Queensland Minerals

A SUMMARY OF MAJOR MINERAL RESOURCES, MINES AND PROJECTS

Fourth edition

Compiled by Terry Denaro, Courteney Ramsden and Dominic Brown

Published by the Queensland Department of Mines and Energy

ISSN 1443-8747
ISBN 1 74172 091 5

Address for correspondence:
Department of Mines and Energy
Block A, 80 Meiers Rd
Indooroopilly, QLD 4068
AUSTRALIA
Phone: +61 7 3362 9506   Fax: +61 7 3362 9368

Queensland Government
Department of Mines and Energy

Acknowledgements

The author wishes to acknowledge the assistance of Len Cranfield and Ian Withnall in the preparation of the Geological Framework section of this report. The desktop publishing work by Sharon Beeston in the presentation of this report is also acknowledged.

Appendix 9, “The Australian Code for Reporting of Mineral Resources and Ore Reserves (The JORC code)”, is reprinted with permission of the Australasian Institute of Mining and Metallurgy.

CONTENTS

Queensland Minerals **Fourth edition**

A SUMMARY OF MAJOR MINERAL RESOURCES, MINES AND PROJECTS

Preamble

The Queensland Minerals publication is designed primarily to provide a summary of the major mineral resources in Queensland and to assist in promoting exploration and mining development. The following report presents known reserves/resources, production and geological information for the significant mines (both operating and abandoned) and prospects in Queensland. In addition to this publication there is a detailed database available on DVD called "Mineral Occurrence and Geology Observations" which contains all available data on mines, prospects and mineral occurrences in Queensland. Deposit summary reports have been produced from this database for the major deposits and are included as Appendixes 1 and 2. Tabulations of geology, resource and production data form the remaining appendices.

Introduction

Queensland is an important mineral producing state in Australia. In 2004–2005 the total value of production of Queensland's minerals was $4.3 billion (excluding coal and petroleum). Over the 10 year period ending June 2002, Queensland's processed mineral exports increased 105% to $A2.98 billion. The mining and processed mineral sectors currently account for more than half of Queensland's total merchandise exports and directly employs >19 000 people.

North Queensland contains several significant deposits including the epithermal gold-silver Pajingo deposit, intrusive-related mesothermal gold systems at Ravenswood and Charters Towers, lateritic nickel–cobalt deposits at Greenvale and Bell Creek, and volcanic-hosted massive sulphide (VHMS) deposits at Balcooma, Dry River South and Surveyor. The Cape York region, in far north Queensland, is well known for having undergone extensive lateritisation, producing large deposits of bauxite at Weipa and Aurukun and kaolin adjacent to the Skardon, Kendall and Pennefather Rivers. Along the east coast of far north Queensland, vast silica sand resources are mined at Cape Flattery.

North-west Queensland is a major base metals province and contains most of the state's giant orebodies, including Mount Isa (incorporating the Enterprise Cu and the Mount Isa, Hilton and George Fisher Ag-Pb-Zn orebodies), Century, Cannington, Ernest Henry, Osborne and Dugald River. This region produces about 74% of the value of metallic minerals recovered in Queensland and is Australia's largest source of copper. The Century zinc-lead-silver mine produces ~8% of the world zinc supply and the Cannington mine is currently the world's largest silver-lead producer. Extensive phosphorite deposits are mined at Phosphate Hill.

In central Queensland, epithermal gold deposits are mined at Cracow. Large lateritic nickel–cobalt resources have been defined in the Marlborough area and are being developed. This region also contains the world's largest deposit of cryptocrystalline magnesite at the Kunwarara Mine, north of Rockhampton. The magnesite is processed into caustic calcined, deadburned and electrofused magnesia, with future plans to diversify products further.

INFRASTRUCTURE

Queensland is positioned in an ideal location for servicing the mining industry, with the State's major mining centres supported by an integrated network of communications, power, water pipelines, fuel access, road, rail, port and airports.

Air Travel

Three international airports located in Brisbane; Townsville and Cairns facilitate overseas travel. Most regional centres are serviced by regular domestic aeroplane flights. However, remote mines usually fly employees out to the mine site using either their own planes or chartered flights.

Road

Queensland roads provide an efficient network of well-maintained major urban and rural roads totalling around 178 000km. Road access reduces transport costs for companies and impacts on their competitive position in the domestic and global marketplace.

Rail

Queensland currently has 9640km of railway line in the rail network, of which 1877km is electrified with a 25 000v 50Hz AC supply. The rail network is narrow gauge (1067mm), except for 99km of standard gauge (1435mm) track between Brisbane and the Queensland–New South Wales border and 36km of dual gauge. Queensland Rail (a Government-owned corporation) provides a fully coordinated commercial rail transport service to the mining industry. Queensland Rail finances funding for all locomotives and wagons required for the mining industry, except in circumstances where specialised equipment is necessary. Queensland Rail also maintains existing rail track and the rollingstock fleet, recovering costs through freight charges. Queensland Rail is the main commercial rail freight operator but third party access to the rail infrastructure is possible under recent rail reform programs.

Ports

The Queensland coastline is host to fifteen modern trading ports, two community ports and numerous non-trading ports. Trading ports predominantly handle bulk commodities, while community ports service local populations with general cargo. Port charges are set by commercial negotiation and there is no set government regulated schedule of fees. However, pilotage and conservancy dues (for channel beacons and marker maintenance) are government regulated.

Seven port authorities administer these ports. The ports of Brisbane, Bundaberg, Mackay, Townsville and Cairns are each managed by individual regional port authorities. The ports of Gladstone and Rockhampton are managed by the Central Queensland Ports Authority. The Ports Corporation of Queensland administers the remaining ports. Seven of these ports are used to export mineral products from the state to the international market.

The Queensland port system's total throughput in 2005–06 was 223.8Mt. Of the total exports of 186.3Mt, coal formed 76.8%, bauxite formed 16.4%, alumina and aluminium formed 2.2%, metals formed 2.2%, petroleum products formed 1.1%, and silica sand formed 0.8%.

The six main mineral handling ports are: -

The Port of Brisbane at Fisherman Islands, 20km east of the Brisbane central business district, is Queensland's largest multi-user and general cargo port. Trade throughput for 2005–06 was 26.7Mt which included the export of 217 272t of silica sand, and 292 052t of mineral ores and sands.

The Port of Gladstone is another multi-user port. Total trade throughput for 2005–06 was 67.23Mt. This included the export of 1 464 436t of cement/cement clinker, 124 048t of calcite, 52 585t of limestone, 100 402t of magnesia, 6119t of electrofused magnesia, 31 558t of magnesite, 351 884t of aluminium and 3 861 326t of alumina.

The Port of Townsville has nine operational berths (five equipped to handle metal and mineral cargo) equipped with bulk handling facilities including pipelines for oil, gas, chemicals and molasses; ship-loaders for sugar and metal concentrates; cranes for containers, metals, nickel ore and break-bulk cargo. Trade throughput for 2005–06 was 9.9Mt which included export of 634 730t of copper concentrate, 123 969t of refined copper, 559 635t of lead concentrate and ingots, 10 779t of nickel, 613 245t of zinc concentrate and ingots, 837 605t of high analysis fertiliser, and 31 037t of sulphuric acid. Imports included 3 313 150t of nickel ore and 232 235t of zinc concentrate.

The Port of Cape Flattery, 200km north of Cairns, is dedicated to the export of silica sand, with an annual capacity of up to 2Mtpa. In 2005–06, exports totalled 1 395 666t of silica sand.

The Port of Weipa, on the Embley River on the west coast of Cape York Peninsula, is a dedicated bauxite export port. Total bauxite throughput for 2005–06 was 17 927 086t. More than 70% of this was shipped to the Queensland Alumina Ltd and Yarwun alumina refineries in Gladstone. The remainder was shipped to the Eurallumina SpA refinery in Italy and a hydrating plant in Korea.

The Port of Karumba, at the mouth of the Norman River in the south-east corner of the Gulf of Carpentaria, is a general purpose port. In 2005–06 the port exported 1 100 400t of zinc concentrate and 135 500t of lead concentrate. Lead-zinc concentrate is pumped via a slurry pipeline from the Century mine, dried and transported on 5000t barges through the shallow inshore waters to larger export vessels.

Water

Water is the lifeblood of the State. The Department of Natural Resources and Water (NRW) manages dams, weirs and irrigation, as well as supplying bulk water for irrigation, mining, industrial and urban use.

NRW may license a company to take water direct from the source (river, stream or underground) or, by agreement, from dams, weirs, pipelines and borefields. Mining companies may also own and operate infrastructure, including dams, weirs, borefields and pipelines. NRW also has the authority to license privately developed water conservation and supply schemes.

The Queensland Government is in the process of implementing a new framework for allocating and managing the State's water resources. This framework is based on a formal water allocation and management planning process that promotes ecological sustainability and facilitates economic development, particularly in regional areas. The framework provides for the trading of water entitlements and the adoption of an effective pricing regime.

Energy

Queensland has substantial reserves of energy, ensuring its ability to provide economical and dependable electricity that is mainly derived from coal-fired power stations. Reserves of natural gas, oil and coal-bed methane supplement industrial and domestic requirements. Competitive market arrangements result in Queensland offering some of the lowest energy prices in the world.

The State currently has a generation capacity of more than 10 000 megawatts, and this increased with the physical connection of Queensland to the national grid in 2001. This ensured that consumers enjoyed the maximum benefits available from the competitive electricity market.

Queensland has considerable reserves of natural gas, which are playing an increasingly important role as a clean and cost-effective energy resource.

Queensland Government policy has also driven the exploration and development of the large coal seam gas (CSG) resources in central Queensland. The completion of a CSG pipeline from the northern Bowen Basin to Townsville will see greater use of CSG in the State's power generation. In 2004, total CSG production increased to approximately 27 Petajoules, equating to about 25% of Queensland's current gas demand.

Smelters/Refineries

Queensland Alumina Ltd Refinery — Gladstone: The Queensland Alumina Ltd (QAL) refinery at Gladstone is the world's largest alumina refinery and is owned by a consortium of three international companies — Comalco Aluminium Ltd (38.6%), Alcan South Pacific Pty Ltd (41.4%) and Rusal (20%). The refinery processes bauxite from Weipa and began production of smelter grade alumina in 1967. At commencement, the alumina production capacity of the refinery was 732 000t per year. Four major expansions have more than trebled QAL's capacity to 3.8Mt of alumina per year. The refinery uses the Bayer process, in which the aluminium component of bauxite ore is dissolved in sodium hydroxide. Alumina trihydrate is precipitated and calcined to produce alumina (aluminium oxide). Output in 2004 totalled 3.77Mt of alumina (website http://www.comalco.com/freedom.aspx?pid=406).

Yarwun Alumina Refinery — Gladstone: The Yarwun alumina refinery is 10km north-west of Gladstone. It is 100% owned by Comalco Aluminium Ltd, a subsidiary of Rio Tinto Aluminium. The first stage of the refinery has an annual capacity of 1.4Mt of smelter-grade alumina. The refinery design allows for expansion to an annual production of >4Mt. The first shipments from the refinery were made in November 2004. Output in 2004 totalled 175 000t of alumina (website http://www.comalco.com/freedom.aspx?pid=407).

Boyne Smelters Ltd — Gladstone: Boyne Smelters Ltd is located on Boyne Island, just south of Gladstone and is owned by a joint venture between Comalco (59.39%) and six junior partners. It is the largest aluminium smelter in Australia and also one of the world's largest.

Alumina is transported by a 10km conveyor from the QAL refinery to Boyne Smelters Ltd (BSL) for the third stage of the aluminium production process — smelting. The smelter began operation in 1982 and uses the Hall-Heroult process to reduce alumina to aluminium metal. Following the commissioning of a $1 billion expansion in 1997, BSL now has an annual production capacity of 490 000t of aluminium.

The smelter operates three reduction lines, a metal casting house, an anode production plant and ancillary facilities. Almost 60% of the aluminium produced is in the form of purity ingot for the Japanese and South East Asian market. T-bar is another purity product produced by the cast house. The remainder is cast as alloy in the form of extrusion billet for further processing in Australia and for export to Asian extrusion mills. Production in 2004 totalled 541 000t of aluminium (website http://www.comalco.com/freedom.aspx?pid=224).

Mount Isa copper and lead smelters — Mount Isa: The Xstrata copper smelter in Mount Isa smelts concentrates from the Mount Isa and Ernest Henry mining projects in north-west Queensland. There are three main stages in the copper smelter — the Copper ISASMELT furnace which produces matte copper (58 to 62% copper), the four converters which produce blister copper (97% copper) and the anode furnace producing copper anode (99.7% copper). The copper anodes produced in Mount Isa are then railed to the Townsville copper refinery for refining to cathode copper.

The copper smelter is undergoing an expansion to increase its capacity from 240 000t per annum to 280 000t per annum by the end of 2006 and to 300 000t per annum during the first half of 2007.

The lead smelter uses an ISASMELT furnace to treat lead concentrates from the Mount Isa, Hilton and George Fisher deposits to produce crude lead that is treated at Xstrata Zinc's United Kingdom refinery to produce high-quality lead, lead alloys and silver (website http://www.xstrata.com/products.php).

Townsville Copper Refinery — Townsville: The Xstrata Townsville copper refinery is one of the world's leading electrolytic copper refineries. It produces 99.99% pure LME Grade A copper cathode from copper anode produced at Mount Isa. The refinery was originally opened in 1959.

The refinery uses the MIM-developed ISA PROCESS, which utilises permanent stainless steel cathode plates in association with copper cathode stripping machinery. The refinery has the capacity to refine 280 000t of copper per year. It is undergoing a A$3 million capital improvement project to convert its fuel source from liquid fuel to coal seam gas (website http://www.xstrata.com/products.php).

Sun Metals Zinc Smelter — Townsville: The Sun Metals Corporation (a subsidiary of Korea Zinc Company Ltd) zinc smelter is located at Stuart, 11km south of Townsville. The smelter commenced production in late 1999 and processes 420 000t per annum of zinc concentrates, mainly sourced from north-west Queensland, to produce ~200 000t of zinc metal. Concentrates are blended on site to provide a consistent chemical composition for the smelting process.

Approximately 360 000t of sulphuric acid is produced as a by-product and is used elsewhere in the state to produce high-quality agricultural fertilisers (website http://www.sunmetals.com.au).

Yabulu Nickel Refinery — Townsville: The Yabulu Nickel Refinery, 25km north-west of Townsville, is 100% owned by Queensland Nickel Pty Ltd, a subsidiary of BHP Billiton. It is one of the largest, most cost efficient lateritic nickel–cobalt plants in the world, with an annual processing capacity of ~3.6 million wet tonnes of lateritic ore. More than 10% of the world's nickel supply and ~8% of the cobalt supply come from Yabulu. The refinery was built in 1974 to process lateritic nickel ore from the Greenvale Mine, but today relies entirely on ore imported from New Caledonia, Indonesia and the Philippines.

A new cobalt plant was commissioned in 1997. The refinery uses a modified Caron hydrometallurgical (ammonia leach) process with an annual production capacity of ~32 000t of nickel and 1900t of cobalt. The refinery is currently implementing a two year, $450 million expansion program called the Yabulu Extension Project, which will extend the metal refining section of the existing refinery to process an intermediate product to be shipped from the primary processing facility at the Ravensthorpe mine in Western Australia. Nickel production capacity will increase to an estimated 76 000t per annum and cobalt capacity will increase to 3500t (website http://www.bhpbilliton.com/bb/ourBusinesses/stainlessSteelMaterials/qniYabuluRefinery.jsp).

GEOLOGICAL FRAMEWORK

(Compiled by Len Cranfield & Ian Withnall)

The geological framework outlined here provides a basic overview of the geology of Queensland and draws particularly on work completed by Geoscience Australia and the Geological Survey of Queensland.

Queensland contains mineralisation in rocks as old as Proterozoic (~1880Ma) and in Holocene sediments, with world-class mineral deposits as diverse as Proterozoic sediment-hosted base metals and Holocene age dune silica sand. Potential exists for significant mineral discoveries in a range of deposit styles, particularly from exploration under Mesozoic age shallow sedimentary cover fringing prospective older terranes.

The geology of Queensland is divided into three main structural divisions: the Proterozoic shield in the north-west and north, the Palaeozoic–Mesozoic Tasman Orogenic Zone (including the intracratonic Permian to Triassic Bowen and Galilee Basins) in the east, and overlapping Mesozoic rocks of the Great Australian Basin (Figure 1).

Proterozoic Shield

Rocks of Proterozoic age crop out in the Mount Isa Orogen and the Murphy Province as well as the McArthur and South Nicholson Basins in the north-west and the Etheridge Province and the Yambo and Coen Inliers and Savannah Province in the north. In addition, rocks of Neoproterozoic – Early Palaeozoic age crop out in the Georgina Basin in north-west Queensland, Iron Range Province in the north, Anakie Province in central Queensland, Cape River Province in the Charters Towers – Greenvale area and Barnard Province in the Innisfail coastal area.

NORTH-WEST QUEENSLAND

Mount Isa Orogen

Rocks of the Mount Isa Orogen are exposed over an area in excess of 50 000km^2 in north-west Queensland, roughly centred on the township of Mount Isa. They have been subdivided into three, broad, north-trending provinces — the **Western Fold Belt Province**, the **Kalkadoon–Ewen Province** and the **Eastern Fold Belt Province** (Figure 1).

The Western Fold Belt Province is subdivided into the Lawn Hill Subprovince in the west and the Leichhardt River Subprovince in the east, separated by the Mount Gordon Fault Zone. The Eastern Fold Belt Province is subdivided from west to east into the Wonga Subprovince, Quamby–Malbon Subprovince and Cloncurry Subprovince (Figure 2).

Detailed summaries of the geology of the Mount Isa area were given by Blake (1987), Blake & others (1990) and Blake & Stewart (1992). Dating of basin phases in the western part of the Mount Isa Orogen and their implication for basin development were reported by Page & Sweet (1998) whereas dating of rocks in the Eastern Fold Belt Province and their implications for crustal evolution was reported by Page & Sun (1998). In 2000, the then Department of Mines and Energy released a synthesis of the geology, tectonic history, metallogenesis and resource potential of the region (Queensland Department of Mines and Energy & others, 2000). The Geological Survey is undertaking a major update to the geology of this region as part of the Smart Exploration and Smart Mining Programs (2005–2010).

