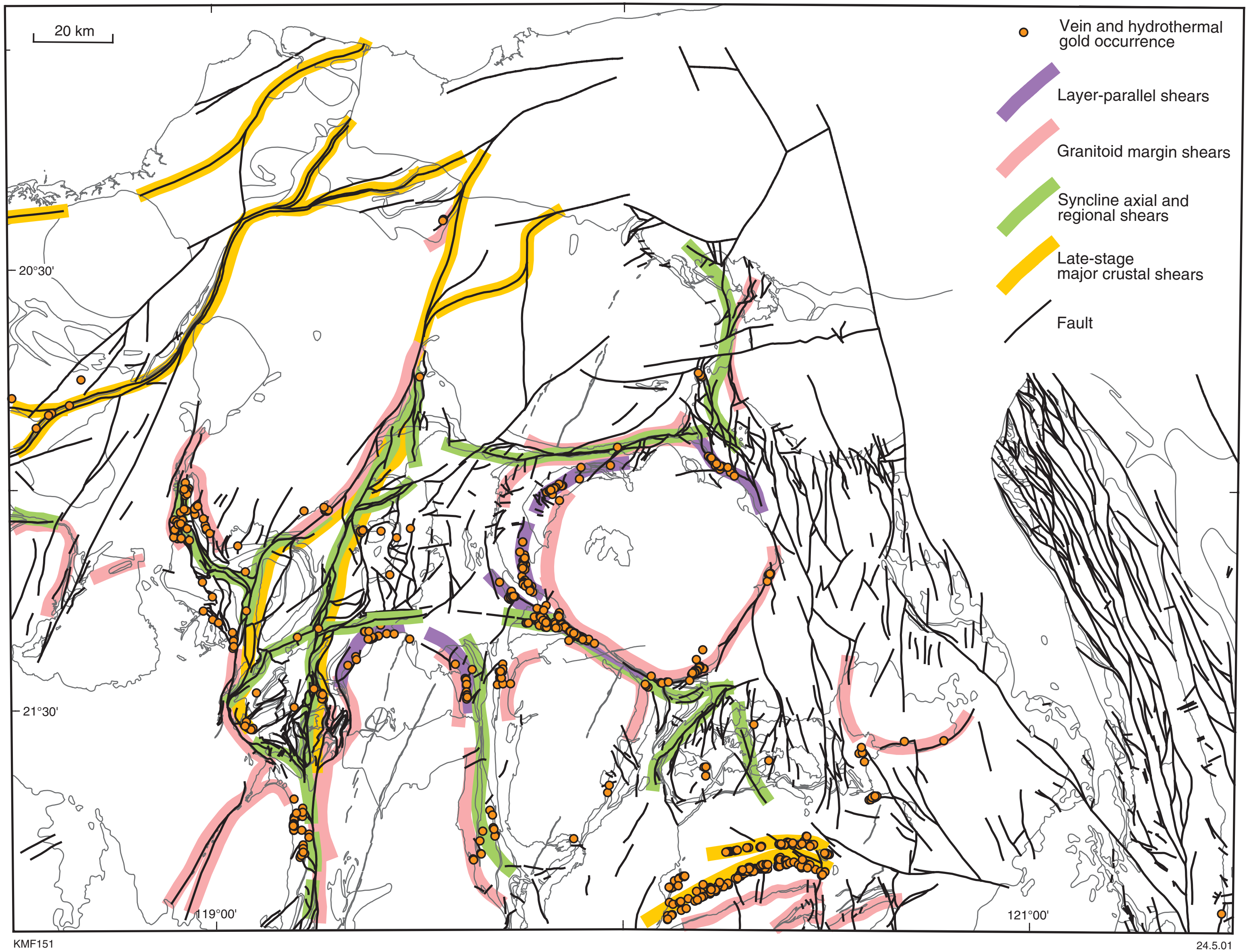

Figure 29. East Pilbara — showing the relationship between the major structural corridors and vein and hydrothermal gold occurrences (after Hickman, 2001a)

Middle Creek line in the Mosquito Creek Basin, suggests that detailed structural analysis is required to fully assess the potential of mineralization in this setting.

In the northwest of the area, a major crustal-scale feature is represented by the interconnecting group of shears that includes the Mallina and Tabba Tabba Shear Zones. This group of shears extends from the western boundary of the Mallina Basin (developed in the Central Pilbara Tectonic Zone) east-northeasterly across the basin, and then follows the eastern boundary of the basin northeastwards as the Tabba Tabba Shear Zone. Recent successful exploration by Resolute Resources has located gold(–antimony–arsenic) deposits in turbiditic fine-grained clastic metasedimentary rocks in the 2970–2945 Ma Mallina Basin in the west Pilbara (Ruddock, 1999; Huston et al., 1999). The gold–antimony–arsenic–tellurium(–bismuth–tungsten) mineralization is in epithermal veins in a zone (Becher, Orange Rock, Opaline Well, and Sams Ridge vein systems) along this connected group of shears in the west Pilbara (Huston et al., 2000; Marshall, 2000), with ages ranging between 2700 and 2750 Ma inferred from the structural setting (Huston et al., 2000). Further exploration is warranted to test the gold potential in areas where shear zones have been identified (e.g. from airborne geophysical surveys and Landsat imagery) in the Mallina Basin, particularly in the northern part of the project area where there is limited outcrop.

In summary, the broad differences in the styles of evolution of the granite–greenstones of the Pilbara and Yilgarn Cratons have determined the contrast in their mineralization styles and their prospectivity for large deposits of vein and hydrothermal gold. The unique temporal focus and craton-wide scale of gold mineralization in the east Yilgarn Craton has favoured the formation of large orebodies adjacent to major, craton-scale, feeder structures. In the east Pilbara, by contrast, most shear zones in greenstone belts are at a more local scale, ranging from 10 to 30 km long, and are related predominantly to vertical movement during diapiric granitoid emplacement.

Based on Hickman's recent interpretation (Hickman, 2001a), Figure 29 shows gold mineralization and the broad structural framework relating to granitoid doming in the EPGGT. Figure 29 distinguishes between the 'proximal', granitoid-marginal shears (granitoid contacts), the layer-parallel shears (parallel to, but some distance from granitoid contacts), and axial shears in the deep synclinal keels of the greenstone belts (in some places forming graben-like structures). Also shown on Figure 29 are east-northeasterly to north-northeasterly trending shear zones and structural corridors that are interpreted as craton-scale structures (Van Kranendonk et al., in prep.). Gold mineralization appears to be related to zones of layer-parallel shears in greenstone belts (rather than granitoid-marginal shears or axial shears) and to craton-scale shears and structural corridors.

There may also be gold potential in areas where these major crustal shear zones are in proximity to granitoids. Margins of some granitoids (in particular the smaller, later granitoids) may have acted as stress modifiers near these zones and provided areas containing pathways and traps for gold-bearing solutions. Examples from the east Yilgarn, such as the structural setting of the Granny Smith orebody where a granitoid has acted as a rigid body deflecting a nearby shear zone and creating a local domain of low mean stress, offer possibilities for similar situations in the east Pilbara (Witt, 2000).

Disseminated and stockwork mineralization in plutonic intrusions

Epithermal mineralization

As stated above, prospectivity for economically significant epithermal deposits in Precambrian rocks is limited to areas where high-level, largely subaerial, volcanic terranes have been preserved. This suggests that in the east Pilbara potential is present in the extensive areas of well-exposed, low-grade greenstones. Only the Miralga Creek gold and base metal deposits and the Meentheena fluorite deposits have been well documented. Marshall (2000), in his review of this deposit type, suggested that potential is also present in the North Pole and McPhee Domes and in the Kelly belt.

Non-epithermal mineralization

The areas also have some potential for other types of vein-hosted mineralization, such as Cu–Mo stockwork, and other types. However, most of the known mineralization is fairly minor.

Pegmatitic mineralization

The recent discovery by SOG, of significant resources of pegmatite-hosted tantalum in the Mount Cassiterite area of the Wodgina centre, suggests that there may be ongoing potential for this mineralization type in areas considered to have been extensively worked in the past.

Regolith — residual and supergene mineralization

Manganese

There is potential for further discoveries of small but high-grade manganese deposits in the 'Pilbara Manganese Province', using geophysical prospecting methods of gravity surveys and magnetic surveys to delineate target areas for drilling.

Regolith — alluvial to beach placer mineralization

Pisolitic iron ore

There is little potential for the discovery of large deposits of pisolitic ore, and it is unlikely that there will be development of the small mesa deposits in the near hinterland of Port Hedland for many years, until the current large inventory of pisolite resources in the Pilbara has been developed and there is a need for further resources.

Regolith — residual to eluvial, and alluvial to beach placer mineralization

Gold, tin–tantalum

There is potential for continuing small-scale gold production from eluvial and alluvial deposits located near the known vein and hydrothermal gold centres, and for small-scale alluvial tin and tantalum production in areas near pegmatites associated with late-tectonic granites within the granitoid complexes, and within greenstone belts adjacent to late-tectonic granite intrusions.

Conclusions

The east Pilbara must still be considered one of the most prospective, under-explored parts of the State for a large range of commodities in a variety of mineralization styles. Since the early mineral discoveries of the late 1880s, exploration in many areas has highlighted prospectivity for gold, tin–tantalum, manganese, iron ore, volcanogenic base metal sulfides, stratabound sedimentary base metal sulfides, and diamonds. The areas of mineralization show a strong relationship to the key events in the stratigraphic, igneous, metamorphic, and tectonic evolution of the area. However, they have yet to be fully tested by the latest geochemical and geophysical methods used by industry, and be assessed in the light of new geological concepts arising from the mapping program and the airborne geophysical surveys of the former National Geoscience Mapping Accord and the current Agreement.

Recent major developments in the understanding of the geological evolution of the east Pilbara, while still somewhat in dispute, have already allowed the recognition of a much better constrained context in which to assess the known mineralization of the area and its potential.

Major recent exploration success in relation to VMS and sedimentary-hosted base metal mineralization in the Sulphur Springs area and in the Throssell Group have highlighted the base metal potential of the area. The Sulphur Springs discovery demonstrated the essential value of detailed geological mapping in combination with high-quality aerial photography even in an area with spectacular exposure. The discoveries in the Throssell Group demonstrate the value of modern conceptual modelling and geophysical methodology.

Gold prospectivity has been enhanced by sophisticated detailed structural analysis in the Warrawoona, Bamboo Creek, Mosquito Creek, and Pilgangoora areas, and further discoveries will probably depend on a combination of regional and local structural analysis to predict the locations of favourable feeder systems and trap sites.

Diamond potential has been significantly boosted by the recognition of the Brockman Dyke as a primary source of gems.

References

ABEYSINGHE, P. B., 1996, Talc, pyrophyllite and magnesite in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 16, 118p.

ABEYSINGHE, P. B., 1998, Limestone and limesand resources of Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 18, 140p.

ABEYSINGHE, P. B., and FETHERSTON, J. M., 1997, Barite and fluorite in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 17, 97p.

ALSTON, T., 1984, West Pilbara project final report on prospecting licences 47/21, 47/22, 47/41, 47/122–127 and exploration licences 47/68, 47/69, 47/81, 47/173 and 47/174: Western Australia Geological Survey, Statutory mineral exploration report, Item 4038 A15241 (unpublished).

ARCHER, R. H., 1977a, Boodarrie, W. A. Sheet 2557-II: Western Australia Geological Survey, 1:50 000 Urban Geology Series.

ARCHER, R. H., 1977b, Port Hedland, W. A. Sheet 2657-III: Western Australia Geological Survey, 1:50 000 Urban Geology Series.

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, p. 261–281.

ATKINSON AND PARTNERS, 1979, A review of the geology and ore potential of the Bamboo Creek Gold Mining Centre, Pilbara Goldfield: Western Australia Geological Survey, Statutory mineral exploration report, Item 6043 A8680 (unpublished).

AZTEC EXPLORATION LTD, 1987, Warrawoona Project Drilling Report, P45/945–959, Marble Bar: Western Australia Geological Survey, Statutory mineral exploration report, Item 6718 A19724 (unpublished).

AZTEC EXPLORATION LTD, 1988, Warrawoona Project Annual Report, E45/350–51, P45/945–959: Western Australia Geological Survey, Statutory mineral exploration report, Item 6718 A25544 (unpublished).

AZTEC EXPLORATION LTD, 1990, Warrawoona Project Annual Report, E45/350–51: Western Australia Geological Survey, Statutory mineral exploration report, Item 6718 A29424 (unpublished).

BACKHOUSE, J., 1979, Palynology of samples form BHP boreholes, Mount Bruce sheet: Western Australia Geological Survey, Palaeontology Report 3/1979 (unpublished).

BAGAS, L., 2000, Geology of the Paterson 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 20p.

BAGAS, L., and FARRELL, T. R., in prep., Nullagine, W. A. Sheet 2954: Western Australia Geological Survey, 1:100 000 Geological Series.

BAGAS, L., and SMITHIES, R. H., 1998, Geology of the Connaughton 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 38p.

BAGAS, L., and VAN KRANENDONK, M. J., in prep., Split Rock, W. A. Sheet 2854: Western Australia Geological Survey, 1:100 000 Geological Series.

BAGAS, L., GREY, K., and WILLIAMS, I. R., 1995, Reappraisal of the Paterson Orogen and Savory Basin: Western Australia Geological Survey, Annual Review 1994–95, p. 55–63.

BAGAS, L., CAMACHO, A., and NELSON, D. R., in prep., Are the Neoproterozoic Lamil and Throssell Groups of the Paterson Orogen allochthonous?: Western Australia Geological Survey, Annual Review 2000–01.

BARLEY, M. E., 1982, Porphyry style mineralization associated with Archaean calc-alkaline igneous activity, Eastern Pilbara, Western Australia: Economic Geology, v. 77, p. 1230–1235.

BARLEY, M. E., 1992, A review of Archaean volcanic-hosted sulfide and sulfate mineralization in Western Australia: Economic Geology, v. 87, p. 855–872.

BARLEY, M. E., 1993, Volcanic, sedimentary and tectonostratigraphic environments of the ~3.46 Ga Warrawoona Megasequence — a review: Precambrian Research, v. 60, p. 47–67.

BARLEY, M. E., 1997, The Pilbara Craton, *in* Greenstone belts *edited by* M. J. de WIT and L. ASHWAL: Oxford University Monographs on Geology and Geophysics no. 35, Clarendon Press, p. 657–664.

BARLEY, M. E., and PICKARD, A. L., 1999, An extensive, crustally derived 3325 to 3310 Ma silicic volcanoplutonic suite in the eastern Pilbara Craton: evidence from the Kelly Belt, McPhee Dome and Corunna Downs Batholith: Precambrian Research, v. 96, p. 41–62.

BARLEY, M. E., DUNLOP, J. S. E., GLOVER, J. E., and GROVES, D. I., 1979, Sedimentary evidence for an Archaean shallow-water volcanic–sedimentary facies, eastern Pilbara Block, Western Australia: Earth and Planetary Science Letters, v. 43, p. 74–84.

BARLEY, M. E., GROVES, D. I., and BLAKE, T. S., 1992, Archaean metal deposits related to tectonics: evidence from Western Australia, *in* The Archaean: terrains, processes and metallogeny *edited by* J. E. GLOVER and S. E. HO: University of Western Australia, Geology Department and University Extension, Publication no. 22, p. 307–324.

BARLEY, M. E., LOADER, S. E., McNAUGHTON, N. J., 1998, 3430 to 3417 Ma calc-alkaline volcanism in the McPhee Dome and Kelly Belt, and growth of the eastern Pilbara Craton: Precambrian Research, v. 88, p. 3–23.

BAXTER, J. L., 1978, Molybdenum, tungsten, vanadium, and chromium in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 11, 140p.

BAXTER, J. L., 1992, Annual Report for the Golden Eagle Project, Nullagine, Western Australia, for Kismet Gold Mining NL: Western Australia Geological Survey, Statutory mineral exploration report, Item 7462, A36923 (unpublished).

BECHER, S. J., 1896, Report on the Pilbara Goldfield, 1894–1895 with references to its geological character: Western Australia Department of Mines, Annual Report, 1895, Appendix 5, p. 28–31.

BECHER, S. J., 1897, Report on Northern Goldfields: Western Australia Department of Mines, Annual Report, 1896, p. 36–39.

BECHER, S. J., 1898, The Nullagine district, Pilbara Goldfield, Western Australia: Inst. Min. Eng. Trans. 1898, v. 16.

BELL, L., 1987, Progress report 20 Mile Sandy Project, Nullagine area: Western Australia Geological Survey, Statutory mineral exploration report, Item 4560 A20916 (unpublished).

BESTER, G. (editor), 2000, Register of Australian Mining 1999/2000: Subiaco, Western Australia, Resource Information Unit, 648p.

BETTENAY, L. F., BICKLE, M. J., BOULTER, C. A., GROVES, D. I., MORANT, P., BLAKE, T. S., and JAMES, B. A., 1981, Evolution of the Shaw batholith — an Archaean granitoid–gneiss dome in the eastern Pilbara, Western Australia, *in* Archaean Geology *edited by* J. E. GLOVER and D. I. GROVES: Geological Society of Australia; 2nd International Archaean Symposium, Perth, W. A., 1980, Proceedings, Special Publication, no. 7, p. 361–372.

BETTENAY, L. F., ROCK, N. M. S., and MATHER, P. J., 1990, Metamorphosed ultramafic lamprophyre dykes of probable late Archaean age from the Shaw batholith area, east Pilbara Block, Western Australia, *in* Mafic dykes and emplacement mechanisms *edited by* A. J. PARKER, P. C. RICKWOOD, and D. H. TUCKER: Second International Dyke Conference, Adelaide, S. A., 1990, Proceedings, Rotterdam, A. A. Balkema, p. 107–117.

BICKLE, M. J., BETTENAY, L. F., BARLEY, M. E., CHAPMAN, H. J., GROVES, D. I., CAMPBELL, I. H., and de LAETER, J. R., 1983, A 3500 Ma plutonic and volcanic province in the Archaean east Pilbara Block: Contributions to Mineralogy and Petrology, v. 84, p. 25–35.

BICKLE, M. J., BETTENAY, L. F., CHAPMAN, H. J., GROVES, D. I., McNAUGHTON, N. J., CAMPBELL, I. H., and de LAETER, J. R., 1989, The age and origin of younger granitic plutons of the Shaw batholith in the Archaean Pilbara Block, Western Australia: Contributions to Mineralogy and Petrology, v. 101, p. 361–376.

BICKLE, M. J., BETTENAY, L. F., CHAPMAN, H. J., GROVES, D. I., McNAUGHTON, N. J., CAMPBELL, I. H., and de LAETER, J. R., 1993, Origin of the 3500–3300 Ma calc-alkaline rocks in the Pilbara Archaean: isotopic and geochemical constraints from the Shaw Batholith: Precambrian Research, v. 60, p. 117–149.

BICKLE, M. J., MORANT, P., BETTENAY, L. F., BOULTER, C. A., BLAKE, T. S., and GROVES, D. I., 1985, Archaean tectonics of the Shaw Batholith, Pilbara Block, Western Australia: structural and metamorphic tests of the batholith concept: *in* Evolution of Archean supracrustal sequences *edited by* L. D. AYERS, P. C. THURSTON, K. D. CARD, and W. WEBER: Geological Association of Canada, Special Paper 28, p. 325–341.

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

BLAKE, T. S., 1993, Late Archean crustal extension, sedimentary basin formation, flood basalt volcanism and continental rifting: the Nullagine and Mount Jope Supersequences, Western Australia: Precambrian Research, v. 60, p. 185–241.

BLAKE, T. S., and CHALMERS, D. I., 1994, A diamondiferous alkaline igneous province in the eastern Pilbara, Western Australia, *in* Notes to accompany conference presentation: Alkane Exploration NL, Australian Diamond Conference, 1994, Perth, 14p (unpublished).

BLATCHFORD, T., 1913, Mineral resources of the North-West Division, investigations in 1912: Western Australia Geological Survey, Bulletin 52, 157p.

BLATCHFORD, T., 1925, Braeside mineral belt and Coobina chromite discovery: Western Australia Department of Mines, Annual Report 1924, p. 78–85.

BLAZEY, E. L., RAYNER, J. M., and NYE, P. B., 1938, Geophysical report on the Bamboo Creek area, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 39, 6p.

BLEWETT, R. S., and HUSTON, D. L., 1999, Deformation and gold mineralisation of the Archaean Pilbara Craton, Western Australia: Australian Geological Survey Organisation, Research Newsletter 30, p. 12–15.

BLEWETT, R. S., WELLMAN, P., RATAJKOSKI, M., and HUSTON, D. L., 2000, Atlas of North Pilbara geology and geophysics, 1:1.5 million scale: Australian Geological Survey Organisation, Record 2000/4.

BLEWETT, R. S., CHAMPION, D. C., SMITHIES, R. H., VAN KRANENDONK, M. J., FARRELL, T. R., and THOST, D., 2001, Wodgina, W. A. Sheet 2655: Western Australia Geological Survey, 1:100 000 Geological Series.

BLEWETT, R. S., HUSTON, D. L., MERNAGH, T. P., and KAMPRAD, J., in prep., The diverse nature of Archaean lode gold deposits of the southwest Mosquito Creek Belt, East Pilbara Craton: Economic Geology.

BLOCKLEY, J. G., 1971a, The lead, zinc and silver deposits of Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 9, 234p.

BLOCKLEY, J. G., 1971b, Geology and mineral resources of the Wodgina District: Western Australia Geological Survey, Annual Report for 1970, p. 38–42.

BLOCKLEY, J. G., 1975, Pilbara manganese province, W. A., *in* Economic geology of Australia and Papua New Guinea *edited by* C. L. KNIGHT: Australasian Institute of Mining and Metallurgy, Monograph 5, p. 1019–1020.

BLOCKLEY, J. G., 1976, The Ord Range tiger-eye deposits: Western Australia Geological Survey, Annual Report for 1975, p. 108–112.

BLOCKLEY, J. G., 1980, Tin deposits of Western Australia with special reference to the associated granites: Western Australia Geological Survey, Mineral Resources Bulletin 12, 184p.

BLOCKLEY, J. G., REID, I. W., and TRENDALL, A. F., 1990, Geological aspects of Australian iron ore discovery and development, *in* Geological aspects of the discovery of some important mineral deposits in Australia *edited by* K. R. GLASSON and J. H. RATTIGAN: Australasian Institute of Mining and Metallurgy, Monograph 17, p. 263–285.

BRANDT, R. T., 1964, The iron ore deposits of the Mount Goldsworthy area, Port Hedland district, Western Australia: Australasian Institute of Mining and Metallurgy, Proceedings, no. 211, p. 157–180.

BRANDT, R. T., 1966, Genesis of the Mount Goldsworthy iron ore deposits, Port Hedland district: Economic Geology, v. 61, p. 999–1009.

BRAUHART, C., 1999, Regional alteration systems associated with Archaean volcanogenic massive sulphide deposits at Panorama, Pilbara, Western Australia: University of Western Australia, PhD thesis (unpublished).

BROOK, W., 1974, Big Stubby zinc deposits, *in* Excursion itinerary on the Marble Bar and Nullagine 1:250 000 Sheet areas: Western Australia Geological Survey, excursion notes (unpublished).

BUICK, R., and BARNES, K. R., 1984, Cherts in the Warrawoona Group: Early Archaean silicified sediments deposited in shallow-water environments *in* Archaean and Proterozoic Basins of the Pilbara, Western Australia: Evolution and mineralization potential *edited by* J. R. MUHLING, D. I. GROVES, and T. S. BLAKE: University of Western Australia, Geology Department and University Extension, Publication, no. 9, p. 37–53.

BUICK, R., and DUNLOP, J. S. R., 1990, Evaporitic sediments of early Archaean age from the Warrawoona Group, North Pole, Western Australia: Sedimentology, v. 37, p. 247–277.

BUICK, R., THORNETT, J. R., McNAUGHTON, N. J., SMITH, J. B., BARLEY, M. E., and SAVAGE, M., 1995, Record of emergent continental crust ~3.5 billion years ago in the Pilbara Craton of Australia: Nature, v. 357, p. 574–577.

BUTLER, R. J. T., 1976, Geology of the Tertiary ironstones in the middle and upper Robe River area, Pilbara Region, Western Australia: University of Western Australia, MSc thesis (unpublished).

CARTER, J. D., 1974, Diamond exploration in Western Australia: Western Australia Geological Survey, Annual Report 1973, p. 73–79.

CASEY, J. J., and WELLS, A. T., 1956, Manganese deposits, Gregory Range, Pilbara Goldfield, W. A.: Australia BMR (now AGSO), Record 1956/8.

CENTOFANTI, J. J. F., 2000, Yarrie iron ore mine, *in* Archaean geology of the Muccan region, East Pilbara Granite–Greenstone Terrane, Western Australia — a field guide: Western Australia Geological Survey, Record 2000/4, p. 15–18.

CHAMPION, D. C., and SMITHIES, R. H., 2000, The geology of the Yule Granitoid Complex, East Pilbara Granite–Greenstone Terrane; evidence for early felsic crust: Western Australia Geological Survey, Annual Review 1999–2000, p. 42–48.

CHIN, R. J., WILLIAMS, I. R., WILLIAMS, S. J., and CROWE, R. W. A., 1980, Rudall, W. A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 22p.

COLLINS, W. J., 1983, Geological evolution of an Archaean batholith: Latrobe University, PhD thesis (unpublished), 315p.

COLLINS, W. J., 1989, Polydiapirism of the Archaean Mount Edgar Batholith, Pilbara Craton, Western Australia: Precambrian Research, v. 43, p. 41–62.

COLLINS, W. J., and GRAY, C. M., 1990, Rb–Sr isotopic systematics of an Archaean granite–gneiss terrain: the Mount Edgar Batholith, Pilbara Block, Western Australia: Australian Journal of Earth Sciences, v. 37, p. 9–22.

COLLINS, W. J., and VAN KRANENDONK, M. J., 1999, Model for the development of kyanite during partial convective overturn of Archaean granite–greenstone terranes: the Pilbara Craton, Australia: Journal of Metamorphic Petrology, v. 17, p. 145–156.

COLLINS, W. J., VAN KRANENDONK, M. J., and TEYSSIER, C., 1998, Partial convective overturn of the Archaean crust in the east Pilbara Craton, Western Australia: driving mechanisms and tectonic implications: Journal of Structural Geology, v. 20, p. 1404–1424.

CONNOLLY, R. R., 1959, Iron ores in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 7, 103p.

CONSOLIDATED MINERALS LIMITED, 2000, Annual Report for 2000.

COOPER, J. A., JAMES, P. R., and RUTLAND, R. W. R., 1982, Isotopic dating and structural relationships of granitoids and greenstones in the eastern Pilbara, Western Australia: Precambrian Research, v. 83, p. 199–236.

CUDAHY, T. J., and RAMANAIDOU, E. R., 1997, Measurement of the hematite:goethite ratio using field visible and near-infrared reflectance spectrometry in channel iron deposits, Western Australia: Australian Journal of Earth Sciences, v. 44, p. 411–420.

CULLERS, R. L., DiMARCO, M. J., LOWE, D. R., and STONE, J., 1993, Geochemistry of a silicified felsic volcaniclastic suite from the Early Archaean Panorama Formation, Pilbara Block, Western Australia — an evaluation of depositional and post-depositional processes with special emphasis on rare-earth elements: Precambrian Research, v. 60, p. 99–116.

DAMMER, D., McDOUGALL, I., and CHIVAS, A. R., 1999, Timing of weathering-induced alteration of manganese deposits in Western Australia: Evidence from K/Ar and $^{40}Ar/^{39}Ar$ dating: Economic Geology, v. 94, p. 87–108.

DAVIDSON, W. A., 1974, De Grey River groundwater investigation: Western Australia Geological Survey, Record 1973/27, 62p.

DAVY, R., 1988, Geochemical patterns in granitoids of the Corunna Downs Batholith, Western Australia: Western Australia Geological Survey, Report 23, p. 51–84.

DAVY, R., and LEWIS, J. D., 1986, The Mount Edgar Batholith, Pilbara area, Western Australia — geochemistry and petrology: Western Australia Geological Survey, Report 17, 44p.

de la HUNTY, L. E., 1955, Report on some manganese deposits in the North West Division, Western Australia: Western Australia Geological Survey, Annual Report 1952, p. 34–40.

de la HUNTY, L. E., 1961, Report on some limonitic iron ore deposits in the vicinity of Port Hedland, Pilbara Goldfield, W. A.: Western Australia Geological Survey, Annual Report 1960, p. 15–21.

de la HUNTY, L. E., 1963, The geology of the manganese deposits of Western Australia: Western Australia Geological Survey, Bulletin 116, 112p.

de la HUNTY, L. E., 1965a, Investigation of manganese deposits in the Mount Sydney – Woodie Woodie area, Pilbara Goldfield: Western Australia Geological Survey, Annual Report 1964, p. 45–49.

de la HUNTY, L. E., 1965b, Manganese ore deposits of Western Australia, *in* Geology of Australian ore deposits (2nd edition) *edited by* J. McANDREW: Commonwealth Mining and Metallurgy Congress, 8th, Australia and New Zealand, 1965, Publications, v. 1, p. 140–146.

DENHOLM, L. S., 1977, Investigation of the ferruginous manganese deposits at Ripon Hills, Pilbara Manganese Province, Western Australia: Australasian Institute of Mining and Metallurgy, Proceedings, no. 264, p. 9–17.

DEPARTMENT OF MINERALS AND ENERGY, 1994, Pastoral leases: prospecting on, exploration on, mining on: Western Australia Department of Minerals and Energy, Information Series no. 5, 4p.

DEPARTMENT OF MINERALS AND ENERGY, 1995, Guidelines for the application of environmental conditions for onshore mineral exploration and development on conservation reserves and other environmentally sensitive land in Western Australia: Western Australia Department of Minerals and Energy, Information Series no. 11, 32p.

DiMARCO, M. J., and LOWE, D. R., 1989a, Stratigraphy and sedimentology of an Early Archaean felsic volcanic sequence, eastern Pilbara Block, Western Australia, with special reference to the Duffer Formation and implications for crustal evolution: Precambrian Research, v. 44, p. 147–169.

DiMARCO, M. J., and LOWE, D. R., 1989b, Shallow water volcaniclastic deposition in the Early Archaean Panorama Formation, eastern Pilbara Block, Western Australia: Sedimentary Geology, v. 64, p. 43–63.

DiMARCO, M. J., and LOWE, D. R., 1989c, Petrography and provenance of silicified Early Archaean volcaniclastic sandstones, eastern Pilbara Block, Western Australia: Sedimentology, v. 36, p. 821–836.

ELLIS, H. A., 1950, Some economic aspects of the principal tantalum-bearing deposits of the Pilbara Goldfield, North West Division: Western Australia Geological Survey Bulletin 104, 93p.

ERIKSSON, K. A., 1981, Archaean platform-to-trough tectonic sedimentation in the eastern Pilbara Block, Australia, *in* Archaean Geology *edited by* J. E. GLOVER and D. I. GROVES: Geological Society of Australia, 2nd International Archaean Symposium, Perth, W. A., 1980, Proceedings, Special Publication, no. 7, p. 235–244.

ERIKSSON, K. A., KRAPEZ, B., and FRALICK, P. W., 1994, Sedimentology of Archaean greenstone belts: signatures of tectonic evolution: Earth Science Reviews, v. 37, p. 1–88.

FARRELL, T. R., in prep., Eastern Creek, W. A. Sheet 3054: Western Australia Geological Survey, 1:100 000 Geological Series.

FERGUSON, K. M., 1998, Mineral occurrences and exploration potential of the north Eastern Goldfields: Western Australia Geological Survey, Report 63, 40p.

FERGUSON, K. M., 1999, The lead, zinc and silver deposits of Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 15, 314p.

FETHERSTON, J. M., 1990, Manganese, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 693–694.

FINUCANE, K. J., 1935a, McPhee's Patch area, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 1, 4p.

FINUCANE, K. J., 1935b, The Nullagine Conglomerates, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 4, 6p.

FINUCANE, K. J., 1936a, The North Pole mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 2, 5p.

FINUCANE, K. J., 1936b, Lalla Rookh mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 3, 7p.

FINUCANE, K. J., 1936c, The Nullagine River concessions, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 5, 5p.

FINUCANE, K. J., 1936d, The Blue Spec gold–antimony quartz veins, Middle Creek–Nullagine district, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 7, 9p.

FINUCANE, K. J., 1936e, Marble Bar mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 8, 9p.

FINUCANE, K. J., 1936f, Bamboo Creek mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 9, 12p.

FINUCANE, K. J., 1937a, Halley's Comet Centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 10, 6p.

FINUCANE, K. J., 1937b, Lalla Rookh gold mine, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 11, 7p.

FINUCANE, K. J., 1938a, Just-in-time conglomerates, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 13, 4p.

FINUCANE, K. J., 1938b, The North Shaw mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 14, 4p.

FINUCANE, K. J., 1938c, McLeod's Find, Dalton mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 15, 4p.

FINUCANE, K. J., 1938d, The Tambourah and Western Shaw mining centres, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 16, 7p.

FINUCANE, K. J., 1938e, The Braeside lead field, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 24, 9p.

FINUCANE, K. J., 1938f, Recent gold discoveries near Wyman's Well, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 25, 4p.

FINUCANE, K. J., 1938g, Halley's Comet and adjacent mines, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 28, 6p.

FINUCANE, K. J., 1939a, The Sharks Well mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 17, 7p.

FINUCANE, K. J., 1939b, Mining centres east of Nullagine, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 19, 22p.

FINUCANE, K. J., 1939c, The Salgash–Apex area, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 21, 4p.

FINUCANE, K. J., 1939d, The Boodalyerrie mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 22, 4p.

FINUCANE, K. J., 1939e, The Yandicoogina mining centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 23, 8p.

FINUCANE, K. J., and SULLIVAN, C. J., 1939, The Twenty Ounce Mining Centre, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 18, 4p.

FINUCANE, K. J., SULLIVAN, C. J., and TELFORD, R. J., 1939, The chrysotile deposits of the Pilbara and Ashburton Goldfields: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 54, 10p.

FINUCANE, K. J., and TELFORD, R. J., 1939a, The tantalite deposits of the Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 46, 8p.

FINUCANE, K. J., and TELFORD, R. J., 1939b, The antimony deposits of the Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 47, 6p.

FINUCANE, K. J., and TELFORD, R. J., 1939c, The Ellarine Hills and Andover iron deposits, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 56, 4p.

FLINT, D. J., and ABEYSINGHE, P. B., 2001, Western Australia mineral exploration and development for 1999 and 2000: Western Australia Geological Survey, 35p.

GIFFORD, A. C., 1990, Blue Spec – Golden Spec gold–antimony deposit, *in* Geology of the mineral deposits of Australia and Papua New Guinea, Volume 1 *edited by* F. E. HUGHES Australasian Institute of Mining and Metallurgy, Monograph 14, p. 155–158.

GLIKSON, A. Y., and HICKMAN, A. H., 1981a, Chemical stratigraphy and petrogenesis of Archaean basic–ultrabasic volcanic units, eastern Pilbara Block, Western Australia, *in* Archaean Geology *edited by* J. E. GLOVER and D. I. GROVES: Geological Society of Australia, 2nd International Archaean Symposium, Perth, W. A., 1980, Proceedings, Special Publication, no. 7, p.287–300.

GLIKSON, A. Y., and HICKMAN, A. H., 1981b, Geochemistry of Archaean volcanic successions, eastern Pilbara Block, Western Australia: Australia BMR (now AGSO), Record 1981/36, 83p.

GLIKSON, A. Y., DAVY, R., and HICKMAN, A. H., 1986, Geochemical data files of Archaean volcanic rocks, Pilbara Block, Western Australia: Australia BMR (now AGSO), Record 1986/14, 10p.

GLIKSON, A. Y., DAVY. R., and HICKMAN, A. H., 1991, Trace metal distribution patterns in basalts, Pilbara Craton, Western Australia, with stratigraphic–geochemical implications: Australia Bureau of Mineral Resources (now AGSO), Record 1991/46, 37p.

GOELLNICHT, N. M., GROVES, I. M., GROVES, D. I., HO, S.E., and McNAUGHTON, N. J., 1988, A comparison between mesothermal gold deposits of the Yilgarn Block and gold mineralization at Telfer and Miralga Creek, Western Australia — indirect evidence for a non-magmatic origin for greenstone-hosted gold deposits, *in* Advances in understanding Precambrian gold deposits, volume II, *edited by* S. E. HO and D. I. GROVES: University of Western Australia, Department of Geology and Extension Service, Publication, no. 12, p. 23–40.

