DEPARTMENT OF MINERALS AND ENERGY
GEOLOGICAL SURVEY OF QUEENSLAND

EINASLEIGH

SECOND EDITION

QUEENSLAND 1:250 000 Geological Series

Explanatory Notes to accompany Einasleigh 1:250 000 Geological Map, Sheet SE 55-9

DEPARTMENT OF MINERALS AND ENERGY
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QUEENSLAND
1:250 000 GEOLOGICAL SERIES - EXPLANATORY NOTES

EINASLEIGH

SECOND EDITION

SHEET SE55 - 9

I.W. WITHNALL & K.G. GRIMES

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CONTENTS

TABLES

FIGURES

SUMMARY

The Einasleigh Sheet area contains two major tectonic provinces. The Georgetown Province in the west consists partly of Proterozoic amphibolite to granulite facies metasedimentary and metabasic rocks intruded by some Proterozoic granitoids and extensive Silurian-Devonian batholiths. The main deformation and metamorphism was at about 1550-1570Ma, although weaker deformation and retrogressive metamorphism probably occurred in the early Palaeozoic. East of the Balcooma Mylonite Zone, early Palaeozoic, greenschist to amphibolite facies metavolcanics and metasediments are intruded by a large Silurian batholith. A belt of Proterozoic rocks along the eastern edge of the Georgetown Province contains amphibolite facies metapelites and mafic/ultramafic complexes. The early Palaeozoic rocks may have been overthrust by the Proterozoic rocks.

The Georgetown Province is separated from the Palaeozoic Broken River Province in the east by the Burdekin and Halls Reward Faults. The Broken River Province consists of Ordovician to Devonian turbiditic, sedimentary rocks with subordinate mainly mafic volcanic rocks. The rocks were deformed by thrusting and folding in the Devonian. The Broken River Province may have been an extensional basin, although alternative hypotheses suggest it was a convergent margin.

Superimposed on these two major tectonic units are largely felsic rocks of the late Palaeozoic North Queensland Volcanic and Plutonic Province, Cainozoic basalts of the McBride, Chudleigh and Wallaroo Basalt Provinces, and unassigned Cainozoic sediments and basalts.

The main minerals worked in the area are gold, base metals and tin, although most of the deposits are small. The Kidston gold mine, since the closure of the Greenvale nickel mine in 1992, is the only current active mine in the area.

Keywords: Regional geology; stratigraphy; structural geology; economic geology; Georgetown Province; Broken River Province; Proterozoic; Cambrian; Ordovician; Silurian; Devonian; Carboniferous; Permian; Tertiary; Quaternary; Einasleigh; Queensland; SE5509.

INTRODUCTION

The Einasleigh 1:250 000 Sheet area lies between latitudes 18°00’ and 19°00’S and longitudes 144°00’ and 145°30’E in the Cairns-Townsville hinterland in north Queensland.

The main settlements in the area are the townships of Mount Surprise and Einasleigh (populations less than 100 each), apart from numerous station homesteads. The township of Greenvale, built to service the Greenvale nickel mine, lies just to the south of the sheet area. The Kidston gold mine, which is near the old township of Kidston (population ca. 10) is worked on a fly-in/fly-out basis and accommodation is provided on-site.

Access to the area is from Townsville and Charters Towers by sealed road through Greenvale to the Lynd junction (Gregory Developmental Road), by sealed road from Cairns to the Lynd junction (Kennedy Developmental Road) and through Mount Surprise to Georgetown (Gulf Developmental Road), and by unsealed roads from Ingham through Camel Creek, and from Hughenden to the Lynd junction (Kennedy Developmental Road).

Good graded roads connect the Lynd junction with Kidston and Einasleigh. Most station homesteads are serviced by graded roads. Networks of vehicle tracks to bores and cattle yards occur throughout the area. A light narrow gauge railway through Mount Surprise and Einasleigh has a weekly service from Cairns. Landing grounds at Einasleigh, Kidston, and some of the larger station homesteads are able to accommodate light aircraft.

The climate is humid tropical with hot wet summers and warm dry winters. The average annual rainfall ranges from 800mm in the northeast to 600mm in the southwest, most falling between November and April. Only light rain falls during the remainder of the year, mainly in the northeast. January is the wettest month with an average of 190mm. The average daily temperature ranges are 20-33° in January and 10-25° in July. The area generally experiences less than 5 days per year of frosts.

The vegetation of the area was described by Perry & others (1964). Most of the area is covered by ironbark woodland and forest, but lancewood woodland occurs on some lateritic mesas and plateaux, and Reid River box woodland is characteristic of deeply weathered rocks of the Broken River Province. The ground cover is mostly kangaroo grass, blue grass, black spear grass, and three-awn grasses, but spinifex grows in some areas, particularly on felsic rocks such as metavolcanics in the Balcooma area and the late Palaeozoic granites.

Grazing and mining are the only industries in the area, although attempts at peanut and sorghum growing have been made on the lateritic plateau northeast of The Lynd. A large active mine is at Kidston (gold) and lateritic nickel and cobalt were mined in a major open-cut mine ar Greenvale until 1992. Tin and topaz in the Mount Surprise area and sapphires in the Lava Plains area are mined on a small scale. Mineral exploration has been active through the region since the late 1960s.

The area is covered by aerial photography at a variety of scales. Black-and-white photography at 1:80 000 was flown by the Commonwealth over the whole area in 1967. The most recent photography for individual 1:100 000 sheet areas is: coloured sets flown by the Commonwealth at 1:25 000 scale for Einasleigh (1972), Mount Surprise (1973) and Conjuboy (1979); and black-and-white sets flown by the State at 1:30 000 scale for Conjuboy (1973-75) and Saint Ronans (1973-75 and 1987), and at 1:25 000 scale for Cashmere (1978 and 1990), Einasleigh (1971), Mount Surprise (1971), and Valley of Lagoons (1979).

The 1:100 000 topographic series maps were published for the whole area in 1973 (based on the 1967 aerial photography), and the Joint Operations Graphic map at 1:250 000 scale, published in 1988, was compiled from these.

The Einasleigh 1:250 000 geological map which these notes accompany was compiled digitally. The digital data are available through the Department of Minerals and Energy Geoscience and Resources Database. Photoscale compilation sheets and composite 1:100 000 scale maps for the whole of the 1:250 000 sheet area are also available in diazo form (paper or film).

These notes were originally issued in preliminary form by Withnall & Grimes (1991).

PREVIOUS INVESTIGATIONS

Leichhardt (1847) and Gregory (1857) both passed through the Einasleigh Sheet area and recorded geological observations. Jack (1887) traversed from The Lynd along the Copperfield River to Einasleigh on the way to Georgetown. Maitland (1891) was the first to describe the geology of the upper Burdekin River valley in the Valley of Lagoons and Wairuna areas. He recognised the boundary between the Precambrian and Palaeozoic rocks along the Burdekin River. Jack (1898) traversed the proposed railway route from Chillagoe to Einasleigh and Georgetown.

The discovery of gold in 1907 near The Oaks (now Kidston) led to examination of the deposits and their regional context by the Geological Survey of Queensland (GSQ) (Marks, 1911). Ball (1914) described the Einasleigh copper mine.

Jensen (1920a, 1923) described the regional geology of the Einasleigh area and considered the metamorphic rocks to be of Precambrian age, although he suggested that they were significantly older than the lower grade metamorphic rocks in the western part of the Georgetown Inlier. Bryan (1925, 1928) introduced the term Einasleigh Series for the generally gneissic rocks in the Einasleigh area and also considered them to be older. Later reviews of Queensland geology (Whitehouse, 1930; Browne, 1933; Bryan & Jones, 1946) agreed that two ages of metamorphic rocks existed in the Georgetown region, but Hills (1946) concluded that they were all of one age. Hill (1951) recognised the main structural elements of the region and introduced the terms Georgetown Massif and Broken River Embayment.

In 1953 and 1954 the Commonwealth Scientific and Industrial Research Organisation carried out a land-use survey of the Leichhardt-Gilbert area, which included the Einasleigh Sheet area (Perry & others, 1964; Twidale, 1956a,b, 1966). This survey included a brief geological study as well as geomorphological studies.

In 1955 the Bureau of Mineral Resources (BMR) carried out an airborne radiometric survey of the Einasleigh Sheet area and adjacent areas (Parkinson & Mulder, 1956). From 1956 to 1958 a joint BMR-GSQ party carried out systematic regional mapping of the Georgetown, Einasleigh, and Clarke River Sheet areas. The results were recorded by White (1959a,b, 1961, 1962a-d, 1965), White & Wyatt (1960a,b,c), White, Wyatt & Bush (1960) and Branch (1966). Progress reports on various aspects of the mapping were given by White & Hughes (1957), White, Branch & Green (1961), Green (1958), White, Stewart & others (1959), White, Best & Branch (1959), Best (1959), Branch (1959), and White & Crespin (1959).

White (1961) introduced the term Georgetown Inlier for the Precambrian rocks of the region. In the Einasleigh Sheet area, the mapping recognised that metamorphic rocks in the Lucky Creek area were lower grade and lithologically distinct from the Einasleigh Metamorphics. The latter were assigned an Archaean age along with higher grade rocks (the Halls Reward Metamorphics) along the eastern margin of the Inlier.

The lower grade rocks, assigned to the Lucky Creek and Paddys Creek Formations were thought to be Proterozoic in age, although White & Hughes (1957) suggested an early Palaeozoic age. The older granitoids were all regarded as Proterozoic and were divided into three units, the Forsayth and McKinnons Creek Granites and the Dido Granodiorite. The late Palaeozoic granitoids were assigned mainly to the Elizabeth Creek and Herbert Granites. Ultramafic/mafic complexes in the Greenvale area were assigned to the Sandalwood Serpentinite and Stenhouse Creek Amphibolite (thought to be Precambrian) and the Boiler Gully Complex (thought to be Devonian). The Palaeozoic rocks of the Broken River Embayment were subdivided and a major unconformity within the sequence was postulated.

K-Ar and Rb-Sr age determinations reported by Richards & others (1966) were mainly on the granitoids and did not resolve the age relationships of the metamorphic rocks. They did establish that some of the granitoids further west in the Georgetown Inlier were of Precambrian age, but most of the rocks in the Einasleigh Sheet area gave Silurian-Devonian ages and it was suggested that a strong thermal event had caused resetting. Black (1973) reanalysed the samples using the Rb-Sr method, but most ages still showed at least partial resetting.

Sheraton & Labonne (1978) studied the petrology and geochemistry of the felsic granitoids and volcanic rocks of northeast Queensland, based on the units as recognised by the BMR-GSQ first-pass reconnaissance mapping.

Subsequent research in the Broken River Embayment and adjacent Georgetown Inlier by Arnold (1975), Arnold & Rubenach (1976), and Arnold & Henderson (1976) made several important changes to the geological interpretation of the region. They recognised that all of the mafic/ultramafic rocks were probably of Precambrian age and suggested that the Halls Reward Metamorphics and Paddys Creek Formation were of similar age and had a gradational contact. They modified the structural terminology to the Georgetown Province and Broken River Province, the latter being divided into the Camel Creek and the Graveyard Creek Subprovinces. This terminology has been adopted by most subsequent authors. Arnold (1975) could find no evidence for the major unconformity recognised by White (1961, 1965) between the Greenvale and Kangaroo Hills Formations in the Camel Creek Subprovince.

Other university studies in the Georgetown Province were by McNaughton (1979, 1980), McNaughton & Wilson (1980, 1983a,b,c), and McNaughton & Withnall (1990) on the Einasleigh Metamorphics, Stanton (1982) on the Mount Misery deposit, Patrick (1978) on the Einasleigh copper mine, and Van der Hor (1988) on the Balcooma area. Hammond (1986) studied large-scale structural relationships, including the development of mylonite and melange throughout north Queensland. Griffin (1977) and Griffin & McDougall (1975) studied the basalts of the McBride Basalt Province and demonstrated that they ranged in age from Oligocene to Holocene. Other studies on the basalts were by Stephenson & Griffin (1976), and Atkinson & others (1975). McNamara (1990) and Gaffney & McNamara (1990) studied the vertebrate faunas in sub-basaltic sediments near Conjuboy. Mockett (1983) studied and named the Tertiary Lake Lucy Formation.

In 1972, the BMR and GSQ began a joint study to remap the Georgetown Province in greater detail, commencing in the central part in the Georgetown and Gilberton 1:250 000 Sheet areas to the west. Preliminary results were reported by Bain & others (1976), Oversby & others (1978) and Withnall, Oversby & others (1980). The Proterozoic stratigraphic framework was extensively modified, all metamorphic rocks being considered to be part of one sequence, the Etheridge Group (Withnall & Mackenzie, 1980; Withnall, 1983).

The granitoids were also subdivided and rocks of Proterozoic, Silurian-Devonian and late Palaeozoic recognised. Black & others (1979) undertook a geochronological study of the deformational/metamorphic history of the central Georgetown Province. Results of dating of some of the granitic rocks were given by Black & McCulloch (1990) and Black & Withnall (1993).

The BMR-GSQ work was reviewed by Withnall, Bain & Rubenach (1980) and Oversby & others (1980), together with previous work in the Einasleigh Sheet area. They divided the Georgetown Province in the Einasleigh Sheet area into the Greenvale and Forsayth Subprovinces, separated by the Balcooma Mylonite Zone. Withnall, Bain & others (1988) gave an updated review of the Proterozoic geology. Bain & Withnall (1980) and Bain & others (1990) reviewed the geology of the mineral deposits. The geology of the central part of the province is described in detail by Withnall (1984) and Bain & others (1985). Withnall (1985a) described the geochemistry of the mafic rocks in the Etheridge Group.

The work was extended to the Einasleigh Sheet area in 1980 and continued by the GSQ alone after 1982. In 1984 the mapping was extended to the Broken River Province and completed in 1985. Preliminary reports on the mapping were given by Withnall (1982), Withnall, Lang & others (1985, 1986), and Warnick & Withnall (1985). Withnall (1989) and Warnick (1989) published detailed reports on the geology of the Georgetown Province. The Broken River Province is described by Withnall, Lang & others (1988) and Withnall & Lang (1993). Geochronology of the Balcooma area was reported by Withnall & others (1991).

The geology of the adjoining Atherton 1:250 000 sheet area is described by Cranfield (1992), Bultitude & others (1993) and Donchak & Bultitude (1994). The results of mineral exploration are reported in the numerous company reports held on open file by the Department of Minerals & Energy, Queensland. Withnall & Bain (1985) presented a bibliography on the mineral deposits of the central Georgetown Province including the western part of the Einasleigh and Clarke River Sheet areas.

PHYSIOGRAPHY

The Einasleigh Sheet area forms the northeastern part of the `Einasleigh Uplands' (Twidale, 1956b, 1966; Perry & others, 1964), and ranges in elevation from 350m in the northwest to 1000m in the central north. The Einasleigh Uplands are drained by the Einasleigh and Copperfield Rivers (part of the Gilbert River System flowing northwest into the Gulf of Carpentaria) and the Herbert and Burdekin Rivers (flowing east and southeast respectively into the South Pacific Ocean). Twidale subdivided the Einasleigh Uplands into five physiographical units, McBride Plateau, Newcastle Range, Einasleigh-Copperfield Plain, Burdekin Uplands, and Uplands and Ranges of the Divide (Figure 1).

The **McBride Plateau** is a circular area about 80km in diameter and about 5000km^2 in area in the central north part of the Einasleigh Sheet area. It is a broad topographic dome attaining a maximum elevation of 1028m in the centre. The plateau consists of Cainozoic basalt, and 164 volcanic centres have been recognised (Griffin, 1977), the majority of which occur in the central part of the dome. They range from low hills formed by eroded plugs to well-preserved cones and shield volcanoes. The dome landform may result from uplift rather than volcanic construction (Stephenson *in* Johnson, 1989, page 93), because basement inliers occur near its centre.

The mapped lavas flowed radially from the central region, and some cover large areas and flowed considerable distances (eg. a 160km flow from the Undara crater) (Stephenson & Griffin, 1976). Extensive lava tube systems are also present (Atkinson & others, 1975). Although some basalts as old as 8Ma are known, most are younger than 3Ma. The most recent flow, from the Kinrara crater (? 000 years BP), flowed down the Burdekin River. Lakes formed along the eastern margin of the plateau by damming of the river systems by the flows (eg. Native Wells Swamp, Walter Plains Lake, G.W. Swamp, and near the Valley of Lagoons).

The **Newcastle Range** extends into the central western and southwestern margin of the sheet area. It has a maximum elevation of 830m and rises about 200m

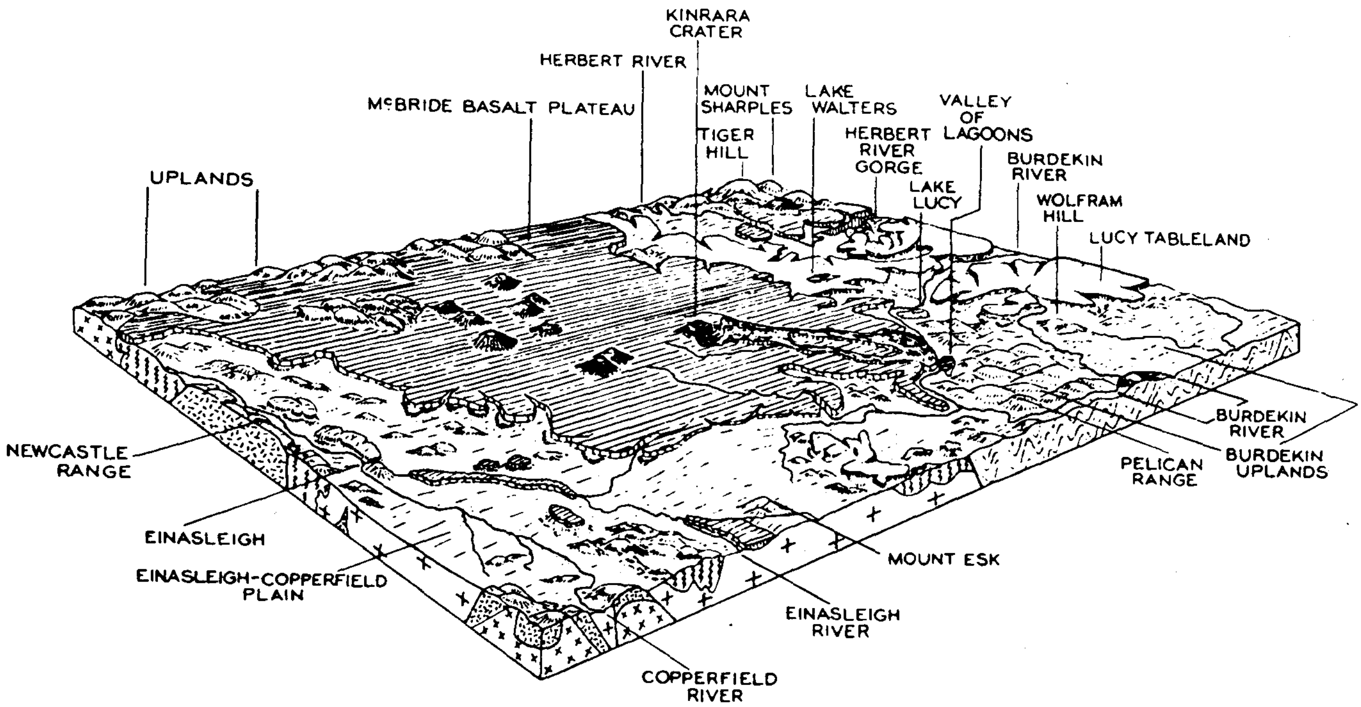


Figure 1. Physiographic units, Einasleigh 1:250 000 sheet area (after White, 1962a).

above the Einasleigh-Copperfield plain. It is very rugged and consists mainly of resistant Carboniferous felsic volcanics and granite.

The **Einasleigh-Copperfield Plain** consists of Proterozoic and early Palaeozoic metamorphic rocks and granitoids, with isolated hills of more resistant metamorphics (generally calc-silicate gneiss), basalt-capped mesas, and granite tors. The elevation is mostly 400 to 500m; local relief rarely exceeds 200m and is usually much less.

The Einasleigh-Copperfield Plain and the McBride Plateau merge into the **Uplands and Ranges of the Divide** which comprises the high plains and ridges on and slightly to the east of the Great Dividing Range. They are composed mainly of metamorphic rocks (in particular felsic metavolcanics) and laterite capped mesas. Mount Esk (726m) is the most conspicuous feature.

The **Burdekin Uplands** form undulating country east of the Dividing Range drained by the Burdekin and Herbert Rivers. The elevation ranges from 400m in the south along the Burdekin River to 868m at Tiger Hill in the northeast. A feature of the region is the Herbert River Gorge, which is cut in late Palaeozoic granitic rocks and begins at the Herbert River Falls (about 100m high) and extends for some 55km to the east into the Ingham Sheet area.

The Burdekin Uplands contain small isolated tablelands, of which the Lucy Tableland of about 500km^2 is the largest. The tablelands consist of Tertiary to Quaternary sediments and deeply weathered basement rocks.

Twidale (1956b) recognised lateritised surfaces, valley-side facets, and nick points, representing three cycles of erosion. Grimes (1979) correlated the two main old land surfaces in the area with named surfaces in the Charters Towers area. The Featherby Surface is an undulating deep weathered surface, and the younger Campaspie Surface is a flat depositional surface which forms the Lucy Tableland and other dissected alluvial plains.

STRATIGRAPHY

The Einasleigh Sheet area contains of two major tectonic provinces. The Georgetown Province occupies the western half of the area and is divided into the Forsayth and Greenvale Subprovinces by the Balcooma Mylonite Zone. The Forsayth Subprovince to the west consists of Proterozoic metamorphic rocks intruded by some Proterozoic granitoids and extensive batholiths of Silurian-Devonian age.

The Greenvale Subprovince contains some Proterozoic metamorphic rocks along its eastern edge, but is now known to consist mostly of early Palaeozoic metavolcanic and metasedimentary rocks and some granitoids, intruded by an extensive Silurian batholith which overlaps the boundary with the Forsayth Subprovince.

The Georgetown Province is separated from the Palaeozoic Broken River Province in the eastern half of the sheet area by the Burdekin and Halls Reward Faults. The Broken River Province is divided into the Camel Creek Subprovince and Graveyard Creek Subprovince (which is more extensive in the Clarke River sheet area to the south) by the Gray Creek Fault. Both consist of Ordovician to Devonian sedimentary rocks with subordinate mainly mafic volcanic rocks.

Superimposed on these tectonic units are the late Palaeozoic igneous rocks of the North Queensland Volcanic and Plutonic Province, Cainozoic basalts of the McBride, Chudleigh and Wallaroo Basalt Provinces, as well as unassigned Cainozoic sediments and basalts.

GEORGETOWN PROVINCE

The geology of the Georgetown Province in the Einasleigh Sheet area is described in more detail by Withnall (1989) and Warnick (1989). Withnall (1984) also described some aspects of the area.

Proterozoic metamorphic rocks

The **Einasleigh Metamorphics**, the most extensive metamorphic rock unit, consist of biotite gneiss and schist, calc-silicate gneiss, leucogneiss, migmatite, granitic gneiss, amphibolite, and minor dolomitic marble and serpentinite. Leucogranite dykes and veins are commonly abundant. Bodies of metagabbro, metadolerite and orthoamphibolite are common in the Einasleigh Metamorphics. They are probably mostly of intrusive origin and are assigned to the **Cobbold Metadolerite** (Withnall & Mackenzie, 1983; Withnall, 1985a), although some could have been extrusive. The Einasleigh Metamorphics were probably originally a sequence of arenite and shale, locally calcareous or dolomitic, intruded by dolerite and metagabbro dykes and sills, and possibly including some mafic lavas and tuff. The rocks are multiply deformed and were metamorphosed mostly in the upper amphibolite facies, although lower amphibolite facies rocks are present along Cassidy Creek northwest of Rosella Plains, and granulite facies assemblages are present in mafic rocks in a 50km long belt from near Einasleigh to northeast of Mount Surprise. Migmatite and granitic gneiss are associated with the higher metamorphic grades. Lower amphibolite facies mica schist and metadolerite are mapped as undivided **Etheridge Group** in a small inlier along Mero Creek near the central northern margin of the sheet area.

A narrow belt consisting mainly of mica schist (locally mylonitised to fine-grained phyllonite) forms the easternmost part of the Georgetown Province in the sheet area, and is assigned to the **Halls Reward Metamorphics**. Cropping out within the belt are abundant amphibolite, metagabbro, and clinopyroxenite assigned to the **Stenhouse Creek Amphibolite**, and serpentinite assigned to the **Sandalwood Serpentinite**. Near Greenvale, these units together comprise the **Boiler Gully Complex**. The grade of metamorphism was mainly middle amphibolite facies. Serpentinite at the northern tip of the **Gray Creek Complex**, which is more extensive in the Clarke River Sheet area, crops out at the southern edge of the sheet area near Greenvale township.

Although previously regarded as being of both Devonian and Precambrian age, the mafic/ultramafic rocks are now all regarded as being of Proterozoic age, having had an identical metamorphic/deformational history to the Halls Reward Metamorphics (Arnold & Rubenach, 1976; Withnall, 1989). Although some of the amphibolite could have been lavas, the mafic/ultramafic rocks were probably mostly emplaced in the Proterozoic as a series of sills and dykes into a sequence consisting mostly of shale and siltstone. The serpentinites may have resulted from *in situ* differentiation in the sills, but some were probably emplaced tectonically after serpentinisation. The latter process probably resulted in the emplacement of the large serpentinite body in the Ordovician Wairuna Formation east of the Burdekin Fault, northeast of the Valley of Lagoons.

Early Palaeozoic metamorphic rocks

Between the Einasleigh Metamorphics and the Halls Reward Metamorphics, a belt of early Palaeozoic metamorphic rocks crops out. The Balcooma Mylonite Zone separates the Einasleigh Metamorphics from the **Balcooma Metavolcanics**, which are a sequence of rhyolitic metavolcanics (volcaniclastics and possibly lava), metasediments (mica schist and quartzite), and minor mafic volcaniclastics and lava. Isotopic dating indicates a Late Cambrian or Ordovician age for metamorphosed porphyry considered to be related to the metavolcanics (Withnall & others, 1991). Metadolerite sills and the Ringwood Park Microgranite, which may be comagmatic with some of the rhyolite, intrude the sequence. The sequence was metamorphosed in the lower to middle amphibolite facies and is multiply deformed. A small horse of phyllitic metasediments along the Lynd Mylonite Zone has been tentatively correlated with the metasediments within the Balcooma Metavolcanics.