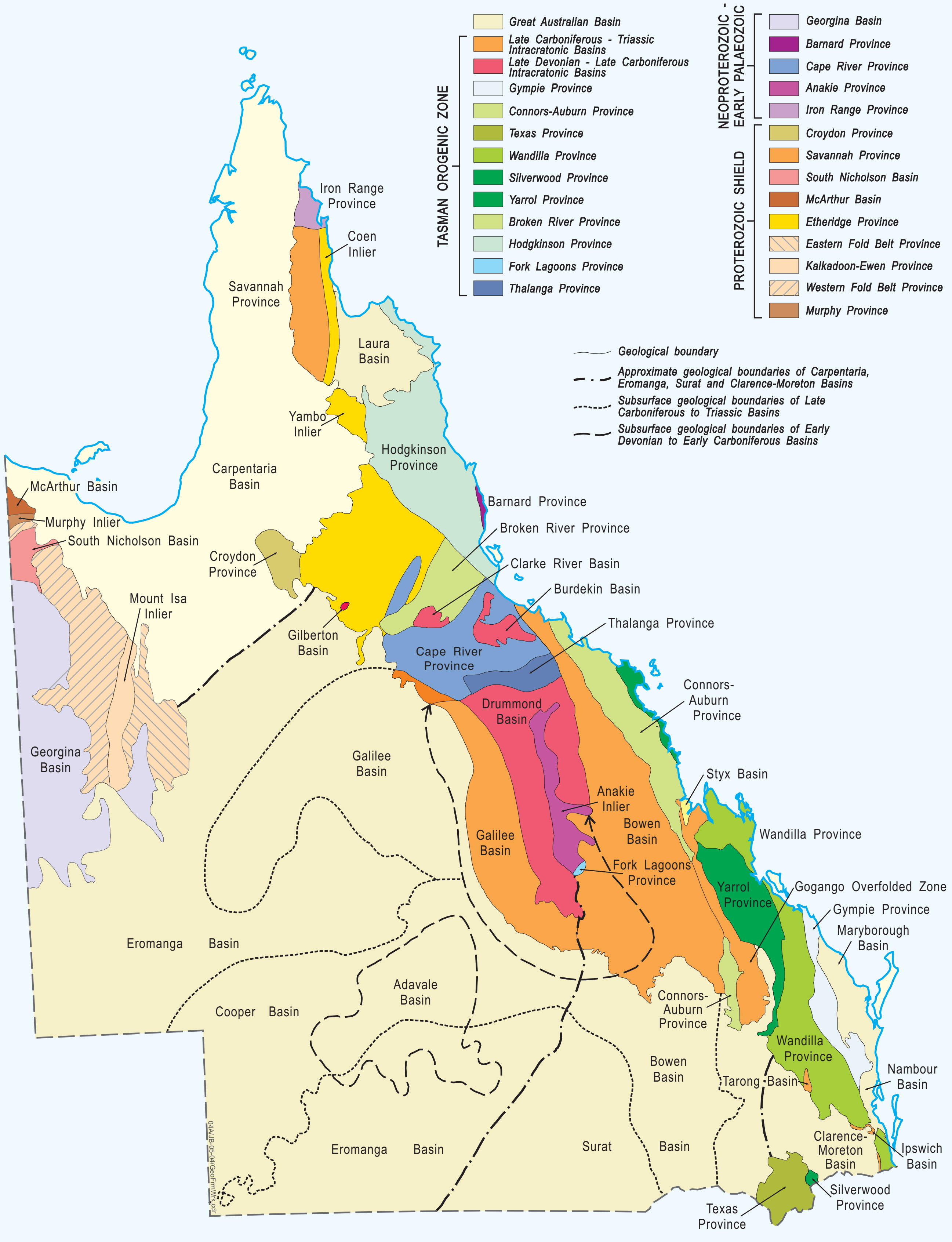
Two major Proterozoic age tectonostratigraphic cycles have been recognised. The earliest cycle is a basement sequence of sedimentary, volcanic and intrusive rocks that were deformed and metamorphosed at around 1870Ma during the Barramundi Orogeny. The later second cycle is represented by three cover sequences, as defined by Blake (1987) that were deposited during extensional tectonism and terminated by the compressional 1590–1495Ma Isan Orogeny. Page & Sweet (1998) have thrown doubt on the concept of discrete cover sequences occurring over the entire Mount Isa Orogen. However, for the purposes of this summary this terminology is maintained with some minor adjustments to take into account the results of more recent age dating.

The three cover sequences are major volcano-sedimentary packages separated by regional unconformities. Cover sequence 1 consists predominantly of 1870–1850Ma age felsic volcanic rocks related to the Barramundi Orogeny that are largely confined to the Kalkadoon–Ewen Province. Cover sequence 2 consists of widely distributed shallow water sedimentary rocks and bimodal volcanic rocks. Page & Sweet (1998) indicate that rocks of cover sequence 2 range in age from ~1790–1705Ma. Cover sequence 3 contains mainly finer-grained sedimentary and carbonate rocks with subordinate volcanic rocks, dated at 1675–1590Ma. Cover sequence 3 occurs predominantly within the Western Fold Belt Province and the western part of the Kalkadoon–Ewen Province. Most sedimentary rocks of the cover sequences were deposited in shallow marine and fluvial environments and most volcanic rocks were deposited subaerially, indicating the presence of a pre-existing continental basement.

At about the same time that rocks of Cover Sequence 3 were deposited in the Western Fold Belt Province, clastic and siliciclastic sediments and mafic volcanics of the Soldiers Cap Group were deposited in the Eastern Fold Belt Province. These rocks have been subjected to more intense deformation than the rocks in the west, with metamorphic grades ranging from greenschist to upper amphibolite.

Granites and mafic intrusions were emplaced at various times before ~1100Ma. Granites older than 1550Ma are metamorphosed and generally deformed. From west to east the main batholiths exposed are the Sybella (1670Ma) in the Western Fold Belt Province, the Kalkadoon and Ewen (1870–1850Ma) in the Kalkadoon–Ewen Province, the Wonga (1750–1725Ma) in the Wonga Subprovince, and the post-orogenic Williams and Naraku Batholiths in the

Queensland Geological Framework



For current interactive resource and tenure maps (updated daily), connect to ...
http://www.nrw.qld.gov.au/mines, then click on interactive maps

Figure 1. Queensland Geological Framework

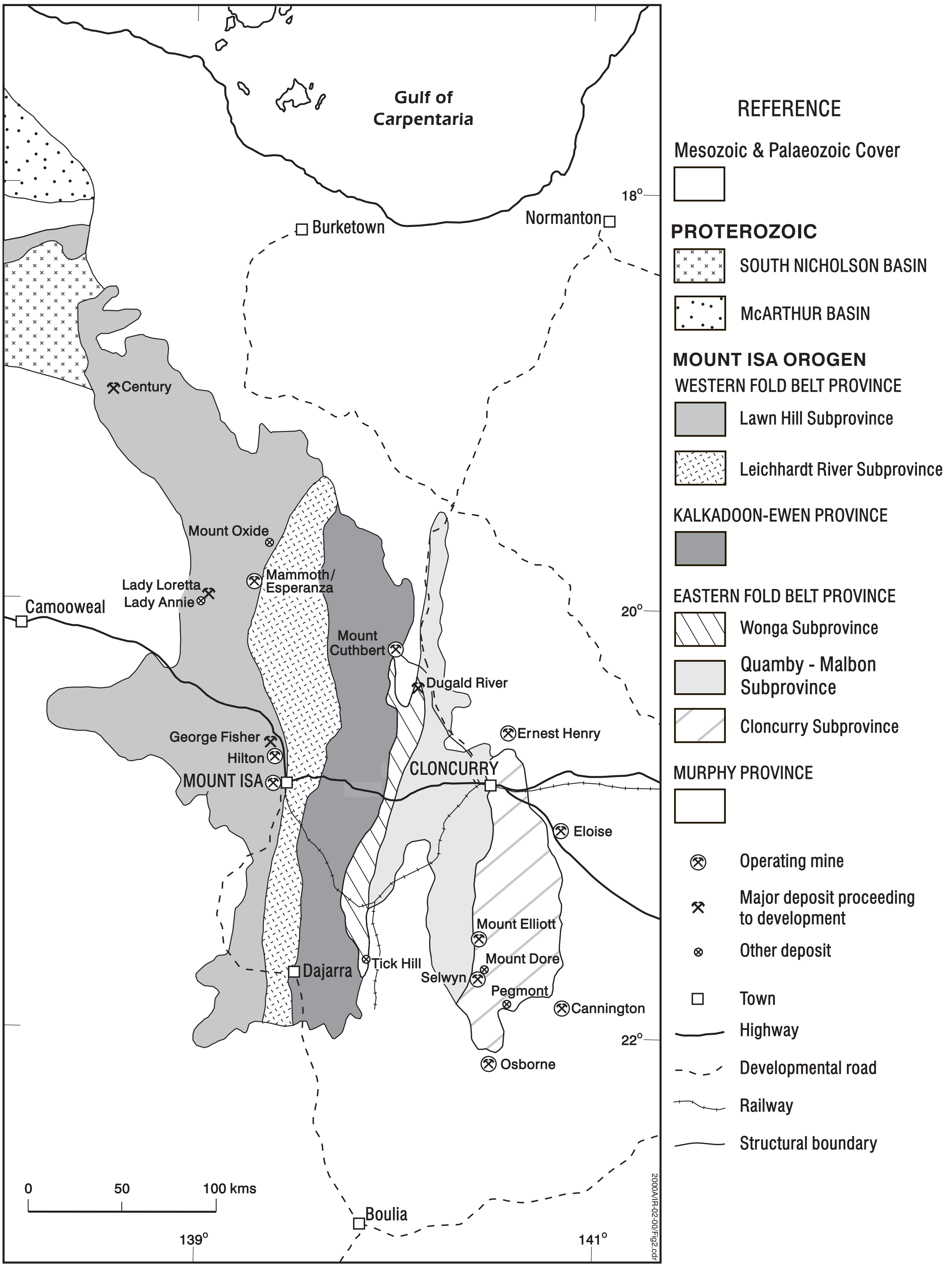


Figure 2. Geological framework of the Proterozoic shield in north-west Queensland

Quamby–Malbon and Cloncurry Subprovinces. Intrusives of the Williams and Naraku Batholiths have been shown to be of at least three different ages (1750–1730Ma, 1545–1530Ma and 1520–1490Ma).

The Mount Isa Orogen has had a complex history of deformation, which has been dominated at different periods by extension, shortening and transcurrent faulting (Blake & Stewart, 1992). The earliest deformation is recorded in basement units that were tightly folded and in places partially melted before the onset of volcanism of cover sequence 1. This early shortening is attributed to the Barramundi Orogeny. The Barramundi compressional event was followed by extension, leading to basin formation and deposition of rocks of cover sequence 2.

Extensional structures also postdated cover sequence 2, and are possibly coeval with the emplacement of the Wonga Batholith and hence are older than 1700Ma. Rocks of cover sequence 3 appear to have been deposited in an extensional basin.

At ~1620Ma an early phase of thrusting and folding resulting from north–south compression took place and was followed at ~1520Ma by the east–west compression of the Isan Orogeny. This event formed the major north-trending upright folds that characterise much of the Mount Isa Orogen. A period of later extension is implied by the intrusion of the Williams and Naraku Batholiths at ~1500Ma. The main faults mapped in the Mount Isa Orogen have kilometre-scale, predominantly strike-slip? sinistral or dextral? displacements. These faults were active during the Proterozoic, and some may have been active also during the Phanerozoic.

Since the discovery of copper and gold near Cloncurry in the 1860s the rocks of the Mount Isa Orogen have been significant producers of copper, lead, zinc and silver. Significant resources remain, with the Mount Isa Orogen containing 21.2% of the world's lead resources, 11% of the world's zinc resources, 5% of the world's silver resources and 1.7% of the world's copper resources.

Four main styles of mineralisation account for the majority of the mineral resources within the rocks of the Mount Isa Orogen.

1. Sediment-hosted Silver–Lead–Zinc

Sediment-hosted silver–lead–zinc accounts for the majority of lead-zinc and a high proportion of the silver resources within Queensland. These deposits occur mainly within the fine-grained sedimentary rocks of cover sequence 3 in the Western Fold Belt Province and include the Black Star (Mount Isa Pb-Zn), Century, George Fisher North, George Fisher South (Hilton) and Lady Loretta deposits. Sediment-hosted base metal mineralisation also occurs within cover sequence 3 equivalents at Dugald River in the Eastern Fold Belt Province.

2. Brecciated Sediment-hosted Copper

Brecciated sediment-hosted copper deposits occur predominantly within rocks of cover sequences 2 and 3 of the Western Fold Belt Province. These copper deposits include the Mount Isa copper orebodies and the Esperanza/Mammoth mineralisation. Mineralisation is commonly hosted by brecciated dolomitic, pyritic and carbonaceous sedimentary rocks or brecciated sandstone proximal to regional fault/shear zones.

3. Iron Oxide–Copper–Gold

Iron oxide–copper–gold deposits consist predominantly of chalcopyrite-pyrite-magnetite/hematite mineralisation that occurs within high-grade metamorphic rocks of cover sequence 2 and the Soldiers Cap Group in the Eastern Fold Belt Province. Deposits of this style include Ernest Henry, Osborne and Selwyn. The Ernest Henry deposit is breccia-hosted, and thus is distinctly different from the stratabound Osborne and Selwyn deposits.

4. Broken Hill Type Silver–Lead–Zinc

Broken Hill type silver–lead–zinc deposits occur within high-grade metamorphic rocks in the Eastern Fold Belt Province. Cannington is the only major example.

Gold has been produced mainly as a by-product of copper from the iron oxide–copper–gold deposits of the Eastern Fold Belt Province. However, a significant exception occurs at the now mined-out Tick Hill deposit where high-grade gold mineralisation occurred within quartz-feldspar 'laminite' bands within a broader strongly strained ?high strain zone in the Corella Formation of the Eastern Fold Belt Province (Forrestal & others, 1998). This deposit forms a remarkable and important exception in that it produced 15 900kg of gold at an extraordinary average grade of 22.5g/t and is a unique but poorly understood deposit style.

Culpeper & others (2000) and Denaro & others (1999a, 1999b, 2001b, 2003a, 2003b, 2004a) provide overviews of the outcropping mineralisation of this orogen by 1:250 000 map sheet.

Murphy Province

The Murphy Province is an east-trending basement high that separates the McArthur Basin to the north from the Mount Isa Orogen to the south (Figure 1). It straddles the Queensland–Northern Territory border some 300km north-west of Mount Isa. The geology of the Province was described by Ahmad & Wygralak (1990) and is summarised below.

The Murphy Province comprises Palaeoproterozoic rocks of the Murphy Metamorphics and the comagmatic Cliffdale Volcanics and Nicholson Granite Complex. The >1880Ma Murphy Metamorphics form the basement rocks and comprise shale, siltstone, sandstone and felsic volcanic rocks that have been regional metamorphosed to greenschist facies schists and gneisses. These rocks are isoclinally folded along east–west axes by north–south compression and are unconformably overlain by the 1860–1850Ma Cliffdale Volcanics. The lower part of the Cliffdale Volcanics is dominated by ignimbrite whereas the upper part consists dominantly of flow-banded alkali rhyolite and minor tuff. The Nicholson Granite Complex consists of granodiorite and granite that intrude both the Murphy Metamorphics and Cliffdale Volcanics.

The Murphy Inlier contains minor to moderate copper, uranium and tin-tungsten mineralisation. Mineralisation and exploration in this region are summarised by Culpeper & others (1999).

McArthur Basin

Rocks of the McArthur Basin occur in both Queensland and the Northern Territory and unconformably overlie the Murphy Province along its northern margin (Figure 1). This basin fill sequence consists essentially of sedimentary and volcanic rocks (Tawallah Group) that are unconformably overlain by sandstone and minor conglomerate of the McArthur Group (Ahmad & Wygralak, 1990).

Within Queensland, the McArthur Basin hosts the Westmoreland (Redtree) uranium deposits. In the Northern Territory, it hosts the major McArthur River (HYC) stratiform lead-zinc-silver deposit.

The Murphy Province and Mc Arthur Basin are covered by the Westmoreland 1:250 000 map sheet, and mineral occurrences for this region were described by Culpeper & others (1999).

South Nicholson Basin

The South Nicholson Basin, which occurs both in Queensland and the Northern Territory, unconformably overlies rocks of the Lawn Hill Subprovince of the Western Fold Belt Province (Figure 1). This basin fill consists predominantly of sandstone, siltstone and shale of the South Nicholson Group. The only significant known mineralisation is sedimentary ironstone in the Constance Range area (Harms, 1965) where oolitic hematite, siderite and chamosite beds occur within the Train Range Ironstone Member. Mineral occurrences and mines from this basin are covered in the report by Culpeper & others (1999).

NORTH QUEENSLAND

Etheridge Province

The Etheridge Province crops out over a significant proportion of north Queensland, extending from Woolgar in the south to Lockhart River in the north (Figure 1). The Province is divided into the Forsayth and Yambo Subprovinces. The geology of the Etheridge Province was outlined by Withnall & others (*in* Bain & Draper, 1997, pages 449–454) with details on the Forsayth Subprovince given in Withnall & others (*in* Bain & Draper, 1997, chapter 3) and Yambo Subprovince in Blewett & Knutson (*in* Bain & Draper, 1997, pages 118–122). The distribution of units in the area was updated as part of the Georgetown GIS product, which forms stage 1 of the North Queensland Gold Study (Withnall & others, 2002).

Rocks of the Forsayth Subprovince crop out in the Georgetown area and constitute a metasedimentary sequence deposited in an intracratonic rift setting between 1700Ma to at least 1650Ma. A major metamorphic and deformational event at ~1550Ma was accompanied by S-type granite emplacement. Two major Proterozoic folding events have affected the rocks of the Forsayth Subprovince, with the second episode corresponding to the peak of metamorphism at ~1550–1555Ma. The first event may have occurred at ~1590Ma, corresponding with the emplacement of S-type granites recently recognised in the Lyndbrook area (unpublished SHRIMP data). At least four additional episodes of folding have also been recognised.

Rocks of the Forsayth Subprovince host important gold mineralisation that includes the Etheridge Goldfield (historic production of >19 500kg Au bullion and an additional 3400kg fine Au and 5500kg Ag). This mineralisation, however, is probably genetically related to Siluro-Devonian and Permo-Carboniferous intrusives of the Pama and Kennedy Provinces. Small, massive, stratabound concentrations of iron and base metal sulphides are known from the base of the Etheridge Group within the Forsayth Subprovince. Mineral occurrences and mines in the Forsayth Subprovince have been described by Barker & others (1996b, 1997), Bruvel & others (1991), Culpeper & others (1990, 1996, 1997), Dash & others (1988), Denaro & Morwood (1997), Denaro & others (2001a), Lam (1994c), Lam & others (1988, 1989), Rees & Genn (1999) and and Sawers & others (1987). Denaro & others (1997) published a resource assessment of the Georgetown–Croydon area, thus providing a useful overview of the mineralisation within the Forsayth Subprovince. An update of the area was provided in the Georgetown GIS (Withnall & others, 2002).

Rocks of the Yambo Subprovince occur in the northern part of the Etheridge Province within the Yambo Inlier and eastern Coen Inlier (Figure 1). They consist of high-grade metasedimentary and meta-igneous rocks that were probably deposited after 1640Ma and are locally metamorphosed to granulite facies. Dating has indicated a major period of emplacement of I and S type granite at ~1580Ma and metamorphism at ~1575Ma. Six regional deformation events have been recognised, but these do not appear to correlate directly with those recognised within the Forsayth Subprovince.