GREGORY, F. T., 1884, North West Coast 1861, *in* Journals of Australian explorations 1846–1858: Brisbane, Government Printer (facsimile edition, 1981, Perth, Hesperian Press), p. 52–98.

GREY, K., WILLIAMS, I. R., MARTIN, D. McB., FEDONKIN, M. A., GEHLING, J. G., RUNNEGAR, B. N., and YOCHELSON, E. L., in prep., New occurrences of 'strings of beads' in the Bangemall Supergroup: a potential biostratigraphic marker horizon: Western Australia Geological Survey, Annual Review 2000–01.

GRIFFIN, T. J., 1990, North Pilbara granite–greenstone terrane, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3. p. 128–158.

GROOM, E. F., 1896, Report of a visit to Nullagine, Pilbara district, to examine the country reported to be diamond yielding: Western Australia Department of Mines, Annual Report 1895, p. 27.

GROVES, D. I., 1993, The crustal continuum model for late-Archaean lode gold deposits of the Yilgarn Block, Western Australia: Mineralium Deposita, v. 28, p. 366–374.

GROVES, D. I., RIDLEY, J. R., BLOEM, E. J. M., GEBRE-MARIAM, M., HRONSKY, J. M. A., KNIGHT, J. T., McNAUGHTON, N. J., OJALA, V. J., VIELREICHER, R. M., HOLYLAND, P. W., and McCUAIG, T. C., 1995, Lode-gold deposits of the Yilgarn Block: products of late-Archaean crustal-scale overpressured hydrothermal systems, *in* Early Precambrian Processes *edited by* M. P. COWARD and A. C. RIES: Geological Society of London, Special Publication, no. 95, p. 155–172.

GROVES, I. M., 1987, Epithermal/porphyry style base- and precious-metal mineralization in the Miralga Creek area, eastern Pilbara Block: University of Western Australia, BSc Honours thesis (unpublished).

HALL, G. C., and KNEESHAW, M., 1990, Yandicoogina–Marillana pisolitic iron deposits, *in* Geology of the mineral deposits of Australia and Papua New Guinea *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, v. 2, p. 1581–1586.

HANCOCK & WRIGHT PROSPECTING PTY LTD, 1984, Surrender report for P45/64, Abydos: Western Australia Geological Survey, Statutory mineral exploration report, Item 6838 A13775 (unpublished).

HAOMA MINING NL, 1999, Annual Report for 1999.

HARMS, J. E., and MORGAN, B. D., 1964, Pisolitic limonite deposits in Northwest Australia: Australasian Institute of Mining and Metallurgy, Proceedings, no. 212, p. 91–124.

HARMSWORTH, R. A., KNEESHAW, M., MORRIS, R. C., ROBINSON, C. J., and SHRIVASTAVA, P. K., 1990, BIF-derived iron ores of the Hamersley Province, *in* Geology of the mineral deposits of Australia and Papua New Guinea, Volume 1, *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 617–642.

HARRIS, B. G., and MacDONALD, S. A., 1986, P45/719 Soanesville, Pilbara Mineral Field: Annual Report for year 1985–86: Western Australia Geological Survey, Statutory mineral exploration report, Item 3701 A18535 (unpublished).

HICKMAN, A. H., 1973, The North Pole barite deposit, Pilbara Goldfield: Western Australia Geological Survey, Annual Report 1972, p. 57–60.

HICKMAN, A. H., 1974, The Meentheena fluorite deposits, Pilbara Goldfield: Western Australia Geological Survey, Annual Report 1973, p. 79–82.

HICKMAN, A. H., 1976, Fluorite porphyry at Ngarrin Creek, Yarrie: Western Australia Geological Survey, Record 1976/3.

HICKMAN, A. H., 1977, Barite deposits near Cooke Bluff Hill, Port Hedland 1:250 000 Geological Sheet, W. A.: Western Australia Geological Survey, Record 1976/22.

HICKMAN, A. H., 1978, Nullagine, W. A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 22p.

HICKMAN, A. H., 1981, Crustal evolution of the Pilbara Block, Western Australia, *in* Archaean geology *edited by* J. E. GLOVER and D. I. GROVES: Geological Society of Australia, Special Publication, no. 7, p. 57–69.

HICKMAN, A. H., 1983, Geology of the Pilbara Block and its environs: Western Australia Geological Survey, Bulletin 127, 266p.

HICKMAN, A. H., 1997, A revision of the stratigraphy of Archaean greenstone successions in the Roebourne–Whundo area, west Pilbara: Western Australia Geological Survey, Annual Review 1996–97, p. 76–81.

HICKMAN, A. H., 2001a, East Pilbara diapirism: new evidence from mapping: Western Australia Geological Survey, Record 2001/5, p. 23–25.

HICKMAN, A. H., 2001b, Geology of the Dampier 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 39p.

HICKMAN, A. H., in prep., Marble Bar, W. A. Sheet 2855: Western Australia Geological Survey, 1:100 000 Geological Series.

HICKMAN, A. H., and BAGAS, L., 1998, Geology of the Rudall 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 30p.

HICKMAN, A. H., and CLARKE, G. L., 1994, Geology of the Broadhurst 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 40p.

HICKMAN, A. H., and GIBSON, D. L., 1982, Port Hedland – Bedout Island, W. A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 28p.

HICKMAN, A. H., and LIPPLE, S. L., 1978, Marble Bar, W. A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 24p.

HICKMAN, A. H., CHIN, R. J., and GIBSON, D. L., 1983, Yarrie, W. A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 33p.

HICKMAN, A. H., THORNE, A. L. and TRENDALL, A. F., 1990, Geology of the Pilbara Craton, *in* Third International Archaean Symposium Excursion Guidebook no. 5 — Pilbara and Hamersley Basin *edited by* S. E. HO, J. E. GLOVER, J. S. MYERS, and J. R. MUHLING: University of Western Australia, Geology Department and University Extension, Publication, no. 21, p. 2–25.

HICKMAN, A. H., VAN KRANENDONK, M. J., and SMITHIES, R. H., 2000, Pilbara Craton evolution: Western Australia Geological Survey, Poster for one-day symposium GSWA 2000 (unpublished).

HITEC ENERGY NL, 2000, Quarterly report to Australian Stock Exchange for the quarter ended 30 September 2000 (unpublished).

HOCKING, R. M., MORY, A. J., and WILLIAMS I. R., 1994, An atlas of Neoproterozoic and Phanerozoic basins of Western Australia, *in* The sedimentary basins of Western Australia *edited by* P. C. PURCELL and R. R. PURCELL: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, W. A., 1994, p. 21–43.

HODGSON, C. J., 1993, Mesothermal lode-gold deposits, *in* Mineral deposit modeling *edited by* R. V. KIRKHAM, W. D. SINCLAIR, R. I. THORPE, and J. M. DUKE: Geological Association of Canada, Special Paper 40, p. 635–678.

HOFFMAN, H. J., GREY, K., HICKMAN, A., and THORPE, R., 1999, Origin of 3.45 Ga coniform stromatolites in the Warrawoona Group, Western Australia: Geological Society of America Bulletin, v. 3, p. 1256–1262.

HORWITZ, R. C., 1987, The unconformity in the Kelly Belt, east Pilbara Craton: Royal Society of Western Australia, Journal, v. 70, p. 49–53.

HORWITZ, R. C., 1990a, The Archaean unconformity at Shay Gap, northeastern Pilbara Craton, *in* The Archaean: Terrains, processes and metallogeny *edited by* J. E. GLOVER and S. E. HO: University of Western Australia, Geology Department and University Extension, Publication, no. 22, p. 51–57.

HORWITZ, R. C., 1990b, Palaeogeographic and tectonic evolution of the Pilbara Craton, Northwestern Australia: Precambrian Research, v. 48, p. 327–340.

HUSTON D. L., BLEWETT, R. S., BAKER, D., and SMITHIES, R. H., 1999, The diverse origin of Archaean lode gold in the north Pilbara, Western Australia: a field excursion guide: Australian Geological Survey Organisation.

HUSTON, D. L., KEILLOR, B., STANDING, J., BLEWETT, R. S., and MERNAGH, T. P., 2000, Epithermal deposits of the central Pilbara tectonic zone: Description and exploration significance: AGSO Research Newsletter, May 2000, p. 34–39.

HUSTON, D. L., SUN S-S., BLEWETT, R. S., HICKMAN, A. H., VAN KRANENDONK, M. J., PHILLIPS, D., BAKER, D., and BRAUHART, C., in prep., The timing of mineralization in the Archaean Pilbara Craton, Western Australia: Economic Geology.

JACKSON, M. P. A., CORNELIUS, R. R., CRAIG, C. H., GANSSER, A., STOCKLIN, J., and TALBOT, C. J., 1990, Salt diapirs of the Great Kavir, Central Iran: Geological Society of America, Memoir 177, 139p.

JAHN, B. M., and SIMONSON, B. M., 1995, Carbonate Pb–Pb ages of the Wittenoom Formation and Carawine Dolomite, Hamersley Basin, Western Australia (with implications for their correlation with Transvaal Dolomite of South Africa): Precambrian Research, v. 72, p. 247–261.

JONES. C. B, 1990, Coppin Gap copper–molybdenum prospect, *in* Geology of the mineral deposits of Australia and Papua New Guinea, Volume 1 *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 141–144.

JONES, F. H., 1938a, The Warrawoona area, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 20, 10p.

JONES, F. H., 1938b, Prospecting of the Coongan – Bamboo Creek area, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 58, 7p.

JONES, F. H., 1939, The country between Sharks and North Shaw, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 26, 3p.

KERRICH, R., and CASSIDY, K. F., 1994, Temporal relationships of lode gold mineralization to accretion, magmatism, metamorphism and deformation — Archean to present: a review: Ore Geology Reviews, v. 9, p. 263–310.

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

KRAPEZ, B., 1984, Sedimentation in a small, fault-bounded basin — the Lalla Rookh Sandstone, East Pilbara Block, *in* Archaean and Proterozoic basins of the Pilbara, Western Australia — Evolution and mineralization potential *edited by* J. R. MUHLING, D. I. GROVES, and T. S. BLAKE: University of Western Australia, Geology Department and University Extension, Publication, no. 9, p. 89–110.

KRAPEZ, B., 1993, Sequence stratigraphy of the Archaean supracrustal belts of the Pilbara Block, Western Australia: Precambrian Research, v. 60, p. 1–45.

KRAPEZ, B., and BARLEY, M. E., 1987, Archaean strike-slip faulting and related ensialic basins: evidence from the Pilbara Block, Australia: Geological Magazine, v. 124, p. 555–567.

KRAPEZ, B., and EISENLOHR, B., 1998, Tectonic settings of Archaean (3325–2775 Ma) crustal–supracrustal belts in the West Pilbara Block: Precambrian Research, v. 88, p. 173–205.

LOUTHEAN, R., 1998, Wodgina adds spice to world-class tantalite role: Paydirt, v. 1, no. 45 (November), p. 1–2.

LOW, G. H., 1961, Report on the exploratory diamond drilling of part of the Mount Goldsworthy (Ellarine Hills) hematite iron ore deposits, Pilbara Goldfield, Western Australia: Western Australia Geological Survey, Annual Report 1960, p. 26–37.

LOW, G. H., 1963, Copper deposits of Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 8, 202p.

LOW, G. H., 1965, Port Hedland, W. A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 15p.

McCUAIG, T. C., and KERRICH, R., 1998, P-T-t-deformation-fluid characteristics of lode gold deposits: evidence from alteration systematics: Ore Geology Reviews, v. 12, p. 381–453.

MacLEOD, W. N., 1966, The geology and iron deposits of the Hamersley Range area, Western Australia: Western Australia Geological Survey, Bulletin 117, 170p.

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.

McNAUGHTON, N. J., COMPSTON, W., and BARLEY, M. E., 1993, Constraints on the age of the Warrawoona Group, eastern Pilbara Block, Western Australia: Precambrian Research, v. 60, p. 69–98.

McNAUGHTON, N. J., GREEN, M. D., COMPSTON, W., and WILLIAMS I. S., 1988, Are anorthositic rocks basement to the Pilbara Craton?: Geological Society of Australia, Abstracts, v. 21, p. 272–273.

McWHAE, J. R. H., PLAYFORD, P. E., LINDNER, A. W., GLENISTER, B. F., and BALME, B. E., 1958, The stratigraphy of Western Australia: Geological Society of Australia, Journal, v. 4, p. 124.

MAITLAND, A. G., 1904, Preliminary report on the geological features and mineral resources of the Pilbara Goldfield: Western Australia Geological Survey, Bulletin 15, 118p.

MAITLAND, A. G., 1905, Further report on the geological features and mineral resources of the Pilbara Goldfield: Western Australia Geological Survey, Bulletin 20, 124p.

MAITLAND, A. G., 1906, Third report on the geological features and mineral resources of the Pilbara Goldfield: Western Australia Geological Survey, Bulletin 23, 92p.

MAITLAND, A. G., 1908, The geological features and mineral resources of the Pilbara Goldfield, with an appendix by A. Montgomery: Western Australia Geological Survey, Bulletin 40, 309p.

MAITLAND, A. G., 1909, Geological investigations in the country lying between 21°30' and 25°30'S latitude and 113°30' and 118°30'E longitude, embracing parts of the Gascoyne, Ashburton and West Pilbara Goldfields: Western Australia Geological Survey, Bulletin 33, 184p.

MARSHALL, A. E., 2000, Low-temperature, low-pressure ('epithermal') vein deposits of the North Pilbara granite–greenstone terrane, Western Australia: Australian Geological Survey Organisation, Record 2000/1, 40p.

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

MARSTON, R. J., 1984, Nickel mineralization in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 14, 272p.

MARTIN, D. McB. and THORNE, A. M., 2001, New insights into the Bangemall Supergroup, Western Australia Geological Survey, Record 2001/5, p. 1–2.

MATHESON, R. S., ANDREWS, P. J., BRANDT, R. T., and LIDDICOAT, W. K., 1965, Iron ore deposits of the Port Hedland district, *in* Geology of Australian ore deposits (2nd edition) *edited by* J. McANDREW: Commonwealth Mining and Metallurgy Congress, 8th, Australia and New Zealand, 1965, Publications, v. 1, p. 132–137.

MILES, K. R., CARROLL, D., and ROWLEDGE, H. P., 1945, Tantalum and niobium: Western Australia Geological Survey, Mineral Resources Bulletin 3, 150p.

MONTGOMERY, A., 1907, Report on the Pilbara and West Pilbara goldfields: Western Australia Department of Mines, Report of the State Mining Engineer, 126p.

MORANT, P., 1995, The Panorama Zn–Cu VMS deposits, Western Australia: Australian Institute of Geoscientists, Bulletin no. 16, p. 75–84.

MORANT, P., 1998, Panorama zinc–copper deposits, *in* Geology of Australian and Papua New Guinean mineral deposits *edited by* D. A. BERKMAN and D. H. MacKENZIE: Australasian Institute of Mining and Metallurgy, Monograph 22, p. 287–292.

MORRIS, R. C., 1985, Genesis of iron ore in banded iron-formation by supergene and supergene metamorphic processes — a conceptual model, *in* Handbook of stratabound and stratiform ore deposits volume 13 *edited by* K. H. WOLF: Amsterdam, Elsevier, p. 73–235.

MORRIS, R. C., 1994, Genesis of high grade iron ore from banded iron-formation (BIF): Geological Society of Australia, 12th Australian Geological Convention, Perth, Abstracts, no. 37, p. 304.

NEALE, J., 1975, Mount Goldsworthy iron deposits, W. A., *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. 932–936.

NELSON, D. R., 1996, Compilation of SHRIMP U–Pb zircon geochronology data, 1995: Western Australia Geological Survey, Record 1996/5, 168p.

NELSON, D. R., 1997, Compilation of SHRIMP U–Pb zircon geochronology data, 1996: Western Australia Geological Survey, Record 1997/2, 189p.

NELSON, D. R., 1998, Compilation of SHRIMP U–Pb zircon geochronology data, 1997: Western Australia Geological Survey, Record 1998/2, 242p.

NELSON, D. R., 1999, Compilation of geochronology data for 1998: Western Australia Geological Survey, Record 1999/2, 222p.

NELSON, D. R., 2000, Compilation of geochronology data for 1999: Western Australia Geological Survey, Record 2000/2, 251p.

NELSON, D. R., in press, Compilation of geochronology data for 2000: Western Australia Geological Survey, Record 2001/2.

NEUMAYER, P., GROVES, D. I., RIDLEY, J. R., and KONING, C. D., 1993, Syn-amphibolite facies Archaean lode gold mineralization in the Mt. York district, Pilbara Block, Western Australia: Mineralium Deposita, v. 28, p. 457–468.

NEUMAYER, P., RIDLEY, J. R., McNAUGHTON, N. J., KINNY, P. D., BARLEY, M. E., and GROVES, D. I., 1998, Timing of gold mineralization in the Mt York district, Pilgangoora greenstone belt, and implications for the tectonic and metamorphic evolution of an area linking the western and eastern Pilbara Craton, Western Australia: Precambrian Research, v. 88, p. 249–265.

NICKEL, E. H., HALLBERG, J. A., and HALLIGAN, R., 1979, Unusual nickel mineralization at Nullagine, Western Australia: Geological Society of Australia, Journal, v. 26, p. 61–71.

NIJMAN, W., de BRUIJNE, K. C. H., and VALKERING, M. E., 1998a, Growth fault control of Early Archaean cherts, barite mounds and chert-barite veins, North Pole Dome, Eastern Pilbara, Western Australia: Precambrian Research, v. 88, p. 25–52.

NIJMAN, W., WIILIGERS, B. J. A., and KRIKKE, A., 1998b, Tensile and compressive growth structures: relationships between sedimentation, deformation and granite intrusion in the Archaean Coppin Gap greenstone belt, Eastern Pilbara, Western Australia: Precambrian Research, v. 88, p. 25–52.

NOLDART, A. J., and WYATT, J. D., 1962, The geology of portion of the Pilbara Goldfield covering the Marble Bar and Nullagine 4-mile map sheets: Western Australia Geological Survey, Bulletin 115, 199p.

O'HALLORAN, M., 1936, Talga Talga, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 6, 5p.

OSTWALD, J., 1992a, Diagenetic and supergene braunites in the Proterozoic Manganese Group, Western Australia: Mineralogical Magazine, v. 56, p. 611–616.

OSTWALD, J., 1992b, Genesis and paragenesis of the tetravalent manganese oxides of the Australian continent: Economic Geology, v. 87, p. 1237–1252.

OSTWALD, J., 1993, Manganese oxide mineralogy, petrography and genesis, Pilbara Manganese Group, Western Australia: Mineralium Deposita, v. 28, p. 198–209.

OVERSBY, V. M., 1976, Isotopic ages and geochemistry of Archaean acid igneous rocks from the Pilbara, Western Australia: Geochimica et Cosmochimica Acta, v. 40, p. 817–829.

OWEN, H. B., 1953, Manganese deposits near Ragged Hills, Gregory Range, North-West Division, Western Australia.: Australia BMR (now AGSO), Record 1953/62.

PERINCEK, D., 1996, The stratigraphic and structural development of the Officer Basin, Western Australia: Western Australia Geological Survey, Annual Review 1995–96, p. 135–148.

PIDGEON, R. T., 1978, 3450 m.y. old volcanics in the Archaean layered greenstone succession of the Pilbara Block, Western Australia: Earth and Planetary Science Letters, v. 37, p. 423–428.

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

PIRAJNO, F., 1994, Hydrothermal mineral deposits: principles and fundamental concepts for the exploration geologist: Springer–Verlag, New York, 709p.

PODMORE, D. C., 1990, Shay Gap – Sunrise Hill and Nimingarra iron deposits, *in* Geology of the mineral deposits of Australia and Papua New Guinea, Volume 1 *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 137–140.

PRESTON, W. A., 1998, Western Australia's iron ore industry: planning for the future: 4th Annual Australasian Iron Ore & Steel Forum, Paper, no. 15, Sydney.

RAMANAIDOU, E. R., HORWITZ, R. C., and MORRIS, R. C., 1991, Channel iron deposits: Australia, Commonwealth Scientific and Industrial Research Organisation, Exploration Geoscience Report, 162R.

RICHARDS, J. R., FLETCHER, I. R., and BLOCKLEY, J. G., 1981, Pilbara galenas: precise isotopic assay of the oldest Australian leads; model ages and growth-curve implications: Mineralium Deposita, v. 16, p. 7–30.

ROCK, N. M. S., and BARLEY, M. E., 1988, Calc-alkaline lamprophyres from the Pilbara Block, Western Australia: Royal Society of Western Australia, Journal, v. 71, p. 7–13.

ROWSTON, D. L., 1965, Gravity survey of manganese deposits in the Mt Sydney – Woodie Woodie area, Pilbara Goldfield: Western Australia Geological Survey, Annual Report 1964, p. 49–51.

RUDDOCK, I., 1999, Mineral occurrences and exploration potential of the west Pilbara: Western Australia Geological Survey, Report 70, 63p.

RYAN, G. R., 1964, A reappraisal of the Archaean of the Pilbara Block: Western Australia Geological Survey, Annual Report 1963, p. 25–28.

SIMONSON, B. M., SCHUBEL, K. A., and HASSLER, S. W. 1993, Carbonate sedimentology of the early Precambrian Hamersley Group of Western Australia: Precambrian Research, v. 60, p. 287–335.

SIMPSON, E. S., 1928, Report on the Pilbara tin and tantalum deposits: Western Australia Department of Mines, Annual Report 1927, p. 223–225.

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

SIMPSON, E. S., 1952, Minerals of Western Australia, Volume 3: Perth, Western Australia, Government Printer, p. 685.

SIMPSON, E. S., and GIBSON, C. G., 1907, The distribution and occurrence of the baser metals in Western Australia: Western Australia Geological Survey, Bulletin 30, 129p.

SMITH, S. G., and GEMMELL, J. B., 1994, Warrabarty prospect: Proterozoic carbonate-hosted zinc–lead mineralization, Yeneena Group: Geological Society of Australia, Abstracts, v. 37, p. 414.

SMITHIES, R. H., 1996, Refinement of the stratigraphy of the Whim Creek Belt, Pilbara granite–greenstone terrain: new field evidence from the Sherlock 1:100 000 sheet: Western Australia Geological Survey, Annual Review 1995–96, p. 118–123.

SMITHIES, R. H., 1997, The Mallina Formation, Constantine Sandstone and Whim Creek Group: a new stratigraphic and tectonic interpretation for part of the western Pilbara Craton: Western Australia Geological Survey, Annual Review 1996–97, p. 83–88.

SMITHIES, R. H., 1998, Geology of the Mount Wohler 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 19p.

SMITHIES, R. H., in prep., White Springs, W. A. Sheet 2654: Western Australia Geological Survey, 1:100 000 Geological Series.

SMITHIES, R. H., HICKMAN, A. H., and NELSON, D. R., 1999, New constraints on the evolution of the Mallina Basin, and their bearing on relationships between the contrasting eastern and western granite–greenstone terranes of the Archaean Pilbara Craton, Western Australia: Precambrian Research, v. 94, p. 11–28.

SMITHIES, R. H., CHAMPION, D. C., and BLEWETT, R. S., 2001, Wallaringa, W. A. Sheet 2656: Western Australia Geological Survey, 1:100 000 Geological Series.

SMITHIES, R. H., NELSON, D. R., and PIKE, G., in press, Detrital and inherited zircon age distributions — implications for the evolution of the Archaean Mallina Basin, Pilbara Craton, northwestern Australia: Sedimentary Geology.

SOLOMON, M., and GROVES, D. I., 1994, The geology and origin of Australia's mineral deposits: Oxford Monographs on Geology and Geophysics, no. 24, 951p.

SULLIVAN, C. J., 1939a, The Moolyella and Cooglegong tinfields, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 57, 7p.

SULLIVAN, C. J., 1939b, The Lalla Rookh – North Shaw area, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 59, 5p.

SWEETAPPLE, M. T., 2000, Characteristics of Sn–Ta–Be–Li industrial mineral deposits of the Archaean Pilbara Craton, Western Australia: Australian Geological Survey Organisation, Record 2000/44, 56p.

TALBOT, H. W. B., 1920, The geology and mineral resources of the Northwest, Central, and Eastern Divisions: Western Australia Geological Survey, Bulletin 83, 217p.

THOM, R., HICKMAN, A. H., and CHIN, R. J., 1979, Nullagine, W. A.: Western Australia Geological Survey, 1:250 000 Geological Series.

THORNE, A. M., and HICKMAN, A. H., 1998, Geology of the Fortescue Group, Pilbara Craton (1:500 000 scale), *in* Geology of the Fortescue Group, Pilbara Craton, Western Australia *by* A. M. THORNE and A. F. TRENDALL: Western Australia Geological Survey, Bulletin 144, Plates 1A–C.

THORNE, A. M., and TRENDALL, A. F., 2001, Geology of the Fortescue Group, Pilbara Craton: Western Australia Geological Survey, Bulletin 144, 249p.

THORPE, R. I., HICKMAN, A. H., DAVIS, D. W., MORTENSEN, J. K., and TRENDALL, A. F., 1992a, Conventional U–Pb zircon geochronology of Archaean felsic units in the Marble Bar region, Pilbara Craton: Precambrian Research, v. 56, p. 169–189.

THORPE, R. I., HICKMAN, A. H., DAVIS, D. W., MORTENSEN, J. K., and TRENDALL, A. F., 1992b, Constraints to models for Archaean lead evolution from precise zircon U–Pb geochronology for the Marble Bar region, Pilbara Craton, Western Australia, *in* The Archaean: Terrains, processes, and metallogeny, *edited by* J. E. GLOVER and S. E. HO: University of Western Australia, Geology Department and University Extension, Publication, no. 22, p. 395–407.

TOWNER, R. R., and GIBSON, D. L., 1983, Geology of the onshore Canning Basin, Western Australia: Australia BMR (now AGSO), Bulletin 215, 51p.

TRAVES, D. M., CASEY, J. N., and WELLS, A. T., 1956, The geology of the southwestern Canning Basin, Western Australia: Australia BMR (now AGSO), Report 29, 74p.

TRAVIS, G. A., KEAYS, R. R., and DAVISON, R. M., 1976, Palladium and iridium in the evaluation of nickel gossans in Western Australia: Economic Geology, v. 71, p. 1229–1243.

TRENDALL, A. F., 1990a, Introduction, Pilbara Craton, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 128.

TRENDALL, A. F., 1990b, Hamersley Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 163–189.

TRENDALL, A. F., 1991, Progress report on the stratigraphy and structure of the Fortescue Group in the Gregory Range area of the eastern Pilbara Craton: Western Australia Geological Survey, Record 1990/10, 38p.

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, 366p.

TWIDALE, C. R., HORWITZ, R. C., and CAMPBELL, E. M., 1985, Hamersley landscapes of the northwest of Western Australia: Revue de Géologie Dynamique et de Géographie Physique, v. 16, p. 173–186.

TYLER, I. M., 1990, Mafic dyke swarms, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 191–194.

TYLER, I. M., FLETCHER, I. R., de LAETER, J. R., WILLIAMS, I. R., and LIBBY, W. G., 1992, Isotope and rare earth element evidence for a late Archaean terrane boundary in the southeastern Pilbara Craton, Western Australia: Precambrian Research, v. 54, p. 211–229.

VAN HAAFTEN, W. M., and WHITE, S. H., 1998, Evidence for multiphase deformation in the Archean basal Warrawoona Group in the Marble Bar area, East Pilbara, Western Australia: Precambrian Research, v. 88, p. 53–66.

VAN KRANENDONK, M. J., 1998, Litho-tectonic and structural components of the North Shaw 1:100 000 sheet, Archaean Pilbara Craton: Western Australia Geological Survey, Annual Review 1997–1998, p. 63–70.

VAN KRANENDONK, M. J., 1999a, North Shaw, W. A. Sheet 2755: Western Australia Geological Survey, 1:100 000 Geological Series.

VAN KRANENDONK, M. J., 1999b, Two-stage degassing of the Archaean mantle: evidence from the 3.46 Ga Panorama volcano, Pilbara Craton: Western Australia, *in* GSWA 99 extended abstracts: New geological data for WA explorers: Western Australia Geological Survey, Record 1999/6, p. 1–3.

VAN KRANENDONK, M. J., 2000, Geology of the North Shaw 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 86p.

VAN KRANENDONK, M. J., in prep., Tambourah, W. A. Sheet 2754: Western Australia Geological Survey, 1:100 000 Geological Series.

VAN KRANENDONK, M. J., and COLLINS, W. J., 1998, Timing and tectonic significance of Late Archaean, sinistral strike-slip deformation in the Central Pilbara Structural Corridor, Pilbara Craton, Western Australia: Precambrian Research, v. 88, p. 207–232.

VAN KRANENDONK, M. J., and COLLINS, W. J., in press, Partial convective overturn of the eastern part of the Archaean Pilbara Craton, Western Australia: field evidence for the diapiric emplacement of granitoid domes: Precambrian Research.

VAN KRANENDONK, M. J., and MORANT, P., 1998, Revised Archaean stratigraphy of the North Shaw 1:100 000 sheet, Pilbara Craton: Western Australia Geological Survey, Annual Review 1997–1998, p. 55–62.

VAN KRANENDONK, M. J., HICKMAN, A. H., SMITHIES, R. H., NELSON, D. R., and PIKE, G., in prep., Geology and tectonic evolution of the Archaean North Pilbara Terrain, Pilbara Craton, Western Australia: Economic Geology.

VEARNCOMBE, S. E., BARLEY, M. E., GROVES, D. I., McNAUGHTON, N. J., MIKUCKI, E. J., and VEARNCOMBE, J. R., 1994, 3.26 Ga black smoker-type sulphide–sulphate mineralization in the Strelley belt, Pilbara Craton, Western Australia: Geological Society of Australia, Abstracts, no. 37, p. 444–445.

VEARNCOMBE, S., BARLEY, M. E., GROVES, D. I., McNAUGHTON, N. J., MIKUCKI, E. J., and VEARNCOMBE, J. R., 1995, 3.26 Ga black smoker-type mineralization in the Strelley belt, Pilbara Craton, Western Australia: Journal of the Geological Society of London, v. 152, p. 587–590.

VEARNCOMBE, S., VEARNCOMBE, J. R., and BARLEY, M. E., 1998, Fault and stratigraphic controls on volcanogenic massive sulphide deposits in the Strelley belt, Pilbara Craton, Western Australia: Precambrian Research, v. 88, p. 67–82.

VEEVERS, J. J., and WELLS, A. T., 1959, Pisolitic ironstone deposits, Port Hedland area, Western Australia: Australia BMR (now AGSO), Record 1959/61.

WATERS, P. J., 1998, The Y2–3 and Y10 iron deposits, Yarrie, *in* Geology of Australian and Papua New Guinean mineral deposits *edited by* D. A. BERKMAN and D. H. MacKENZIE: Australasian Institute of Mining and Metallurgy, Monograph 22, p. 371–374.

WELLS, A. T., 1959, Yarrie — 4-mile Geological Series: Australia BMR (now AGSO), Explanatory Notes, no. 16, Sheet F/51-1, 15p.

WILHELMIJ, H. R., and DUNLOP, J. S. R., 1984, A genetic stratigraphic investigation of the Gorge Creek Group in the Pilgangoora Syncline, *in* Archaean and Proterozoic Basins of the Pilbara, Western Australia — evolution and mineralization potential *edited by* J. R. MUHLING, D. I. GROVES, and T. S. BLAKE: University of Western Australia, Geology Department and University Extension, Publication, no. 9, p. 68–88.

WILLIAMS, I. R., 1989, Balfour Downs, W. A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 38p.

WILLIAMS, I. R., 1990, Yeneena Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 277–282.

WILLIAMS, I. R., 1999a, Geology of the Muccan 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 39p.

WILLIAMS, I. R., 1999b, Warrawagine, W. A. Sheet 3056: Western Australia Geological Survey, 1:100 000 Geological Series.

WILLIAMS, I. R., 2000, Geology of the Cooragoora 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 23p.

WILLIAMS, I. R., in prep., Yarrie, W. A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series.

WILLIAMS, I. R., and BAGAS, L., 1999, Geology of the Throssell 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 24p.

WILLIAMS, I. R., and BAGAS, L. in prep., Mount Edgar, W. A. Sheet 2955: Western Australia Geological Survey, 1:100 000 Geological Series.

WILLIAMS, I. R., and HICKMAN, A. H., 2000, Archaean geology of the Muccan region, East Pilbara Granite–Greenstone Terrane, Western Australia — a field guide: Western Australia Geological Survey, Record 2000/4, 30p.

WILLIAMS, I. R., and MYERS, J. S., 1990, Paterson Orogen, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 274–275.

WILLIAMS, I. R., and TRENDALL, A. F., 1998a, Geology of the Braeside 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 39p.

WILLIAMS, I. R., and TRENDALL, A. F., 1998b, Geology of the Isabella 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 24p.

WILLIAMS, I. R., and TRENDALL, A. F., 1998c, Geology of the Pearana 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 33p.

WILLIAMS, I. R., VAN KRANENDONK, M. J., and HICKMAN, A. H., 1999, Excursion guide to the geology of the Muccan and North Shaw 1:100 000 sheets, East Pilbara Granite–Greenstone Terrane: Western Australia Geological Survey excursion guide (unpublished).

WILLIAMS, I. S., and COLLINS, W. J., 1990, Granite–greenstone terranes of the Pilbara Block, Australia, as coeval volcano-plutonic complexes; evidence from U–Pb zircon dating of the Mount Edgar Batholith: Earth and Planetary Science Letters, v. 97, p. 41–53.

WILLIAMS, I. S., PAGE, R. W., FROUDE, D., FOSTER, J. J., and COMPSTON, W., 1983, Early crustal components in the Western Australian Archaean: Zircon U–Pb ages by ion microprobe analysis from the Shaw Batholith and Narryer Metamorphic Belt: Geological Society of Australia, 6th Australian Geological Convention, Canberra, Abstracts, no. 9, p. 169–171.

WILSON, R. C., 1922, The asbestos deposits of the Pilbara and West Pilbara Goldfields, Northwest Division: Western Australia Geological Survey, Annual Report, 1921, p. 39–49.

WINGATE, M. T. D., 1999, Ion microprobe baddeleyite and zircon ages for Late Archaean mafic dykes of the Pilbara Craton, Western Australia: Australian Journal of Earth Sciences, v. 46, p. 493–500.

WINTER, T., 2000, New float looks to February listing: Resource Information Unit, Gold Gazette, v. 5, no. 31 (December), p. 2–3.

WITT, W. K., 2000, Archaean lode gold deposits and the granite connection, *in* Geology and field aspects of ore deposits: Western Australia Geological Survey, In-house short course (unpublished).

WITT, W. K., and VANDERHOR, F., 1996, An overview of mesothermal gold deposits in the Archaean Yilgarn Craton, Western Australia, *in* Mesothermal gold deposits: a global overview: University of Western Australia, Geology Department and University Extension, Short Course Extended Abstracts, Publication, no. 27, p. 42–46.

WITT, W. K., HICKMAN, A. H., TOWNSEND, D., and PRESTON, W. A., 1998, Mineral potential of the Archaean Pilbara and Yilgarn Cratons, Western Australia, *in* Geology and mineral potential of major Australian mineral provinces: Australian Geological Survey Organisation, Journal of Australian Geology and Geophysics, v. 17, p. 201–221.

WOODWARD, H. P., 1890, Summary of work done, third report 1888, *in* Annual general report of the Government Geologist for 1888–1889: Perth, Western Australia, Government Printer, p. 34–37.

WOODWARD, H. P., 1891, The Pilbara Goldfield: Western Australia Geological Survey, Annual general report for 1890, p. 22–28.

WOODWARD, H. P., 1895, Other localities at which gold has been found, *in* Mining handbook to the Colony of Western Australia, 2nd edition: Perth, Government Printer, p. 15–116.

WOODWARD, H. P., 1911, The geology and ore deposits of the West Pilbara Goldfield: Western Australia Geological Survey, Bulletin 41, 137p.

YATES, M. G., 1990, Geological report on the geochemical sampling and structural analysis of the Golden Eagle Project, Nullagine, Report number WA90/057: Western Australia Geological Survey, Statutory mineral exploration report, Item 7462 A31162 (unpublished).

