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ABSTRACT

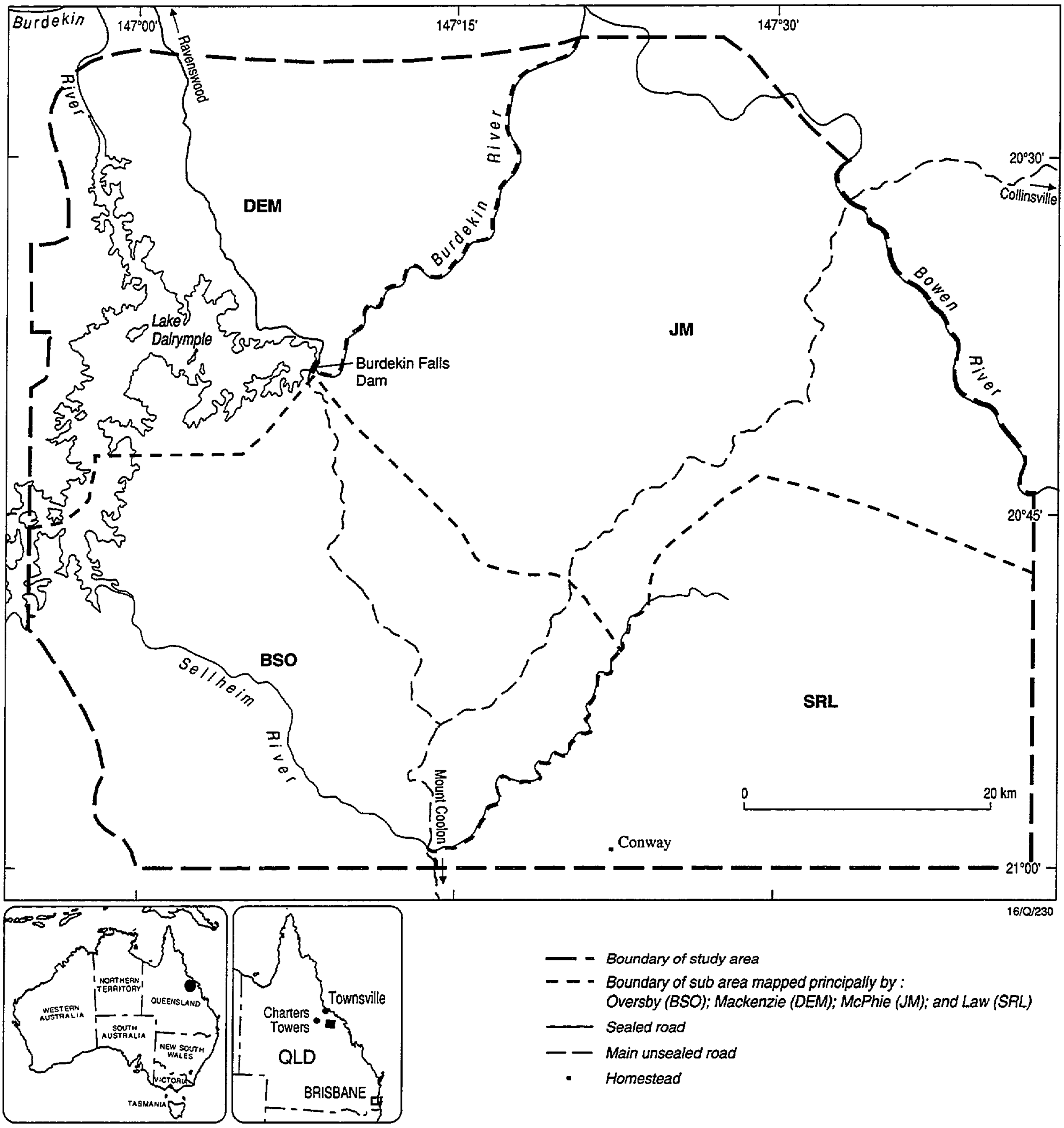
The Burdekin Falls Dam - "Conway" study area lies in the Townsville-Mackay hinterland of northeastern Queensland, to the southeast of Charters Towers. The area straddles parts of several major tectonic provinces (Lolworth-Ravenswood Block, Anakie Inlier, Drummond Basin, Bowen Basin); a late Palaeozoic magmatic overprint (North Queensland Igneous Province) is also conspicuous. The area has the potential to contain a range of copper-lead-zinc and gold-silver deposit types. This study was undertaken to update the geological framework of the area specifically in order to evaluate its potential for epithermal-type gold deposits. It was initiated as a complement to prospect-scale investigations being undertaken in the vicinity of "Conway" homestead.

Gold deposits in the vicinity of "Conway" are hosted by probable Early Carboniferous andesitic lavas and tuffs with sedimentary rocks, which make up the Bimurra Volcanics; this unit is low in the local Drummond Basin sequence. Probable Late Devonian and/or Early Carboniferous rocks which are similar to those of the Bimurra Volcanics, and which occupy the lowest part of the Drummond Basin sequence, occur to the north in the Stones Creek Volcanics. This unit is considered to have equivalent economic potential to the Bimurra Volcanics. It is accompanied by an un-named volcanic member of the probable Early Carboniferous Star of Hope Formation which contains less andesitic material and thus may have reduced potential for epithermal-type gold deposits.

