Geological framework

(Compiled by I.W. Withnall & L.C. Cranfield)

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 North Australian Craton in the north-west and north, the Paleozoic–Mesozoic Tasman Orogen (including the intracratonic Permian to Triassic Bowen and Galilee Basins) in the east, and overlapping Mesozoic rocks of the Great Australian Basin (Figure 1). The structural framework of Queensland has recently been revised in conjunction with production of a new 1:2 million-scale geological map of Queensland (Geological Survey of Queensland, 2012), and also the volume on the geology of Queensland (Withnall & others, 2013). In some cases the divisions have been renamed. Because updating of records in the Mineral Occurrence database—and therefore the data sheets that accompany this product—has not been completed, the old nomenclature as shown in Figure 1 is retained here, but the changes are indicated in the discussion below.

North Australian Craton

Proterozoic rocks crop out in north-west Queensland in the Mount Isa Province as well as the McArthur and South Nicholson Basins and in the north as the Etheridge Province in the Georgetown, Yambo and Coen Inliers and Savannah Province in the Coen Inlier. In addition, Neoproterozoic – early Paleozoic rocks 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.

Mount Isa Province

Rocks of the Mount Isa Province are exposed over an area in excess of 50 000 km^2 in north-west Queensland, roughly centred on the township of Mount Isa. The rocks can be divided into three subprovinces of differing character and history (Figure 1). Early Paleoproterozoic basement forms the Kalkadoon–Leichhardt Subprovince, a meridional belt dividing the younger domains that comprise the Eastern and Western fold belt subprovinces. Recent work by the Geological Survey of Queensland (2011) has divided the Mount Isa Province into 15 domains (Figure 2), and the records in the Mineral Occurrence database have been updated to reflect this nomenclature. The Kalkadoon–Leichhardt Subprovince corresponds to the Kalkadoon–Leichhardt Domain, the Western Fold Belt Subprovince comprises the Century, Mount Oxide, Sybella and Leichhardt River domains, and the Eastern Fold belt Province comprises the Mary Kathleen, Mitakoodi, Tommy Creek, Marimo–Staveley, Doherty – Fig Tree, Kuridala – Selwyn, Soldiers Cap and Canobie domains. In the north-west, the Camooweal–Murphy Domain includes rocks of the Murphy Province, McArthur Basin and South Nicholson Basin. The most recent summaries of the geology of the Mount Isa Province are by Withnall & Hutton (2013) and the Geological Survey of Queensland (2011).

The precise age and context of the Kalkadoon–Leichhardt Subprovince remains unresolved. Its rock assemblages registered deformation and metamorphism, generally to amphibolite grade, during the Barramundi Orogeny, which was widespread in the North Australian Craton at 1900–1870 Ma (Etheridge, Rutland & Wyborn, 1987; Betts & others, 2006). For the Mount Isa Inlier, this episode of orogenesis reflects east–west contraction (Blake & Stewart, 1992).

In the north-west an east-trending basement high separates the McArthur Basin to the north from the South Nicholson Basin to the south (Figure 1). It is sometimes referred to as the Murphy Tectonic Ridge and was described by Ahmad & Wygralak (1990). It comprises the comagmatic 1860–1850 Ma Cliffdale Volcanics and Nicholson Granite Complex.

Protoliths of late Paleoproterozoic metasedimentary rocks of the Eastern and Western fold belts were generally marine sediments deposited during three discrete episodes of basin formation (Jackson, Scott & Rawlings, 2000; Southgate & others, 2000; Betts & others, 2006). The Leichhardt Superbasin (1790–1730 Ma) is best represented in the Western Fold Belt, along the north–south Leichhardt Rift (Derrick, 1982; O'Dea & others, 1997b) at the western margin of the Kalkadoon–Leichhardt Domain. Its basin fill includes the products of bimodal volcanism.

Successions of the Calvert Superbasin (1720–1670 Ma) were deposited in half-grabens formed by north-west–south-east extension. They consist largely of marine siliciclastics locally intercalated with rift-related volcanics. Successions of the Isa Superbasin (1670–1590 Ma), best represented in the Western Fold Belt, are predominantly marine siliciclastics with geometries that relate to extensional faulting. Inversion history for the Leichhardt and Calvert superbasins remains unclear but involved significant granitic plutonism. The Isan Orogeny, terminal to the basinal development, involved components of both north–south and east–west shortening strain and extensive plutonism. Although these generalisations apply to the inlier as a whole,