YEATS, C. J., McNAUGHTON, N. J., TUETTGER, D., BATEMAN, R., GROVES, D. I., HARRIS, J. L., and KOHLER, E., 1999, Evidence for diachronous Archean lode gold mineralization in the Yilgarn Craton, Western Australia: A SHRIMP U–Pb study of intrusive rocks: Economic Geology, v. 94, p. 1259–1276.

ZEGERS, T. E., 1996, Structural, kinematic and metallogenic evolution of selected domains of the Pilbara granitoid–greenstone terrain: implications for mid Archean tectonic regimes: Netherlands, University of Utrecht, Transactions of the Faculty of Earth Sciences, no. 146, 208p.

ZEGERS, T. E., WHITE, S. H., de KEIJZER, M., and DIRKS, P., 1996, Extensional structures during deposition of the Warrawoona Group in the eastern Pilbara Craton, Western Australia: Precambrian Research, v. 80, p. 89–105.

ZEGERS, T. E., de KEIJZER, M., PASSCHIER, C. W., and WHITE, S. H., 1998, The Mulgandinnah shear zone and Archaean crustal-scale strike-slip zone, eastern Pilbara, Western Australia: Precambrian Research, v. 88, p. 233–248.

ZEGERS, T. E., WIJBRANS, J. R., and WHITE, S. H., 1999, 40Ar/39Ar age constraints on tectonothermal events in the Shaw area of the eastern Pilbara granite–greenstone terrain (W. Australia): 700 Ma of Archaean tectonic evolution: Tectonophysics, v. 311, p. 45–81.

Appendix 1

List of mineral occurrences in the east Pilbara

*** KEY TO OPERATING STATUS**

Bold numbers	Operating mine
Bold and italic numbers	Abandoned mine
Plain numbers	Mineral deposit
Italic numbers	Mineral occurrence or prospect

KEY TO COMMODITY CODES

(Minor commodities shown in brackets)

Ag	Silver	Fe	Iron	Pb	Lead
As	Arsenic	Fl	Fluorite	PGE	Platinum Group Elements
Asbc	Asbestos, chrysotite	Fsp	Feldspar	Sb	Antimony
Au	Gold	Gp	Gypsum	Sn	Tin
Brl	Beryl	Hg	Mercury	Ta	Tantalum
Brt	Barite	Li	Lithium	Teye	Tiger eye
Cd	Cadmium	Mica	Mica	Tlc	Talc
Cr	Chromium	Mn	Manganese	U	Uranium
Cu	Copper	Mo	Molybdenum	V	Vanadium
Dmd	Diamond	Nb	Niobium	W	Tungsten
Emer	Emerald	Ni	Nickel	Zn	Zinc

KEY TO LOCATIONS

EAST	MGA Easting
NORTH	MGA Northing
Z	Zone

No*	COMMODITY	EAST	NORTH	Z	NAME
PRECIOUS MINERAL					
Kimberlite and lamproite intrusions					
6341	Dmd	802237	7632536	50	Brockman Dyke (Dmd)
Pegmatitic					
2796	Brl Sn Ta	737900	7612456	50	Curlew Emerald (Brl)
3101	Brl	717791	7698968	50	Turkey Camp Well (Brl)
4986	Brl Gems	701120	7678622	50	McPhees Hill (Brl)
4987	Gems Brl	737900	7612450	50	Calverts White Quartz Hill (Brl)
6048	Mica Brl	719738	7704156	50	Biscay Well (Brl Mica)
8009	Brl	659950	7635800	50	Mt Francisco West (Brl)
Sedimentary - banded iron-formation (taconite)					
8618	Teye	724344	7755017	50	Ord Range 1 (Teye)
8620	Teye	723446	7755371	50	Ord Range 2 (Teye)
8621	Teye	722745	7756169	50	Ord Range 3 (Teye)
8630	Teye	722861	7758804	50	Ord Range 4 (Teye)
Regolith - alluvial to beach placers					
2916	Dmd	197044	7575489	51	Nullagine 1 (Dmd)
5239	Dmd	200581	7577906	51	Cooks Hill (Dmd)
5972	Dmd	199635	7574411	51	Nullagine 2 (Dmd)
5974	Dmd	203235	7580611	51	Banana Hill 2 (Dmd)
6110	Dmd	277135	7648961	51	Carawine (Dmd)
6168	Dmd	200335	7577611	51	Brooks Hill (Dmd)
6170	Dmd	203455	7579911	51	Banana Hill 1 (Dmd)
6197	Dmd	203135	7580611	51	Banana Hill 3 (Dmd)

PRECIOUS METAL

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
1589	Au	674587	7704556	50	Cookes Hill (Au)
2779	Au	780371	7631277	50	Blue Bar (Au)
2780	Au	779579	7627998	50	Blue Bar East (Au)
2781	Au	779457	7629354	50	Blue Bar Northwest (Au)
2782	Au	698340	7664246	50	Breccia Hill (Au)
2784	Au	797268	7636902	50	Charlie (Au)
2786	Au	782801	7649364	50	Halleys Comet (Au)
2792	Au	791781	7641418	50	Copenhagen (Au Cu)
2793	Au	791781	7641418	50	Copenhagen (Au)
2798	Au	776487	7593936	50	Edelweiss (Au)
2807	Au	786097	7656078	50	Homeward Bound Opit (Au)
2808	Au	699348	7669358	50	Iron Stirrup (Au)
2814	Au	799566	7637920	50	Klondyke Queen 1 (Au)
2815	Au	736422	7670451	50	Lalla Rookh South Reef (Au)
2817	Au	736561	7670533	50	Lalla Rookh North Reef (Au)
2821	Au	699679	7668856	50	Lynas Find (Au)
2823	Au	697400	7664610	50	Main Hill (Au)
2826	Au	701411	7676772	50	McPhees North Opit (Au)
2833	Au	750064	7665218	50	Normay (Au)
2836	Au	700840	7671192	50	Old Faithful Southeast (Au)
2843	Au	771045	7622665	50	Sharks Gully (Au)
2845	Au	727200	7621368	50	Soanesville 1 (Au)
2856	Au	730359	7588678	50	Western Shaw Surprise (Au)
2857	Au	729204	7584633	50	Western Shaw Attwood (Au)
2864	Au	699675	7668856	50	Yellowstone (Au)
2865	Au	697877	7666338	50	Zakanaka South (Au)
2884	Fe	713630	7662140	50	Perfect Stranger (Au)
2902	Au	800696	7677447	50	Little Las Vegas (Au)
2903	Au	801121	7680348	50	TR 8407H (Au)
2904	Au	808613	7680707	50	Talga King (Au)
2905	Au	793731	7673686	50	North Star Mine (Au)
2906	Au	793553	7675069	50	McPhees Reward (Au)
2908	Au	796428	7675842	50	Galatea (Au)
2909	Au	786023	7661850	50	White Angel (Au)
2910	Ag	810482	7685261	50	Telfer Road (Au)
2911	Au	736500	7670642	50	North Alma (Au)
2912	Au	736503	7670600	50	Lalla Rookh 22 (Au)
2913	Au	730590	7670641	50	Lalla Rookh 23 (Au)
2918	Au	806464	7598539	50	Coongan (Au Pb As Cu)
2931	Au	712248	7638802	50	Terrys Prospect (Au)
2932	Au	712108	7638298	50	Sudden Jerk Anomaly B (Au)
2935	Au	708180	7642976	50	Jeffs Hill (Au)
2936	Au	706909	7643775	50	Golden Cockatoo (Au)
2937	Au Ag	749537	7641626	50	Island (Au)
2938	Au	704575	7645953	50	Yandee (Au)
2946	Au Ag	773787	7586986	50	Triberton Ck D (Au)
2947	Au	777737	7588476	50	Table Top (Au)
2948	Au	777637	7588106	50	Table Top South (Au)
2949	Au Ag	792277	7674281	50	Talga Talga (Au)
2957	Au	711901	7636468	50	Cavendish Anom H (Au Cu Pb Zn Hg)
2958	Au	712130	7636909	50	Cavendish Anom J (Au)
2967	Au	726573	7591932	50	Western Chief (Au)
2968	Au	726398	7591599	50	Tambourah King (Au)
2969	Au	726564	7591764	50	Western Chief No 1 South (Au)
2970	Au	726466	7591250	50	Alexandria (Au)
2971	Au	726565	7591250	50	Young Australian No1 (Au)
2972	Au	726576	7590986	50	Young Australian (Au)
2973	Au	726540	7590476	50	Kushmattie (Au)
2974	Au	702877	7670278	50	Mt York Mali (Au)
3017	Au	714998	7617956	50	Magnifique (Au)
3042	Au	779920	7627606	50	Blue Bar 1 (Au)
3043	Au	779827	7627840	50	Blue Bar 2 (Au)
3046	Au	780256	7629367	50	Blue Bar 3 (Au)
3049	Au	780368	7630046	50	Blue Bar 4a (Au)
3050	Au	778935	7626124	50	Blue Bar 4 (Au)
3051	Au	780338	7626303	50	Blue Bar 5 (Au)
3053	Au	794976	7643935	50	Fire Place (Au)
3056	Au	771977	7582486	50	Triberton (Au)
3057	Au	779740	7629246	50	Blue Bar 6 (Au)
3062	Au	779750	7627946	50	Blue Bar 7 (Au)
3073	Au	790735	7644411	50	Apex (Au)
3075	Au	726737	7598347	50	Logans Find (Au)
3076	Au	726744	7593864	50	Kirkpatrick (Au)
3078	Au	728897	7596011	50	The Star (Au)
3079	Au	728874	7594982	50	The Lode (Au)
3084	Au	734281	7624769	50	McLeod's Reward (Au)
3085	Au	734353	7624532	50	Daltons No2 Shaft (Au)
3086	Au	734486	7624366	50	Daltons (Au)
3087	Au	734511	7623931	50	Daltons South (Au)
3088	Au Cu	734667	7623282	50	Thomas Shaft (Au Cu)
3089	Au	734344	7623543	50	Eclipse 1 (Au)
3090	Au	734274	7623369	50	Eclipse 2 (Au)
3095	Au	748940	7638896	50	North Shaw South (Au)
3096	Au	751040	7639446	50	North Shaw East (Au)
3097	Au	752940	7639346	50	North Shaw East 2 (Au)
3110	Ag	703741	7657946	50	Valley of Gossans (Ag)
3111	Au Ag	703590	7656346	50	Valley of Gossans (Au)
3114	Au Ag As	703514	7657280	50	Valley of the Gossans B (Au)
3115	Au	726690	7591831	50	Federal (Au)
3116	Au	726608	7592346	50	Tambourah Queen (Au)
3117	Au	726654	7593430	50	Morning Star (Au)
3118	Au	726493	7592203	50	Duke of Wellington (Au)
3119	Au	726654	7592759	50	Worlds Fair (Au)
3120	Au	726686	7593128	50	Sadlers (Au)
3121	Au	728370	7584518	50	Western Shaw Reef (Au)
3125	Au	728300	7584208	50	Western Shaw No 1 South (Au)
3126	Au	728187	7584140	50	General Gordon No 1 South (Au)
3127	Au	728082	7583918	50	General Gordon (Au)
3128	Au	728014	7583689	50	Western Shaw Consol and Ext (Au)
3129	Au	728849	7586126	50	Trafalgar No 2 South (Au)
3130	Au	728837	7586373	50	Trafalgar No 1 South (Au)
3131	Au	728849	7586781	50	Trafalgar (Au)
3132	Au	728838	7585883	50	Pink Eye (Au)
3133	Au	727294	7594799	50	Long Lead (Au)
3135	Au	747688	7638425	50	Big Bertha (Au Cu)
3136	Au	747578	7638363	50	El Dorado (Au Cu)
3137	Au	747268	7638458	50	Eldorado West Extension (Au)
3138	Au	747189	7638446	50	Eldorado West Reef (Au)
3139	Au	746829	7638069	50	Leviathan (Au)
3140	Au	746794	7638397	50	Nil Desperandum (Au)
3141	Au	747286	7638689	50	El Dorado North (Au)
3142	Au Cu	745390	7640068	50	Auroria (Au Cu)
3145	Au	796123	7675756	50	Galatea West (Au)
3153	Au	795519	7672126	50	Jubilee (Au)
3154	Au	792917	7674608	50	McPhee's Reward WSW (Au)
3161	Au	745082	7664909	50	Democrat (Au Cu)
3162	Au	745549	7665614	50	Big Lode (Au)
3164	Au	744844	7665356	50	Big Lode 2 (Au)
3190	Au	735954	7670580	50	Alma Reef (Au)
3191	Au	736038	7670876	50	Alma North Reef (Au)
3192	Au	736789	7670747	50	Lucknow Reef (Au)
3193	Au	735690	7671485	50	Bergamina (Au)
3230	Au	772099	7582235	50	Triberton North 1 (Au)
3231	Au	773913	7583826	50	Coongan North (Au)
3233	Au Cu	713561	7654317	50	Rivierra (Au Cu)
3234	Au Cu	713289	7654777	50	Electra (Au Cu)
3239	Au	715489	7645811	50	Obelix (Au)
3240	Au	711872	7640423	50	Mercury Hill Sipa (Au)
3241	Au	733760	7641006	50	Agrippa Ridge (Au)
3243	Au	717690	7625166	50	Soanesville 2 (abd) (Au)
3259	Au	745540	7640076	50	North Shaw (Au Cu Pb)
3260	Au	752090	7654226	50	Taipan Ridge (Au)
3261	Au	757541	7665766	50	Golden Shower (Au)
3262	Au	745420	7665466	50	Mickeys Find (Au)

PRECIOUS METAL

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No*	COMMODITY	EAST	NORTH	Z	NAME
3263	Au	746301	7638176	50	Struck? (Au Ag As Cu Pb)
3267	Au	733980	7624596	50	North Shaw 1 (Au)
3268	Au	734490	7624426	50	North Shaw 2 (Au)
3310	Au	701390	7676696	50	McPhees East Lode (Au)
3311	Au	701355	7676706	50	McPhees West Lode 2 (Au)
3313	Au	701440	7676846	50	McPhees West Lode 1 (Au)
3314	Au	701120	7676426	50	McPhees West Lode 3 (Au)
3324	Au	701090	7676226	50	McPhees South (Au)
3325	Au	786336	7657694	50	Ironclad (Au)
3331	Au	786537	7657986	50	Nabob (Au)
3332	Au	786077	7657216	50	Jo Jo (Au)
3333	Au	786018	7657172	50	Jo Jo Delaportes (Au)
3334	Au	786205	7656992	50	Jo Jo South East (Au)
3345	Au	786207	7656836	50	Reward (Au)
3346	Au	786157	7656696	50	Great Oversight (Au)
3347	Au	786287	7656416	50	Outward Bound (Au)
3348	Au	786307	7656316	50	Outward Bound East (Au)
3349	Au	786007	7656226	50	Homeward Bound (Au)
3350	Au	786437	7656116	50	Shamrock Marble Bar (Au)
3351	Au	786637	7656126	50	True Blue (Au)
3352	Au	785633	7655679	50	Coongan Star (Au)
3353	Au	785927	7655496	50	Anglo French (Au)
3354	Au	786087	7655356	50	Rufus Henry (Au)
3355	Au	785879	7655265	50	Stray Shot (Au)
3357	Au	786137	7655506	50	Viking (Au)
3358	Au	794381	7675408	50	McPhees Reward Northeast 1 (Au)
3359	Au	795462	7676244	50	McPhees Reward Northeast 2 (Au)
3360	Au	793926	7674985	50	McPhees Qtzite 1 (Au)
3361	Au	794674	7675406	50	McPhees Qtzite 2 (Au)
3362	Au	794263	7675143	50	McPhees Basalt 1 (Au)
3363	Au	770948	7627724	50	Mt Ada Main/No2 (Au)
3364	Au	770948	7627572	50	Golden Gift West Reef North (Au)
3365	Au	771070	7626111	50	Mt Florence (Au)
3366	Au	756867	7637976	50	Callina Prosp (Au)
3367	Au	772587	7630056	50	Mt Ada Northeast Prospect (Au)
3368	Au	782978	7649220	50	Prices Find (Comet) (Au)
3369	Au	783205	7648394	50	McKinnons Alexander (Au)
3370	Au	783018	7648237	50	Manolis Find (Au)
3371	Au	782544	7647508	50	Fritz and Lawrence Find (Au)
3372	Au	783815	7648171	50	McKays Find (Au)
3373	Au	782901	7648130	50	Manolis West (Au)
3377	Au	697624	7668979	50	Ned Kelly (Au)
3379	Au	786410	7658576	50	Nabob North (Au)
3381	Au	791265	7640811	50	Euro (Au)
3382	Au	793892	7640355	50	Hannay and Miller (Au)
3383	Au	791135	7642711	50	Fletcher Smitheram (Au)
3386	Au	790175	7644621	50	Salgash (Au)
3387	Au	789915	7644871	50	Towers (Au)
3388	Au	789775	7644881	50	Phoenix (Au)
3389	Au	789343	7645128	50	Wymans Leader (Au)
3421	Au	791733	7641435	50	Petersens (Au)
3422	Au	791815	7641376	50	Camerons (Au)
3431	Au	798182	7638894	50	Gauntlet (Au)
3432	Au	798037	7638886	50	Rangitira (Au)
3437	Au	798685	7638629	50	Dodger (Au)
3438	Au	798570	7638700	50	Treble Event (Au)
3439	Au	797651	7639217	50	Golden Gauntlet (Au)
3440	Au	797488	7639269	50	Gift (Au)
3441	Au	797154	7639618	50	Great Western (Au)
3442	Au	799486	7637946	50	Klondyke Queen 2 (Au)
3443	Au	799281	7638130	50	Klondyke No 1 West (Au)
3445	Au	799117	7638276	50	Nelson (Au)
3446	Au	799077	7638226	50	Klondyke Boulder East (Au)
3448	Au	799023	7638311	50	Wheel of Fortune (Dawson City) (Au)
3450	Au	798827	7638346	50	Klondyke Boulder (Au)
3451	Au	796651	7640090	50	Bow Bells (Au)
3453	Au	196057	7627856	51	Pryces Find East (Au)

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No*	COMMODITY	EAST	NORTH	Z	NAME
3454	Au	195307	7625076	51	Pryces Find West (+Alluv) (Au)
3462	Au	798046	7637609	50	Imperialist (Au)
3464	Au	796393	7640495	50	Bow Bells No 1 (Au)
3466	Au	795711	7640775	50	Chance (Au)
3467	Au	794314	7640882	50	Tom Thumb 1 (Au)
3468	Au	794356	7640968	50	Carnoustie (Au)
3470	Au	793777	7641552	50	Princept (Au)
3474	Au	793818	7640251	50	Trump 1 (Au)
3476	Au	794087	7641156	50	Cutty Sark East (Au)
3480	Au	799900	7637580	50	Klondyke King (Au)
3575	Au	702950	7671956	50	McPhees 1 (Au)
3576	Au	702757	7671606	50	McPhees 5 (Au)
3593	Au	799566	7637920	50	Klondyke No 1 East (Au)
3595	Au	799837	7637806	50	Klondyke No 2 East (Au)
3598	Au	799947	7637706	50	Admiral Dewey (Au)
3604	Au	800572	7637446	50	Dead Camel (Au)
3613	Au	799577	7638126	50	Klondyke Block (Au)
3614	Au	800626	7637697	50	Saint George (Au)
3615	Au	800782	7637321	50	Cuban (Au)
3617	Au	800987	7637226	50	Brittania (Au)
3618	Au	801202	7637176	50	Kopckes Reward (Au)
3622	Au	207299	7629065	51	Uncle Tom Yandicoogina (Au)
3652	Au	209441	7629987	51	Black Shepherd Shannon (Au)
3653	Au	208120	7630452	51	Lone Hand Yandcoogina (Au)
3655	Au	208454	7630589	51	Eastern (Au)
3656	Au	207467	7629393	51	Lady Adelaide (Au)
3657	Au	207135	7629461	51	Aunt Sally (Au)
3659	Au	206711	7628600	51	Trilby (Au)
3968	Au	789190	7641991	50	Coronation Ridge Prospect (Au)
3969	Au	789335	7641931	50	Coronation Ridge 2 (Au)
4004	Au	212987	7680960	51	Bulletin (Au)
4006	Au	211637	7681336	51	Bamboo King (Au)
4014	Au	210795	7682286	51	Kitchener (Au)
4028	Au	210997	7681786	51	Bonnie Doone (Au)
4029	Au	210537	7682544	51	Bamboo Queen (Au)
4043	Au	210035	7682866	51	South Perseverance (Au)
4045	Au	210417	7682706	51	Federation (Au)
4047	Au Ni	209900	7683050	51	Prophecy (Au)
4049	Au	209697	7683206	51	Prophecy North (Au)
4057	Au	209900	7683050	51	Mount Prophecy UG (Au)
4065	Au	209837	7683316	51	Mount Prophecy OPit (Au)
4068	Au	209537	7683326	51	Prince Charlie (Au)
4071	Au	209455	7683336	51	Princess May (Au)
4074	Au	209415	7683386	51	Alpha Thistle (Au)
4078	Au	210715	7682136	51	The Cave (Au)
4079	Au	210535	7682256	51	Forest Abbey (Au)
4080	Au	210455	7682366	51	Black Angel (Au)
4081	Au	210275	7682556	51	Black Queen (Au)
4083	Au	211515	7681226	51	Nil Desperandum (Au)
4090	Au	211037	7682156	51	Hidden Treasure (Au)
4096	Au	211415	7681800	51	Puzzle (Au)
4108	Au	714635	7616881	50	Miracle (Au)
4109	Au	716635	7616281	50	Old Timers North (Au)
4111	Au Ag	716135	7615961	50	Old Timers South (Au)
4116	Au	207037	7703436	51	Friendly Stranger UG (Au)
4120	Au	207437	7703306	51	Friendly Stranger OPit 1 (Au)
4121	Au	207087	7703656	51	Friendly Stranger OPit 2 (Au)
4122	Au	206457	7704276	51	Battler (Au Ag)
4153	Au	215107	7679452	51	Seven Oaks UG (Au)
4154	Au	216132	7678561	51	Seven Oaks OPit (Au)
4253	Au	219065	7577591	51	Barton West Main No 4 (Au)
4255	Au	219125	7577641	51	Barton Main No 3 (Au)
4256	Au	219165	7577741	51	Barton Main No 2 (Au)
4257	Au	219195	7577791	51	Barton No 1 (Au)
4258	Au	219265	7578011	51	Middle Creek (Au)
4262	Au Cu Pb	219499	7578326	51	Elsie Jane (Au)
4263	Au	219685	7578626	51	Hopetoun (Au)

PRECIOUS METAL

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No*	COMMODITY	EAST	NORTH	Z	NAME
4266	Au	219858	7578794	51	Hopetoun North 1 (Au)
4267	Au	220606	7579645	51	Middle Ck GML 133 (Au)
4268	Au	221485	7579251	51	All Nations (Au)
4270	Au	222300	7579241	51	Federation East (Au)
4273	Au	222134	7579731	51	Federation North (Au)
4274	Au	223615	7580111	51	Little Wonder West 1 (Au)
4275	Au	223847	7580044	51	Little Wonder (Au)
4287	Au	223935	7580011	51	Eureka (Au)
4290	Au	224155	7580021	51	Eureka East 1 (Au)
4293	Au	224415	7580061	51	Eureka East 2 (Au)
4294	Au	224755	7579991	51	Central Southwest (Au)
4304	Au	224845	7580291	51	Central Northwest (Au)
4308	Au	225135	7580341	51	Central North (Au)
4309	Au	225155	7580201	51	Central (Au)
4312	Au	225435	7580231	51	Central East 2 (Au)
4315	Au	225585	7580091	51	Uncle Tom Southwest 1 (Au)
4318	Au	225825	7580181	51	Uncle Tom (Au)
4321	Au	226055	7579981	51	Bow Bells Middle Ck (Au)
4323	Au	229415	7582541	51	Mountain Maid (Au)
4327	Au	220345	7578551	51	Onion (Au)
4329	Au	220355	7578781	51	Yes No (Au)
4345	Au Sb	218265	7584441	51	Blue Spec (Au Sb)
4348	Au Sb	217085	7584231	51	Golden Spec (Au Sb)
4354	Au Sb	225005	7585711	51	Branchis PA (Au Sb)
4355	Au Sb	231145	7586491	51	Billjim (Au Sb)
4357	Au Sb	232905	7586161	51	Golden Gate (Au Sb)
4358	Au Sb	231175	7586641	51	Billjim North (Au Sb)
4360	Au Sb	231671	7586891	51	Billjim Northeast 2 (Au Sb)
4366	Au Sb	236445	7580831	51	Galtee More (Au Sb)
4371	Au Sb	236415	7581491	51	Galtee More North 2 (Au Sb)
4372	Au Sb	235625	7580901	51	Ard Patrick (Au Sb)
4373	Au Sb	235485	7581051	51	Latest Surprise (Au Sb)
4374	Au Sb	238825	7580191	51	Rattler (Au Sb)
4376	Au Sb	242245	7583991	51	Reward (Au Sb)
4377	Au Sb	241815	7583931	51	Federal (Au Sb)
4380	Au Sb	241610	7583971	51	Parnell (Au) Sb
4381	Au Sb	241695	7584051	51	Parnell North 1 (Au Sb)
4383	Au Sb	241505	7584311	51	Parnell North 2 (Au Sb)
4384	Au Sb	241225	7584041	51	Parnell West 2 (Au Sb)
4385	Au Sb	241525	7583861	51	Parnell West 1 (Au Sb)
4400	Au	252075	7597911	51	Crescent (Au)
4401	Au	252535	7597981	51	Crescent East (Au)
4403	Au	253285	7598421	51	Thistle (Au)
4404	Au	253435	7598511	51	Rose (Au)
4405	Au	253715	7598631	51	Jerk (Au)
4406	Au	253795	7598691	51	Shamrock Nullagine (Au)
4407	Au	252965	7598591	51	Harp (Au)
4414	Au	253245	7598811	51	Dohertys Reward East (Au)
4434	Au	253345	7598941	51	Morning Star 2 (Au)
4440	Au	254055	7598931	51	Mount Olive (Au)
4457	Au	249265	7609541	51	Little Elsie (Au)
4458	Au	250315	7609641	51	Elsie (Au)
4470	Au	793841	7640346	50	Trump 2 (Au)
4524	Au	201868	7574980	51	Day Dawn (Au)
4530	Au	202172	7574699	51	Victory Ext 51 (Au)
4533	Au	202765	7574974	51	Victory East Ext 134 (Au)
4534	Au	202458	7574892	51	Victory (Au)
4536	Au	203939	7575375	51	Great Eastern (Au)
4537	Au	203047	7576611	51	Enterprise (Au)
4538	Au	204285	7577321	51	Sunrise No 1 (Au)
4539	Au	204110	7577071	51	Sunrise (Au)
4542	Au	205295	7577801	51	Promise (Au)
4544	Au	205495	7577661	51	Try Again (Au)
4548	Au	205635	7577821	51	Fishers Reward (Au)
4550	Au	202678	7568066	51	Golden Eagle 1 (Au)
4561	Au	212135	7575110	51	Mundalla (Au)
4562	Au	209637	7573153	51	Castlemaine (Au)

PRECIOUS METAL

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No*	COMMODITY	EAST	NORTH	Z	NAME
4565	Au	214114	7575440	51	Margie (Au)
4566	Au	209131	7571901	51	Valentine (Au)
4567	Au	212127	7573731	51	Alice (Au)
4568	Au	212237	7573606	51	Happy Wanderer (Au)
4570	Au	209956	7573791	51	Mount Daniel (Au)
4588	Au	790693	7642977	50	Crystal Tuff (Au)
4589	Au	796636	7640191	50	Bow Bells North (Au)
4602	Ag Cu	806905	7600360	50	Emu Creek 2 (Ag Cu Au)
4622	Au	656940	7700187	50	Mount Berghaus (Au))
4675	Au	708410	7642921	50	Mercury Hill (Au)
4750	Au	342236	7571251	51	Fletchers Find (Au)
4766	Au	209982	7605272	51	McPhees (Au)
4967	Au Sb	232635	7586541	51	Jumbo 1 (Au Sb)
4968	Au Sb	232855	7586601	51	Jumbo 2 (Au Sb)
4970	Au	774066	7583686	50	P45/244 1 (Au)
5011	Au	726613	7591255	50	Tambourah P45/1564 1 (Au)
5012	Au	726562	7590549	50	Tambourah P45/1564 2 (Au)
5077	Au	206731	7628642	51	Uncle Tom Southwest 2 (Au)
5079	Au	206319	7628492	51	Trig Well (Au)
5080	Au	207835	7629661	51	Lady Adelaide Northeast 3 (Au)
5081	Au	208115	7629521	51	Lady Adelaide East Northeast (Au)
5256	Au	213505	7680736	51	Bamboo Bulletin East (Au)
5258	Au	207301	7629131	51	Cyclone (Au)
5259	Au	205835	7626951	51	Invincible (Au)
5260	Au	699240	7664246	50	Mt York Gossan Hill (Au)
5436	Au Cu	746533	7640091	50	North Shaw Northwest (Cu Au)
5446	Au	728342	7584152	50	General Gordon Northeast (Au)
5447	Au	728835	7584953	50	W Shaw No1 East (Au)
5453	Au	726563	7592168	50	Duke of Wellington Southeast (Au)
5455	Au	726460	7591938	50	Tambourah King No1 East 1 (Au)
5456	Au	726421	7591754	50	Tambourah King No1 East 2 (Au)
5459	Au	726695	7591490	50	Western Chief No 3 (Au)
5460	Au	726427	7591604	50	Tambourah King No1 South (Au)
5467	Au	699287	7664356	50	Gossan Hill (Au)
5468	Au	701137	7676256	50	McPhees South Pit (Au)
5469	Au	700605	7678243	50	Birthday Gift (Au Ta?)
5473	Au	793936	7640599	50	Golden Gate (Au)
5474	Au	793760	7640742	50	Golden Gate Northwest (Au)
5475	Au	794290	7640921	50	Tom Thumb 2 (Au)
5476	Au	793937	7641112	50	Cutty Sark West (Au)
5477	Au	795305	7641530	50	Seven Dials (Au)
5478	Au	795458	7641329	50	Seven Dials Southeast 1 (Au)
5479	Au	795457	7641328	50	Seven Dials Southeast 2 (Au)
5481	Au	795766	7640684	50	May Be Southwest (Au)
5482	Au	795785	7640731	50	May Be (Au)
5483	Au	796054	7640539	50	May Be Southeast (Au)
5484	Au	796397	7640452	50	Bow Bells No 1 West (Au)
5485	Au	796610	7640291	50	Bow Bells North Reef (Au)
5499	Au	797296	7639512	50	Great Western Southeast (Au)
5500	Au	798314	7638868	50	Gauntlet East (Au)
5503	Au	798822	7638541	50	Klondyke Boulder North (Au)
5504	Au	798054	7639012	50	Gauntlet Northwest 1 (Au)
5505	Au	798570	7638700	50	Treble Event (Au)
5511	Au	800243	7637869	50	Klondyke King Blocks No 1 East (Au)
5512	Au	800467	7637798	50	St George No 1 West (Au)
5513	Au	800632	7637626	50	St George East (Au)
5515	Au	798788	7638444	50	Klondyke Boulder North (Au)
5516	Au	798580	7638615	50	Klondyke Boulder Northwest (Au)
5517	Au	798529	7638640	50	Klondyke Boulder Northwest 2 (Au)
5518	Au	797937	7638936	50	Rangitira West (Au)
5526	Au	797407	7639496	50	Gauntlet No3 Northwest 2 (Au)
5536	Au	798237	7638956	50	Gauntlet North (Au)
5539	Au	799802	7637986	50	Brought to Light (Au)
5547	Au	800197	7637676	50	Klondyke Queen 488 (Au)
5549	Au	800387	7637506	50	Klondyke Queen Ext (Au)
5555	Au	800912	7637556	50	St George No 1 East (Au)
5562	Au	801462	7637001	50	Daylight (Au)

No*	COMMODITY	EAST	NORTH	Z	NAME
PRECIOUS METAL					
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5563	Au	801647	7636916	50	Juneau (Au)
5564	Au	801762	7636856	50	Criterion (Au)
5565	Au	801947	7636741	50	Criterion Southeast (Au)
5567	Au	802327	7637116	50	Lone Hand Warrawoona (Au)
5569	Au	789195	7641991	50	Coronation Ridge 1 (Au)
5573	Au	770962	7627702	50	Mt Ada East Stope (Au)
5574	Au	770835	7627746	50	Mt Ada Northwest 1 Stope (Au)
5576	Au	770867	7627591	50	Mt Ada South (Au)
5577	Au	770767	7627836	50	Mt Ada Northwest 2 (Au)
5579	Au	771000	7627530	50	Golden Gift East and West (Au)
5580	Au	771025	7627436	50	Golden Gift South (Au)
5586	Au	771106	7626282	50	Mt Florence North 1 (Au)
5587	Au	771114	7626334	50	Mt Florence North 2 (Au)
5588	Au	768337	7631456	50	Mt Joy (Au)
5589	Au	771028	7624459	50	Burrow Well Southeast (Au)
5590	Au	771163	7623730	50	Burrow Well Southeast 2 (Au)
5591	Au	771198	7623608	50	Burrow Well Southeast 3 (Au)
5592	Au	771222	7623111	50	Burrow Well South (Au)
5593	Au	700540	7675060	50	Venus (Au)
5601	Au	799080	7638000	50	Klondyke Boulder South (Au)
5602	Au	782261	7626303	50	Laura Anne (Au)
5605	Au	794626	7643224	50	Owens Gully 1 (Au)
5606	Au	794871	7642937	50	Owens Gully 2 (Au)
5608	Au Cu	786637	7641456	50	Fieldings Gully (Au Cu)
5616	Au	209019	7634731	51	Mt Edgar Granite (Au)
5617	Au	209365	7630026	51	Black Shepherd Black & White (Au)
5618	Au	209305	7630041	51	Black Shepherd Edith (Au)
5619	Au	208348	7630444	51	Eastern Southwest (Au)
5620	Au	208161	7630222	51	Eastern Southwest 2 (Au)
5621	Au	207746	7629420	51	Lady Adelaide Northeast 2 (Au)
5622	Au	207635	7629551	51	Lady Adelaide Northeast (Au)
5623	Au	207685	7629341	51	Lady Adelaide Southeast (Au)
5624	Au	207163	7629024	51	Uncle Tom West (Au)
5625	Au	207064	7628943	51	Uncle Tom West End (Au)
5627	Au	789695	7641751	50	Coronation Ridge 3 (Au)
5628	Au	789835	7641741	50	Coronation Ridge 4 (Au)
5629	Au	789857	7640836	50	Mt Lyall (Au)
5630	Au	791235	7640361	50	Fieldings Gully B 1 (Au)
5631	Au	791695	7640291	50	Fieldings Gully C 1 (Au)
5632	Au	791115	7642691	50	Crystal Tuff Southeast (Au)
5633	Au	788605	7642961	50	Coronation North (Au)
5634	Au	790075	7643091	50	Crystal Tuff Northwest (Au)
5635	Au	790235	7642861	50	Crystal Tuff Southwest (Au)
5638	Au	799427	7638106	50	Klondyke Queen Northeast (Au)
5639	Au	800097	7637816	50	Klondyke Queen 488 West (Au)
5640	Au	800417	7637456	50	Klondyke Queen Ext North (Au)
5641	Au	800797	7637086	50	Cuban South (Au)
5642	Au	791737	7641566	50	Copenhagen North 1 (Au)
5643	Au	791727	7641806	50	Copenhagen North 2 (Au)
5644	Au	791617	7641926	50	Copenhagen North 3 (Au)
5645	Au	790807	7642086	50	Copenhagen Northwest (Au)
5649	Au	201710	7574934	51	Day Dawn No1 South (Au)
5654	Au	202551	7568058	51	Golden Eagle 2 (Au)
5655	Au	211768	7573496	51	Shearers Deposit (Au)
5656	Au	212136	7573454	51	Otways (Au)
5658	Au	219905	7578911	51	Hopetoun North 2 (Au)
5661	Au	221395	7579221	51	All Nations South (Au)
5662	Au	221495	7579431	51	All Nations North 1 (Au)
5663	Au	221505	7579591	51	All Nations North 2 (Au)
5664	Au	221523	7579720	51	All Nations North 3 (Au)
5665	Au	220665	7579621	51	Hopetoun North 6 (Au)
5666	Au	220645	7579091	51	All Nations Southwest (Au)
5667	Au	220405	7578861	51	Yes No Northeast (Au)
5668	Au	223465	7580121	51	Little Wonder West 2 (Au)
5669	Au	223655	7579841	51	Little Wonder South 1 (Au)
5670	Au	223375	7579881	51	Little Wonder South 2 (Au)
5671	Au	223255	7579941	51	Little Wonder 1 Southwest (Au)