Original relationships between sub-Drummond Basin basement elements (Lolworth-Ravenswood Block and Anakie Inlier) in the study area are unclear. Basement material in scattered outcrops and xenoliths between the closest definite occurrences of the two tectonic provinces cannot confidently be assigned to one rather than the other. Inferred relationships between undivided Seventy Mile Range Group rocks and Mount Windsor Volcanics of the Lolworth-Ravenswood Block in the study area suggest that the stratigraphic position represented is one at or near which volcanogenic copper-lead-zinc deposits could be localised.

The mid(?)-Carboniferous to earliest Permian magmatic overprint of the North Queensland Igneous Province is manifested in the study area as voluminous rhyolitic and dacitic ignimbrites, assigned to the Bulgonunna Volcanic Group, and as widespread granitoid bodies of up to batholithic dimensions. Stratigraphic and structural relationships in the Bulgonunna Volcanic Group are intricate; the overall stratigraphic framework in particular has not yet been fully resolved, despite field research being supplemented by high-resolution U-Pb zircon geochronology and a focussed palaeomagnetic investigation. Partial caldera collapses probably occurred along a fault zone followed by the Burdekin River, and other zones farther south, during extrusion of some ignimbrite units. Such zones should be expected to have exerted an influence on the localisation of intermediate-

Fig. 1. Location of the Burdekin Falls Dam - "Conway" area.



to high-level mineral deposits, possibly including the gold-silver-bismuth veins around "Ukalunda" whose age and affiliation are still uncertain. Subvolcanic intrusive bodies associated with the Bulgonunna Volcanic Group have potential for breccia-hosted gold deposits; this is more particularly so in view of the parallelism of several structural trends in and adjacent to the preserved volcanics to trends of some mineralised "corridors" evident at a broader regional scale, particularly to the north.

North Queensland Igneous Province magmatic overprinting in the study area merged with early rifting and subsidence of the Bowen Basin, via extrusion of andesitic and basaltic Lizzie Creek Volcanics lavas, intrusion of broadly bimodal dyke swarms, and channelling of Mount Wickham Rhyolite along part of the remobilised contact zone between the Thomson and New England Orogens (Millaroo Fault Zone). The Millaroo Fault Zone in particular should have considerable economic potential, although not apparent in exposed rocks.

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INTRODUCTION

Purpose and Scope of Study

As shown in Figure 1, the area of the investigation reported on here lies approximately between Latitudes 20° 25' to 21° 00' South and Longitudes 146° 55' to 147° 40' East. It covers the whole of the Glendon 1:100 000 Sheet area, plus adjoining parts of the Ravenswood, Strathalbyn, Harvest Home, and Collinsville Sheet areas. This report is an explanatory text to the accompanying 1:100 000-scale map.

Fieldwork which forms the basis of this report was undertaken as part of a joint AGSO (then BMR) and Queensland Department of Minerals and Energy (Geological Survey) project. The project's aim was to reach an integrated, and predictive, deposit- to regional-scale understanding of epithermal-type gold distribution in the northern Drummond Basin and/or its precursor/successor tectonic elements. In particular, it was hoped to clarify the age and setting of gold occurrences for comparison with the significant Pajingo deposit. This deposit is located approximately 70 km west-northwest of study area. It was the first of the new-generation of significant gold deposits to be located (in 1983, with the first gold pour being made four years later) in this part of northeastern Queensland, and it was a true "greenfields" discovery whose epithermal nature was appreciated at a very early stage. It was recognised that any demonstrable similarities between the study area and the Pajingo area would enhance both prospectivity of the former, and the potential for eventual exploitation of known occurrences. In addition, demonstrable similarities with Pajingo would increase the predictive capability of our work. The research was a continuation of systematic mapping undertaken previously by the Geological Survey of Queensland in the Mount Coolon and Byerwen 1:100 000 Sheet areas, to the south of "Conway" homestead (Hutton et al.1991). In particular, our work benefitted substantially from a study of Bulgonunna volcanics undertaken as part of that mapping (Law 1988).

Colour aerial photographs covering the entire study area at 1:28 000-nominal scale were produced by the-then Division of National Mapping in April and June, 1988. Responsibilities for field research were mainly apportioned on a subarea basis (Fig. 1), with varying amounts of overlap where appropriate. As an exception, D.W. examined granitoids throughout the entire study area, as part of a wider-ranging programme extending north to Charters Towers. The 1:100 000-scale map was derived from an initial synthesis of field observations, presented as 24 Field Compilation Sheets (cf. Oversby et al. 1991) at aerial photograph scale. The map incorporates many refinements of interpretation, and some significant reinterpretations, of the initial synthesis.

At the time of beginning work in 1987, a spatial relationship between known epithermal-type gold deposits and volcanic rocks had been established from private-enterprise mineral exploration in the "Conway" area. We wanted to clarify whether deposits were associated with the major volcanic-dominated unit previously mapped as the Bulgonunna Volcanics, or some other less well-known unit or units. As a consequence of this focussing of research effort, the stratigraphy and structure of sequences other than volcanic-dominated ones have been considered quite superficially. Much of the information and conclusions relating to such non-volcanic sequences follow those of earlier workers, though not always uncritically.