The Balcooma Metavolcanics are bounded to the east by the Silurian Dido Tonalite, which separates them from the **Lucky Creek Metamorphic Group** that contains from west to east, Lugano Metamorphics, Eland Metavolcanics, and Paddys Creek Phyllite. The **Lugano Metamorphics** are the highest grade (upper greenschist to lower amphibolite facies) and consist of biotite leucogneiss, quartzite, amphibolite, and minor marble. The leucogneiss and quartzite may have been feldspathic arenite, shale, and tuff. Some of the amphibolite was clearly basaltic lava, but some is strongly layered and may have been para-amphibolite or mafic tuff. The unit was intruded by the strongly deformed Cockie Springs Tonalite. The **Eland Metavolcanics** are a sequence of metamorphosed andesitic to basaltic volcaniclastic rocks, but also include minor marble and metachert. The unit was metamorphosed in the greenschist facies, and the rocks have a strong, commonly mylonitic foliation. The **Paddys Creek Phyllite** is predominantly phyllite (greenschist facies metapelite) and commonly also has a mylonitic foliation. It is faulted against the Halls Reward Metamorphics along the Nickel Mine Fault.

The relationships between each of these units is uncertain, although the Paddys Creek Phyllite interfingers with and may overlie the Eland Metavolcanics. White (1962a, 1965) considered the rocks to be of Proterozoic age, but younger than the Halls Reward Metamorphics. However, it is likely that the Eland Metavolcanics and Paddys Creek Phyllite, at least, are of early Palaeozoic age like the Balcooma Metavolcanics. The age of the Lugano Metamorphics is less certain, because it has some similarities to the Einasleigh Metamorphics immediately west of the Balcooma Mylonite Zone. The contact with the Eland Metavolcanics may be a thrust. The unit is tentatively assigned an early Palaeozoic age.

PRE-CARBONIFEROUS GRANITOIDS IN THE GEORGETOWN PROVINCE

Several large batholiths and several smaller plutons have been mapped in the Einasleigh Sheet area. The nomenclature of these was given by Warnick & Withnall (1985). The ages of most of the pre-Carboniferous granitoids are still uncertain, but the majority are now considered to be of Silurian-Devonian age, rather than Proterozoic (Warnick, 1989).

Proterozoic granitoids

The **Mywyn Granite** is the only named granitoid unit regarded as being most likely of Proterozoic age. It is a strongly foliated porphyritic biotite granite, and is strongly radioactive like the known Proterozoic granitoids in the Forsayth Batholith in the central part of the Georgetown Province (Bain & others, 1990; Withnall, Bain & others, 1988).

Unnamed granitoids of Proterozoic age include mapped areas of leucogranite and pegmatite in the Einasleigh Metamorphics. These contain common screens of metamorphic rocks and grade into dyke swarms. They are deformed with the metamorphic rocks. An irregularly shaped pluton of foliated biotite granite along the Kennedy Developmental Road north of The Oasis, and several other small plutons intruding the Einasleigh Metamorphics elsewhere, may be Proterozoic.

Early Palaeozoic granitoids

The **Ringwood Park Microgranite** (variably porphyritic microgranite and minor biotite granite) forms several small plutons intruding the Balcooma Metavolcanics. It has been deformed and metamorphosed with them and is probably comagmatic with some of the metavolcanics. It is therefore of Cambrian or Ordovician age. The **Cockie Spring Tonalite** which intrudes the Lugano Metamorphics is similar to the Dido Tonalite, but is more strongly deformed and recrystallised. It is therefore given a tentative Ordovician age. Ordovician tonalites intrude the Gray Creek Complex and Judea Formation in the Broken River Province in the Clarke River Sheet area (Withnall & Lang, 1993).

Silurian-Devonian granitoids

The **Dido Tonalite**, a foliated hornblende-biotite tonalite forming a large batholith extending into the Clarke River Sheet area, is the only granitoid in the Einasleigh Sheet area definitely dated as Silurian by isotopic means. Black & McCulloch (1990) determined a U-Pb zircon age of 431^{+10}_{-20}Ma for the unit. The **McKinnons Creek Granite**, a poorly exposed biotite-muscovite granite, is thought to intrude the Dido Tonalite in the Clarke River Sheet area, and is regarded as of Silurian or Devonian age.

The **Oak River Granodiorite**, the largest component of the Copperfield Batholith, was previously thought to be of Proterozoic age (Withnall & others, 1976). It is a composite unit, ranging from foliated hornblende-biotite tonalite to porphyritic biotite granodiorite. Rb-Sr biotite ages of 388 to 400Ma have been determined by Black, (1973 and unpublished data). These could be at least partially reset, but whole-rock $^{87}Sr/^{86}Sr$ ratios are dissimilar to known Proterozoic granitoids from the Georgetown Province and are almost identical to the Silurian-Devonian Robin Hood Granodiorite in the adjacent Georgetown Sheet area. Therefore the Oak River Granodiorite is likely to be also of Silurian-Devonian age along with the **Beverly Hills Granite**, a muscovite leucogranite, which intrudes it. Other granites in contact with the Oak River Granodiorite and forming part of the Copperfield Batholith, the **Eleven-B Granite** (muscovite granite) and **Quinine Spring Granite** (porphyritic to equigranular biotite-muscovite granite similar to the McKinnons Creek Granite) are probably also of Silurian-Devonian age.

Less certain in age is the **Mount Webster Granite** (muscovite-biotite granite to granodiorite), which forms the northern part of the batholith. Because of its local strong foliation, it was considered by Warnick & Withnall (1985) to be Proterozoic. However, it is now thought to be Silurian-Devonian for several reasons. Firstly, the Oak River Granodiorite and Dido Tonalite are both foliated; secondly the pluton has the same general trend as the Oak River Granodiorite and their respective northwestern contacts are aligned; and thirdly, the Mount Webster Granite is not strongly radioactive like the known Proterozoic granites in the Forsayth Batholith. Image-processed BMR airborne radiometric data show close similarities between the Mount Webster Granite and most other Silurian-Devonian granitoids in the Georgetown Province. Likewise, a small circular pluton, the **Mount Juliet Granite** (biotite-muscovite granite) is probably Silurian-Devonian.

The **Puppy Camp Granodiorite** (unfoliated porphyritic to equigranular biotite and muscovite-biotite granodiorite) is almost certainly of Silurian-Devonian age like the petrographically similar White Springs Granodiorite in the adjacent Georgetown Sheet area.

Unnamed granitoids of probable Silurian-Devonian age include leucogranites intruding the Oak River Granodiorite, a small circular leucogranite pluton along Ellendale Creek, and a large area of poorly exposed biotite-muscovite granodiorite in the Black Spring Creek area, northwest of Mount Surprise. The last area was assigned by Warnick (1989) to the Blackman Gap Complex, a unit recognised in the adjacent Atherton Sheet area. However, the radiometric characteristics of the area are significantly different to that of the Blackman Gap Complex and more like that of the Silurian-Devonian granitoids. In the northeastern part of the sheet area, an area of foliated hornblende-biotite tonalite which intrudes the Halls Reward Metamorphics may be related to the Dido Tonalite or Cockie Spring Tonalite and is given a tentative Silurian age.

PALAEOZOIC ROCKS OF THE BROKEN RIVER PROVINCE

In the Einasleigh Sheet area, the rocks of the Broken River Province are predominantly highly deformed turbiditic sedimentary rocks and mafic lavas. White (1959a, 1962a) divided them into five formations. As pointed out by Arnold (1975), the strong deformation and stratal disruption due to thrusting, and the lack of age control make resolution of primary superpositional relationships very difficult, if not impossible. Nevertheless, the existing nomenclature has been retained, because White's formations are distinct mappable units on lithological grounds.

Arnold (1975) divided the Broken River Province into the Camel Creek and Graveyard Creek Subprovinces, which are separated by the Gray Creek Fault. In the Einasleigh Sheet area, the Graveyard Creek Subprovince is limited to a small area of **Judea Formation** cropping out between the Halls Reward Fault and the inferred projection of the Gray Creek Fault from the northern end of the Gray Creek Complex. The Judea Formation consists of mudstone and quartzose arenite and is similar to the **Wairuna Formation** on the other side of the fault. The Wairuna Formation also contains belts of altered basalt lava up to 50km long locally associated with jasper and chert. The Wairuna Formation is faulted against the Halls Reward Metamorphics along the Burdekin Fault and to the east is probably faulted against the Greenvale and Pelican Range Formations. The age is uncertain, but is probably Ordovician because of similarities to the Judea Formation which contains Early Ordovician graptolites (Withnall, Lang & others, 1988; Withnall & Lang, 1993). The **Pelican Range Formation** is similar to the Wairuna Formation, but quartzose arenite is more abundant. It is probably of a similar age. Minor basalt occurs near Hopewell Creek.

A small area of volcaniclastic arenite and mudstone on the southern edge of the sheet area near Greenvale township is mapped as Late Ordovician **Carriers Well Formation**, which is more extensive to the south.

The **Greenvale Formation** consists mainly of lithofeldspathic arenite and mudstone. The age of the Greenvale Formation is uncertain, but it is tentatively regarded as Late Ordovician to Early Silurian. The Greenvale and Pelican Range Formations form a zone 10 to 15km wide of alternating north-trending belts. Most of these are probably tectonically interleaved as imbricate thrust slices (Withnall, Lang & others, 1988; Withnall & Lang, 1993), but some of the smaller belts of quartzose arenite may be interbedded with the more labile sediments.

The **Perry Creek Formation** forms a belt to the east of this zone, and consists of quartzose to lithofeldspathic arenite and mudstone. The arenites are more quartzose and less lithic than those in the Greenvale Formation. Altered basalt and minor chert and jasper are also present. A Silurian age is based on corals and conodonts from limestone lenses which crop out in the Clarke River Sheet area and are thought to be allochthonous. A small area of hornfelsed arenite, mudstone, and basalt at the head of Camel Creek is also assigned to the Perry Creek Formation.

The **Kangaroo Hills Formation** forms the eastern half of the Camel Creek Subprovince in the Einasleigh Sheet area and extends into the Ingham Sheet area. It is probably faulted against the main belt of Perry Creek Formation, but could overlie the small area at the head of Camel Creek. Two subunits are recognised. The lowermost (SDk_1) is dominated by mudstone with minor arenite, and was previously mapped as Greenvale Formation (White, 1962a) and was supposed to be unconformably overlain by the Kangaroo Hills Formation. The base of the upper unit (SDk_2) (the former `unconformity') is marked by abundant polymictic conglomerate, commonly containing limestone clasts. However, no structural discordance is apparent, and the rocks are now regarded as part of a conformable sequence. The upper unit is characterised by more abundant, commonly very thick arenite. The arenite in the Kangaroo Hills Formation is lithofeldspathic to feldspathic, but less lithic than the Greenvale Formation and less quartzose than the Perry Creek Formation. Limestone clasts in the conglomerates and some larger allochthonous limestone lenses, northwest of Gadara homestead, contain Early Devonian (Lochkovian) conodonts (B. Fordham, personal communication, 1988).

All the units described above show characteristics of turbidite sequences. Partial Bouma cycles are common, particularly in the thinner-bedded facies. Another feature common to all of the units is melange or `broken formation'. Its significance is discussed under Structural Geology.

DEVONIAN-CARBONIFEROUS SEDIMENTARY ROCKS OVERLYING THE GEORGETOWN PROVINCE

Early Devonian

A small area of marine sedimentary rocks lying on the Georgetown Province was first described by Arnold & Henderson (1976) and assigned to the **Blue Rock Creek beds**. Sandstone, shale, limestone and minor conglomerate crop out in a small partly fault-bounded block overlying the Halls Reward Metamorphics in the Anthill Creek area, southwest of Wairuna. Arnold & Henderson (1976) suggested a Silurian to Early Devonian age, but coral fossils collected during this survey suggest an Early Devonian age (J.S. Jell, personal communication, 1986). This survey located several other smaller areas near Wairuna. Another larger area of partly hornfelsed sandstone, shale and minor conglomerate, faulted against the Halls Reward Metamorphics in the northwestern part of the sheet area near the junction of Cameron Creek and the Herbert River, is tentatively assigned to the Blue Rock Creek beds. White (1962a) assigned the rocks to the Mount Garnet Formation, a now obsolete unit (Bultitude & others, 1987) that was recognised in the Hodgkinson Province.

Two small areas of Early Devonian sedimentary rocks assigned to the **Conjuboy Formation** by Withnall (1989) crop out in the Balcooma area, and consist of quartzose sandstone and calcareous mudstone containing sporadic lenses of bioclastic limestone. The rocks are partly fault-bounded against and unconformably overlie the Einasleigh Metamorphics and Balcooma Metavolcanics. The rich, well-preserved coral and conodont fauna is of Emsian age (J.S. Jell, personal communication, 1982).

Late Devonian-Carboniferous

Sporadic, partly fault-bounded Late Devonian to Carboniferous sedimentary rocks crop out in the eastern Georgetown Inlier. They consist mainly of mostly gently dipping, fluviatile sandstone and minor mudstone (including redbeds) and are described by Withnall (1989) and Withnall & Lang (1993). The main outcrop areas are along Nine-Mile Creek, the headwaters of Spring Creek (12km north of Wyandotte), several areas along the Burdekin Fault between Lucky Downs and Wairuna, and underlying the Newcastle Range Volcanics. The presence of redbeds and northerly-directed palaeocurrents in the Nine-Mile Creek area suggests that the rocks there are related to the Bulgeri Formation in the Bundock Basin in the Broken River Province to the south. The Late Devonian Bulgeri Formation was deposited in a system of braided rivers which drained dominantly northwards (Withnall, Lang & others, 1988; Withnall & Lang, 1993). Other areas may be correlatives of the Early Carboniferous Clarke River Group. Marsden (1972) suggested that a Devonian sedimentary basin extended across the Georgetown Province at least as far west as Gilberton. Bain & others (1985) and Withnall & Lang (1993) showed that largely fluviatile sedimentary rocks (assigned to the **Gilberton Formation**) are preserved sporadically over the province in small fault blocks or beneath Carboniferous volcanic sequences, such as those beneath the Newcastle Range Volcanic Group in the western part of the sheet area. Palynological data suggest ages ranging from Famennian to Visean for the Gilberton Formation (Jell & Playford, 1985). The rocks are likely to be remnants of a large fluviatile system which drained eastwards across the Georgetown Province and possibly connected with a system draining north from the Broken River Province.

CARBONIFEROUS VOLCANIC ROCKS

Extensive areas of Late Palaeozoic, mainly felsic volcanic and related intrusive rocks which crop out over the Georgetown Province were first studied systematically by Branch (1966). More recent work has been reviewed by Oversby & others (1980) and Oversby (1985) and will be described in more detail by Oversby & Mackenzie (in preparation). In the Einasleigh Sheet area, the volcanic rocks are represented by the Newcastle Range Volcanic Group, the Butlers Volcanic Group, and the Bally Knob and Glen Gordon Volcanics. The age of the volcanic units is probably largely Carboniferous. Black (unpublished data) dated the Newcastle Range Volcanic Group at 327±4Ma, and the related intrusive rocks at 320±4Ma in a Rb-Sr whole rock isotopic study.

The **Newcastle Range Volcanic Group** crops out along the western part of the sheet area. It is more extensive in the adjoining Georgetown Sheet area (Bain & others, 1985, in preparation), where several subgroups corresponding to the infill of major cauldron subsidence structures are recognised.

The **Eveleigh Volcanic Subgroup** extends into the Einasleigh Sheet area forming the eastern Newcastle Range. The lowermost **Yellow Jacket Rhyolite**, which overlies a basal sedimentary sequence assigned to the Gilberton Formation, is a heterogeneous unit consisting of volcanic lutite, arenite, and rudite, andesite to basaltic andesite, and rhyolitic ignimbrite. The overlying sequence of **Beril Peak Rhyolite**, **Mosaic Gully Rhyolite**, and **Shrimp Creek Rhyolite** (in ascending stratigraphic order) are all rhyolitic ignimbrite units with differing lithic and crystal contents (see Table 1).

The **Cumbana Rhyolite** in the northwest of the sheet area is part of the **Nammarong Volcanic Subgroup**, and is also largely rhyolitic ignimbrite with minor andesite and volcanic lutite and rudite.

In the southwestern part of the Einasleigh Sheet area, the **Butlers Volcanic Group**, consist of the **Edmonds Creek Rhyolite**, a unit of rhyolitic lava overlain by the **McLennons Creek Rhyolite** which consists of rhyolitic ignimbrite sheets of differing crystal content. The Butlers Volcanic Group lies within the Lochaber Ring Complex.

The main area of **Bally Knob Volcanics** is northeast of Wyandotte. The rocks were first described by Withnall (1989), who recognised four main units. The lowermost unit of crystal-rich dacitic tuff(?) crops out along the western side of the main outcrop area and is faulted against a unit of crystal-poor rhyolitic ignimbrite. The ignimbrite is overlain by aphyric dacitic lava, the most widespread unit in the Bally Knob Volcanics. The uppermost unit of rhyolitic lava overlies the dacitic lava, and in places directly overlies both the rhyolitic ignimbrite and dacitic tuff. A small outlier of rhyolitic ignimbrite overlain by rhyolite lava crops out near Balcooma and is included in the Bally Knob Volcanics. The main area is arcuate in outline, suggesting that it is part of a volcanic cauldron subsidence structure. The outer (eastern) margin is probably faulted.

The **Glen Gordon Volcanics** are restricted to a small area in the northeast corner of the sheet area. They extend into the adjoining Atherton Sheet area where they are much more widespread and were described by Branch (1966) and Bultitude & others (1985). The rocks in this sheet area consist mainly of andesitic lava and dacitic ignimbrite. White (1962a) mapped the rocks as Sunday Creek Volcanics, but Branch (1966) assigned those in the Einasleigh Sheet area to the Glen Gordon Volcanics.

CARBONIFEROUS-PERMIAN INTRUSIVE ROCKS

Large granitoid batholiths of Carboniferous to Permian age occur in the northern part of the sheet area and extend into the Atherton Sheet area. The Carboniferous to Permian granitoids are all part of a group of I-type rocks which crop out extensively through the Atherton-Georgetown region (Richards, 1980; Bultitude & others, 1990). The group is dominated by felsic compositions (SiO_2 = 62-78%; average SiO_2 = 74%) and characterised by a fractionation trend of increasing K_2O, Fe/Mg, Rb, F, Th, U and decreasing TiO_2, MgO, CaO, P_2O_5, Eu, Sr, Ba, Ni, Cr, V, Sc, and Co with increasing SiO_2. Previous isotopic studies have yielded ages of 330-280 Ma and initial $^{87}Sr/^{86}Sr$ ratios of about 0.71 (Black, 1978; Johnston & Black, 1987).

The batholiths are herein given informal names, which in part follow Richards (1980). The Cumbana Batholith in the northwest contains the **Elizabeth Creek Granite** which consists of highly fractionated pink biotite granite. The name was previously given by White (1959a, 1962a, 1965), Best (1962), and Branch (1966) to all similarly highly fractionated granites through the Einasleigh-Atherton region. It is now restricted to the type area in the Cumbana Batholith. A biotite/total rock pair gave a Rb-Sr age of 318Ma (Black, unpublished data). A pluton of less fractionated hornblende-biotite granite, the **Bonnor Creek Granite**, is the other main component of the Cumbana Batholith in the Einasleigh Sheet area, apart from some unassigned microgranite and intrusive rhyolite.

The Tate Batholith extends just into the northern edge of the Einasleigh Sheet area, where the **Mullindie Granite** is the only named component. Unassigned, commonly altered granite makes up the remainder of the batholith in this sheet area.

The **Whitewater Granite** forms a separate smaller batholith surrounded almost entirely by Quaternary basalt east of Mount Surprise. It intrudes Einasleigh Metamorphics on its western margin.

The largest area of late Palaeozoic granitoids is herein described as to the Herbert Batholith. White (1959a, 1962a, 1965) assigned the whole area to the Herbert River Granite. Branch (1966) applied this name to all the less fractionated granitoids of the region. Our mapping has restricted the **Herbert River Granite** to a unit of porphyritic hornblende(?)-biotite granite in the vicinity of the Herbert River Falls. The remainder of the batholith has been divided into nine units, most of which are unnamed and are described in Table 2. Hutton *in* Withnall & others (1985) recognised 16 plutons, but some of them have been grouped together here. Two of the larger units have been named the **Princess Hills Granite** and **Minnamoolka Granite**. The name **Tiger Hill Microgranite** was given by White (1959a, 1962a) to a small intrusion north of Glen Ruth homestead.

The **Caterpillar Range Microgranite** forms numerous flat-roofed intrusions into the Eveleigh Volcanic Subgroup as well as ring dykes around the margins of the cauldron subsidence structure and separate ring structures in the basement. The **Mount Departure Microgranite** forms a ring dyke along the southern edge of the Cumbana Rhyolite. The outermost part of the **Lochaber Ring Complex** is a ring dyke system of microgranite and rhyolite. Some of the microgranite is assigned to the **Sues Creek Microgranite** which also forms a flat-roofed intrusion into the Butlers Volcanic Group. The eastern part of the ring complex consists of unassigned microgranite intruded by numerous gently dipping rhyolite cone sheets, in turn intruded by a large pluton of **Lochaber Granite**. The **Noel Micromonzonite** forms a small circular intrusion into the Sues Creek Microgranite and McLennons Creek Rhyolite. The Bally Knob Volcanics are intruded by unassigned microgranite, porphyritic microdiorite or dolerite, and gabbro.

Several plutons of biotite granite to granodiorite up to 3 km in diameter intrude the Camel Creek Subprovince in a northeast-trending line from the Greenvale-Camel Creek road near Frasers Creek to the headwaters of Redbank Creek at the edge of the Lucy Tableland. Hornfelsing of the Perry Creek Formation north of Lincoln Springs homestead indicates that the Lucy Tableland is partly underlain by similar granitoids. This conclusion is supported by the results of drilling by North Broken Hill (Young, 1979). The plutons are surrounded by aureoles up to 2 km wide and characterised by ‘spotting’ in Palaeozoic mudstones. Other areas of ‘spotted’ mudstone, such as near Wolfram Hill, may be related to ‘blind’ plutons. Minimum ages obtained by Richards & others (1966), using the K-Ar method, and corrected using the decay constants of Steiger & Jager (1977), were 357Ma from the pluton at Rocky Dam, and 322Ma from the head of Perry Creek. This suggests that the belt of intrusions is of Early Carboniferous age or older, and is significantly older than the other Carboniferous felsic rocks in the region.

Apart from the larger intrusive units described and mentioned above, numerous small intrusive bodies occur elsewhere. Rhyolite and microgranite dykes and small plugs are particularly common west of the Copperfield River in a belt between the Lochaber Ring Complex and the eastern Newcastle Range. They may reflect a large granite batholith at depth. The Kidston breccia pipe occurs on the eastern edge of this belt.

Swarms of dolerite dykes, mostly orientated approximately east-west, intrude the Mount Webster Granodiorite northeast of Einasleigh and the Einasleigh Metamorphics near the Daintree mine.

CAINOZOIC STRATIGRAPHY

The Cainozoic stratigraphy comprises small discontinuous sediments of old valleys, lakes and broader flood plains. The sediments include low order valley deposits which grade into colluvial and residual deposits derived from the underlying rocks. There are also deep weathering profiles and duricrusts of several ages, and extensive basaltic lava flows.

Early to mid Tertiary sediments (Ts)

The oldest Cainozoic sediments in the area are mapped as ‘Ts’. These consist of fluvial and colluvial sandstones and mudstones with local conglomerates. Some well-bedded claystones with plant fragments may be lacustrine. These deposits have been deeply weathered in most places. Well sorted and cross-bedded sandstones occur in places but the fluvial deposits are generally poorly sorted and poorly bedded. This might be in part due to the deep weathering, which would have obscured the bedding and converted any labile grains into a clay matrix. However, some of the massive and poorly sorted deposits are low order valley deposits which are of mixed colluvial and low energy fluvial origin. These form small, discontinuous deposits which are hard to identify on aerial photographs and difficult to map on the ground as they can grade into *in situ* regolith on deeply weathered basement rocks. The morphostratigraphic setting in some areas indicates that there are several ages of deposit mapped as 'Ts' (Figure 2).

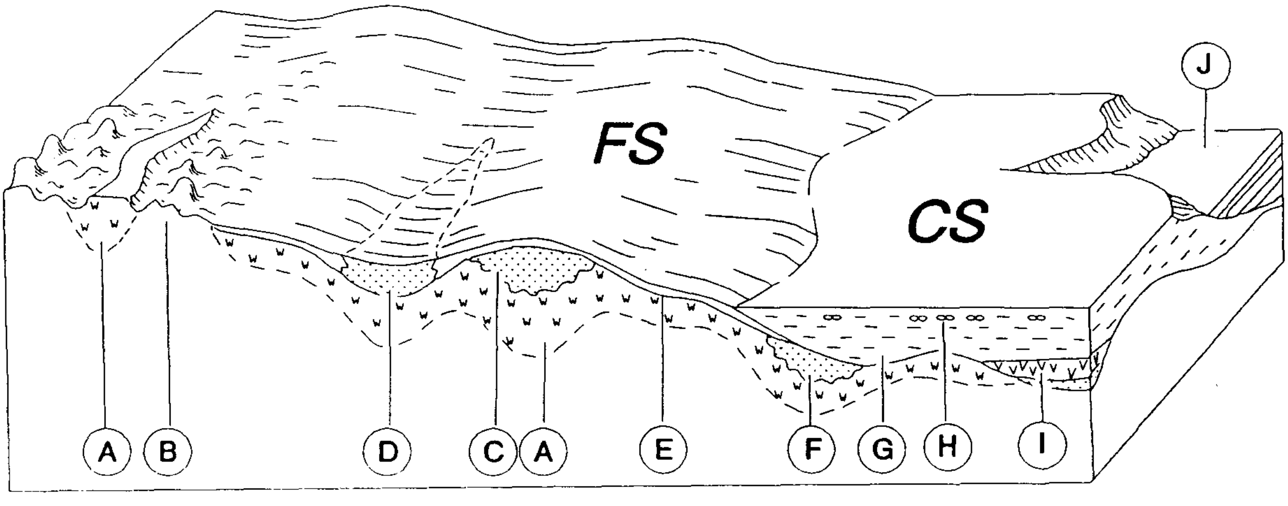
The oldest sediments predate the formation of the undulating mid Tertiary Featherby Surface, and now occur as isolated patches on the higher parts of the surface. Younger deposits lie in depressions within the surface and probably formed as the surface evolved. Still later deposits appear to bury parts of the Featherby Surface, and also the older basalts which fill silcreted valleys within that surface (see Ta unit). These morphostratigraphically based distinctions are not possible in most areas, and so a single 'Ts' unit has been used on the maps. No diagnostic fossils have been found. Most of the 'Ts' areas cannot be assigned a reliable date beyond that of early to middle Tertiary'.