The Yambo Subprovince has no significant defined mineral resources. Mineral occurrences and mines in the Yambo Inlier are covered in reports by Culpeper (1993), Culpeper & Burrows (1992), Denaro & others (1994b) and Lam & others (1991). Mineral occurrences in the eastern Coen Inlier are described by Culpeper & Burrows (1992), Culpeper & others (1992b), Denaro & Morwood (1992b) and Denaro & others (1993).

Savannah Province

The Savannah Province is a north–south trending belt of mainly metasediments, with lesser amounts of metadolerite and amphibolite, that forms the western part of the Coen Inlier in Cape York Peninsula (Figure 1). The geology of the Savannah Province was summarised by Blewett (*in* Bain & Draper, 1997, pages 454–455) and details of the constituent units are described by Blewett & others (*in* Bain & Draper, 1997, chapter 4).

The Savannah Province consists primarily of greenschist to upper amphibolite facies metasediments intruded by metadolerite and amphibolite. The metasediments are mainly slate, phyllite, schist and gneiss interbedded with massive quartzite. They are interpreted as having been deposited between 1585Ma and 1550Ma in a shallow water environment within an intracontinental setting. Six penetrative regional deformation events have been recognised, with the climax event associated with a prograde low-P high-T metamorphism and largely S-type magmatism at 407Ma.

Rocks of the Savannah Province host small gold-quartz vein deposits that are probably related to late Palaeozoic I-type magmatism. Small stratiform/stratabound massive and disseminated sulphide mineralisation is also present. Mineral occurrences within the province have been recorded by Culpeper & Burrows (1992), Culpeper & others (1992b), Denaro & Morwood (1992b, 1992c) and Denaro & others (1993).

Croydon Province

A sequence of Mesoproterozoic S-type volcanic rocks and related granites in the Croydon area in the western part of the Georgetown Inlier is assigned to the Croydon Province (Figure 1). Mackenzie (*in* Bain & Draper, 1997, pages 455–458) outlined the overall geology of this province and the component units were described by Withnall & others (*in* Bain & Draper, 1997, chapter 3). Denaro & Morwood (1997) provide an overview of the mineralisation.

Exposed rocks of the Croydon Province are rhyolitic to dacitic ignimbrite, rhyolite and rare andesite of the Croydon Volcanic Group, granites of the Esmeralda Supersuite and shallow-water quartzose, mainly arenaceous sedimentary rocks of the Inorunie Group, which unconformably overlie the Croydon Volcanic Group. The Croydon Volcanic Group and Esmeralda Supersuite are contained within a cauldron subsidence structure that is likely to have been emplaced at ~1550Ma, at the close of the main deformation event in the Forsayth Subprovince.

Significant mesothermal gold deposits of the Croydon Goldfield (historic production of ~60 000 kg Au bullion) are hosted by rocks of the Croydon Province. This mineralisation was regarded by Denaro & others (1997) as being related to Proterozoic volcanism. However, dating of the associated alteration indicates a possible Permo-Carboniferous age (Henderson, 1989).

NEOPROTEROZOIC–EARLY PALAEOZOIC

Several areas of Neoproterozoic–Early Palaeozoic rocks in central, northern and north-west Queensland have been assigned to the Iron Range, Cape River, Barnard and Anakie Provinces and the Georgina Basin.

Iron Range Province

Rocks of the Iron Range Province are exposed over ~450km^2 in the northern part of the Coen Inlier in Cape York Peninsula (Figure 1). Blewett (*in* Bain & Draper, 1997, pages 458–459) described the overall geology of the Iron Range Province and Blewett & others (*in* Bain & Draper, 1997, chapter 4) described the component units.

The Iron Range Province contains a single mapped unit (the Sefton Metamorphics) that is composed of a variety of rock types of predominantly sub-greenschist to greenschist facies, including schist, quartzite, greenstone, limestone, marble and calc-silicate. The age of the Iron Range Province is interpreted as younger than detrital zircons dated at ~1130Ma but the age of metamorphism is unknown. Little significant mineralisation is associated with these rocks. Mineralisation in the Iron Range Province was described by Bruvel & Morwood (1992) and Denaro & Morwood (1992a, 1992b).

Cape River Province

The Cape River Province forms several widely spaced outcrop areas of metamorphic rocks in the Charters Towers region. Each area has been assigned a separate stratigraphic name, namely, the Cape River, Running River, Argentine and Charters Towers Metamorphics. Withnall & Hutton (*in* Bain & Draper, 1997, pages 459–462) described the overall geology of the Cape River Province and Hutton & others (*in* Bain & Draper, 1997, chapter 6) outlined the geology of each of the component units.

All units within the Cape River Province consist predominantly of psammo-pelitic metamorphic rocks with subordinate mafic volcanic rocks and local areas of banded iron formation. These units probably formed a single terrane before being dismembered by granite emplacement in the Palaeozoic and overlain by younger basin fill. Although the age of rocks in the Cape River Province is uncertain, magmatic zircons in granites intruding Cape River Metamorphics show SHRIMP U-Pb zircon ages ranging from 469±12Ma to 493±10Ma, providing a minimum age constraint of Late Cambrian or early Ordovician. A maximum age for the province is constrained by dates of 1145±21Ma for detrital zircons within the Cape River Metamorphics.

The structure of the Cape River Province is poorly understood. The main fabric is manifested as a spaced differentiated foliation that is interpreted as a second-generation fabric, possibly correlatable with the main deformation in the Anakie Province (at ~510Ma). Little significant mineralisation is genetically associated with the rocks of the Cape River Province, but minor magnetite has been recorded in banded iron formation. Mineralisation in the province has been described by Gunther & others (1994), Garrad (1996), Hartley (1996), Hartley & Dash (1992), Lam (1994a, 1994b, 1996), Morwood & Dash (1996), Morwood & others (2001) and Sennitt & Hartley (1994).

A belt of metamorphic rocks in the extreme east of the Georgetown Inlier (west of the Broken River Province), comprising gneiss, mica schist and mafic/ultramafic complexes, was previously thought to be part of the Etheridge Province. It is now regarded as part of the Cape River Province (Withnall & others, 2002, 2003). Rocks within this belt belong to the Oasis and Halls Reward Metamorphics. They are separated from the Etheridge Province by the Lynd Mylonite Zone. The ultramafic complexes are associated with lateritic nickel deposits such as the Greenvale deposit.

Barnard Province

Rocks of the Barnard Province occur along the coast and on several islands in the Innisfail area in north Queensland (Figure 1). The overall geology of the Barnard Province is given in Bultitude & others (*in* Bain & Draper, 1997, pages 462–464 and chapter 7) and Garrad & Bultitude (1999).

The Barnard Metamorphic Province forms a narrow north-trending belt east of the Russell–Mulgrave Shear Zone in north Queensland and includes the Barnard Metamorphics and Babalangee Amphibolite. Rock types comprise phyllite, meta-arenite, quartzite, 'greenstone', schist and gneiss. Metamorphic grades are mainly of greenschist facies but are locally up to hornblende granulite facies. The high-grade zones are commonly spatially associated with areas of Ordovician granite, which intrudes the metamorphic rocks. Three main regional deformation events are recognised. The second-generation fabric is an intense crenulation cleavage or schistosity that forms the main foliation in most outcrops. The Ordovician granites contain a pervasive fabric correlated with the second-generation foliation in the metamorphic rocks, thus implying a maximum age of late Ordovician for the second deformation. The metamorphic rocks of the Barnard Province are probably an uplifted lower plate basement assemblage on the south-eastern margin of the Hodgkinson Province. The presence of anomalously high metamorphic grade rocks implies that the unit may consist of several discrete fault blocks. No significant mineral resources are known within the rocks of the Barnard Province. Mineral occurrences in the province were described by Garrad & Rees (1995).

Anakie Province

The Anakie Province contains predominantly metamorphic rocks of Neoproterozoic—early Palaeozoic age that are assigned to the Anakie Metamorphic Group (Figure 1). The geology was outlined by Withnall & others (1995).

The Anakie Metamorphic Group (Figure 3) includes mica schist, quartzite, meta-arenite and greenstone. Three major deformations and subsequent minor folding events have affected the metamorphic rocks. The first deformation produced a strong foliation parallel to relict bedding. Bedding is best preserved in the thinly bedded quartzite units, which are deformed by tight asymmetric second-generation folds. Within metapelites, the first generation fabric is strongly overprinted by a second-generation layer differentiated crenulation cleavage that is axial planar to tight second-generation folds. The third period of deformation produced north-east trending upright folds that are overprinted by later more open east trending regional folds and some south-east trending folds. Metamorphism was of the low pressure-high temperature type, accompanied the first and second deformations, and ranged from greenschist to amphibolite facies. The depositional age of the Anakie Metamorphic Group is uncertain although K-Ar age dating suggests that the rocks were deformed and metamorphosed at ~510Ma (Withnall & others, 1996).

The only significant resource within the Anakie Province is that of the Peak Downs deposit, where copper mineralisation is present in ironstone, muscovite-quartz schist and chlorite-quartz schist. Mineralisation within the province has been described by Denaro & others (2004b), Garrad & Lam (1993), Lam (2005b) and Lam & Garrad (1993).

Ordovician sedimentary rocks outcropping along the south-eastern margin of the Anakie Province are assigned to the **Fork Lagoons Province** (Figure 1 and Figure 3). The contact between rocks of the Fork Lagoons Province and the Anakie Metamorphic Group to the north-west occurs along a steeply dipping thrust zone. Withnall & others (1995) described the geology of the Fork Lagoon Province and the Fork Lagoon beds.

The metamorphic rocks of the Anakie Province are intruded by a large composite assemblage of Middle–Late Devonian mainly I-type granitoids of the **Retreat Batholith** (Figure 3). Rock types range in composition from diorite through monzodiorite and granodiorite to granite. Rb-Sr ages range from 366Ma to 385Ma. The geology of the Retreat Batholith was described in detail by Withnall & others (1995).

Volcanic rocks consisting predominantly of mafic lavas and lesser volcaniclastics assigned to the Theresa Creek Volcanics unconformably overlie the Anakie Metamorphic Group south-west of Clermont (Figure 3). The Teresa Creek Volcanics are unconformably overlain by the Silver Hills Volcanics (the basal sequence of the Drummond Basin). Geochemical studies of the Theresa Creek Volcanics and Retreat Batholith indicate that they are genetically related.

No significant mineral resources are associated with the Retreat Batholith or Theresa Creek Volcanics.

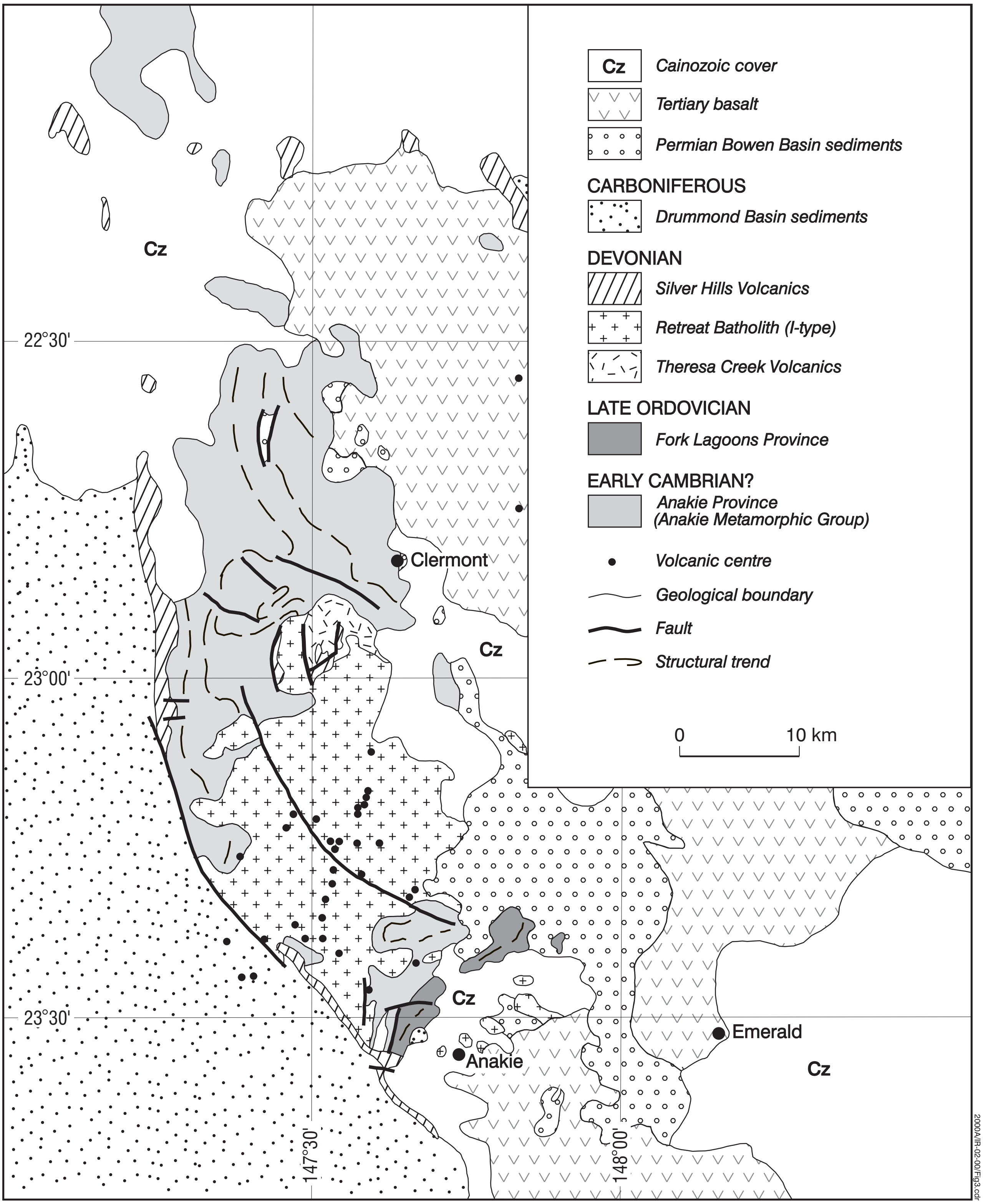


Figure 3. General geology of the southern Anakie Inlier (after Withnall & others, 1995)

Georgina Basin

The Georgina Basin is a large intracratonic basin in Queensland and the Northern Territory that flanks the western and south-western margins of the Mount Isa Orogen. It occupies an area of ~325 000km^2 of which ~90 000km^2 are in Queensland (Figure 1). The geology of the Georgina Basin was outlined by Smith (1972) and Shergold & Druce (1980).

The basin fill is mainly Cambrian to Middle Ordovician age marine sedimentary rocks. The Cambrian and Early Ordovician rocks are dominantly carbonate rocks with minor sandstone and siltstone whereas the Middle Ordovician rocks are dominated by siltstone and sandstone. Silurian(?) to Devonian freshwater sandstone and Permian boulder beds overlie rocks of the early Palaeozoic Georgina Basin succession and are thought to represent younger successions laid down in superimposed basins (Allen, 1975). The Georgina Basin was deformed by minor to moderate folding and faulting throughout with moderate to strong folding, faulting and overthrusting along the southern margin.

Phosphatic marine sediments (phosphorite) occur in the Middle Cambrian and Middle Ordovician rocks of the basin. The Middle Cambrian rocks host significant phosphate resources that include the Phosphate Hill deposit. Mineral occurrences within the Georgina Basin have been described by Denaro & others (1999a, 1999b, 2001b, 2003a, 2003b).

TASMAN OROGENIC ZONE

Rocks of the Tasman Orogenic Zone occur throughout eastern Australia, from the islands of Torres Strait south to Tasmania. Within Queensland, the zone can be subdivided into the Northern Tasman (north Queensland) and Northern New England (south-east to central Queensland) Orogenic Zones. The Northern Tasman Orogenic Zone consists predominantly of early Palaeozoic, fairly deep-marine quartz-rich sandstone and mudstone intercalated with submarine mafic and felsic volcanic rocks. The Northern New England Orogen consists of middle Palaeozoic to early Mesozoic marine to continental sedimentary and volcanic rocks. Details on the subdivision of the Tasman Orogenic Zone were given by Day & others (1978) and the tectonic development and metallogeny of the zone was outlined by Murray (1986).

The tectonic history of the Tasman Orogenic Zone commences in the early Palaeozoic with deep marine turbiditic sedimentation with juxtaposition of diverse facies, local mostly submarine volcanic belts, and local deformation, magmatism and metamorphism. This was followed in the mid-Silurian to Late Devonian by deformation and progressive termination of deep-marine conditions, magmatism, crustal thickening and extensional collapse followed by a major accretionary phase that culminated in the mid-Carboniferous, although the convergent plate boundary continued an eastwards migration into the early Mesozoic (Coney & others, 1990). Numerous distinct geological provinces have been assigned for the rocks of the Tasman Orogenic Zone. Those within Queensland are summarised below.

NORTHERN TASMAN OROGENIC ZONE

Rocks of the Northern Tasman Orogenic Zone in north Queensland and have been subdivided into the Thalanga, Hodgkinson and Broken River Provinces based on age and geological setting. The inter-regional Macrossan, Pama and Kennedy igneous and volcanic provinces have also been defined.

Thalanga Province

Hutton & Withnall (*in* Bain & Draper, 1997, pages 469–471) summarised the geology of the Thalanga Province, and the details of its component units were summarised by Hutton & others (*in* Bain & Draper, 1997, chapter 6). The mapping of the units was revised by Withnall & others (2002, 2003).

The Thalanga Province includes two belts of Late Cambrian to early Ordovician volcanic rocks and volcanogenic sediments (Figure 1). The main belt is south of the Ravenswood Batholith in the Charters Towers area and consists of deep water sedimentary rocks and subaqueous felsic and mafic to intermediate volcanic rocks assigned to the Seventy Mile Range Group. These rocks have been metamorphosed to mainly sub-greenschist to greenschist facies. A second belt occurs within the eastern part of the Etheridge Province. It consists of two units — the Balcooma Metavolcanics comprising marine or possibly subaerial rhyolitic metavolcanics, metasediments and minor mafic volcaniclastics and lava and the Lucky Creek Metamorphic Group comprising leucogneiss, quartzite, amphibolite, phyllite, andesitic meta-volcanics, and minor marble. The Balcooma Metavolcanics were metamorphosed to lower to middle amphibolite facies and the Lucky Creek Metamorphic Group to upper greenschist to lower amphibolite facies. Three major deformations are recognised within the Seventy Mile Range Group whereas the Balcooma Metavolcanics preserve a steep schistosity that may be a second generation fabric. The Lucky Creek Metamorphic Group contains a relatively pervasive shallowly dipping mylonitic foliation.

The Balcooma Metavolcanics and Seventy Mile Range Group host significant volcanic-hosted massive sulphide (VHMS) resources including the Balcooma, Highway–Reward and Thalanga deposits. The mineral occurrences of the Thalanga Province have been described by Barker & others (1997), Denaro & others (2004b), Hartley & Dash (1993), Hartley (1996), Lam (1994c, 1995b) and Sennitt & Hartley (1994).