A progression of preliminary conclusions arising from our fieldwork may be traced in brief reports by Law et al. (1989), Ewers et al. (1989), Department of Primary Industries and Energy (1989), Oversby et al. (1990), McPhie et al. (1990), Black et al. (1990), Ewers et al. (1991), and Oversby et al. (1991). Data and conclusions from the deposit-scale research, and specific regional applications arising from it, have been presented by Ewers (1989, 1990a, 1990b, 1991), Ewers & Hoffman (1992), Ewers et al. (1990), Ewers, Mackenzie et al. (1993), Ewers, Wood et al. (1993), and Ewers et al. 1994. The prospecting activity for epithermal-type deposits around "Conway", which prompted our work and the related studies, has been summarised by Ewers, Wood et al. (1993).

Supplementary investigations pertinent to our understanding of the regional geological framework in the study area, have been undertaken by Black (1994) and Klootwijk et al. (1993). These reports are summarised by their authors in Appendices 2 and 3, respectively, of this text. As will be discussed further below, the age of part of the Bulgonunna Volcanic Group remains in dispute. Sparse geophysical data available at the time of our study are also summarised (Appendix 4).

In descriptions of igneous rocks below, we follow the convention of Oversby et al. (1991, p. 4) regarding abundances of pyroclastic lithic clasts and crystals grains and phenocrysts crystallised *in situ*, where appropriate, based on volume percentage contents. Contents were estimated visually from hand specimens and thin sections using the American Geological Institute's data sheet 15.1 (Deitrich et al. 1982) as a guide.

Formal nomenclature of intrusive igneous and pyroclastic rocks follows IUGS recommendations (e.g. Le Maitre, 1989). One informal name, used as a convenient shorthand descriptor of a particularly distinctive type, is "elvan"(cf. Bates & Jackson, 1980, p. 201), In our usage, this is a microgranite-microgranodiorite containing quartz and/or feldspar phenocrysts in a notable combination of moderate to high abundance and large size (commonly one centimetre or more). Typically, "elvans" make up late-stage subvolcanic stocks, plugs and dykes throughout the North Queensland Igneous Province; they are characteristic of ring-dyke systems.

During most of the duration of map and text preparation, the American DNAG timescale (Palmer 1983) was used as a definitive guide to the interpretation of geochronological data in terms of geological Periods and Epochs. In this timescale, the Devonian/Carboniferous boundary is given an age of 360 Ma, the mid-Carboniferous is approximately 310 Ma, and the Carboniferous/Permian boundary is 286 Ma. However, according to the most recent AGSO timescale (Jones & others 1995), these ages should be 354 Ma, 325 Ma, and 298 Ma respectively. The youngest age obtained from Bulgonunna Volcanic Group (Arundel Rhyolite) rocks, of 299.1 to 287.9 Ma taking uncertainty limits into account, was entirely

Late Carboniferous (Westphalian-Stephanian) according to the DNAG timescale, but straddles the Permian-Carboniferous boundary (Stephanian to Sakmarian) in the AGSO scheme. This accounts for a conspicuous discrepancy between map unit codes based on Cub, indicating an Upper Carboniferous position (i.e. Late Carboniferous age), for Bulgonunna Volcanic Group rocks, and the Early Permian younger age limit quoted in Appendix 2. While the Cub notation based on the DNAG timescale is misleading, unless or until the age of the boundary is revised upwards again, it has the slightly redeeming feature of maintaining conformity with earlier maps (e.g. Paine & Cameron 1972; Levingston 1981).

With one exception, a traditional name is used for the various tectonic entities discussed here. The one exception is our North Queensland Igneous Province, which is used in AGSO's electronic database system for the Coastal Ranges Igneous Province of Stephenson & Griffin (1976) and Henderson (1980), and the "North Queensland volcanic and plutonic province" of Day et al. (1983).

Geochemical and geochronological data from samples acquired during the study have been entered into AGSO's ROCKCHEM and OZCHRON databases. Because the electronic database system was not fully developed until after completion of our field research and initial synthesis, supporting SITES, OUTCROPS, and ROCKS entries have been made only for the analysed and dated samples, rather than for all field observation sites as is now mandatory. Palaeomagnetic data reside in an informal database which is currently (May, 1994) in process of being converted to the AGSO standard format (Oracle 6.0).

Where quoted in this text, grid references are given to six figures, preceded by four digits which denote the relevant 1:100 000 Sheet area (see map).

Location, Access, and Population

Burdekin Falls Dam, which impounds Lake Dalrymple, lies approximately 150 km southeast of Charters Towers. It can be reached from there, via Mingela and Ravenswood, by a sealed road. It can also be reached from Collinsville, which is 130 km to the east, by good- to moderate-quality unsealed shire roads, via "Strathmore" homestead, and from Mount Coolon, about 90 km to the south-southeast. "Conway" homestead is about 50 km southeast of Burdekin Falls Dam. A causeway across the Burdekin River at the foot of the dam connects the main northern and southern access routes; however, it is impassable in dam-overflow conditions. In addition to the main access routes, the study area is served internally by several homestead roads, and a network of minor tracks (some along fences and power lines). These minor tracks tend to be more numerous, and in better condition, in the southern half of the area.