Tin bearing sediments with associated silcretes occur in a series of belts following old drainage lines (Burger, 1987). Though now dissected, the palaeodrainage was probably part of the Featherby Surface. The tin bearing deposit at Ugly Corner is associated with two plugs dated at 21-22Ma by K-Ar (Sutherland, 1977, and personal communication).

Deep weathering profiles and duricrusts of the Featherby Surface (Td & screen)

Erosion and local deposition in the Late Cretaceous and Early Tertiary formed an undulating land surface, the Featherby Surface of Grimes (1979). This surface and the underlying Tertiary sediments and older rocks were deeply weathered to form thick mottled and pallid zones and ferruginous or siliceous duricrusts. The weathering profile has been partly or wholly stripped from large parts of the area. The Featherby Surface and its weathering profile are best preserved on granites in the Cashmere area (Figure 3). Elsewhere the surface is preserved as scattered mesas and tablelands.

The weathering profile is over 50m thick, but the base is gradational and irregular. In places near Cashmere, belts of thick deeply weathered material lying beside hills of fresh granite are interpreted as areas of deeper weathering beneath old drainage lines (see Figure 2). The upper part of the profile is generally a thick



FS: Featherby Surface; **CS:** Campaspe Surface; **A:** Deep weathering profile is deeper beneath old valleys; **B:** Hills of fresh rock adjoin depressions of weathered rock; **C:** Oldest Ts deposits predate the Featherby Surface; **D:** Younger Ts deposits are contemporaneous with formation of the FS; **E:** TQr soil and colluvial blankets of the FS; **F:** Ts may underlie Ta sediments in places; **G:** Ta sediments bury the FS; **H:** nodular ferricrete of the Campaspe Surface; **I:** Valley filling basalts underlie the Ta in places; **J:** Quaternary alluvium in erosional valleys.

Figure 2. Block diagram showing relationship between old land surfaces and Cainozoic sediments.

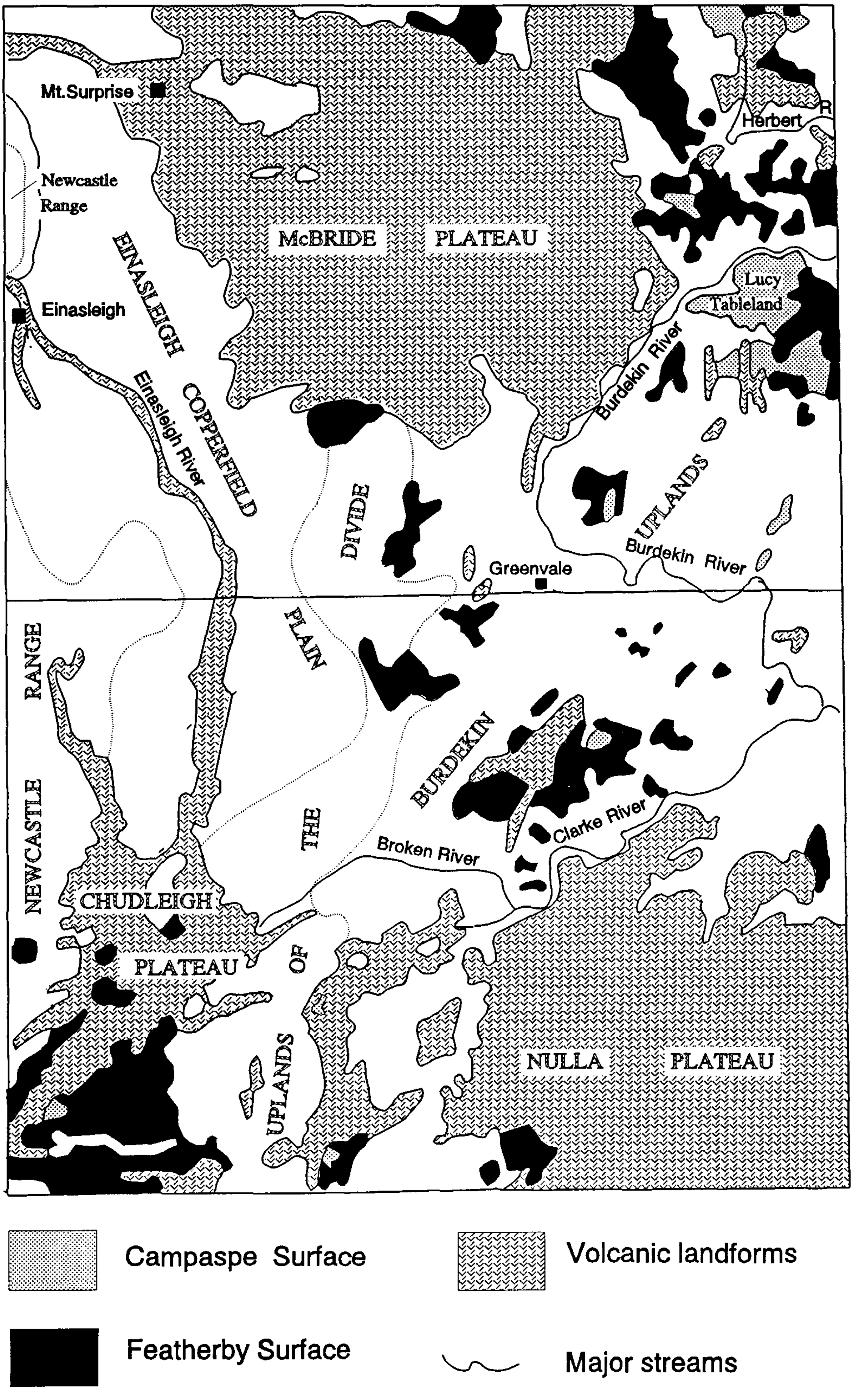


Figure 3. Old land surfaces in the Einasleigh and Clarke River 1:250 000 Sheet areas.

ferruginised zone, locally indurated to form massive ferricrete or undifferentiated duricrusts. Silcretes occur locally and are commonly associated with Tertiary sediments in palaeo-drainage lines. They generally occur as solid bands several metres thick, but cut out abruptly at the margins of the valleys. In some places the silcrete occurs as discrete nodules up to 2m in diameter. In the Lake Lucy area silcreted palaeo-valleys have been filled by basalt flows dated at 19 and 27Ma by K-Ar (Stephenson, *in* Johnson, 1989, page 96). Some of the silcretes may have formed at a different time to the main weathering profile. At Greenvale the deep weathering of a serpentinite body has formed an economic nickel-cobalt orebody (Burger, 1979, 1987). The products of deep weathering are shown on the map in several ways. Where the deep weathering profile is well preserved and extensive it is generally concealed beneath a thick soil cover mapped as 'TQr'. Duricrusts are exposed on scarps, as small mesas and in the floors of palaeo-drainage lines. They have been mapped as 'Td' with superscripts indicating the composition where this is distinctive: 'q' for silcrete and 'f' for ferricrete. Areas which have been dissected, but in which the mottled or pallid zone is still extensively preserved are shown by a screen pattern overprinted on the colour of the underlying rock unit.

Basalt Provinces

The Tertiary to Quaternary basaltic rocks are discussed in regional reviews by Stephenson & others (1980) and Stephenson *in* Johnson (1989, pages 93-96). Three main basalt provinces, McBride, Wallaroo, and Chudleigh, are represented in the sheet area, as well as some smaller areas of generally older rocks.

The main basalt provinces are of late Tertiary and Quaternary age and are described below. Older dissected basalt remnants occur in several areas.

In the Einasleigh Sheet area some `Tb' basalt flows and plugs around the southwestern edge of the McBride Province, near Rosella Plains, are significantly older than the rest of the province and are therefore not included in it. Griffin & McDougall (1975) determined K-Ar ages of around 8Ma. Farther south, a basalt mesa about 8km southwest of Carpentaria Downs homestead was dated at 7.9Ma by K-Ar (unpublished AMDEL report to GSQ, 1985).

An isolated hawaiite plug at Stockmans Hill, 5km northwest of Einasleigh and dated at 29Ma (unpublished AMDEL report to BMR, 1982), is the oldest Cainozoic basalt in the sheet area. Another isolated lava field occurs south of the Lucy Tableland where two flows dated at 19 and 27Ma (Stephenson, *in* Johnson, 1989, page 96) define complex branching patterns suggesting flow northwards down an ancient drainage system. An eruption centre has been identified at Noname Hill, but the source of the western flows is not known. Sutherland (1977) recognised two small plugs at Ugly Corner, 8km west of Camel Creek, and later dated these at 21.6 and 21.2Ma (personal communication). Nephelinite cropping out in a low lying basalt area 10-15km west of Greenvale township has been dated at 11.0Ma (unpublished AMDEL report to GSQ, 1985).

The **McBride Basalt Province** was named by Twidale (1956b) and described by Best (1960) and White (1965), but the most comprehensive study was by Griffin (1977), who recognised 164 volcanic centres. The geochronology was studied by Griffin & McDougall (1975). All the rocks in the province are herein assigned to the **McBride Basalt Group**. The province is a large basaltic dome about 80km across and nearly 500m thick. There are many lava and cinder cones and craters. The oldest rocks of the group are undifferentiated basalts (TQm) which comprise more than half of the province and have ages between 2.7 and 0.5Ma. Ages of the younger Quaternary flows, which can be mapped out on the basis of their surface morphology, are given in Table 1.

Most of the younger units have been named. The most extensive unit, the **Undara Basalt**, covers 1550km^2 and is 0.19Ma in age. Lava from the Undara Crater flowed 160km down the Einasleigh River, and another flow 90km long entered the Lynd River in the Atherton Sheet area (Stephenson & Griffin, 1976). The youngest lavas form the **Kinrara Basalt** which was erupted from the Kinrara Crater. An apparent K-Ar age of 70 000 to 50 000 years was regarded as a maximum by Griffin & McDougall (1975). Basaltic rocks in the McBride Province are predominantly nepheline-normative and include nephelinite, basanite, hawaiite, and mugearite. One occurrence of phonolite at Phonolite Hill, about 8km south of Undara Crater, has been recorded. Mantle and lower-crustal xenoliths and megacrysts are present locally (Griffin, 1977; Stephenson & others, 1980; Rudnick & others, 1986).

The **Wallaroo Basalt Province** is a small area of basalt about 20km east of the McBride Province and probably separate from it. Basalt flowed down a former Herbert River valley from four known vents. Rock types are alkali basalt and hawaiite. Ages of 6.6Ma (Stephenson *in* Johnson, 1989, page 93) and 5.5Ma (unpublished AMDEL report to GSQ, 1985) have been obtained.

Two flows of Quaternary age from the **Chudleigh Province**, which occurs mainly in the southwestern part of the Clarke River Sheet area, crop out along the Einasleigh and Copperfield Rivers. The latter is probably the oldest, but has not been dated. The flow along the Einasleigh River was erupted from Barkers Crater near the head of the river, and has been dated at 0.26Ma (unpublished AMDEL report to BMR, 1982). This flow has a similar length to the long flow from the Undara Crater.

Stephenson *in* Johnson (1989, page 93) reported that the dominant rocks in the provinces are moderately to strongly nepheline-normative basalts. Rock types include nephelinite, basinate, and mildly undersaturated alkali basalt, hawaiite, and minor mugearite. Upper-mantle and lower-crustal xenoliths are common at several localities.

Late Tertiary sediments

The Lucy Tableland forms the most widespread area of Tertiary sediments (Ta) in the Einasleigh Sheet area. They consist of interbedded, high energy, very coarse to granule sized sandstones and conglomerates and lower energy sandy mudstones, together with a few lacustrine kaolinitic claystones and a bed of impure diatomite (Mockett, 1983). Mockett postulated an arid to semi-arid climate with high energy streams forming fan like deposits. The lacustrine deposits might be the result of basalt damming of the streams. The formation could be up to 100m thick, based on drilling by North Broken Hill (Young, 1979), but has an irregular basal topography and is generally less than 60m. Some scarp sections show a series of well-defined terraces, probably the result of zones of induration rather than lithological bedding.

The unit appears to have buried the Featherby Surface and hills of the latter poke up through it in places. Areas of older `Ts' sediments beneath the Featherby Surface in this area are lithologically similar to those of the Lucy Tableland and in places show a similar degree of deep weathering effects. This raises the problem that the basal parts of the `Ta' unit might be the older `Ts' unit. No unconformities have been recognised, but the morphostratigraphy of the area suggests that `Ts' sediments could well be extending under the `Ta' (Figure 2). The `Ta' unit appears to overlie deeply weathered red `mud' with possible relict basalt textures, at several points along the scarp north of Lucy Creek.

A linear body of fresh basalt at Lake Lucy Hut, on line with the westernmost of these occurrences, yielded a K-Ar date of greater than 18.52Ma (J. Stephenson, personal communication, 1985). Stephenson (*in* Johnson, 1989, page 96) reported another date of 27Ma from this area. The basalts in this area sit in a bifurcating series of north-south trending palaeo-valleys and overlie valley floor silcretes (Td) developed on thin earlier Tertiary sandstones.

The top of unit `Ta' is a flat depositional surface, which Grimes (1979) correlated with the Campaspe Surface that occupies a similar morphostratigraphic position in the Charters Towers area. However, the generally greater degree of deep weathering here might indicate an older age. To the west of the Burdekin River, unit `Ta' underlies basalt flows of the late Pliocene to Pleistocene McBride Province. The local flows that overlie the formation have not been dated, but Griffin & McDougall (1975) report a K-Ar date of 1.3Ma from similar flows 20km to the west, which indicates a likely upper age limit for the sediments. The sum of this evidence suggests a late Tertiary age for the formation.

The sequence of events in the Lake Lucy area is interpreted as:

(1) erosion to form an undulating topography (the Featherby Surface) with northerly flowing valleys in the area south of Lake Lucy;

(2) deep weathering of the surface and silicification of the alluvial deposits in these valleys;

(3) several basalt flows from Noname Hill and elsewhere flowed down the valleys prior to 18Ma;

(4) possible further deep weathering of the upper parts of these flows;

(5) burial of the Featherby Surface and the basalts by the fluvial deposits of unit `Ta', the top of which might be equivalent to the Campaspe Surface;

(6) further deep weathering of the area (TQd) which affected unit `Ta' and the upper parts of the basalts;

(7) burial of the western area by Late Tertiary and Quaternary basalt flows, and dissection elsewhere that stripped the soft weathered tops off the older basalt flows.

A critical assumption in this model is the interpretation of the `red mud' areas as the deep weathered parts of the basalt flows. There is some opposition to this interpretation from J. Stephenson & R. Coventry (personal communication).

Residual soil and colluvium (TQr)

Thick soil covers are associated with the weathering profiles on the Featherby Surface and the Campaspe Surface throughout the region. Younger soil cover and colluvium obscures the older rocks in several other areas. Where possible the underlying rock unit is indicated by its letter symbol on the map.

Late Tertiary to Quaternary alluvial and colluvial deposits (TQa)

Dissected high level alluvial plains and colluvial slopes occur in several places in the valleys of the Herbert and Burdekin Rivers. Fluvial sediments interbedded with basalt flows are also mapped as `TQa', but basalt-dammed lacustrine deposits are described below as `TQl'. The depositional surface of these units is correlated with the Campaspe Surface in the Charters Towers area, and the sediments are of a similar age to the Campaspe Formation. However, it is possible that these deposits may have formed at several stages during the late Tertiary and early Quaternary. Nodular ferricretes are commonly found on these surfaces and the deposits have been affected by some deep weathering, though not to the same extent as the older Cainozoic units.

Basalt-dammed lakes (TQl, Ql)

A large area of sediments was deposited in the Conjuboy-Wyandotte area in lakes formed by damming of streams by Tertiary and Quaternary basalts. Poorly cemented diatomite beds with a high kaolinitic content are intercalated with lenses of claystone, sandstone and conglomerate in a shallow irregular basin about 100km^2 in area.

Investigations by Metals Exploration Ltd (1983) suggest a very irregular basement topography and a highly variable depositional regime, not conducive for the deposition of large high-grade diatomite deposits. These deposits have been buried by younger basalt flows.

Smaller deposits, which also contain diatomites, occur interbedded with basalts in the Cashmere area. Some of these have been described by White & Crespin (1959).

Some basalt-dammed lakes, such as Walters Plain Lake, are continuing to intermittently accumulate fine-grained lake deposits and are mapped as `Ql'. A sandy beach ridge (Qlc) has formed at the western edge of Walters Plains Lake, but older lake deposits continue for some distance to the west.

Late Tertiary weathering

In the Late Tertiary and possibly into the early Quaternary, deep weathering continued, though to a lesser degree, and formed nodular ferricretes with poorly developed weathering profiles (TQd). These occur on the stable land surfaces which existed at that time: the Campaspe Surface on the TQa units, the surface of the Lucy Tableland and also on the undissected remnants of the Featherby Surface. Where the effects of this weathering are overprinted on the older weathering profiles, they are difficult to recognise. However, the nodular ferricrete is a distinctive feature of this younger weathering event.

Quaternary alluvium (Qpa, Qa, Qha)

Alluvial deposits occur along the main drainage lines of the area. The composition tends to reflect the local provenance. The older flood plains and terraces are mapped as `Qpa'. The modern stream deposits are mapped as `Qha', and `Qa' is used for intermediate levels, or as an undifferentiated unit in smaller valleys.

STRUCTURE

GEORGETOWN PROVINCE

Precambrian deformation

The Einasleigh Metamorphics are structurally complex, having been multiply deformed and metamorphosed. At least six deformation events have been recorded in the Etheridge Group elsewhere in the Georgetown Province, although some of the later ones are weak and may have little effect on the gneissic rocks of the Einasleigh Metamorphics. The most obvious fabrics in the Einasleigh Metamorphics are the foliation in the gneiss, schist and migmatite, and mineral elongation in the amphibolite. The layering in the gneiss probably reflects original sedimentary layering, transposed parallel to the main foliation, which probably developed largely during the second deformation, although S_1 is rarely observed. One or more sets of outcrop-scale folds ranging from tight or isoclinal to open are common.

Some large-scale fold structures with wavelengths up to 6km and east-west axial planes are outlined by trend-lines and strike-ridges in the Douglas Range and near Black Knob in the northwestern part of the sheet area. These may be F_3 structures. A large synform outlined by calc-silicate gneiss at Mount Esk in the south may be an F_4 structure. Black & others (1979) attempted to date the deformation events using the Rb-Sr whole-rock isochron method. D_1 was dated at about 1570Ma, D_2 at 1470Ma, D_3 at 970Ma, and D_4 at 400Ma, but more recent work throws doubt on all but the first of these (Black & Withnall, 1993; Withnall, 1989). It is likely that both D_1 and D_2 occurred in the interval between about 1550 and 1570Ma, and were associated with metamorphism which ranged in grade from lower amphibolite to granulite facies.

The Halls Reward Metamorphics were also multiply deformed. Lithological layering is transposed parallel to a strong pervasive S_2 schistosity, which is folded by large-scale folds trending north-northeast and outlined by belts of amphibolite. The structure is described in more detail by Arnold & Rubenach (1976) and Withnall (1989). Mylonites are well developed in places. In most places the mylonitic foliation is steeply dipping, but west of Greenvale township it dips at moderate angles and has a north-northeast-trending stretching lineation. The mylonitised schist (phyllonite) resembles the Paddys Creek Phyllite, and was mapped as such by previous workers (White, 1962a; Green, 1958; Arnold & Rubenach, 1976). The mylonite in the Halls Reward Metamorphics could be related to the regional D_3 event recognised in the central part of the Georgetown Province.

Early Palaeozoic deformation

Mylonite zones are an important characteristic of the eastern part of the Georgetown Province. Some form relatively narrow linear belts up to 2km wide, for example the Balcooma, Lynd, and Far East Mylonite Zones, as well as even narrower zones adjacent to the Burdekin, Nickel Mine, and Halls Reward Faults. In all of these, the mylonitic foliation is now vertical or steeply dipping. Details of stretching lineations and movement senses on these zones are mostly unavailable. Both transcurrent movement and thrusting may have been involved. The Lynd Mylonite Zone shows evidence of east-block-up movement, and the opposite sense is inferred for the Balcooma Mylonite Zone (Withnall, 1989).

The other type of mylonite is the relatively pervasive mylonitic foliation observed through the Eland Metavolcanics, Paddys Creek Phyllite, and parts of the Lugano Metamorphics. The foliation is commonly layer-differentiated and is parallel to the gross lithological layering. Well-developed stretching lineations are common, particularly in the Eland Metavolcanics, where they are defined by stretched clasts. The foliation in the Eland Metavolcanics and Paddys Creek Phyllite dips moderately to shallowly northwest or southeast, suggesting an originally flat-lying fabric folded by open, northeast to north-northeast trending folds. The stretching lineations are orientated east-southeast and west-northwest.

Withnall (1989) interpreted the originally flat-lying fabric and stretching lineations as being related to large-scale thrusting with east-southeast/west-northwest movement. The shear sense is not known, but Withnall (1989) postulated west-over-east movement, the Halls Reward Metamorphics being a sheet of Etheridge Group thrust from the west. The foliation in the Lugano Metamorphics and Cockie Spring Tonalite is generally steeper than in the Eland Metavolcanics or Paddys Creek Phyllite, and the lineations plunge moderately steeply to the southwest. The reason for these differences is not known, but the structure may be related to that in the Balcooma Metavolcanics. Later folds trend northeast to north-northeast with shallow plunges, and several large-scale folds have been mapped, the most conspicuous being that outlined by the Ol_q subunit in the Lugano Metamorphics.

The Balcooma Metavolcanics mainly dip steeply east-southeast or southeast, and throughout most of the area have a single non-domainal schistosity, taken to be S_1, which also dips moderately steeply and mainly southeast. The Ringwood Park Microgranite, which may be co-magmatic with the Balcooma Metavolcanics, is also weakly foliated. S_0/S_1 vergence relationships and rare sedimentary younging are consistent with the area being on the western overturned limb of a major F_1 anticline, the hinge and eastern limb of which have been engulfed by the Dido Tonalite. The fold plunges about 45° to the south-southwest (Withnall, 1989). A second foliation (a partly differentiated crenulation cleavage) is locally present, but is rare over most of the area, particularly in the metavolcanic rocks. It is best developed in the north around the Balcooma prospect where it is locally a layer-differentiated schistosity. In this area, the main foliation, S_1, and bedding both have relatively shallow dips and are deformed by at least three later generations of folds (Huston & Taylor, 1990; Huston, 1990). F_1, F_2, and F_3 are coaxial and plunge about 20° south-southwest.

The ages of deformation in the Balcooma Metavolcanics and Lucky Creek Metamorphic Group are not certain. Withnall (1989) suggested that the thrusting and possibly the folding in the Balcooma Metavolcanics occurred in the Late Ordovician or Early Silurian, prior to commencement of deposition of the Graveyard Creek Group in the Broken River Province. Mylonite in the Halls Reward Mylonite Zone gave a Rb-Sr isochron age of 429±31Ma (L.P. Black, unpublished data). The later northeast to north-northeast folding may have occurred during D_1 in the Camel Creek Subprovince, possibly in the Early Devonian (ca. 400Ma), and at the same time as folding with similar orientations in the Einasleigh Metamorphics and Halls Reward Metamorphics. However, as pointed out by Withnall (1989), the absence of **angular** unconformities in the Graveyard Creek Subprovince at this time is difficult to reconcile with a major regional deformation. It is likely, however, that uplift and emplacement of some of the granitoids occurred in the Early Devonian.

Most of the pre-Carboniferous granitoids are, at least locally, weakly foliated, the main exception being the Puppy Camp Granodiorite. The Dido Tonalite locally has a conspicuous, strong, north-northeast-trending foliation defined by aligned quartz grains, mafic minerals, and xenoliths. The Oak River Granodiorite is also commonly foliated, particularly in the southwest. At the southern end of the Mount Webster Granodiorite, a particularly strong, steeply plunging lineation is present.

Apart from the major fault zones related to mylonites, few other faults were mapped in the Georgetown Province. This apparent paucity is probably due to the lack of conspicuous markers, depth of weathering and low relief. However, in the Greenvale Subprovince, east to northeast-trending faults, mostly with dextral displacement of up to 1.5 km, are evident.

Structure of late Palaeozoic rocks

The Devonian and Carboniferous rocks overlying the Georgetown Inlier generally have only shallow dips. Moderate dips, such as those in the Conjuboy Formation, may be related to down-faulting.

In the adjoining sheet areas, the Georgetown Province is overlain and intruded by extensive late Palaeozoic plutonic and volcanic complexes, commonly described as cauldrons and/or cauldron subsidence structures (Branch, 1966; Oversby & others, 1980), ring complexes, and associated granitoids. The granitoids extend into the northern part of the Einasleigh Sheet area. The Eveleigh Volcanic Subgroup and Cumbana Rhyolite, which extend into the western part of the sheet area, are representatives of cauldron subsidence structures, which together make up the composite Newcastle Range volcano-tectonic subsidence structure (Oversby & others, 1980). The cauldron subsidence structures are bounded by systems of linear faults and ring fractures defined by microgranite dykes. The Bally Knob Volcanics may be a small, isolated cauldron subsidence structure. In the southwest, the Lochaber Ring Complex includes microgranite and rhyolite ring dykes, rhyolite cone sheets, and granite plutons. The Butlers Volcanic Group also appears to lie within the structure. The Newcastle Range subsidence structure and the Lochaber Ring Complex lie within a major gravity low, suggesting that they are underlain at depth by a large granite batholith. Numerous felsic dykes, which intrude the Oak River Granodiorite in a belt between the Lochaber Ring Complex and the Newcastle Range subsidence structure, may reflect this batholith.

BROKEN RIVER PROVINCE

The Broken River Province is separated from the Georgetown Province by the Burdekin Fault, which was recognised by White (1961, 1962a,b, 1965) and named the Burdekin River Fault Zone. As previously noted, Arnold (1975) recognised that the Broken River Province can be divided into the Camel Creek and Graveyard Creek Subprovinces by the Gray Creek Fault. Bell (1980) suggested that the Burdekin Fault and the Gray Creek Fault were part of the same structure. Therefore, Withnall (1985b, 1989) renamed the fault segments which separate the Graveyard Creek Subprovince from the Georgetown Province as the Halls Reward and Teddy Mount Faults; the Burdekin Fault is restricted to the fault which separates the Camel Creek Subprovince from the Georgetown Province. The Gray Creek, Halls Reward, and Burdekin Faults are inferred to meet near Lucky Downs homestead. The Burdekin and Gray Creek Faults are generally interpreted as thrust faults along which the Georgetown Province was thrust over the Camel Creek Subprovince (Hammond, 1986; Withnall, Lang & others, 1988).