No*	COMMODITY	EAST	NORTH	Z	NAME
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5672	Au	222865	7579551	51	Little Wonder 3 Southwest (Au)
5674	Au	222300	7579241	51	Federation West (Au)
5675	Au	222035	7579311	51	Federation North 1 (Au)
5676	Au	221905	7579311	51	Federation Northwest (Au)
5677	Au	221175	7579361	51	All Nations West (Au)
5678	Au	221255	7579431	51	All Nations Northwest (Au)
5679	Au	219475	7578021	51	Middle Ck East (Au)
5680	Au	219895	7578091	51	Elsie Jane East 2 (Au)
5681	Au	219005	7577501	51	Middle Ck South (Au)
5682	Au	224555	7580161	51	Eureka East 3 (Au)
5683	Au	225265	7580211	51	Central East 1 (Au)
5684	Au	224965	7580191	51	Central West 1 (Au)
5685	Au	224775	7580141	51	Central West 2 (Au)
5687	Au	225595	7580181	51	Uncle Tom West (Au)
5688	Au	229325	7582511	51	Mountain Maid West (Au)
5690	Au	236605	7581521	51	Galtee More Northeast 2 (Au Sb)
5691	Au	236375	7580761	51	Galtee More Southwest (Au Sb)
5692	Au	241385	7584211	51	Parnell West 3 (Au Sb)
5694	Au	241645	7584301	51	Parnell North 3 (Au Sb)
5695	Au	241825	7583991	51	Federal North (Au Sb)
5699	Au	253265	7598891	51	Morning Star Southwest (Au)
5700	Au	253215	7598751	51	Dohertys Reward West (Au)
5701	Au	253045	7598641	51	Harp Northeast (Au)
5703	Au	252785	7598551	51	Harp Southwest (Au)
5704	Au	253555	7598901	51	Morning Star East (Au)
5706	Au	224865	7585691	51	Branchis West (Au Sb)
5707	Au Sb	231225	7586531	51	Billjim East 1 (Au Sb)
5708	Au Sb	231355	7586521	51	Billjim East 2 (Au Sb)
5709	Au Sb	230855	7586391	51	Billjim West (Au Sb)
5710	Au	234595	7586191	51	Golden Gate East (Au)
5712	Au	250255	7609841	51	Elsie Abd North 1 (Au)
5717	Au	250195	7609791	51	Elsie Abd North 2 (Au)
5718	Au	250095	7609721	51	Elsie Abd North 3 (Au)
5721	Au Cu	786467	7641506	50	Fieldings Gully West (Au)
5722	Ag Au Cu Pb	787077	7641486	50	Fieldings Gully East (Ag Au Pb Cu)
5729	Au	221025	7578931	51	All Nations South Southwest (Au)
5730	Au	220055	7579121	51	Hopetoun North 3 (Au)
5731	Au	220475	7579551	51	Hopetoun North 5 (Au)
5732	Au	218785	7577291	51	Middle Ck South 2 (Au)
5733	Au	218505	7577511	51	Barton West (Au)
5734	Au	219195	7577731	51	Barton North (Au)
5735	Au	219675	7578311	51	Elsie Jane East 1 (Au)
5736	Au	220535	7578681	51	Onion Northeast (Au)
5739	Au	220295	7579341	51	Hopetoun North 4 (Au)
5740	Au	220525	7579301	51	Hopetoun Northeast (Au)
5741	Au	220955	7579541	51	All Nations Northwest 1 (Au)
5744	Au	221555	7579331	51	All Nations East (Au)
5746	Au	223015	7579931	51	Little Wonder 2 Southwest (Au)
5747	Au	222845	7579930	51	Little Wonder 4 Southwest (Au)
5749	Au	222705	7579691	51	Little Wonder 5 Southwest (Au)
5751	Au	222435	7579701	51	Little Wonder 6 Southwest (Au)
5752	Au	222845	7579431	51	Little Wonder 7 Southwest (Au)
5753	Au	223385	7579751	51	Little Wonder 8 Southwest (Au)
5755	Au	223355	7579711	51	Little Wonder 9 Southwest (Au)
5756	Au	223125	7579361	51	Little Wonder 10 Southwest (Au)
5757	Au	225415	7580151	51	Central East 3 (Au)
5759	Au	225295	7580011	51	Central East 4 (Au)
5760	Au	225365	7580341	51	Central East 5 (Au)
5761	Au	225835	7580271	51	Uncle Tom North (Au)
5762	Au	226655	7580061	51	Bow Bells East (Au)
5763	Au Sb	236585	7580911	51	Galtee More Northeast 1 (Au Sb)
5764	Au	241145	7584191	51	Parnell West 4 (Au Sb)
5765	Au	241025	7584311	51	Parnell West 5 (Au Sb)
5766	Au Sb	236205	7581241	51	Galtee More North 1 (Au Sb)
5767	Au Sb	236365	7581311	51	Galtee More North 1 (Au)
5768	Au Sb	236735	7580961	51	Galtee More Northeast 3 (Au Sb)
5769	Au Sb	236665	7581241	51	Galtee More Northeast 4 (Au Sb)

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No*	COMMODITY	EAST	NORTH	Z	NAME
5771	Au Sb	236955	7581481	51	Galtee More Northeast 5 (Au Sb)
5772	Au Sb	235565	7581631	51	Ard Patrick North (Au Sb)
5773	Au Sb	235265	7580501	51	Ard Patrick South (Au Sb)
5774	Au Sb	235885	7580861	51	Ard Patrick Southeast (Au Sb)
5775	Au	225935	7580281	51	Camel Ck 1 (Au)
5776	Au	226035	7580241	51	Camel Ck 2 (Au)
5777	Au	225995	7580211	51	Camel Ck 3 (Au)
5779	Au	779667	7627846	50	Blue Bar 8 (Au)
5798	Au	779977	7627806	50	Blue Bar 9 (Au)
5799	Au	779787	7629456	50	Blue Bar 10 (Au)
5813	Au	776445	7594622	50	Corboy (Au)
5814	Au	777397	7589856	50	Victory (Coongan) (Au)
5815	Au	777237	7590236	50	Victory Northwest (Au)
5824	Au	250560	7607480	51	Elsie Abd South (Au)
5825	Au	249828	7611063	51	Elsie Abd North (Au)
5893	Au	791587	7641426	50	Copenhagen East 1 (Au)
5894	Au	791557	7641506	50	Copenhagen East 2 (Au)
5895	Au	798907	7638726	50	Klondyke Boulder Northeast (Au)
5896	Au	788337	7649206	50	Petersens Mine (Au)
5897	Au	791667	7645776	50	Apex Northeast 2 (Au)
5898	Au	791037	7644606	50	Apex Northeast 1 (Au)
5899	Au	803777	7636056	50	Horrigan Pk Northwest (Au)
5903	Au	799197	7638296	50	Dodge City East (Au)
5904	Au	798467	7638906	50	Gauntlet Northeast (Au)
5905	Au	798217	7639056	50	Gauntlet Northwest 2 (Au)
5907	Au	706937	7649456	50	White Cockatoo (Au)
5908	Au	704487	7653206	50	Frank Elliotts (Au)
5917	Au	777087	7593426	50	Corboy Southeast (Au)
5918	Au	774537	7589406	50	Triberton Ck C (Au)
5919	Au	210437	7605336	51	McPhee Prosp (Au)
5960	Au	222395	7616245	51	Bridget Creek South (Au)
5967	Au	240385	7578711	51	Lands End 2 (Au)
5968	Au	241230	7579560	51	Off Chance (Au)
5969	Au	240115	7579721	51	Belle Vue (Au)
5970	Au	241215	7579661	51	Off Chance North (Au)
5971	Au	229395	7586361	51	Borehole (Au Sb)
5973	Au	225315	7653891	51	Expectation (Au)
5975	Au	225705	7653781	51	Bullgerina (Au)
5976	Au	225865	7654311	51	Mia Mia (Au)
5977	Au	225035	7652261	51	Black Douglas (Au)
5978	Au	225735	7654031	51	Royal (Au)
5979	Au	225665	7654181	51	Twenty Ounce (Au)
5989	Au	779937	7651856	50	Tassy Queen Northwest (Au)
6073	Au	219105	7577561	51	Barton East (Au)
6179	Au	226385	7607261	51	Valley Road (Au)
6187	Au Sb	221735	7585311	51	Green Stripe (Au Sb)
6190	Au Sb	229535	7586291	51	Apex (Au Sb)
6191	Au Sb	231135	7586461	51	Billjim Southeast (Au) Sb
6196	Au Sb	221235	7585251	51	Green Stripe West (Au Sb)
6198	Au Sb	216915	7584211	51	Blue Spec West 1 (Au Sb)
6199	Au Sb	216735	7584191	51	Blue Spec West 2 (Au Sb)
6200	Au Sb	216455	7584161	51	Blue Spec West 3 (Au Sb)
6201	Au Sb	216295	7584131	51	Blue Spec West 4 (Au Sb)
6202	Au Sb	215955	7584041	51	Blue Spec West 5 (Au Sb)
6203	Au Sb	218705	7584561	51	Blue Spec East 1 (Au Sb)
6204	Au Sb	218825	7584601	51	Blue Spec East 2 (Au Sb)
6205	Au Sb	218825	7584601	51	Blue Spec North Shaft (Au Sb)
6206	Au Sb	224595	7585471	51	Branchis East 1 (Au Sb)
6207	Au Sb	224735	7585501	51	Branchis East 2 (Au Sb)
6208	Au Sb	224875	7585551	51	Branchis East 3 (Au Sb)
6214	Au Sb	232055	7586581	51	Billjim East 3 (Au Sb)
6215	Au Sb	232215	7586671	51	Billjim East 4 (Au Sb)
6216	Au Sb	231285	7586761	51	Billjim Northeast 1 (Au Sb)
6217	Au Sb	231935	7586761	51	Billjim Northeast 3 (Au Sb)
6219	Au Sb	230985	7586201	51	Billjim Southwest 1 (Au Sb)
6220	Au Sb	230815	7586161	51	Billjim Southwest 2 (Au Sb)
6264	Au	698237	7668486	50	Pilgangoora 1 (Au)

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No*	COMMODITY	EAST	NORTH	Z	NAME
6265	Au	698537	7667856	50	Pilgangoora 2 (Au)
6280	Au	702907	7671846	50	McPhees 2 (Au)
6281	Au	702867	7671766	50	McPhees 3 (Au)
6282	Au	702827	7671636	50	McPhees 4 (Au)
6286	Au	703230	7672306	50	McPhees 6 (Au)
6291	Au Ta	700167	7676026	50	McPhees Southwest (Au Ta?)
6292	Au Ta	700597	7676656	50	McPhees Northwest (Au)
6293	Au	701017	7675416	50	McPhees South (Au?)
6309	Au	754007	7663486	50	North Pole (Au)
6370	Au	194832	7625426	51	Pryces Find Northwest 1 (Au)
6371	Au	194557	7625776	51	Pryces Find Northwest 2 (Au)
6374	Au Pb	200037	7626456	51	House Ck 1 (Au)
6376	Au	198535	7626261	51	House Ck 2 (Au)
6377	Au	198865	7626141	51	House Ck 3 (Au)
6378	Au	200465	7626441	51	House Ck 4 (Au)
6419	Au	221805	7580311	51	Carsons Reward 1 (Au)
6421	Au	222135	7580361	51	Carsons Reward 2 (Au)
6423	Au	221955	7580011	51	Cowboy (Au)
6571	Au	795617	7640906	50	Chance Northwest (Au)
6572	Au	796167	7640416	50	May Be Southeast 1 (Au)
6573	Au	796257	7640346	50	May Be Southeast 2 (Au)
6574	Au	796377	7640276	50	May Be Southeast 3 (Au)
6575	Au	797577	7639196	50	Golden Gauntlet West (Au)
6576	Au	797727	7639146	50	Golden Gauntlet East (Au)
6639	Au	201475	7567791	51	Golden Eagle Southwest (Au)
6640	Au	202505	7567891	51	Golden Eagle South (Au)
6641	Au	204935	7569201	51	Golden Eagle Northeast (Au)
6642	Au	201475	7566791	51	Golden Eagle Southwest 2 (Au)
6643	Au	201855	7571131	51	Golden Eagle North Northwest (Au)
6644	Au	202785	7570681	51	Golden Eagle North (Au)
6645	Au	204385	7571161	51	Golden Eagle North Northeast 1 (Au)
6646	Au	204735	7571401	51	Golden Eagle North Northeast 2 (Au)
6654	Au Pb Cu As Sb	210415	7603061	51	Gold Show Hill (Au)
6657	Au	212515	7574121	51	Five Mile (Au)
6658	Au	216805	7575871	51	Middle Ck Southwest 1 (Au)
6659	Au	216635	7576251	51	Middle Ck Southwest 2 (Au)
6660	Au	215035	7575331	51	Middle Ck Southwest 3 (Au)
6663	Au	214715	7575371	51	Middle Ck Southwest 4 (Au)
6664	Au	214605	7575751	51	Middle Ck Southwest 5 (Au)
6665	Au	214465	7575981	51	Middle Ck Southwest 6 (Au)
6666	Au	214945	7575471	51	Middle Ck Southwest 7 (Au)
6667	Au	215025	7575641	51	Middle Ck Southwest 8 (Au)
6668	Au	215585	7575361	51	Middle Ck Southwest 9 (Au)
6669	Au	213755	7574551	51	Margie South 1 (Au)
6670	Au	213495	7574341	51	Margie South 2 (Au)
6671	Au	213585	7574141	51	Margie South 3 (Au)
6672	Au	213965	7575261	51	Margie Northeast 1 (Au)
6673	Au	214165	7575611	51	Margie Northeast 2 (Au)
6674	Au	699207	7670836	50	Pilgan 1 (Au)
6675	Au	208708	7574052	51	Airport (Au)
6676	Au	700137	7671616	50	Old Faithful (Au)
6677	Au	700277	7676606	50	McPhees 7 (Au)
6708	Au	212337	7573816	51	Paul's Leader (Au)
6710	Au	204037	7575356	51	Great Eastern Ext (Au)
6712	Au	210335	7575781	51	Ali (Au)
6713	Au	210535	7572811	51	Lee (Au)
6714	Au	214535	7576421	51	Tracey (Au)
6715	Au	213535	7574511	51	Carol (Au)
6716	Au	210035	7572561	51	Kerry (Au)
6717	Au	206635	7572161	51	Sharon (Au)
6723	Au	212365	7574911	51	Lotus (Au)
6724	Au	212435	7574561	51	Area A (Au)
6725	Au	208337	7571591	51	Shulyta (Au)
6726	Au	208967	7571911	51	Maju Hill (Au)
6767	Au	260725	7612787	51	Nullagine M45/225 (Au)
6869	Au	235768	7587233	51	Mosquito Ck 4 (Au)
6881	Au	211575	7681456	51	Boundary (Au)

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No*	COMMODITY	EAST	NORTH	Z	NAME
6889	Au	229902	7586080	51	Golden Spec E46/516 (Au)
7013	Au	785637	7653216	50	Dawn 1 (Au)
7014	Au	786407	7652236	50	Dawn 2 (Au)
7015	Au	785977	7651836	50	Dawn 3 (Au)
7016	Au	786067	7651616	50	Dawn 4 (Au)
7017	Au	785957	7651556	50	Dawn 5 (Au)
7019	Au	786117	7651436	50	Dawn 6 (Au)
7020	Au	787217	7651436	50	Dawn 7 (Au)
7021	Au	787117	7650616	50	Dawn 8 (Au)
7022	Au	787377	7650626	50	Dawn 9 (Au)
7023	Au	788087	7650676	50	Dawn 10 (Au)
7024	Au	787277	7650296	50	Dawn 11 (Au)
7025	Au	787547	7650256	50	Dawn 12 (Au)
7026	Au	787427	7650056	50	Dawn 13 (Au)
7051	Au	705020	7669140	50	Siver Dollar (Au)
7100	Au	741037	7631656	50	Daltons Ck 1 (Au)
7103	Au	743237	7633056	50	Daltons Ck 2 (Au)
7114	Au	220005	7579611	51	Corboys 1 (Au)
7117	Au	220305	7579691	51	Corboys 2 (Au)
7441	Au	760582	7703795	50	Doms Hill (Au)
7454	Au	671537	7698156	50	Turner R (Au)
7463	Au	211245	7681076	51	Welcome (Au)
7464	Au	212085	7680646	51	Nil Desperandum Southeast 1 (Au)
7465	Au	210487	7682656	51	Wheel of Fortune (Au)
7466	Au	209955	7682956	51	Perseverance (Au)
7468	Au	212445	7680146	51	Nil Desperandum Southeast 2 (Au)
7470	Au	212535	7680846	51	Bulletin West (Au)
7471	Au	212465	7680996	51	Bulletin West 2 (Au)
7472	Au	214425	7680706	51	Bulletin East 2 (Au)
7473	Au	210735	7682356	51	No 1 Timbuctoo (Au)
7474	Au	211555	7681526	51	Premier (Au)
7477	Au	210215	7683000	51	True Blue Bamboo Ck (Au)
7512	Au	236305	7586700	51	Mosquito Ck 1 (Au)
7514	Au	236465	7586660	51	Mosquito Ck 2 (Au)
7515	Au	236525	7586690	51	Mosquito Ck 3 (Au)
7516	Au	237565	7586430	51	Mosquito Ck 5 (Au)
7517	Au	238045	7586260	51	Mosquito Ck 6 (Au)
7518	Au	238175	7586360	51	Mosquito Ck 7 (Au)
7519	Au	238215	7586425	51	Mosquito Ck 8 (Au)
7521	Au	797635	7587100	50	Kellys Ridge (Au)
7523	Au	767290	7743310	50	Mine Well 1 (Au)
7524	Au	767240	7743140	50	Mine Well 2 (Au)
7525	Au	767120	7742960	50	Mine Well 3 (Au)
7534	Au	224900	7580850	51	Central North 1 (Au)
7535	Au	225375	7581100	51	Central North 2 (Au)
7536	Au	226240	7581180	51	Camel Ck North 1 (Au)
7537	Au	226690	7581160	51	Camel Ck North 2 (Au)
7540	Au	229322	7581314	51	20 Mile Sandy East 1 (Au)
7541	Au	229185	7580740	51	20 Mile Sandy East 2 (Au)
7542	Au	229435	7580660	51	20 Mile Sandy East 3 (Au)
7543	Au	229615	7580930	51	20 Mile Sandy East 4 (Au)
7544	Au	229755	7580770	51	20 Mile Sandy East 5 (Au)
7545	Au	229505	7582830	51	Mountain Maid North 1 (Au)
7546	Au	229855	7583020	51	Mountain Maid North 2 (Au)
7547	Au	229765	7582480	51	Mountain Maid East (Au)
7548	Au	231105	7582370	51	Mountain Maid East 2 (Au)
7549	Au	231455	7582250	51	Mountain Maid East 3 (Au)
7550	Au	231315	7581200	51	Mountain Maid Southeast 1 (Au)
7551	Au	231445	7581240	51	Mountain Maid Southeast 2 (Au)
7552	Au	231565	7581300	51	Mountain Maid Southeast 3 (Au)
7553	Au	232255	7581710	51	Mountain Maid East 4 (Au)
7554	Au	233295	7581920	51	Mountain Maid East 5 (Au)
7555	Au	234475	7581310	51	Latest Surprise East (Au)
7556	Au	235145	7580910	51	Latest Surprise Southeast (Au)
7557	Au	235435	7582590	51	Ard Patrick North 2 (Au)
7558	Au	237375	7581330	51	Galtee More Northeast 6 (Au)
7559	Au	236765	7580520	51	Galtee More Southeast (Au)

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No*	COMMODITY	EAST	NORTH	Z	NAME
7561	Au	236285	7588490	51	Mosquito Ck 9 (Au)
7562	Au	235245	7586540	51	Mosquito Ck 12 (Au)
7563	Au	236455	7588440	51	Mosquito Ck 10 (Au)
7565	Au	237325	7585960	51	Mosquito Ck 11 (Au)
7566	Au	232905	7586680	51	Golden Gate North (Au)
7567	Au Sb	229955	7586410	51	Borehole Northeast (Au Sb)
7569	Au	706562	7665436	50	Lalla Rookh (Au)
7598	Au	786300	7654950	50	Augusta No 1 South (Au)
7599	Au	785890	7651210	50	Franklin (Au)
7600	Au	782540	7648460	50	Gleaming Dawn (Au)
7601	Au	782740	7648260	50	Guba (Au)
7602	Au	787290	7650650	50	Gwalia (Au)
7604	Au	785980	7657080	50	Iron Duke (Au)
7605	Au	786190	7656960	50	Keep It Dark 2 (Au)
7615	Au	782360	7647660	50	Coongan R (Au)
7616	Au	786470	7650780	50	Golden Knot (Au)
7617	Au	782140	7647860	50	Lucknow Central (Au)
7618	Au	785900	7655960	50	Marble Bar 288 (Au)
7619	Au	785240	7659360	50	New Chum Railway (Au)
7620	Au	786430	7654960	50	Progress (Au)
7621	Au	786000	7661860	50	Queen of the West (Au)
7622	Au	782640	7647960	50	Alethia (Au)
7623	Au	786400	7657560	50	Betty Boo (Au)
7624	Au	787290	7651100	50	Big Schist (Au)
7625	Au	787160	7651510	50	Big Schist North (Au)
7626	Au	782920	7649520	50	Sydney (Au)
7627	Au	783040	7648200	50	Repeater (Au)
7628	Au	787720	7649560	50	Halleys Comet North (Au)
7629	Au	783470	7648260	50	Laura Dawn (Au)
7630	Au	793200	7674900	50	Talga Blink (Au)
7632	Au	786440	7657800	50	Two Tickets (Au)
7633	Au	777400	7589840	50	Stirling (Au)
7637	Au	793380	7674800	50	Black Cat (Au)
7638	Au	794630	7640100	50	Town (Au)
7639	Au	794040	7640100	50	Rising Moon (Au)
7640	Au	207440	7632260	51	Jupiter (Au)
7641	Au	240640	7578900	51	Lands End 1 (Au)
7644	Au	201540	7566940	51	Miss Victoria (Au)
7645	Au	270750	7613200	51	Boodalyerrie (Au)
7741	Au	732300	7625910	50	Dalton (Au)
7742	Au	743070	7633810	50	Chocolate Hill (Au)
7767	Au	705550	7667410	50	Todds Find (Au)
7768	Au	705670	7666660	50	Adamsons (Au)
7770	Au	705700	7666320	50	Exeter (Au)
7774	Au	698600	7667760	50	Darius 2 (Au)
7775	Au	700840	7666700	50	Cleopatra (Au)
7777	Au	701370	7663800	50	Gloucester (Au)
7783	Au	730400	7589450	50	Tambourah 1 (Au)
7784	Au	728550	7590480	50	Tambourah 2 (Au)
7785	Au	728830	7593930	50	Tambourah 3 (Au)
7840	Au	206190	7569700	51	North Dromedary (Au)
7883	Au	697667	7666500	50	Zakanaka North (Au)
8020	Au	698580	7667800	50	Darius 1 (Au)
8021	Au	699240	7668000	50	Iron Stirrup South 2 (Au)
8363	Au	662999	7692600	50	Lost Arc (Au)
8365	Au	666200	7695800	50	Last Crusade (Au)
8366	Au	667000	7696300	50	WMC (Au)

Stratabound volcanic and sedimentary - sedimentary-hosted sulfide

No*	COMMODITY	EAST	NORTH	Z	NAME
7459	Au	756783	7681133	50	Contact Ck (Au)

Stratabound sedimentary - clastic-hosted

No*	COMMODITY	EAST	NORTH	Z	NAME
3102	Au	782370	7647792	50	Just In Time (Au)
3103	Au	781192	7649809	50	Tasmanian Queen (Au)
3244	Au	730861	7625996	50	Keep it Dark 1 (Au)
3258	Au	757170	7641226	50	Virgin Creek (Au)
4465	Au	200025	7577784	51	Grants Hill (Au)
4467	Au	200341	7578023	51	Freak of Nature (Au)

PRECIOUS METAL

Stratabound sedimentary - clastic-hosted

No*	COMMODITY	EAST	NORTH	Z	NAME
4469	Au	200305	7578322	51	Upper Barneys Hill Deans (Au)
4471	Au	200128	7578374	51	Barneys Hill Lower 1 and 2 (Au)
4472	Au	200208	7578486	51	Barneys Hill Upper Success (Au)
4474	Au	200122	7578662	51	Barneys Hill No 1 North (Au)
4478	Au	200707	7578384	51	Golden Crown (Au)
4480	Au	200609	7578627	51	Golden Promise (Au)
4483	Au	200157	7578485	51	Barneys Hill Lower No 3 (Au)
4485	Au	200035	7578383	51	Barneys Lower No 4 (Au)
4487	Au	200450	7577748	51	Cooks Hill (Au)
5823	Au	725380	7610800	50	Tambina (Au)
7438	Au	199385	7577241	51	Beaton Ck (Au)
7643	Au	199746	7577640	51	Trinity (Au)

Regolith - residual and supergene

No*	COMMODITY	EAST	NORTH	Z	NAME
2	Au	214625	7575061	51	Middle Creek 2 (Au)
2941	Au Cu	752867	7639476	50	North Shaw (Au Cu)
3113	Au	703790	7657346	50	Valley of the Gossans A (Au)
4591	Ag Cu	766000	7636400	50	Sharks Gully (Ag Cu)
4971	Au	773850	7583781	50	P45/244 2 (Au)
6579	Ag	810897	7685071	50	Murphy Well (Ag Cu)

Regolith - alluvial to beach placers

No*	COMMODITY	EAST	NORTH	Z	NAME
2802	Au	787244	7650949	50	Four Mile Alluv 1 (Au)
2803	Au	786489	7650530	50	Four Mile Alluv 2 (Au)
2811	Au	779893	7625177	50	Kangaroo Flat Alluv (Au)
2850	Au	728913	7594298	50	Tambourah Alluv (Au)
2942	Au	728340	7638946	50	Strelley Alluv 1 (Au)
2943	Au	714440	7636346	50	Strelley Alluv 2 (Au)
3080	Au	716414	7617816	50	Abydos Alluv (Au)
3082	Au	726896	7620505	50	Spring Gully Alluv (Au)
4190	Au	206353	7685981	51	Nuggety Gully North Alluv (Au)
4194	Au	206691	7685743	51	Nuggety Gully South Alluv (Au)
4197	Au	215577	7678728	51	Seven Oaks Alluv (Au)
4198	Au	218780	7675802	51	Strattons Alluv (Au)
4199	Au	206831	7703319	51	Friendly Stranger Alluv (Au)
4224	Au	720460	7661321	50	Pincunah Alluv 1 (Au)
4226	Au	719140	7660886	50	Pincunah Alluv 2 (Au)
4248	Au	757731	7642029	50	Virgin Creek Alluv (Au)
4494	Au	200216	7577544	51	Conglomerate Ck Yeo (Au)
4496	Au	200171	7577743	51	Conglomerate Ck Alluv (Au)
4497	Au	200906	7577690	51	Cookes Ck Alluv (Au)
4499	Au	201638	7578358	51	One Mile Ck Alluv (Au)
5274	Au	205985	7568601	51	South Dromedary (Au)
5276	Au	245505	7593987	51	Mosquito Ck Alluv 1 (Au)
5277	Au	237971	7594200	51	Mosquito Ck Alluv 2 (Au)
5438	Au	729086	7587173	50	W Shaw Alluv 1 (Au)
5439	Au	729218	7587173	50	W Shaw Alluv 2 (Au)
5442	Au	728255	7584620	50	W Shaw Alluv 3 (Au)
5444	Au	728140	7584660	50	Western Shaw Alluv 4 (Au)
5603	Au	794400	7643260	50	Owens Gully Alluv (Au)
5604	Au	794405	7643658	50	Owens Gully Alluv 2 (Au)
5816	Au	773857	7580956	50	Corboy Alluv 1 (Au)
5817	Au	774137	7584156	50	Corboy Alluv 2 (Au)

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
5818	Au	775837	7573556	50	OpalineWell Alluv 1 (Au)
5819	Au	775137	7576056	50	OpalineWell Alluv 2 (Au)
5939	Au	785937	7656006	50	Marble Bar Alluv 1 (Au)
5940	Au	787187	7652656	50	Marble Bar Alluv 2 (Au)
6415	Au	714835	7617011	50	Miracle Alluv (Au)
6656	Au	208473	7685870	51	Bamboo Ck Alluv 1 (Au)
7008	Au	787187	7651416	50	Dawn Alluv 1 (Au)
7010	Au	787237	7650956	50	Dawn Alluv 2 (Au)
7012	Au	787137	7650776	50	Dawn Alluv 3 (Au)
7501	Au	786300	7657300	50	Marble Bar Alluv 3 (Au)
7504	Au	793637	7674160	50	Talga Talga Alluv 1 (Au)
7505	Au	794237	7674560	50	Talga Talga Alluv 2 (Au)
7631	Au	787140	7656360	50	True Find (Au)

PRECIOUS METAL

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
7738	Au	727835	7667240	50	Brass Buckle (Au)
7851	Au	207695	7686965	51	Bamboo Ck Alluv (Au)

Regolith - residual to eluvial placers

No*	COMMODITY	EAST	NORTH	Z	NAME
2917	Au	199935	7575951	51	Nullagine Eluv (Au)
3054	Au	770302	7639021	50	Glen Herring A Eluv (Au)
3055	Au	766000	7638292	50	Glen Herring B Eluv (Au)
4107	Au	714838	7617091	50	Soanesville Eluv (Au)
5458	Au	726695	7591490	50	Western Chief No 3 Eluv (Au)
7503	Au	793337	7674940	50	Talga Talga Eluv (Au)

STEEL INDUSTRY METAL

Disseminated and stockwork in plutonic intrusions

No*	COMMODITY	EAST	NORTH	Z	NAME
3272	Mo	727650	7665446	50	North Shaw (Mo)
7739	Mo	727640	7653090	50	Greisen (Mo)

Pegmatitic

No*	COMMODITY	EAST	NORTH	Z	NAME
4866	W	751057	7615601	50	Cooglegong Peg (W)
4976	W	235505	7605521	51	MC 395L (McLeod) (W)
4977	W	235455	7603201	51	Cookes Ck McLeods (W)
4978	W	761703	7613150	50	Burrows Well (W)
6297	W	235555	7603131	51	Cookes Ck Macleods Shear Zone (W)
6298	W	235585	7602891	51	Cookes Ck Macleods Shear Z S (W)
6392	W	232335	7607621	51	Cookes Ck 2 (W)
6395	W	234605	7604921	51	Cookes Ck 3 (W)
6396	W	235596	7602881	51	Cookes Ck McLeods S (W)
6397	W	237935	7602781	51	Cookes Ck Blue Bar (W)
6398	W	236165	7604361	51	Cookes Ck Mine (W)
6401	W	235175	7605061	51	Cookes Ck 4 (W)
6402	W	233705	7606321	51	Cookes Ck 5 (W)
6408	W	237435	7603231	51	Big Hill 1 (W)
6410	W	237935	7603441	51	Big Hill 3 (W)
6411	W	238575	7603761	51	Big Hill 4 (W)
6412	W	238235	7603081	51	Cookes Ck Blue Bar Northeast 1 (W)
6413	W	238375	7603261	51	Cookes Ck Blue Bar Northeast 2 (W)
6414	W	238535	7603211	51	Cookes Ck Blue Bar Northeast 3 (W)

Orthomagmatic mafic and ultramafic - layered mafic intrusions

No*	COMMODITY	EAST	NORTH	Z	NAME
2987	Cu Ni	724257	7622106	50	Pool Valley 1 (Cu Ni)
2990	Cu Ni	724287	7621206	50	Pool Valley 2 (Cu Ni)
2993	Cu Ni	713766	7627764	50	Camel Flat 3 (Cu Ni)
2999	Cu Ni Zn	729875	7618991	50	Soanesville Northeast (Zn Mn)
3008	Ni	713766	7627764	50	Soanesville CF 4 (Ni)
3247	Cu Ni PGE	724211	7621526	50	Soanesville (Ni Cu PGE)
6033	Cr	771681	7687843	50	Pear Creek 2 (Cr)
6246	Ni	229505	7602891	51	Cookes Ck Anomaly Hill (Ni)
6247	Ni	229195	7602921	51	Cookes Ck Anomaly Hill West 2 (Ni)
6248	Ni	229955	7603121	51	Cookes Ck Anomaly Hill West 1 (Ni)
6249	Ni	237365	7601061	51	Cookes Ck Middle East (Ni)
6250	Ni	239685	7602761	51	Cookes Ck Far East (Ni)
3251	Ni	725191	7663416	50	Strelley (Ni)
4097	Cr	712200	7636529	50	McAlister 1 (Cr)
4103	Cr	712157	7636338	50	McAlister 2 (Cr)
4232	Cr	208647	7676902	51	Nobb Well (Cr Ni)
4235	Ni	209737	7683056	51	Bamboo Prospect (Ni)
4981	Cr	771076	7688265	50	Pear Ck (Cr)
5925	Ni	703337	7640856	50	Abydos (Ni)
6016	Cr	717337	7614956	50	Pincunah Hill East (Cr)
7467	Cr	792309	7685058	50	Talga (Cr)
7480	Ni Cu	763637	7696406	50	Farrel Well (Cu Ni)
7736	Ni	720930	7660800	50	Strelley Gorge (Ni)
7915	Ni	238175	7601940	51	Cooke Ck (Ni)
3045	Cu Ni	791385	7640381	50	Fieldings Gully B 2 (Ni Cu Au?)
3094	Cu Ni	713167	7636227	50	Abydos Prospect B (Cu Ni)
4979	W	671431	7656813	50	Wodgina Scheelite (W)
5270	W	670181	7655455	50	West Wodgina (W)
5646	Ni	790997	7640456	50	Fieldings Gully B3 (Ni)

STEEL INDUSTRY METAL

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
5711	W	237205	7602911	51	Big Hill 2 (W)
5924	Ni	197900	7602300	51	Otways Prospect (Ni)
6294	W	237945	7602891	51	Cookes Ck Blue Bar Shaft (W)
6295	W	237955	7602741	51	Cookes Ck Blue Bar Glory Hole (W)
6296	W	236085	7604381	51	Cookes Ck Macleods Qtz Vein (W)
6417	W	231395	7608241	51	Cookes Ck 6 (W)
6418	W	233185	7606741	51	Cookes Ck 7 (W)
8486	Ni	793452	7673709	50	Talga Talga (Ni)