Apart from "Conway" and several other homesteads, the area contains no permanent settlements. The main land-use activity is beef cattle-grazing, with as-yet small-scale and sporadic mining. Expanding tourism and recreation facilities are centred on Lake Dalrymple near the dam.

Climate, Physiography and Drainage

The climate is subtropical monsoonal, with about 650 mm of rain per year falling mainly between December and March. The entire area lies within the Burdekin River drainage basin, and was originally traversed by a major U-bend segment of that river, and by sections of two major tributaries, the Bowen and Sellheim Rivers. The Burdekin River is now dammed approximately 200 m upstream (northwest) of Burdekin Falls. The impounded water forms Lake Dalrymple, whose surface is about 150 m above sea level. Up to three significant floods affect the Burdekin River (the fifth largest in Australia) each year; many aspects of channel morphology at, and in the gorge downstream from, the still-spectacular falls below the dam can be linked to flood hydraulics (Wohl 1992).

Physiographically, the study area lies entirely within the "Northern Hills" province (CSIRO 1967). Physiographic tracts range from plains separating high-relief tablelands and mesa-like landforms in the south, to irregular and high-relief highlands in the centre and central-north. These highlands make up the crest and western fall of the northern Leichhardt Range; the irregular eastern front of the range is subparallel to the course of the Bowen River, and to that of the Burdekin River downstream of the Bowen junction. The three highest summits in the study area are: Mount Constance (grid reference 8356-413087, 573 m); Mount Wickham (grid reference 8357-457403, 554 m); and Mount Landsborough (grid reference, 8356-342898, 549 m). There is a direct relationship between relief in the study area and the density and quality of sub-Cainozoic rock exposures. Exposures are of moderate to high density and quality in the north and northeast. They deteriorate southwards (particularly in the southeast), where Cainozoic cover rocks and/or weathering profiles become increasingly common. The tablelands and mesas made up of such Cainozoic material are conspicuous near "Conway", and farther south.

Vegetation in the study area is mainly open dry sclerophyll woodland dominated by "ironbark" species (predominantly *Eucalyptus culleni*).

The location of Glendon Creek shown on our map conforms with the standard, and most readily obtained, 1:100 000- and 1:250 000-scale topographical coverages. However, a 1:25 000 map produced by the Queensland Department of Mapping and Surveying (1978) shows Glendon Creek to be the main south-trending watercourse which passes to the east of "Glendon" homestead. The shorter northeast-trending watercourse which joins this about 200 m north of the homestead is named as Spring Creek, rather than Glendon Creek. We think that this identification of the longer watercourse as Glendon Creek is correct (i.e. conforms to traditional local use). However, we have followed the standard 1:100 000 and 1:250 000 placement of Glendon Creek on our geological map, and in relevant discussions which follow, to avoid confusion. Similarly, we believe from the holder of Pyramid Station that Mount Dalrymple and The Pyramid should be interchanged

- hence the apparently erroneous Mount Dalrymple Prospect (no 29) adjacent to The Pyramid on our map. However, we have retained the names in their "official" positions in all instances other than that of the Mount Dalrymple Prospect.

Geological Setting and Previous Investigations

Most of the study area is underlain by rocks of the southeastern Lolworth-Ravenswood Block, northern Anakie Inlier, northern Drummond Basin, and southern North Queensland Igneous Province (see map). The easternmost part of the area contains the northwestern Bowen Basin, as well as a manifestation of the Millaroo Fault Zone, postulated to mark the contact of the Lolworth-Ravenswood Block and Anakie Inlier with the concealed northern New England Orogen. The regional geology, relationships, and significance of these tectonic elements have been discussed succinctly by Henderson (1980), Day & others (1983), and Coney & others (1990). In any terms, the study area is unusual and important in embracing parts of so many major pre-Cainozoic elements and their contacts.

The Lolworth-Ravenswood Block extends into the northern part of the study area from Charters Towers and vicinity. It consists of: mainly low grade Cambrian to Early Ordovician marine and continental calc-alkaline felsic volcanics and clastic sediments; local higher-grade and possibly Proterozoic metamorphic rocks; up to three generations of tight to isoclinal folds with west and west-northwest trending axes; a large synorogenic mid- to Late Ordovician granodiorite batholith; and a postorogenic Late Silurian to Early Devonian granite batholith with subsidiary plutons. The Anakie Inlier extends into the southern part of the study area from the Clermont - Rubyvale district.The Inlier exposes: mainly low- to medium-grade Cambrian to Early Ordovician, and possibly at least in part Proterozoic, marine sediments and mafic volcanics; possible Late Ordovician clastic sediments, limestone, and volcanics; Lower to Middle Devonian low grade marine sediments; two or more generations of tight to isoclinal folds, axes northeast-trending in Ordovician and older rocks, probably north-trending in Devonian ones; and a postorogenic Devonian granodiorite batholith.