Hodgkinson Province

The Hodgkinson Province consists of early to middle Palaeozoic turbiditic sedimentary rocks with subordinate limestone, chert and basic volcanic rocks that extend for ~500km from south of Innisfail to Cape Melville and inland for ~150km from the coast to the Palmerville Fault (Figure 1). Detailed descriptions of the geology of the Hodgkinson Province are included in Bultitude, Domagala & others (in Bain & Draper, 1997, chapter 7), Bultitude, Garrad & others (in Bain & Draper, 1997, chapter 7) and Garrad & Bultitude (1999).

The dominant rock types are quartzo-feldspathic arenite and mudstone, which represent deep-water density current deposits, interlayered with subordinate conglomerate, chert, metabasalt and minor shallow-water limestone; these for the Hodgkinson Formation. Older siliciclastic rocks of probable early Ordovician age are preserved in fault-bounded lenses adjacent to the Palmerville Fault along the western margin of the province. Within the Hodgkinson Province, the rocks are strongly folded and are disrupted into north-trending fault-bounded belts each of which is extensively disrupted by numerous thrust faults. The province has undergone generally sub-greenschist facies metamorphism, with localised higher-grade zones associated with contact aureoles around late Palaeozoic intrusives. The Hodgkinson Province has been affected by several significant deformational events of both regional and local extent.

The tectonic setting for the Hodgkinson Province remains controversial. Some workers (*eg* Henderson, 1980) have interpreted that the Hodgkinson Province succession accumulated in a fore-arc-accretionary wedge setting located to the east of an active continental magmatic arc. Recent work by the Geological Survey, however, favours an extensional rather than compressional regime, with a possible rifted continental margin or back-arc basin setting (Garrad & Bultitude, 1999).

Rocks of the Hodgkinson Formation host significant mesothermal quartz vein-hosted gold mineralisation, including the hard rock and derived alluvial deposits of the Hodgkinson and Palmer goldfields. A detailed study of mineralisation in the Hodgkinson Goldfield was given by Peters (1987). This mineralisation is thought to have formed from metamorphic fluids produced during the devolatilisation of the sedimentary pile (slate-belt style) with distribution of fluids localised along major shear zones (Phillips & Powell, 1992). Quartz-stibnite veins that locally crosscut these gold-only veins are probably sourced from a separate fluid phase that moved along separate flow paths, although a metamorphic source is still envisaged (Garrad & Bultitude, 1999). The Hodgkinson Province locally hosts significant skarn mineralisation such as that at Red Dome, where Permian-Carboniferous intrusives of the Kennedy Province intrude carbonate-rich rocks of the Chillagoe Formation. The Chillagoe Formation is also host to significant limestone resources. Mineralisation within the Hodgkinson Province has been summarised by Bruvel & others (1991), Clarke & others (1994), Culpeper & others (1990, 1994), Dash & Cranfield (1993), Dash & Morwood (1994), Dash & others (1988, 1991), Denaro & others (1992, 1994a, 1994b), Garrad (1993), Garrad & Rees (1995), Lam (1993), Lam & Genn (1993), Lam & others (1988, 1991), Morwood & Dash (1996) and Sawers & others (1987).

Broken River Province

The Broken River Province consists of Ordovician to Devonian marine sedimentary rocks with subordinate, mainly mafic volcanic rocks and Late Devonian to early Carboniferous fluviatile and minor shallow marine sedimentary rocks. These are exposed over an area of ~7000km^2 in the Clarke River area (Figure 1). The geology of the Broken River Province is given by Withnall & Lang (1993), Withnall (*in* Bain & Draper, 1997, pages 476–479) and Withnall & others (*in* Bain & Draper, 1997, chapter 8).

The Province has been divided into the Camel Creek Subprovince and Graveyard Creek Subprovince, separated by the Gray Creek Fault (Arnold & Henderson, 1976).

The Camel Creek Subprovince is more complexly deformed than the Graveyard Creek Subprovince and consists predominantly of alternating, fault-bounded packages of Ordovician to Early Devonian age quartz-rich and quartz-intermediate turbidites, tholeiitic basalt and calc-alkaline lavas and volcaniclastic rocks. It is overlain by the Late Devonian to Carboniferous Clarke River Basin, which contains continental sedimentary rocks and subordinate felsic volcanic rocks.

In the Graveyard Creek Subprovince, a basal unit of tholeiitic basalt, quartz keratophyre and quartz-rich turbidites is overlain unconformably by Silurian to Middle Devonian age shallow marine conglomerate, feldspathic and lithofeldspathic sandstone, volcaniclastics, mudstones and limestone. In the Late Devonian, the pull-apart Bundock Basin developed in the south-west of the subprovince and received a thick sequence of fluviatile and some shallow marine sedimentary rocks.

The Broken River Province hosts significant limestone resources. In addition, podiform chromite resources (*eg* Gray Creek South) as well as lateritic nickel–cobalt resources (*eg* Lucknow) are hosted by the Graveyard Creek Subprovince. Small slate-belt style gold occurrences have also been recognised. Mineral occurrences in the Broken River Province have been described by Barker & others (1997), Lam (1994a, 1994c, 1995a, 1995b, 1996), Morwood & Dash (1996) and Morwood & others (2001).

Macrossan Province

Ordovician age plutonic rocks in north Queensland are assigned to the Macrossan Province (Hutton, Bultitude & Withnall, *in* Bain & Draper, 1997, chapter 14). These are principally I-type granites and mafic intrusives in the Ravenswood Batholith in the Charters Towers area and S-type and hornblende-bearing granites in the Fat Hen Complex adjacent to the Lolworth Batholith (Figure 4). A small area of Ordovician S-type granites also intrudes rocks of the Barnard Province along the coastline near Innisfail.

No significant mineralisation is attributed to rocks of the Macrossan Province, although Ordovician granites in the Charters Towers area do host significant gold mineralisation thought to be associated with Devonian intrusive activity of the Pama Province.These deposits are described by Hartley & Dash (1993).

Pama Province

Silurian–Devonian granitic rocks in north Queensland are assigned to the Pama Province (Hutton, Knutson & others, *in* Bain & Draper, 1997, chapter 14). These rocks extend as a discontinuous belt from the Coen Region in Cape York southwards to the Georgetown and Charters Towers regions (Figure 4). Pama Province rocks make up a large proportion of the Cape York Peninsula Batholith in Cape York, the Nundah, Tate, Robin Hood, Copperfield, White

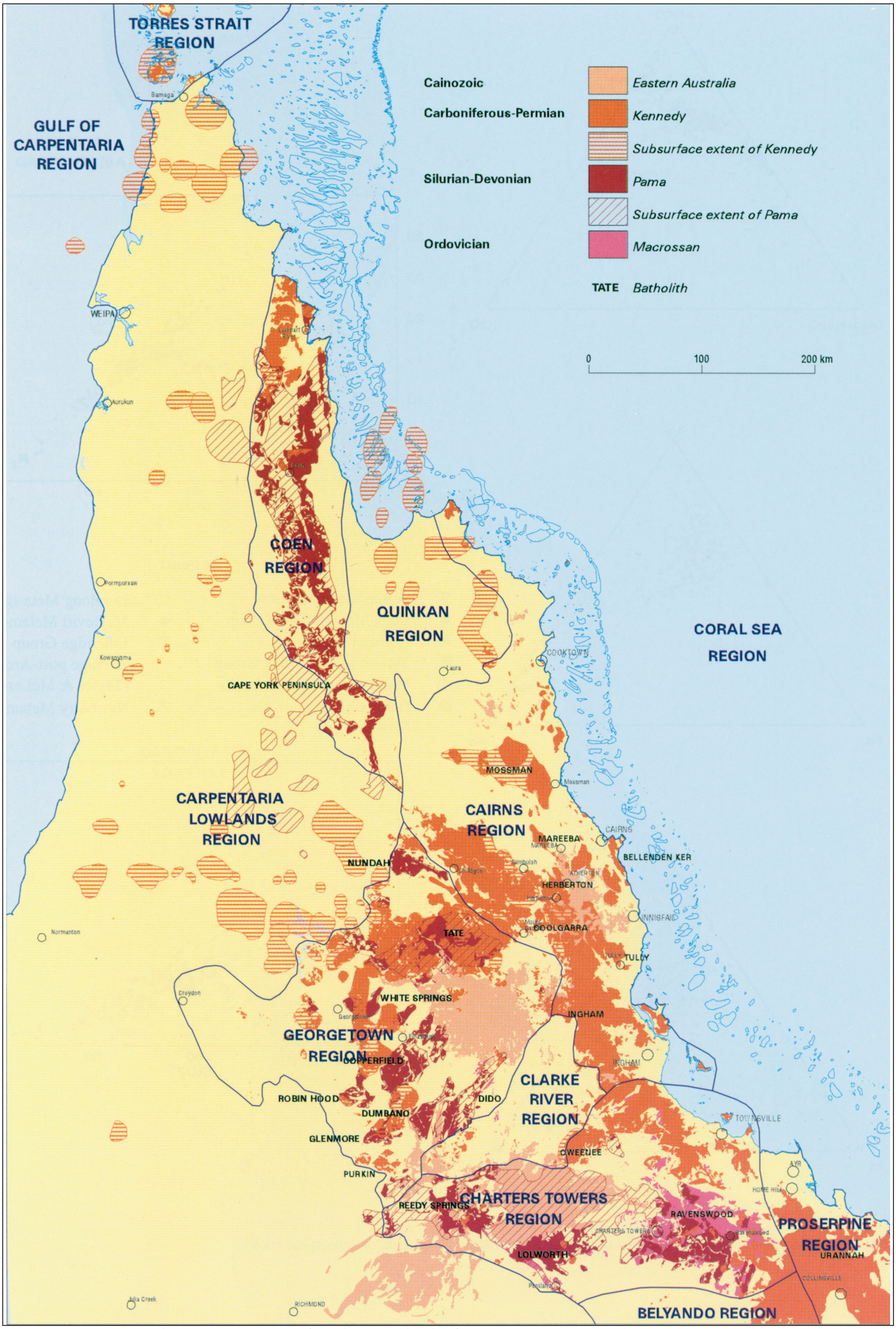


Figure 4. Inter-regional Igneous Provinces of north Queensland (after Bain & Draper, 1997)

Springs, Glenmore, Dumbano and Dido Batholiths in the Georgetown region and the Ravenswood, Lolworth and Reedy Springs Batholiths in the Charters Towers region. The Pama Province rocks of Cape York comprise mostly S-type granite and leucogranite and some I-type granodiorite, whereas in the Georgetown and Charters Towers regions they are mostly I-type granitic rocks. The subdivision of the Pama Province in the Georgetown and Charters Towers regions was modified by Withnall & others (2002, 2003).

Alteration associated with mesothermal quartz-gold-base metal sulphide vein deposits of the Etheridge Goldfield is considered to be of Silurian-Devonian age based on isotopic age dates (Bain & others, 1998). It is thought that these deposits are genetically linked to fluid circulation systems associated with emplacement of the Silurian-Devonian granites in the area. Dating of alteration associated with mesothermal quartz vein mineralisation in the Charters Towers area also indicates a Devonian age (Carr & others, 1988; Morrison, 1988). This mineralisation may be related to igneous activity associated with the Pama Province although a metamorphic origin has also been postulated (Hutton & others, 1994).

Kennedy Province

Early Carboniferous to Early Permian igneous rocks extending throughout north Queensland are assigned to the Kennedy Province (Mackenzie & Wellman, *in* Bain & Draper, 1997, pages 488–500). This province extends from south of Bowen north-west through Cape York Peninsula and across Torres Strait (Figure 4). Most of these igneous rocks are concentrated in two belts, the Townsville–Mornington Island Belt and the Badu–Weymouth Belt. The Townsville–Mornington Island Belt extends parallel to the coast from near Home Hill, south-east of Townsville, to the Atherton area and then west to the limit of pre-Mesozoic exposure north of Georgetown. The Badu–Weymouth Belt extends from the Mount Carter–Cape Weymouth area in eastern Cape York Peninsula to Badu Island in southern Torres Strait and into Papua New Guinea. The Kennedy Province has been subdivided into several subprovinces, the boundaries of which largely reflect the underlying/enclosing basement provinces as outlined in Table 1.

Table 1. Subprovinces of the Kennedy Province
(after Mackenzie & Wellman, *in* Bain & Draper, 1997)

Igneous Subprovince	Corresponding Basement Province
Jardine	Northern Savannah Province; Iron Range Province
Lakefield (concealed)	Lakefield Basin
Daintree	Hodgkinson Province (northern)
Herberton	Hodgkinson Province (southern)
Tate	(North-eastern Forsayth Subprovince), Etheridge Province
Kidston	(Main part of Forsayth Subprovince), Etheridge Province
Kangaroo Hills	Broken River Province
Paluma	Cape River Province; Thalanga Province
Connors	Drummond Basin; northern New England Province

Rocks of the Kennedy Province are largely I-type intrusives and extrusives that form major batholiths and volcanic 'fields'. A-type extrusives occur mainly in the Herberton Subprovince whereas A-type intrusives occur largely within the Kidston Subprovince. S-type intrusives occur within the Daintree Subprovince. The rocks commonly occur in large cauldron subsidence structures and are interpreted to be the result of crustal melting in an extensional (or transtensional), possibly back-arc, tectonic environment.

Rocks of the Kennedy Province have been responsible for a diverse group of mineral deposit styles throughout north Queensland. These include porphyry-related breccia gold deposits (of which Kidston and Mount Leyshon are examples), vein and greisen type tin deposits (including those of the Herberton and Cooktown tinfields) and skarn deposits such as Red Dome.

NORTHERN NEW ENGLAND OROGEN

Within Queensland, the Northern New England Orogen forms the eastern part of the Tasman Orogenic Zone and is subdivided into a number of geological provinces.

Silverwood Province and older blocks within the Yarrol Province

The oldest tectonostratigraphic sequences of the northern New England Orogen range in age from mid-Ordovician to Middle Devonian. They occur in the **Silverwood Province** (van Noord, 1999), and in inliers and structural blocks within the **Yarrol Province** (the Stanage, Craigilee, Calliope and Philpott Blocks of Day & others, 1983), and comprise volcaniclastic sediments, coralline limestone lenses, and some primary volcanic rocks. Their submarine environment of deposition, the lack of quartz in sedimentary units, and the geochemistry of volcanic and related intrusive rocks support an island arc origin. Day & others (1978, 1983) interpreted all the component blocks in this linear belt as part of a single arc, the Calliope Volcanic Arc. However, the recent recognition that individual structural blocks contain lithologically distinct but coeval sequences suggests that they may not have been directly related, but in fact represent a number of separate exotic terranes (Yarrol Project Team, 1997, 2003; Simpson & others, 1998; Murray & others, 2003).

By far the most important metalliferous deposit within this Ordovician to Middle Devonian island arc assemblage is the world-class Mount Morgan gold–copper deposit. It occurs within a belt of Middle Devonian volcanic and sedimentary rocks forming a roof pendant in a Late Devonian tonalite intrusion. Two main theories have been proposed for the genesis of the Mount Morgan mineralisation. The mineralisation has been proposed as a Devonian volcanogenic massive sulphide pipe deposit (*eg* Taube, 1986) and as a structurally controlled Devonian replacement body related to the Mount Morgan Tonalite (*eg* Arnold & Sillitoe, 1989). Recent work, however, indicates it forms an end member of the volcanic-hosted massive sulphide type (Messenger & others, 1997). These rocks also contain substantial resources of high-grade limestone. An updated interpretation of this deposit using a variation of the volcanic-hosted massive sulphide model, but emphasising the separation of the gold and copper mineralisation as separate events was presented by Blake (2003). Mineralisation in the Mount Morgan 1:100 000 Sheet area has been described by Morwood (2002b).

Wandilla, Texas, Yarrol and Connors–Auburn Provinces and Gogango Overfolded Zone

The basic tectonostratigraphic framework of the New England Orogen was established as a Late Devonian–Carboniferous convergent continental plate margin above a west-dipping subduction zone (Day & others, 1978). Three parallel belts representing accretionary wedge (east), fore-arc basin (centre), and continental margin magmatic arc (west) have been described.

Rocks of the accretionary wedge form the **Wandilla** and **Texas Provinces**. They consist of a stack of deep water sedimentary and volcanic rocks that are generally steeply dipping, structurally complex, and sparsely fossiliferous. In the Wandilla Province, a gross regional stratigraphy is preserved, with a western (oldest) assemblage characterised by radiolarian jasper and chert, a central belt of volcaniclastic greywacke and argillite, and an enigmatic eastern (youngest) sequence of quartzose sandstone and argillite. Limited age control is provided by radiolarians and conodonts from chert, conodonts from sparse limestone lenses, and by the occurrence in the central belt of a persistent horizon of greywacke beds containing ooliths, which must have been sourced from Lower Carboniferous limestones of the fore-arc basin to the west. Mineral resources in the Wandilla Province have been described by Burrows (2004), Cranfield & Garrad (1991), Cranfield & others (2001), Garrad & Withnall (2004b), Lam (2005a), Morwood (2002a, 2003) and Randall & others (1996).

The accretionary wedge assemblage in the Texas Province has been folded into a large-scale double orocline (Murray & others, 1987). The Texas Province also contains numerous allochthonous lenses of Lower Carboniferous coralline limestone (Flood, 1999). Overall, the accretionary wedge is sparsely mineralised, but it does contain some slate belt type gold-bearing veins and stockworks in the Warwick area and at Kingston, south of Brisbane, and small high-grade manganese deposits. Mineralisation in the Stanthorpe-Texas-Inglewood area of the Texas Province was described by Denaro (1989) and Denaro & Burrows (1992).

The accretionary wedge is separated from the fore-arc basin sequence to the west by the major Yarrol Fault System, which is marked by serpentinite lenses. In the Marlborough area, these ultramafic rocks form an extensive flat-lying thrust sheet of early Palaeozoic ocean floor and upper mantle material. Significant lateritic nickel–cobalt deposits have been developed as enriched residual deposits on the ultramafics during a Cainozoic deep weathering event (Garrad & Withnall, 2004b).

The **Yarrol Province** consists mainly of a fore-arc basin sequence of Late Devonian to Carboniferous age. The basin fill mainly comprises volcaniclastic sedimentary rocks deposited on a marine shelf that was shallower to the west and became progressively more emergent with time. The Lower Carboniferous part of the sequence is characterised by the widespread development of oolitic limestone. The fore-arc basin succession unconformably overlies the Middle Devonian and older rocks (Kirkegaard & others, 1970; Leitch & others, 1992). The fore-arc basin succession is only sparsely mineralised except in the vicinity of later intrusives. Mineralisation in the Yarrol Province is summarised in reports by Burrows (2004), Garrad & Withnall (2004a, 2004b), Lam (2004, 2005a), Morwood (2002a, 2002b, 2003) and Morwood & Blake (2002).