Regolith - residual and supergene

No*	COMMODITY	EAST	NORTH	Z	NAME
3503	Mn	264842	7651078	51	Ripon Hills (Mn)
4240	Mn	214192	7705629	51	Six Mile Well (Mn)
4626	Ni	731437	7575556	50	Garden Creek 1 (Ni)
4627	Ni	730587	7571956	50	Garden Creek 2 Ni
4683	Mn	311435	7632352	51	Mount Sydney (Mn)
4704	Mn	295636	7661602	51	Braeside 1 (Mn)
4705	Mn	317226	7607151	51	Woodie Woodie (Mn)
4707	Mn	297236	7581951	51	Skull Springs (Mn)
4709	Mn	316336	7595481	51	Mike (Mn)
4710	Mn	318316	7599401	51	Lox (Mn)
4711	Mn	317186	7602551	51	Green Snake 1 (Mn)
4712	Mn	316786	7602551	51	Green Snake 2 (Mn)
4713	Mn	317785	7604751	51	Chutney (Mn)
4714	Mn	316756	7603351	51	Bell (Mn)
4715	Mn	315735	7608931	51	Austen (Mn)
4716	Mn	315886	7609311	51	Cracker (Mn)
4717	Mn	316235	7613471	51	Radio Hill (Mn)
4718	Mn	313636	7613502	51	Whooowe (Mn)
4719	Mn	316736	7608701	51	Mac (Mn)
4720	Mn	296816	7619701	51	Pearana 1 (Mn)
4721	Mn	314816	7611551	51	Pearana 2 (Mn)
4722	Mn	314556	7610101	51	Pearana 3 (Mn)
4723	Mn	317566	7605921	51	Pearana 4 (Mn)
4724	Mn	319466	7600651	51	Pearana 5 (Mn)
4725	Mn	319556	7600101	51	Burnt (Mn)
4726	Mn	317236	7595401	51	Pearana 7 (Mn)
4727	Mn	317356	7586471	51	Pearana 8 (Mn)
4728	Mn	318266	7585951	51	Pearana 9 (Mn)
4729	Mn	318986	7585021	51	Max (Mn)
4730	Mn	317285	7577751	51	Pearana 11 (Mn)
4731	Mn	319236	7576511	51	Pearana 12 (Mn)
4732	Mn	321996	7571771	51	Pearana 13 (Mn)
4733	Mn	322236	7572001	51	Pearana 14 (Mn)
4734	Mn	299235	7595351	51	Depot Creek (Mn)
4735	Mn	296466	7581631	51	Skull Springs Southwest (Mn)
4736	Mn	295836	7581251	51	Davis Crossing (Mn)
4741	Mn	295756	7569501	51	Pearana 16 (Mn)
4742	Mn	297136	7568151	51	Pearana 17 (Mn)
4744	Mn	297736	7566951	51	Pearana 18 (Mn)
5219	Mn	265750	7654750	51	Ripon Hills A (Mn)
5220	Mn	265000	7654557	51	Ripon Hills B (Mn)
5221	Mn	265157	7653773	51	Ripon Hills C (Mn)
5222	Mn	266147	7654230	51	Ripon Hills D (Mn)
5223	Mn	266056	7653309	51	Ripon Hills E (Mn)
5224	Mn	265505	7651950	51	Ripon Hills F (Mn)
5225	Mn	264686	7652526	51	Ripon Hills G (Mn)
5226	Mn	267083	7650533	51	Ripon Hills I (Mn)
5227	Mn	266907	7651206	51	Ripon Hills J (Mn)
5228	Mn	261244	7652841	51	Ripon Hills K (Mn)
5231	Mn	276579	7644031	51	Ripon Hills Southeast (Mn)
5232	Mn	264428	7641578	51	Ripon Hills South (Mn)
6088	Mn	318635	7607861	51	Brumby (Mn)
6089	Mn	318835	7608961	51	Crystal Flats (Mn)
6090	Mn	318285	7577011	51	Pearana Rock Hole (Mn)
6092	Mn	311135	7583161	51	Pearana 10 (Mn)
6096	Mn	286635	7576161	51	Redmond (Mn)
6097	Mn	291235	7581311	51	Sunset Hill (Mn)

STEEL INDUSTRY METAL

Regolith - residual and supergene

No*	COMMODITY	EAST	NORTH	Z	NAME
6098	Mn	302135	7617161	51	Carawine (Mn)
6099	Mn	293135	7587361	51	Snake Hill (Mn)
6100	Mn	299635	7600161	51	Boondamana (Mn)
6108	Mn	299135	7576361	51	Stockyard Ck (Mn)
7192	Mn	291635	7583161	51	Skull Springs West (Mn)
7196	Mn	284935	7575761	51	Donkey (Mn)
7526	Mn	297285	7582510	51	Skull Springs North (Mn)
7527	Mn	297885	7581860	51	Piglet (Mn)
7907	Mn	318300	7604600	51	Extension Cord (Mn)
7908	Mn	316500	7610150	51	Big Mack (Mn)
7910	Mn	316500	7609040	51	Deity (Mn)
7916	Mn	318210	7599660	51	Hanna (Mn)
8003	Mn	292500	7670500	51	Koongalin Creek (Mn)
8478	Mn	812435	7737056	50	Nimingarra (Mn)
8708	Mn	763000	7697400	50	Pear Creek (Mn)

SPECIALITY METAL

Disseminated and stockwork in plutonic intrusions

No*	COMMODITY	EAST	NORTH	Z	NAME
5540	W	237761	7603154	51	Cookes Ck EL46/5 (W)

Pegmatitic

No*	COMMODITY	EAST	NORTH	Z	NAME
2858	Ta	675315	7655845	50	Wodgina Gwalia (Sn Ta Li)
2861	Ta Sn	673990	7657000	50	Wodgina Main Lode (Sn Ta Li Brl)
2863	Ta	670769	7657125	50	Wodgina West (Ta)
2887	Ta Brl Sn	698796	7713100	50	Tabba Tabba (Ta Brl Sn)
3038	Li Sn	698237	7671256	50	Pilgangoora 2 (Li)
3083	Nb Ta	677878	7674068	50	Cinnamon Ck Peg (Ta Nb)
3100	Ta Brl	709722	7728105	50	Strelley Mine (Ta Brl Sn)
4806	Sn	673734	7656345	50	Mt Cassiterite Main Lode (Sn Ta)
4807	Sn	673784	7656411	50	Mt Cassiterite North (Sn)
4808	Sn	673767	7655825	50	Mt Cassiterite South (Sn)
4809	Sn	674119	7655666	50	Tinstone Mine (Sn Ta)
4810	Sn	674292	7656428	50	Wodgina Star (Sn)
4811	Sn	673785	7655503	50	Commonwealth (Sn)
4813	Sn	674248	7656074	50	Mt Cassiterite YZ (Sn)
4814	Ta	673717	7655039	50	Mt Cassiterite Terra Nova (Ta)
4815	Sn	673701	7654530	50	Mt Cassiterite Chamberlain (Sn)
4816	Ta	673906	7656288	50	Mt Cassiterite East (Ta)
4819	Sn	674094	7656419	50	Mt Cassiterite Hazlewood (Sn)
4821	Ta	674006	7656907	50	Anchorite (Ta)
4823	Ta Brl	673837	7659050	50	Rock Hole Lode (Ta Brl)
4824	Ta	674050	7658760	50	Rock Hole Lode (Sn Ta)
4825	Sn	670906	7658324	50	West Wodgina 2 (Sn)
4826	Sn	671137	7658026	50	West Wodgina 1 (Sn)
4827	Sn	670817	7657196	50	Wodgina Prince (Sn)
4828	Sn Ta	671037	7657836	50	West Wodgina 4 (Sn Ta Li)
4829	Sn	670517	7656136	50	Referenda (Sn)
4845	Sn	799719	7659299	50	Moolyella Creek (Sn)
4848	Sn	801765	7659749	50	Moolyella 2 (Sn)
4849	Sn	800784	7659545	50	Moolyella 3 (Sn)
4850	Sn	801701	7656282	50	Moolyella 4 (Sn)
4854	Sn	752145	7618874	50	Stutzs PA (Sn)
4865	Sn Ta	751664	7607338	50	Cooglegong Peg (Sn Ta)
4878	Sn	740118	7611015	50	Tambina Ck (Sn)
4879	Sn W	770656	7615517	50	Twin Rocks (Sn W)
4883	Li Sn	669665	7649875	50	Stannum (Sn Li)
4884	Sn Li	669440	7650166	50	Stannum North (Sn Li)
4885	Sn Li	670631	7651936	50	Comet (Sn Li)
4888	Sn Ta	668490	7650640	50	Stannum West (Sn Ta)
4891	Brl	668680	7650993	50	Stannum West (Brl)
4895	Sn	667545	7647550	50	Siffleetes Reward (Sn)
4897	Sn	667484	7647739	50	Siffleetes Reward North (Sn)
4899	Brl	667146	7647045	50	Mills Find (Brl)
4900	Sn	663625	7639540	50	Bright Star (Sn)
4905	Sn	661050	7636122	50	Francisco (Sn)
4908	Brl Ta	661125	7636432	50	Francisco (Ta Brl)

SPECIALITY METAL

Pegmatitic

No*	COMMODITY	EAST	NORTH	Z	NAME
4909	Brl	660887	7636501	50	Francisco 1 (Brl)
4910	Brl	660819	7635881	50	Francisco 2 (Brl)
4913	Brl Ta Nb	669318	7639405	50	Numbana (Brl Ta Nb Li)
4939	Ta Sn Brl Nb	700349	7713745	50	Tabba Tabba Main or Simpsonite (Ta)
4941	Sn	700274	7713480	50	Tabba Tabba Crawfords (Sn)
4944	Ta Sn	700206	7713913	50	Tabba Tabba North Workings (Ta)
4948	Ta Brl Sn	700462	7713622	50	Tabba Tabba South Workings (Ta)
4949	Ta	699541	7714995	50	Crawfords (Ta)
4950	Ta Sn	700584	7714174	50	Crawfords (Ellis) (Ta)
5269	Sn	670907	7658006	50	Wodgina Queen (Sn)
5275	Sn	659165	7636488	50	Edie Emma (Sn)
6003	Cu Ta	717937	7603856	50	Mundine Well North (Cu Ta)
6004	Ta	717537	7603056	50	Mundine Well North (Ta)
6005	Li	725837	7596356	50	Tambourah North 1 (Li)
6006	Li	726137	7599756	50	Tambourah North 2 (Li)
6045	Ta	717838	7693856	50	Turkey Camp Well (Ta)
6047	Brl Ta	720737	7704156	50	Biscay Well (Brl Ta)
6050	Ta	699738	7685056	50	Trig Hill Well (Ta)
6051	Brl	700988	7683856	50	Trig Hill Well Southeast (Brl)
6055	Ta Brl Fsp	683438	7724056	50	Pippingarra West (Ta Brl)
6056	Ta Brl	684538	7724256	50	Pippingarra East (Ta Brl)
6270	Ta	696907	7668576	50	Coffin Bore Northeast 1 (Ta)
6271	Ta	696137	7669456	50	Coffin Bore North (Ta)
6272	Ta	697337	7668506	50	Coffin Bore Northeast 2 (Ta)
6273	Ta Sn	698037	7671156	50	Pilgangoora 4 (Ta Sn)
6274	Sn	698357	7672176	50	Pilgangoora 5 (Ta Sn)
6275	Sn Ta	698337	7672026	50	Pilgangoora 6 (Ta Sn)
6322	Sn	670987	7657626	50	West Wodgina 4 (Sn)
7382	Ta W Mo Nb	800737	7659006	50	Pegmatite Gully (Sn Ta)
7416	Nb	801137	7658199	50	Roadside (Sn Ta)
7424	Nb Sn Ta	801717	7659950	50	Sth Ceremonial Dam (Sn Ta)
7445	Li Ta Sn	698057	7671626	50	Pilgangoora 3 (Li)
7446	Li Ta Sn	698937	7674316	50	Pilgangoora 1 (Li)
7448	Li Ta Sn	697877	7670056	50	Pilgangoora 5 (Li)
7449	Ta Li Sn	697977	7670756	50	Pilgangoora 4 (Li)
7450	Li Ta Sn	697977	7669356	50	Pilgangoora 6 (Li)
7451	Li Ta Sn	698077	7669036	50	Pilgangoora 7 (Li)
8005	Sn Ta Li	676400	7718700	50	Bore Ck (Sn Ta Li)
8006	Sn	659500	7669420	50	Kangan North (Sn)
8007	Sn Ta	657370	7667570	50	Kangan (Sn Ta)
8008	Sn	661760	7635400	50	Mt Francisco (Sn)
8172	Sn	804870	7656000	50	Moolyella Lode (Sn)

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
2830	Ta	673927	7656213	50	Mount Cassiterite (Sn)
2940	Sn	697745	7640690	50	Yandee (Sn)
4985	Hg	203105	7597131	51	Lionel Prospect 2 (Hg)

Stratabound volcanic and sedimentary - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
4984	Hg	202965	7597481	51	Lionel Prospect 3 (Hg)

Regolith - alluvial to beach placers

No*	COMMODITY	EAST	NORTH	Z	NAME
2783	Ta Sn	763831	7607642	50	Breens (Ta Sn Li)
2785	Sn Ta	757106	7608182	50	Combos Alluv (Sn)
2788	Sn Ta	744045	7615862	50	Cooglegong Alluv (Ta Sn Li)
2789	Sn Ta Li	757880	7611000	50	Cooglegong Ck Alluv (Sn Ta Li)
2790	Sn	765126	7607015	50	Coomba Ck Alluv (Sn)
2791	Sn Ta Li	746590	7577204	50	Coondina Alluv (Sn Ta Li)
2800	Sn Ta Li	758649	7603664	50	Eleys Ck (Sn)
2801	Sn Ta Li	749986	7603309	50	Five Mile Ck 2 (Sn Ta Li)
2804	Sn Ta Li	763933	7618287	50	Hartigans Alluv (Sn Ta Li)
2806	Sn Li Ta	752741	7597449	50	Hillside Alluv (Sn)
2820	Sn Ta Li	699787	7675245	50	Lynas Find Alluv (Sn)
2829	Sn Ta	803520	7656253	50	Moolyella Alluv (Sn Ta)
2832	Sn Ta	745992	7619844	50	Mulgandinnah Alluv (Sn Ta)
2837	Sn Ta Li	695287	7671032	50	Pilgangoora 1 Alluv (Sn)
2842	Sn Ta	700000	7591550	50	Coonarie Ck Alluv (Sn Ta)
2844	Ta	745136	7607877	50	Shaw R Alluv (Sn Ta)

SPECIALITY METAL

Regolith - alluvial to beach placers

No*	COMMODITY	EAST	NORTH	Z	NAME
2846	Sn Ta	750137	7621456	50	Spear Hill Alluv (Sn)
2851	Sn Ta	676366	7661961	50	Tin Ck Alluv (Sn Ta)
2852	Sn Ta	737184	7609440	50	Trigg Hill Alluv 1 (Sn Ta)
2860	Ta	674540	7659021	50	Wodgina Alluv (Sn Ta Li)
2901	Sn	756840	7601296	50	Shaw River Alluv (Sn Ta)
3009	Sn	765141	7608646	50	Wood Ck Alluv (Sn)
3012	Sn	758841	7604546	50	Eleys Ck Alluv (Sn)
3013	Sn	756337	7608856	50	Combos Ck Alluv (Sn)
3014	Sn Ta	747140	7601546	50	Five Mile Ck Alluv (Sn)
3015	Sn	749937	7603206	50	Bonana Ck Alluv (Sn)
3016	Sn	748840	7618146	50	Cooglegong Ck Alluv (Sn)
3023	Sn	751506	7597172	50	Old Shaw Ck (Sn)
3024	Sn	745272	7615304	50	Banana Ck A (Sn)
3026	Sn	757802	7599276	50	Long Tin Ck (Sn)
3030	Sn	751960	7612863	50	Lower Cooglegong Ck (Sn)
3099	Sn	746023	7630674	50	Shaw River Tin North Alluv (Sn)
4833	Sn	798224	7659924	50	Macdonalds Lead Alluv (Sn)
4835	Sn	798399	7661062	50	Huntsmans Alluv (Sn)
4836	Sn	799740	7663886	50	Moolyella Ck Alluv 1 (Sn)
4837	Sn	799463	7657231	50	Mud Springs Alluv (Sn)
4839	Sn	801921	7654671	50	Prospectors Ck Alluv 1 (Sn)
4840	Sn	805536	7660135	50	6 Mile Ck Alluv (Sn)
4841	Sn	797115	7661318	50	Brockmans Ck Alluv (Sn)
4843	Sn	799426	7663183	50	Moolyella Ck Alluv 2 (Sn)
4844	Sn	799503	7662849	50	Moolyella Ck Alluv 3 (Sn)
4852	Sn Ta	808718	7658501	50	Eight Mile Ck Alluv (Sn Ta)
4853	Sn	795971	7663644	50	DC 666 Alluv (Sn)
4867	Sn	749984	7615872	50	Cooglegong Ck Alluv (Sn)
4868	Sn	744035	7616573	50	Banana Ck Alluv (Sn)
4869	Sn	743436	7616039	50	Shaw Patch Ck Alluv (Sn)
4870	Sn	747312	7625518	50	Cooglegong Ck North Alluv (Sn)
4871	Sn	755810	7600316	50	Black Range Ck Alluv (Sn)
4874	Sn	738966	7602536	50	Tambourah Ck Alluv 1 (Sn)
4875	Sn	738913	7603135	50	Tambourah Ck Alluv 2 (Sn)
4876	Sn	737502	7600830	50	Tambourah Ck Alluv 3 (Sn)
4880	Sn	769686	7615810	50	Split Rock 1 Alluv (Sn)
4881	Sn	769418	7614629	50	Split Rock 2 Alluv (Sn)
4886	Sn	666240	7649933	50	Stannum W Alluv (Sn)
4887	Sn Ta	667437	7650208	50	Stannum Alluv (Sn Ta)
4892	Sn	667993	7650790	50	Stannum Alluv (Sn)
4902	Sn	662949	7637333	50	Mt Francisco Alluv (Sn)
4911	Ta Sn	660787	7636867	50	Francisco Alluv 1 (Sn Ta)
4912	Sn Ta	660227	7635787	50	Francisco Alluv 2 (Sn Ta)
4925	Sn	749619	7578642	50	Coondina DC285 Alluv (Sn)
4926	Sn	747966	7578091	50	Coondina DC281 Alluv (Sn)
4927	Sn	747334	7578013	50	Coondina DC282 Alluv (Sn)
4928	Sn	746407	7577540	50	Johnstons North (Sn)
4929	Sn	746485	7576575	50	Johnstons South (Sn)
4934	Sn	744619	7574919	50	Duffer Well Southwest 1 (Sn)
4935	Sn	745030	7578779	50	Duffer Well Southwest 2 (Sn)
4972	Ta Nb Sn Brl	698136	7669401	50	Pilgangoora Alluv 4 (Ta Sn)
4973	Ta Sn Nb	698863	7670256	50	Pilgangoora Alluv 3 (Ta Sn)
4974	Ta Nb Sn	698631	7671687	50	Pilgangoora Alluv 2 (Ta Sn)
4975	Ta Nb Sn	698565	7672264	50	Pilgangoora Alluv 1 (Ta Sn)
6064	Sn	804787	7675806	50	Garden Ck 1 Alluv (Sn)
6065	Sn	805288	7676256	50	Garden Ck 2 Alluv (Sn)
6109	Ta	751137	7619156	50	Spear Hill South Alluv (Sn Ta)
6172	Sn	753337	7619556	50	Spear Hill Alluv Flats (Sn)
6175	Sn	763437	7623156	50	Coolyia Ck Alluv (Sn)
6178	Sn	763436	7617856	50	Strawberry Ck Alluv (Sn)
6323	Ta Sn	671187	7658576	50	W Wodgina Alluv 1 (Sn)
6325	Sn Ta	671037	7658206	50	W Wodgina Alluv 2 (Sn)
6328	Sn Ta	670697	7657626	50	W Wodgina Alluv 3 (Sn)
6329	Ta Sn	670817	7657096	50	W Wodgina Eluv/Alluv (Sn)
6330	Sn Ta	670387	7655916	50	W Wodgina Alluv 4 (Sn)
6331	Ta	669237	7654516	50	W Wodgina Alluv 5 (Sn)
6332	Sn Ta	669437	7653506	50	W Wodgina Alluv 6 (Sn)

SPECIALITY METAL

Regolith - alluvial to beach placers

No*	COMMODITY	EAST	NORTH	Z	NAME
6334	Sn Ta	668337	7652656	50	W Wodgina Alluv 7 (Sn)
6335	Ta Nb	686037	7657806	50	E Wodgina Pinnacles Hill Alluv (Ta Nb)
6361	Sn	760737	7619856	50	Marshall Ck Alluv (Sn)
7372	Sn	799837	7658856	50	Moolyella Alluv 1 (Sn)
7373	Sn	799287	7658306	50	Moolyella Alluv 2 (Sn)
7374	Sn	798137	7659756	50	Moolyella Alluv 3 (Sn)
7375	Sn	797600	7661906	50	Moolyella Alluv 4 (Sn)
7376	Sn	800137	7663256	50	Moolyella Alluv 5 (Sn)
7377	Sn	801087	7661385	50	Moolyella Alluv 6 (Sn)
7378	Sn	800587	7656906	50	Prospectors Ck Alluv 2 (Sn)
7379	Sn	800287	7662930	50	Dead Donkey Lead (Sn)
7380	Sn	802237	7662287	50	Five Mile Ck (Sn)
7442	Ta	700012	7684856	50	Trig Well Alluv 2 (Sn Ta)
7455	Ta	763007	7695436	50	Crawford Bore (Ta)
7895	Sn	711740	7696000	50	Crawford Bore Alluv (Sn)
8138	Sn	685840	7621700	50	Pinga Ck Alluv 2 (Sn)
8139	Sn	683940	7638400	50	Turner R Alluv 1 (Sn)
8140	Sn	684040	7647460	50	Turner R Alluv 2 (Sn)
8141	Sn Ta Nb	681100	7644400	50	Stannum Alluv (Sn Ta Nb)
8142	Sn	685920	7621210	50	Pinga Ck Alluv 1 (Sn)
8143	Sn	686290	7619900	50	Pinga Ck Alluv South 1 (Sn)
8145	Sn	686440	7619260	50	Pinga Ck Alluv 3 (Sn)
8146	Sn Ta	688200	7619710	50	Pinga Ck Alluv (Sn Ta)

Regolith - residual to eluvial placers

No*	COMMODITY	EAST	NORTH	Z	NAME
2900	Sn	743740	7615446	50	Shaw River Eluv (Sn Ta)
3007	Sn	755837	7600256	50	Old Shaw Alluv/Eluv (Sn)
4855	Sn	747369	7623113	50	Cooglegong 1 Eluv (Sn)
4856	Sn	750991	7619978	50	Cooglegong 2 Eluv (Sn)
4857	Sn	752103	7619506	50	Cooglegong 3 Eluv (Sn)
4858	Sn	747026	7617668	50	Cooglegong 4 Eluv (Sn)
4859	Sn	751071	7617816	50	Cooglegong 5 Eluv (Sn)
4860	Sn	752873	7617046	50	Cooglegong 6 Eluv (Sn)
4861	Sn	744895	7615153	50	Cooglegong 7 Eluv (Sn)
4862	Sn	745453	7615089	50	Cooglegong 8 Eluv (Sn)
4863	Sn	745580	7613891	50	Cooglegong 9 Eluv (Sn)
4877	Sn	736916	7609589	50	Trig Hill Eluv (Sn)

BASE METAL

Disseminated and stockwork in plutonic intrusions

No*	COMMODITY	EAST	NORTH	Z	NAME
2896	Cu Pb Zn	808217	7601926	50	Copper Hills (Cu)
2953	Cu	797087	7587736	50	Kellys (Cu)
4155	Cu Mo	199514	7687599	51	Coppin Gap (Cu Mo)
4962	Cu Mo	220765	7615481	51	Gobbos 1 (Cu Mo)
4963	Cu	219685	7614761	51	Gobbos 2 (Cu Mo)
5920	Cu Mo	217087	7605236	51	Reedies Prosp 1 (Cu Mo)
5921	Cu Mo	217087	7605906	51	Reedies Prosp 2 (Cu Mo)
5922	Cu Mo	216807	7606286	51	Reedies Prosp 3 (Cu Mo)
5923	Cu Mo	220587	7616006	51	Gobbos Prosp (Cu Mo)
5932	Cu	215755	7618541	51	Lightning Ridge Southwest (Cu)
5933	Cu Mo	219085	7620211	51	Lightning Ridge (Cu Mo)

Pegmatitic

No*	COMMODITY	EAST	NORTH	Z	NAME
6054	Cu	676138	7714956	50	Malinda Well Southwest (Cu)

Orthomagmatic mafic and ultramafic - komatiitic or dunitic

No*	COMMODITY	EAST	NORTH	Z	NAME
3374	Zn	716608	7613329	50	Dead Bullock Well (Cu Zn Ni)
6017	Cu	718920	7623800	50	Soanesville 1 (Cu)
6018	Cu	726530	7623806	50	Soanesville 2 (Cu)
3264	Cu	734780	7623146	50	North Shaw 14 (Cu)
3265	Cu	734470	7623466	50	North Shaw 13 (Cu)
3266	Cu	734521	7623836	50	North Shaw 3 (Cu)
3273	Cu	714431	7637466	50	North Shaw 6 (Cu)
3274	Cu	713561	7636796	50	North Shaw 7 (Cu)
3275	Cu	713370	7636266	50	North Shaw 8 (Cu)
3276	Cu	712891	7622146	50	North Shaw 9 (Cu)
5913	Cu Ni	229635	7608156	51	Copper Gorge East (Cu Ni)

BASE METAL

Orthomagmatic mafic and ultramafic - komatiitic or dunitic

No*	COMMODITY	EAST	NORTH	Z	NAME
6015	Zn	716637	7612306	50	Dead Bullock Well (Zn)

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
2934	Cu	711176	7639210	50	Sudden Jerk (Cu)
2950	Pb	744440	7664928	50	Miralga (Pb)
2951	Zn	762735	7661299	50	Miralga (Pb Zn)
2954	Cu	794700	7586000	50	Budjan (Cu)
2959	Cu	792987	7646026	50	Salgash 1 (Cu)
2992	Cu	746767	7638406	50	North Shaw 1 (Cu)
2995	Cu	752157	7641506	50	North Shaw 2 (Cu)
3044	Au Cu	789921	7640773	50	Fieldings Gully (Cu Pb Au)
3047	Cu Ni	791935	7640221	50	Fieldings Gully C 2 (Ni Cu)
3048	Cu	793105	7639891	50	Fieldings Gully East (Cu)
3074	Au Ag Cu	806137	7598726	50	Copper Hills South (Cu)
3093	Cu	794737	7585206	50	Ryans Prospect (Cu)
3098	Cu	798154	7587563	50	Kellys East (Cu)
3143	Cu	797717	7586413	50	Kellys South (Cu)
3157	Cu Ag	745541	7664790	50	Breens 2 (Cu)
3160	Cu Ag	745828	7664790	50	Breens 1 (Cu)
3163	Cu	745808	7664651	50	Breens 3 (Cu)
3232	Cu	657623	7661808	50	Basset (Cu)
3246	Cu Pb Sn	715290	7629176	50	Cardinal (Cu Sn Pb)
3248	Zn Sn Cu	729490	7654626	50	Wheal of Fortune (Zn Cu Sn)
3269	Cu	746421	7635496	50	North Shaw 4 (Cu)
3271	Cu	753741	7664866	50	North Shaw 5 (Cu)
3279	Cu	707860	7639596	50	North Shaw 10 (Cu)
3280	Cu	719091	7623946	50	North Shaw 11 (Cu)
3282	Cu	707640	7638566	50	North Shaw 12 (Cu)
3297	Pb	758390	7664796	50	Miralga Ck (Ba Pb)
3965	Cu	810067	7603639	50	Vuggy Hill (Cu)
3966	Cu Zn	807679	7597462	50	Zinc Hill (Cu Zn)
4072	Cu	721628	7660696	50	Strelley (Cu)
4159	Mo	200452	7685854	51	Coppin Gap (Pb)
4175	Pb Cu	234192	7684697	51	17 Mile Well (Cu Pb)
4180	Pb	224077	7683857	51	Lance Bore (Pb)
4204	Cu Au	720494	7659706	50	Strelley Pool (Cu Au)
4213	Cu	207117	7703646	51	Friendly Stranger (Cu)
4214	Cu	233140	7711160	51	Du Valles (Cu)
4219	Cu	193624	7692490	51	Kittys Well 1 (Cu)
4221	Cu	192893	7692044	51	Kittys Well 2 (Cu)
4222	Cu	237340	7704650	51	Post Office Well (Cu)
4223	Cu Mo	236671	7687894	51	17 Mile Well (Mo Cu)
4225	Cu	236000	7683750	51	17 Mile Well 1 (Cu)
4228	Pb Cu	237340	7677860	51	17 Mile Well 2 (Cu)
4603	Cu	806387	7599706	50	Emu Ck 3 (Cu)
4619	Pb	783644	7657843	50	Miralga (Pb)
4633	Cu	807437	7602356	50	Copper Hills West 1 (Cu)
4637	Zn Ag Pb Cu	806937	7600156	50	Emu Creek 4 (Cu Pb)
4639	Pb Ag Fl	236350	7604450	51	Cookes Ck (Pb)
4640	Zn Cu Pb Ag Au Cd	209535	7601011	51	Quartz Circle (Zn Cu Pb Ag Au)
4642	Pb Ag	782877	7694055	50	Coongan Siding 1 (Pb Ag)
4646	Cu Zn	803453	7679844	50	Murphy Well (Zn Cu Pb Ag)
4647	Zn Cu Au Ag	207667	7704974	51	Yarrie South 1 (Cu)
4648	Cu Au Pb Zn	764687	7659296	50	Miralga Ck C (Au Pb Zn Ag)
4650	Pb	752034	7607765	50	Hillside (Pb)
4651	Pb Zn Ag	792886	7582925	50	Sandy Ck (Pb Zn)
4652	Zn Cu Pb Ag Brt	698562	7610362	50	Abydos (Zn Cu)
4653	Pb	724579	7619700	50	Soanesville (Pb)
4654	Pb	700081	7678696	50	Lynas Find (Pb Fl Ag?)
4655	Pb Ag Au	694598	7713760	50	Tabba Tabba (Pb)
4658	Pb Ag	655610	7631129	50	Wodgina (Pb Zn)
4660	Pb Zn Ag	297475	7675122	51	Barker Well (Pb)
4661	Cu Pb	296836	7684352	51	Camel Hump South (Cu)
4663	Pb	307797	7644222	51	Ragged Hills (Pb)
4670	Ag Pb Cu Zn	307147	7646486	51	Ragged Hills East (NW) (Pb Ag Zn)
4671	Pb Zn Ag	302350	7653563	51	Devons Cut (Pb Zn Ag)
4672	Pb Ag	299637	7658874	51	Mt Brockman North (Pb)

BASE METAL

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
4673	Pb Ag Zn	300147	7663051	51	Lightning R Moxom Well (Pb Zn Ag V)
4674	Pb Ag	302217	7665235	51	Koongalin Hill (Pb)
4679	Cu	295836	7685052	51	Camel Hump (Cu)
4681	Pb Ag	301734	7666882	51	North Koongallin Hill (Pb Ag)
4682	Pb Ag	297868	7670928	51	Gossan Hill (Pb)
4690	Zn Cu	320146	7660052	51	Warroo (Zn Cu)
4691	Cu Zn	317286	7664952	51	Warroo North (Cu Zn)
4695	Zn Pb Ag	339236	7633752	51	Grevillea (Zn Pb Ag)
4697	Pb	300135	7672712	51	Braeside 1 (Pb)
4698	Pb	300691	7664607	51	Braeside 2 (Pb)
4699	Ag Pb	302160	7657931	51	Braeside 3 (Pb)
4700	Ag Pb	300270	7657656	51	Braeside 4 (Pb)
4701	Cu Pb	307339	7645156	51	Ragged Hills Northwest (Pb Cu)
4702	Pb Ag	307770	7645579	51	Ragged Hills East (Southeast) (Pb Ag)
4751	Pb	329036	7587971	51	Pearana 1 (Pb)
4752	Pb	329986	7591621	51	Pearana 2 (Pb)
4755	Cu	330835	7600551	51	Pearana (Cu)
4765	Cu	201334	7601836	51	Lionel 1 (Cu)
4767	Cu	216535	7612501	51	Otways West (Cu)
4768	Cu	217156	7612548	51	Otways East (Cu)
4796	Cu	288109	7690420	51	Barramine 1 (Cu)
4797	Cu Ag	288880	7689478	51	Barramine 2 (Cu)
4851	Pb Zn Ag	239335	7569861	51	Coondoon Ck (Zn Pb)
4889	Cu	669975	7651766	50	Comet 1 (Cu)
4890	Cu	670231	7651409	50	Comet 2 (Cu)
4893	Cu	667486	7649909	50	Stannum West (Cu)
4982	Cu	214301	7614196	51	Otways Northwest (Cu)
5009	Ag Cu Au	788172	7649333	50	Marble Bar South (Cu Au)
5010	Cu	707855	7639781	50	Abydos Northeast (Cu)
5014	Cu	779546	7619938	50	Marble Bar 1 (Cu)
5015	Cu	667323	7650090	50	Stannum (Cu)
5016	Cu	666764	7651325	50	Stannum Northeast (Cu)
5018	Cu	233134	7705397	51	Callawa (Cu)
5020	Cu Au Zn Ag	206550	7703902	51	Yarrie South 2 (Cu)
5021	Cu	201363	7601393	51	Lionel South 1 (Cu)
5022	Cu	809270	7605537	50	Emu Ck East (Cu)
5023	Cu	805139	7600640	50	Boobina Ck (Cu)
5024	Cu	790330	7640984	50	Copenhagen West (Cu)
5025	Cu	788085	7644403	50	Copenhagen West 2 (Cu)
5026	Cu	770829	7630239	50	Sharks Gully 1 (Cu)
5027	Cu	746461	7638491	50	Roy Hill - North Shaw (Cu)
5028	Cu	729003	7668107	50	Wilson Mine (Cu)
5029	Cu	707984	7605326	50	Woodstock Stn (Cu)
5031	Cu	676085	7715192	50	Boodarrie Stn (Cu)
5034	Cu	661411	7634770	50	Mt Francisco (Cu)
5050	Cu	807831	7605619	50	Copper Hills North (Cu)
5055	Cu	800489	7588137	50	Copper Hills 10m South (Cu)
5082	Cu Zn Pb	208321	7629691	51	Lady Adelaide East (Cu)
5142	Pb Zn Ag	307512	7646074	51	Ragged Hills East (East) (Pb Ag)
5157	Pb	297247	7674484	51	Barkers Well South (Pb)
5158	Pb	294518	7671216	51	Koongalin Ck (Pb)
5160	Pb Cu	300047	7666155	51	North Koongalin West (Pb)
5218	Pb Ag	783937	7686956	50	Coongan Siding 2 (Pb Ag)
5283	Cu Ag	219885	7617322	51	Wallabirdee Ridge 1 (Cu)
5284	Cu Au Ag	219455	7618161	51	Wallabirdee Ridge 2 (Cu)
5423	Au	746976	7639917	50	North Shaw North (Cu)
5607	Ni Cu	792138	7640150	50	Fieldings Gully D (Ni Cu)
5723	Cu	789877	7640726	50	Mt Lyall South (Cu Au)
5801	Cu	777823	7683781	50	Gorge Range (Cu)
5812	Pb Brt	755170	7666992	50	North Pole (Ba Pb)
5832	Cu Pb	237815	7572511	51	Coondoon Ck (Pb Cu)
5877	Cu	719400	7623906	50	Soanesville (Cu)
5906	Cu	792957	7646896	50	Salgash 2 (Cu)
5934	Cu Mo Zn Ag	219855	7617761	51	Berrys Qtz Vein (Cu Ag)
5937	Cu	761487	7656076	50	Shady Camp Well (Cu)
5947	Cu	808017	7602926	50	W Copper Hills (Cu)
5948	Cu	806737	7601711	50	Copper Hills West 2 (Cu)

BASE METAL

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
5949	Cu	199135	7602461	51	Hendersons (Cu)
5988	Cu	805435	7600861	50	Copper Hills West 3 (Cu)
5995	Cu	775037	7599856	50	Coongan (Cu)
5996	Cu	767437	7637856	50	Glen Herring (Cu)
6115	Cu	297247	7673676	51	Barkers Well South (Cu)
6117	Cu	297056	7668945	51	Gossan Hill South (Pb)
6118	Cu Zn	306335	7647661	51	Ragged Hills 2 (Cu Zn)
6120	Cu Pb Zn	308235	7646461	51	Ragged Hills 3 (Pb Cu)
6122	Pb Cu	308235	7646461	51	Ragged Hills 4 (Pb Cu)
6123	Zn	308505	7645431	51	Ragged Hills 5 (Zn)
6124	Pb Ag	308485	7646021	51	Ragged Hills East(?) (Pb)
6180	Cu Ag	226734	7607961	51	Richmans Hill (Cu Ag)
6234	Zn Ag Cd	209585	7600835	51	Quartz Circle (Zn Ag Cd)
6251	Zn	214985	7598991	51	Cookes Ck Far West (Zn)
6263	Cu Ag	696437	7668406	50	Coffin Bore (Cu Pb Zn)
6416	Cu	221335	7616461	51	North Stock (Cu)
6637	Cu	200685	7602591	51	Hendersons East (Cu)
6638	Cu	200035	7601261	51	Hendersons South (Cu)
6806	Cu Au Ag	216935	7617262	51	Bridget E45/656 1 (Cu Ag Au)
6807	Cu	221035	7614167	51	Bridget E45/656 2 (Cu Ag Au)
6809	Cu	221935	7608056	51	Bridget E45/656 3 (Cu Ag Au)
6976	Cu Zn Ag Pb	805587	7600286	50	Boobina Ck East (Cu)
6977	Cu	806587	7599426	50	Emu Creek 4 (Cu)
6978	Cu	806567	7599206	50	Emu Creek 5 (Cu)
6979	Cu	805937	7602116	50	Copper Hills West 4 (Cu)
6980	Cu	805177	7599756	50	Boobina Ck South (Cu)
6981	Cu	810687	7605576	51	Copper Hills Northwest (Cu)
7033	Au Ag Zn	764686	7659756	50	Miralga Ck B (Au Zn Pb Ag)
7034	Au Ag Cu Pb Zn	765297	7658956	50	Miralga Ck A (Au Pb Zn Ag)
7035	Au Pb Ag Zn	765037	7658656	50	Miralga Ck D (Au Pb Zn Ag)
7036	Au Pb Zn Ag	765337	7657556	50	Miralga Ck E (Au Pb Zn Ag)
7037	Au Ag Pb Zn	765537	7656856	50	Miralga Ck F (Au Pb Zn Ag)
7338	Cu	216895	7612651	51	Otways Northeast (Cu)
7443	Cu	197465	7687311	51	Kitty Gap (Cu)
7456	Cu Ni	766090	7756156	50	Highway (Ni Cu)
7457	Cu Pb	204207	7696406	51	Bamboo Ck (Cu Pb)
7469	Cu Pb	764237	7700741	50	Farrel Well (Cu Pb)
7735	Au Cu	720630	7660160	50	Price of Love (Cu Au)
7737	Cu Au	718630	7654100	50	Honeyeater (Cu Au)