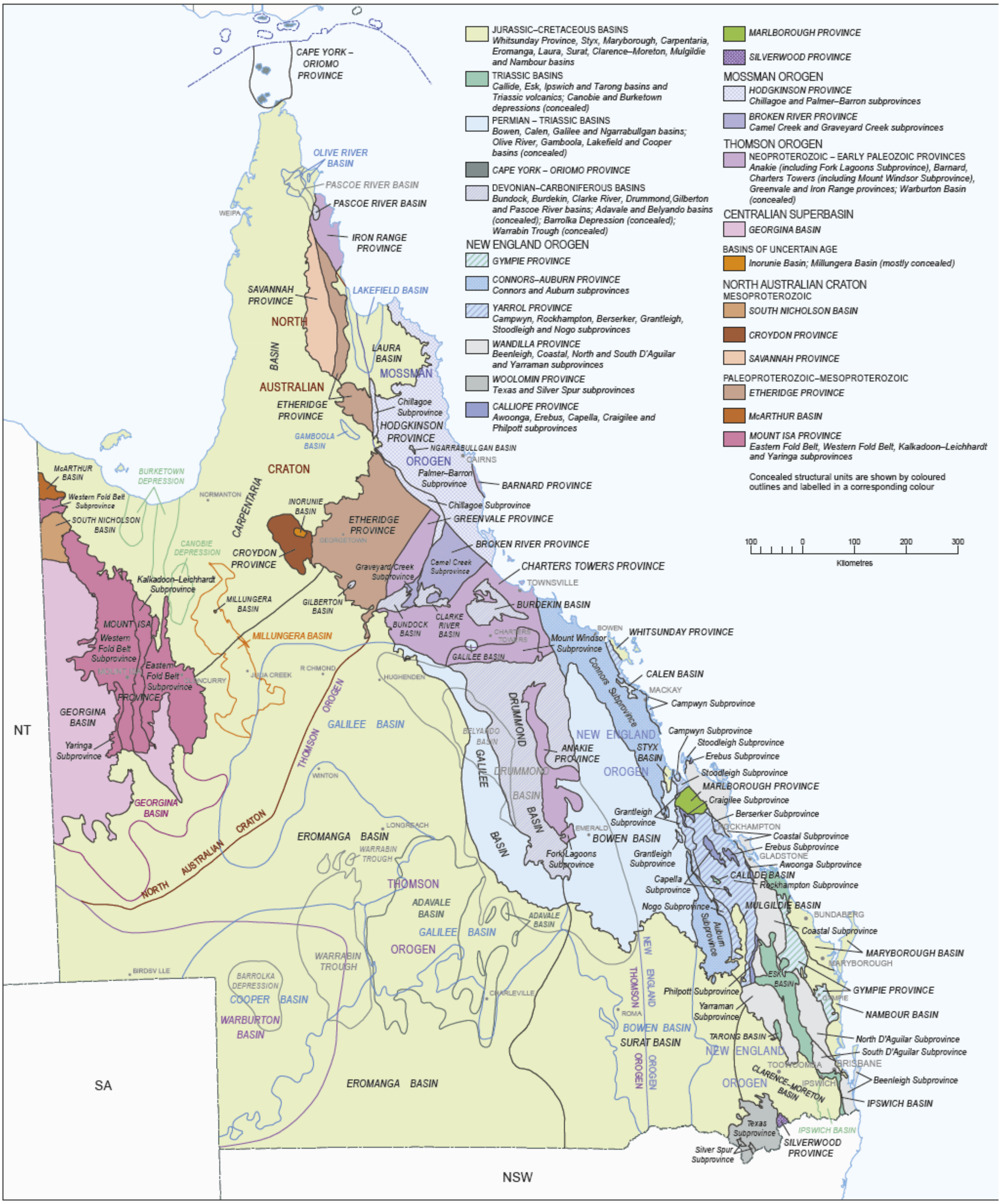

Figure 1. Structural framework map of Queensland (Jell, 2013)