The **Connors–Auburn Province** was interpreted by Day & others (1978) as a Late Devonian to Carboniferous magmatic arc. However, recent re-mapping and dating demonstrate that the most extensive plutonic and volcanic rocks are of late Carboniferous and Early Permian age (Holcombe & others, 1997; Withnall & others, 1998; Hutton & others, 1999). It now appears that these mafic and felsic rocks represent only the final products of subduction-related magmatism. There are some early Carboniferous mafic to felsic volcanics and granites in the Connors Subprovince, but these are not present in the Auburn Subprovince. Representatives of the Late Devonian arc have been interpreted in the western part of the Yarrol Province located to the east of the Connors–Auburn Province in what was previously regarded as the fore-arc basin sequence (Blake & others, 1998). The upper age limit of the Late Devonian-Carboniferous convergent margin tectonism is uncertain, but it appears to have persisted through much of the Carboniferous. Surprisingly little mineralisation is associated with this western belt of magmatic rocks.

Lower Permian strata that overlie the Upper Devonian–Carboniferous fore-arc basin and accretionary wedge sequences have recently been interpreted as the fill of a series of extensional basins that developed at the same time as the Bowen Basin to the west. This interpretation is consistent with the fact that many outcrops of the Permian rocks unconformably overlie Lower Carboniferous or older rocks, implying removal or non-deposition of a substantial part of the stratigraphic section.

Opposed to this concept of formation of extensional basins at the beginning of the Permian is the presence of continuous and uniform sequences of Carboniferous–Permian marine rocks in some areas and the calculation of tectonic subsidence rates for the Lower Permian sequences. These calculations provide little if any evidence for significant crustal thinning caused by pull-apart or rift histories. Some Lower Permian rocks are prospective for a volcanic hosted massive sulphide (VHMS) style of mineralisation. The Mount Chalmers gold–copper deposit is a classic Kuroko-type deposit, and the nearby Develin Creek prospect and the Silver Spur silver–lead deposit in the Texas area are also considered to represent VHMS mineralisation. Early Permian volcanic rocks along the western side of the Connors–Auburn Province that host the Cracow epithermal gold deposit are equated to the extensional event that formed the Bowen Basin. Mineralisation within the Connors–Auburn Province has been described by Burrows (2004), Garrad & Withnall (2004a, 2004b) and Lam (2004, 2005a).

The Late Permian Hunter–Bowen Orogeny deformed the rocks of the New England Orogen, producing WNW directed thrusting and associated folding.

The **Gogango Overfolded Zone** is a belt of strongly cleaved sandstone, mudstone, and deformed mafic to felsic volcanic rocks that separates the Connors–Auburn Province into a northern and a southern section. Stratigraphic, sedimentological and structural studies (Fergusson, 1991; Fergusson & others, 1994; Fielding & others, 1994; Withnall & others, 1998) have led to the conclusion that the Gogango Overfolded Zone is simply a part of the Bowen Basin that was more intensely deformed by thrusting during the Hunter–Bowen Orogeny. Mineralisation in this area has been described by Burrows (2002), Garrad & Withnall (2004a, 2004b), Lam (2005a) and Morwood (2002b).

Gympie Province

The geology of the Gympie Province was outlined by Cranfield & others (1997). This province is unique as it contains the only record of Early Triassic marine rocks in eastern Australia. It comprises the Kin Kin Subprovince in the south (containing the Gympie Goldfield) and the Broween Subprovince.

The province comprises Early Permian to Early Triassic arc-related mafic to felsic volcanic, volcaniclastic and marine sedimentary rocks in a north-north-westerly trending belt extending from Nambour to west of Bundaberg in southern Queensland.

The rocks have long been considered to represent a unique stratotectonic unit that does not fit into the overall palaeogeographic pattern of the Tasman Orogenic Zone (Day & others, 1978). It has therefore been proposed as an exotic terrane that collided with the continent in the Triassic (*eg* Harrington, 1983; Cawood, 1984; Waterhouse & Sivell, 1987).

Mineralisation in the Gympie Province is dominated by gold associated with the emplacement of Early to Middle Triassic and Late Triassic plutonic and volcanic rocks of the South-East Queensland Volcanic and Plutonic Province. The most significant mineralisation is within the Gympie Goldfield (historic production in excess of 108 000kg fine Au) in which structurally controlled mesothermal low-sulphide quartz reefs are associated with Late Triassic granodiorite and the north-west trending Inglewood Structure. Although the fluid source is thought to be primarily related to granodiorite, the composition of the host rocks, in particular the presence of carbonaceous shales, has played a significant role in concentrating the gold mineralisation within the quartz lodes (Kitch & Murphy, 1990). Mineralisation in the Gympie Province has been described by Barker & others (1993), Cranfield & Garrad (1991), Cranfield & others (1997) and Randall & others (1996).

South-East Queensland Volcanic and Plutonic Province

The South-East Queensland Volcanic and Plutonic Province is a grouping used for volcanic and plutonic rocks of Late Permian–Triassic age within south-east Queensland. Rock types consist mainly of I-type intrusives and comagmatic continental volcanic rocks. Intrusive compositions range from layered gabbro to granite, with granodiorite the most common composition. Gust & others (1993) proposed that active subduction produced the voluminous Late Permian and Early Triassic plutonism, and was replaced by an extensional phase marked by bimodal and alkalic magmatism in the Late Triassic.

Early–Late Triassic intrusives of the South-East Queensland Volcanic and Plutonic Province are associated with gold mineralisation within the Gympie Province including that of the Gympie Goldfield. In addition, porphyry-style mineralisation such as that at Coalstoun Lakes is associated with intrusions of the South-East Queensland Volcanic and Plutonic Province. Late Triassic skarn-related deposits include Mount Biggenden and Ban Ban Springs.

Intracratonic Basins

Palaeozoic–early Mesozoic sedimentary basins overlying the 'basement' rocks within the state are also assigned to the Tasman Orogenic Zone. These are listed in Table 2.

The Early Devonian to Early Carboniferous basins are largely unmineralised, with the important exception of the Drummond Basin (Figure 1) which developed between the Late Devonian and early Carboniferous and contains a thick succession of continental sedimentary and volcanic rocks with sporadic marine beds near its base. Olgers (1972)

Table 2. Intracratonic Basins of the Tasman Orogenic Zone

Age	Northern Queensland	Central Queensland	Western Queensland	Southern Queensland
Late Carboniferous to Triassic	Ngarrabullan; Olive River	Bowen; Callide; Galilee; Miclere	Cooper	Ipswich; Tarong
Early Devonian to early Carboniferous	Bundock; Burdekin; Clarke River; Gilberton; Pascoe River	Drummond	Adavale	

subdivided the basin fill into three cycles. Cycle 1 comprises the volcanic and sedimentary rocks at the base of the basin, which are unconformably overlain by a sequence of quartzose and feldspathic, dominantly fluvial sedimentary rocks (Cycle 2). Cycle 3 records a return to volcanic and volcanolithic-rich sedimentary rocks. The basin hosts significant epithermal gold mineralisation such as the Pajingo (Vera-Nancy) and Wirralie deposits within early Carboniferous volcanic rocks currently thought to be part of the Cycle 1 group of rocks. Mineralisation in the northern part of the Drummond Basin is described by Denaro & others (2004b).

The Gilberton Basin sedimentary rocks are known to host stratabound fluorite-uranium-molybdenum mineralisation such as the Maureen deposit, where mineralisation is apparently confined to relatively coarse, fluviatile arkosic sediments of the Gilberton Formation. Mineralisation, however, is probably genetically related to igneous activity of the Kennedy Province, although it also strongly controlled by sedimentary and diagenetic features (O'Rourke, 1975). Limestone resources are known from the Burdekin Basin and oil shale occurs within the Galilee Basin.

The late Carboniferous to Triassic basins are also poorly mineralised, with the exception of the Permian Miclere Basin, in which the basal conglomeratic unit hosts the Miclere gold deposits (Lam, 2005b). Basins such as Ipswich, Tarong, Callide and Bowen contain significant coal resources.

GREAT AUSTRALIAN BASIN

Rocks of the Great Australian Basin occur predominantly in western Queensland, with several isolated basins in the east (Figure 1). The Great Artesian Basin includes the Eromanga, Carpentaria, Surat, Laura, Mulgildie, Nambour, Maryborough and Clarence-Moreton Basins.

The Mesozoic age sediments of the Great Australian Basin are dominantly continental in origin and were deposited in huge sags in the early Mesozoic surface of Queensland. Deformation of these basinal sediments is characteristically mild and the structural trends are generally inherited from the older basement rocks.

On the whole the Great Australian Basin is poorly mineralised. However, the basin does host significant coal, coal seam gas, hydrocarbon and artesian water resources, and significant oil shale and vanadium resources occur with the Toolebuc Formation of the Eromanga Basin.

CAINOZOIC SEDIMENTS, VOLCANICS, AND WEATHERING

During the Cainozoic, tectonism was generally mild with western areas experiencing rejuvenation of existing fault and fold structures and a continuation of crustal sagging over the sites of older basins, forming features such as the Karumba Basin in the State's north. Tectonic activity was more pronounced in eastern regions, where epeirogenic uplift, block faulting and extensive basaltic eruptions occurred. Onshore numerous, narrow fault controlled basins were formed; including the significant oil shale deposits within the Nagoorin, Narrows and Yaamba basins. These basins locally contain thick sequences of basaltic volcanics of Paleocene to Eocene age.

Table 3 lists the Cainozoic basins of Queensland.

Younger Cainozoic (mainly basaltic) volcanic rocks are irregularly distributed along the whole length of the continental margin of Queensland and are assigned to the Eastern Australian Cainozoic Igneous Province. These rocks range in age from early Miocene to Pleistocene. A detailed subdivision and description of Cainozoic intraplate volcanics is given in Johnson & others (1989).

Table 3: Cainozoic Basins of Queensland

Northern Queensland	Central Queensland	Western Queensland	Southern Queensland
Karumba	Biloela; Casuarina; Duaringa; Herbert Creek; Hillsborough; Lowmead; Nagoorin; Narrows; Water Park; Yaamba	Marion; Noranside; Old Cork; Springvale	Amberley; Booval; Elliott; Oxley; Petrie; Pomona, Beaudesert

Repeated deep-weathering during the Cainozoic produced significant bauxite and kaolin resources such as the Weipa and Skardon River deposits on Cape York and magnesite resources such as the Kunwarrara deposit near Rockhampton. Opal deposits formed as a result of the deep weathering processes in western Queensland. These deposits are concentrated in the Winton and Quilpie regions. In addition, significant heavy mineral and silica sand resources are found within dune systems along the coast. Significant alluvial deposits of gold and tin occur within Cainozoic alluvium, particularly in north Queensland, and alluvial sapphire deposits are worked at Anakie in the central Queensland gemfields.

REFERENCES

AHMAD, M. & WYGRALAK, A.S., 1990: Murphy Inlier and environs — regional geology and mineralization. In Hughes, F.E. (Editor): Geology of the Mineral Deposits of Australia and Papua New Guinea. *The Australasian Institute of Mining and Metallurgy Monograph Series*, **14**, 819–826.

ALLEN, C.M., WILLIAMS, I.S., STEPHENS, C.J. & FIELDING, C.R., 1998: Granite genesis and basin formation in an extensional setting: the magmatic history of the northern-most New England Orogen. *Australian Journal of Earth Sciences*, **45**, 875–888.

ALLEN, R.J., 1975: Petroleum resources of Queensland 1975. *Geological Survey of Queensland, Report* **87**.

ARNOLD, G.O. & HENDERSON, R.A., 1976: Lower Palaeozoic history of the southwestern Broken River Province, North Queensland. *Journal of the Geological Society of Australia*, **23**, 73–93.

ARNOLD, G.O. & SILLITOE, R.H., 1989: Mount Morgan gold-copper deposit, Queensland, Australia: Evidence for an intrusion-related replacement origin. *Economic Geology*, **84**, 1805–1816.

BAIN, J.H.C., 1985: Developing models for gold genesis in northern Queensland . *BMR Research Newsletter*, **2**, 9–10.

BAIN, J.H.C. & DRAPER, J.J., 1997: North Queensland Geology. *Australian Geological Survey Organisation Bulletin 240, and Queensland Department of Mines and Energy Queensland Geology* **9**.

BAIN, J.H.C., WITHNALL, I.W., BLACK, L.P., ETMINAN, H., GOLDING, S.D. & SUN, S.S., 1998: Towards an understanding of the age and origin of mesothermal gold mineralisation in the Etheridge Goldfield, Georgetown region, north Queensland. *Australian Journal of Earth Sciences*, **45**, 247–263.

BARKER, R.M., BURROWS, P.E, GENN, D.L.P. & CULPEPER, L.G., 1997: Mineral occurrences in the Einasleigh 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1997/05**.

BARKER, R.M., BURROWS, P.E., SCOTT, M., GENN, D.L.P. & CRANFIELD, L.C., 1993: Mineral occurrences, Gympie and Laguna Bay 1:100 000 Sheet areas. *Queensland Geological Record* **1993/14**.

BARKER, R.M., EVANS, P.E., GENN, D.L.P. & CULPEPER, L.G., 1996a: Review of mineral exploration in the Einasleigh 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1996/11**.

BARKER, R.M., GENN, D.L.P., BURROWS, P.E. & DENARO, T.J., 1996b: Summary of geology, mineral occurrences and company exploration in the Red River and Normanton 1:250 000 Sheet areas. *Queensland Geological Record* **1996/03**.

BLAKE, D.H., 1987: Geology of the Mount Isa Inlier and environs, Queensland and Northern Territory. *Bureau of Mineral Resources, Geology and Geophysics, Australia, Bulletin* **225**.

BLAKE, D.H., ETHERIDGE, M.A., PAGE, R.W., STEWART, A.J., WILLIAMS, P.R. & WYBORN, L.A.I., 1990: Mount Isa Inlier — regional geology and mineralisation. *In* Hughes, F.E. (Editor): *Geology of the Mineral Deposits of Australia and Papua New Guinea*, The Australian Institute of Mining and Metallurgy, 915–925.

BLAKE, D.H. & STEWART, A.J., 1992: Stratigraphic and tectonic framework, Mount Isa Inlier. *In* Detailed Studies of the Mount Isa Inlier. *AGSO Bulletin* **243**, 1–11.

BLAKE, P.R., 2003: Where is the next Mount Morgan? *Digging Deeper Symposium Proceedings* on CD. Geological Survey of Queensland.

BLAKE, P.R., CROUCH, S.B.S., DOMAGALA, J. & HAYWARD, M.A., 1995: Review of mineral exploration within the Mount Morgan (8950) and Bajool (9050) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1995/01**.

BLAKE, P.R., HAYWARD, M.A., SIMPSON, G.A., OSBORNE, J.H. & MURRAY, C.G., 1996: Review of mineral exploration within the Biloela (9049), Calliope (9149), Monto (9148) and Scoria (9048) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1996/12**.

BLAKE, P.R., SIMPSON, G.A., FORDHAM, B.G., & HAYWARD, M.A., 1998: The Yarrol fore-arc basin: a complex suite of volcanic facies and allochthonous limestone blocks. *Geological Society of Australia Abstracts*, **49**, 42.

BRUVEL, F.J., BULTITUDE, R.J., CULPEPER, L.G., GARRAD, P.D., LAM, J.S.F. & MORWOOD, D.A., 1991: Mineral occurrences — Ravenshoe 1:100 000 Sheet area, Queensland. *Queensland Resource Industries Record* **1991/05**.

BRUVEL, F.J. & MORWOOD, D.A., 1992: Mineral occurrences — Cape Weymouth 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/04**.

BURROWS, P.E., 1991: Mine production data, Palmer Goldfield (compiled from Annual Reports of the Department of Mines 1877-1981). *Queensland Resource Industries Record* **1991/18**.

BURROWS, P.E., 2004: Mines, mineralisation and mineral exploration in the Rookwood, Ridgelands and Rockhampton 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **2004/03**.

BURROWS, P.E. & CULPEPER, L.G. 2000: Mineral exploration in the Dobbyn 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **2000/02**.

CARR, G.R., DEAN, J.A. & MORRISON, G.W., 1988: Lead isotopes as an exploration technique and as an aid in genetic modelling for gold deposits in north-east Queensland. *In* Goode, A.D.T. & Bosma, L.I. (Compilers): Bicentennial Gold 88, Extended Abstracts Oral Programme, *Geological Society of Australia, Abstracts* **22**, 265–271.

CAWOOD, P.A., 1984: The development of the SW Pacific margin of Gondwana; correlations between the Rangitata and New England orogens. *Tectonics*, **3**, 539–553.

CLARKE, G.W., MORWOOD, D.A. & DASH. P.H., 1994: Review of the Ollera Creek Mineral Field, north Queensland. *Queensland Geological Record* **1994/08**.

CONEY, P.J., EDWARDS, A., HINE, R., MORRISON, F. & WINDRIM, D., 1990: The regional tectonics of the Tasman orogenic system, eastern Australia. *Journal of Structural Geology*, **12**, 519–543.

CRANFIELD, L.C., 1999: *Gympie, Special Sheet 9445, Part 9545, Queensland, 1:100 000 Geological Map Commentary.* Queensland Department of Mines and Energy, Brisbane.

CRANFIELD, L.C., DONCHAK, P.J.T., RANDALL, R.E. & CROSBY, G.C., 2001: Geology and mineralization of the Yarraman Subprovince, south-east Queensland. *Queensland Geology* **10**.

CRANFIELD, L.C. & GARRAD, P.D., 1991: Mines and prospects in the Maryborough 1:250 000 Sheet area. *Queensland Resource Industries Record* **1991/03**.

CRANFIELD, L.C., SHORTEN, G., SCOTT, M. & BARKER, R.M., 1997: Geology and mineralisation of the Gympie Province. *Geological Society of Australia Special Publication* **19**, 128–147.

CULPEPER, L.G., 1993: Mineral occurrences — Carpentaria and Karumba Basins, Cape York Peninsula, Queensland. *Queensland Geological Record* **1993/19**.

CULPEPER, L.G. & BURROWS, P.E., 1992: Mineral occurrences — Hann River 1:250 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/18**.

CULPEPER, L.G., BURROWS, P.E., BARKER, R.M., DENARO, T.J. & GENN, D.L.P., 1997: Geology, mineralisation and company exploration in the Georgetown and Forsayth 1:100 000 Sheet areas, north Queensland. *Queensland Geological Record* **1997/08**.

CULPEPER, L.G., BURROWS, P.E. & DENARO, T.J., 1996: Summary of the geology, mineral occurrences and company exploration in the Forest Home and North Head 1:100 000 Sheet areas. *Queensland Geological Record* **1996/10**.

CULPEPER, L.G. & DENARO, T.J, 1999: Mineral exploration in the Camooweal 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record*, **1999/03**.

CULPEPER, L.G., DENARO, T.J., BURROWS, P.E. & MORWOOD, D.A., 1999: Mines and mineralisation of the Westmoreland 1:250 000 Sheet area, north-west Queensland *Queensland Geological Record* **1999/06**.