The structure of the Camel Creek Subprovince is complex and not well understood. The rocks have been folded by at least two major events. A feature of the deformation is the development of melange or broken formation, which consists of clasts of arenite and siltstone (and locally chert) from millimetres to many metres long in a matrix of cleaved mudstone. Contacts with non-disrupted rocks are commonly gradational. Melange is developed in all of the units in the Camel Creek Subprovince, as well as the Judea Formation in the Graveyard Creek Subprovince.

It is particularly well developed in the Wairuna, Pelican Range, and Greenvale Formations. Most of the individual melange zones are difficult to map out, but one zone in the Kangaroo Hills Formation can be traced for at least 13 km from Noname Creek east-northeast to Lincoln Springs homestead, and is referred to as the Lincoln Springs Shear Zone.

The melange was interpreted as pre-D_1 by Arnold (1975), possibly representing an accretionary wedge in a subduction complex (Henderson, 1980, 1987). However, Hammond (1986) suggested that it was associated with the formation of a thrust duplex and slaty cleavage-related folding entirely during D_1. However, it is possible that both pre- and syn-D_1 melange are present. The melange in the Judea Formation predates the Llandoverian basal part of the Graveyard Creek Group, and it is possible that some of the melange in the Camel Creek Subprovince is related.

The relationships between most of the units in the Camel Creek Subprovince are probably tectonic, although interfingering stratigraphic relationships may occur locally. The western half of the subprovince is dominated by westward-younging, alternating belts of quartz-rich (Wairuna and Pelican Range Formations) and quartz-intermediate units (Greenvale and Perry Creek Formations). Large-scale fold closures are rare. Farther east, in the Kangaroo Hills Formation, younging reversals are more common and folds can be mapped out, but the same westward asymmetry is evident (Withnall & Lang, 1993). Together with the overall younging from Ordovician to Early Devonian, these features suggest that the subprovince is an imbricate stack of thrust sheets oversteepened by ramping and/or later shortening after thrusting ceased. The folds are associated with slaty cleavage.

Northeast-trending F_2 folds reorientated the F_1 folds in the Kangaroo Hills Formation. The major folds have wavelengths of about 20km, but also occur at outcrop scale and are also associated with a slaty cleavage locally. A feature of the F_2 folds is that they are sharply truncated against the north-trending, fault-bounded belts of Pelican Range and Perry Creek Formations. The north-trending bounding faults may have acted as vertical decollements. Later folds with easterly trends can be recognised at outcrop scale.

The ages of D_1 and D_2 are constrained by the Early Devonian conodont age of the Kangaroo Hills Formation and the latest Devonian or early Tournaisian age of the unconformably overlying basal Clarke River Group in the Clarke River Sheet area. D_1 has generally regarded as Early Devonian, the age of a disconformity in the Graveyard Creek Subprovince (Withnall & Lang, 1993), but this is by no means certain. Hammond (1986) explained the lack of angular discordance in the Graveyard Creek Subprovince by it having ridden ‘piggy-back’ on the overthrust sheet of cratonic rocks above the duplex. D_2 could be Frasnian and reflected by a weak angular unconformity in the Graveyard Creek Subprovince at the base of the Bundock Creek Group. It is possible that D_1 and D_2 are separate phases of the one event in the Late Devonian.

GEOLOGICAL HISTORY

Precambrian

The geological history of the Georgetown Province, as known, began with the deposition of the Etheridge Group, originally a shallow water sequence of fine-grained, locally calcareous or dolomitic quartzose to feldspathic sandstone, siltstone, and mudstone (Withnall, Bain & others, 1988). Mafic rocks intruded as sills and emplaced as lavas in the sequence are tholeiitic and are geochemically similar to modern basalts in various extensional settings (Withnall, 1985a).

Consequently, Withnall (1985a) and Withnall, Bain & others (1988) suggested that they were the expression of convective mantle upwelling which produced extension of the crust, resulting in a shallow epicontinental sea. The Halls Reward Metamorphics are largely pelitic and may be a deeper marine sequence. The significance of the associated ultramafic/mafic complexes is uncertain. They could represent the axis of the extension, where large mafic plutons which differentiated *in situ* could have been emplaced. Alternatively, more extreme extension there possibly formed at least incipient oceanic crust. The location adjacent to the Burdekin Fault, which later became the Precambrian-Palaeozoic margin, suggests an old suture or crustal weakness along which Palaeozoic thrusting could occur (see below).

The original age of the Etheridge Group is not known. Black & McCulloch (1984) suggested that the rocks could be as old as 2.5Ga from Sm-Nd evidence, but this more likely reflects the age of the provenance (Withnall, 1985; Withnall, Bain & others, 1988). The rocks are certainly older than 1570Ma, when they were deformed and metamorphosed at grades ranging from greenschist to granulite facies. The rocks in the Einasleigh Sheet area, which are amphibolite and granulite facies, represent the deepest parts of the metamorphic pile. The rocks were deformed at least twice in the Proterozoic, probably between 1570 and 1550Ma. A third folding event may have occurred later in the Proterozoic, possibly around 970Ma.

Ordovician to Early Devonian

In the early Palaeozoic, probably the Late Cambrian to Early Ordovician, mafic to felsic calc-alkaline and minor tholeiitic volcanic rocks were erupted, mainly in a subaqueous environment, probably on the continental crust of the Georgetown Province. These rocks are the Balcooma and Eland Metavolcanics and Lugano Metamorphics. They were probably related to subduction and represent the initial deposition in the northern part of the Tasman Orogen, although Withnall (1985c) suggested that they may be allocthonous terranes. They were intruded by high-level intrusives, which were probably comagmatic with the volcanics. Fine-grained quartz-rich sedimentary rocks (the Paddys Creek Phyllite) are also present, and may have overlain the volcanic sequences. The volcanism was accompanied by copper and lead-zinc exhalative mineralisation. Similar rocks occur in the Lolworth-Ravenswood Province near Charters Towers, and Henderson (1986) suggested that they formed in an Andean setting on continental crust.

The early Palaeozoic rocks were metamorphosed and deformed by folding and thrusting, probably in the Ordovician. Withnall (1989) suggested that the cratonic rocks of the Georgetown Province were thrust over the magmatic arc from the west. This is discussed further below in relation to the Broken River Province.

Discussion of a tectonic model for the Broken River Province needs to also consider the Hodgkinson Province, because if, as is likely, the Provinces were continuous, they should have had similar tectonic settings. Prior to our work, two different tectonic models had been proposed.

Arnold (1975; and *in* Arnold & Fawckner, 1980) suggested that prior to the Silurian the quartz[a]rich turbidites were deposited along a quiescent cratonic margin. During the Silurian this became the site of subduction and a magmatic arc, the latter now represented by the Silurian-Devonian granitoids in the Georgetown Province. Quartz-intermediate turbidites derived from the arc and its uplifted basement were deposited in the arc-trench gap, where they were contemporaneously deformed. The model was developed for the Broken River Province, but has been extended to the Hodgkinson Province by various authors including Henderson (1980). Henderson (1987) elaborated on the model, incorporating oblique-slip subduction and overthrusting by the Georgetown Province. The Graveyard Creek Subprovince was interpreted as part of a forearc basin, now largely hidden by the overthrust Georgetown Province. In this model the Camel Creek Subprovince and part of the Hodgkinson Province were subduction complexes. The abundant melange, which is similar to that in subduction complexes, the predominant westward facing, and the presence of volcanic detritus, particularly in the Greenvale Formation, **are** consistent with the models of Arnold and Henderson.

An alternative model, put forward for the Hodgkinson Province by Fawckner (1981, and *in* Arnold & Fawckner, 1980), might also apply to the Broken River Province. He argued that the Hodgkinson Province was formed by crustal extension, after an initial period of magmatic activity prior to the Silurian. The voluminous tholeiitic basalts in the western part of the Hodgkinson Province and **lack** of volcanic detritus in the Hodgkinson sediments are not easily accommodated in a forearc basin model. Regional gravity suggests the Hodgkinson Province is underlain by continental crust (Fraser & others, 1977), but that the Camel Creek Subprovince might be at least partly underlain by oceanic crust (Mathur & Shaw, 1982).

Current workers in the Hodgkinson Province favour a model similar to Fawckner's (Bultitude & others, 1990), and suggest that the Hodgkinson Province was intracratonic and formed along the lines postulated for extensional basins by Lister & others (1986). The Barnard Metamorphics on the coast near Innisfail may represent the eastern cratonic block. An upwelling mantle diapir may have produced thinning and extension of the crust, and generation of tholeiitic basalt. Sedimentation continued into the late Devonian or Fammenian before any major deformation. Deformation was by intra-cratonic thrusting with the craton being thrust over the Hodgkinson Province from the west (Hammond, 1986).

In the Broken River Province, Early Ordovician basalt and keratophyre in the Judea Formation are the oldest known rocks (cropping out in the Clarke River Sheet area). They are overlain by quartz-rich turbidites. The quartz-rich turbidites and tholeiitic basalt in the Camel Creek Subprovince (Wairuna and Pelican Range Formations) could also be Early Ordovician and together with the Judea Formation could have formed in an extensional regime after the cessation of subduction and arc volcanism represented by the metavolcanics in the eastern Georgetown Province. The Late Ordovician volcanics and volcaniclastics of the Carriers Well Formation and Everetts Creek Volcanics (in the Clarke River Sheet area) in the west of the Camel Creek Subprovince may represent another phase of arc magmatism, although they have a limited areal extent. They are mixed with quartz-rich sediments derived from the craton. This pattern of mixed provenance continues to the east, where the Greenvale Formation (dominated by lithic arenite with a significant volcanic component) appears to interfinger locally with the quartz-rich Pelican Range Formation.

If the Late Ordovician volcanism was subduction-related, it is possible that the extensive melange in the Ordovician rocks was produced in a subduction complex rather than all being related to terminal deformation in the Early Devonian as Hammond (1986) suggested. Alternatively, it could have resulted from deformation in the Late Ordovician when the Georgetown Province is thought to have been thrust over the Cambro-Ordovician magmatic arc along the Balcooma Mylonite Zone (Withnall, 1989). The Judea Formation was also deformed by thrusting over cratonic rocks at that time. Movement on the major mylonite zones that cut the Georgetown Province may also have occurred in the Late Ordovician. They apparently predate the main Silurian-Devonian batholiths.

The Silurian Perry Creek Formation is relatively quartz-rich, reflecting a greater input from the craton although some volcanic detritus is still evident. The Early Devonian Kangaroo Hills Formation contains significantly less volcanic detritus. The waning proportion of volcanic detritus is consistent with progressive erosion of the Cambrian and Ordovician volcanics and exposure of the basement, and it is not necessary to invoke an active volcanic arc in the Silurian. Minor tholeiitic basalts in the Perry Creek Formation are more consistent with an extensional setting than an accretionary prism, although it could be argued that they represent off-scrapings of oceanic crust. However, this is an unlikely origin for the much more voluminous Silurian basalts farther north in the Hodgkinson Province.

In the Early Silurian, the Graveyard Creek Subprovince developed where the western edge of the postulated Hodgkinson/Camel Creek extensional basin met the Clarke River Fault. It was possibly a small pull-apart basin. Although entirely to the south of the Einasleigh Sheet area, a brief outline of its history is relevant to a discussion of the history of the Broken River Province as a whole. The Graveyard Creek Group was deposited on a basement of deformed Judea Formation. The arenites in the group are mainly feldspathic with minor volcanic and metamorphic input, like those of the Perry Creek Formation. The main provenance was the Georgetown Province. Dramatic thickness changes and diamictites containing olistoliths of metamorphic rocks and allocthonous limestone suggest active faulting along the northern boundary and within the basin. Minor contemporaneous volcanism is evident from a thin tuffaceous interval in the north. This may be related to emplacement of the Dido Tonalite in the Georgetown Province in the Early Silurian. The batholith may have been generated by underplating or melting at the base of the tectonically thickened crust. However, there is no evidence for long-lived contemporaneous volcanism, as would be expected in a fore-arc basin.

No rocks younger than Early Devonian are known from the Camel Creek Subprovince. This apparent cessation of deposition coincides with isotopic ages of around 400Ma from the extensive plutonic rocks in the adjacent Georgetown and Lolworth-Ravenswood Provinces (Black, 1973; Black & others, 1979). In the Einasleigh Sheet area, these rocks include the Copperfield Batholith, Puppy Camp Granodiorite, and McKinnons Creek Granite. It is uncertain whether the isotopic ages record the actual emplacement or simply uplift and final resetting of isotopic `clocks'. The uplift was probably greatest in the Douglas Range area, where the highest grade metamorphic rocks are now exposed. The deformation of the Camel Creek Subprovince, which resulted in the pattern of imbricate thrust slices and some of the melange, may also have occurred, or at least begun, at this time. The Burdekin and Gray Creek Faults mark the western limit of the thrusting. Hammond (1986) suggested that these faults formed the roof thrust of a major duplex with the craton being thrust over the Camel Creek Subprovince. Further north in the Hodgkinson Province, deposition continued, and there is no evidence for early Devonian deformation. If there really was an Early Devonian event in the Camel Creek Subprovince, this is a major difference between the two provinces and is yet to be satisfactorily explained.

The Clarke River Fault, which marks the southern edge of the Broken River Province in the Clarke River Sheet area, could have acted as a tear fault marking the southern limit of thrusting. Correlations between rocks in the eastern Georgetown Province with similar units in the Lolworth-Ravenswood Province, as well as the shape of the orocline in the southern part of the Camel Creek Subprovince, are consistent with transcurrent sinistral movement.

The 400Ma-event was associated with extensive gold mineralisation in the Etheridge Goldfield to the west (Bain & others, 1990). In the Einasleigh Sheet area, some of the small base metal vein deposits and possibly minor gold mineralisation such as at Balcooma and Lucky Creek, could have occurred at this time. Some of the syn-deformational Amanda Bel mineralisation may also be of this age.

The uplift of the Georgetown Province was accompanied and followed by extensive erosion. By the Late Devonian, about 10 to 15km of cover had been removed from the Silurian-Devonian granitoids.

Devonian to Early Carboniferous

The Graveyard Creek Subprovince was largely unaffected by the postulated Early Devonian deformation possibly because it was riding on the upper cratonic plate or was underlain by thicker continental crust. After a short hiatus, sedimentation continued with the deposition of mainly carbonate and siliciclastic shelf sediments from the late Lochkovian to the Givetian. The remnants preserved on the Georgetown Province, the Conjuboy Formation and Blue Rock Creek beds, indicate that sedimentation was not restricted to the present limits of the Graveyard Creek Subprovince. A slight angular unconformity in the Graveyard Creek Subprovince in the early Frasnian could have been associated with the second deformation producing major northeast-trending folds in the Camel Creek Subprovince. The deformation could have been related to extensive sinistral movement on the Clarke River Fault.

After a short hiatus in the Frasnian, deposition of the Bundock Creek Group commenced in the Graveyard Creek Subprovince in the Clarke River Sheet area. The lower part is a tectonically influenced alluvial plain and fan sequence containing redbeds. The fans merged with streams flowing towards the Hodgkinson Province, across the Georgetown Province, where remnants of fluviatile rocks are preserved. A major regional transgression in the latest Devonian to early Tournaisian is recorded in the middle of the Bundock Creek Group and the basal part of the Clarke River Group, but no marine rocks are known in the Einasleigh Sheet area. Palaeocurrent directions reversed at this time, possibly in response to deformation of the Hodgkinson Province to the north and closing off of the sea in that direction. Later in the Tournaisian, perhaps in response to fault movements to the north, there was a major regressive phase. Braided rivers, dominantly draining a plutonic/metamorphic source covered the area. The Gilberton Formation and some of the other areas of fluviatile rocks on the Georgetown Province may represent parts of this system.

Late Carboniferous to Permian

In the Late Carboniferous, voluminous eruptions of calc-alkaline felsic magma, mainly as rhyolitic ignimbrite, occurred throughout the Cairns-Townsville hinterland. In the Einasleigh Sheet area, these are represented by the Newcastle Range Volcanic Group, Butlers Volcanic Group, and Bally Knob Volcanics. The volcanic rocks are associated with cauldron subsidence structures. Explosive eruption of voluminous ignimbrites above a magma chamber was accompanied or followed immediately by relatively gradual basin or trough-like subsidence (Oversby & others, 1980; Oversby & Mackenzie, in preparation). The magma chamber ascended along ring fractures and was emplaced passively into the overlying volcanic pile by stoping. Vertical segmentation of the country rocks resulted in flat-roofed intrusions. Associated with the eruption of these ignimbrite sequences was the emplacement of extensive granitoid batholiths such as the Cumbana, Tate, and Herbert River Batholiths, probably extending into the Permian. These may also have been associated with extrusive equivalents, but if so, they have been eroded. The Butlers Volcanic Group and Lochaber Ring Complex may represent an intermediate level of exposure, where a small remnant of the volcanics are still preserved with their plutonic equivalents.

The Carboniferous-Permian magmatic activity was associated with the formation of widespread, but generally small tin-tungsten and topaz deposits in greisens and veins, within both the granites and their country rocks. Small base metal deposits may have also formed at this time. However, by far the most important event was the emplacement of the breccia pipe at Kidston and the accompanying hydrothermal alteration and gold mineralisation.

The magmas are interpreted to have been derived from an extensive, relatively old and homogeneous infracrustal protolith, that may originally have been the product of crustal underplating (Bultitude & others, 1990). Some characteristics of the late Palaeozoic volcanic fields of north Queensland are consistent with magma generation in response to a shallowly westward-dipping subduction zone (Sheraton & Labonne, 1978). However, Oversby & others (1980) pointed out that the lack of any obvious indications of a late Palaeozoic trench, lack of apparent back-arc rifting, and no signs of geochemical or temporal polarity are problems in applying a subduction model. The volcanics could conceivably formed in response to some other tectonic regime.

Cainozoic

No record of Mesozoic deposition is present and the area may have been largely erosional. In the Tertiary erosion with some local deposition resulted in the formation of an undulating surface, the Featherby Surface, which by mid Tertiary was stable enough for extensive deep weathering to occur beneath it. Ferruginous weathering profiles formed on most of the surface, but silcretes formed along some valleys.

Episodic basaltic volcanism occurred in the area from the late Oligocene onwards. The oldest basalt is the isolated plug at Stockmans Hill near Einasleigh (29Ma), but no flows are preserved. Flows were erupted in the Lake Lucy area and flowed down a north-directed drainage system (opposite to the modern drainage) in the late Oligocene (27Ma) and early Miocene (19Ma). Other flows preserved as remnants, dated at 11Ma near Greenvale, about 8Ma in the Carpentaria Downs area, and about 6Ma in the Wallaroo Province, may represent once more extensive lava fields. The most extensive volcanism preserved occurred in the McBride Province where basalts were erupted sporadically from the late Pliocene (2.7Ma) throughout the Pleistocene, possibly to almost Holocene times. Stream and lake sediments are interbedded with the basalt flows in many places. Some of the older flows have been deeply weathered.

Erosion in the latter part of the Tertiary dissected the Featherby Surface and fluvial sediments were deposited in valleys and small basins. The most extensive deposits are those preserved in the Lucy Tableland. The depositional surfaces on these sediments have been correlated with the Campaspe Surface in the Charters area. These sediments were also deeply weathered, but not as extensively as the rocks beneath the Featherby Surface. A nodular ferricrete formed on the late Tertiary sediments and also on the flatter parts of the older Featherby Surface. Lake deposits, including diatomites, formed where streams were dammed by basalt flows.

Continuing erosion in the Quaternary dissected the weathered rocks. Fluvial deposition occurred at several levels in the modern valleys.

ECONOMIC GEOLOGY

All of the significant mines and mineral prospects are briefly described here. Reference is made to the results of recent mining company investigations on them. Numerous other exploration surveys have been done in the sheet area since the late 1950s. Reports recording the results of these surveys are filed at the Department of Minerals and Energy in Brisbane, and can be accessed with the aid of the Department's QERI database.

ALUMINO-SILICATES

The quartzite unit (Ol_q) in the Lugano Metamorphics is a potential source of kyanite for use in the manufacture of refractories. However, there is no record of investigations of the unit for such purposes having been carried out. The quartzite contains up to 25% kyanite (Withnall, 1989), although in places it is replaced by phyllosilicates. The quartzite forms prominent ridges just south of the Conjuboy-Greenvale road and at Dido Hill and Iron Knob.

Another quartzite ridge in the Balcooma Metavolcanics near the Balcooma Mylonite Zone west of Balcooma was described by Timmins (1990). It contains widespread kyanite and andalusite with lesser corundum, diaspore, muscovite, topaz, apatite, and aluminium phosphates.

ANTIMONY

A small antimony prospect at **The Gap**, about 6km west-southwest of Carpentaria Downs homestead, was worked in the mid-1960s. About 7t of ore was mined, but not high enough in grade for sale. Small stibnite-bearing quartz veins are associated with altered rhyolite dykes (J.V. Warnick, personal communication, 1981).

Minor stibnite also occurs in some of the gold deposits such as the **Blue Ant** in the newly discovered `Amanda Bel goldfield' (Teale & others, 1989) (see below).

BARITE

Sporadic barite is associated with the Einasleigh copper deposit, the Kaiser Bill gossan, and the Barium prospect (Perkin, 1971; Onley, 1979). Stratiform lenses of barite, up to 2m thick and up to 50m long, occur widely in the calc-silicate gneiss facies (Pe_1) east of Far East Mylonite Zone (Whitcher, 1981). They contain weak copper mineralisation. None of the deposits is large or economically significant.

CHROMITE

Minor chromite has been recorded from the Sandalwood Serpentinite in the Boiler Gully Complex (White, 1965, page 113), but no deposits of economic significance are known.

COPPER-LEAD-ZINC

Deposits hosted by Proterozoic metamorphic rocks

Within this sheet area and the adjoining Georgetown and Clarke River Sheet areas, the Einasleigh Metamorphics host more than 20 base-metal occurrences which are thought to be stratiform and/or stratabound (Bain & Withnall, 1980; Bain & others, 1990). Work by companies has indicated that in regional terms, the deposits are concentrated at the transition from the dominantly psammitic calc-silicate gneiss facies (Pe_1) to the psammopelitic biotite gneiss facies (Pe_3) (Klaric, 1977; Onley, 1978; Teluk, 1978; Whitcher, 1981). In general, copper mineralisation (commonly associated with baritic lodes) occurs in the calc-silicate facies, whereas zinc mineralisation, with lead in some cases, occurs in the biotite gneiss facies. Detailed studies of the Einasleigh copper deposit (Patrick, 1978), and the Mount Misery lead-zinc prospect in the adjoining Georgetown Sheet area (Stanton, 1982), have established the stratiform and possibly exhalative nature of the deposits. It is likely that most of the other base metal deposits described from the Einasleigh Metamorphics have a similar form and origin.

The **Einasleigh** copper mine was described by Marks (1911), Ball (1914), and the Queensland Department of Mines (1953). It was worked between 1898 and 1924 and was the largest copper producer in the Georgetown Province. Recorded production was 136 412t of ore, which yielded 8237t of copper, 71.2kg of gold, and 4083kg of silver. Most of it was from a single, steeply dipping lode (about 10m by 75m at a depth of 90m) which tapered vertically and horizontally into lower grades that could not be worked economically. Current indicated and inferred `reserves', based on detailed assessment by Combined Mining and Exploration NL, who dewatered the workings and drilled from underground, are about 200 000t of ore containing 2.13% Cu and including about 20 000t of 4.5% Cu (Dewar, 1972). Other exploration at the mine was reported by Perkin (1971).

The orebodies are steeply dipping lenses of quartz-biotite-garnet-feldspar-barite gneiss containing pyrrhotite, chalcopyrite, cubanite (Radke, 1973), minor pyrite, sphalerite, and traces of molybdenite and gold. Immediately adjacent to the deposit are small bodies of garnetite, ferruginous barite-andradite, and oligoclase-carbonate rocks. The main host rocks are biotite gneiss, migmatite, pelitic schist, calc-silicate gneiss, and amphibolite. The deposits and their host rocks have been multiply deformed and highly metamorphosed. Microstructural studies by Patrick (1978) showed that the sulphide minerals were present before D_2 and possibly before D_1. He suggested that the deposit formed in response to the introduction of H_2S/HS^- bearing Ca-Ba-rich metalliferous brines, possibly of volcanic origin, during deposition in a shallow marine environment.

The **Teasdale** mine, which produced 31.5t of secondary copper ore averaging 5.4% in 1909 has been examined by Carpentaria Exploration Co. Pty Ltd (Rawlins & Simpson, 1968) and McIntyre Mines Pty Ltd (Burban, 1975). The main mineralised zone is about 600m long and consists of two bands of gossanous quartz-magnetite gneiss up to 20m wide. Seven holes drilled by McIntyre Mines intersected mineralised zones up to 26m wide. The best intersections were 2.5m of 2.35% Cu, 8.7m of 1.1% Cu, 4.4m of 1.44% Cu. A section of the deposit was estimated to contain 28 000t of 0.58% Cu per vertical metre over a length of 360m.

Small rich patches of secondary ore were worked at the **Kaiser Bill** mine, but the actual production was not recorded. The gossan is 900m long and up to 30m wide. It was drilled by Carpentaria Exploration Co. Pty Ltd (Rawlins & Simpson, 1968). According to Burban (1975), the deposit contains 6.3Mt of 0.45% Cu mineable by opencut to 90m. Barite occurs sporadically in the gossan, and although Rawlins & Simpson (1968) suggested that the deposit is localised in a shear zone and was related to late Palaeozoic granite, it is more likely that the deposit has a similar origin to the Einasleigh and Teasdale deposits, and is of Proterozoic age.

The **Railway Flat** prospect, discovered by CRA Exploration Pty Ltd about 2.5km southwest of Einasleigh, contains a small tonnage of lead-zinc mineralisation, but details are still confidential. It occurs in the biotite gneiss facies close to the transition with the calc-silicate gneiss facies.