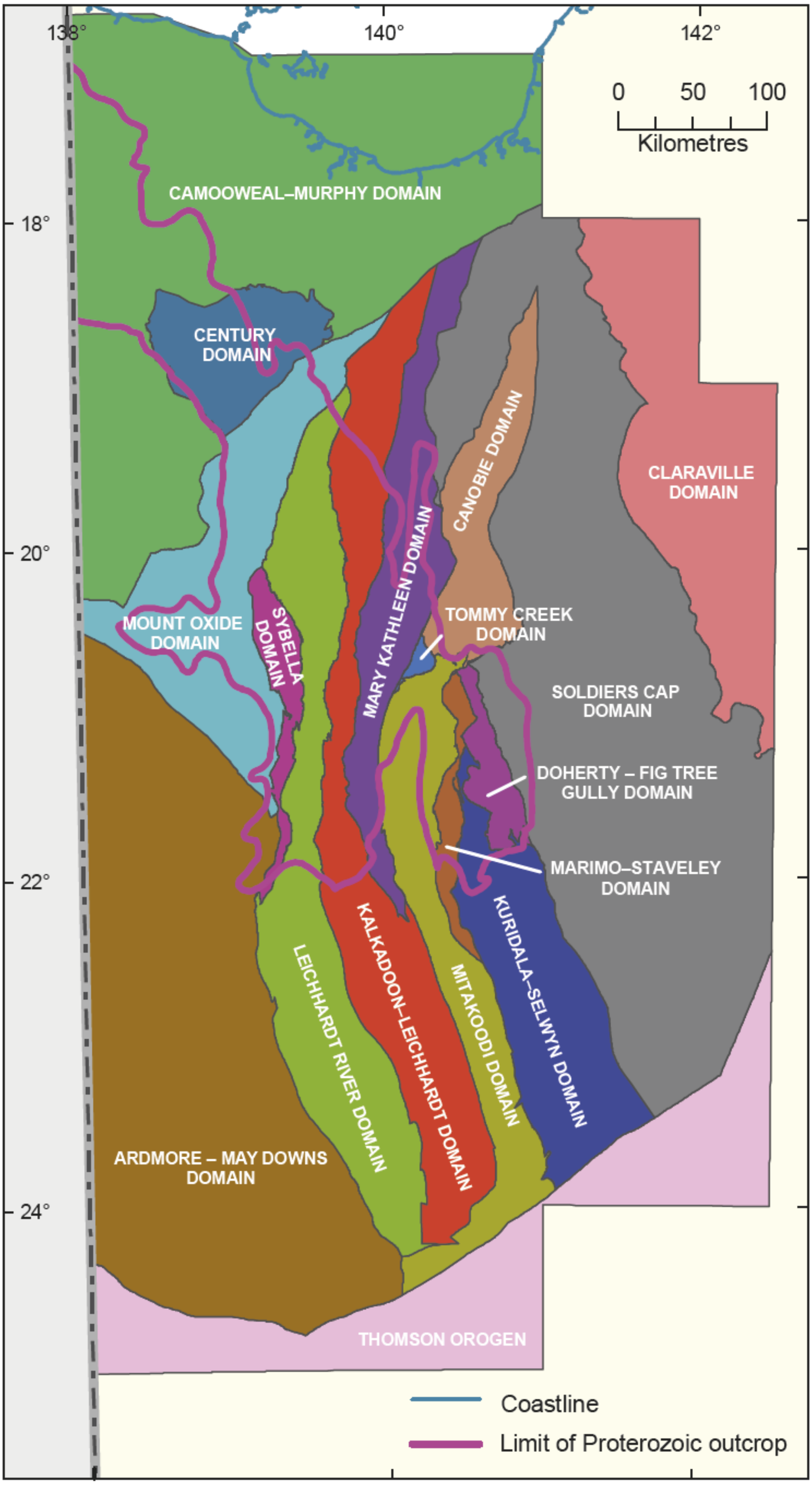

Figure 2. Solid geology map of the Mount Isa Province (Jell, 2013)

different areas within its compass show considerable diversity, as recognised in the most recent assessment (Geological Survey of Queensland, 2011), in which 15 domains are recognised.

Rocks of the Mount Isa Province have been overprinted by regional metasomatism to an extraordinary degree. The inlier is host to globally significant base metal deposits (Geological Survey of Queensland, 2011), with some 11% of the world's Pb and Zn resources (Wallis & others, 1998). Stratiform Pb–Zn–Ag ore bodies are considered to be syngenetic/diagenetic in origin (McGoldrick & Large, 1998; Large & others, 2005; Chapman, 2004), whereas the origin of stratabound copper and iron oxide copper–gold deposits are thought to involve deep crustal fluids (Perkins, 1984), in some cases linked to plutonism (Wang & Williams, 2001).

The assembly of Proterozoic geology of north-western Queensland includes small parts of the Paleoproterozoic McArthur Basin (Sweet & others, 1981), which is broadly correlative with the superbasin successions of the Mount Isa Province, the early Paleoproterozoic Murphy inlier (Ahmad & Wygralak, 1990) and the Mesoproterozoic South Nicholson Basin (Jackson & others, 1999) extending across the Northern Territory border between Lawn Hill and the Gulf of Carpentaria. The relationship of the Mount Isa Province to other Proterozoic provinces of the North Australian Craton to the west, such as the Tennant Creek, Arunta and Tanami provinces, is impeded by expanses of Phanerozoic sedimentary cover and remains contentious (Greene, 2010). However, the interpretation of late Paleoproterozoic superbasinal successions of the Mount Isa Province as backarc to a plate boundary to the east (Cawood & Korsch, 2008) or south (Betts & others, 2006) is widely held.

Granites and mafic intrusions were emplaced at various times before ~1100 Ma. Granites older than 1550 Ma are metamorphosed and generally deformed. From west to east the main batholiths exposed are the Sybella (1670 Ma) in the Western Fold Belt Province, the Kalkadoon and Ewen (1870–1850 Ma) in the Kalkadoon–Leichhardt Domain, the Wonga (1750–1725 Ma) in the Mary Kathleen Domain, and the post-orogenic Williams and Naraku Batholiths in the domains to the east. Intrusives of the Williams and Naraku Batholiths have been shown to be of at least three different ages (1750–1730 Ma, 1545–1530 Ma and 1520–1490 Ma).

The Mount Isa Province 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 the Leichhardt Superbasin. 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 the Leichhardt Superbasin.