Both the Ravenswood-Lolworth Block and Anakie Inlier have been regarded as exposed parts of the Thomson Fold Belt or Orogen of Kirkegaard (1974) and Murray & Kirkegaard (1978). The belt is commonly perceived as one of several distinctive Queensland components of the more extensive Tasman Orogen (e.g. Murray, 1990), although some workers (e.g. Henderson, 1980) have seen it as a straightforward northern continuation of the Lachlan belt, and thus not deserving of a separate name. Most of the Thomson belt is concealed. The western part of the belt probably overlies Proterozoic rocks; an apparently stratigraphically low association of mafic metavolcanics and serpentinite in the central and southern Anakie Inlier has been taken to indicate the possibility of an oceanic basement to the eastern part of the belt. The belt has been inferred to have developed inboard (i.e. on the hangingwall side) of a west-dipping subduction zone. In this scenario, Lower Palaeozoic rocks of the Lolworth-Ravenswood Block accumulated in an arc (Murray & Kirkegaard 1978) or back-arc (Henderson 1986) setting.

An arc setting may also be represented in at least part of the Anakie Inlier sequence (Murray 1990).

In a supra-regional context, the Thomson belt occupied a very limited area and time span at the extremity of a Palaeozoic orogenic system nearly 20 000 km long which developed along the Pacific margin of Gondwanaland, and extended into Australia from Antactica and the northern Andes (Coney & others 1990).

The Drummond Basin extends into the study area from the Nogoa River west of Springsure. This "transitional" (Geological Society of Australia 1971) tectonic element is usually treated as a late part of the Thomson belt. The basin mainly contains: essentially unmetamorphosed Late Devonian to Early Carboniferous fluvial siltstones, sandstones, and conglomerates; stratigraphically low calc-alkaline felsic volcanics; and approximately mid-Carboniferous open folds with moderately dipping limbs, axes north- to north-northwest- and northeast-trending. The Drummond Basin evidently developed in an intracratonic, and probably fundamentally extensional (Hutton & others 1991; Johnson & Henderson 1991), environment. A back-arc situation has most commonly been envisaged, with the coeval Andean-type arc being at the site of the Connors Arch (see map).

The North Queensland Igneous Province is most extensive to the north of the study area, although it may extend as far south as Broad Sound, just beyond Mackay. The Province is dominated by: unmetamorphosed mid- and Late Carboniferous to Early Permian rhyolitic ignimbrite-dominated sequences; granitic to granodioritic batholiths and subsidiary plutons; and cauldron structures variably deformed internally by subsidence. The scattered components of the Province overlie and intrude older tectonic elements throughout northeastern Australia. In the study area, the Anakie Inlier and eastern Drummond Basin are more extensively affected than the Lolworth-Ravenswood Block. The North Queensland Igneous Province was probably extensional to some degree at all scales (cf. Oversby 1987). It has most commonly been compared to an Andean magmatic arc (cf. Murray & others 1987); that part of the Province lying within the study area, and granitoid representatives in the Connors Arch, have been treated as shallow western and deeper eastern parts respectively of a single "Urannah Arc" (Allen 1993, 1994), separated by Bowen Basin rifting. Tectonism controlling development of the North Queensland Igneous Province could possibly have involved a special and unusual, perhaps unique, interplay of subduction and "membrane tectonics" (cf. Oversby 1988, 1995).

Some authors (e.g. Henderson 1980; Oversby & others, 1980) include upper Devonian and Lower Carboniferous volcanics of the Drummond Basin sequence in the roughly equivalent Coastal Ranges Igneous Province. We do not follow that approach with the North Queensland Igneous Province (and thus justify use of the new name), because the two tectonic entities appear to have been temporally separate, with no developmental overlap.

The exposed Bowen Basin extends into the easternmost part of the study area from the Springsure - Emerald district. The basin contains: mostly unmetamorphosed Permian to

Middle Triassic continental and marine clastic sediments, limestone, and coal; broad and open folds, axes north-northwest- to northwest-striking. The mildly deformed western part of the basin extending into the study area contrasts with its syndepositionally unstable and more deformed eastern part. The Bowen Basin has mostly been regarded as a foreland trough which developed to the west of a deformed (during the mid-Carboniferous) and rising northern New England Orogen, probably as a continuation of the Sydney and Gunnedah Basins. However, its origin is far from certain (Hammond 1987, cf. Allen 1993, 1994), and its evolution was not at all straightforward (Murray 1990b). A case can be made for a developmental continuum or overlap between latest North Queensland Igneous Province and earliest Bowen Basin evolution during Early Permian time.

The Millaroo Fault Zone also occurs in the easternmost part of the study area. This zone has been considered to be a probable continuation of the Palmerville Fault farther north. It has also been identified as the local reflection of an otherwise concealed contact between the Thomson and northern New England Orogens (cf. Appendix 4). During late Palaeozoic time, the zone probably underwent little, if any, displacement; however, it may have played an important part in channelling magmas through the middle(?) and upper crust crust to the surface (cf. Oversby & others 1980).