Stratabound volcanic and sedimentary - sedimentary-hosted sulfide

No*	COMMODITY	EAST	NORTH	Z	NAME
2944	Cu Pb Zn	714890	7629046	50	Soanesville CF4 (Zn Cu Pb)
2956	Cu Au	729467	7591516	50	Tambourah (Cu Au)
4551	Cu Au Zn	733417	7644786	50	Leilira Ck (Cu Zn Au)
4614	Cu Pb Zn Ag	259055	7572081	51	Coondamar Ck Mogul (Zn Cu Pb)
5828	Cu Pb Zn	258815	7572861	51	Coondamar Ck CEC (Cu Pb Zn)
5829	Cu	258035	7573611	51	Coondamar Ck Grit (Cu)
5830	Cu Pb Zn Ag Au	256745	7576761	51	Coondamar Horse Ck (Cu Pb Zn Ag)
6303	Zn	753407	7665846	50	North Pole E2-2 (Zn)
7460	Zn	779036	7762777	50	Supply Well (Zn)
2928	Cu	701767	7669726	50	Hazelby (Cu)
4983	Cu	223265	7617981	51	Bridget Northeast 4 (Cu)
5096	Cu	786133	7653989	50	Marble Bar (Cu)
6223	Cu Zn Ag Au	223295	7617541	51	Bridget Northeast 1 (Cu)
6224	Cu	219685	7616021	51	Bridget Northeast 2 (Cu)
6225	Cu	220685	7616291	51	Bridget Northeast 3 (Cu)
6229	Zn Cu	223715	7617691	51	Bridget Northeast 1 (Cu Zn)
6259	Cu	701537	7669576	50	Hazelby Southwest (Cu)
6261	Cu	701927	7669656	50	Hazelby Southeast (Cu)
6267	Cu	701097	7669716	50	Hazelby West 1 (Cu)
6268	Cu Zn	700927	7669536	50	Hazelby West 2 (Cu)
6304	Zn	753617	7665676	50	North Pole East 4 (Zn)
6306	Zn	753727	7665536	50	North Pole East 2-4 (Zn)
6307	Pb Ag	754157	7662706	50	North Pole Stubbs Prospect (Pb Ag)
6337	Cu	202435	7597341	51	Lionel 2 (Cu)
6338	Cu	202245	7597211	51	Lionel 3 (Cu)
6339	Cu	202755	7597091	51	Lionel 4 (Cu)

BASE METAL

Stratabound volcanic and sedimentary - sedimentary-hosted sulfide

No*	COMMODITY	EAST	NORTH	Z	NAME
2777	Zn Pb Cu	736560	7650380	50	Bernts (Zn Pb)
2778	Pb Ag Zn	785792	7651100	50	Big Stubby (Zn Pb Cu Brt)
2847	Cu Zn	728886	7659650	50	Sulphur Springs (Zn Cu)
3052	Cu	728807	7667597	50	Strelley Gorge Northeast (Cu)
3235	Cu Zn	731347	7646075	50	Breakers (Zn Cu)
3236	Cu Zn	727687	7642282	50	Man Of War (Zn Cu)
3237	Cu Zn	726029	7639927	50	Anomaly 45 (Zn Cu)
3238	Cu Zn	727940	7638516	50	Jamesons (Cu Zn)
3242	Brt Pb Zn	710481	7642446	50	Mad Hatters (Zn Pb Brt)
3252	Cu	728490	7665716	50	Double Bar (Cu)
3253	Cu	728290	7666176	50	Double Bar Ext (Cu)
3270	Zn	753870	7665856	50	North Shaw (Zn)
4592	Ag Cu	766000	7636400	50	Sharks Gully 2 (Cu)
4615	Cu Zn Ag	225655	7608141	51	Copper Gorge (Zn Cu Ag)
4620	Cu Zn Pb Ag Au	213670	7635955	51	Lennons Find Hammerhead (Zn Pb)
4628	Cu Pb Zn Sb Au	219398	7578382	51	Middle Ck (Au Cu Zn Pb Ag Sb)
4634	Cu Pb Au	784587	7641506	50	Fieldings Gully (Cu Pb)
4635	Cu Pb	782550	7575866	50	Coongan R (Cu Pb)
4636	Zn Cu Pb	714987	7629026	50	Abydos (Zn)
5085	Cu Pb Zn	212775	7635400	51	Tiger (Zn Pb Cu)
5086	Cu	212154	7635333	51	Lennons Find West 2 (Cu)
5087	Cu Zn Ag	215015	7637312	51	Bronze Whaler (Cu Zn Ag)
5089	Cu Zn Pb Ag	214619	7636795	51	Mako East Zone (Zn Pb Cu Ag)
5090	Cu Zn Pb Ag	214374	7636558	51	Mako Zone (Cu Zn Pb Ag)
5091	Cu Pb Zn	212720	7635598	51	Grey Nurse East (Zn Cu Pb)
5092	Cu Pb Zn	211985	7635452	51	Grey Nurse (Zn Ag)
6182	Zn Pb Ag	228486	7607661	51	Violet Hill (Zn Pb Cd Ag)
6368	Cu	202135	7596461	51	Malachite Ck (Cu)
7336	Cu	216700	7612561	51	Otways (Cu)
7499	Zn Cu Brt	721337	7623336	50	Soanesville (Zn Cu)
7730	Zn Cu Pb Au Ag	732360	7653400	50	Kangaroo Caves (Zn Cu)
7732	Zn Cu	723740	7658650	50	Roadmaster (Zn Cu)

Stratabound sedimentary - clastic-hosted

No*	COMMODITY	EAST	NORTH	Z	NAME
4680	Pb Zn	314236	7690352	51	Baton (Pb Zn)
4692	Cu Pb Zn	336556	7629651	51	Rainbow (Cu Zn)
4693	Cu Pb Zn	336136	7626952	51	Holly (Zn Pb Cu)
4694	Pb Zn	336585	7656402	51	Warrabarty (Zn Pb)
4696	Zn Pb Ag	325935	7672252	51	Hammerhead (Pb Ag Zn)
6114	Cu Pb Zn	336000	7624350	51	Rainbow South (Cu Pb Zn)

IRON

Vein and hydrothermal - undivided

No*	COMMODITY	EAST	NORTH	Z	NAME
4754	Fe	340336	7576881	51	Pearana (Fe)

Stratabound sedimentary - clastic-hosted

No*	COMMODITY	EAST	NORTH	Z	NAME
4137	Fe	221827	7721766	51	Yarrie 10 (Fe)

Sedimentary - banded iron-formation (supergene enriched)

No*	COMMODITY	EAST	NORTH	Z	NAME
2775	Fe Cu Zn	704419	7643789	50	Abydos North (Fe)
2839	Fe	703999	7650070	50	Pincunah East (Fe)
2840	Fe	696558	7658888	50	Pincunah North (Fe)
3250	Fe	724040	7663716	50	Strelley Gorge (Fe)
4128	Fe	218787	7718639	51	Yarrie 2/3 (Fe)
4201	Fe	199000	7730000	51	Shay Gap (Deposits 3 & 4) (Fe)
4206	Fe	200827	7728688	51	Hematite Hill (Fe)
5406	Fe	193435	7734261	51	Sunrise Hill (Deposit 4 West) (Fe)
5407	Fe	191635	7736661	51	Sunrise Hill West (Fe)
5413	Fe	187250	7737350	50	Nimingarra (Deposit F) (Fe)
5414	Fe	197735	7731461	51	Shay Gap (Deposits 1 & 2) (Fe)
5415	Fe	205135	7724961	51	Cundaline Ridge (Fe)
5418	Fe	219135	7715611	51	Callawa (Fe)
5983	Fe	198135	7607861	51	Lionel North (Fe)
6058	Fe	764838	7747456	50	Mt Goldsworthy (Fe)
7102	Fe	196362	7687747	51	Kitty Gap (Fe)
7381	Fe	728340	7759434	50	Ridley No 4 (Fe)
7879	Fe	188200	7741200	51	Nimingarra (Deposits B & C) (Fe)
7990	Fe	723677	7754292	50	Ord Ridley (Fe)
9116	Fe	192250	7734800	51	Sunrise Hill (Deposit 1) (Fe)
9117	Fe	195500	7733700	51	Shay Gap (Deposit 7) (Fe)
9118	Fe	192750	7734600	51	Sunrise Hill (Deposit 2) (Fe)
9119	Fe	192900	7734300	51	Sunrise Hill (Deposit 3) (Fe)
9120	Fe	192300	7734650	51	Sunrise Hill (Deposit 6) (Fe)
9121	Fe	190600	7738500	51	Midnight Ridge (Fe)
9122	Fe	190750	7742350	51	Nimingarra (Deposit A) (Fe)
9123	Fe	187300	7739000	51	Nimingarra (Deposit D) (Fe)
9124	Fe	187100	7738250	51	Nimingarra (Deposit E) (Fe)

Sedimentary - banded iron-formation (taconite)

No*	COMMODITY	EAST	NORTH	Z	NAME
2930	Fe	777141	7625146	50	Blue Bar (Fe)
7740	Fe	713810	7648980	50	Pincunah (Fe)

Regolith - alluvial to beach placers

No*	COMMODITY	EAST	NORTH	Z	NAME
2841	Fe	692900	7653000	50	Pincunah South (Fe)
2881	Fe	695942	7660485	50	Cinnamon Ck 1 (Fe)
2882	Fe	696146	7659045	50	Pincunah North 2 (Fe)
2883	Fe	698787	7656726	50	Pincunah North 3 (Fe)
2885	Fe	713538	7662432	50	Strelley 1 (Fe)
2886	Fe	713536	7663431	50	Strelley 2 (Fe)
3245	Fe	710440	7626466	50	Abydos (Fe)
3254	Fe	714370	7668496	50	Lalla Rookh (Fe)
3255	Fe	714240	7659496	50	Lalla Rookh South (Fe)
3256	Fe	717140	7656626	50	Ironmount (Fe)
3277	Fe	710140	7626746	50	North Shaw 1 (Fe)
3278	Fe	708900	7627716	50	North Shaw 2 (Fe)
3281	Fe	708250	7628626	50	North Shaw 3 (Fe)
6059	Fe	716438	7745956	50	Grengarra Well 1 (Fe)
6060	Fe	717037	7746756	50	Grengarra Well 2 (Fe)
6061	Fe	684937	7736956	50	Pundano Well 1 (Fe)
6062	Fe	687038	7737056	50	Pundano Well 2 (Fe)
6063	Fe	690238	7737056	50	Pundano Well 3 (Fe)
7191	Fe	204000	7610461	51	McPhee Ck (Fe)
7787	Fe	694130	7654840	50	Pincunah North (Fe)
7914	Fe	222500	7720250	51	Yarrie Crustals (Fe)
7988	Fe	701135	7736860	50	Table Hill (Fe)
7989	Fe	720000	7752260	50	Muccangarra North (Fe)
7999	Fe	701730	7658960	50	Tank Pool East (Fe)
8000	Fe	687200	7702700	50	Wallaringa Peak (Fe)
8001	Fe	664700	7699300	50	Indee East (Fe)
8002	Fe	662200	7698700	50	Indee West (Fe)
8746	Fe	675712	7655162	50	Wodgina Alluv (Fe)
8747	Fe	673125	7650159	50	Wodgina South Alluv (Fe)

Regolith - residual and supergene

No*	COMMODITY	EAST	NORTH	Z	NAME
4210	Fe	212800	7725800	51	Cattle Gorge (Fe)
7991	Fe	762135	7746960	50	Mount Goldsworthy Satellites (Fe)
9138	Fe	764200	7747000	50	Mount Goldsworthy crustals (Fe)
9139	Fe	187700	7740000	51	Nimingarra crustals (Fe)
9140	Fe	221900	7719800	51	Yarrie crustals (Fe)

ENERGY MINERAL (U)

Stratabound sedimentary - clastic-hosted

No*	COMMODITY	EAST	NORTH	Z	NAME
3609	U	770441	7659146	50	Alcoa (U)
6010	U	768337	7654756	50	Shady Camp Well (U)
6012	U	768437	7651156	50	Shady Camp Well (U Au)

INDUSTRIAL MINERAL

Disseminated and stockwork in plutonic intrusions

No*	COMMODITY	EAST	NORTH	Z	NAME
3944	Fl	231345	7690594	51	Ngarrin Creek (Fl)

Pegmatitic

No*	COMMODITY	EAST	NORTH	Z	NAME
7458	Mica Fsp	684430	7724200	50	Pippingarra (Mica, Fsp)

No*	COMMODITY	EAST	NORTH	Z	NAME
INDUSTRIAL MINERAL					
Orthomagmatic mafic and ultramafic - undivided					
5950	Asbc	199385	7601211	51	Lionel (Asbc)
5980	Asbc	200965	7602711	51	Lionel 1 (Asbc)
5981	Asbc	198705	7602161	51	Lionel 2 (Asbc)
5997	Asbc	719037	7608956	50	Olivine (Asbc)
5998	Asbc	721487	7608311	50	Peisses Quest (Asbc)
6002	Asbc	720437	7607856	50	Fibre Queen (Asbc)
6008	Asbc	776337	7606056	50	Split Rock 1 (Asbc)
6009	Asbc	776787	7618356	50	Split Rock 2 (Asbc)
6019	Asbc	727037	7618656	50	Soanesville 1 (Asbc)
6020	Asbc	727637	7617356	50	Soanesville 2 (Asbc)
6021	Asbc	726687	7616706	50	Soanesville 3 (Asbc)
6022	Asbc	729237	7611706	50	Soanesville 4 (Asbc)
6031	Asbc	808038	7683656	50	Talga Peak (Asbc)
6032	Asbc	793538	7684856	50	Talga River (Asbc)
6233	Asbc	691987	7582606	50	White Range (Asbc)
6627	Asbc	200975	7601611	51	Lionel 3 (Asbc)
6628	Asbc	201235	7601161	51	Lionel 4 (Asbc)
6629	Asbc	201235	7600811	51	Lionel 5 (Asbc)
6631	Asbc	200835	7601311	51	Lionel 6 (Asbc)
6632	Asbc	198285	7602011	51	Lionel 7 (Asbc)
6633	Asbc	197585	7601861	51	Lionel 8 (Asbc)
Vein and hydrothermal - undivided					
834	Tlc	660848	7636618	50	Mount Francisco (Tlc)
2879	Asbc	702302	7716144	50	Old Tabba (Asbc)
2880	Asbc	721042	7660876	50	Strelley Gorge (Asbc)
2980	Asbc	785388	7638607	50	Marshs (Asbc)
3911	Fl	237494	7649457	51	Meentheena (Fl)
4769	Fl	238062	7649400	51	Meentheena 1 (Fl)
4770	Fl	237730	7649037	51	Meentheena 2 (Fl)
4771	Fl	237809	7647654	51	Meentheena 3 (Fl)
4772	Fl	239790	7648211	51	Meentheena 4 (Fl)
4773	Fl Cu Pb	239803	7648948	51	Meentheena 6 (Fl Cu Pb)
4774	Pb Fl	750448	7616408	50	Boddingtons (Pb Fl)
4776	Fl W Pb	236165	7604361	51	Cookes Ck (Fl W)
4778	Fl	272814	7589372	51	Eastern Creek (Fl)
4782	Fl	704522	7673046	50	McPhees Range (Fl Pb)
8732	Brt	229100	7620800	51	Police Creek (Brt)
Stratabound volcanic and sedimentary - undivided					
2834	Brt	753728	7663515	50	North Pole Dresser (Brt)
2933	Brt	711629	7637991	50	Sudden Jerk (Brt)
3171	Brt	753132	7659193	50	Dresser 1 (Brt)
3172	Brt	752636	7659110	50	Dresser 2 (Brt)
3173	Brt	753048	7666235	50	North Pole 1 (Brt)
3174	Brt	753613	7665784	50	North Pole 2 (Brt)
3175	Brt	753500	7664715	50	North Pole 3 (Brt)
3187	Brt Pb Ag	753832	7664505	50	North Pole 4 (Brt)
3188	Brt	754170	7663978	50	North Pole 5 (Brt)
6038	Brt	780038	7678706	50	Cooke Bluff Hill (Brt)
6039	Brt	747238	7683856	50	Miralga Ck 1 (Brt)
6041	Brt	748188	7685306	50	Miralga Ck 2 (Brt)
6042	Brt	749940	7688660	50	Miralga Ck 3 (Brt)
6044	Brt	751938	7688756	50	Miralga Ck 4 (Brt)
Stratabound sedimentary - undivided					
2939	Brl	705914	7643726	50	Yandee (Brt)
4748	Brt	326286	7567351	51	Wootha Wootha Ck (Brt)
4749	Gp	326806	7569301	51	Pearana (Gp)
Sedimentary - undivided					
5982	Brt	200635	7610761	51	Lionel N (Brt)

Appendix 2

WAMIN and EXACT databases

WAMIN database (mineral occurrences)

The WAMIN (Western Australian mineral occurrence) database of the Geological Survey of Western Australia (GSWA) contains geoscience attribute information on mineral occurrences in Western Australia. The database includes textual and numeric information on the location of the occurrences, location accuracy, mineral commodities, mineralization-style classification, order of magnitude of resource tonnage and estimated grade, ore and gangue mineralogy, details of host rocks, and both published and unpublished references. Each of the occurrences in WAMIN is identified by a unique 'deposit number'.

The WAMIN database uses a number of authority tables to constrain the essential elements of a mineral occurrence, such as the operating status, the commodity group, and the style of mineralization. In addition, there are parameters that dictate whether the presence of a mineral or an analysed element is sufficiently high to rank occurrence status; this report only deals with mineral occurrences. These and other attributes were extracted either from open-file mineral exploration reports in WAMEX (Western Australian mineral exploration database) or from the published literature.

Those elements of the database that were used to create the symbols for mineral occurrences and tabular information displayed in Plates 1 and 1A, and Appendix 1 of this report, are:

- occurrence number and name (deposit number and name)
- operating status (font style of deposit number)
- position and spatial accuracy (symbol position)
- commodity group (symbol colour)
- mineralization style (symbol shape).

The elements of the database used for symbology in Plates 1 and 1A and Appendix 1 are operating status, commodity group, and mineralization style. These parameters have previously been defined for the GSWA mineralization mapping projects that have been completed for prospectivity enhancement studies of southwest Western Australia (Hassan, 1998), the north Eastern Goldfields (Ferguson, 1998), the Bangemall Basin (Cooper et al., 1998), the west Pilbara (Ruddock, 1999), and the east Kimberley (Hassan, 2000).

Operating status

The database includes mineralization sites (referred to as deposits) ranging from small, but mineralogically significant, mineral occurrences up to operating mines. The classification includes all MINEDEX sites with established resources: MINEDEX is the Department of Minerals and Energy (now Department of Mineral and Petroleum Resources (MPR)) mines and mineral deposits information database (Townsend et al., 1996, 2000). All occurrences in the WAMIN database are assigned a unique, system-generated number (deposit number). The font style of this number (bold, italicized, and so on) is used as the coding to indicate operating status both on the face of the map and in Appendix 1 of this Report. The system used is:

- Mineral occurrence — any economic mineral exceeding an agreed concentration and size found in bedrock or regolith (italic serif numbers, e.g. *1212*).
- Prospect — any working or exploration activity area that has found subeconomic mineral occurrences, and from which there is no recorded production (italic serif numbers, e.g. *1138*).
- Mineral deposit — economic minerals for which there is an established resource figure (serif numbers, e.g. 1137).
- Abandoned mine — workings that are no longer operating, or are not on a care-and-maintenance basis, and for which there is recorded production, or where field evidence suggests that the workings were for more than prospecting purposes (bold–italic sans serif numbers, e.g. ***2321***).
- Operating mine — workings that are operating, including on a care-and-maintenance basis, or that are in development leading to production (bold sans serif numbers, e.g. **1106**).

The names of the occurrences, and any synonyms that may have been used, are derived from the published literature and from open-file reports (in WAMEX). Names that appear in the MINEDEX database have been used where possible, although there may be differences created because MINEDEX uses site names based on overall production and resources, whereas WAMIN may show names of individual occurrences at a MINEDEX site.

Commodity group

The WAMIN database includes a broad grouping that is based on the potential end-use or typical end-use of the

Table 2.1. WAMIN authority table for commodity groups

Commodity group	*Typical commodities*	*Symbol colour*
Precious mineral	Diamond, semi-precious gemstones	
Precious metal	Ag, Au, PGE	
Steel-industry metal	Co, Cr, Mn, Mo, Nb, Ni, V, W	
Speciality metal	Li, REE, Sn, Ta, Ti, Zr	
Base metal	Cu, Pb, Zn, Sb	
Iron	Fe	
Aluminium	Al (bauxite)	
Energy mineral	Coal, U	
Industrial mineral	Asbestos, barite, kaolin, talc, fluorite	
Construction material	Clay, dimension stone, limestone	

principal commodities comprising a mineral occurrence. The commodity group, as listed in Table 2.1, determines the particular colour for the mineral occurrence symbols in Plates 1 and 1A, and Appendix 1.

The commodity groupings are based on those published by the Mining Journal (1998) with modifications, as shown in Table 2.2, to suit the range of minerals and end-uses for the mineral output of Western Australia.

Mineralization style

There are a number of detailed schemes for classifying mineral occurrences into groups representing different styles of mineralization, with the scheme of Cox and Singer (1986) probably being the most widely used. The application of this scheme in Western Australia would necessitate modifications to an already complex scheme, along the lines of those adopted by the Geological Survey of British Columbia (Lefebure and Ray, 1995; Lefebure and Hoy, 1996). Representing the style of mineralization on the face of a map cannot be simply and effectively achieved if the scheme adopted is too complex.

The Geological Survey of Western Australia has adopted the principles of ore deposit classification from Evans (1987) with some modifications based on Edwards and Atkinson (1986). This scheme works on the premise that 'If a classification is to be of any value it must be

Table 2.2. Modifications made to the Mining Journal Ltd (1998) commodity classification

Commodity group (Mining Journal Ltd, 1998)	*Commodities*	*Changes made for WAMIN commodity group*
Precious metals and minerals	Au, Ag, PGE, diamonds, other gemstones	Diamond and other gemstones in precious minerals group; Au, Ag, and PGE in precious metals group
Steel-industry metals	Iron ore, steel, ferro-alloys, Ni, Co, Mn, Cr, Mo, W, Nb, V	Fe in iron group
Speciality metals	Ti, Mg, Be, REE, Zr, Hf, Li, Ta, Rh, Bi, In, Cd, Sb, Hg	Sn added from major metals; Sb into the base metals group
Major metals	Cu, Al, Zn, Pb, Sn	Cu, Pb, and Zn into the base metals group; Al (bauxite) into aluminium group; Sn in speciality metals
Energy minerals	Coal, U	No change
Industrial minerals	Asbestos, sillimanite minerals, phosphate rock, salt, gypsum, soda ash, potash, boron, sulfur, graphite, barite, fluorspar, vermiculite, perlite, magnesite/magnesia, industrial diamonds, kaolin	No change

Table 2.3. WAMIN authority table for mineralization styles and groups

Mineralization style	*Typical commodities*	*Group symbol*[(a)]
Carbonatite and alkaline igneous intrusions	Nb, Zr, REE, P	☆
Kimberlite and lamproite intrusions	Diamond	
Disseminated and stockwork in plutonic intrusions	Cu, Mo, Au	⬡
Greisen	Sn	
Pegmatitic	Sn, Ta, Nb, Li	
Skarn	W, Mo, Cu, Pb, Zn, Sn	
Orthomagmatic mafic and ultramafic — komatiitic or dunitic	Ni, Cu, Co, PGE	✚
Orthomagmatic mafic and ultramafic — layered-mafic intrusions	Ni, Cu, Co, V, Ti, PGE, Cr	
Orthomagmatic mafic and ultramafic — undivided	Ni, Cu, Co, V, Ti, PGE, Cr	
Vein and hydrothermal — undivided	Au, Ag, Cu, Pb, Zn, Ni, U, Sn, F	◇
Vein and hydrothermal — unconformity	U	
Stratabound volcanic and sedimentary — volcanic-hosted sulfide	Cu, Zn, Pb, Ag, Au, Ba	△
Stratabound volcanic and sedimentary — sedimentary-hosted sulfide	Pb, Zn, Cu, Ag	
Stratabound volcanic and sedimentary — volcanic oxide	Fe, P, Cu	
Stratabound volcanic and sedimentary — undivided	Pb, Zn, Cu, Ag, Au, Fe, Ba	
Stratabound sedimentary — carbonate-hosted	Pb, Zn, Ag, Cd	□
Stratabound sedimentary — clastic-hosted	Pb, Zn, Cu, Au, Ag, Ba, Cd, U	
Stratabound sedimentary — undivided	Pb, Ba, Cu, Au	
Sedimentary — banded iron-formation (supergene enriched)	Fe	
Sedimentary — banded iron-formation (taconite)	Fe	
Sedimentary — undivided	Mn	
Sedimentary — basin	Coal, bitumen	○
Regolith — alluvial to beach placers	Au, Fe pisolites, Ti, Zr, REE, diamond, Sn	▭
Regolith — calcrete	U, V	
Regolith — residual and supergene	Al, Au, Ni, Co, Mn, V, Fe crustals, Fe scree	
Regolith — residual to eluvial placers	Au, Sn, Ti, Zr, REE, diamond	
Undivided	Various	▽

NOTE: (a) The white symbol colour used in this table does not indicate the commodity group in Table 2.1

capable of including all known ore deposits so that it will provide a framework and a terminology for discussion and so be of use to the mining geologist, the prospector and the exploration geologist'. The system below is based on an environmental–rock association classification, with elements of genesis and morphology where they serve to make the system simpler and easier to apply and understand (Table 2.3).

To fully symbolize all the mineralization style groups would result in a system that is too complex. As the full details of the classification are preserved in the underlying WAMIN database, the chosen symbology has been reduced to nine shapes (Table 2.3).

Mineral occurrence determination limits

Any surface expression of mineralization (gossan or identified economic mineral) is an occurrence. Subsurface or placer mineralization is included as an occurrence where it meets the criteria given in Table 2.4.

Professional judgement is used if shorter intercepts or surface occurrences at higher grade (or vice versa) are involved. Any diamonds or gemstones would be mineral occurrences, including diamondiferous kimberlite or lamproite.

EXACT database (exploration activities)

The EXACT[*] database is a GIS-based spatial index, for exploration activities in WAMEX, which has been developed by the GSWA to improve access to information in open-file mineral exploration reports (Ferguson, 1995). A major limitation to data retrieval in WAMEX, in its current form, is the difficulty in selecting reports that cover a specific area and, further, in precisely locating various individual exploration activities described within a selected report.

In the current WAMEX database, when spatial parameters are used to make data searches, the results of

* The EXACT database is a GIS-based spatial index of **EX**ploration **ACT**ivities. This term supersedes the acronym SPINDEX (Spatial Index) used in Cooper et al. (1998), Ferguson (1998), and Hassan (1998).

Table 2.4. Suggested minimum intersections for mineral occurrences in drillholes or trenches

Element	*Intersection length (m)*	*Grade*
Hard rock and lateritic deposits		
Gold	>5	>1 ppm
Silver	>10	>1 ppm
Platinum	>0.5	>1 ppm
Lead	>5	>0.5%
Zinc	>5	>2%
Copper	>5	>0.5%
Nickel	>5	>0.5%
Cobalt	>5	>0.1%
Chromium	>0.2	>5% Cr_2O_3
Vanadium	>5	>0.1%
Tin	>5	>0.02%
Iron	>5	>40% Fe
Manganese	>5	>25%
Uranium	>5	>1000 ppm U
Diamonds	na	any diamonds
Tantalum	>5	>200 ppm
Tungsten	>5	>1000 ppm (0.1%)
Placer deposits		
Gold	na	>300 mg/m^3 in bulk sample
Diamonds	na	any diamonds
Heavy minerals	>5	>2% ilmenite

searches are constrained to very large areas. The smallest search polygon that can be effectively used to locate reports in WAMEX is the area of a 1:50 000-scale sheet. Even though a query may be entered as a single point (either MGA or latitude/longitude coordinates), the resulting search will produce all reports for the 1:50 000-scale sheet in which that single point is located. Hence, for example, it is not possible to restrict report selection to small areas of prospective ground of particular interest to the user. As a consequence these WAMEX searches are time consuming, and they have become more time consuming as the number of open-file reports has increased with continuing releases of data.

The EXACT spatial index overcomes this problem and allows easy access to data on specific areas of previous exploration activity. It also provides a spatial representation of the intensity of past exploration, thereby highlighting prospective areas that may have been lightly or inadequately tested by various earlier exploration methods.

The spatial index consists of an attribute database, developed in Microsoft Access, which is linked to ArcView for spatial representation. In the CD-ROM, the dataset includes tabulated textual and numeric information that has been retrieved from open-file mineral exploration reports and attached to individual exploration activities. The areas of exploration activity are digitized (as polygons, lines, or points) using the computer-assisted drafting (CAD) system Microstation, converted into Arc/Info, and then transferred into ArcView to enable an interactive display of EXACT. The positional data are digitized from hard-copy maps and plans in mineral exploration reports, using various

Table 2.5 Types of exploration activity detailed in the EXACT database

Activity type	*Description*
Geological	
GEOL	Geological mapping
AMS	Airborne multispectral scanning
LSAT	Landsat TM data
Geophysical	
AEM	Airborne electromagnetic surveys
AGRA	Airborne gravity surveys
AMAG	Airborne magnetic surveys
ARAD	Airborne radiometric surveys
MAG	Magnetic surveys
EM	Electromagnetic surveys (includes TEM, SIROTEM)
GEOP	Other geophysical surveys (includes IP, resistivity)
GRAV	Gravity surveys
RAD	Radiometric surveys (includes downhole logging)
SEIS	Seismic surveys
Geochemical	
SOIL	Soil surveys
SSED	Stream-sediment surveys
REGO	Regolith surveys (includes laterite, pisolite, ironstone, and lag)
NGRD	Non-gridded geochemical surveys (includes chip, channel, dump, and gossan)
ACH	Airborne geochemistry
Mineralogical	
HM	Heavy mineral surveys
Drilling	
DIAM	Diamond drilling
ROT	Rotary drilling (predominantly percussion drilling)
RAB	RAB drilling (includes other shallow geochemical drilling such as auger)
RC	RC drilling
Mineral resources	
MRE	Mineral resource estimate
Hydrogeological	
HYDR	Groundwater surveys

published sources (geological maps, topographic maps, and TENGRAPH — MPR's electronic tenement-graphics system) for georeference purposes. The types of exploration activity detailed are essentially those used in WAMEX, with some rationalization, and these are listed in Table 2.5. In the table, the 25 activities are grouped as follows:

- Geological activities (and remote sensing activities)
- Geophysical activities
- Geochemical activities
- Mineralogical activities
- Drilling activities
- Mineral resources
- Hydrogeological activities.

The above groups relate to those specified in the statutory guidelines for mineral exploration reports (Department of Minerals and Energy, 1995).

For each separate exploration activity the following statistics have been compiled:

- description of activity
- sample types and numbers
- elements analyzed (asterisk symbol (*) against elements for a rough guide to anomalism)
- metres of drilling and number of holes
- scales of presentation of data in reports.

The activity data are also linked in the dataset to the following related information taken from WAMEX:

- A-numbers (WAMEX accession numbers for individual reports)
- I-numbers (WAMEX item numbers for single or groups of reports on microfiche or CD)
- company or companies that submitted reports
- period of exploration (years)
- mineral commodities sought
- summaries (annotations) of exploration projects included in individual item numbers.

In ArcView, the exploration activities are included as spatial **themes**, which are displayed as polygons, lines, or points on the interactive on-screen map known as the **view**. The **table of contents** (i.e. map legend) provided alongside the **view** allows access to the **themes**, so that any **theme** or combination of **themes** may be displayed. Details (taken from attribute tables) of any **theme** can be accessed on screen, and **queries** can be carried out either as spatial queries through a **view** or as textual queries direct from the attribute tables. Further details (with examples) of displays, queries, charts, and view layouts are provided by Ferguson (1995).

References

COOPER, R. W., LANGFORD, R. L., and PIRAJNO, F., 1998, Mineral occurrences and exploration potential of the Bangemall Basin: Western Australia Geological Survey, Report 64, 42p.

COX, D. P., and SINGER, D. A., 1986, Mineral deposit models: United States Geological Survey, Bulletin 1693, 379p.

DEPARTMENT OF MINERALS AND ENERGY, 1995, Guidelines for mineral exploration reports on mining tenements: Perth, Department of Minerals and Energy (now Department of Mineral and Petroleum Resources), 12p.

EDWARDS, R., and ATKINSON, K., 1986, Ore deposit geology and its influence on mineral exploration: London, Chapman and Hall, 466p.

EVANS, A. M., 1987, An introduction to ore geology: Oxford, Blackwell Scientific Publications, 358p.

FERGUSON, K. M., 1995, Developing a GIS-based exploration-activity spatial index for the WAMEX open-file system: Western Australia Geological Survey, Annual Review 1994–95, p. 64–70.

FERGUSON, K. M., 1998, Mineral occurrences and exploration potential of the north Eastern Goldfields: Western Australia Geological Survey, Report 63, 40p.

HASSAN, L. Y., 1998, Mineral occurrences and exploration potential of southwest Western Australia: Western Australia Geological Survey, Report 65, 38p.

HASSAN, L. Y., 2000, Mineral occurrences and exploration potential of the east Kimberley: Western Australia Geological Survey, Report 74, 83p.

LEFEBURE, D. V., and HOY, T., (editors), 1996, Selected British Columbia Mineral Deposit Profiles, Volume 2 — Metallic Deposits: British Columbia Ministry of Employment and Investment, Open File 1996-13, 171p.

LEFEBURE, D. V., and RAY, G. E., (editors), 1995, Selected British Columbia Mineral Deposit Profiles, Volume 1 — Metallics and Coal: British Columbia Ministry of Employment and Investment, Open File 1995-20, 135p.

MINING JOURNAL LIMITED, 1998, Mining Annual Review, Volume 2 — Metals & Minerals: London, Mining Journal Limited, 112p.

RUDDOCK, I., 1999, Mineral occurrences and exploration potential of the west Pilbara: Western Australia Geological Survey, Report 70, 63p.

TOWNSEND, D. B., GAO MAI, and MORGAN, W. R., 2000, Mines and mineral deposits of Western Australia: digital extract from MINEDEX — an explanatory note: Western Australia Geological Survey, Record 2000/13, 28p.

TOWNSEND, D. B., PRESTON, W. A., and COOPER, R. W., 1996, Mineral resources and locations, Western Australia: digital dataset from MINEDEX: Western Australia Geological Survey, Record 1996/13, 19p.

Appendix 3

Description of digital datasets on CD-ROM

There are three principal components of this study, which are this report, Plates 1 and 1A, and a CD-ROM containing digital datasets for use with database or GIS software. The CD-ROM includes all the data used to compile the map and Report, and also includes files of explorationand mining activity, geophysical, remote sensing, and topographic data. The CD-ROM also includes the files necessary for viewing the data in the ArcView GIS environment, and a self-loading version of the ArcExplorer software package modified to suit this particular dataset.