At ~1620 Ma an early phase of thrusting and folding resulting from north–south compression took place and was followed between 1550 Ma and 1520 Ma 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 Province. A period of later extension is implied by the intrusion of the Williams and Naraku Batholiths at ~1500 Ma. The main faults mapped in the Mount Isa Province have kilometre-scale, predominantly strike-slip 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 Province have been significant producers of copper, lead, zinc and silver. Significant resources remain, with the Mount Isa Province 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 Province.

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 the Isa Superbasin in the Western Fold Belt Subprovince 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 Isa Superbasin 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 Leichhardt, Calvert and Isa Superbasin of the Western Fold Belt Subprovince. 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 in the Eastern Fold Belt Subprovince. 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 major example, but several smaller currently subeconomic deposits such as Pegmont are known.

Gold has been produced mainly as a by-product of copper from the iron oxide–copper–gold deposits of the Eastern Fold Belt Subprovince. 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 Subprovince (Forrestal & others, 1998). This deposit forms a remarkable and important exception in that it produced 15 900 kg of gold at an extraordinary average grade of 22.5 g/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.

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 McArthur 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).

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). The most recent summary of the entire region can be found in Withnall & Hutton (2013).

Rocks of the Forsayth Subprovince crop out in the Georgetown area and constitute a metasedimentary sequence deposited in an intracratonic rift setting between 1700 Ma to at least 1650 Ma. A major metamorphic and deformational event at ~1550 Ma 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 ~1550–1555 Ma. The first event may have occurred at ~1590 Ma, 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 >19 500 kg Au bullion and an additional 3400 kg fine Au and 5500 kg 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 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 1640 Ma and are locally metamorphosed to granulite facies. Dating has indicated a major period of emplacement of I and S type granite at ~1580 Ma, followed by metamorphism at ~1575 Ma. 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, which 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 1585 Ma and 1550 Ma 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 407 Ma.

Rocks of the Savannah Province host small gold-quartz vein deposits that are probably related to late Paleozoic 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) and Withnall & Hutton (2013). 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 ~1550 Ma, 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 Paleozoic

Several areas of Neoproterozoic – Early Paleozoic rocks in central, northern and north-west Queensland have been assigned to the Iron Range, Cape River (now Charters Towers and Greenvale provinces), Barnard and Anakie Provinces and the Georgina Basin.

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 Province. It occupies an area of ~325 000 km^2 of which ~90 000 km^2 are in Queensland (Figure 1). The geology of the Georgina Basin was outlined by Smith (1972) and Shergold & Druce (1980). An up-to-date summary is given by Jell (2013).

The basin fill is mainly Cambrian to Middle Ordovician 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 Paleozoic 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 Mossman, Thomson and New England Orogens. The Thomson Orogen consists mainly of latest Neoproterozoic to Ordovician rocks and crops out in the Anakie, Charters Towers, Greenvale and Innisfail areas, but is mostly buried by younger basins in south-western Queensland. Rocks in the Iron range area in Cape York Peninsula may also be part of the Thomson Orogen. The Mossman Orogen consists predominantly of early Paleozoic, fairly deep-marine quartz-rich sandstone and mudstone intercalated with submarine mafic and felsic volcanic rocks. The New England Orogen consists of middle Paleozoic 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 most recent review of the elements within the Tasman Orogenic Zone is by Withnall & others (2013).

Thomson Orogen

Charters Towers Province (formerly Cape River Province)

The Charters Towers 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 units referring to them as the Cape River Province, and Hutton & others (*in* Bain & Draper, 1997, chapter 6) outlined the geology of each of the component units. The province is now referred to as the Charters Towers Province (Geological Survey of Queensland, 2012), Withnall & others (2013), Fergusson & Henderson (2013), but most records in the Mineral Occurrence Database still reflect the old nomenclature.

All units within the Charters Towers 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 Paleozoic and overlain by younger basin fill. Although the age of rocks in the Charters Towers Province is uncertain, magmatic zircons in granites intruding Cape River Metamorphics show SHRIMP U-Pb zircon ages ranging from 469 ± 12 Ma to 493 ± 10 Ma, providing a minimum age constraint of Late Cambrian or early Ordovician. A maximum age for the province is constrained by dates of 1145±21 Ma for detrital zircons within the Cape River Metamorphics.

The structure of the Charters Towers 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 ~510 Ma). Little significant mineralisation is genetically associated with the rocks of the Charters Towers 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).

Mount Windsor Subprovince (formerly 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, as defined by these authors, 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. These are now referred to as the Mount Windsor Subprovince of the Charters Towers Province (Withnall & others, 2013; Fergusson & Henderson, 2013), but the Mineral Occurrence Database still reflects the old nomenclature.

Three major deformations are recognised within the Seventy Mile Range Group, which hosts significant volcanic-hosted massive sulphide (VHMS) resources including the Highway–Reward and Thalanga deposits. The mineral occurrences of the Thalanga Province were described by Barker & others (1997), Denaro & others (2004b), Hartley & Dash (1993), Hartley (1996), Lam (1994c, 1995b) and Sennitt & Hartley (1994).