The **Daintree** deposit yielded 1197t of hand-picked supergene ore averaging 16.5% Cu and 12.5g/t Ag, mostly from a shear zone. Marks (1911) noted a large quantity of low-grade mineralisation in addition to the supergene enrichment. Investigations by Laskan Minerals Pty Ltd (1971) and Anglo American Ltd (Gaunt & McNaughton, 1975) suggest that the deposit contains about 660 000t of 1.6% primary copper and 200 000t of 1-3% secondary copper. The deposit is hosted by calc-silicate gneiss, which is locally sheared and epidotised. Coarse grains of chalcopyrite, minor pyrite, and rare pyrrhotite and molybdenite are disseminated through the gneiss and elongated parallel to the metamorphic layering. they are thus pre-metamorphic and may be syngenetic. Chalcopyrite is also in retrogressed zones associated with shearing. Getty Oil Development Corporation (1981) drilled three percussion holes to test possible extensions of the lode, but no significant mineralisation was found. A hole drilled into the known lode intersected 1.76% Cu over 34m.

At **Ironstone Knobs**, Otter Exploration NL discovered two discrete gossanous ironstone layers with anomalous zinc and copper. They were drilled by Getty Oil Development Corporation (Davies, 1980) and at depth consist of massive to disseminated pyrrhotite and pyrite with minor sphalerite and molybdenite. One hole intersected 8.3m of 0.44% Zn and 400ppm Cu, and another intersected five zones 1 to 8m wide over 130m, assaying up to 0.52% Zn. The ironstone can be traced for at least 8km.

Another body of massive and disseminated pyrite/pyrrhotite, possibly at the same `horizon', was drilled at the **Well grid** by Getty Oil Development Corporation (1981), revealing similar low grades of zinc and copper to Ironstone Knobs.

Drilling of induced polarisation anomalies at the **McLean grid** located only small amounts of disseminated sulphides, but assays of up to 0.26% Zn were obtained over true widths of about 10m (Whitcher, 1981, Getty Oil Development Corporation, 1981). These occurrences are east of the Far East Mylonite Zone, probably in a repetition of the same `horizon' in a fold hinge.

Several small gossans crop out elsewhere in the Einasleigh Metamorphics to the north of Einasleigh, but little is known about them. They may be related to Carboniferous intrusive and volcanic activity like the small prospects in the McMillan Creek area in the adjacent Georgetown Sheet area (Withnall, 1978). The **Patsy** was described by Perkin (1971).

The **Halls Reward (or Ninety Mile)** mine near Lucky Downs homestead produced 12 836t of ore containing 2236t of Cu, 66.9kg Au and 196kg Ag between 1933 and 1958. The ore shoot measured 3m by 16m by 40m in a steeply dipping shear zone, 300-600m long, at the contact between the Halls Reward Metamorphics and altered Stenhouse Creek Amphibolite. The ore was mostly malachite, but cuprite, tenorite, and minor native copper were also present. Stringers of chalcocite, covellite, and disseminated pyrite and chalcopyrite occurred at the 38m level. The deposit was previously described by Morton (1941, 1943), Denmead (1947b), Connah (1959), White & others (1961), and White (1965). Several other small cupriferous gossans worked by small pits or shallow shafts occur in the Halls Reward Metamorphics. Copper may have been mobilised from the Stenhouse Creek Amphibolite.

Deposits hosted by early Palaeozoic metamorphic rocks

The **Balcooma** copper-zinc-lead massive sulphide deposit was discovered in 1978 by Carpentaria Exploration Co. Pty Ltd. It is now owned by Lachlan Resources NL. The exploration history and geology are described by Harvey (1984a,b), Huston (1988, 1990), and Huston & Taylor (1990). Gulson & Vaasjoki (1987) described the lead isotope systematics of the deposit.

The mineralisation is hosted by a metapelite lens within a meta-arenite sequence within the Balcooma Metavolcanics. Several lenses of felsic volcaniclastics also occur within the sequence, which has been intruded by felsic sills. Huston (1990) and Huston & Taylor (1990) consider that at least three distinct mineralised `horizons', two lead-zinc and one copper, are present. The central copper `horizon' contains massive pyrite-chalcopyrite and magnetite within an envelope of variably chloritised staurolite-bearing metapelite adjacent to a folded quartz-feldspar porphyry body. Copper mineralisation is invariably associated with the porphyry which is not chloritised and which cuts the mineralisation. The upper and lower, zinc-lead-dominated `horizons' consist of massive sphalerite-galena-pyrite-chalcopyrite associated with pyritic quartz-muscovite schist interpreted as metamorphosed quartz-sericite alteration. Gahnite-bearing quartzite associated with some of this alteration-type is interpreted as exhalite. The orebodies plunge about 20^o southwest, parallel to the lineations in the surrounding rocks. Evidence from mineral textures support the interpretation that the deposit is a strongly deformed massive sulphide deposit of the volcanogenic type (Huston, 1990).

Total indicated and inferred resources are 2.9Mt containing 3.1% Cu and 0.4g/t Au, and 1.2Mt containing 0.9% Cu, 8.2% Zn, 3.9% Pb, and 56g/t Ag.

The **Surveyor** zinc-lead deposit is about 2km southwest of the Balcooma deposit, probably at the same stratigraphic position in the Balcooma Metavolcanics. The gossans were originally discovered by Geopeko Ltd in about 1976, and the deposit has been investigated jointly by Noranda Australia Ltd, Pioneer Minerals Exploration Ltd, and Lachlan Resources NL since 1983. A summary of the geology was given by Robertson Research (Australia) Pty Ltd (1985). The main body is a lens of massive sulphide (sphalerite, galena, and pyrite) closely folded into a synform with an attenuated east limb and a thicker (average 9m) west limb and extending down plunge (20^o southwest) for 200m. The upper contact is sharp whereas the footwall contact is diffuse, grading down through banded sulphides with metachert interbeds into stringer veins and disseminations characterised by the appearance of chalcopyrite. Pyritic disseminated mineralisation with only minor base metal sulphides occurs below the stringer zone. An oxidised zone with cerussite and anglesite extends to about 50m with a discontinuous supergene zone containing chalcocite at its base.

Reserves are 0.48Mt at 19.7% Zn, 7.3% Pb, 0.8% Cu, 146g/t Ag, and 1g/t Au in the main body, and 0.23Mt at 6.9% Zn, 2.0% Pb, 1.6% Cu, 89g/t Ag, and 0.8g/t Au in the stringer zone.

The **Dry River South** zinc-lead deposit (Huston & Taylor, 1990) is about 1km south-southwest along strike from the Surveyor prospect and is similar to the zinc-lead bodies at Balcooma and Surveyor. It was discovered by Carpentaria Exploration Co. Pty Ltd. It contains an inferred resource of 1.1Mt of 10.6% Zn, 3.4% Pb, 0.8% Cu, and 85g/t Ag.

The **Wyandotte (or Dry River)** copper prospect is hosted by the Lugano Metamorphics. Blebs and streaks of pyrite and chalcopyrite are aligned within the foliation in amphibolite and some quartz-chlorite-feldspar-carbonate-magnetite schist, which are interlayered with barren felsic gneiss. Exploration by Shell Minerals Exploration (Australia) Pty Ltd suggested that the deposit contains at least 450 000t of 2.5% Cu in two shoots 10m wide and at least 60m and 100m long, respectively (Ward & West, 1975; Davis, 1983).

Several other small copper prospects are known from the Lucky Creek Metamorphic Group. At the **Milldown (or Judy Ann)** prospect, malachite staining occurs in amphibolite, and at **Cockie Well**, malachite-stained pillow basalt and breccia crops out (Davis, 1983). Drilling of bulk cyanide leach gold anomalies at the Cockie Well prospect located no significant mineralisation (Jackson, 1989). The **Gate grid** in the Eland Metavolcanics has been prospected by trenching and has anomalous gold values (Davis, 1986).

At the **Silver Hills** prospect, east of Wyandotte homestead, minor Pb-Zn-Ag-Cu mineralisation occurs in a shear zone in the Eland Metavolcanics adjacent to the eastern faulted contact of the Carboniferous Bally Knob Volcanics (Davis, 1983).

Deposits in other units

The **Just As (or Mount Jardine)** prospect occurs in the large dyke of Caterpillar Range Microgranite near Mount Nigger. Marks (1911) reported its discovery. Small anastomosing veins of galena, azurite, and malachite occur in a shear zone which can be traced north-northwest for 120m (Mitchell, 1969).

The **Mount Blister** prospect is hosted by the Silurian-Devonian Kangaroo Hills Formation, and consists of a thin gossanous quartz vein up to 0.4m wide in a shear zone (Bussard, 1971; Brunker, 1970). Some galena is present and values of 40g/t Ag are reported. Malachite and gossan occur in parallel shears in a zone about 6m wide at a small prospect about 3km north of Lincoln Springs homestead (Brunker, 1970).

DIATOMITE

Four diatomite deposits associated with Cainozoic basalts were discovered by the BMR-GSQ mapping in the 1950s (White & Crespin, 1959; White, 1965). The **Conjuboy** deposits are the largest and crop out in Wyandotte and Spring Creeks. The area potentially has an area of 100km^2 and diatomite up to 20m thick was recorded by Werner (1973). However, Metals Exploration Ltd (1983) showed that the diatomite is not continuous under the basalt. The diatomite is kaolinitic and intercalated with claystone and sandstone. Grade evaluation indicated that it has properties suitable for manufacture of lightweight bricks and refractory insulating bricks, but that considerable upgrading would be necessary before it would be suitable for use as a filter agent.

Other deposits at **Cashmere** and **Gleneagle** are much smaller and are not known to have been investigated in detail, but are apparently of higher grade than the Conjuboy deposits. Impure diatomite also occurs to the west of **Walters Plains Lake.**

GEMSTONES

The O’Briens Creek topaz field about 30km northwest of Mount Surprise is the source of most of Australia’s finest gem-quality topaz. Alluvial workings now extend beyond the catchment of O’Briens Creek, which is a tributary of Lancewood Creek. Most of the deposits are in the adjoining Atherton Sheet area. The topaz and small amounts of aquamarine are derived from veins and greisens in the Elizabeth Creek Granite.

Small diamonds have been found in the gravels with the topaz at O’Briens Creek. Exploration by several companies, in particular CRA Exploration Pty Ltd (Fielding, 1986, 1987), has failed to find any indications of kimberlites in the region.

Gem-quality blue sapphires have been mined in the **Lava Plains** area since the early 1970s. They occur in shallow colluvium, eluvium, and alluvium adjacent to and within current watercourses, along with zircon and olivine. They were probably originally megacrysts in lavas or pyroclastics erupted from a very limited number of vents, such as the feature known locally as Mines Hill (Krosch & Cooper, 1990). The area is covered by Departmental Area 135D, the intention being to exclude Authorities to Prospect (now Exploration Permits) and to allow only small-scale mining by limiting the size of leases. However, since the mid 1980s, large-scale mining has been carried out by amalgamating leases. The recorded value of gems produced from 1985 to 1988 was $340 000, but the actual production is likely to have been much higher. Krosch & Cooper (1990) estimated that the field had a life of only 1 to 2 more years.

Poor quality chrysoprase occurs with the lateritic nickel deposits at Greenvale, Minnamoolka, and Valley of Lagoons (Krosch, 1990). Mauve to lilac garnet in gravels along Junction Creek, southeast of Mount Surprise, is probably derived from porphyroblasts in granite gneiss in the Douglas Range area.

GOLD

The Einasleigh Sheet area contains one of Australia’s largest current gold producers, the **Kidston** mine. Alluvial gold was first discovered at Kidston in 1907 (Cameron, 1908; Marks, 1911), and up to 1910, approximately 620kg of alluvial gold was won. The narrow quartz veins were mined by small-scale shafts and opencuts, as well as bulk-mining in sizeable opencuts in the Wise Knob area between 1915 and 1921 (Jensen, 1920b). Most mines closed in 1924, but intermittent mining continued until 1948. Total production for this early period was 225 000t of ore which returned 1309kg of gold at an average grade of about 6g/t.

The deposit was tested by Gold Mines of Australia in the 1930s (Coldham, 1934), and Anaconda Australia Inc. in 1965-67 (Hannes & Dalgarno, 1967) and 1974-77 (Turner, 1976). Anaconda geologists recognised the deposit as a major gold-bearing breccia pipe, but concluded it was subeconomic at the prevailing gold prices. Placer Exploration Ltd took over the option in 1978, and after extensive exploration drilling, developed a major mine operated by Kidston Gold Mines Ltd. Reserves were estimated at 44.4Mt at 1.76g/t Au and 2.2g/t Ag. Production from 1985 to 1993 was 59 882kg of gold from 37.3Mt of milled ore. Head grade during the first three years, when oxidised ore was mined, averaged 2.3g/t Au, dropping thereafter to about 1.5g/t in the primary ore. Exploration since mining commenced has extended the reserves. At December 1993, proved and probable reserves were 33.1Mt at 1.13g/t gold and 1.94g/t silver. Mining is expected to continue until at least 1999.

The geology of the deposit has been described by Mustard (1983, 1986), Wilson & others (1986), Baker (1987, 1988), and Baker & Tullemans (1990). The Kidston breccia is situated near the contact of the Silurian-Devonian Oak River Granodiorite and Proterozoic Einasleigh Metamorphics. It is spatially and temporally related to Carboniferous rhyolite and porphyritic microgranite dykes and plugs on the eastern edge of a dyke swarm which extends from the Lochaber Ring Complex to the Newcastle Range volcano-tectonic subsidence area, and which is associated with a gravity low. A further control may be the intersection of major lineaments such as the Gilberton and Noel Faults with the dyke swarm and contact.

The breccia pipe is trapezoid in plan, approximately 1100m by 900m, with the long axis orientated northeasterly. The margins are sharp and generally dip steeply inwards. Marginal zones of breccia containing predominantly metamorphic or granodiorite clasts (depending on the adjacent wallrocks) grade into a core of polymictic breccia containing some fragments of rhyolite. Clasts range from a few millimetres to more than 200m. The matrix of small clasts and mineral fragments is less than 20% of the breccia by volume. Collapse is considered to be the most likely mechanism (Baker & Tullemans, 1990). Wises Hill in the southwest of the pipe (now removed by mining) was formed by a small pre-breccia rhyolite plug. Both pre- and post-breccia dykes are present.

Hydrothermal alteration is pervasive. Open spaces in the breccia are filled by hydrothermal minerals, and small clasts and the matrix are completely altered. Sericite and carbonate are the main alteration minerals, but are accompanied by tourmaline, orthoclase, and quartz in the breccia matrix. Most of the gold is post-breccia in a semi-continuous band in the outer portion of the breccia pipe, and the bulk of it is in the matrix as late-stage cavity infills. A lesser amount is in marginal sheeted quartz veins. Gold is mostly present as discrete grains from 20 to 100 microns in diameter and the remainder is in pyrite and arsenopyrite as small inclusions or in solid solution. About 80% is recovered in the cyanide leach carbon-in-pulp milling process. Sulphides in decreasing order of abundance are pyrite, pyrrhotite, sphalerite, chalcopyrite, molybdenite, galena, bismuthinite, and a bismuth telluride. The sulphides were oxidised to an average depth of 25m. About 25% of the silver is in the gold, but the rest may be associated with the galena. Isotopic dating of quartz-sericite alteration at Kidston by Rb-Sr total-rock analysis gave an age of 321 ±15Ma (Bain & others, 1984), which corresponds well with the age of the Newcastle Range Volcanic Group and related intrusives.

About 24km northwest of Kidston at **Mount Borium** (**Borans Whisper and Lucky Trail**), gold was discovered in 1909, but mostly worked in 1934-35 when 0.78kg bullion was produced from about 13t of ore. A further 5t was smelted for 0.43kg of gold and 0.28kg silver. The lodes consist of a narrow vein at the footwall contact of a rhyolite dyke and a zone of altered granodiorite up to 2m thick impregnated with pyrite and sphalerite (Reid, 1934; Corbett, 1982b). Some breccia is present in the area, but is not mineralised.

Minor alluvial gold workings occur 12km west of Kidston at **Mount Joyce** adjacent to a large porphyry dyke (Corbett, 1982a).

Another small alluvial gold occurrence was discovered in 1909, about 10km north of Einasleigh at **Mount Adler**, adjacent to a ring dyke of Caterpillar Range Microgranite. It was described briefly by Marks (1911). The source of gold was not found.

Minor gold mineralisation was located along the **Lynd Mylonite Zone** about 13km west of The Oasis by Keela-Wee Exploration NL (Peden, 1988). Initial drilling intersected pyrite and included 8m of 6.6g/t Au, but further drilling found no other worthwhile intersections.

The **Balcooma goldfield**, about 10km east-northeast of The Oasis, was discovered in about 1895, but nothing is recorded about it apart from Warden’s reports in the Annual Reports of the Department of Mines from 1895 to 1898. Recorded production was 591t crushed for a yield of 27.71kg gold. Several narrow reefs (about 12cm wide) were worked in metadolerite and metasediments of the Balcooma Metavolcanics, and alluvial gold was reported from most of the creeks and gullies draining the metadolerite in a belt about 10km long.

At the **Iron Knob** prospect, southeast of Wyandotte homestead in the Lugano Metamorphics, gossanous pyritic mica schist, mildly anomalous in gold and zinc, was investigated by Noranda Australia Ltd (Konopa, 1988a), but extensive gridding, soil geochemistry, geophysics, and drilling failed to locate any significant mineralisation.

Trenching and drilling at the **Lucky Dip** prospect by Noranda Australia Ltd (Konopa, 1988b) located only very low-grade values (8m at 0.14g/t). The prospect is at the northern end of the Lucky Creek goldfield, which was worked from 1903 to 1912. Most of the reefs are in the adjoining Clarke River Sheet area.

In the Camel Creek area, the **Blue Ant, Blue Gold, Cockatoo**, and **Sandy Gold** prospects are part of the newly discovered 'Amanda Bel goldfield', of which the Golden Ant deposit being worked by the Camel Creek gold mine in the adjoining Ingham Sheet area is the most significant deposit (Teale & others, 1989). The deposits occur as veins in shear zones, possibly melanges, in the Kangaroo Hills Formation. The deposits are considered to have a range of ages from syn-D_1 to syn-D_3, and were still being evaluated at the time of writing.

NICKEL-COBALT

The nickeliferous laterites of the **Greenvale** area were first investigated by the BMR in 1957 (White & others, 1961; White, 1965). This work was followed up by Metals Exploration NL and Freeport Minerals Co., who established reserves of 40Mt of ore averaging 1.57% Ni and 0.2% Co. Mining commenced in 1974 and ceased in 1992. Total production was 428 762t of nickel and 35 776t of cobalt. Wallis (1994) summarised the mining.

The main orebody was developed on the Sandalwood Serpentinite in the Boiler Gully Complex, and has been described by Fletcher & Couper (1975) and Burger (1979, 1982, 1987). The deposit formed by oxidation and leaching of serpentinite and the redistribution and concentration of its metal content (originally about 0.3% Ni and 0.01% Co) by migrating acidic groundwater under sufficiently balanced rates of weathering and erosion.

The orebody was crudely stratified consisting of weathered serpentinite (saprolite) overlain by limonitic laterite. Overburden comprised pisolitic laterite and soil. The saprolite itself contained a lower sub-ore grade zone 5 to 10m thick containing 0.4 to 0.6% Ni and 0.02% Co. In the upper zone, nickel reached its maximum concentration, but was highly variable with basement fracturing being the principal control because of its influence on groundwater permeability.

The base-of-ore was very irregular and the zone was typically 5 to 10m thick. Grades of 3% Ni were common and reached 10 to 15% Ni locally. Cobalt grades remained low. The maximum cobalt grades were in the limonite zone, which was 5 to 10m thick; they averaged about 0.25%, but were locally up to 0.5%. Nickel grades averaged 1.2 to 1.4%. In addition to these ore types, massive siliceous ore (1.2-1.3% Ni and 0.05-0.08% Co) formed irregular lenses and bands up to 30m across in the saprolite and limonite zones. Boxwork siliceous ore (up to 6% Ni and 0.15-0.2% Co) was associated with zones of intense fracturing up to 5m wide.

At **Minnamoolka**, AO (Australia) Pty Ltd established the existence of four subeconomic lateritic nickel deposits containing a total of 26Mt averaging 0.73% Ni and 3.15Mt averaging 1.27% Ni (Zeissink, 1977). The deposits range from 1.5 to 25m in thickness, and generally contain 0.01 to 0.07% Co, although one deposit contains 0.5%.

Weathered serpentinite near the Two Pinnacles, about 14km east of Wyandotte homestead, was tested by costeaning, possibly in the early 1960s, but no details are available. Another serpentinite body intruding the Wairuna Formation, about 15km north-northeast of Valley of Lagoons homestead has a well-developed laterite cap in places. Shallow auger drilling by Onslow Mining Pty Ltd (Hartley, 1972) gave poor results, but the main cap was not tested.

TIN

Alluvial tin has been worked extensively in streams draining the Carboniferous Elizabeth Creek Granite in the northwest part of the sheet area. Other areas occur northwest of Camel Creek homestead in the headwaters of Redbank and Perry Creeks, in and around small stocks of Carboniferous biotite granite. No production figures are available, but the most intensive period of production was in the 1970s and early 1980s.

Ugly Corner, a Tertiary deep lead deposit partly capped by basalt and silcrete and containing cassiterite and minor gold, was first described by Denmead (1947a). It was investigated by Metals Exploration Ltd (Thompson, 1980) who found that mineralisation is low-grade and restricted to narrow gutters.

No significant lode tin deposits are known in the sheet area, although the alluvial tin in the Elizabeth Creek and Camel Creek areas was presumably shed from numerous small lode or vein deposits in and adjacent to the Carboniferous granites. Morton (1944b) described small prospects in the Carboniferous Whitewater Granite east of Mount Surprise. Greisens in the Einasleigh Metamorphics at **Kellys Grid**, west of Mount Surprise, were investigated by CSR Ltd (Scott & Johnston, 1985) and found to contain only minor tin and tungsten.

TUNGSTEN

At **Damper Hill**, 16km east-southeast of Mount Surprise, minor tungsten mineralisation is associated with a siliceous greisen in the apical portion of a Carboniferous multiphase porphyritic granite stock (Hammond, 1984). Sheeted quartz-topaz-wolframite veinlets also occur in the country rocks of Einasleigh Metamorphics.

Two tungsten deposits in the Camel Creek area were described by Morton (1944a), Levingston (1952), and Brunker (1970). The **Perry Creek** scheelite deposit is hosted by a small pluton of biotite granite, about 18km northwest of Camel Creek homestead. The scheelite occurs in narrow quartz veins in a fissure or shear zone about 1-2m wide trending east-southeast for 1.2km. It was worked in 1944 and again in about 1970. Only about 8t of concentrate were produced altogether. The deposit was drilled by Great Northern Mining in 1981, but the results are still confidential. About 7km south-southwest, minor wolfram mineralisation occurs at **Wolfram Hill** in gently dipping quartz veins up to 0.5m wide in hornfelsed Kangaroo Hills Formation. About 20t of hand-picked concentrates were produced between 1937 and 1947.

URANIUM

The **Oasis** uranium prospect is 13km northwest of The Oasis and was investigated in detail by Esso Exploration and Production Australia Inc. (Tucker, 1979). Primary uraninite occurs in quartz-chloraite-biotite schist of the Einasleigh Metamorphics in a roof pendant in the Proterozoic Mywyn GRanite. Significant grades (average of 0.13% U_3O_8 over a width of 2.9m) occur over a strike length of 200m and to a depth of 100m. The Mywyn Granite has a high radiometric background, and the uranium was probably mobilised from the granite.

WATER

Water of good quality can be obtained from the major streams. many of these contain running water for most of the year, because they are fed from sandy unconsolidated material beneath Cainozoic basalts. Swamps and lakes are common around the edges of the McBride basalt Province. Reasonable supplies of good stock water are usually obtained from shallow bores in the thick alluvial deposits along streams and beneath the Cainozoic basalts. Such supplies are supplemented by earth dams on most properties.