Mineral occurrences (WAMIN)

The mineral occurrence dataset (from WAMIN, the Western Australian mineral occurrence database) as used in this report and on Plates 1 and 1A is described in Appendix 2. The dataset on the CD-ROM includes textual and numeric information on:

- location of the occurrences (MGA coordinates, latitude and longitude, geological province, location method, and accuracy)
- commodities and commodity group
- mineralization classification and morphology
- order of magnitude of resource tonnage and estimated grade
- mineralogy of ore and gangue
- details of host rocks
- both published and unpublished references.

EXACT

The EXACT dataset (from EXACT, Geological Survey of Western Australia's spatial index of exploration activities) as used in this Report is described in Appendix 2. The dataset on CD-ROM contains spatial and textual information (derived from WAMEX open-file reports) defining the locations and descriptions of exploration activities in the area. EXACT, for the east Pilbara area, was compiled between 1998 and 2000, and contains information on types of mineral exploration activity such as statistics relating to:

- report numbers
- sample types and numbers
- elements assayed
- metres of drilling and number of holes
- scales of presentation of the data.

Positional data were taken from hard-copy maps of various scales, from company reports (in WAMEX), located from coordinate and/or geographical information (from topographic maps or Landsat images), and then digitized. Table 2.5 (in Appendix 2) lists the exploration activity types.

The activity data are linked to more general data concerning the individual open-file reports (commonly defined in WAMEX by accession A-numbers) and individual exploration projects (commonly defined in WAMEX by open-file item I-numbers). This information includes the company or companies involved in the project, the commodities explored for, the timing of the project, names of localities in the project, and a summary (annotation) of the project, including exploration concept, activities, and a synopsis of results.

WAMEX

All relevant open-file company mineral exploration reports for the area, indexed in the WAMEX* database held by the former Department of Minerals and Energy, now Department of Mineral and Petroleum Resources (MPR), were referred to for this study. Information extracted from these reports was used to analyse the historical trends in exploration activity and target commodities.

MINEDEX

The MINEDEX* database (Townsend et al., 1996, 2000) has current information on all mines, process plants, and deposits, excluding petroleum and gas, for Western Australia. Mineral resources included in MINEDEX must conform to the Joint Ore Reserves Committee (JORC) (1999) code to be included in the database. The database contains information relevant to WAMIN under the following general headings:

- commodity group and minerals
- corporate ownership and percentage holding
- site type and stage of development
- location data (a centroid) including map, shire, mining district, and centre
- current mineral resource estimates
- mineralization type
- tectonic unit
- tenement details.

* WAMEX and MINEDEX are available on the MPR website

MINEDEX contains all the relevant resource information and WAMIN uses the unique MINEDEX site number as a cross-reference for this information. WAMIN may contain pre-resource global estimates that do not conform to the JORC (1999) code, and are not included in MINEDEX.

TENGRAPH

The TENGRAPH* database (MPR's electronic tenement-graphics system) shows the position of mining tenements relative to other land information. TENGRAPH provides information on the type and status of the tenement and the name(s) and address(es) of the tenement holders (Department of Minerals and Energy, 1994). It should be borne in mind that the tenement situation is constantly changing and that current tenement plans should be consulted before making any landuse-based decisions or applying for tenements.

Solid geology and regolith

The solid geology and regolith incorporates an interpretation of the study area, at 1:100 000 scale, based on a recent compilation of the Geological Survey of Western Australia (GSWA) mapping, the Australian Geological Survey Organisation's (AGSO) lithological digital compilation of the east Pilbara, aeromagnetics (TMI images), and Landsat TM imagery. The full details of the solid geology and regolith are on the CD-ROM. The regolith on Plates 1 and 1A is a simplified version of the digital dataset on the CD-ROM, and uses two overprints to distinguish relict and depositional regimes. The CD-ROM also includes a large number of solid geology and regolith units that are smaller than 250 000 m^2 in area that were omitted from Plates 1 and 1A for simplicity.

Geophysics

The aeromagnetic data covering the area are presented in the form of a total magnetic intensity (TMI) colour image. The data used to create the image were flown in 1995 for the National Geoscience Mapping Accord (between AGSO and GSWA), mostly at a line spacing of 400 m, and gridded to a cell size of 800 m for the colour image. More-detailed data, gridded to a cell size of 100 m, may be obtained from AGSO.

Measurements of the background radiation using an airborne crystal usually took place concurrently with the AGSO aeromagnetic surveys over the area. The colour image on the CD-ROM shows the comparative K–Th–U ratios as red–green–blue (RGB). The data are relatively disparate in nature as variations in the crystal size and flying height were not tightly constrained over the area.

A regional gravity survey by AGSO, at a nominal station spacing of 11 km, is presented in the digital dataset as an image showing the Bouguer anomaly, gridded to a cell size of 5 km.

* TENGRAPH is available on the MPR website

Landsat

Landsat TM imagery has been acquired for all the 1:250 000-scale map sheets in the east Pilbara study. The raw data are available commercially through the Remote Sensing Services section of the Department of Land Administration (DOLA). Images are included in the digital package that preserve the original 25 m pixel size, but these cannot be reverse-engineered back to any bands or band ratios of the original 6-band dataset.

Both image datasets comprise a patchwork of 1:250 000-scale map tiles. The simplest of the two uses a decorrelation stretch of the first principal component of bands 1, 2, 3, 4, 5, and 7, written out as an 8-bit dataset that can be viewed as a monochrome image. The second, more complex, image can be viewed in colour, and was created using a decorrelation stretch of bands 4, 5, and 7.

Cultural features

Selected roads and tracks are given as a single dataset, and range from sealed highways through shire roads to major station tracks. The digital data in this file were captured by digitizing from Landsat imagery.

Place names for the area, in a separate file, are given for major hills, stations, and communities. More-comprehensive topographical and cultural data, including drainage, can be obtained from the Australian Land Information Group (AUSLIG).

References

DEPARTMENT OF MINERALS AND ENERGY, 1994, TENGRAPH customer user manual: Perth, Department of Minerals and Energy (now Department of Mineral and Petroleum Resources), 50p.

FERGUSON, K. M., 1995, Developing a GIS-based exploration-activity spatial index for the WAMEX open-file system: Western Australia Geological Survey, Annual Review 1994–95, p. 64–70.

JOINT ORE RESERVES COMMITTEE OF THE AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY, AUSTRALIAN INSTITUTE OF GEOSCIENTISTS, and MINERALS COUNCIL OF AUSTRALIA (JORC), 1999, Australasian code for reporting of mineral resources and ore reserves: Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists, and Minerals Council of Australia, 16p.

TOWNSEND, D. B., GAO MAI, and MORGAN, W. R., 2000, Mines and mineral deposits of Western Australia: digital extract from MINEDEX — an explanatory note: Western Australia Geological Survey, Record 2000/13, 28p.

TOWNSEND, D. B., PRESTON, W. A., and COOPER, R. W., 1996, Mineral resources and locations, Western Australia: digital dataset from MINEDEX: Western Australia Geological Survey, Record 1996/13, 19p.

Appendix 4

Summary table of mineral production from the east Pilbara, and tables of production figures for the commodities iron ore, manganese, tantalum, tin, gold, lead, copper, tungsten, beryl, and barite

Table 4.1. Summary of mineral production from the east Pilbara

Commodity	*Period*	*Ore/Concentrate/ Commodity*
Iron ore	1966–2000	206.0 Mt
Manganese	1954–2000	3.216 Mt
Tantalum	1905–1991	1 629.38 t
Tin	1899–1991	17 060.51 t
Gold	1897–1995	22 498.028 kg
Lead	1925–1960	4 832.59 t
Copper	1907–1971	
Copper ore		597.5 t
Cupreous ore		17 092.28 t
Tungsten	1951–1967	
Scheelite ore and conc.		5.59 t
Wolframite ore and conc.		25.7 t
Beryl	1943–1965	1 800.56 t
Barite	1970–1991	129 505.34 t

Table 4.2. Iron ore production in the east Pilbara area (1966–2000)

Mining area	*Period* [(a) (b)]	*Iron ore (Mt)* [(c)]
Mount Goldsworthy	1966–1972	32.7
Mount Goldsworthy, Shay Gap – Sunrise Hill	1973–1982	65.1
Shay Gap – Sunrise Hill	1983–1988	28.8
Shay Gap – Sunrise Hill, Nimingarra	1989–1993	30.3
Nimingarra, Yarrie, Shay Gap – Sunrise Hill	1994–1995	14.2
Yarrie, Nimingarra	1996–2000	34.9
Total		**206.0**

NOTES: (a) Mount Goldsworthy commenced 1966; Shay Gap – Sunrise Hill commenced 1973; Nimingarra commenced 1989; Yarrie commenced 1994
(b) Mount Goldsworthy closed 1982; Shay Gap – Sunrise Hill closed 1995
(c) Includes iron ore for export and for domestic operations

SOURCE: For all tables — MINEDEX database held in Department of Minerals and Energy (now Department of Mineral and Petroleum Resources)

Table 4.3. Manganese production in the east Pilbara area (1954–2000)

Mine group *Operator*	*Period*	*Ore (t)*	*Contained manganese (t)*
Mount Sydney			
Mount Sydney Manganese Pty Ltd[(a)]	1954–1969	448 742	227 894
D. F. D. Rhodes Pty Ltd	1958–1965	58 439	29 247
Longreach Manganese Pty Ltd	1969–1970	57 389	28 056
Nimingarra			
Pindan Pty Ltd	1959–1962	19 661	8 674
Woodie Woodie			
Dampier Mining Co Ltd	1970–1971	55 560	26 692
Mount Sydney Manganese Pty Ltd, Portman Mining Ltd, Boral Resources (WA) Ltd	1990	364 577	–
Portman Mining Ltd, Boral Resources (WA) Ltd	1991	209 640	–
Portman Mining Ltd	1992–1993	650 702	–
Portman Mining Ltd, Valiant Consolidated Ltd[(b)]	1994–1996	727 230	–
Valiant Consolidated Ltd[(b)]	1997	176 990	–
Consolidated Minerals Limited[(b)]	1998–2000	447 121	–
Total		**3 216 051**	

NOTES: (a) Production includes Northern Minerals Syndicate 1952–1954
(b) Production includes Mike deposit, 12 km south of Woodie Woodie

Table 4.4. Tantalum production from the east Pilbara (up to 1991)

Mining Centre tenements or company	*Period*	*Tantalite ore and concentrates (t)*	*Contained Ta_2O_5 (t)*
Abydos			
VCL	1965	0.08	0.028
Total		**0.08**	**0.028**
Cooglegong			
DC 53, etc	1968–1970	466.32	11.579
VCL	1955–1958	0.09	0.029
Total		**466.41**	**11.608**
Eleys			
DC 281, etc	1968–1971	81.65	8.552
Total		**81.65**	**8.552**
Hillside			
MC 1033	1970	0.17	0.082
Total		**0.17**	**0.082**
Kangan Station			
PA 818	1943	0.01	–
PA 2096	1944	0.04	–
Total		**0.05**	
Moolyella			
DC 195, DC 201, etc	1967–1973	14.02	3.821
MC 45, MC668, etc	1979–1982	126.0	45.35
VCL	1955–1968	[a]1.33	[a]0.824
Total		[a]**141.35**	[a]**49.995**
Mount Francisco			
MC 294, 306	1954	1.73	1.303
MC 350	1956	0.04	0.009
MC 340	1956	0.07	0.015
MC 390	1957	0.05	0.032
VCL	1963–1965	1.94	0.301
Total		**3.83**	**1.659**
Pilgangoora			
MC 160–162	1942	0.67	0.319
MC 221–222	1950–1953	[a]3.72	[a]2.454
MC 381	1956	5.68	2.542
MC 174, 175	1955–1957	6.04	2.502
MC 291, 425, 427, 381, 385	1956–1959	11.46	5.013
MC 291	1956	0.65	0.303
MC 421, 422, 423	1955–1959	[a]2.03	[a]1.129
MC 382	1956	5.63	2.677
MC 290	1960	1.51	0.767
MC 45/920, DC 45/155	1979–1984	227	71.659
VCL	1948–1964	[a]2.21	[a]0.909
Total		[a]**266.6**	[a]**90.274**
Pippingarra			
MC 313	1953–1958	[a]6.66	[a]3.223
MC 297	1955	[a]0.03	[a]0.023
Total		[a]**6.69**	[a]**3.246**
Shaw River			
VCL	1962	0.12	3.30
Total		**0.12**	**3.30**
Strelley			
MC 106	1962–1964	0.65	0.371
VCL	1964	0.02	0.010
Total		**0.67**	**0.381**
Tabba Tabba			
ML 317	1928	1.02	–
ML 321, 322	1928	0.58	–
MC 312, 360	1955	[a]0.26	[a]0.188
MC 116	1957–1963	6.59	4.110
MC 116	1963	0.25	0.015
MC 621	1962–1965	0.34	0.171

Table 4.4. (continued)

Mining Centre tenements or company	*Period*	*Tantalite ore and concentrates (t)*	*Contained Ta_2O_5 (t)*
MC 674	1966	0.05	0.018
VCL	1969	1.46	1.047
Total		**10.55**	
Trig Hill			
VCL	1961–1964	0.38	0.189
Total		**0.38**	**0.189**
Twin Sisters	1969	0.16	0.079
Total		**0.16**	**0.079**
Western Shaw			
Kincora Pty Ltd	1982–1984	80	24.326
Total		**80**	**24.326**
Wodgina			
VCL	1905–1907	52.33	–
ML 86, 87, 95	1905–1930	106.17	–
ML 86, 87, 95, etc (Tantalite Ltd)	1932–1947	90.07	–
ML 293	1925	2.03	–
ML 352	1932	0.46	–
ML 89	1934	0.51	–
MC 260	1955–1959	2.21	1.348
MC 373, 378, 380, 389, DC 109	1956	0.57	0.365
MC 107	1956	0.61	0.0306
MC 107, 355	1957–1968	3.23	1.951
PA 2413	1953	1.28	0.975
PA 2438	1955	[(a)]0.15	[(a)]0.107
PA 2454, 2456, 2458	1956	[(a)]0.37	[(a)]0.240
DC 126, 127, MC 364, 365	1956	[(a)]3.06	[(a)]1.908
VCL	1961–1971	2.53	1.063
DC 732	1968	2.83	0.880
DC 45/553, etc MC 45/107, etc (Goldrim Mining Aust. Ltd)	1978–1986	79	38.146
Goldrim Mining Aust. Ltd	1989–1991	[(b)]103	49.876
Pan West Tantalite Pty Ltd	1990	87	38.941
Total		**567**	
Upper Five Mile Creek			
MC 69, 83, 84, 86	1954–1959	[(a)]3.48	[(a)]2.229
MC 77	1955	[(a)]0.19	[(a)]0.127
VCL	1956	[(a)]0.05	[(a)]0.033
Total		**3.67**	
Total all areas		**1 629.38**	

NOTES: (a) includes mixed tantalite–columbite production
(b) concentrate figure estimated, based on tin recovered and previous grades from tenements

Table 4.5. Tin production from the East Pilbara (up to 1991)

Mining Centre tenements or company	*Period*	*Tin ore and concentrates (t)*	*Contained tin (t)*
Abydos			
VCL	1951–1966	0.18	0.12
DC 497	1965–1974	32.51	22.8
MC 45/384	1977	5	3
DC 700, 672	1985–1986	50	34
Total		**87.69**	**59.92**
Cooglegong			
VCL	Pre-1902–1970	1 930.08	–
DC 25, 26	1949–1955	185.14	125.56
DC 25, 26	1957–1959	84.17	58.21
DC 49, 50	1952–1954	4.92	3.50
DC 60	1954	0.21	0.15
DC 26, 27, 105	1955–1958	86.32	59.18
DC 53, 54, 57, 58, 103, 60, 143	1955–1975	2 398.84	1 365.08
DC 48, 49, 50, 129, 213, MC 382	1957–1963	169.71	113.72
MC 1203 etc	1970	3.67	2.49
Total		**4 858.06**	
Coondina			
DC 281, etc	1965–1968	51.86	35.30
MC 2158	1970–1972	25.34	18.54
MC 1457	1970–1973	34.54	24.89
PA2893	1970	15.89	11.19
VCL	1970–1972	23.94	17.5
MC 5433	1973	2.68	1.88
MC 1348, 1349	1973–1976	226.60	155.73
Total		**381.03**	**265.03**
Corunna Downs			
VCL	1965	0.85	0.59
Total		**0.85**	**0.59**
Eleys			
DC 32, 254, 281	1959–1973	1 509.67	849.87
VCL	1961–1963	4.25	2.91
Total		**1 513.92**	**852.78**
Marble Bar			
VCL	1961–1973	7.48	5.17
Total		**7.48**	**5.17**
Mills Find			
VCL	1906	0.86	–
Total		**0.86**	
Moolyella			
ML 22	1899–1901	42.93	–
ML 20, 21, 23	1899–1902	104.65	–
ML 16	1899–1901	9.22	–
ML 10, 12, 15, 18, 31	1899–1901	52.53	–
ML 5	1899–1900	26.42	–
ML 19	1899	2.0	–
ML 6	1899	1.52	–
ML 43, 44	1900–1903	33.02	–
ML 46	1900–1902	12.19	–
ML 45	1900	15.24	–
ML 13	1900	32.67	–
ML 11	1900	1.12	–
ML 29	1900	2.29	–
VCL	Pre-1902–1968	3 196.76	–
MC 152	1939–1940	2.59	–
MC 148	1940	0.56	–
DC 14, 16, 19, 22	1941–1953	20.55	–
DC 15	1942–1944	5.03	–
DC 68	1954–1956	57.89	38.88
DC 196	1956	28.3	19.27

Table 4.5. (continued)

Mining Centre tenements or company	*Period*	*Tin ore and concentrates (t)*	*Contained tin (t)*
MC 448	1956	0.70	0.44
DC 201, 195	1958–1973	2 752.97	1 934.01
MC 449	1958	22.38	14.95
DC 228, 229	1959–1967	464.79	319.92
DC 276, etc	1963–1968	139.29	94.30
DC 257	1962	0.83	0.57
DC 257	1963	3.13	1.97
DC 303	1963	6.49	4.46
TA 13	1963	0.55	0.39
MC 691, etc	1964–1971	181.77	121.71
DC 564	1964–1966	0.49	0.30
DC 474	1964	0.77	0.54
DC 654	1964–1966	0.49	0.30
MC 745	1965	1.14	0.77
DC 258	1965	0.74	0.46
PA 2733	1965	0.51	0.38
PA 2750	1965	0.21	0.12
DC 535	1966–1969	11.47	7.42
MC 815	1966–1968	3.56	2.39
DC 546	1966–1971	12.53	8.36
DC 276	1966–1968	6.39	4.20
DC 705	1966	0.70	0.48
DC 586, etc	1967	3.75	2.50
DC 493	1969	22.07	15.35
MC 871	1970	19.42	13.99
DC 684	1970	23.20	15.96
DC 585	1971	2.63	1.73
DC 195	1973–1978	516.00	366
MC 700	1973-1975	9.00	6.09
MC 45/668, etc	1978–1988	1 009.00	–
Total		**8 863.99**	
Mount Francisco			
MC 390	1957	0.13	–
VCL	1963–1965	1.60	0.84
PA 2751	1965	0.25	0.18
MC 910	1967	5.76	3.08
Total		**7.74**	
Old Shaw			
ML 39, 40, 41, 42	1899–1901	6.86	–
Sundry claims	Pre-1902–1935	225.56	–
Total		**232.42**	
Pilgangoora			
Sundry claims	1947–1956	1.03	–
MC 174, 175	1956	1.47	0.91
MC 291, 381	1956	0.83	0.62
MC 291, 425	1956–1958	10.19	6.76
MC 381, 385	1957	0.20	0.12
MC 45/920, DC 45/755	1979–1982	90.00	30.00
Total		**103.72**	
Spearhill			
MC 45/383, etc	1975	105.49	63.29
Total		**105.49**	**63.29**
Split Rock			
DC 481	1966–1969	34.95	23.46
Total		**34.95**	**23.46**
Shaw River			
VCL	1966	1.86	1.34
Total		**1.86**	**1.34**
Strelley			
MC 106	1963	0.06	0.02
VCL	1963	0.04	0.03
Total		**0.10**	**0.05**

Table 4.5. (continued)

Mining Centre tenements or company	*Period*	*Tin ore and concentrates (t)*	*Contained tin (t)*
Tabba Tabba			
Sundry claims	1916–1929	119.69	–
ML 313, 362	1935–1957	11.37	–
PA 2611	1960	0.56	0.38
VCL	1960	0.30	–
Total		**131.92**	
Tambourah			
DC 691, etc	1966–1968	7.64	5.02
Total		**7.64**	**5.02**
Western Shaw	1982–1985	186.00	–
Total		**186.00**	
Wodgina			
ML 77	1902–1907	6.20	–
Sundry claims	1903–1952	57.63	–
ML 84	1904–1909	149.73	–
ML 93	1906–1907	9.82	–
ML 89	1906–1910	14.94	–
ML 88	1906	0.36	–
ML 85	1906	3.00	–
ML 84, 93, 148	1908–1919	200.27	–
ML 178	1910–1914	3.56	–
ML 203	1912–1914	1.63	–
ML 195	1912	0.36	–
ML 192	1912	0.30	–
ML 213	1912	1.07	–
ML 198	1912	0.91	–
ML 255	1913–1915	2.49	–
ML 86, 87, 95	1917	5.08	–
MC 109	1965	4.00	2.15
DC 732	1968	3.99	2.46
VCL	1970	1.12	0.67
MC 45/10093, 10095	1982	10.00	–
DC 45/553, etc MC 45/107, etc (Goldrim Mining Aust. Ltd)	1978–1991	58.00	–
Total		**534.46**	
Upper 5 Mile Creek			
MC 92, 93	1955	0.33	0.20
Total		**0.33**	**0.20**
Total all areas		**17 060.51**	

Table 4.6. Gold production in the east Pilbara (1897–1983 and 1985–1998)

Mining Centre	*Period*	*Gold mined (kg)*	*Alluvial and dollied gold (kg)*	*Total gold (kg)*
Bamboo Creek	1897–1983	2 186.95	33.703	2 220.656
	1985–1995	4 279.949	–	4 279.949
Boodalyerrie	1897–1983	17.91	8.081	25.992
Breens Find	1897–1983	2.078	–	2.078
Eastern Creek	1897–1983	307.599	0.533	308.132
Elsie	1897–1983	52.266	0.122	52.388
Lallah Rookh	1897–1983	80.48	0.149	80.692
Marble Bar	1897–1983	5 103.83	30.281	5 134.112
McPhees Creek	1897–1983	4.29	–	4.29
Middle Creek	1897–1983	717.806	–	717.806
Moolyella	1897–1983	0.293	–	0.293
Mosquito Creek	1897–1983	399.945	1.647	401.592
North Pole	1897–1983	109.23	16.013	125.243
	1988–1994	1 052.675	–	1 052.675
North Shaw	1897–1983	26.305	–	26.305
Nullagine	1897–1983	2 612.32	56.024	2 668.344
Pilgangoora	1897–1983	20.488	0.517	21.005
	1995–1998	3 822.867	–	3 822.867
Sharks	1897–1983	69.132	1.061	70.193
Talga	1897–1983	57.655	2.897	60.552
Tambourah	1897–1983	65.166	7.913	73.079
Twenty Mile Sandy	1897–1983	140.684	0.528	141.212
Warrawoona	1897–1983	934.165	0.942	935.107
Western Shaw	1897–1983	25.476	0.622	26.098
Wymans Well	1897–1983	45.25	1.334	46.584
Yandicoogina	1897–1983	195.976	4.808	200.784
Total		**22 330.79**	**167.175**	**22 498.028**

Table 4.7. Historical lead production from the east Pilbara (up to 1983)

Mining Centre or tenements	*Period*	*Lead ore and concentrate (t)*	*Average grade (%)*	*Contained lead (t)*
Abydos Station	1949	1.00	78.0	0.78
Total		**1.00**	**78.0**	**0.78**
Doolena Gap				
MC 330	1955	8.17	59.49	4.86
Total		**8.17**	**59.49**	**4.86**
North Pole				
PA 2274	1945	1.06	56.6	0.60
Total		**1.06**	**56.6**	**0.60**
Braeside (Ragged Hills)				
ML 295	1925–1928	46.74	69.64	32.55
ML 288	1925–1927	28.96	65.02	18.83
ML 289	1925	1.52	69.74	1.06
ML 297	1926–1929	21.18	68.70	14.55
MC 170, 171	1947–1950	39.27	68.60	26.94
MC 189	1949–1960	4 408.38	66.96	2 952.07
MC 194	1949–1951	18.19	41.12	7.48
MC 184, 190	1949	19.29	74.70	14.41
MC 185, 186	1949	31.71	65.97	20.92
MC 195	1949	3.15	68.57	2.16
MC 198	1949	5.63	70.52	3.97
MC 203	1949	4.83	69.36	3.35
MC 215	1949	4.26	65.02	2.77
MC 216	1950	6.51	68.20	4.44
MC 206	1951	4.48	72.10	3.23
MC 227	1952–1954	32.87	61.48	20.21
MC 249	1952	4.96	54.84	2.72
MC 193	1952	6.8	40.59	2.76
MC 184	1953–1956	16.50	65.94	10.88
MC 185	1955	5.74	65.33	3.75
MC 255	1953–1955	14.31	69.18	9.90
MC 267	1955	9.98	73.55	7.34
MC 450	1958	11.24	57.56	6.47
PA 2256	1949	14.97	66.93	10.02
PA 2257	1949	0.70	74.28	0.52
PA 2258	1949	0.75	76.00	0.57
PA 2263	1949	4.48	49.33	2.21
PA 2295	1949	3.96	68.94	2.73
PA 2336	1951	5.28	70.08	3.70
PA 2366	1952	10.85	60.65	6.58
PA 2375	1952	13.95	50.04	6.98
PA 2399	1953	2.61	58.24	1.52
PA 2511	1956	16.94	76.51	12.96
VCL	1953	1.37	68.61	0.94
Total		**4 832.59**	**67.56**	**3 258.10**

Table 4.8. Historical copper production from the east Pilbara (up to 1983)

Mining Centre	*Tenements*	*Period*	*Copper ore and concentrates (t)*	*Cupreous ore and concentrates (t)*	*Average grade (%)*	*Contained copper (t)*
Copper Hills	GML 314	1952–1964	–	15 455.67	12.58	1 944.77
	GML 314	1952–1964	49.22	–	35.08	17.27
	PA 746	1955	–	2.84	13.17	0.37
	PA 746	1956	422.95	–	24.52	103.7
	MC 103, 104, 105, 109	1955–1957	–	151.88	17.27	26.89
	MC 117	1955–1962	–	118.47	18.65	22.08
Total			**472.17**	**15 728.86**	**13.05**	**2 114.52**
Glen Ellen Pool	PA 859	1964	–	38.08	27.01	10.28
	PA 857	1964	–	18.44	18.15	1.84
	MC 382	1964–1966	–	252.66	16.94	42.79
	MC 382	1966–1971	–	200.48	21.73	43.58
Total				**509.66**	**19.33**	**98.56**
Lionel	PA 817	1961	–	30.95	16.27	5.03
	PA 816	1961–1962	–	51.84	12.71	6.59
	MC 377 (ex PA816 & 817)	1962–1965	–	198.08	14.04	27.80
	MC 112	1956	–	39.62	16.55	6.56
	PA 853	1964	–	0.99	7.00	0.07
			39.71	–	25.71	10.21
Total			**39.71**	**375.23**	**15.30**	**67.63**
Middle Creek	PA 809	1961	–	4.04	8.88	0.36
	PA687	1951	7.62	–	5.38	0.41
Total			**7.62**	**4.04**	**6.60**	**0.77**
Dohertys	MC 806	1965	–	5.36	13.5	0.72
		1965	–	4.07	12.4	0.51
Total				**9.43**	**13.04**	**1.23**
Lalla Rookh	PA 2730	1964–1965	–	13.81	15.03	2.08
Total				**13.81**	**15.03**	**2.08**
Marble Bar	MC 1614	1970	–	14.4	17.12	2.50
	PA 2874	1969	–	26.33	20.69	5.45
	PA 2474	1955	–	57.32	9.6	5.5
	ML 185	1911	11.20	–	14.9	1.67
Total			**11.2**	**98.28**	**13.81**	**15.12**
Boodalyerrie		1954	–	0.95	13.2	0.12
Total				**0.95**	**13.2**	**0.12**
Boodarrie Station	PA 2508	1956	–	1.22	5.90	0.07
Total				**1.22**	**5.90**	**0.07**
Mount Berghaus	1954		–	1.20	9.20	0.11
Total				**1.20**	**9.20**	**0.11**
Mount Francisco	PA 2529	1957	–	4.24	4.23	0.18
Total				**4.24**	**4.23**	**0.18**
North Pole	MC 209	1955–1957		289.56	12.16	35.22
		1911	9.5	–	14.84	1.41
		1957	43.52	–	11.17	4.86
Total			**53.02**	**289.56**	**12.11**	**41.49**
North Shaw	PA 2585	1959	–	2.2	15.8	0.35
	PA 2506	1956	–	1.59	17.4	0.28
	PA 2492	1955	–	1.26	14.2	0.18
		1907	7.89	–	24.46	1.93
Total			**7.89**	**5.05**	**21.17**	**2.74**
Pilgangoora	MC 439	1956	–	10.81	7.50	0.81
	PA 2680	1963	–	16.32	9.52	1.55
		1964	–	23.36	7.45	1.74
Total				**50.49**	**8.14**	**4.1**
Stannum	PA 2687	1963	–	3.71	6.25	0.23
Total				3.71	6.25	0.23
Stinking Pool	MC 633	1963	–	10.43	6.25	0.91
Total				**10.43**	**6.25**	**0.91**

Table 4.8. (continued)

Mining Centre	*Tenements*	*Period*	*Copper ore and concentrates (t)*	*Cupreous ore and concentrates (t)*	*Average grade (%)*	*Contained copper (t)*
Woodstock	GML 1141	1958	–	9.09	8.12	0.74
Total				**9.09**	**8.12**	**0.74**
Wymans Well		1954	–	2.09	13.87	0.29
Total				2.09	13.87	0.29
Yandicoogina	PA2614	1960	–	28.92	13.84	4.00
			5.89	–	15.86	0.93
Total			**5.89**	**28.92**	**14.16**	**4.93**
Total all areas			**597.5**	**17 092.28**		

Table 4.9. Tungsten production from the east Pilbara (1951–1967)

Mining Centre tenements or company	*Period*	*Scheelite ore and concentrates (t)*	*Wolframite ore and concentrates (t)*	*WO_3 (t)*
Nullagine				
GML 307	1957	3.05	–	0.138
Total		**3.05**		**0.138**
Cookes Creek				
MC 60, 61	1954	2.54	–	1.228
MC395	1967	–	0.70	0.409
Total		**2.54**	**0.70**	**1.637**
Lower Mosquito Creek				
MC 26, 27, 28	1951–1953	–	19.17	12.535
VCL	1951	–	3.15	2.168
MC 30, 31, 32	1952	–	1.91	1.248
Total			**24.23**	**15.951**
Talga Talga				
VCL	1951	–	0.15	0.095
Total			**0.15**	**0.095**
Burrows Well				
MC 244, 245	1952	–	0.62	0.414
Total			**0.62**	**0.414**
Total all areas		**5.59**	**25.7**	

Table 4.10. Beryl production from the east Pilbara (up to 1991)

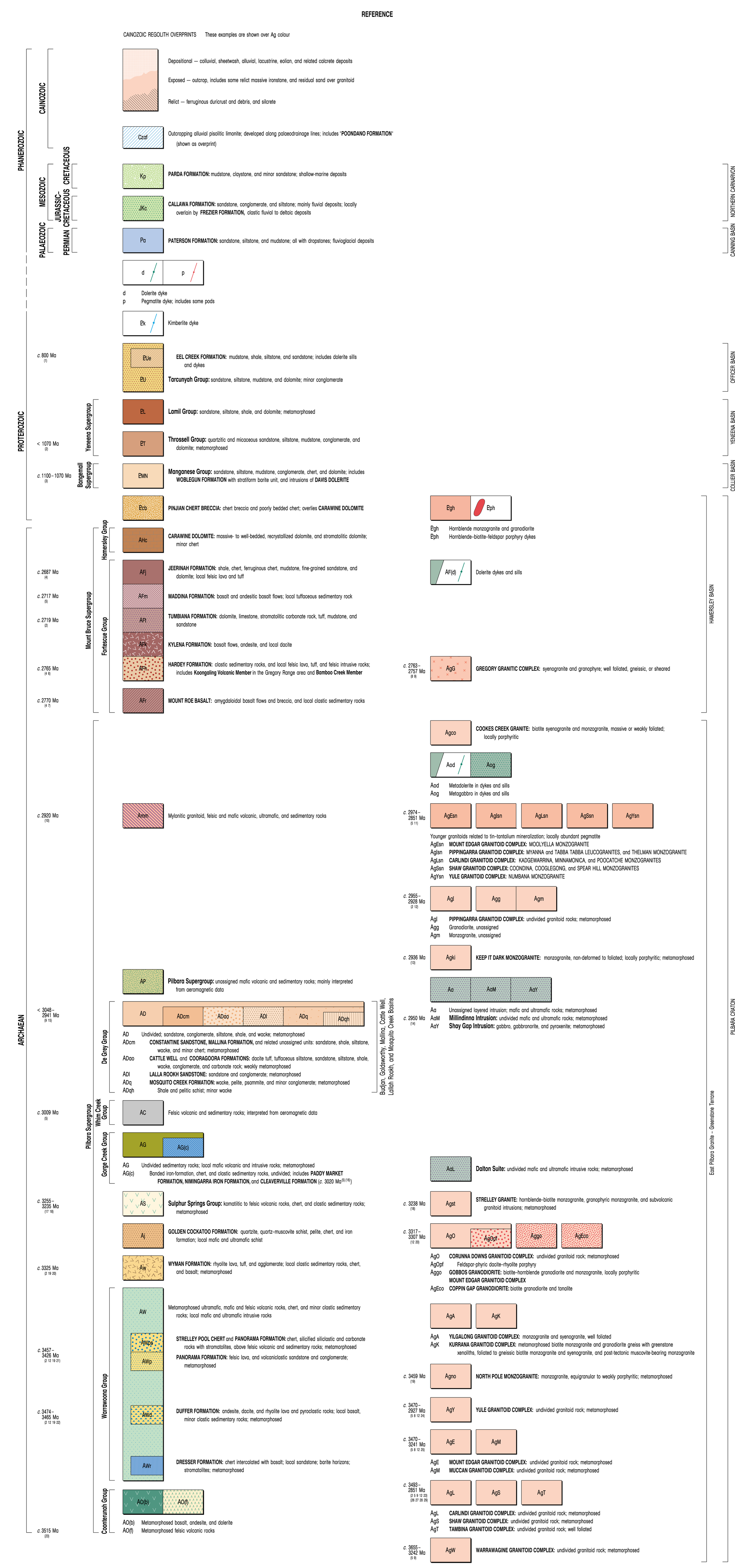
Mining Centre tenements or company	*Period*	*Beryl ore (t)*	*BeO (t)*
Abydos			
VCL	1952–1960	13.97	1.664
PA 2639	1962	3.84	0.410
Total		**17.81**	**2.074**
Ailsa Downs			
VCL	1951–1954	61.68	7.427
Total		**61.68**	**7.427**
Cooglegong			
VCL	1948–1963	96.18	11.375
Total		**96.18**	**11.375**
Eleys			
VCL	1954	0.60	0.073
Total		**0.60**	**0.073**
Hillside Station			
VCL	1953–1955	3.27	0.401
PA 2555	1957	6.98	0.888
Total		**10.23**	**1.289**
Lalla Rookh			
VCL	1952	4.41	0.454
Total		**4.41**	**0.454**
Moolyella			
PA 2462	1954	5.10	0.51
VCL	1954	5.95	0.652
Sundry producers	1971	1.15	0.115
Total		**12.2**	**1.277**
Mount Francisco			
ML 365	1947–1949	27.98	3.534
VCL	1948–1961	55.34	6.597
MC 234	1951–1954	6.82	0.825
PA 2413, MC 306	1952	2.96	0.373
MC 294, 306, PA 2413	1953–1955	4.86	0.560
MC 286	1953–1955	18.51	1.980
PA 2411	1953	10.53	1.206
MC 304	1954–1965	68.68	8.128
MC 350	1954–1957	47.44	5.545
MC 340, 343	1954–1963	19.84	2.406
MC 311	1954	2.12	0.259
MC 393, PA 2467	1955	2.19	0.264
PA 2442	1955	0.58	0.070
PA 2534	1956–1958	2.75	0.328
PA 2559	1957–1959	8.97	1.070
ML 370	1958–1963	31.05	3.594
PA2591, MC614	1959–1962	9.77	1.112
MC 512	1959	14.12	1.594
Total		**334.52**	**39.444**
Nimingarra			
VCL	1960	26.38	2.876
Total		**26.38**	**2.876**
Pilgangoora			
MC 385	1955	2.11	0.267
Total		**2.11**	**0.267**
Pippingarra			
MC 297	1953–1957	17.83	2.127
MC 313	1953–1957	180.13	21.684
VCL	1953–1958	4.86	0.591
MC 301	1953	1.33	0.126
PA 2437	1953	0.84	0.102
Total		**204.81**	**24.630**
Strelley			
MC354, PA 2416	1953–1958	16.82	1.941
MC 283	1954–1956	2.02	0.208
PA 2459	1955	1.20	0.143