The second belt, formerly assigned to the Thalanga Province, occurs within the eastern part of the Georgetown Inlier, within the Greenvale Province, but has not been renamed as a subprovince. It is described below.

Greenvale Province (formerly part of the Cape River Province)

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 was recognised as part of the Cape River Province (Withnall & others, 2002, 2003), but is now referred to as the Greenvale Province (Withnall & others, 2013; Fergusson & Henderson, 2013), because it is separated from the rest of the former Cape River Province (now Charters Towers Province) by the intervening Broken River Province. However it is likely to be continuous with the Charters Towers Province at deeper crustal levels. 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–cobalt–scandium deposits such as the Greenvale and Lucknow deposits.

Two units formerly assigned to the Thalanga Province in this area are: the Balcooma Metavolcanic Group 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 Metavolcanic Group was metamorphosed to lower to middle amphibolite facies and the Lucky Creek Metamorphic Group to upper greenschist to lower amphibolite facies. The Balcooma Metavolcanic Group preserves 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 and Surveyor deposits.

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), Garrad & Bultitude (1999) and Fergusson & Henderson (2013).

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 Paleozoic age that are assigned to the Anakie Metamorphic Group (Figure 1). The geology was outlined by Withnall & others (1995) and Fergusson & Henderson (2013).

The Anakie Metamorphic Group 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 ~510 Ma (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 Subprovince** (Figure 1). 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**. Rock types range in composition from diorite through monzodiorite and granodiorite to granite. Rb-Sr ages range from 366 Ma to 385 Ma. 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.

Iron Range Province

Rocks of the Iron Range Province are exposed over ~450 km^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 ~1130 Ma 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).