CULPEPER, L.G., DENARO, T.J., BURROWS, P.E. & MORWOOD, D.A., 2000: Mines and mineralisation of the Dobbyn 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **2000/03**.

CULPEPER, L.G., DENARO, T.J., MORWOOD, D.A. & BURROWS, P.E., 1994: Mineral occurrences — Butchers Hill, Cooktown, Battle Camp and Kennedy Bend 1:100 000 Sheet areas, Cape York Peninsula, Queensland. *Queensland Geological Record* **1994/12**.

CULPEPER, L.G., DENARO, T.J., WILLMOTT, W.F., WHITAKER, W.G., BRUVEL, F.J., MORWOOD, D.A. & SHIELD, C.J., 1992a: Review of mineral exploration, Cape York Peninsula, 1969 to 1990. *Queensland Resource Industries Record* **1992/10**.

CULPEPER, L.G., GARRAD, P.D. & BURROWS, P.E., 1992b: Mineral occurrences — Ebagoola 1:250 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/14**.

CULPEPER, L.G., LAM, J.S., MORWOOD, D.A. & BURROWS, P.E., 1990: Mineral occurrence data sheets — Bellevue 1:100 000 Sheet area. *Queensland Resource Industries Record* **1990/04**.

DASH, P., BARKER, R.M., MORWOOD, D.A., CULPEPER, L.G. & LAM, J.S.F., 1991: Mineral occurrences — Atherton 1:100 000 Sheet area. *Queensland Resource Industries Record* **1991/14**.

DASH, P. H. & CRANFIELD, L.C., 1993: Mineral occurrences, Rumula 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1993/17**.

DASH, P., GARRAD, P. & MITCHELL, G., 1988: Mineral occurrence data sheets, Chillagoe 1:100 000 map Sheet area, Metallogenic Studies Program. Geological Survey of Queensland Record 1988/17.

DASH, P.H. & MORWOOD, D.A., 1994: Mineral occurrences, Cairns 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1994/06**.

DAY, R.W., MURRAY, C.G. & WHITAKER, W.G., 1978: The eastern part of the Tasman Orogenic Zone. *Tectonophysics*, **48**, 327–364.

DAY, R.W., WHITAKER, W.G., MURRAY, C.G., WILSON, I.W. & GRIMES, K.G., 1983: Queensland Geology, A companion volume to the 1:2 500 000 scale geological map (1975). *Geological Survey of Queensland Publication*, **383**.

DENARO, T.J., 1989: Mineral occurrences — Inglewood, Texas and Ashford 1:100 000 Sheet areas. Geological Survey of Queensland Record 1989/32.

DENARO, T.J., 1992: A compilation of mine production data for the Stanthorpe Mining District from Annual Reports of the Department of Mines. *Queensland Resource Industries Record* **1992/12**.

DENARO, T.J., 1993: Mineral occurrences — Torres Strait 1:250 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Geological Record* **1993/18**.

DENARO, T.J. & BURROWS, P.E., 1992: Mineral occurrences — Stanthorpe and Drake 1:100 000 Sheet areas, Queensland. *Queensland Resource Industries Record* **1992/08**.

DENARO, T.J. & CULPEPER, L.G., 1999a: Mineral exploration in the Westmoreland 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **1999/01**.

DENARO, T.J. & CULPEPER, L.G., 1999b: Mineral exploration in the Lawn Hill 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **1999/02**.

DENARO, T.J., CULPEPER, L.G., BURROWS, P.E. & MORWOOD, D.A., 1999a: Mines and mineralisation, of the Camooweal 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **1999/04**.

DENARO, T.J., CULPEPER, L.G., BURROWS, P.E., & MORWOOD, D.A., 2001a: Mining history of the Woolgar Goldfield, north Queensland. *Queensland Geological Record* **2001/05**.

DENARO, T.J., CULPEPER, L.G., BURROWS, P.E., & MORWOOD, D.A., 2004a: Mines, mineralisation, and mineral exploration in the Cloncurry 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **2004/01**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 1993: Mineral occurrences — Coen, Rokeby and Silver Plains 1:100 000 Sheet areas, Cape York Peninsula, Queensland. *Queensland Geological Record* **1993/09**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 1994a: Mineral occurrences, Helenvale 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Geological Record* **1994/13**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 1994b: Mineral occurrences, Laura 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Geological Record* **1994/14**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 1999b: Mines and mineralisation of the Lawn Hill 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **1999/05**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 2001b: Mines and mineralisation of the Mount Isa 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **2001/03**.

DENARO, T.J., KYRIAZIS, Z., FITZELL, M.J., MORWOOD, D.A. & BURROWS, P.E., 2004b: Mines, mineralisation and mineral exploration in the northern Drummond Basin, central Queensland. *Queensland Geological Record* **2004/06**.

DENARO, T.J. & MORWOOD, D.A., 1992a: Mineral occurrences — Temple Bay 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/13**.

DENARO, T.J. & MORWOOD, D.A., 1992b: Mineral occurrences — Lockhart River and Cape Sidmouth 1:100 000 Sheet areas, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/20**.

DENARO, T.J. & MORWOOD, D.A., 1992c: Mineral occurrences, Wenlock 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/21**.

DENARO, T.J. & MORWOOD, D.A., 1997: Geology, mineralisation and company exploration in the Croydon 1:250 000, and Gilbert River and Esmeralda 1:100 000 Sheet areas, north Queensland. *Queensland Geological Record* **1997/01**.

DENARO, T.J., MORWOOD, D.A., DUGDALE, J.S. & GARRAD, P.D., 1992: Mineral occurrences — Cape Melville 1:250 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/01**.

DENARO, T.J., WITHNALL, I.W., BAIN, J.H.C. & MACKENZIE, D.E., 1997: *Mineral resource assessment — Georgetown–Croydon area*. Queensland Minerals and Energy Review Series, Queensland Department of Mines and Energy.

DENARO, T.J., WITHNALL, I.W., CULPEPER, L.G., BURROWS, P.E. & MORWOOD, D.A., 2003a: Mines, mineralisation and mineral exploration in the Duchess and Boulia 1:250 000 Sheet areas, north-west Queensland. *Queensland Geological Record* **2003/04**.

DENARO, T.J., WITHNALL, I.W., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 2003b: Mines, mineralisation and mineral exploration in the Urandangi 1:250 000 sheet area, north-west Queensland. *Queensland Geological Record* **2003/02**.

DUGDALE, J.S., 1991: Compilation of mine production data for the Cooktown, Thursday Island and Weipa mining districts from Annual Reports of the Department of Mines (1884-1988/89). *Queensland Resource Industries Record* **1991/01**.

FAWCKNER, J.F., 1981: Structural and stratigraphic relations and a tectonic interpretation of the western Hodgkinson Province, northeastern Australia. Ph.D. Thesis, James Cook University of North Queensland, Townsville, Department of Earth Sciences.

FERGUSSON, C.L., 1991: Thin-skinned thrusting in the northern New England Orogen, central Queensland, Australia. *Tectonics*, **10**, 797–806.

FERGUSSON, C.L., HENDERSON, R.A. & LEITCH, E.C., 1994: Tectonics of the New England Fold Belt in the Rockhampton Gladstone region, central Queensland. *In* Holcombe, R.J., Stephens, C.J. & Fielding, C.R.(Editors): *1994 Field Conference, Capricorn region, central coastal Queensland.* Geological Society of Australia Inc. (Queensland Division), 1–16.

FERGUSSON, C.L., HENDERSON, R.A., LEITCH, E.C. & ISHIGA, H., 1993: Lithology and structure of the Wandilla terrane, Gladstone-Yeppoon district, central Queensland, and an overview of the Palaeozoic subduction complex of the New England Fold Belt. *Australian Journal of Earth Sciences*, **40**, 403–414.

FIELDING, C.R., HOLCOMBE, R.J. & STEPHENS, C.J., 1994: A critical evaluation of the Grantleigh Trough, east-central Queensland. *In* Holcombe, R.J., Stephens, C.J. & Fielding, C.R. (Editors): *1994 Field Conference, Capricorn region, central coastal Queensland.* Geological Society of Australia Inc. (Queensland Division), 17–30.

FLOOD, P.G., 1999: Exotic seamounts within Gondwanan accretionary complexes, eastern Australia. *In* Flood, P.G.(Editor): *New England Orogen NEO '99 Conference.* Earth Sciences, School of Physical Sciences and Engineering, University of New England, Armidale, 23–29.

FORRESTAL, P.J., PEARSON, P.J., COUGHLIN, T. & SCHUBERT, C.J., 1998: Tick Hill Gold Deposit. *In* Hughes, F.E. (Editor): *Geology of the Mineral Deposits of Australia and Papua New Guinea*. The Australian Institute of Mining and Metallurgy, 699–706.

GARRAD, P.D., 1991: A compilation of mine production data for Herberton Mining District from Annual Reports of the Department of Mines (1883-1989). *Queensland Resource Industries Record* **1991/04**.

GARRAD, P.D., 1993: Mineral occurrences, Mount Mulligan 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1993/11**.

GARRAD, P.D., 1996: Mineral occurrences of the Lolworth, Pentland and White Mountains 1:100 000 Sheet areas, north Queensland. *Queensland Geological Record* **1996/06**.

GARRAD, P.D. & BULTITUDE, R.J., 1999: *Geology, mining history and mineralisation of the Hodgkinson and Kennedy Provinces, Cairns region, north Queensland*. Queensland Minerals and Energy Review Series, Queensland Department of Mines and Energy.

GARRAD, P.D. & LAM, J.S.F., 1993: Mineral occurrences, Emerald 1:250 000 Sheet area. *Queensland Geological Record* **1993/02**.

GARRAD, P.D. & REES, I.D., 1995: Mineral occurrences, Innisfail 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1995/03**.

GARRAD, P.D. & WITHNALL, I.W., 2004a: Mineral occurrences and district analysis — Banana, Theodore and Scoria 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **2004/02**.

GARRAD, P.D. & WITHNALL, I.W., 2004b: Mineral occurrences — Saint Lawrence and Port Clinton 1:250 000 Sheet areas, central Queensland. *Queensland Geological Record* **2004/07**.

GUNTHER, M.C., MORWOOD, D.A., DENARO, T.J. & DASH, P.H., 1994: Mineral occurrences of the Kangaroo Hills Mineral Field. *Queensland Geological Record* **1994/03**.

GUST, D.A., STEPHENS, C.J. & GRENFELL, A.T., 1993: Granitoids of the northern NEO: their distribution in time and space and their tectonic implications. *In* Flood, P.G. & Aitcheson, J.L. (Editors): *NEO '93 Conference Proceedings*. Department of Geology and Geophysics, University of New England, 565–571.

HARMS, J.E., 1965: Iron ore deposits of Constance Range. *In* McAndrew, J. (Editor): *Geology of Australian Ore Deposits.* Eighth Commonwealth mining and metallurgical congress Australia and New Zealand, The Australian Institute of Mining and Metallurgy, Melbourne, 264–269.

HARRINGTON, H.J., 1983: Correlation of the Permian and Triassic Gympie Terrain of Queensland with the Brooks Street and Maitai terranes of New Zealand. *In, Permian Geology of Queensland*, Geological Society of Australia, Queensland Division, Brisbane, 431–436.

HARTLEY, J.S., 1996: Mineral occurrences — Ravenswood 1: 100 000 Sheet area. *Queensland Geological Record* **1996/02**.

HARTLEY, J.S. & DASH, P.H., 1993: Mineral occurrences, Charters Towers 1:100 000 Sheet area. *Queensland Geological Record* **1993/06**.

HAYWARD, M.A., DOMAGALA, J., BLAKE, P.R., SIMPSON, G.A. & CROUCH, S.B.S., 1995: Review of mineral exploration within the Rookwood (8851) and Ridgelands (8951) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1995/02**.

HENDERSON, G.A.M., 1989: Notes on Croydon, North Queensland, fieldwork July/August 1988 and results of K/Ar dating of sericitic alteration. *Bureau of Mineral Resources, Geology and Geophysics, Australia, Record* **1989/46**.

HENDERSON, R.A., 1980: Structural outline and summary geological history for north-eastern Australia. *In* Henderson, R.A. & Stephenson, P.J. (Editors):*The Geology and Geophysics of North-eastern Australia.* Geological Society of Australia, Queensland Division, Brisbane, 1–26.

HOLCOMBE, R.J., STEPHENS, C.J., FIELDING, C.R., GUST, D., LITTLE, T.A., SLIWA, R., McPHIE, J. & EWART, A., 1997: Tectonic evolution of the northern New England Fold Belt: Carboniferous to Early Permian transition from active accretion to extension. *Geological Society of Australia Special Publication* **19**, 66–79.

HUTTON, L.J., RIENKS, I.P., TENISON WOODS, K., HARTLEY, J.S. & CROUCH, S.B.S., 1994: A geochemically and structurally based interpretation of the Ravenswood Batholith, North Queensland. *In* Henderson, R.A. & Davis, B.K. (Editors): Extended conference abstracts. New developments in geology and metallogeny: northern Tasman Orogenic Zone. James Cook University of North Queensland, Department of Earth Sciences, *Economic Geology Research Unit, Contribution* **50**, 3–6.

HUTTON, L.J., WITHNALL, I.W., BULTITUDE, R.J., VON GNIELINSKI, F.E. & LAM, J.S., 1999: South Connors-Auburn-Gogango Project: progress report on investigations during 1998. *Queensland Geological Record* **1999/7**.

JOHNSON, R.W., KNUTSON, J., TAYLOR, J. & ROSS, S., 1989. *Intraplate volcanism in eastern Australia and New Zealand.* Cambridge University Press in association with the Australian Academy of Science.

KIRKEGAARD, A.G., SHAW, R.D. & MURRAY, C.G., 1970: Geology of the Rockhampton and Port Clinton 1:250 000 sheet areas. *Geological Survey of Queensland Report* **38**.

KITCH, R.B. & MURPHY, R.W., 1990: Gympie Gold Field. *In* Hughes, F.E. (Editor): *Geology of the Mineral Deposits of Australia and Papua New Guinea.* The Australian Institute of Mining and Metallurgy, 1515–1518.

LAM, J.S.F., 1993: Summary of the mineral occurrences of the Mossman 1:100 000 Sheet area (7965), north Queensland. *Queensland Geological Record* **1993/13**.

LAM, J.S.F., 1994a: Summary of company exploration and mineral occurrences of the Chudleigh Park 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1994/15**.

LAM, J.S.F., 1994b: Summary of company exploration and mineral occurrences of the Maryvale 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1994/19**.

LAM, J.S.F., 1994c: Summary of mineral occurrences and company exploration of the Lyndhurst 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1994/20**.

LAM, J.S.F., 1995a: Summary of mineral occurrences and company exploration of the Clarke River 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1995/05**.

LAM, J.S.F., 1995b: Summary of mineral occurrences and company exploration of the Burges 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1995/06**.

LAM, J.S.F., 1996: Summary of company exploration and mineral occurrences of the Wando Vale 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1996/01**.

LAM, J.S.F., 1998: A review of company exploration for metalliferous deposits in the Mundubbera 1:250 000 Sheet area. *Queensland Geological Record* **1998/04**.

LAM, J.S, 2004: A review of company exploration and metalliferous mineralisation in the Mackay 1:250 000 Sheet area, central Queensland. *Queensland Geological Record* **2004/04**.

LAM, J.S, 2005a: A review of mines and metalliferous mineralisation in the Mundubbera 1:250 000 Sheet area, *Queensland. Queensland Geological Record* **2005/01**.

LAM, J.S, 2005b: A review of exploration, mines and metalliferous mineralisation in the Clermont 1:250 000 map Sheet area. *Queensland Geological Record* **2005/02**.

LAM, J.S.F. & GARRAD, P.D., 1993: Mineral occurrences — Monteagle (8352) & Albro (8252) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1993/01**.

LAM, J.S.F. & GENN, D.L.P., 1993: Mineral occurrences, South Palmer River 1:100 000 north Queensland. *Queensland Geological Record* **1993/26**.

LAM, J.S.F., DENARO, T.J., BURROWS, P.E. & GARRAD, P.D., 1991: Summary of the mineral occurrences of the Maytown 1:100 000 Sheet Area (7765), north Queensland. *Queensland Resource Industries Record* **1991/10**.

LAM, J.S.F., DENARO, T.J., GARRAD, P.D., HOLMES, P. & KAY, J., 1989: The mineral occurrences of the Lyndbrook 1:100 000 Sheet area. *Geological Survey of Queensland Record* **1989/06**.

LAM, J.S.F., GARRAD, P. & MITCHELL, G., 1988: Mineral occurrence data sheets, Bullock Creek 1:100 000 map Sheet area, Metallogenic Studies Program. Geological Survey of Queensland Record 1988/12.

LEITCH, E.C., FERGUSSON, C.L., & HENDERSON, R.A., 1992: Geological note: The intra-Devonian unconformity at Mount Gelobera, south of Rockhampton, central Queensland. *Australian Journal of Earth Sciences*, **39**, 121–122.

MESSENGER, P.R., GOLDING, S.D. & TAUBE, A., 1997: Volcanic setting of the Mount Morgan Au–Cu deposit, central Queensland: implication for ore genesis. *Geological Society of Australia Special Publication* **19**, 109–127.

MORRISON, G.W., 1988: Palaeozoic gold deposits of northeast Queensland. *In* Morrison, G.W. (Editor): Epithermal and porphyry style gold deposits in North Queensland. James Cook University of North Queensland, Townsville, Department of Earth Sciences, *Economic Geology Research Unit, Contribution*, **29**, 11–21.

MORWOOD, D.A., 1992: Compilation of mine production data for the Kangaroo Hills Mineral Field, north Queensland, from Annual Reports of the Department of Mines (1887-1990). *Queensland Resource Industries Record* **1992/09**.

MORWOOD, D.A., 2002a: Mineral occurrences — Monto, Calliope and Biloela 1:100 000 Sheet areas. *Queensland Geological Record* **2002/02**.

MORWOOD, D.A., 2002b: Mineral occurrences — Mount Morgan 1:100 000 Sheet area. *Queensland Geological Record* **2002/03**.

MORWOOD, D. A., 2003: Mineral occurrences — Gladstone and Cape Capricorn 1:100 000 Sheet areas. *Queensland Geological Record* **2003/01**.

MORWOOD, D.A. & BLAKE, P.R., 2002: Mineral occurrences — Bajool 1:100 000 Sheet area. *Queensland Geological Record* **2002/01**.

MORWOOD, D.A. & DASH, P.H., 1996: Mineral occurrences of the Ingham 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1996/05**.

MORWOOD, D.A. & DENARO. T.J., 2000: Mineral exploration in the Mount Isa 1:250 000 Sheet area, north-west Queensland. *Queensland Geological Record* **2000/01**.

MORWOOD, D.A., DRAPER, J.J., EWINGTON, D.J., GUNTHER, M.C. & DENARO, T.J., 2001: Mineral occurrences of the Townsville 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **2001/02**.