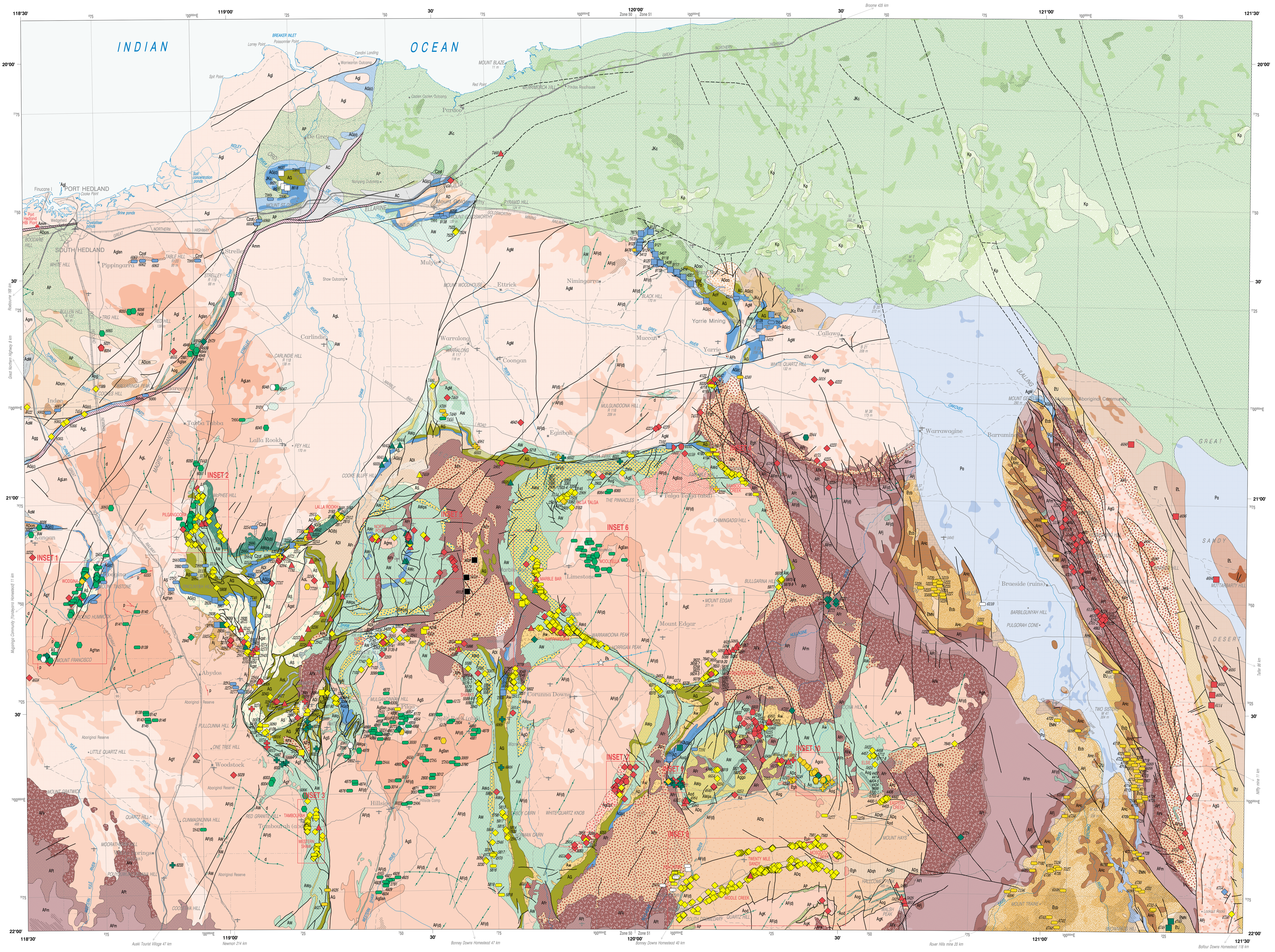
Table 4.10. (continued)

Mining Centre tenements or company	*Period*	*Beryl ore (t)*	*BeO (t)*
PA 2523	1956	0.66	0.079
MC 106	1957–1960	2.47	0.232
MC 106	1961–1964	15.39	1.743
Total		**38.56**	**4.347**
Tabba Tabba			
VCL	1955–1961	1.82	0.228
PA 2447	1955	0.30	0.038
MC 116	1956–1964	47.63	5.317
PA 2531	1956–1958	0.61	0.078
MC 312	1960	1.99	0.200
Total		**52.35**	**5.860**
Wallareenya			
MC 360	1955	0.84	0.099
Total		**0.84**	**0.099**
Wodgina			
MC 107 etc	1943–1953	766.36	87.458
MC 107	1958	0.92	0.075
PA 2116	1944	4.36	0.575
PA 2104	1944	47.43	5.727
PA 2096	1944	3.37	0.445
VCL	1945–1962	90.14	10.89
PA 2337	1950	1.01	0.128
PA 2410	1953	0.76	0.098
PA 2438	1954	4.22	0.460
MC 305, 314, 315, 355	1955	0.65	0.075
MC 352	1956	4.34	0.491
PA 2575	1957–1960	4.15	0.474
Total		**927.71**	**106.892**
Upper 5 Mile Creek			
VCL	1954–1958	3.46	0.351
MC 83, 84	1955	0.85	0.099
PA 775	1957	1.39	0.168
PA 774	1957	1.34	0.157
PA 790	1958	2.53	0.318
Total		**9.57**	**1.092**
20 Mile Creek			
PA 785	1958	0.60	0.061
Total all areas		**1 800.56**	

Table 4.11. Barite production from the east Pilbara (up to 1991)

Mining Centre tenements or company	*Period*	*Barite (t)*
North Pole		
MC 1102 (Associated Minerals Pty Ltd)	1970	528.34
MC 45/1522 Dresser Minerals International Inc	1976–1991	128 977
Total		**129 505.34**





SYMBOLS

Horizontal control; major

Abandoned (abd)

Watercourse

Mining centre MARBLE BAR

Treatment plant

Refer to Plate 1A for insets INSET 1

MINERAL OCCURRENCES

The detailed list of mineral occurrences is in Appendix 1 of Report 81

MINERALIZATION STYLES

- Kimberlite, lamproite, and carbonatite mineralization
- Orthomagmatic mafic and ultramafic mineralization
- Pegmatitic, skarn, greisen, and porphyry mineralization
- Vein and hydrothermal mineralization
- Stratabound volcanic and sedimentary mineralization
- Stratabound sedimentary mineralization
- Mineralization in the regolith

MINERAL COMMODITIES

- Precious mineral (Dmd, Emer, Gems)
- Precious metal (Au, Ag)
- Steel industry metal (Mn, Ni, W, Cr, Mo)
- Speciality metal (Sn, Ta, Li)
- Base metal (Cu, Pb, Zn, Sb)
- Iron
- Energy mineral (U)
- Industrial mineral
- Construction material

KEY TO OPERATING STATUS

Bold numbers	Operating mine
Bold and italic numbers	Abandoned mine
Plain numbers	Mineral deposit
Italic numbers	Mineral occurrence or prospect

MINERAL OR ROCK COMMODITIES

Antimony	Sb	Manganese	Mn
Chromium	Cr	Molybdenum	Mo
Copper	Cu	Nickel	Ni
Diamond	Dmd	Silver	Ag
Emerald	Emer	Tantalum	Ta
Gemstones	Gems	Tin	Sn
Gold	Au	Tungsten	W
Lead	Pb	Uranium	U
Lithium	Li	Zinc	Zn

Mineral occurrence data compiled by K. M. Ferguson, E. P. W. Peiris, and I. Ruddock

Geology and geochronology compiled by A. H. Hickman, F. Vanderhor, M. J. Van Kranendonk, I. R. Williams, and L. Bagas, using published GSWA maps (see sheet index) and RATAJKOSKI, M., BLEWETT, R. S., WELLMAN, P., and HUSTON, D. H., 2000, North Pilbara synthesis GIS: Australian Geological Survey Organisation, GIS Dataset-Regional Geoscience, CD-ROM

Geochronology by:

(2) D. R. Nelson, in press, GSWA Record 2001/2.
(4) N. T. Arndt et al., 1991, Australian Journal of Earth Sciences, v. 38, p. 261–281.
(5) D. R. Nelson, 1998, GSWA Record 1998/2, p. 56–58, 87–89, 133–135, 157–159, 166–171.
(6) R. T. Pidgeon, 1984, Australian Journal of Earth Sciences, v. 31, p. 237–242.
(7) M. T. D. Wingate, 1999, Australian Journal of Earth Sciences, v. 46, p. 493–500.
(8) D. R. Nelson, 1996, GSWA Record 1996/5, p. 143–155.
(9) D. R. Nelson, 1999, GSWA Record 1999/2, p. 94–103, 122–139, 163–169.
(10) A. H. Hickman, 2001, Geology of Dampier 1:100 000 Sheet, GSWA Explanatory Notes, p. 9.
(11) P. D. Kinny, 2000, written communication.
(12) D. R. Nelson, 2000, GSWA Record 2000/2, p. 70–89, 105–112, 126–132, 137–151, 168–171, 195–198, 203–206.
(13) M. J. Van Kranendonk, 2000, Geology of North Shaw 1:100 000 Sheet, GSWA Explanatory Notes, p. 50.
(14) R. H. Smithies, 1998, Geology of Mount Wohler 1:100 000 Sheet, GSWA Explanatory Notes, p. 19.
(15) R. H. Smithies et al., 1999, Precambrian Research, v. 94, p. 11–28.
(16) D. R. Nelson, 1997, GSWA Record 1997/2, p. 183–186.
(17) R. I. Thorpe, 1996, written communication.
(18) C. Brauhart, 1999, University of Western Australia PhD thesis (unpublished).
(19) R. I. Thorpe et al., 1992, Precambrian Research, v. 56, p. 169–189.
(20) M. E. Barley and A. L. Pickard, 1999, Precambrian Research, v. 96, p. 41–62.
(21) M. E. Barley et al., 1998, Precambrian Research, v. 88, p. 3–23.
(22) N. J. McNaughton et al., 1998, Precambrian Research, v. 60, p. 69–98.
(23) R. Buick et al., 1995, Nature, v. 357, p. 574–577.
(24) M. J. Van Kranendonk, 2000, written communication.
(25) I. S. Williams and W. J. Collins, 1990, Earth and Planetary Science Letters, v. 97, p. 41–53.
(26) D. E. L. Baker, 2001, written communication.
(27) N. J. McNaughton et al., 1998, Geological Society of Australia, Abstracts, no. 21, p. 271–273.
(28) I. S. Williams et al., 1993, Geological Society of Australia, Abstracts, no. 9, p. 169–171.
(29) T. E. Zegers, 1996, Geologica Ultraiectina, no. 146, 208p.

Other references:

(1) L. Bagas et al., 1995, GSWA Annual Review 1994–95, p. 55–63.
(3) D. McB. Martin and A. M. Thorne, 2001, GSWA Record 2001/5, p. 1–2.

Edited by C. Strong, K. Greenberg, and G. Loan

Cartography by A. Francois, S. Collopy, and E. Theedom

Mineralization information on this map is from non-confidential data held in the WAMIN database, GSWA at December 2000

Topography from the Department of Land Administration with modifications from geological field survey

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Department of Mineral and Petroleum Resources

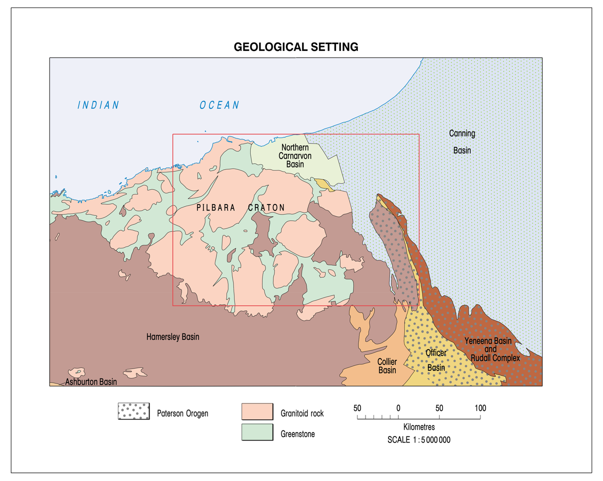
Geological Survey of Western Australia

TIM GRIFFIN
DIRECTOR

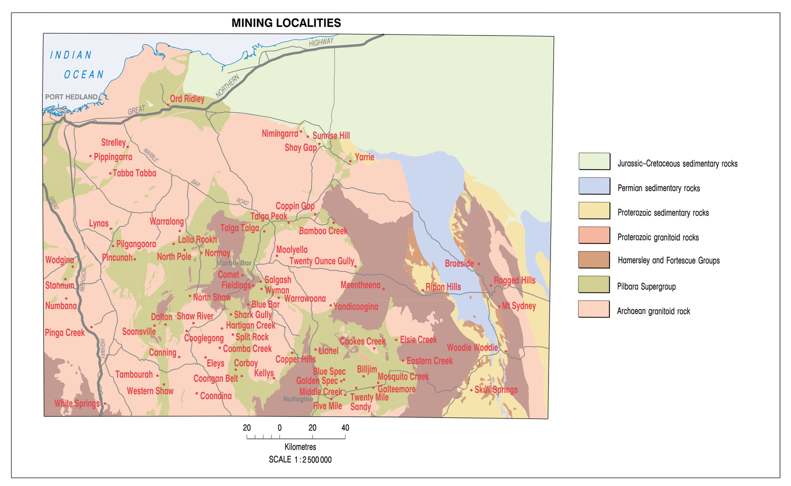
SCALE 1:500 000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION

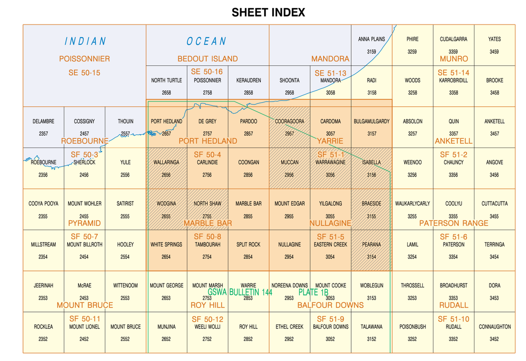
GEOLOGICAL SETTING

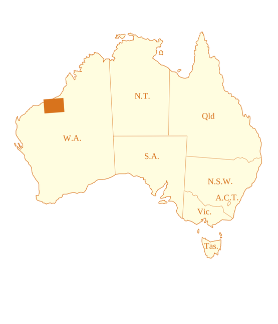


MINING LOCALITIES



SHEET INDEX



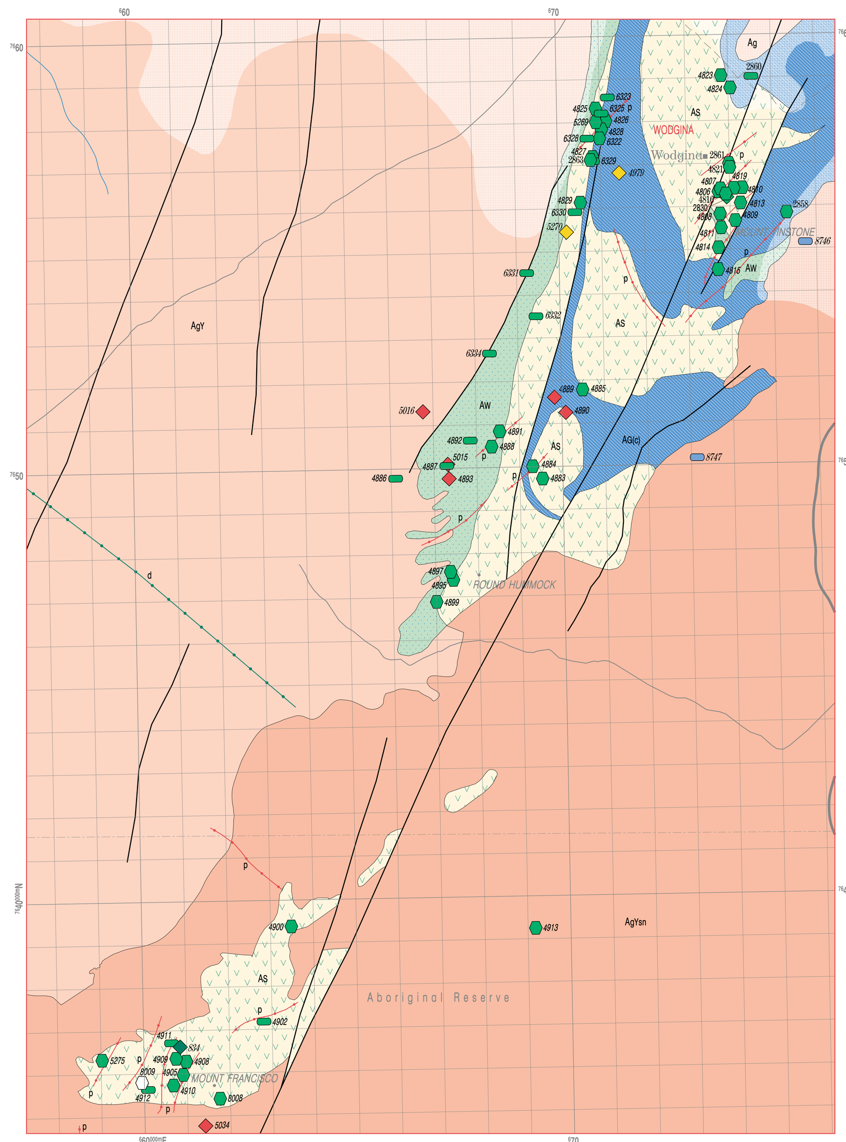


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

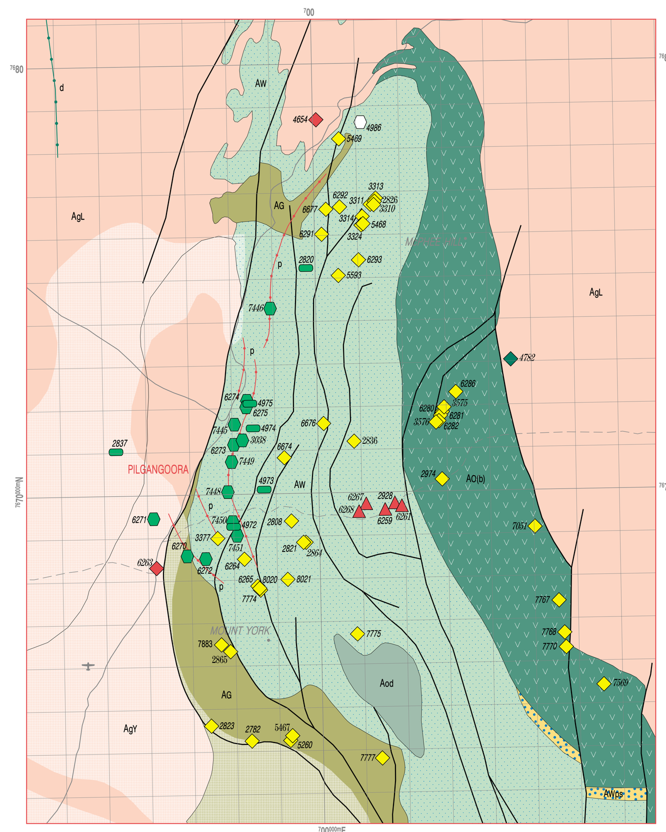
REPORT 81 PLATE 1

MINERALIZATION AND GEOLOGY OF THE EAST PILBARA

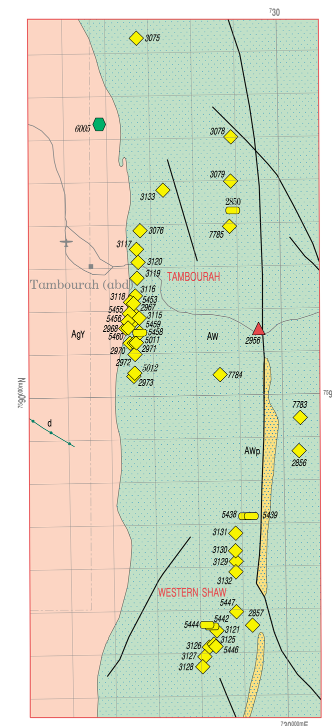
INSET 1 WODGINA AREA



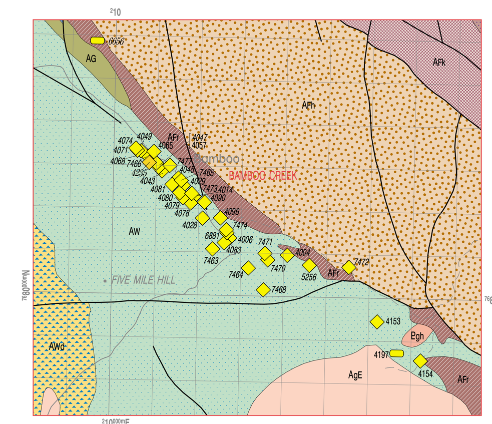
INSET 2 PILGANGOORA AREA



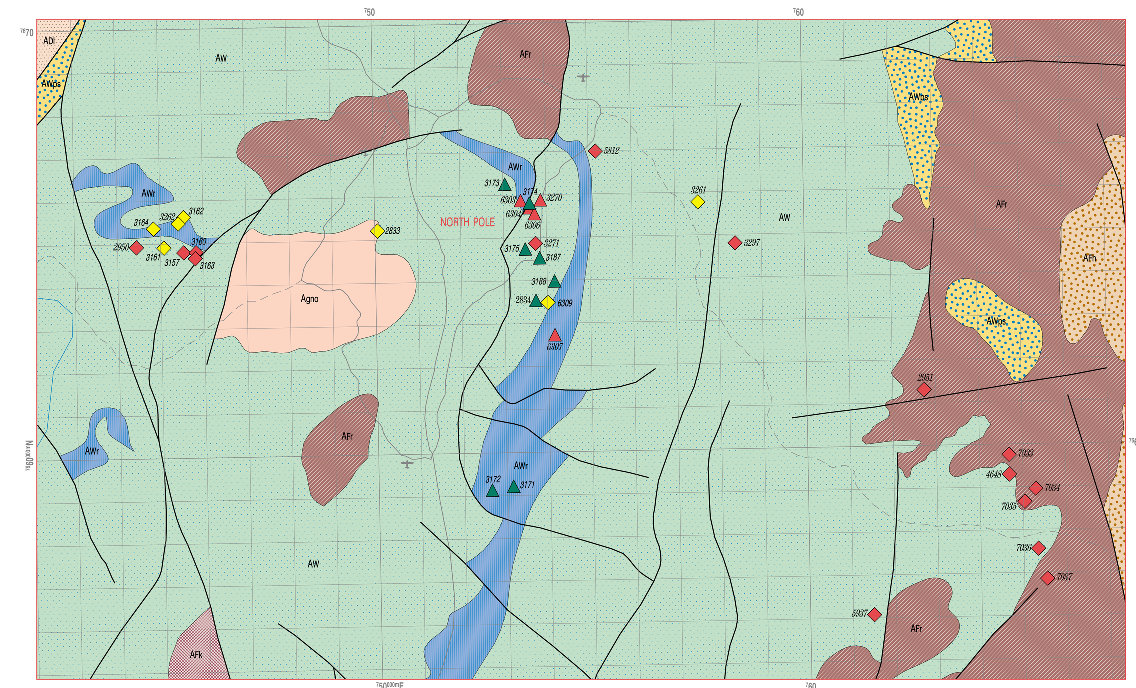
INSET 3 TAMBOURAH AREA



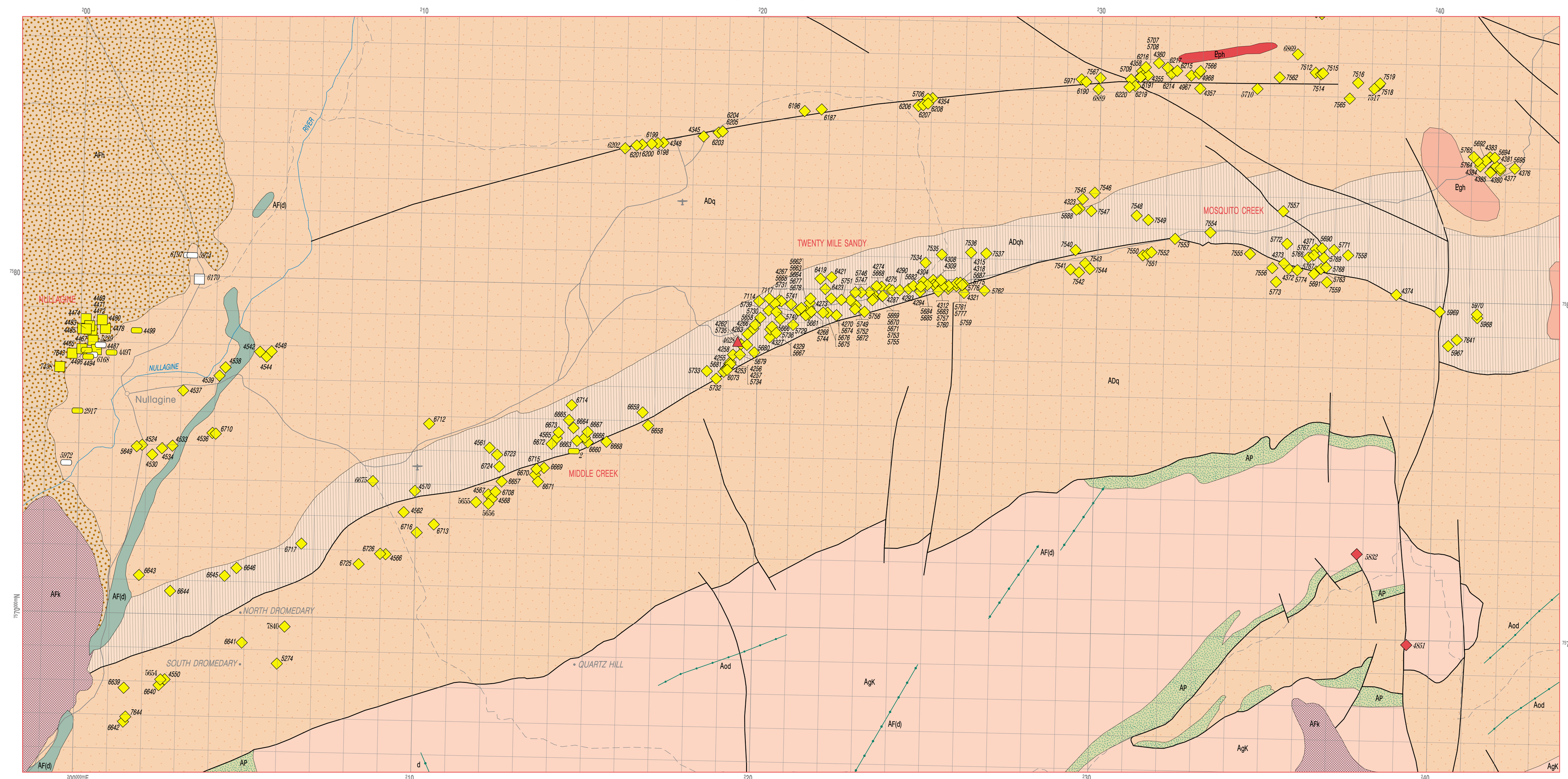
INSET 4 BAMBOO CREEK AREA



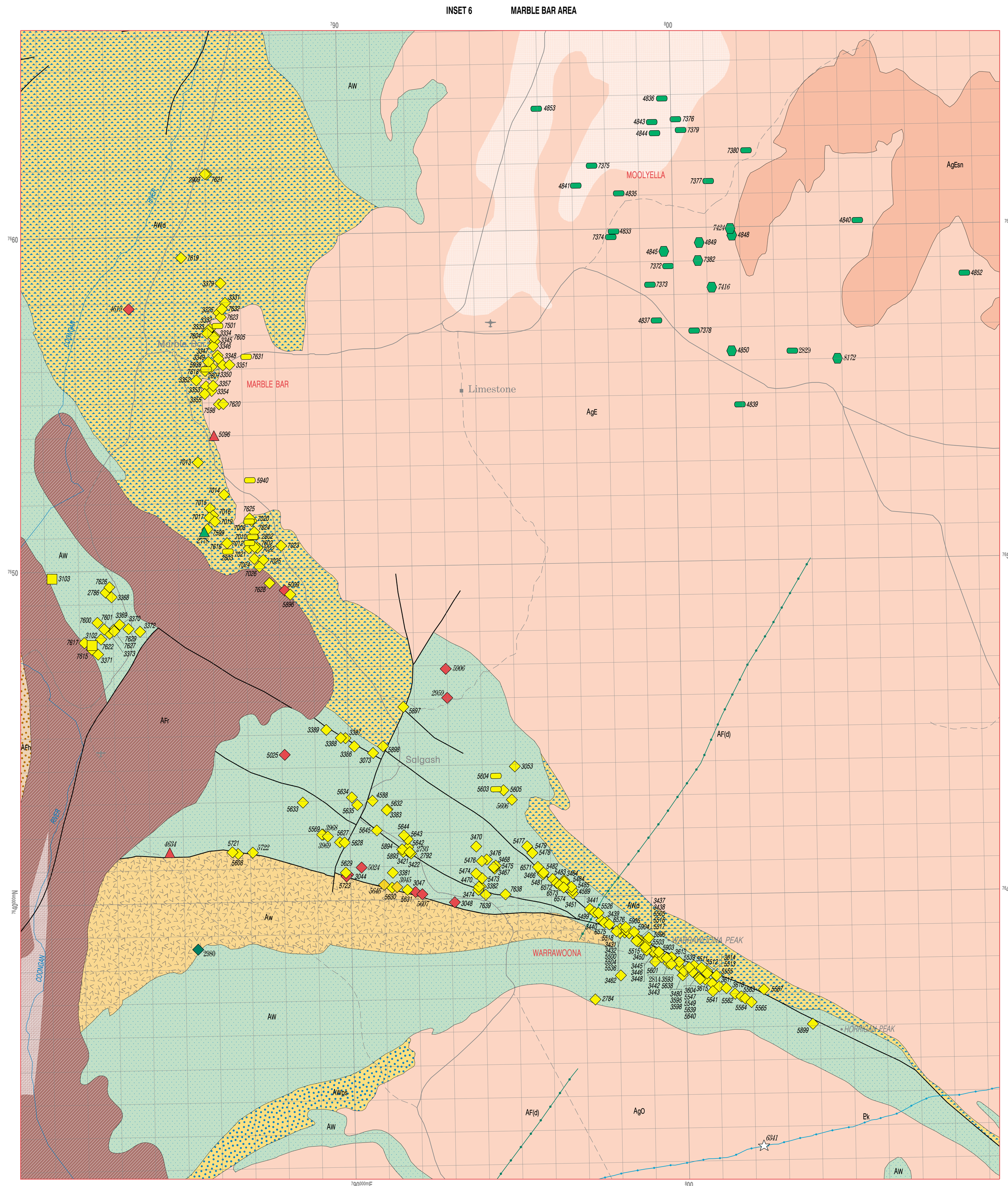
INSET 5 NORTH POLE AREA



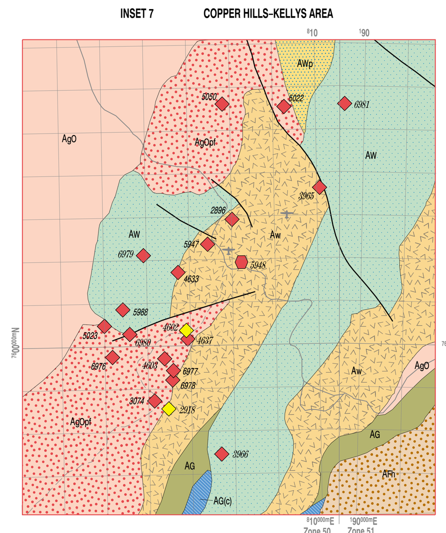
INSET 8 NULLAGINE AREA



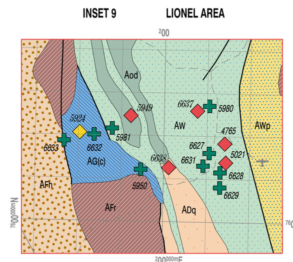
INSET 6 MARBLE BAR AREA



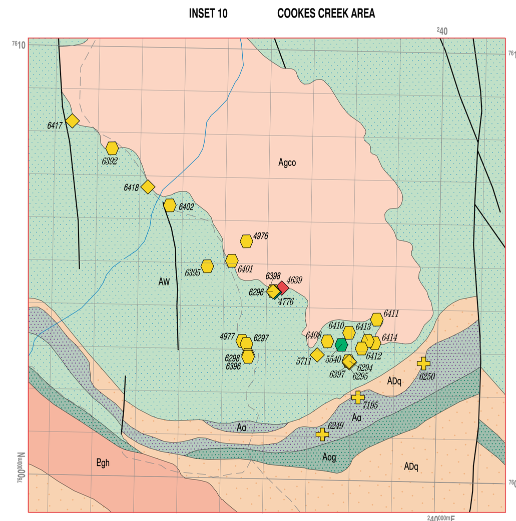
INSET 7 COPPER HILLS–KELLYS AREA



INSET 9 LIONEL AREA



INSET 10 COOKES CREEK AREA



MINERAL OCCURRENCES

The detailed list of mineral occurrences is in Appendix 1 of Report 81

MINERALIZATION STYLES

- Kimberlite, lamproite, and carbonatite mineralization
- Orthomagmatic mafic and ultramafic mineralization
- Pegmatitic, skarn, greisen, and porphyry mineralization
- Vein and hydrothermal mineralization
- Stratabound volcanic and sedimentary mineralization
- Stratabound sedimentary mineralization
- Mineralization in the regolith

MINERAL COMMODITIES

- Precious mineral (Dmd, Emer, Gems)
- Precious metal (Au, Ag)
- Steel industry metal (Mn, Ni, W, Cr, Mo)
- Speciality metal (Sn, Ta, Li)
- Base metal (Cu, Pb, Zn, Sb)
- Iron
- Energy mineral (U)
- Industrial mineral
- Construction material

KEY TO OPERATING STATUS

Bold numbers	Operating mine
Bold and italic numbers	Abandoned mine
Plain numbers	Mineral deposit
Italic numbers	Mineral occurrence or prospect

FOR REFERENCE SEE PLATE 1

Department of Mineral and Petroleum Resources

CLIVE BROWN, M.L.A.
MINISTER FOR STATE DEVELOPMENT
JIM LIMERICK
DIRECTOR GENERAL

Geological Survey of Western Australia

TIM GRIFFIN
DIRECTOR

SCALE 1:100 000

1000 0 1 2 3 4 5 6 7 8 9 10

Metres Kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 1000 metre interval of the Map Grid Australia Zones 50 and 51

The Map Grid Australia (MGA) is based on the Geocentric Datum of Australia 1994 (GDA94)
GDA94 positions are compatible within one metre of the datum WGS84 positions

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

REPORT 81 PLATE 1A

MINERALIZATION AND GEOLOGY OF THE EAST PILBARA—INSET MAPS