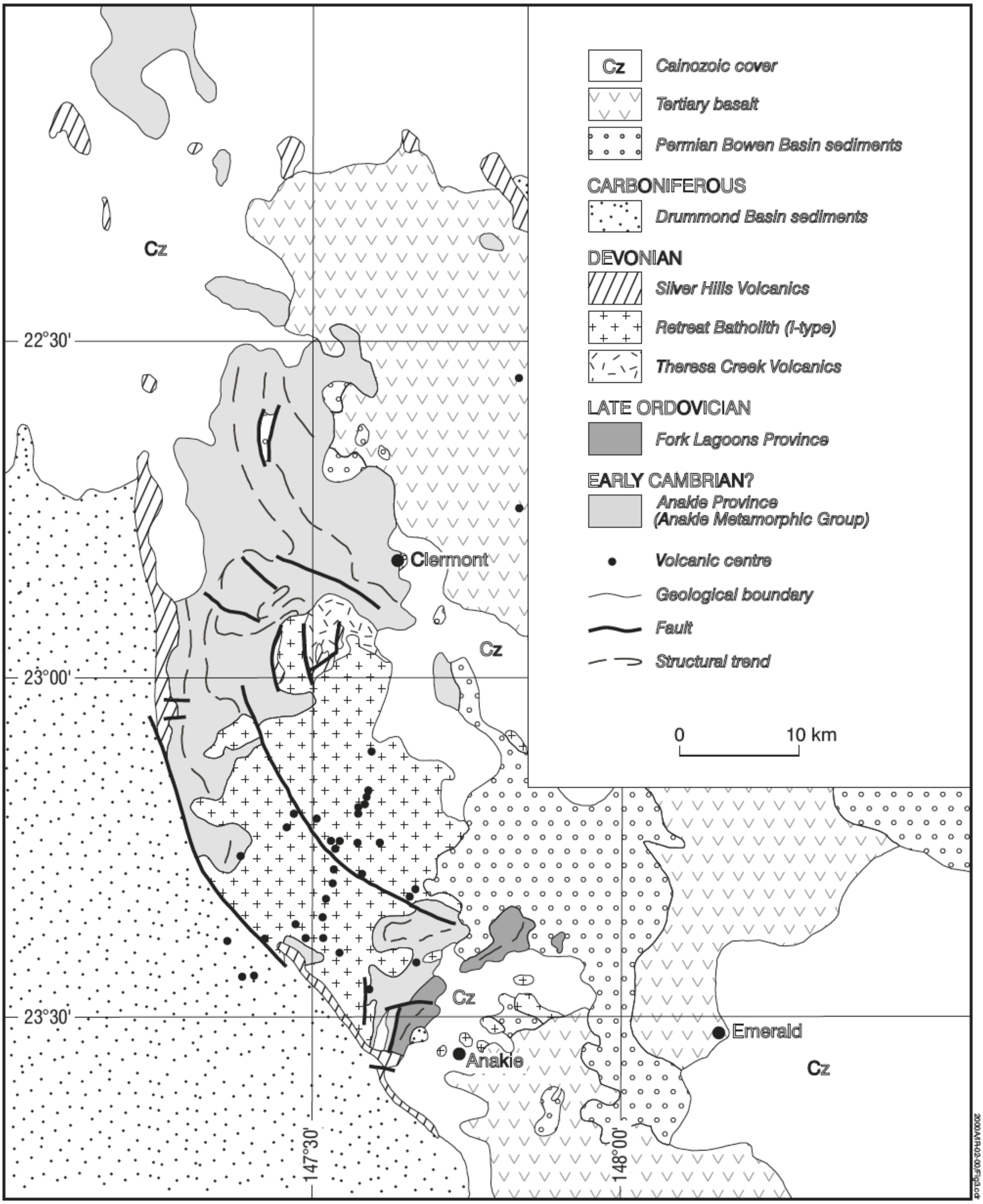

Figure 3. General geology of the southern Anakie Inlier (after Withnall & others, 1995)

Mossman Orogen

Rocks of the Mossman Orogen in north Queensland and have been subdivided into the Hodgkinson and Broken River Provinces (Withnall & others, 2013; Henderson & others, 2013). They are intruded by the inter-regional Macrossan, Pama and Kennedy igneous and volcanic provinces (Figure 3).

Hodgkinson Province

The Hodgkinson Province consists of early to middle Paleozoic turbiditic sedimentary rocks with subordinate limestone, chert and basic volcanic rocks that extend for ~500 km from south of Innisfail to Cape Melville and inland for ~150 km 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) and Henderson & others (2013).

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 Paleozoic 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 (e.g. Henderson, 1980) have interpreted that the Hodgkinson Province succession accumulated in a fore-arc–accretionary wedge setting 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 ~7000 km^2 in the Clarke River area (Figure 1). The geology of the Broken River Province is given by Withnall & Lang (1993), Withnall & others (*in* Bain & Draper, 1997, chapter 8 and pages 476–479) and Henderson & others, 2013.

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 (*e.g.* Gray Creek South) as well as lateritic nickel–cobalt–scandium resources (*e.g.* Lucknow) are hosted by the Gray Creek Complex, a basement inlier of Greenvale Province rocks enclosed 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). In the new Geology of Queensland volume (Withnall & others, 2013; Fergusson & Henderson, 2013), igneous provinces have been referred to as igneous associations, but apart from this, the Macrossan Igneous Association is identical in concept, age and extent to the 'Macrossan Province'. 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 3). 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 were assigned to the Pama Province (Hutton, Knutson & others, *in* Bain & Draper, 1997, chapter 14). In the new Geology of Queensland volume (Withnall & others, 2013; Henderson & others, 2013), they were referred to as the Pama Igneous Association, which otherwise is identical in concept, age and extent to the 'Pama Province'. These rocks extend as a discontinuous belt from the Coen Region in Cape York southwards to the Georgetown and Charters Towers regions (Figure 3). Pama Province rocks make up a large proportion of the Cape York Peninsula Batholith in Cape York, the Nundah, Tate, Robin Hood, Copperfield, White 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 were assigned to the Kennedy Province (Mackenzie & Wellman, *in* Bain & Draper, 1997, pages 488–500). In the new Geology of Queensland volume (Withnall & others, 2013; Champion & Bultitude, 2013), they were referred to as the Kennedy Igneous Association, which otherwise is similar in concept, age and extent to the 'Kennedy Province'. This province extends from south of Bowen north-west through Cape York Peninsula and across Torres Strait (Figure 3). 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, 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.

New England Orogen

The New England Orogen forms the eastern part of the Tasman Orogenic Zone and in Queensland is subdivided into several geological provinces.

Silverwood Province and older blocks within the Yarrol Province

The oldest tectonostratigraphic sequences of the 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 enclosed within the **Yarrol Province** (the Stanage, Craigilee, Calliope and Philpott Blocks of Day & others, 1983). These older rocks in the Yarrol Province are now assigned to the Calliope Province, which contains the Awoonga, Erebus, Capella, Craiglee and Philpott Subprovinces (Withnall & others, 2013; Donchak & others (2013), but the database currently retains the old nomenclature. The Awoonga Subprovince corresponds to the former Calliope Subprovince, the Erebus Subprovince to the former Mount Holly Subprovince, and the Capella Subprovince includes the former Mount Morgan and Kroombit Subprovinces. The Craiglee and Philpot Subprovinces are unchanged.

The rocks 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 (Simpson & others, 1998; Murray & others, 2003, 2012).

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 the Late Devonian Mount Morgan 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 (*e.g.* Taube, 1986) and as a structurally controlled Devonian replacement body related to the tonalite (*e.g.* 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 was described by Morwood (2002b).