Scattered outliers of Tertiary sedimentary rocks (Suttor Formation) in the study area record fluvial and lacustrine deposition. Scarce Tertiary basalts provide a diffuse spatial, and possibly temporal, link between the Eocene-Oligocene Mingela Province (mainly plugs) and the Pliocene-Pleistocene Nebo Province (plugs and flows, central volcanoes) (e.g. Stephenson & others 1980) to the north and south of the study area respectively. The development of Cainozoic volcanic provinces throughout eastern Australia has been related to continental migration over "hotspots" in a series of papers by Sutherland (e.g. 1991).

The first brief geological observations in the Burdekin Falls Dam - "Conway" area were made by Ludwig Leichhardt in 1845, while resting-up between 28th March and 2nd April beside the Suttor River opposite Mount McConnell. Leichardt recorded that Mount McConnell was composed of a variety of "domite" (strictly, an altered porphyritic oligoclase-biotite trachyte named from an occurrence in the Auvergne district of France - cf. Bates & Jackson 1980 p. 184); sienite [*sic*] was noted on nearby hills. The river gravel " . . . . furnished quite a collection of primitive rocks . . . . " (Leichardt 1847 p. 200). Subsequent more systematic early investigations in and adjacent to the Burdekin Falls Dam - "Conway" area (e.g. Jack 1889) were undertaken in support of active mineral (mainly gold) prospecting and exploitation, as in the present study. The results of more recent first-generation regional mapping have been summarised in syntheses presented by Olgers (1972), Dickins & Malone (1973), and Levingston (1981). Collectively, these syntheses contain a very comprehensive bibliography of relevant literature up to approximately 1980.

Russo & others (1985), Bock & others (1986), and Burton & Lawson (1988) presented information relating specifically to the design and construction of Burdekin Falls Dam.

Acknowledgments

This investigation was initiated in 1987 by Dr R.W. ("Dick") Henley, the then-Chief of the Division of Petrology and Geochemistry in BMR, after consultations with senior staff from the Exploration Department of BHP-Utah Minerals International, Asia Pacific Division. Agreement was reached that Dr Greg R. Ewers (BMR) would direct a programme of specialist research at BHP's "Conway" gold prospects. The investigation reported on here would complement the specialist studies, and facilitate their evaluation within a context of more than local scope and significance. In its initial phases, the investigation benefited considerably from the supervision and advice of Drs Henley and R.W. ("Wally") Johnson.

Queensland Water Resources Commission staff at Burdekin Falls Dam and, in 1987, Bowen Shire road construction personnel to the south of the dam, unstintingly provided advice, assistance and facilities, without which field research in the area would have proceeded far less efficiently. Graziers throughout the study area were invariably friendly and cooperative, and freely granted access to land under their control. Aspects of that part of the study undertaken by D.E.M. in the northwest benefited from discussions with Hunter Resources' field personnel in 1988.

Jocelyn McPhie acknowledges the receipt of a Queen Elizabeth II Fellowship, which enabled her to participate in research at BMR.

VOLCANIC, SEDIMENTARY, AND METAMORPHIC ROCKS

LOLWORTH - RAVENSWOOD BLOCK

Rocks belonging to the Lolworth - Ravenswood Block crop out only in the northwest. They are unconformably overlain by, or (more commonly) in structural contact with, several Drummond Basin and Coastal Ranges Igneous Province depositional units down to the level of the Stones Creek Volcanics. Stratigraphic contacts with these overlying units appear to be erosional, rather than depositional, "feather edges".

Cape River Metamorphics, ЄOc (*ЄOc of Oversby et al. 1991*)

The Cape River Metamorphics (Henderson 1986 - previously Cape River Beds) consists of micaceous (muscovite + biotite) and subsidiary non-micaceous quartz-feldspar schists and quartzite, with arenites (quartzose, quartzofeldspathic, and lithic), and thin-bedded fine arenites and siltites. The unit is of unknown thickness.

Seventy Mile Range Group Undivided, ЄOs, and Mount Windsor Volcanics, ЄOsw (*ЄOs, ЄOw of Oversby et al. 1991*)

An unknown thickness of rocks tentatively assigned to the undivided Seventy Mile Range Group (Henderson 1986) crops out in Glenroy Creek, 11 km north of "Glenroy" outstation. The sequence appears to occupy a graben-like structure and contains well-sorted feldspathic and quartz-feldspar arenites, silty feldspathic arenite, and minor flow-banded rhyolitic lavas(?). The arenites have been regionally(?) metamorphosed and/or altered, and intensely hornfelsed (presumably by the Stuart Pocket Granite - below) to assemblages containing quartz, plagioclase, and K-feldspar together with various combinations of biotite, hornblende, chlorite, sericite, epidote-clinozoisite, calcite, and prehnite.

The feldspathic, rather than lithic, labile component in the arenites, and the associated rhyolites, suggest that the sequence has affinities with the supra-Mount Windsor Volcanics Trooper Creek Formation of Henderson (1986), rather than underlying Puddler Creek Formation. This is consistent with the field indications of stratigraphic relationships (below), and is significant in terms of mineral deposit potential (as discussed further below under "Metalliferous Mineral Deposits and Economic Potential").