Table 1. Stratigraphy of the Einasleigh 1:250 000 Sheet

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
QUATERNARY					
Qha	clay, silt, sand, gravel		Quaternary (Holocene)	active stream channel alluvium and low terraces	
Qa	clay, silt, sand, gravel		Quaternary	flood plain alluvium	
Ql	clay, silt		Quaternary	lacustrine deposits	
Qlc	sand		Quaternary	lacustrine beach ridges	
Qpa	clay, silt, sand, gravel		Quaternary (Pleistocene)	flood plain alluvium on high terraces	
Chudleigh Basalt Group Qb	olivine basalt		Pleistocene (0.26Ma for the basalt along the Einasleigh River)		
Kinrara Basalt Qmk	olivine basalt	part of McBride Basalt Group	Pleistocene (<40 000 years - Griffin & McDougall, 1975)		Griffin, 1977; Griffin & McDougall, 1975
Murronga Basalt Qmm	olivine basalt	part of McBride Basalt Group	Pleistocene (0.15Ma - Griffin & McDougall, 1975)		Griffin, 1977; Griffin & McDougall, 1975
Undara Basalt Qmu	olivine basalt	part of McBride Basalt Group	Pleistocene (0.19Ma - Griffin & McDougall, 1975)		Griffin, 1977; Griffin & McDougall, 1975
Boomerang Basalt Qmo	olivine basalt	part of McBride Basalt Group	Pleistocene (0.23Ma - Griffin & McDougall, 1975)		Griffin, 1977; Griffin & McDougall, 1975
Mount Razorback Basalt Qmr	olivine basalt	part of McBride Basalt Group	Pleistocene (<0.27Ma - Griffin & McDougall, 1975)		Griffin, 1977; Griffin & McDougall, 1975
Racecourse Knob Basalt Qmc	olivine basalt	part of McBride Basalt Group	Pleistocene (>0.20Ma - Griffin & McDougall, 1975)	large shield volcano; most of lava older than that dated	Griffin, 1977; Griffin & McDougall, 1975
Mount Joy Basalt Qmj	olivine basalt	part of McBride Basalt Group	Pleistocene (<0.4Ma - Griffin & McDougall, 1975)	not dated directly	Griffin, 1977; Griffin & McDougall, 1975
Silent Hill Basalt Qms	olivine basalt	part of McBride Basalt Group	Pleistocene (0.37Ma - Griffin & McDougall, 1975)		Griffin, 1977; Griffin & McDougall, 1975
Middle Mountain Basalt Qmd	olivine basalt	part of McBride Basalt Group	Pleistocene (0.89Ma - Griffin & McDougall, 1975)		Griffin, 1977; Griffin & McDougall, 1975
Qmp	olivine basalt	part of McBride Basalt Group	Pleistocene?	lava from The Depression crater	Griffin, 1977

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
TERTIARY-QUATERNARY					
TQm	olivine basalt	undivided McBride Basalt Group	Pliocene to Pleistocene (0.5 to 2.7Ma - Griffin & McDougall, 1975)		Griffin, 1977; Stephenson & others, 1980; Stephenson *in* Johnson, 1989, pages 93-96
TQl	claystone, diatomite (indicated by superscript `d') and minor sandstone		Tertiary (Pliocene?)	lacustrine deposits related to damming by basalts	
TQr	clay, silt, sand, gravel (superscript `c' indicates clay)		Late Tertiary to Quaternary	lacustrine deposits related to damming by basalts	
TQd	nodular ferricrete and associated weathering profile		Late Tertiary to Quaternary		
TQa	sandy clay and silt, minor pebbles and cobbles		Late Tertiary		
TERTIARY					
Ta	clayey quartzose sandstone and conglomerate, sandy mudstone, and claystone; minor diatomite	unconformably overlies Kangaroo Hills Formation; possibly overlies Ts. Overlain by Quaternary basalt.	Late Tertiary		
Tb	olivine basalt, minor nephelinite		mainly late Miocene; some late Oligocene to early Miocene in Lake Lucy area		Stephenson *in* Johnson, 1989, pages 93-96
Td	duricrust including ferricrete and silcrete (superscripts `f' and `q' resp.); mainly derived from residual soil, colluvium, and some bedrock				
Ts	clayey quartzose sandstone, sandy claystone, laminated siltstone and minor conglomerate		Tertiary	generally affected by deep weathering	

Table 1 (continued)

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
PERMIAN?					
Pr	rhyolitic breccia, crystal-poor to crystal-rich rhyolitic ignimbrite, and porphyritic rhyolite and dacite	possibly overlies Herbert River Granite and CPg_5	Permian?		
CARBONIFEROUS					
Glen Gordon Volcanics Cl	dark grey andesitic lava, crystal-poor to crystal-rich dacitic ignimbrite	intruded by Carboniferous or Permian granite	Carboniferous	more extensive in the Atherton Sheet area	Branch, 1966; Bultitude & others, 1985
Bally Knob Volcanics	see below	unconformably overlies and faulted against early Palaeozoic Balcooma Metavolcanics, Eland Meta- volcanics and Silurian Dido Tonalite; intruded by unnamed microgranite and gabbro or diorite, unconformably overlain by Tertiary sediments and McBride Basalt Group	Carboniferous		Withnall, 1989
Cbr_2	pink to brown, sparsely porphyritic, flow-banded rhyolite	unnamed member of Bally Knob Volcanics; overlies all other subunits and probably overlies unnamed microgranite			
Cbd_2	green aphyric dacite	unnamed member of Bally Knob Volcanics; overlies Cbr_1 and overlain by Cbr_2; intruded by unnamed diorite or gabbro			
Cbr_1	pink to brown, crystal-poor rhyolitic ignimbrite	unnamed member of Bally Knob Volcanics; unconformably overlies or faulted against early Palaeozoic Balcooma Metavolcanics and Silurian Dido Tonalite; faulted against Cbd_1 and overlain by Cbd_2 and Cbr_2; unconformably overlain by Tertiary basalt			

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Cbd_1	purple crystal-rich dacitic tuff?	unnamed member of Bally Knob Volcanics; faulted against Silurian Dido Tonalite and Cbr_1; overlain by Cbd_2 and Cbr_2; unconformably overlain by Tertiary sediments and McBride Basalt Group			
Newcastle Range Volcanic Group	see constituent units below	disconformably(?) overlies Late Devonian to Early Carboniferous Gilberton Formation; intruded by Carboniferous Elizabeth Creek Granite and Mount Departure and Caterpillar Microgranite	Carboniferous (327 4Ma - Oversby & Mackenzie, in preparation)	previously Newcastle Range Volcanics (White, 1962a, 1965; Branch, 1966); in this area contains Eveleigh and Nammarong Volcanic Subgroups and their constituent units	Branch, 1966; Oversby & Mackenzie, in preparation
Nammarong Volcanic Subgroup	see Cumbana Rhyolite	part of Newcastle Range Volcanic Group; intruded by Carboniferous Elizabeth Creek Granite and Mount Departure Microgranite	Carboniferous	in this sheet area contains Cumbana Rhyolite	Oversby & Mackenzie, in preparation
Cumbana Rhyolite Cc	grey to brown or purple, moderately crystal-rich to crystal-rich rhyolitic ignimbrite with locally abundant lithic clasts; minor aphyric andesite and crystal-rich volcanic lutite to volcanic rudite (tuff?)	part of Nammarong Volcanic Subgroup of Newcastle Range Volcanic Subgroup; intruded by Carboniferous Elizabeth Creek Granite and Mount Departure Microgranite	Carboniferous	previously Cumbana Rhyolite Porphyry (Branch, 1966)	Oversby & Mackenzie, in preparation
Eveleigh Volcanic Subgroup	see constituent units below	disconformably(?) overlies Late Devonian to Early Carboniferous Gilberton Formation; intruded by Caterpillar Microgranite	Carboniferous	in this sheet area contains Yellow Jacket, Beril Peak, Mosaic Gully, and Shrimp Creek Rhyolites	Oversby & Mackenzie, in preparation
Shrimp Creek Rhyolite Cs	grey to brown, crystal-rich rhyolitic ignimbrite with variable amounts of hornblende and biotite; locally lithic rich	part of Eveleigh Volcanic Subgroup of Newcastle Volcanic Group; overlies the Mosaic Gully Rhyolite	Carboniferous		Oversby & Mackenzie, in preparation
Mosaic Gully Rhyolite Co	brown crystal-poor to crystal-rich rhyolitic ignimbrite, locally containing sparse chlorite	part of Eveleigh Volcanic Subgroup of Newcastle Volcanic Group; overlies Beril Peak Rhyolite and overlain by Shrimp Creek Rhyolite; intruded by Caterpillar Microgranite	Carboniferous		Oversby & Mackenzie, in preparation
Beril Peak Rhyolite Cr	grey to brown crystal-free rhyolitic ignimbrite	part of Eveleigh Volcanic Subgroup of Newcastle Volcanic Group; overlies Yellow Jacket Rhyolite and overlain by Mosaic Gully Rhyolite; intruded by Caterpillar Microgranite	Carboniferous		Oversby & Mackenzie, in preparation

Table 1 (continued)

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Yellow Jacket Rhyolite Cy	grey, brown and purple, crystal-poor to crystal-rich rhyolitic ignimbrite with locally abundant lithic clasts; minor greyish green sparsely porphyritic hornblende-pyroxene andesite and basaltic andesite; rhyolitic volcanic lutite, arenite and rudite	part of Eveleigh Volcanic Subgroup of Newcastle Volcanic Group; overlies Late Devonian to Early Carboniferous Gilberton Formation and overlain by Beril Peak Rhyolite; intruded by Caterpillar Microgranite	Carboniferous		Oversby & Mackenzie, in preparation
Butlers Volcanic Group	see constituent units below	unconformably overlies Proterozoic Einasleigh Metamorphics and Siluro-Devonian Oak River Granodiorite; intruded by Carboniferous Sues Creek Microgranite and Noel Micromonzonite	Carboniferous	previously Butlers Volcanics (White, 1962a,b, 1965; Branch, 1966); in this sheet area, contains Edmonds Creek Rhyolite and McLennons Creek Rhyolite	Branch, 1966; Oversby & Mackenzie, in preparation
McLennons Creek Rhyolite Cm	grey to pink, crystal-rich rhyolitic ignimbrite and brown crystal-poor to moderately crystal-rich rhyolitic ignimbrite	part of Butlers Volcanic Group; unconformably overlies Proterozoic Einasleigh Metamorphics and Silurian-Devonian Oak River Granodiorite; overlies Edmonds Creek Rhyolite; intruded by Carboniferous Sues Creek Microgranite and Noel Micromonzonite	Carboniferous		Oversby & Mackenzie, in preparation
Edmonds Creek Rhyolite Ce	brown to purple, sparsely porphyritic rhyolitic lava	part of Butlers Volcanic Group; unconformably overlies Proterozoic Einasleigh Metamorphics; overlies Ballynure Rhyolite (in Clarke River Sheet area) and overlain by McLennons Creek Rhyolite	Carboniferous		Oversby & Mackenzie, in preparation
LATE DEVONIAN TO CARBONIFEROUS					
Gilberton Formation DCn	micaceous feldspathic sandstone, polymictic conglomerate, and mudstone	unconformably overlies Proterozoic leucogranite (Pg_1) and Silurian-Devonian Puppy Camp Granodiorite; disconformably(?) overlain by Carboniferous Yellow Jacket Rhyolite	Late Devonian or Early Carboniferous	basement-derived, fluviatile	Oversby & Mackenzie, in preparation

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
DC	quartzose to feldspathic and locally volcaniclastic sandstone and mudstone, including redbeds	unconformably overlies Proterozoic Einasleigh and Halls Reward Metamorphics and Ordovician Wairuna Formation	Late Devonian to Early Carboniferous	fluviatile; at least partly equivalent to Late Devonian Bulgeri Formation in Bundock Basin and/or Early Carboniferous Venetia Formation in Clarke River Basin (Withnall, Lang & others, 1988; Withnall & Lang, 1993)	Withnall, 1989
EARLY DEVONIAN					
Conjuboy Formation Dc	quartzose to feldspathic sandstone, mudstone, and coralline limestone	unconformably overlies and faulted against Proterozoic Einasleigh Metamorphics and early Palaeozoic Balcooma Metavolcanics	Early Devonian (Emsian); corals and conodonts		Withnall, 1989
Blue Rock Creek beds Db	micaceous feldspathic sandstone and pebble to cobble conglomerate, siltstone, shale, and limestone	faulted against and unconformably overlies Proterozoic Halls Reward Metamorphics	Early Devonian; corals		Arnold & Henderson, 1976; Withnall & Lang, 1993
SILURIAN TO EARLY DEVONIAN					
Kangaroo Hills Formation	see below	faulted (thrust?) against Ordovician Pelican Range Formation and Silurian Perry Creek Formation; intruded by unnamed Carboniferous granite plutons and Princess Hills Granite; unconformably overlain by Tertiary sediments and basalt	?Silurian to Early Devonian; Lochkovian conodonts in allochthonous limestone in SDk_2	turbidites; generally cleaved; local melange zones, eg. Lincoln Springs Shear Zone	White, 1962a, 1965; Withnall, Lang & others, 1988; Withnall & Lang, 1993
SDk_2	feldspathic to lithofeldspathic arenite and mudstone; local polymictic conglomerate with limestone clasts; minor allochthonous limestone blocks	unnamed member of Kangaroo Hills Formation. Overlies SDk_1	Early Devonian	generally more proximal facies?	
SDk_q	quartzose to subfeldspathic arenite and mudstone	unnamed member of Kangaroo Hills Formation in unit SDk_2			
SDk_1	mudstone and feldspathic to lithofeldspathic arenite	unnamed member of Kangaroo Hills Formation; overlain by SDk_2	Late Silurian to Early Devonian?	generally more distal facies?	

Table 1 (continued)

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Perry Creek Formation Sp	quartzose to lithofeldspathic sublabile to labile arenite, mudstone, and minor chert; local melange	faulted (thrust?) against Ordovician Pelican Range Formation and Late Silurian or Early Devonian Kangaroo Hills Formation; may be overlain by latter	Silurian; corals and conodonts in allochthonous limestone in Clarke River Sheet area	turbidites; commonly strongly cleaved	White, 1962a, 1965; Withnall, Lang & others, 1988; Withnall & Lang, 1993
Sp_v	altered aphyric tholeiitic basalt; minor chert	unnamed member of Perry Creek Formation		locally pillowed	
ORDOVICIAN TO SILURIAN?					
Greenvale Formation OSn	lithofeldspathic arenite, mudstone, and minor polymictic conglomerate; local melange	probably faulted (thrust?) against Ordovician Wairuna and Pelican Range Formations	unfossiliferous but probably Late Ordovician or Early Silurian	turbidites; generally cleaved; local melange	White, 1962a, 1965; Withnall, Lang & others, 1988; Withnall & Lang, 1993
Pelican Range Formation OSp	quartzose arenite and mudstone; local melange	probably faulted (thrust?) against Ordovician to Silurian Wairuna, Greenvale, and Perry Creek Formations	unfossiliferous but probably Ordovician because of similarities to Judea Formation	turbidites; strongly tectonised with abundant melange; strongly cleaved	White, 1962a, 1965; Withnall, Lang & others, 1988; Withnall & Lang, 1993
OSp_v	altered aphyric tholeiitic basalt; minor chert and jasper	unnamed member of Pelican Range Formation		locally pillowed	
ORDOVICIAN					
Wairuna Formation Ow	mudstone, siltstone, quartzose arenite, chert and jasper; local melange	faulted against Proterozoic Halls Reward Metamorphics along Burdekin Fault; probably faulted against ?Ordovician Greenvale and Pelican Range Formations; intruded by tectonically emplaced serpentinite, and by Carboniferous Princess Hills granite	Ordovician (probably Early) because of similarities to Judea Formation	strongly tectonised, abundant melange locally; strongly cleaved	White, 1962a, 1965; Withnall, Lang & others, 1988; Withnall & Lang, 1993
Ow_j	jasper and chert	unnamed members in Wairuna Formation		generally as lenses too small to map	
Ow_v	altered aphyric tholeiitic basalt and minor chert and jasper	unnamed members in Wairuna Formation		locally pillowed	
Judea Formation Oj	fine-grained quartzose arenite and mudstone, local melange	faulted against Halls Reward Metamorphics along Halls Reward Fault and Wairuna Formation along Gray Creek Fault	Early Ordovician	more extensive in Clarke River Sheet area	Arnold & Henderson, 1976; Withnall, Lang & others, 1988; Withnall & Lang, 1993

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Carriers Well Formation Oc	feldspatholithic (volcanic) arenite and mudstone	faulted against Gray Creek Complex along Gray Creek Fault	Late Ordovician	very small area near Greenvale township; more extensive in Clarke River Sheet area	White, 1962a, 1965; Withnall, Lang & others, 1988; Withnall & Lang, 1993
LATE CAMBRIAN TO ORDOVICIAN					
Lucky Creek Metamorphic Group	see constituent units below	faulted against Proterozoic Halls Reward Metamorphics along Nickel Mine Fault; intruded by early Palaeozoic Cockie Spring Tonalite and Silurian Dido Tonalite; unconformably overlain by Carboniferous Bally Knob Volcanics and Cainozoic McBride Basalt Group	early Palaeozoic (Ordovician?)	previously Lucky Creek Formation (White, 1962a,b, 1965); contains Lugano Metamorphics, Eland Metavolcanics, and Paddys Creek Phyllite	White, 1962a,b, 1965; Withnall, 1989
Paddys Creek Phyllite Op	phyllite and quartzite, locally mylonitic	part of Lucky Creek Metamorphic Group; faulted against Proterozoic Halls Reward Metamorphics along Nickel Mine Fault; may interfinger with and overlie Eland Metavolcanics (or could be a thrust contact)	early Palaeozoic (Ordovician?)	strongly deformed with pervasive mylonitic foliation; lower greenschist facies metamorphism	White, 1962a, 1965; Withnall, 1989
Eland Metavolcanics Oa	chlorite and actinolite schist (andesitic to dacitic metavolcanics) with common relict plagioclase phenocrysts and metavolcanic clasts; local marble, volcaniclastic meta-arenite, phyllite, and metachert; commonly mylonitic	part of Lucky Creek Metamorphic Group; relationship to Lugano Metamorphics uncertain (may be thrust); may interfinger with and underlie Paddys Creek Phyllite (or could also be thrust contact); faulted against Proterozoic Halls Reward Metamorphics	probably early Palaeozoic (Ordovician?)	strongly deformed with pervasive mylonitic foliation; greenschist facies metamorphism	Withnall, 1989
Lugano Metamorphics Ols	biotite gneiss, mica schist, quartzite, leucogneiss, laminated amphibolite (para-amphibolite?) and minor marble	part of Lucky Creek Metamorphic Group; relationships with Eland Metavolcanics uncertain (may be thrust); intruded by early Palaeozoic Cockie Spring Tonalite and Silurian Dido Tonalite	tentatively early Palaeozoic (possibly Proterozoic)	multiply deformed; greenschist to lower amphibolite facies metamorphism	Withnall, 1989
Ol_q	quartzite containing kyanite and pyrophyllite	unnamed member		possibly zone of intense argillic alteration prior to metamorphism	Withnall, 1989
Ol_a	amphibolite; local pillow lavas	unnamed member			Withnall, 1989

Table 1 (continued)

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Balcooma Metavolcanics	see below	faulted against Einasleigh Metamorphics along Balcooma Mylonite Zone; intruded by Cambro-Ordovician Ringwood Park Microgranite and Silurian Dido Tonalite; unconformably overlain by Carboniferous Bally Knob Volcanics and Cainozoic McBride Basalt Group	Late Cambrian or Ordovician (U-Pb zircon dating - Withnall & others, 1991)	divided into 5 main subunits; multiply deformed; lower to middle amphibolite facies metamorphism	Withnall, 1989; Withnall & others, 1991
ꞒOb$_t$	laminated to thickly bedded siliceous metatuff?	unnamed member			
ꞒOb$_s$	mica schist and quartzite grading into gneiss; minor metarhyolite and metatuff or meta-arenite	unnamed members; 4 main intervals			
ꞒOb$_d$	strongly foliated, dark grey metarhyolite (possibly ignimbrite) containing sparse plagioclase phenocrysts	unnamed member			
ꞒOb$_a$	meta-andesitic volcaniclastics and lava	unnamed member			
ꞒOb$_r$	pink, grey or cream, variably schistose and porphyritic rhyolitic metavolcanics (mainly clastics); local volcanic breccia; grade into muscovite schist	two main unnamed members and some smaller lenses			
PROTEROZOIC					
undivided Etheridge Group P̲t	mica schist and quartzite	intruded by Carboniferous Mullindie Granite; unconformably overlain by Cainozoic basalt	early Proterozoic	lower amphibolite facies; small inlier NE of Mt Surprise	

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Einasleigh Metamorphics	see below	faulted against Cambro-Ordovician Balcooma Metavolcanics along Balcooma Mylonite Zone; intruded by Proterozoic, Siluro-Devonian and Carboniferous granitoids; unconformably overlain by Carboniferous volcanics and Cainozoic basalts	early Proterozoic; older than 1570Ma (Black & others, 1979)	divided into 4 unnamed members; includes areas of unmapped amphibolite (Cobbold Metadolerite) and small granitoid bodies; multiply deformed; mainly upper amphibolite facies, locally lower amphibolite; granulite facies between Einasleigh and Mt Surprise	White (1962a, 1965); Warnick (1989); Withnall (1989)
Pe3	biotite gneiss, mica schist, and quartzite, grading locally into migmatite and granite gneiss; local laminated amphibolite (para-amphibolite or metatuff?); local calc-silicate gneiss	lithofacies of Einasleigh Metamorphics			
Pem	white dolomitic marble containing tremolite	lenses in Pe3		restricted to a small area NW of The Oasis	Withnall, 1989
Pe2	leucocratic quartzofeldspathic granofels and gneiss	lithofacies of Einasleigh Metamorphics		generally too small to map; small units near Daintree Cu mine	
Pe1	calc-silicate (mainly hornblende-diopside) gneiss; subordinate biotite gneiss and schist	lithofacies of Einasleigh Metamorphics			
Halls Reward Metamorphics Ph	mica schist, biotite gneiss, and pegmatite; locally mylonitised	faulted against Ordovician Judea and Wairuna Formations along Burdekin and Halls Reward Faults respectively, and early Palaeozoic Paddys Creek Phyllite along Nickel Mine Fault; intruded by Proterozoic Boiler Gully Complex and Silurian Dido Tonalite	Proterozoic	multiply deformed; amphibolite facies metamorphism	White (1962a, 1965); Arnold & Rubenach (1976); Withnall (1989)

Table 2. Intrusive Units of the Einasleigh 1:250 000 Sheet area

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
CARBONIFEROUS TO PERMIAN					
CPr	unassigned intrusive rhyolite and dacite	intrudes a wide variety of rocks from Proterozoic to Carboniferous age	Carboniferous to Permian	also dykes labelled \`rh' on map	
CPmg	unassigned pink to grey, commonly porphyritic microgranite to microgranodiorite	intrudes a wide variety of units from Proterozoic to Carboniferous age	Carboniferous to Permian	also dykes labelled \`mg' on map	
CPa	unassigned microdiorite, dolerite, gabbro, and intrusive andesite	intrudes Proterozoic Einasleigh Metamorphics and Carboniferous Bally Knob Volcanics	Carboniferous to Permian	also dyke swarms labelled \`dl' intruding Proterozoic Einasleigh Metamorphics and Silurian-Devonian Mount Webster Granodiorite	
CPg	unassigned granitoid; mainly fine to medium -grained, equigranular to porphyritic biotite granite; commonly altered and deeply weathered	intrudes Proterozoic Einasleigh and Halls Reward Metamorphics and unassigned Etheridge Group; overlain by Cainozoic sediments and basalt	Carboniferous to Permian	parts of the Herbert River and Tate Batholiths	
Tiger Hill Microgranite CPgt	pink to grey biotite microgranite with coarse-grained segregations	possibly intrudes CPg_1	Carboniferous to Permian	part of the Herbert River Batholith	White, 1959a, 1962a; Branch, 1966
Herbert River Granite CPgh	pink to grey, porphyritic hornblende(?)-biotite granite; equigranular near margins	in contact with Princess Hills and Minnamoolka Granites and CPg_5 but exact relationships unknown; overlain by Tertiary basalt	Carboniferous to Permian	part of the Herbert River Batholith; previously applied to whole batholith and similar grey granitoids elsewhere in adjoining sheet areas, but now restricted to pluton in the original type area	White, 1959a, 1962a; Branch, 1966; Withnall & others, 1985
Princess Hills Granite CPgp	pink to cream, medium to coarse-grained biotite granite	intrudes Proterozoic Halls Reward Metamorphics, Ordovician Wairuna Formation, and Silurian-Devonian Kangaroo Hills Formation; in contact with Herbert River Granite but exact relationship unknown; overlain by Cainozoic sediments	Carboniferous to Permian	part of the Herbert River Batholith	

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Minnamoolka Granite CPgm	pink to white, slightly porphyritic biotite granite	overlain by Tertiary sediments and McBride Basalt Group	Carboniferous to Permian	part of the Herbert River Batholith	
CPg_5	hornblende(?)-biotite granite to granodiorite	in contact with Princess Hills Granite but exact relationship unknown	Carboniferous to Permian	part of the Herbert River Batholith	
CPg_4	grey, fine to medium-grained hornblende-biotite granodiorite	in contact with CPg_2 but exact relationship unknown; intrudes Proterozoic Einasleigh Metamorphics	Carboniferous to Permian	part of the Herbert River Batholith	
CPg_3	dark grey to white, fine to medium-grained biotite-hornblende granodiorite commonly containing hornblende phenocrysts	probably intrudes Herbert River Granite and Princess Hills Granite	Carboniferous to Permian	part of the Herbert River Batholith	
CPg_2	pink to white, porphyritic biotite granite	intrudes Proterozoic Einasleigh Metamorphics; overlain by Cainozoic sediments	Carboniferous to Permian	part of the Herbert River Batholith	
CPg_1	pink to red, fine to medium-grained biotite granite, locally containing blocks of fine granodiorite	in contact with Herbert River Granite, but exact relationship unknown; overlain by Cainozoic sediments	Carboniferous to Permian	part of the Herbert River Batholith	
CARBONIFEROUS					
Whitewater Creek Granite Cgw	grey and pink biotite granite with subsidiary porphyritic biotite microgranite	intrudes Proterozoic Einasleigh Metamorphics; unconformably overlain by Tertiary-Quaternary McBride Basalt Group	Carboniferous		
Mullindie Granite Cgm	white to pink, fine to medium-grained, slightly porphyritic biotite granite	intrudes Proterozoic unassigned Etheridge Group; unconformably overlain by Tertiary-Quaternary McBride Basalt Group	probably Carboniferous	extends into Atherton Sheet area where it is part of Tate Batholith	
Mount Departure Microgranite Cgd	grey to brown, abundantly porphyritic microgranite with sparse chlorite	intrudes Carboniferous Cumbana Rhyolite; overlain by Quaternary Undara Basalt	Carboniferous	forms a ring dyke around southern margin of Nammarong Cauldron Subsidence Structure	Oversby & Mackenzie, in preparation
Caterpillar Microgranite Cgc	grey to brown abundantly porphyritic microgranite containing sparse chlorite	intrudes Proterozoic Einasleigh Metamorphics and unassigned leucogranite, Silurian-Devonian Puppy Camp Granodiorite, and Carboniferous Eveleigh Volcanic Subgroup	Carboniferous	forms ring structures	Oversby & Mackenzie, in preparation

Table 2 (continued)

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Elizabeth Creek Granite Cgz	pink biotite granite with subsidiary microgranite	intrudes Proterozoic Einasleigh Metamorphics (in Georgetown Sheet area) and Carboniferous Newcastle Range Volcanic Group; intruded by unnamed rhyolite and microgranite and possibly by Bonnor Creek Granite; overlain by Quaternary Undara Basalt	Carboniferous; Rb-Sr biotite age of 318Ma (Black, unpublished data)	part of Cumbana Batholith; more extensive in Atherton, Georgetown, and Red River Sheet areas; previously applied to granites of similar petrographic character throughout region, but now restricted to Cumbana Batholith	Branch, 1966; Sheraton & Labonne, 1978; Oversby & Mackenzie, in preparation
Bonnor Creek Granite Cgb	pink to grey hornblende-biotite granite	possibly intrudes Carboniferous Elizabeth Creek Granite	Carboniferous	part of Cumbana Batholith; more extensive in Atherton Sheet area	
Noel Micromonzonite Cgn	grey hornblende-augite quartz-micromonzonite	intrudes Carboniferous McLennons Creek Rhyolite (Butlers Volcanic Group) and Sues Creek Microgranite	Carboniferous		Branch, 1966; Oversby & Mackenzie, in preparation
Lochaber Granite Cgl	pink, fine to medium-grained biotite granite	intrudes Proterozoic Einasleigh Metamorphics, and a complex of Carboniferous microgranite and rhyolite cone sheets	Carboniferous	part of Lochaber Ring Complex	Branch, 1966; Oversby & Mackenzie, in preparation
Sues Creek Microgranite Cgs	pink porphyritic hornblende-biotite and biotite microgranite	intrudes Proterozoic Einasleigh Metamorphics, Silurian-Devonian Oak River Granodiorite, and Carboniferous Butlers Volcanic Group	Carboniferous	forms part of the outer ring dyke of the Lochaber Ring Complex as well as flat-roofed plutons	Branch, 1966; Oversby & Mackenzie, in preparation
Cg	grey biotite granite and granodiorite	intrudes Ordovician to Early Devonian Greenvale and Kangaroo Hills Formations; overlain by Tertiary sediments of Lucy Tableland	Carboniferous; minimum K-Ar biotite age of 357Ma (Richards & others, 1966)	forms several small plutons in a NE-trending line in the Camel Creek area	Withnall, Lang & others, 1988; Withnall & Lang, 1993
SILURIAN TO EARLY DEVONIAN					
Puppy Camp Granodiorite SDgp	pale grey equigranular to slightly porphyritic muscovite-biotite and biotite granodiorite	intrudes Proterozoic Einasleigh Metamorphics; overlain by Carboniferous Newcastle Range Volcanic Group	Silurian or Early Devonian		Warnick & Withnall, 1985; Warnick, 1989
Mount Juliet Granite Sdgj	grey, medium to coarse-grained, biotite-muscovite granite and granodiorite	intrudes Proterozoic Einasleigh Metamorphics; possibly intrudes Mount Webster Granodiorite	Proterozoic or Silurian to Early Devonian	part of the Copperfield Batholith	Warnick & Withnall, 1989; Warnick, 1989