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

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

Rocks of the accretionary wedge form the **Wandilla** Province along the coast, and the **Texas Subprovince** further inland. The Texas Subprovince is part of the **Wooloomin Province**, which is better developed in New South Wales. 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 sandstone beds containing ooliths, which must have been sourced from early Carboniferous limestones of the forearc basin to the west. Mineral resources in the Wandilla Province were 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 Subprovince has been folded into a large-scale double orocline (Murray & others, 1987). The Texas Subprovince also contains numerous allochthonous lenses of early 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 forearc 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 Paleozoic 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** was described most recently by Murray & others (2012) and Donchak & others (2013). It consists mainly of a Late Devonian to Carboniferous forearc basin succession, assigned to the Rockhampton Subprovince in the south and the Campwyn Subprovince along the coast between Marlborough and Mackay. The basin fill mainly consists of volcaniclastic sedimentary rocks deposited on a marine shelf that was shallower to the west and became progressively more emergent with time. The early Carboniferous part of the sequence is characterised by the widespread development of oolitic limestone. The forearc basin succession unconformably overlies the Middle Devonian and older rocks (Kirkegaard & others, 1970; Leitch & others, 1992). The forearc 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).

West of the Yarrol Province, the **Connors–Auburn Province** is a linear belt of predominantly subaerial, terrestrial felsic volcanics and granitoids of the Auburn Subprovince in the south and the Connors Subprovince in the north (Withnall & others, 2009). The northern part of the Connors Subprovince is dominated by plutonic rocks, which are also abundant in the southern part of the Auburn Subprovince. The two subprovinces form broad arches flanked by Permian sediments of the Bowen Basin and are separated by deformed equivalents of those sediments in the Gogango Thrust Zone. Most of the magmatic belt is late Carboniferous – early Permian, but some volcanics and granitoids are early Carboniferous and considered to represent an Andean-style, continental volcanic arc associated with the Yarrol Province forearc assemblage and the accretionary wedge of the Wandilla Province. Towards the top of the volcanic succession in the latest Carboniferous – early Permian, a transition to a more bimodal association (along with geochemical patterns) suggests development of an extensional setting with thinning crust that heralded the onset of deposition in the Bowen Basin (to which the volcanic rocks are basement). Bimodal dyke swarms in the northern Connors Subprovince may be related to this extension.

Early Permian strata that overlie the Late Devonian – Carboniferous forearc 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 early Carboniferous or older rocks, implying removal or non-deposition of a substantial part of the stratigraphic section.

Some early 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 – Triassic Hunter–Bowen Orogeny deformed the rocks of the New England Orogen, producing WNW directed thrusting and associated folding.

The Bowen Basin is a major element of Queensland geology, characterised by a thick Permian–Triassic succession of marine siliciclastics succeeded by coal measures, which continues south beneath the Great Australian Basin into New South Wales as the Gunnedah and Sydney basins (Korsch & Totterdell 2009a, 2009b). Although rich in coal, it is poorly mineralised.

The **Gogango Overfolded Zone or Thrust 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, 2009) 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. There is no evidence that the Connors–Auburn Province was a positive feature during deposition in the Bowen Basin and it is therefore thought that the arching results from later tectonism. The boundary between the Gogango Thrust Zone and the less deformed Yarrol Province is a line of major east dipping roof thrusts, but it is likely that the Bowen Basin originally extended eastwards because there is no obvious basin marginal facies. 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 Brooweena 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 (*e.g.* 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 108 000 kg 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 in 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

Paleozoic – 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.

Table 2. Incratonic 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	

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) 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. 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.

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

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).

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 Kunwarara 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 Paleozoic history of the south-western 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**.

BETTS, P.G., GILES, D., MARK, G., LISTER, G.S., GOLEBY, B.R. & AILLERES, L., 2006: Synthesis of the Proterozoic evolution of the Mount Isa Inlier. *Australian Journal of Earth Sciences*, **53**, 187–211.

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 forearc 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.

CAWOOD, P.A. & KORSCH, R.J., 2008: Assembling Australia: Proterozoic building of a continent, *Precambrian Research*, **166**, 1–38.

CHAMPION, D.C. & BULTITUDE, R.J., 2013: Chapter 6 Kennedy Igneous Association. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 473–513.

CHAPMAN, L.C., 2004: Geology and mineralisation styles of the George Fisher Zn-Pb-Ag deposit, Mount Isa, Australia. *Economic Geology*, **99**, 233–55.

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 mineralisation 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., 2011: A review of Queensland's non-energy mineral deposits and resources. *Queensland Geological Record* **2011/10**.

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**.

DERRICK, G.M. 1982: A Proterozoic rift zone at Mount Isa, Queensland, and implications for mineralisation. *BMR Journal of Australian Geology & Geophysics*, **7**, 81–92.

DONCHAK, P.J.T., PURDY, D.J., WITHNALL, I.W., BLAKE, P.R. & JELL, P.A., 2013: Chapter 5 New England Orogen. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 305–472.

ETHERIDGE, M.A., RUTLAND, R.W.R. & WYBORN, L.A.I., 1987: Orogenesis and tectonic processes in the Early to Middle Proterozoic of northern Australia. *American Geophysical Union, Geodynamic Series*, **17**, 131–47.