These rocks partly overlie, and may partly interfinger with, the Mount Windsor Volcanics. The latter, the most extensively exposed of the sub-Drummond Basin sedimentary and volcanic units in the northern part of the area, may overlie the Cape River Metamorphics. It consists predominantly of pale grey to pale greenish-grey, sparsely porphyritic, sporadically flow-banded and locally spherulitic, rhyolite of uncertain origins. This rock is characteristically intensely sheared and/or brittle-fractured, and variably altered. Quartz veins (individuals and stockworks) and disseminated fine pyrite are common. In a few places, the rhyolite is extremely fine-grained, suggesting possible quenching by emplacement into water or near-surface wet sediment.

The rhyolite is associated with small volumes (not shown on the map) of aphanitic andesite to basalt, sparsely porphyritic dacite to andesite, pelitic schist and very rare rhyolitic to dacitic ignimbrite. Some or all of these minor rock types may properly belong to some unit, or units, other than the Mount Windsor Volcanics.

Local occurrences of metarhyolite and metabasalt surrounded by probable Ukalunda Beds, in the vicinities of Sandy Creek and the Sandalwood - Desmond Creek junction of the northeastern study area may represent structural interleaves of the Mount Windsor Volcanics

Some rocks in the northwest included in intrusive groupings CPr_1 and CPr_3 which cut undivided Seventy Mile Range Group and/or Mount Windsor Volcanics could be related to the latter, rather than being of late Palaeozoic age.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Mount Windsor Volcanics (their unit 67) rocks are (tentative) I-types, unfractionated, oxidised, and high-potassium (based on thirteen analyses, including four unpublished AGSO ones). Stolz (1994) has related the geochemical and neodymium isotopic characteristics of all three formations which make up the Seventy Mile Range Group to subduction tectonics.

ANAKIE INLIER

Rocks in the north-trending Anakie Inlier are overlapped by, and/or structurally juxtaposed against Drummond Basin and younger sequences. Deposition may have extended from the Proterozoic (Henderson 1980) to the early Middle Devonian (Day et al. 1983) although it was interrupted, at least locally, by one (Ordovician?) or more significant phase/s of folding and metamorphism. Granitoid intrusion probably continued until the late Middle Devonian.

Anakie Metamorphics? (not shown on the map)

The Anakie Metamorphics were named (originally as Anakie Series) from Anakie (Jensen 1921). Regionally, the unit consists of a tightly folded assemblage of quartz-muscovite and "knotted" schists, phyllite, slate, quartzite, lithic sandstone, and minor limestone and volcanic rocks. The assemblage has traditionally been regarded as being of probable early Palaeozoic age (e.g. Olgers 1972, Day et al. 1983). However, Henderson (1980) compared the assemblage with a similar one in the Lolworth-Ravenswood Block, and considered a Proterozoic age more likely.

Previous workers failed to recognise the Anakie Metamorphics in the map area. However, Hutton et al. (1991) considerably extended the mapped distribution of the unit (although represented mostly by very low grade rocks) in the Mount Coolon 1:100 000 Sheet area. This suggested the possibility of occurrences even farther north, and a connection with rocks of the Lolworth-Ravenswood Block (see below under Uncertain "Basement/s").

The Anakie Metamorphics may be represented, at least to the extent of local structural interleavings, by steeply dipping metasedimentary rocks in the middle and upper drainages of Sandy Creek and around the Sandalwood - Desmond Creek. The rocks are all shown as tentative Ukalunda Beds on the map. However, the well-foliated nature of some outcrops suggests that Anakie Metamorphics could be present.

Ukalunda Beds, Dk (*Dk of Oversby et al. 1991*)

As currently used, the formation-rank Ukalunda Beds were named and defined by Malone et al. (1966). A varied marine fauna indicates that they are probably of Middle Devonian age. The differentiation of the Ukalunda Beds and the Anakie Metamorphics is not everywhere clear (cf. Malone et al. 1966; Hutton et al. 1991).

Regionally, the Ukalunda Beds contain siltstones, sandstones and limestones; local variations in the proportions of these rock types have been used as the basis for informal subdivision. The unit is believed to have been folded and cleaved (to a substantial degree locally), and mildly metamorphosed, during an event commonly equated with the Tabberabberan Orogeny.

Hornfelsed rocks tentatively assigned to the Ukalunda Beds occur in two small (the most extensive about 0.5 km^2) inliers surrounded by Palaeozoic granitoids in the middle and upper drainages of Sandy Creek (about 3 km east of the old Burdekin River weir). Similar rocks also occur in a more extensive area nearby, from southeast to northwest of the junction of Sandalwood and Desmond Creeks. The rocks are dark blue, cleaved to foliated, and range from metamudstone to metaconglomerate. They contain common quartz veins, some of which are intricately folded. Bedding, where recognisable, is medium to thick and tabular; dips are steep to vertical. Cleavage is commonly subparallel to bedding; northwest strikes, subparallel to contacts with adjacent granitoids, are typical. Distinctly schistose, phyllosilicate-rich, rocks are present locally. As well as being intruded by granitoids, the rocks in and to the west of Sandalwood Creek are believed to be overlain unconformably by probable Stones Creek Volcanics and ignimbrite assigned to the Collins Creek Rhyolite (Bulgonunna Volcanic Group). Metavolcanics (closely brittle-fractured, greenish-grey, spherulitic and siliceous metarhyolite and dark bluish-green "spotted" metabasalt), which are included in the probable Ukalunda Beds, crop out in an area of presumed structural complexity cut by numerous late Palaeozoic (CPr_3) dykes, approximately 3 km northwest of the junction of Sandalwood and Desmond Creeks.