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Quinine Spring Granite SDgq	grey equigranular to porphyritic biotite-muscovite granite and granodiorite; local muscovite granite and pegmatite	intrudes Proterozoic Einasleigh Metamorphics; in contact with Oak River Granodiorite but relationship not known; overlain by Tertiary McBride Basalt Group	Silurian to Early Devonian	part of Copperfield Batholith	Warnick & Withnall, 1985; Warnick, 1989
Mount Webster Granodiorite SDgw	locally strongly foliated, pale grey to pinkish grey, muscovite-biotite granodiorite	intrudes Proterozoic Einasleigh Metamorphics	Proterozoic or Silurian to Early Devonian	part of the Copperfield Batholith	Warnick & Withnall, 1989; Warnick, 1989
Beverly Hills Granite SDgb	locally foliated, white and cream to pink, muscovite and biotite-muscovite leucogranite; commonly pegmatitic	intrudes Silurian-Devonian Oak River Granodiorite	Silurian to Early Devonian	part of Copperfield Batholith	Warnick & Withnall, 1985; Warnick, 1989
Eleven-B Granite SDge	foliated, pink to grey, equigranular to porphyritic biotite and biotite-muscovite granite	intrudes Proterozoic Einasleigh Metamorphics; possibly intrudes Oak River Granodiorite	probably Silurian to Early Devonian	part of the Copperfield Batholith	Warnick & Withnall, 1989; Warnick, 1989
SDgl	leucogranite with sparse biotite and muscovite; locally pegmatitic	intrudes Proterozoic Einasleigh Metamorphics and Silurian-Devonian Oak River Granodiorite	Silurian or Early Devonian	in southern part of Copperfield Batholith	
Oak River Granodiorite Sdgo	locally foliated, grey porphyritic biotite granodiorite and foliated grey hornblende-biotite tonalite	intrudes Proterozoic Einasleigh Metamorphics; intruded by Beverly Hills and unnamed leucogranite; in contact with Eleven-B and Quinine Spring Granites but relationship unknown	Silurian or Early Devonian; minimum age of 400Ma (Oversby & Mackenzie, in preparation)	major part of Copperfield Batholith; granodiorite mainly to west of Oak and Copperfield Rivers; areas of abundant metamorphic enclaves indicated by symbol $SDgo_m$	Bain & others, 1976; Warnick, 1989
McKinnons Creek Granite SDgm	foliated, cream biotite-muscovite granite	intrudes Proterozoic Einasleigh Metamorphics and Silurian Dido Tonalite (in Clarke River Sheet area)	Silurian or Early Devonian	crops out very poorly	White, 1962a,b, 1965; Withnall, 1989
Dido Tonalite Sgi	foliated, grey hornblende-biotite tonalite and quartz-diorite	intrudes Proterozoic Einasleigh and Halls Reward Metamorphics, and early Palaeozoic Balcooma Metavolcanics and Lugano Metamorphics; overlain by Carboniferous Bally Knob Volcanics and Cainozoic McBride Basalt Group	Early Silurian; 431^{+10}_{-20}Ma (U-Pb zircon dating - Black & McCulloch, 1990)		White, 1962a,b, 1965; Withnall, 1989

Table 2 (continued)

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
SDg	locally foliated, muscovite-biotite granite and granodiorite	intrudes Proterozoic Einasleigh Metamorphics; intruded by Carboniferous Elizabeth Creek Granite and unassigned microgranite; overlain by Quaternary Undara Basalt	probably Silurian to Early Devonian	large pluton NW of Mount Surprise and small circular pluton S of Puppy Camp Granodiorite; former previously referred to as Blackman Gap Complex (Warnick, 1989)	Warnick, 1989
?Sg	foliated, grey hornblende-biotite tonalite with abundant amphibolite xenoliths	intrudes Proterozoic Halls Reward Metamorphics	Silurian?	in Cashmere area similar to Dido Tonalite	
LATE CAMBRIAN TO ORDOVICIAN?					
Cockie Spring Tonalite Ogc	strongly foliated hornblende-biotite tonalite and tonalitic gneiss	intrudes Lugano Metamorphics	probably early Palaeozoic (Ordovician?)	deformed and metamorphosed with Lugano Metamorphics	Withnall, 1989
Ringwood Park Microgranite ЄOgr	foliated pink equigranular to porphyritic microgranite and biotite granite	intrudes Balcooma Metavolcanics; intruded by Silurian Dido Tonalite; unconformably overlain by Carboniferous Bally Knob Volcanics and Cainozoic McBride Basalt Group	Late Cambrian or Ordovician	metamorphosed and deformed with Balcooma Metavolcanics with which it is probably comagmatic	Withnall, 1989
PROTEROZOIC					
$\underline{P}g_2$	biotite and muscovite-biotite granite and granodiorite, commonly foliated	intrudes the Einasleigh Metamorphics	middle Proterozoic		
$\underline{P}g_1$	leucogranite and pegmatite, commonly foliated; contains muscovite or sparse biotite	intrudes the Einasleigh Metamorphics	middle Proterozoic	also abundant through metamorphics as small bodies too small to map	
Mywyn Granite $\underline{P}gm$	foliated grey porphyritic biotite granite	intrudes the Einasleigh Metamorphics	middle Proterozoic	high radiometric background	Warnick & Withnall, 1985; Warnick, 1989
$\underline{P}s$	serpentinite	intrudes the Halls Reward Metamorphics and Einasleigh Metamorphics	Proterozoic	equivalent to the Sandalwood Serpentinite; in Einasleigh Metamorphics, restricted to one small body NW of The Oasis	

Unit and map symbol	Rock type	Relationships	Age	Remarks	References
Pa	amphibolite and metagabbro	intrudes the Halls Reward Metamorphics	Proterozoic	equivalent to the Stenhouse Creek Amphibolite	
Boiler Gully Complex	see below	intrudes the Halls Reward Metamorphics	Proterozoic; Ar^{39}-Ar^{40} minimum ages (Black & others, 1979)	previously regarded as Devonian	Green, 1958; White, 1965; Arnold & Rubenach, 1976; Withnall, 1989
Sandalwood Serpentinite Pbs	serpentinite; minor clinopyroxenite and metagabbro	part of Boiler Gully Complex. Intrudes Halls Reward Metamorphics	Proterozoic	originally thought to be older than the Boiler Gully Complex (Green, 1958; White, 1965), but Withnall (1989) redefined it as a component of the complex	Green, 1958; White, 1965; Withnall, 1989
Stenhouse Creek Amphibolite Pbn	amphibolite, metagabbro, and minor clinopyroxenite	part of Boiler Gully Complex. Intrudes Halls Reward Metamorphics	Proterozoic	originally thought to be older than Boiler Gully Complex (Green, 1958; White, 1965), but Withnall (1989) redefined it as a component of the complex	Green, 1958; White, 1965; Arnold & Rubenach, 1976; Withnall, 1989
Gray Creek Complex Pys	serpentinite	faulted against the Wairuna and Judea Formations	Proterozoic; Ar^{39}-Ar^{40} minimum ages (Black & others, 1979)	more extensive in the Clarke River Sheet area where it also contains clinopyroxenite, metagabbro and amphibolite	Green, 1958; White, 1962b, 1965; Arnold & Rubenach, 1976; Withnall, Lang & others, 1988; Withnall & Lang, 1993
Cobbold Metadolerite Pc	orthoamphibolite, metagabbro; local mafic granulite	intrudes the Einasleigh Metamorphics	early Proterozoic		Withnall & Mackenzie, 1983; Withnall, 1985

REFERENCES

ARNOLD G.O., 1975: A structural and tectonic study of the Broken River Province, north Queensland. James Cook University of North Queensland, Ph.D. Thesis.

ARNOLD, G.O. & FAWCKNER, J.F., 1980: The Broken River and Hodgkinson Provinces. *In* Henderson, R.A. & Stephenson, P.J., (Editors): *The Geology and Geophysics of Northeastern Australia*. Geological Society of Australia, Queensland Division, Brisbane, 175-189.

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

ARNOLD, G.O. & RUBENACH, M.J., 1976: Mafic-ultramafic complexes of the Greenvale area, north Queensland. Devonian intrusions or Precambrian metamorphics? *Journal of the Geological Society of Australia*, **23**, 119-139.

ATKINSON, A., GRIFFIN, T.J. & STEPHENSON, 1975: A major lava tube system from Undara volcano, north Queensland. *Bulletin Volcanologique*, **39**, 1-28.

BAIN, J.H.C. & WITHNALL, I.W., 1980: Mineral deposits of the Georgetown region, northeast Queensland. *In* Henderson, R.A. & Stephenson, P.J., (Editors): *The Geology and Geophysics of Northeastern Australia*. Geological Society of Australia Inc., Queensland Division, Brisbane, 129-148.

BAIN, J.H.C., WITHNALL, I.W. & BLACK, L.P., 1984: Some aspects of the geology and geochronology of gold mineralisation in the Georgetown region, Queensland, Australia. *Geological Society of Australia Abstracts*, **12**, 44.

BAIN, J.H.C., WITHNALL, I.W. & OVERSBY, B.S., 1976: Geology of the Forsayth 1:100 000 Sheet area (7660) north Queensland - Georgetown Project Progress Report. Bureau of Mineral Resources, Australia, Record 1976/4.

BAIN, J.H.C., WITHNALL, I.W., OVERSBY, B.S. & MACKENZIE, D.E., 1985: Geology of the Georgetown region, Queensland, 1:250000 map. Bureau of Mineral Resources, Australia.

BAIN, J.H.C., WITHNALL, I.W., OVERSBY, B.S. & MACKENZIE, D.E., 1990: Proterozoic inliers and Palaeozoic igneous provinces of north Queensland: regional geology and mineral deposits. *In* Hughes, F.E. (Editor): Geology of the mineral deposits of Australia and Papua New Guinea. *Australasian Institute of Mining and Metallurgy Monograph*, **14**, 963-978.

BAKER, E.M., 1987: Brecciation, mineralisation and alteration of the Kidston gold deposit. **Proceedings Pacific Rim Congress 87**, The Australasian Institute of Mining and Metallurgy, Melbourne, 29-33.

BAKER, E.M., 1988: Geologic, petrographic and fluid inclusion study of breccia hosted gold mineralisation at Kidston, north Queensland, Australia. James Cook University of North Queensland, Ph. D. Thesis.

BAKER, E.M. & TULLEMANS, F.J., 1990: The geology of the Kidston gold deposit. *In* Hughes, F.E., (Editor): Geology of the Mineral Deposits of Australia and Papua New Guinea. *Australasian Institute of Mining and Metallurgy, Monograph* **14**, 1461-1466.

BALL, L.C., 1914: The Einasleigh Freehold copper mine, N.Q. *Geological Survey of Queensland Publication* **246**.

BELL, T.H., 1980: The deformation history of northeastern Queensland - a new framework. *In* Henderson, R.A., & Stephenson, P.J., (Editors): *The Geology and Geophysics of Northeastern Australia*. Geological Society of Australia Inc., Queensland Division, Brisbane, 307-313.

BEST, J.G., 1959: Cainozoic basalts on the Einasleigh 4-Mile Sheet, north Queensland. Bureau of Mineral Resources, Australia, Record 1959/117.

BEST, J.G., 1960: Some Cainozoic basaltic volcanoes in north Queensland, Australia. Bureau of Mineral Resources, Australia, Record 1960/78.

BEST, J.G., 1962: Atherton - 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes*, E/55-5.

BLACK, L.P., 1973: Tables of isotopic ages from the Georgetown Inlier, north Queensland. Bureau of Mineral Resources, Australia, Record 1973/50.

BLACK, L.P., 1978. Isotopic ages of rocks from the Georgetown-Mt Garnet-Herberton area, north Queensland. *Bureau of Mineral Resources, Geology and Geophysics, Australia, Report* **200**; *BMR Microform* MF-28.

BLACK, L.P., BELL, T.H., RUBENACH, M.J. & WITHNALL, I.W., 1979: Geochronology of discrete structural-metamorphic events in a multiply deformed Precambrian terrain. *Tectonophysics*, **54**, 103-137.

BLACK, L.P. & McCULLOCH, M.T., 1984: Sm-Nd ages of the Arunta, Tennant Creek and Georgetown Inliers of northern Australia. *Australian Journal of Earth Sciences*, **31**, 49-60.

BLACK, L.P. & McCULLOCH, M.T., 1990: Recurrent felsic magmatism: an isotopic case history from the Georgetown Inlier, Queensland. *Geochimica Cosmochimica Acta*, in press.

BLACK, L.P. & WITHNALL, I.W., 1993: The ages of Proterozoic granites in the Georgetown Inlier of northeastern Australia, and their relevance to the dating of tectonothermal events. *AGSO Journal of Australian Geology and Geophysics*, **144**, 331-341.

BRANCH, C.D., 1959: Progress report on upper Palaeozoic intrusions controlled by ring fractures near Kidston, north Queensland. Bureau of Mineral Resources, Australia, Record 1959/104.

BRANCH, C.D., 1966: Volcanic cauldrons, ring complexes, and associated granites of the Georgetown Inlier, Queensland. *Bureau of Mineral Resources, Australia, Bulletin* **76**.

BROWNE, W.R., 1933: A possible correlation of certain Precambrian granites of Australia and some deductions therefrom. *Journal of the Royal Society of New South Wales*, **66**, 405-419.

BRUNKER, R.L., 1970: Preliminary reconnaissance of Greenvale A's to P 767M and 746M. *Onslow Mining Pty Ltd*. Held by the Department of Minerals & Energy, Queensland as CR 4147.

BRYAN, W.H., 1925: Earth movements in Queensland. *Proceedings of the Royal Society of Queensland*, **37**, 1-82.

BRYAN, W.H., 1928: Metamorphic rocks of Queensland. *Australian Association for the Advancement of Science, Report* **19**, 30-45.

BRYAN, W.H. & JONES, O.A., 1946: The geological history of Queensland. *Papers of the University of Queensland, Department of Geology*, **2**(12), 1-103.

BULTITUDE, R.J., CRANFIELD, L.C., HEGARTY, R.A., HALFPENNY, R.W., RIENKS, I.P. & DOMAGALA, J., 1985: Summary of results of field work in the Mossman and Atherton 1:250 000 Sheet areas, 1984 field season - RGMP Progress Report. Geological Survey of Queensland, Record 1985/31.

BULTITUDE, R.J., DONCHAK, P.J., DOMAGALA, J., FORDHAM, B.G. & CHAMPION, D.C., 1990: Geology and tectonics of the Hodgkinson Province, north Queensland. *In Proceedings Volume III, Pacific Rim Congress 90*. The Australasian Institute of Mining and Metallurgy, Melbourne, Australia, 75-81.

BULTITUDE, R.J., DONCHAK, P.J.T., DOMAGALA, J. & FORDHAM, B.G., 1993: The Pre-Mezozoic stratigraphy and structure of the western Hodgkinson province and environs. *Queensland Geological Record* **1993/29**.

BULTITUDE, R.J., GREEN, P.M. & DOMAGALA, J., 1987: Revision of the stratigraphy of the southwestern Hodgkinson Province. *Queensland Government Mining Journal*, **88**, 187-191.

BURBAN, B., 1975: Report on exploration activity for the period April-December, 1975 for A to P 1479M, Einasleigh, Queensland. *Otter-Beaver Exploration NL*. Held by the Department of Minerals & Energy, Queensland.

BURGER, P.A., 1979: The Greenvale nickel laterite orebody. *In* Evans, D.J.I., Shoemaker, R.S. & Veltman, H. (Editors): *International Laterite Symposium*. Society of Mining Engineers of the American Institute of Mining, Metallurgical and Petroleum Engineers Inc., New York, 2.

BURGER, P.A., 1982: The Greenvale lateritic nickel-cobalt deposit. *In* Withnall, I.W. (Editor): *1982 Field Conference, Charters Towers-Greenvale area*. Geological Society of Australia, Queensland Division, Brisbane, 52-61.

BURGER, P.A., 1987: Cainozoic landscape evolution, lateritic Ni/Co, and alluvial cassiterite orebodies; Greenvale/Blue Range area, north Queensland. James Cook University of North Queensland, MSc Thesis.

BURGER, P.A., 1992: EPM 8790, Valley of Lagoons, Qld. First and final report, 16th September 1992. Held by the Department of Minerals and Energy, Queensland as CR 23954.

BUSSARD, D.A., 1971: A to P 767M, west of Ingham, annual reports for 1970 and 1971. Onslow Mining Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 4042.

CAMERON, W.E., 1908: The Oaks alluvial rush. *Annual reports of the Department of Mines, Queensland for 1907*, 170.

COLDHAM, J.C., 1934: Report on the Oaks Goldfield. Gold Mines of Australia Ltd. Held by the Department of Minerals & Energy, Queensland as CR 1022.

CONNAH, T.H., 1959: Ninety Mile copper mine. *Queensland Government Mining Journal*, **60**, 525-532.

CORBETT, G.J., 1982a: Six monthly report for the period January 30-July 29, 1982, and final report, A to P 2871M - Oak River. Kidston Gold Mines Ltd. Held by the Department of Minerals & Energy, Queensland as CR 11253.

CORBETT, G.J., 1982b: Six monthly report for the period March 23-September 22, 1982, and final report, A to P 2950M - Mount Borium. Kidston Gold Mines Ltd. Held by the Department of Minerals & Energy, Queensland as CR 11814.

CRANFIELD, L.C., 1992: Geology of the Lyndbrook 1:100 000 Sheet area (7762) north Queensland. Queensland Resource Industries Record 1992/19.

DAVIES, B., 1980: Six monthly report, A to P 1939M, Daintree, north Queensland. Getty Oil Development Corporation. Held by the Department of Minerals & Energy, Queensland as CR 8631.

DAVIS, R.J., 1983: A to P 3392M Dido Hill, six monthly report 24.12.82-3.06.83. Noranda Australia Ltd. Held by the Department of Minerals & Energy, Queensland as CR 12689.

DAVIS, R.J., 1986: Six monthly report for the period 24.12.85 to 23.06.86 on A to P 3392M. Noranda Australia Ltd. Held by the Department of Minerals & Energy, Queensland as CR 15711.

DENMEAD, A.K., 1947a: Camel Creek tin, Kangaroo Hills Field. *Queensland Government Mining Journal*, **48**, 328.

DENMEAD, A.K., 1947b: Ninety Mile copper mine. *Queensland Government Mining Journal*, **48**, 402-403.

DEWAR, G.J., 1972: Combined Mining and Exploration NL-North Interior Explorations Pty Ltd joint venture exploration of the Einasleigh copper mine, Einasleigh, north Queensland. Combined Mining and Exploration NL. Held by the Department of Minerals & Energy, Queensland as CR 7941.

DONCHAK, P.J.T. & BULTITUDE, R.J., 1994: Geology of the Atherton 1:250 000 sheet.. *Queensland Geological Record* **1994/5**.

FAWCKNER, J.F., 1981: Structural and stratigraphic relations and a tectonic interpretation of the western Hodgkinson Province, northeastern Australia. James Cook University of North Queensland, PhD Thesis.

FIELDING, D.C., 1986: Herbert River, A to P 4026M, Atherton area, north Queensland. Report for the second six months of tenure December 10, 1985-June 9, 1986 and final report. CRA Exploration Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 15752.

FIELDING, D.C., 1987: Mount Surprise, A to P 3973M, Georgetown area, northwest Queensland. Fifth six months of tenure 7.12.86-6.6.87 and final report: diamonds. CRA Exploration Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 16746.

FLETCHER, K. & COUPER, J., 1975: Greenvale nickel laterite, north Queensland. *In* Knight, C.L. (Editor): *Economic Geology of Australia and Papua New Guinea, Volume 1, Metals*. Australasian Institute of Mining and Metallurgy, Melbourne, 995-1001.

FRASER, A.R., DARBY, F. & VALE, K.R., 1977: The reconnaissance gravity survey of Australia: qualitative analysis of results. *Bureau of Mineral Resources, Australia, Report* **198**. BMR Microform MF15.

GAFFNEY, E.S. & McNAMARA, G.C., 1990: A Meiolaniid turtle from the Pleistocene of northern Queensland. *Memoir of the Queensland Museum. De Vis Symposium Special Volume.*

GAUNT, F. & McNAUGHTON, N.J., 1975: Final report for the Daintree copper prospect, A to P 1167M. Australian Anglo-American Ltd. Held by the Department of Minerals & Energy, Queensland as CR 5153.

GETTY OIL DEVELOPMENT CORPORATION, 1981: A to P 1937M, Daintree, north Queensland. Six monthly report to 11.5.81. Held by the Department of Minerals & Energy, Queensland as CR 9594.

GREEN, D.H., 1958: The geology and petrology of the Gray Creek area, north Queensland. Bureau of Mineral Resources, Australia, Record 1958/110.

GREGORY, A.C., 1857: Papers relating to an expedition recently undertaken for the purpose of exploring the northern portion of Australia. *Eyre & Spottiswood, London*.

GRIFFIN, T.J., 1977: The geology, mineralogy and geochemistry of the McBride basaltic province, northern Queensland. James University of North Queensland, PhD Thesis.

GRIFFIN, T.J. & McDOUGALL, I., 1975: Geochronology of the Cainozoic McBride volcanic province, northern Queensland. *Journal of the Geological Society of Australia*, **22**, 387-397.

GRIMES, K.G., 1979: The stratigraphic sequence of old land surfaces in northern Queensland. *BMR Journal of Australian Geology and Geophysics*, **4**, 33-46.

GULSON, B.L. & VAASJOKI, M., 1987: Lead isotope data from the Thalanga, Dry River, and Mount Chalmers base metal deposits and their bearing on exploration and ore genesis in eastern Australia. *Australian Journal of Earth Sciences*, **34**, 159-174.

HAMMOND, J.M., 1984: Fourth half yearly and final report for A to P 3287M, Damper Hill prospect, Mt Surprise, NE Queensland. Amax Australia (Operations) Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 13341.

HAMMOND, R.L., 1986: Large scale structural relationships in the Palaeozoic of northeastern Queensland: melange and mylonite development, and the regional distribution of strain. James Cook University of North Queensland, PhD Thesis.

HANNES, G.S. & DALGARNO, C.R., 1967: Final report on gold mineralisation, Kidston, north Queensland. Anaconda Australia Inc. Held by the Department of Minerals & Energy, Queensland as CR 2255.

HARTLEY, J.S., 1972: A to P 767M. Progress report for year ended December 31, 1971. Onslow Mining Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 4042.

HARVEY, K.J., 1984a: The discovery of the Balcooma massive sulphide deposit. *In* Geoscience in the Development of Natural Resources. *Geological Society of Australia, Abstracts*, **12**, 218-219.

HARVEY, K.J., 1984b: The geology of the Balcooma massive sulphide deposit, north-east Queensland. James Cook University of North Queensland, MSc Thesis.

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

HENDERSON, R.A., 1986: Geology of the Mt Windsor Subprovince - a Lower Palaeozoic volcano-sedimentary terrane in the northern Tasman Orogenic Zone. *Australian Journal of Earth Sciences*, **33**, 343-364.

HENDERSON, R.A., 1987: An oblique subduction and transform faulting model for the evolution of the Broken River Province, northern Tasman Orogenic Zone. *Australian Journal of Earth Sciences*, **34**, 237-249.

HILL, D., 1951: Geology. *In Handbook for Queensland*. Australian Association for the Advancement of Science, Brisbane, 13-24.

HILLS, E.S., 1946: Some aspects of the tectonics of Australia. *Journal of the Royal Society of Australia*, **79**, 67-91.

HUSTON, D.L., 1988: Aspects of the geology of massive sulphide deposits from the Balcooma district, northern Queensland and Roseberry, Tasmania: implications for ore genesis. University of Tasmania, PhD Thesis.

HUSTON, D.L., 1990: The stratigraphic and structural setting of the Balcooma volcanogenic massive sulphide lenses, northern Queensland. *Australian Journal of Earth Sciences*, **37,** 423-440.

HUSTON, D.L. & TAYLOR, T.W., 1990: Dry River copper and lead- zinc-copper deposits. *In* Hughes, F.E. (Editor): Geology of the Mineral Deposits of Australia and Papua New Guinea. *Australasian Institute of Mining and Metallurgy, Monograph*, **14**, 1519-1526.

JACK, R.L., 1887: Geological observations in north Queensland. *Geological Survey of Queensland Publication,* **35**.

JACK, R.L., 1898: The Chillagoe mining district and the projected railway. *Geological Survey of Queensland Publication,* **134**.

JACKSON, J.C., 1989: A to P 4002M, Kangaroo Creek, report for six months ended 15/11/88 and final report. Carpentaria Exploration Co. Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 19668.

JELL, J.S. & PLAYFORD, G., 1985: Broken River Embayment and Burdekin-Star Shelf (*in* Roberts, J., Australia). *In* Wagner, R.H., Winkler Prins, C.F. & Granados, L.F. (Editors): The Carboniferous of the World, II. *IUGS Publication No.* **20**, 62-69.

JENSEN, H.I., 1920a: The geology, mineral prospects and future of North Queensland. *Queensland Geographical Journal*, **34-35**, 23-26.

JENSEN, H.I., 1920b: The Kidston goldfield. *Queensland Government Mining Journal*, **21**, 186-192.

JENSEN, H.I., 1923: The geology of the Cairns hinterland and other parts of north Queensland. *Geological Survey of Queensland Publication,* **274**.