MURRAY, C.G., 1986: Metallogeny and tectonic development of the Tasman Fold Belt System in Queensland. *Ore Geology Reviews* **1**, 315–400.

MURRAY, C.G., BLAKE, P.R., HUTTON, L.J., WITHNALL, I.W., HAYWARD, M.A., SIMPSON, G.A. & FORDHAM, B.G. 2003: Discussion and reply. Yarrol terrane of the northern New England Fold Belt: forearc or backarc? Discussion. *Australian Journal of Earth Sciences*, **50**, 271–278.

MURRAY, C.G., FERGUSSON, C.L., FLOOD, P.G., WHITAKER, W.G. & KORSCH, R.J., 1987: Plate tectonic model for the Carboniferous evolution of the New England Fold Belt. *Australian Journal of Earth Sciences*, **34**, 213–236.

OLGERS, F., 1972: Geology of the Drummond Basin, Queensland. *Bureau of Mineral Resources, Australia Bulletin*, **132**.

O'ROURKE, P.J., 1975: Maureen uranium fluorine, molybdenum prospect, Georgetown. *In* Knight, C.L. (Editor): *Economic Geology of Australia and Papua New Guinea. 1. Metals*. The Australian Institute of Mining and Metallurgy, Melbourne, 764–769..

OSBORNE, J.H., SIMPSON, G.A., BLAKE, P.R., HAYWARD, M.A., CROUCH, S.B.S. & DOMAGALA, J., 1997: Review of mineral exploration within the Rockhampton (9051), Cape Capricorn (9151) and Gladstone (9150) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1997/03**.

PAGE, R.W. & SWEET, I.P., 1998: Geochronology of basin phases in the western Mount Isa Inlier, and correlation with the McArthur Basin. *Australian Journal of Earth Sciences* **45**, 219–232.

PAGE, R.W. & SUN, S.S., 1998: Aspects of geochronology and crustal evolution in the Eastern Fold Belt, Mount Isa Inlier. *Australian Journal of Earth Sciences* **45**, 343–361.

PETERS, S.G., 1987: Geology, lode descriptions and mineralisation of the Hodgkinson Goldfield, north-eastern Queensland. James Cook University of North Queensland, Townsville, Department of Earth Sciences. *Economic Geology Research Unit, Contribution* **20**.

PHILLIPS, G.N. & POWELL, R., 1992: Gold only provinces and there common features.*Economic Geology Research Unit, Contribution* **43**.

QUEENSLAND DEPARTMENT OF MINES AND ENERGY, TAYLOR WALL & ASSOCIATES, SRK CONSULTING PTY LTD & ESRI AUSTRALIA, 2000: *North-west Queensland Mineral Province Report*. Queensland Department of Mines and Energy, Brisbane.

RANDALL, R E., OSBORNE, J. H., DONCHAK, P. J.T., CROSBY, G. C. & SCOTT, M., 1996: Review of mineral exploration and known mineral occurrences within the Goomeri (9345), Nambour (9444) and Nanango (9344) 1:100 000 Sheet areas, south-east Queensland. *Queensland Geological Record* **1996/04**.

REES, I.D. & GENN, D.L.P., 1999: Mineral occurrences – Gilberton 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1999/08**.

SAWERS, J.D., HAYWARD, M.A., COOPER, W., DASH, P.H., GARRAD, P.D., ISHAQ, S. & LAM, J.S.F., 1987: Metallogenic Studies Program, Mungana 1:100 000 Sheet, mineral occurrence data sheets. Geological Survey of Queensland Record 1987/29.

SENNITT, C.M. & HARTLEY, J.S., 1994: Mineral occurrences: Homestead 1:100 000 Sheet area , north Queensland. *Queensland Geological Record* **1994/16**.

SHERGOLD, J.H. & DRUCE, E.C., 1980: Upper Proterozoic and Lower Palaeozoic rocks of the Georgina Basin. *In* Henderson, R.A. & Stephenson, P.J. (Editors): *The Geology and Geophysics of North-eastern Australia* . Geological Society of Australia, Queensland Division, 149–174.

SIMPSON, G.A., BLAKE, P.R., MURRAY, C.G., HAYWARD, M.A. & FORDHAM, B.G., 1998: Evidence for mid-Paleozoic exotic terranes in the Yarrol Province, central Queensland. *Geological Society of Australia Abstracts*, **49**, 408.

SMITH, K.G., 1972: Stratigraphy of the Georgina Basin. *Bureau of Mineral Resources, Australia, Bulletin*, **111**.

TAUBE, A., 1986: The Mount Morgan gold–copper mine and environment, Queensland: A volcanogenic massive sulphide deposit associated with penecontemporaneous faulting. *Economic Geology*, **81**, 1322–1340.

VAN NOORD, K.A.A., 1999: Basin development, geological evolution and tectonic setting of the Silverwood Group. *In* Flood, P.G. (Editor): *New England Orogen NEO '99 Conference*. Earth Sciences, School of Physical Sciences and Engineering, University of New England, Armidale, 163–180.

WALLIS, D.S., DRAPER, J.J., DENARO, T.J., 1998: Palaeo- and Mesoproterozoic mineral deposits in Queensland. *AGSO Journal of Australian Geology and Geophysics*, **17**(3), 47–59.

WATERHOUSE, J.B. & SIVELL, W.J., 1987: Permian evidence for trans-Tasman relationships between east Australia, New Caledonia and New Zealand. *Tectonophysics*, **142**, 227–240.

WITHNALL, I.W., BLAKE, P.R., CROUCH, S.B.S., TENNISON WOODS, K., GRIMES, K.G., HAYWARD, M.A., LAM, J.S., GARRAD, P. & REES, I.D., 1995: Geology of the southern part of the Anakie Inlier, central Queensland. *Queensland Geology*, **7**.

WITHNALL, I.W., GOLDING, S.D., REES, I.D. & DOBOS, S.K., 1996: K-Ar dating of the Anakie Metamorphic Group: evidence for an extension of the Delamerian Orogeny into central Queensland. *Australian Journal of Earth Sciences*, **43**, 567–572.

WITHNALL, I.W, HUTTON, L.J., RIENKS, I.P., BULTITUDE, R.J., VON GNIELINSKI, F.E., LAM, J.S., GARRAD, P.D. & JOHN, B.H., 1998: South Connors–Auburn–Gogango Project: progress report on investigations during 1997. *Queensland Geological Record* **1998/1**.

WITHNALL, I.W., HUTTON, L.J., GARRAD, P.D., JONES, M.R. & BLIGHT, R.L. 2002: *North Queensland Gold and Base Metal Study Stage 1 Preliminary data release — Georgetown GIS*. Geological Survey of Queensland, Department of Natural Resources and Mines, digital data released on CD-ROM.

WITHNALL, I.W., HUTTON, L.J. & BLIGHT, R.L. 2003: *North Queensland Gold and Base Metal Study Stage 2 Preliminary data release — Charters Towers GIS*. Geological Survey of Queensland, Department of Natural Resources and Mines, digital data released on CD-ROM.

WITHNALL, I.W. & LANG, S.C. (Editors), 1993: Geology of the Broken River Province, North Queensland. *Queensland Geology*, **4**.

YARROL PROJECT TEAM, 1997: New insights into the geology of the northern New England Orogen in the Rockhampton–Monto Region, Central Coastal Queensland: Progress Report on the Yarrol Project. *Queensland Government Mining Journal*, **98**, 11–26.

YARROL PROJECT TEAM, 2003: *Central Queensland Regional Geoscience Data —Yarrol GIS*. Department of Natural Resources, Mines and Water.

OVERVIEW OF MINERAL COMMODITIES FOR QUEENSLAND

Queensland's major mineral deposits are summarised below by commodity type. General geological descriptions of the major deposit models are included where appropriate. Summary resource and reserve figures are calculated by using all classification levels unless otherwise stated. Efforts has been made to ensure that resource figures quoted are not inclusive of other resource details tabulated, to ensure a clear understanding of the deposits' magnitude. The resource classification scheme used is the Australasian Code for Reporting of Minerals Resources and Ore Reserves (The JORC Code) and is included as **Appendix 9**.

More detailed information for individual mines and prospects is available in the 'Mineral Deposit Summary Sheets' included as **Appendixes 1 and 2**. The following information has been compiled from company reports, announcements and published documents. Commodity reviews and personal communications have also been extensively sourced.

Tabulations of mineral resources for Queensland are included as **Appendixes 3 to 7**. Information tabulated includes the total metal content for the various reserve and resource classifications by deposit and commodity, contained metal grouped by host rock age, total production details, deposit models versus host rock provinces, and individual resources for each major deposit in Queensland. Only small to giant sized mineral deposits have been used in the tabulations. The size classification used is defined in **Appendix 8**. **Appendixes 10 and 11** provide listings of the names and contact details of individuals and companies active in mining and exploration in Queensland.

Antimony

Quartz-stibnite veins are widely distributed in eastern Queensland, with concentrations in the Hodgkinson and Broken River Provinces and, to a lesser extent, in the Gympie Province. The main centres of past antimony production include the Neardie mine (north-east of Gympie) the Northcote deposit, the Woodville deposit and the Mitchell River area (west of Cairns in far north Queensland). Current antimony production in Queensland comes from the silver–lead–zinc orebodies at Mount Isa (Black Star), where antimony is a by-product from the refining of the base metal concentrates.

Small scale mining of high-grade antimony vein deposits has occurred intermittently since 1873. Total historical Queensland production is ~5 500t of antimony metal and concentrates. Future antimony production may come from the development of small to medium-sized gold-antimony deposits in the Hodgkinson and Broken River Provinces (Table 4).

Antimony deposits can be classified as simple (structurally-controlled antimony gold veins) or complex. With the exception of the Mount Isa mineralisation, almost all antimony mineralisation in Queensland is simple and is characterised by a high variability in grade along the vein system.

Table 4. Major antimony deposits of Queensland

Deposit Name	Total contained antimony in resources and reserves (t)	Total contained gold in resources and reserves (kg)	Total other metals in resources and reserves
Antimony Reward	13 197		
Belfast Hill	1031	341	
Black Bess	3591	1875	
East Leadingham	885	1275	
Emily	598	1558	
Emily South	86	501	
Ethel	2035	1596	
Neardie	543		
Nightflower	2298		42 645kg Ag 12 547t Pb 4932t Zn
Retina	12 300	168	
Tunnel Hill	1236	797	
Total	**37 800**	**8111**	

Creek, Marlborough, Oldman South and Yaamba magnesite deposits formed in a similar environment. The world-class *in situ* resources of medium- to high-grade cryptocrystalline magnesite at Kunwarara (29.3Mt of contained magnesite, including Oldman South) place Queensland in a prime position to take up a significant world market share of magnesium production in the future.

Perlite

Total Queensland perlite production in 2005–06 was 6657t. This small level of production understates the significant known resources at the Nychum deposit, in north Queensland, which is considered to be the largest perlite deposit in the world.

Perlite is a form of volcanic glass that expands by up to 30 times its original volume when heated to temperatures between 727 ºC and 1127ºC. Expansion occurs by the vaporisation of the 2–6% combined water in perlite's structure, producing a light cellular material with excellent insulating properties. Expanded perlite has a very low thermal conductivity and a loose weight that can be as low as ~40kg/m^3. Commercially, any volcanic glass that will 'pop' on heating to form a lightweight frothy material is called perlite. Perlite is used as a refractory mineral, an insulator, as a filter medium and in horticulture. Queensland perlite is of a high quality compared with similar quality products that are available only from Mexico.

Perlite is often associated with Tertiary age rhyolitic lava flows. Two major perlite deposits are currently being mined in Queensland — the large Nychum (Wrotham) perlite deposit, 50km north-west of Chillagoe in far north Queensland, and the smaller Numinbah (Agee) deposit in the McPherson Range, south-east of Beechmont in southern Queensland.

The Nychum deposit is 6.5km long, 3km wide and 30m thick, with outcropping material displaying a thin bloom of aluminium oxide, the only indication of weathering. The perlite occurs as discrete layers in the Early Permian Nychum Volcanics of the Kennedy Province. The resource at Nychum may contain up to 700Mt. Current mining is by small open cut techniques. The perlite is crushed to 1.1mm size prior to expansion. Production in 2004–05 was 5200t. Nychum expanded perlite is brilliant white in comparison with the grey colour of Numinbah perlite. Present perlite processing is achieving an expanded product with a density of ~50kg/m^3. Perlite from Nychum is also used as ultra lightweight aggregate in plaster and concrete, as a prime ingredient in insulating board and ceiling tiles, and as loose fill insulation.

The Numinbah deposit is a zone of volcanic glass within the Lamington Group of the Tertiary Lamington Volcanic Subprovince (Eastern Australian Cainozoic Igneous Province). About 15 000–20 000t of perlite is stockpiled at a time from campaign-style open cut and underground mining operations; the ore is crushed, screened, dried and bagged on site. Intermittent mining has occurred for ~30 years; production in 2005–06 totalled 6657t. The perlite is expanded in Sydney after road transport from the mine. Numinbah perlite contains the ideal amount of water for expansion and produces a physically strong product. Expansion produces a 15-fold increase in volume.

Phosphate

Total phosphate production in Queensland in 2005–06 was 861 300t of diammonium phosphate and monoammonium phosphate from 2 082 658t of phosphate rock. All of this production came from the Phosphate Hill operations in north-west Queensland. Queensland's known phosphate rock resources total 3Bt from a series of large marine sedimentary phosphorites that are hosted by Early to Middle Cambrian rocks of the Georgina Basin (Table 14). The Beetle Creek Formation is the main host and consists of a sequence of phosphatic siltstone (phosphorite) and chert that overlies limestone, sandstone and conglomerate. Only the Phosphate Hill deposit is currently being mined. Commercial phosphate rock is calcium phosphate together with various impurities, including calcium and magnesium carbonates, iron oxides, clay, silica and fluorine. The major use of phosphate rock is in the manufacture of fertilisers.

Phosphate rock was produced at Phosphate Hill from 1975 to 1978 by Broken Hill South. WMC Ltd acquired the deposit in 1980 and subsidiary Queensland Phosphate Ltd resumed production from 1981 to 1983. In 1996, WMC Fertilizers commenced development of a new mine at Phosphate Hill with the construction of an acid plant at Mount Isa and ammonia, phosphoric acid, beneficiation and granulation plants at Phosphate Hill. Production commenced in January 2000.

Processing of phosphate rock involves reacting phosphoric acid with liquid ammonia in different proportions to produce high analysis monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers. BHP Billiton acquired the Phosphate Hill operation in 2005 and sold it to Incitec Pivot Ltd in August 2006.

Silica and Foundry Sands

Queensland silica and foundry sand production in 2005–06 was 2.08Mt, of which 71% came from the Cape Flattery operations in far north Queensland. Current Queensland resources and reserves of silica and foundry sands total >1.499Bt.

Silica sand deposits fringe the Queensland coastline as Pleistocene to Holocene coastal deposits that extend up to 12km inland and average 25–30m in thickness. Large sand masses form as high transgressive or parabolic dunes, as beachridge barriers or as tidal delta sands.

Beachridge barrier deposits form parallel to the coast, incorporating former beach strand lines. Large transgressive parabolic sand dunes were initiated by blowouts of beachridges and have evolved under conditions of persistent

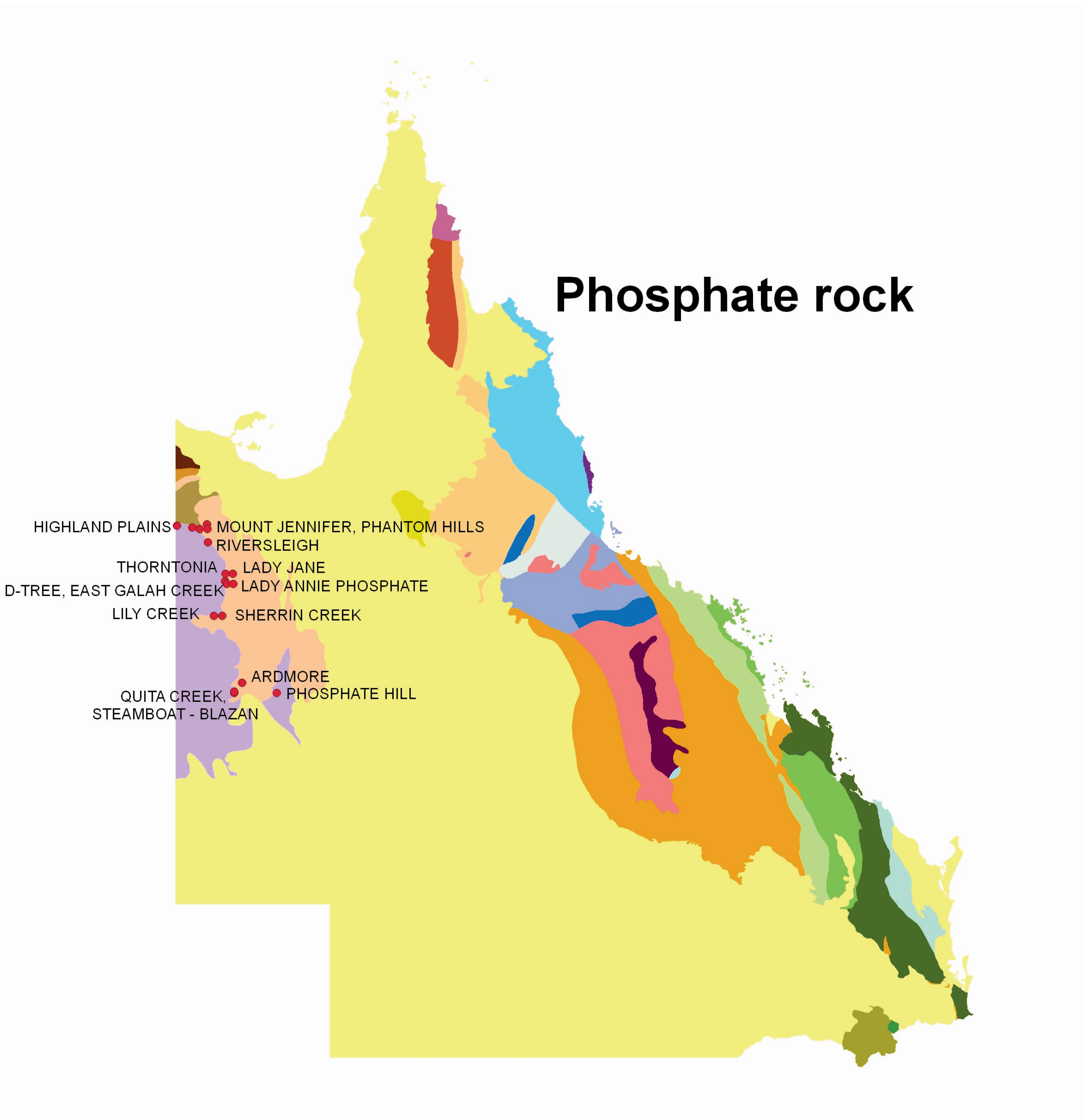

Phosphate rock
HIGHLAND PLAINS
MOUNT JENNIFER, PHANTOM HILLS
RIVERSLEIGH
THORNTONIA
LADY JANE
D-TREE, EAST GALAH CREEK
LADY ANNIE PHOSPHATE
LILY CREEK
SHERRIN CREEK
ARDMORE
QUITA CREEK,
STEAMBOAT - BLAZAN
PHOSPHATE HILL

Table 14. Major phosphate deposits in Queensland

Deposit Name	Total phosphate rock resource (Mt)
Ardmore	1419
Babbling Brook Hill	38
D-Tree	339
East Galah Creek	20.7
Highland Plains	84
Lady Annie Phosphate	293
Lady Jane	193
Lily Creek	191
Mount Jennifer	20.7
Mount O'Connor	42
Phantom Hills	45.4
Phosphate Hill	127.6
Quita Creek	30
Riversleigh	11.4
Sherrin Creek	175
Steamboat – Blazan Creek	24
Thorntonia	47.4

south-easterly winds on an exposed coastal aspect, with sand supplies continually provided by an erosional shoreline during marine transgressions.