FAWCKNER, J.F., 1981: Structural and stratigraphic relations and a tectonic interpretation of the western Hodgkinson Province, north-eastern 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.F. & HENDERSON, R.A., 2013: Chapter 3 Thomson Orogen. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 113–224.

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 Paleozoic 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**.

GEOLOGICAL SURVEY OF QUEENSLAND, 2011: *North-west Queensland Mineral and Energy Province report*. Queensland Department of Employment, Economic Development and Innovation, Brisbane.

GEOLOGICAL SURVEY OF QUEENSLAND, 2012: *Queensland Geology, Scale 1:2 000 000*. Department of Natural Resources and Mines, Brisbane.

GREENE, D.C., 2010: Neoproterozoic rifting in the southern Georgina Basin, central Australia: implications for reconstructing Australia in Rodinia. *Tectonics*, **29**, TC5010, 1–20. doi:10.1029/2009TC002543.

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.

HENDERSON, R.A., DONCHAK, P.J.T. & WITHNALL, I.W., 2013: Chapter 4 Mossman Orogen. In: Jell, P.A. (Editor): Geology of Queensland. Geological Survey of Queensland, Brisbane, 225–304.

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**.

JACKSON, M.J., SWEET, I.P., PAGE, R.S. & BRADSHAW, B.E., 1999: The South Nicholson and Roper Groups: Evidence for the Early Mesoproterozoic Roper Superbasin. Australian Geological Survey Organisation, Record 1999/19.

JACKSON, M.J., SCOTT, D.L. & RAWLINGS, D.J. 2000: Stratigraphic framework for the Leichhardt and Calvert superbasins: review and correlations of the pre-1700 Ma successions between Mt Isa and McArthur River. *Australian Journal of Earth Sciences*, **47**, 381–403.

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.

LARGE, R.R., BULL, S.W., McGOLDRIC, P.J., WALTERS, S., DERRICK, G.M. & CARR, G.R., 2005: Stratiform and strata-bound Zn-Pb-Ag deposits in Proterozoic sedimentary basins, northern Australia. Economic Geology, 100, 931–63.

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.

LEVY, I.W. & STOREY, N.J.M., 1990: Horn Island gold deposit. *In:* HUGHES, F.E. *Geology of the Mineral Deposits of Australia and Papua New Guinea,* The Australasian Institute of Mining and Metallurgy, 1451–1454.

McGOLDRICK, P.J. & LARGE, R.R., 1998: Proterozoic stratiform sediment-hosted Zn-Pb-Ag deposits. *AGSO Journal of Australian Geology & Geophysics*, **17**, 189–96.

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: Paleozoic gold deposits of north-east 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., CROUCH, S.B.S., HAYWARD, M.A., ROBERTSON, A.D.C. & SIMPSON, G.A., 2012: Geology of the Yarrol Province and associated rocks of the northern New England Orogen. *Queensland Geology*, **13**, 1–524.

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.

O'DEA, M.G., LISTER, G.S., BETTS, P.G. & POUND, K.S. 1997: A shortened intraplate rift system in the Proterozoic Mount Isa Terrane, NW Queensland, Australia. *Tectonics*, **16**, 425–41.

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

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**.

PERKINS, W.G. 1984: Mount Isa silica–dolomite ore bodies: result of a synorogenic hydrothermal alteration system. *Economic Geology*, **79**, 601–37.

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 Paleozoic 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**.

SOUTHGATE, P.N., BRADSHAW, B.E., DOMAGALA, J., JACKSON, M.J., IDNURM, M., KRASSAY, A.A., PAGE, R.S., SAMI, T.T., SCOTT, D.L., LINDSAY, J.F., McCONACHIE, B.A. & TARLOWSKI, C., 2000: Chronostratigraphic basin framework for Palaeoproterozoic rocks (1730–1575 Ma) in northern Australia and implications for mineralisation, *Australian Journal of Earth Sciences*, **47**, 461–85.

SWEET, I.P., MOCK, C.M. & MITCHELL, J.E., 1981: *Seigal, Northern Territory, Hedleys Creek Queensland, 1:100 000 geological map commentary*. Bureau of Mineral Resources, Australia, Canberra.

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.

von GNIELINSKI, F.E., 1996: Regional Geology, Exploration, Development and Failure of the Horn Island Gold Mine and its Environmental Clean-up. *MSc thesis at the Department of Geology, James Cook University of North Queensland*, June 1996.

WALLIS, D.S., DRAPER, J.J., DENARO, T.J., 1998: Paleo- 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., HENDERSON, R.J., CHAMPION, & JELL, P.A., 2013: Chapter 1 Introduction. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 1–21.

WITHNALL, I.W. & HUTTON, L.J., 2013: Chapter 2 North Australian Craton. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 23–111.

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., HUTTON, L.J., BULTITUDE, R.J., von GNIELINSKI, F.E. & RIENKS, I.P., 2009: Geology of the Auburn Arch, southern Connors Arch and adjacent parts of the Bowen Basin and Yarrol Province, central Queensland. *Queensland Geology*, **12**, 1–461.

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