JOHNSON, R.W., 1989: *Intraplate Volcanism in Eastern Australia and New Zealand*. Cambridge University Press, Cambridge, 408.

JOHNSTON, C. & BLACK, L.P., 1987: Rb/Sr systematics of the Coolgarra Batholith, north Queensland. *Australian Journal of Earth Sciences*, **33**, 309-324.

KLARIC, R., 1977: Gossan testing in Mount Misery-Dreadnought- Teasdale area, A to P 1497M, north Queensland. CRA Exploration Pty Ltd. Held by the Department of Minerals & Energy, Queensland (confidential).

KONOPA, S., 1988a: Report on areas relinquished 23.12.87 from A to P 3392M, Dido Hill. Noranda Australia Ltd. Held by the Department of Minerals & Energy, Queensland as CR 17911.

KONOPA, S., 1988b: Report for the six months ended 23.12.87 on A to P 3392M, Dido Hill. Noranda Australia Ltd. Held by the Department of Minerals & Energy, Queensland as CR 19155.

KROSCH, N.J., 1990: Queensland mineral commodity report - chrysoprase. *Queensland Government Mining Journal*, **91**, 165-169.

KROSCH, N.J. & COOPER, W., 1990: Queensland mineral commodity report - sapphire. *Queensland Government Mining Journal*, **91**, 299-306.

LASKAN MINERALS PTY LTD, 1971: Part A - report on operations to December 30, 1970, A to P 763M; Part B - results of diamond drilling, A to P 763M, Daintree copper prospect. Held by the Department of Minerals & Energy, Queensland CR 3823.

LEICHHARDT, L., 1847: *Overland Expedition from Moreton Bay to Port Essington*. Boone, London.

LEVINGSTON, K.R., 1952: Perry Creek Wolfram and scheelite workings - Camel Creek Holding. *Queensland Government Journal*, **53**, 878-881.

LISTER, G.S., ETHERIDGE, M.A. & SYMONDS, P.A., 1986: Detachment faulting and the evolution of passive continental margins. *Geology*, **14**, 246-250.

MAITLAND, A.G., 1891: Geology and mineral resources of the Upper Burdekin. *Geological Survey of Queensland Publication*, **71**.

MARKS, E.O., 1911: The Oaks and eastern portion of the Etheridge Goldfield. *Queensland Government Mining Journal*, **12**, 9-18; also *Geological Survey of Queensland Publication,* **234**.

MARSDEN, M.A.H., 1972: The Devonian history of north-eastern Australia. *Journal of the Geological Society of Australia*, **19**, 125-162.

MATHUR, S.P. & SHAW, R.D., 1982: Australian orogenic belts: evidence for evolving plate tectonics? *Earth Evolution Sciences*, **4**, 281-308.

McNAMARA, G.C., 1990: The Wyandotte local fauna: a new, dated, Pleistocene vertebrate fauna from northern Queensland. *Memoir of the Queensland Museum. De Vis Symposium Special Volume.*

McNAUGHTON, N.J., 1979: The extent and age of a granulite facies metamorphism in the Einasleigh Metamorphics east of the Newcastle Range, north Queensland. *Queensland Government Mining Journal*, **80**, 126-131.

McNAUGHTON, N.J., 1980: An isotopic, geochemical and structural study of the Proterozoic Einasleigh Metamorphics, northern Queensland. University of Queensland, PhD Thesis.

McNAUGHTON, N.J. & WILSON, A.F., 1980: Problems in oxygen isotope geothermometry in mafic granulite facies rocks from near Einasleigh, northern Queensland. *Precambrian Research*, **13**, 77-86.

McNAUGHTON, N.J. & WILSON, A.F., 1983a: ^{13}C-rich marbles from the Proterozoic Einasleigh Metamorphics, northern Queensland. *Journal of the Geological Society of Australia*, **30**, 175-178.

McNAUGHTON, N.J. & WILSON, A.F., 1983b: The geochemical and oxygen isotope affinities of Proterozoic mafic granulites from the Einasleigh Metamorphics, northern Queensland. *Precambrian Research*, **21**, 21-37.

McNAUGHTON, N.J. & WILSON, A.F., 1983c: On the age of D_4 in the Georgetown Inlier, northern Queensland. *Search*, **14**, 272-273.

McNAUGHTON, N.J. & WITHNALL, I.W., 1990: Carbonate ^{13}C and ^{18}O depletion during regional metamorphism. *In* Herbert, H.K. & Ho, S.E. (Editors): Stable Isotopes and fluid processes in mineralisation. *Geology Department and University Extension, The University of Western Australia, Publication* **23**, 277-289.

METALS EXPLORATION LTD, 1983: A to P 2630M `Conjuboy West' Queensland. Final and six month report for period ended September 25, 1982. Held by the Department of Minerals & Energy, Queensland as CR 11568.

MITCHELL, J.W., 1969: Report on areas retained February, 1969. A to P 479M - Etheridge district, north Queensland. Mines Administration Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 2936.

MOCKETT, N., 1983: The geology of the Lake Lucey area, north Queensland, with special reference to the clay mineralogy. James Cook University of North Queensland, BSc Honours Thesis.

MORTON, C.C., 1941: Ninety Mile copper mine. *Queensland Government Mining Journal*, **42**, 6-7.

MORTON, C.C., 1943: Ninety Mile copper mine Greenvale Holding. *Queensland Government Mining Journal*, **44**, 68-69.

MORTON, C.C., 1944a: Wolfram and tin possibilities - Elizabeth Creek Mount Surprise. *Queensland Government Mining Journal*, **45**, 9-10.

MORTON, C.C., 1944b: Perry Creek scheelite, Camel Creek Holding. *Queensland Government Mining Journal*, **45**, 94.

MUSTARD, H.M., 1983: Breccia forming processes at the Kidston gold deposit. James Cook University of North Queensland, BSc Honours Thesis.

MUSTARD, H.W., 1986: Geology and genesis of the Kidston gold deposit, Australia. *In* MacDonald, A.J. (Editor): *Proceedings of Gold '86, an international symposium on the geology of gold*. Toronto, 404-415.

ONLEY, P.G., 1978: Report on exploration activity for 1977, Einasleigh A to P 1497M, Queensland. CRA Exploration Pty Ltd. Held by the Department of Minerals & Energy, Queensland (confidential).

ONLEY, P.G., 1979: Einasleigh A to P 1497M, north Queensland. Annual report for year ended 31/12/78. CRA Exploration Pty Ltd. Held by the Department of Minerals & Energy, Queensland (confidential).

OVERSBY, B.S., 1985: Northern subprovince (*in* Roberts, J., Australia). *In* Wagner, R.H., Winkler Prins, C.F. & Granados, L.F. (Editors): The Carboniferous of the World, II. *IUGS Publication No.* **20**, 71-75.

OVERSBY, B.S., BLACK, L.P. & SHERATON, J.W., 1980: Late Palaeozoic continental volcanism in northeastern Australia. *In* Henderson, R.A. & Stephenson, P.J. (Editors): *The Geology and Geophysics of Northeastern Australia*. Geological Society of Australia, Queensland Division, Brisbane, 247-268.

OVERSBY, B.S. & MACKENZIE, D.E., in preparation: Geology of late Palaeozoic ignimbrites and associated rocks in the Georgetown region, northeast Queensland. *Australian Geological Survey Organisation, Record* **1994/20.**

OVERSBY, B.S., WITHNALL, I.W., BAKER, E.M. & BAIN, J.H.C., 1978: Georgetown Project Progress Report - Geology of the Georgetown 1:100 000 Sheet area (7661), north Queensland; part A. Bureau of Mineral Resources, Australia, Record 1978/44.

PARKINSON, W.D. & MULDER, J.M., 1956: Preliminary report on airborne scintillograph survey at Chillagoe and Einasleigh- Gilberton, Queensland, 1955. Bureau of Mineral Resources, Australia, Record 1956/63.

PATRICK, J.P., 1978: The geology and origin of the sulphide deposit and the high-grade Precambrian metamorphic rocks at Einasleigh, northeastern Australia. James Cook University of North Queensland, MSc Thesis.

PEDEN, R., 1988: A to P 4278M, `The Lynd', combined fifth six monthly and final report for period ended 2.11.88. Keela-Wee Exploration. Held by the Department of Minerals & Energy, Queensland as CR 19058.

PERKIN, D.J., 1971: Final report, A to P 535M(1), Einasleigh. Trans-Australian Exploration Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 3593.

PERRY, R.A, SLEEMAN, J.R., TWIDALE, C.R., PRICHARD, R.O., LAZARIDES, M. & COLLINS, F.H., 1964: General report on lands of the Leichhardt-Gilbert area, Queensland, 1953-54. *Commonwealth Scientific and Industrial Research Organisation, Australia, Land Research Series No.* **11**.

QUEENSLAND DEPARTMENT OF MINES, 1953: Einasleigh copper mine. *In, Geology of Australian Ore Deposits*. Fifth Empire Mining and Metallurgical Congress, Melbourne, 1, 751-755.

RADKE, F., 1973: Thermal metamorphism of a massive sulphide ore at the Einasleigh mine, north Queensland. *Australian Mineral Development Laboratories, Bulletin*,**15**.

RAWLINS, R.J. & SIMPSON, C.J., 1968: A to P 357M - Einasleigh. Final report. Carpentaria Exploration Co. Pt*y Ltd*. Held by the Department of Minerals & Energy, Queensland as CR 2507B.

REID, J.H., 1934: Mr C. Furber's workings, Einasleigh district. Unpublished memorandum to the Chief Government Geologist, Geological Survey of Queensland 28/5/1934.

RICHARDS, D.G., 1980: Palaeozoic granitoids of northeastern Australia. *In* Henderson, R.A. & Stephenson, P.J. (Editors): *The Geology and Geophysics of Northeastern Australia*. Geological Society of Australia, Queensland Division, Brisbane, 229-246.

RICHARDS, J.R., WHITE, D.A., WEBB, A.W. & BRANCH, C.D., 1966: Isotopic ages of acid igneous rocks in the Cairns hinterland, north Queensland. *Bureau of Mineral Resources, Australia, Bulletin* **88**.

ROBERTSON RESEARCH AUSTRALIA PTY LTD, 1985: Surveyor 1-zinc-lead-silver-gold deposit. *In Prospectus, Noranda Pacific Limited*, 26-29.

RUDNICK, R.L., McDONOUGH, W.F., McCULLOCH, M.T. & TAYLOR, S.R., 1986: Lower crustal xenoliths from Queensland, Australia: evidence for deep crustal assimilation and fractionation of continental basalts. *Geochimica et Cosmochimica Acta*, **50**, 1099-1115.

SCOTT, P.A. & JOHNSTON, A.C., 1985: A to P 3461M, Forlorn Creek, Qld, final report on exploration for six months ending 28.1.85. CSR Ltd. Held by the Department of Minerals & Energy, Queensland as CR 14129.

SHERATON, J.W. & LABONNE, B., 1978: Petrology and geochemistry of acid igneous rocks of northeast Queensland. *Bureau of Mineral Resources, Australia, Bulletin*, **169**.

STANTON, R.L., 1982: Metamorphism of a stratiform sulphide orebody at Mount Misery, Einasleigh, Queensland, Australia: 1 - Observations; 2 - Implications. *Transactions of the Institute of Mining and Metallurgy (Section B: Applied Earth Science)*, **91**, B47-B80.

STEIGER, R.H. & JAGER, E., 1977: Subcommission on Geochronology: convention on the use of decay constants in geochronology and cosmochronology. *Earth and Planetary Science Letters*, **36**, 359-362; also *in* Cohee, G.V., Glaessner, M.F. & Hedberg, H.D. (Editors): Contributions to the Geologic Time Scale. *American Association of Petroleum Geologists*, *Studies in Geology*, **6**, 67-71.

STEPHENSON, P.J. & GRIFFIN, T.J., 1976: Some long basaltic lava flows in north Queensland. *In* Johnson, R.W. (Editor): *Volcanism in Australia*. Elsevier, Amsterdam, 41-51.

STEPHENSON, P.J., GRIFFIN, T.J. & SUTHERLAND, F.L., 1980: Cainozoic volcanism in northeastern Australia. *In* Henderson, R.A. & Stephenson, P.J. (Editors): *The Geology and Geophysics of Northeastern Australia*. Geological Society of Australia, Queensland Division, Brisbane, 349-374.

SUTHERLAND, F.L., 1977: Cainozoic basalts of the Mt Fox area, north Queensland. *Australian Museum, Record*, **30**, 532-534.

TEALE, G.S., PLUMRIDGE, C.L., LYNCH, J.E. & FORREST, R.J., 1989: The Amanda Bel Goldfield: a significant new gold province; *In Proceedings, North Queensland Gold '89 Conference*. The Australasian Institute of Mining and Metallurgy, Melbourne, 103-109.

TELUK, J.A., 1978: Annual report, Werrington A to P 1578M, north Queensland, report for year ended 31.12.77. Newmont Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 6595.

THOMPSON, G., 1980: Ugly Corner, A to P 1897M, final report. Metals Exploration Ltd. Held by the Department of Minerals & Energy, Queensland as CR 8419.

TIMMINS, A.L., 1990: A phosphate and fluorine bearing assemblage developed in the lower Palaeozoic deformed volcanics of the Balcooma-Dry River region. *In* Carter, R.M. (Editor): Report on the activities of the Geology Department and Economic Geology Research Unit 1989. *Contributions of the Economic Geology Research Unit, James Cook University of North Queensland*, **36**, 62-63.

TUCKER, D.C., 1979: ML 1070 Oasis, Annual Report to Queensland Mines Department. Esso Exploration and Production Australia Inc. Held by the Department of Minerals & Energy, Queensland as CR 6095.

TURNER, A.R., 1976: Geology and mineralisation of the Kidston breccia pipe. Anaconda Australia Inc.

TWIDALE, C.R., 1956a: Chronology of denudation in northwest Queensland. *Bulletin of the Geological Society of America*, **67**, 867-882.

TWIDALE, C.R., 1956b: A physiographic reconnaissance of some volcanic provinces in north Queensland, Australia. *Bulletin Volcanologique*, **2**, 3-23.

TWIDALE, C.R., 1966: Geomorphology of the Leichhardt-Gilbert area, north-west Queensland. *Commonwealth Scientific and Industrial Research Organisation, Australia, Land Research Series No.* **16**.

VAN DER HOR, F., 1988: Structural geology of the Balcoma-Dry River area, northeast Australia with emphasis on the inter- relation between deformation and metamorphism. James Cook University of North Queensland, PhD Thesis.

WALLIS, D.S., 1994: Queensland mineral commodity report - nickel and cobalt. *Queensland Government Mining Journal*, **95** (August), 28—36.

WARD, C.W. & WEST, K.N., 1975: Final report on A to P 1286M, Lucky Creek area, Queensland. Shell Minerals Exploration (Australia) Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 5474.

WARNICK, J.V., 1989: Pre-Carboniferous geology of the Mount Surprise-Einasleigh region. *Queensland Department of Mines, Report*, **2**, 103-129.

WARNICK, J.V. & WITHNALL, I.W., 1985: New and revised names for intrusive units in the Einasleigh region. *Queensland Government Mining Journal*, **86**, 102-105.

WERNER, C.J., 1973: Relinquishment report on A to P 1192M. Diatomite Development Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 4454.

WHITCHER, I.G., 1981: Final report on exploration of the Daintree area, north Queensland, incorporating A's to P 1939M 2382M, and 2501M, between May and August, 1981. Getty Oil Development Corporation. Held by the Department of Minerals & Energy, Queensland as CR 9862.

WHITE, D.A., 1959a: New names in Queensland stratigraphy, Parts 2, 3, and 4. *Australian Oil and Gas Journal*, **5**(9), 31-36; **5**(10), 31-36; **5**(11), 26-28.

WHITE, D.A., 1959b: New stratigraphic units in north Queensland geology. *Queensland Government Mining Journal*, **60**, 442-447.

WHITE, D.A., 1961: Geological history of the Cairns-Townsville hinterland, north Queensland. *Bureau of Mineral Resources, Australia, Report* **59**.

WHITE, D.A., 1962a: Clarke River - 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* E/55-13.

WHITE, D.A., 1962b: Einasleigh - 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* E/55-9.

WHITE, D.A., 1962c: Gilberton - 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* E/54-16.

WHITE, D.A., 1962d: Georgetown - 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* E/54-12.

WHITE, D.A., 1965: The geology of the Georgetown/Clarke River area, Queensland. *Bureau of Mineral Resources, Australia, Bulletin* **71**.

WHITE, D.A., BEST, J.G. & BRANCH, C.D., 1959: Progress report on regional geological mapping, north Queensland, 1958. Bureau of Mineral Resources, Australia, Record 1959/115.

WHITE, D.A., BRANCH, C.D. & GREEN, D.H., 1961: Geology of the Halls Reward copper mine area, north Queensland. *Queensland Government Mining Journal*, **62**, 1-14.

WHITE, D.A. & CRESPIN, I., 1959: Some diatomites of north Queensland. *Queensland Government Mining Journal*, **60**, 191- 193.

WHITE, D.A. & HUGHES, K.K., 1957: Progress report on geological mapping, north Queensland, 1956. Bureau of Mineral Resources, Australia, Record 1957/58.

WHITE, D.A., STEWART, J.R., BRANCH, C.D., GREEN, D.H. & WYATT, D.H., 1959: Progress report on the regional geological mapping of north Queensland, 1957, Gray Creek, Broken River, and Clarke River areas. Bureau of Mineral Resources, Australia, Record 1959/114.

WHITE, D.A. & WYATT, D.H., 1960a: The Precambrian of the Etheridge-Einasleigh-Cardross area, northern Queensland. *In* Hill, D. & Denmead, A.K. (Editors): Geology of Queensland. *Journal of the Geological Society of Australia*, **7**, 62-74.

WHITE, D.A. & WYATT, D.H., 1960b: Silurian - the upper Burdekin River Valley. *In* Hill, D. & Denmead, A.K. (Editors): Geology of Queensland. *Journal of the Geological Society of Australia*, **7**, 123-128.

WHITE, D.A. & WYATT, D.H., 1960c: The Permo-Carboniferous of north Queensland. *In* Hill, D. & Denmead, A.K. (Editors): Geology of Queensland. *Journal of the Geological Society of Australia*, **7**, 177-180.

WHITE, D.A., WYATT, D.H. & BUSH, W.E., 1960: Devonian geology of the upper Burdekin River valley, north Queensland. *In* Hill, D. & Denmead, A.K. (Editors): Geology of Queensland. *Journal of the Geological Society of Australia*, **7**, 149-154.

WHITEHOUSE, F.W., 1930: The geology of Queensland. *Australian Association for the Advancement of Science, Report* **20**, 23-29.

WILSON, G.I., LEWIS, R.W., GALLO, J.B. & TULLEMANS, F.J., 1986: The geology of the Kidston mine. *In* Berkman, D.A. (Editor): *Publications of the 13th Congress Volume 2, Geology and Exploration*. 13th Congress of the Council of Mining and Metallurgical Institution and The Australian Institute of Mining and Metallurgy, Singapore, 235-242.

WITHNALL, I.W., 1978: Mines and mineral deposits of the Georgetown 1:100 000 Sheet area, Queensland. *Geological Survey of Queensland, Report*, **100**.

WITHNALL, I.W., 1982: The geology of the Greenvale-Balcooma area. *In* Withnall, I.W. (Editor): *1982 Field Conference, Charters Towers-Greenvale area*. Geological Society of Australia, Queensland Division, Brisbane, 31-46.

WITHNALL, I.W., 1983: The Robertson River Subgroup and Cobbold Metadolerite - revised Proterozoic units in the Georgetown Inlier, north Queensland. *Queensland Government Mining Journal*, **84**, 182-190.

WITHNALL, I.W., 1984: Stratigraphy, structure and metamorphism of the Proterozoic Etheridge and Langlovale Groups, central Georgetown Inlier, north Queensland. Geological Survey of Queensland, Record 1984/59.

WITHNALL, I.W., 1985a: Geochemistry and tectonic significance of Early Proterozoic mafic rocks from the Etheridge Group, Georgetown Inlier, north Queensland. BMR Journal of Australian Geology and Geophysics, **9**, 339-351.

WITHNALL, I.W., 1985b: Pre-Devonian geology of the Graveyard Creek Subprovince, Broken River Province (Embayment), north Queensland. Geological Survey of Queensland, Record 1985/32.

WITHNALL, I.W., 1985c: Suspect terranes along the Precambrian/Palaeozoic margin, Greenvale area, north Queensland. *In* Leitch, E. (Editor): Third Circum-Pacific Terrane Conference extended abstracts. *Geological Society of Australia, Abstracts*, **14**, 247-250.

WITHNALL, I.W., 1989: Precambrian and Palaeozoic geology of the southeastern Georgetown Inlier, north

Queensland. *Queensland Department of Mines Report*, **2**, 1-102.

WITHNALL, I.W. & BAIN, J.H.C., 1985: Mineral deposits of the Georgetown region, Queensland: production figures and bibliography. Bureau of Mineral Resources, Australia, Record 1985/10 (BMR Microform MF 213).

WITHNALL I.W., BAIN J.H.C., DRAPER, J.J., MACKENZIE, D.E. & OVERSBY, B.S., 1988: Proterozoic stratigraphy and tectonic history of the Georgetown Inlier, northeastern Queensland. *Precambrian Research*, **40/41**, 429-446.

WITHNALL, I.W., BAIN, J.H.C. & OVERSBY, B.S., 1976: New and revised names for intrusive rock units in the Forsayth and Georgetown 1:100 000 Sheet areas, north Queensland. *Queensland Government Mining Journal*, **77**, 228-231.

WITHNALL, I.W., BAIN, J.H.C. & RUBENACH, M.J., 1980: The Precambrian geology of northeastern Queensland. *In* Henderson, R.A. & Stephenson, P.J. (Editors): *The Geology and Geophysics of Northeastern Australia*. Geological Society of Australia, Queensland Division, Brisbane, 109.

WITHNALL, I.W., BLACK, L.P. & HARVEY, K.J., 1991: Geology and geochronology of the Balcooma area - part of an early Palaeozoic magmatic belt in north Queensland. *Australian Journal of Earth Sciences*, **38**, 15-29.

WITHNALL, I.W., & GRIMES, K.G., 1991: Explanatory notes on the Einasleigh 1:250 000 Geological Sheet. *Queensland Resource Industries Record* **1991/15**.

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

WITHNALL, I.W., LANG, S.C., JELL, J.S., McLENNAN, T.P.T., TALENT, J.A., MAWSON, R., FLEMING, P.J.G., LAW, S.R., MACANSH, J.D., SAVORY, P., KAY, J.R. & DRAPER, J.J., 1988: Stratigraphy, sedimentology, biostratigraphy, and tectonics of the Ordovician to Carboniferous Broken River Province, north Queensland. *Australasian Sedimentologists Group Field Guide Series No.* **5**. Geological Society of Australia.

WITHNALL, I.W., LANG, S.C., SCOTT, M., MACANSH, J.D. & WARNICK, J.V., 1986: Summary of results from the 1985 field season in the Einasleigh and Clarke River 1:250 000 Sheet areas - RGMP Progress Report. Geological Survey of Queensland, Record 1986/21.

WITHNALL, I.W., LANG, S.C., WARNICK, J.V., SCOTT, M., McLENNAN, T.P.T., LAW, S.R. & HUTTON, L.J., 1985: Summary of results from the 1984 field season in the Einasleigh & Clarke River 1:250 000 Sheet areas - RGMP Progress Report. Geological Survey of Queensland, Record 1985/30.

WITHNALL, I.W. & MACKENZIE, D.E., 1980: New and revised stratigraphic units in the Proterozoic Georgetown Inlier, north Queensland. *Queensland Government Mining Journal*, **81**, 28-43.

WITHNALL, I.W. & MACKENZIE, D.E., 1983: Definition of the Proterozoic Langlovale Group, Georgetown Inlier, north Queensland. *Queensland Government Mining Journal*, **84**, 193-194.

WITHNALL, I.W., OVERSBY, B.S., BAKER, E.M. & BAIN, J.H.C., 1980: Geology of the Gilberton 1:100 000 Sheet area (7659), north Queensland: data record. Bureau of Mineral Resources, Australia, Record 1980/2.

YOUNG, D.I., 1979: A to P 2035M, Lucy Tableland area, report for six months ended November 8, 1979. North Broken Hill Ltd. Held by the Department of Minerals & Energy, Queensland as CR 7586.

ZEISSINK, H.E., 1977: Final report, A to P 1289M (previously 671M). AO (Australia) Pty Ltd. Held by the Department of Minerals & Energy, Queensland as CR 6383A.

FURTHER PUBLICATIONS AVAILABLE ON RELATED TOPICS

Geological Survey of Queensland Publication, **383**.
Queensland Geology - a companion volume to the 1:2 500 000 scale geological map (1975). R.W. Day, W.G. Whitaker, C.G. Murray, I.H. Wilson & K.G. Grimes. 1983. $36.00 ppah.

Queensland Department of Mines Report, **2**.
(i) PreCambrian and Palaeozoic geology of the south-eastern Georgetown Inlier, North Queensland. I.W. Withnall.
(ii) Pre-Carboniferous Geology of the Mount Surprise Einasleigh Region, North Queensland.
J.V. Warnick. 1988. $15.00 ppah.

Queensland Geology **4**.
Geology of the Broken River Province, North Queensland 1993. I.W. Withnall & S.C. Lang. $102.00 ppah.

Geological Survey of Queensland Record 1984/59.
Withnall I.W. Stratigraphy, Structure and Metamorphism of the Proterozoic Etheridge and Langlovale Groups, central Georgetown Inlier, N. Qld. (P.O.A.)

Geological Survey of Queensland Record 1985/30.
Withnall I.W., Lang S.C., Warnick J.V., Scott M., McLennan T.P.T., Law S.R., Hutton L.J. Summary of Results from the 1984 field Season in the einasleigh and Clarke River 1:250 000 sheet areas. RGMP Progress Report. (P.O.A.)

Geological Survey of Queensland Record 1986/21. Withnall I.W., Lang S.C., Scott M., Macansh J.D., Warnick J.V. & Hutton L.J. Summary of results from the 1985 Field Season in the Einasleigh and Clarke River 1:250 000 sheet areas - RGMP Progress report. (P.O.A.)

Queensland Resource Industries Record **1992/19**.
Cranfield, L.C. Geology of the Lyndbrook 1:100 000 sheet area (7762) north Queensland. (P.O.A.)

Queensland Geological Record **1994/5**. Geology of the Atherton 1:250 000 sheet. P.J.T. Donchak & R.J. Bultitude. (P.O.A.)