The Cape Flattery Silica Mine is Queensland's largest producer of silica sand and has total resources of 1.2Bt. The resource occurs within a large dunefield that covers ~580km^2 north of Cooktown and consists predominately of white, sharp featured, transgressive, elongate-parabolic active dunes stabilised by vegetation. The dunes occupy a low interdune sandplain that is 5–10m above sea level and are interspersed with numerous dune lakes and swamps.

North Stradbroke Island contains significant silica sand resources and mining is carried out at the Myora and Vance deposits. These occur in deeply leached, older Holocene and Pleistocene sand masses with a podsolic soil profile with a deep A2 layer of pure silica sand that is the focus of mining operations. Unimin purchased the Stradbroke Island assets of ACI in March 2001 and is currently mining silica sand from the Myora deposit on ML 7064 and processing the sand through a plant sited on adjoining ML 1124. After processing, the silica sand is trucked to Hospital Point at Dunwich and barged to Brisbane for export and domestic sales.

Silica sand mining also occurs at the Iveragh deposit at Tannum Sands, 20km south-east of Gladstone. This deposit is an old beachridge barrier system and contains a 4Mt resource. The sand is used in the manufacture of cement clinker at Gladstone.

The Mourilyan sand deposit, near Innisfail in north Queensland, is a complex comprising an inner and outer beachridge barrier. The inner beachridge barrier is Pleistocene in age and is locally covered by low, degraded transgressive dunes. The outer beachridge barrier is of Holocene age. Samples collected by Pioneer Concrete Pty Ltd in the 1980s all contained >99% silica. Calcifer Industrial Minerals Pty Ltd has applied for mining leases over this deposit, which contains an indicated 10.7Mt of silica sand.

The Olive River Dunefield forms a roughly triangular-shaped, low coastal plain on the east coast of Cape York Peninsula. This dunefield extends along the coast from Olive River north to Shelbourne Bay and inland up to 15km. It is Quaternary in age and overlies Jurassic to Cretaceous, flat-lying quartzose sediments of the Carpentaria Basin. The deposit contains both active and older stabilised lateritised parabolic dunes that are aligned with the prevailing south-east winds. The dunes consist almost entirely of quartz sand, with a heavy mineral content of 0.024–0.206% (mainly ilmenite and zircon). The total silica sand resource, including the Shelburne Silica deposit, is estimated as

Appendix 2

Summary report for major prospects in Queensland

The following section presents detailed information for each of Queensland's significant prospects or abandoned mines. Mineral deposits are presented in alphabetic order. Each mineral deposit report contains information about the location, commodities, size classification, production, resources/reserves, mining styles, tenures, host rocks, mineral deposit models, mineralisation ages and other comments.

The resource information recorded does not duplicate resources documented as reserves or under any other resource classification. For example, if a published 'measured, indicated and inferred resource' includes the 'proved and probable ore reserves', these reserves are not recorded. However, if published reserves are in addition to the published resources they they are recorded separately. Open file information sources such as company annual reports, quarterly reports and stock exchange announcements have been used, where available, to ensure current information is captured. Most resource and reserve figures are in accordance with the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC code), which is included as **Appendix 9.** Some older resource figures are not in accordance with the JORC code. Individual summary reports indicate whether or not the resource and reserve figures are JORC compliant. All sources used are referenced wherever possible.

Production figures listed have been derived mainly from Department of Mines and Energy statistical returns, with additional detail from published sources and company annual and quarterly reports.

493654 **LADY ANNIE PHOSPHATE**

MINERAL OCCURRENCE, ACTIVE PROSPECT

Descriptive Location: 26 KM WEST-SOUTH-WEST OF GUNPOWDER, 105KM NNW OF MT ISA.

1:100 000 sheet Number and Name: 6758 MAMMOTH MINES

Grid Reference: AMG Zone 54 302293 mE 7814132 mN Latitude -19.7585 Longitude 139.1131 Date Recorded: 2/January/2007

Other Names for Deposit / Mine

Lady Annie

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	LARGE	>200 000 000 tonnes PHR

Production Details

Period: 1-Jan-1972 to 31-Dec-1972 663 tonnes ore

PHOSPHATE ROCK (PHOSPHORITE) 663.0 tonnes

Period: 1-Jan-1974 to 31-Dec-1974 64,000 tonnes ore

PHOSPHATE ROCK (PHOSPHORITE) 64,000.0 tonnes

Published Reserves/Resources

BR 5122 Published in 1990

MEASURED - INDICATED MINERAL RESOURCE 293,000,000 tonnes Ore @

293,000,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: Averages 16.6% P2O5.

Resource figures listed above are NOT JORC compliant.

Published Reference ID	Year	Author
BR 5122	1990	FREEMAN, M.J., SHERGOLD, J.H., MORRIS, D.G., & WALTER, M.R.

Late Proterozoic And Palaeozoic Basins Of Central And Northern Australia - Regional Geology And Mineralisation.

In Hughes, F.E., (Editor): Geology and Mineral Deposits of Australia and Papua New Guinea. The Australasian Institute of Mining and Metallurgy Monograph Series, 14, 1125-1133.

Major Mining Related Events

Year Commenced		Year Completed	Comments
1967	to	1967	Discovery of rock phosphate at Lady Annie by Broken Hill South Ltd.
1972	to	1974	100t/day pilot grinding & flotation plant commissioned. Ore excavated and treated for bulk testing of deposit.

Mining Operations	Comments
SHAFTS	
OPEN CUT MINING	

Tenure Type/Number	SHARE	Company Name/Surname
MDL 348	100.00%	SOUTHERN CROSS FERTILIZERS PTY LTD

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Beetle Creek Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE	MIDDLE CAMBRIAN	Dominantly pelletal phosphorite.

Comments

The deposit occurs in a succession of dolomitic siltstone and shale with occasional beds of quartz sandstone. As many as five separate phosphatic horizons, attaining a composite thickness of 29m have been recognised.

Southern Cross Fertilizers Pty Ltd has applied for MDL 348 over the deposit. BHP Billiton acquired Southern Cross Fertilizers when it took over WMC. In August 2006, BHP Billiton sold Southern Cross Fertilizers to Incitec Pivot Ltd.

Web Page

www.incitec.com

491346 **LADY JANE**

MINERAL OCCURRENCE, ACTIVE PROSPECT

Descriptive Location: 33KM WNW OF GUNPOWDER, 120KM NNW OF MT ISA.

1:100 000 sheet Number and Name: 6758 MAMMOTH MINES

Grid Reference: AMG Zone 54 301621 mE 7836165 mN Latitude -19.5594 Longitude 139.1090 Date Recorded: 2/January/2007

Other Names for Deposit / Mine

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	MEDIUM	200 000 - 200 000 000 tonnes PHR

Production Details

Published Reserves/Resources

BR 5122 Published in 1990

MEASURED - INDICATED MINERAL RESOURCE 193,000,000 tonnes Ore @
193,000,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: Average grade 17.6% P2O5.

Resource figures listed above are NOT JORC compliant.

Published Reference ID	Year	Author
BR 5122	1990	FREEMAN, M.J., SHERGOLD, J.H., MORRIS, D.G., & WALTER, M.R.

Late Proterozoic And Palaeozoic Basins Of Central And Northern Australia - Regional Geology And Mineralisation.
In Hughes, F.E., (Editor): Geology and Mineral Deposits of Australia and Papua New Guinea. The Australasian Institute of Mining and Metallurgy Monograph Series, 14, 1125-1133.

Major Mining Related Events

Year Commenced	Year Completed	Comments

Mining Operations

Tenure Type/Number	SHARE	Company Name/Surname
MDL 347	100.00%	SOUTHERN CROSS FERTILIZERS PTY LTD

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Beetle Creek Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE	MIDDLE CAMBRIAN	Pelletal, replacement and mudstone phosphorite.

Comments

Currently under application for MDL 347 by Southern Cross Fertilizers Pty Ltd. Southern Cross Fertilizers was acquired by BHP Billiton when it took over WMC. BHP Billiton sold Southern Cross Fertilizers to Incitec Pivot Ltd in August 2006.

Web Page

www.incitec.com

491114 D-TREE

MINERAL OCCURRENCE, ABANDONED PROSPECT

Descriptive Location: 44 KM WEST OF GUNPOWDER,115KM NORTH OF MT ISA.

1:100 000 sheet Number and Name: 6658 UNDILLA

Grid Reference: AMG Zone 54 285120 mE 7820165 mN Latitude -19.7022 Longitude 138.9500 Date Recorded: 2/January/2007

Other Names for Deposit / Mine

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	LARGE	>200 000 000 tonnes PHR

Production Details

Published Reserves/Resources

BR 5122 Published in 1990 **D-TREE**

INFERRED MINERAL RESOURCE 339,000,000 tonnes Ore @
339,000,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: Averages 16% P2O5.

Resource figures listed above are NOT JORC compliant.

Published Reference ID	Year	Author
BR 5122	1990	FREEMAN, M.J., SHERGOLD, J.H., MORRIS, D.G., & WALTER, M.R.

Late Proterozoic And Palaeozoic Basins Of Central And Northern Australia - Regional Geology And Mineralisation.
In Hughes, F.E., (Editor): Geology and Mineral Deposits of Australia and Papua New Guinea. The Australasian Institute of Mining and Metallurgy Monograph Series, 14, 1125-1133.

Major Mining Related Events

Year Commenced	Year Completed	Comments

Mining Operations

Tenure Type/Number		SHARE	Company Name/Surname	Christian Name
EPM	14753	33.00%	BURT	Terence John
EPM	14753	33.00%	KIRKBY	Robert William
EPM	14753	33.00%	GALWAY	Judy-Anne

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Beetle Creek Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE MIDDLE CAMBRIAN

Comments

The D-Tree deposit includes the Bean Tree, North Galah Creek, South Galah Creek and Slate Creek deposits.

Web Page

491447 THORNTONIA

MINERAL OCCURRENCE, ABANDONED PROSPECT

Descriptive Location: 44 KM NORTH-WEST OF GUNPOWDER, 125KM NNW OF MT ISA.

1:100 000 sheet Number and Name: 6658 UNDILLA

Grid Reference: AMG Zone 54 286121 mE 7836165 mN Latitude -19.5578 Longitude 138.9613 Date Recorded: 2/January/2007

Other Names for Deposit / Mine

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	MEDIUM	200 000 - 200 000 000 tonnes PHR

Production Details

Published Reserves/Resources

Company Report 3159 Published in 1970

INDICATED MINERAL RESOURCE 47,400,000 tonnes Ore @
47,400,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: Average grade 18.1% P2O5.

Resource figures listed above are NOT JORC compliant.

Published Reference ID Year Author

Major Mining Related Events

Year Commenced Year Completed Comments

Mining Operations

Tenure Type/Number	SHARE	Company Name/Surname
EPM 12866	100.00%	MOUNT ISA MINES LIMITED

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Beetle Creek Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE MIDDLE CAMBRIAN

Comments

This limestone deposit covers an area of approximately 4.2km2.

Web Page

www.xstrata.com

494076 LILY CREEK

MINERAL OCCURRENCE, ABANDONED PROSPECT

Descriptive Location: 86 KM NORTH-WEST OF MOUNT ISA.

1:100 000 sheet Number and Name: 6657 YELVERTOFT

Grid Reference: AMG Zone 54 263620 mE 7744565 mN Latitude -20.3824 Longitude 138.7352 Date Recorded: 2/January/2007

Other Names for Deposit / Mine

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	MEDIUM	200 000 - 200 000 000 tonnes PHR

Production Details

Published Reserves/Resources

BR 5107 Published in 1996

INFERRED MINERAL RESOURCE 191,000,000 tonnes Ore @
191,000,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: Average grade of 14.9% P2O5

Resource figures listed above are NOT JORC compliant.

Published Reference ID	Year	Author
BR 5107	1996	DRAPER, J.J.

Phosphate - Queensland Mineral Commodity Report.

Queensland Government Mining Journal, 97 (1131), 14-25.

Major Mining Related Events

Year Commenced	Year Completed	Comments

Mining Operations

Tenure Type/Number		SHARE	Company Name/Surname
EPM	14912	100.00%	KING EAGLE RESOURCES PTY LIMITED

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Beetle Creek Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE	MIDDLE CAMBRIAN

Comments

The development of this deposit appears unlikely in the short term because of the cover depth and the current development of much larger and more easily mined deposits at Phosphate Hill.

Web Page

494100 **SHERRIN CREEK**

MINERAL OCCURRENCE, ABANDONED PROSPECT

Descriptive Location: 71 KM NORTH-WEST OF MOUNT ISA.

1:100 000 sheet Number and Name: 6657 YELVERTOFT

Grid Reference: AMG Zone 54 280920 mE 7744965 mN Latitude -20.3809 Longitude 138.9009 Date Recorded: 2/January/2007

Other Names for Deposit / Mine

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	MEDIUM	200 000 - 200 000 000 tonnes PHR

Production Details

Published Reserves/Resources

BR 5107 Published in 1996

INFERRED MINERAL RESOURCE 175,000,000 tonnes Ore @
175,000,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: Average grade of 16.5% P2O5.

Resource figures listed above are NOT JORC compliant.

Published Reference ID	Year	Author
BR 5107	1996	DRAPER, J.J.

Phosphate - Queensland Mineral Commodity Report.

Queensland Government Mining Journal, 97 (1131), 14-25.

Major Mining Related Events

Year Commenced	Year Completed	Comments

Mining Operations

Tenure Type/Number	SHARE	Company Name/Surname
EPM 14912	100.00%	KING EAGLE RESOURCES PTY LIMITED

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Beetle Creek Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE MIDDLE CAMBRIAN

Comments

Web Page

491206 **HIGHLAND PLAINS**

MINERAL OCCURRENCE, ABANDONED PROSPECT

Descriptive Location: 12.4KM WSW OF MUSSELBROOK MINING CAMP AREA, 255KM NW OF MT ISA.

1:100 000 sheet Number and Name: 6560 MUSSELBROOK

Grid Reference: AMG Zone 54 185121 mE 7938165 mN Latitude -18.6238 Longitude 138.0160 Date Recorded: 2/January/2007

Other Names for Deposit / Mine

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	MEDIUM	200 000 - 200 000 000 tonnes PHR

Production Details

Published Reserves/Resources

Company Report 15312 Published in 1986

MEASURED - INDICATED MINERAL RESOURCE 84,000,000 tonnes Ore @
84,000,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: >=10% P_2O_5 cutoff. Average grade is 13.4% P_2O_5, 4.3% Al_2O_3, 5.4% Fe_2O_3 and 1.0% CO_2.

Resource figures listed above are NOT JORC compliant.

Published Reference ID **Year** **Author**

Major Mining Related Events

Year Commenced Year Completed Comments

Mining Operations

Tenure Type/Number	SHARE	Company Name/Surname
EPM 14906	100.00%	KING EAGLE RESOURCES PTY LIMITED

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Border Waterhole Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE MIDDLE CAMBRIAN

Comments

Web Page

493685 QUITA CREEK

MINERAL OCCURRENCE, ABANDONED PROSPECT

Descriptive Location: 56KM SOUTH-WEST OF DAJARRA; 27KM S OF ARDMORE HS, 134KM SSW OF MT ISA.

1:100 000 sheet Number and Name: 6754 ARDMORE

Grid Reference: AMG Zone 54 306921 mE 7578567 mN Latitude -21.8864 Longitude 139.1312 Date Recorded: 2/January/2007

Other Names for Deposit / Mine

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	MEDIUM	200 000 - 200 000 000 tonnes PHR

Production Details

Published Reserves/Resources

BR 5107 Published in 1996

MEASURED - INDICATED MINERAL RESOURCE 30,000,000 tonnes Ore @
30,000,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: Average grade of 7.42% P2O5.

Resource figures listed above are NOT JORC compliant.

Published Reference ID	Year	Author
BR 5107	1996	DRAPER, J.J.

Phosphate - Queensland Mineral Commodity Report.
Queensland Government Mining Journal, 97 (1131), 14-25.

Major Mining Related Events

Year Commenced	Year Completed	Comments

Mining Operations

Tenure Type/Number	SHARE	Company Name/Surname
EPM 14905	100.00%	KING EAGLE RESOURCES PTY LIMITED

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Beetle Creek Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE MIDDLE CAMBRIAN

Comments

Web Page

507566 STEAMBOAT - BLAZAN CREEK

MINERAL OCCURRENCE, ABANDONED PROSPECT

Descriptive Location: 132KM SSW OF MT ISA, 25KM S OF ARDMORE HOMESTEAD

1:100 000 sheet Number and Name: 6754 ARDMORE

Grid Reference: AMG Zone 54 307121 mE 7581167 mN Latitude -21.8629 Longitude 139.1334 Date Recorded: 25/October/2006

Other Names for Deposit / Mine

Commodities	Size	Size Definition
PHOSPHATE ROCK (PHOSPHORITE)	MEDIUM	200 000 - 200 000 000 tonnes PHR

Production Details

Published Reserves/Resources

Company Report 6987 Published in 1979

INFERRED MINERAL RESOURCE 24,000,000 tonnes Ore @
24,000,000 Tonnes PHOSPHATE ROCK (PHOSPHORITE)

Comments/Cut Off Factor: Average grade of 17.7% P2O5.

Resource figures listed above are NOT JORC compliant.

Published Reference ID Year Author

Major Mining Related Events

Year Commenced Year Completed Comments

Mining Operations

Tenure Type/Number	SHARE	Company Name/Surname
EPM 14905	100.00%	KING EAGLE RESOURCES PTY LIMITED

Host Rock/Cover Sequences

Structural Unit	*Formation Name/Age*
GEORGINA BASIN	Beetle Creek Formation / MIDDLE CAMBRIAN to MIDDLE CAMBRIAN

Deposit Model

GENERAL ORE BODY MODEL	SEDIMENT-HOSTED DEPOSIT
DETAILED ORE BODY MODEL	UPWELLING TYPE PHOSPHATE

Mineralisation Age

ORE	CAMBRIAN	Phosphorite

Comments

Web Page