The most intensely deformed of the rocks tentatively regarded as Ukalunda Beds could be Anakie Metamorphics, as discussed above. The Mount Windsor Volcanics may also be represented by the local occurrences of metavolcanic rocks.

We follow previous workers (e.g. Paine et al. 1972) in confidently recognising the Ukalunda Beds in a series of outcrop areas in the central-east part of the study area (middle Mary Creek - Peak John Well - southern Mount Constance). These occurrences are at the northwestern edge of a discontinuous, but major, outcrop of the formation which extends east and north-northeast to here from the type area in the southwest, via Mount Wyatt (central-south). Definite Ukalunda Beds to the west-northwest of Peak John Well are in steep juxtaposition with (faulted against?) rocks to the northwest which are tentatively assigned to subunit DCs_1 of the Stones Creek Volcanics (below), but which could also be Ukalunda Beds (or distal Bimurra Volcanics). The Ukalunda Beds are also in faulted(?) contact with Locharwood Rhyolite and un-named unit Cub_{21} (Bulgonunna Volcanic Group - below). As in the northeast, rocks considered to be definite Ukalunda Beds are distinguished by the development of phyllosilicate minerals and the presence of a distinct cleavage, presumably due to low-grade regional metamorphism. These features, and the local abundance of quartz veins, suggest that the rocks have undergone substantially stronger deformation than have adjacent Bulgonunna Volcanic Group units; hornfelsing by late Palaeozoic granitoids is not particularly obvious. Cream, dark blue and purple interbedded quartzite, micaceous sandstone, and slaty mudstone are the most common rock types.

Rocks assigned to the Ukalunda Beds in the type area and elsewhere in the area are predominantly mid greenish-grey to greenish-brown silty mudstones, with other rock types mostly being rare to subsidiary. Thin limestone (marble) lenses occur sporadically to the southeast of Mount Landsborough. Stringers and veinlets of quartz are locally common. The rocks are not conspicuously folded, and a "cleavage" developed in the mudstones may be sedimentary fissility rather than a true deformational feature. Differentiation between the Ukalunda Beds and the Mount Wyatt Formation (below) follows previous work where mudstones are also dominant in the latter unit.

Gold has been mined from the Ukalunda Beds at the Salopia (28 on the map), Southern Cross (24), and Golden Ridge (25) Mines, and gold plus copper from the "Copper Contact Zone" with Percy Douglas Granodiorite at the Big Hope Mine (23); tentative Ukalunda Beds are host to gold at the Leichhardt Vale Mine (9). Silver has been won from the unit at the Birthday Gift Mine (26), and copper at the Margaretta Mine (31) (mines 9, 23-25, 31 = Mount Wyatt Goldfield; 28 = Ukalunda Silver Field). Ukalunda Beds also occur (with CPr_1-type rhyolite and andesitic Bimurra Volcanics) in the Battery Hill (6) and Blue Gum (14) (gold) Prospects. A Pb-Zn skarn prospect (Mount David, 37) occurs in Ukalunda Beds about 2 km south of the Blue Gum Prospect.

BASEMENT MATERIAL OF UNCERTAIN AFFILIATION

The xenolith population in a late Palaeozoic granitoid (a component of un-named grouping CPg_{10} - below) about 3 km north of "Glendon" homestead includes dark grey metasedimentary rock and well-foliated schist. Some of the schist displays a distinct crenulation cleavage superimposed on its foliation, evidence of significant multiple deformations. These xenoliths could represent Anakie Inlier and/or Lolworth - Ravenswood Block "basement".

Muscovite schist clasts occur in a heterolithic breccia associated with dominant dacitic ignimbrite (currently tentatively included in the Star of Hope Formation subunit Cls_2 - see below for further discussion), also in the northeast. The clasts were observed in a tributary of Collins Creek, 5.3 km south-southeast of "Glendon" homestead. Although the clasts could conceivably have travelled for up to a few tens of kilometres from source, they are considered to be indicative of the presence of high grade metamorphics at depth in the general area. Again, this material could have been derived from either of the two potential "basements" in the area.

Nearby, gneissic granite occurs in very limited and generally poor outcrops in an area too small to show on the map, 6 km northwest of the junction of Sandalwood and Desmond Creeks, surrounded by unfoliated rocks assigned to un-named granite unit CPg_3. Foliated granitoids are not known to occur elsewhere in the late Palaeozoic plutons of the northeastern Burdekin Falls Dam - "Conway" area; the occurrence is accordingly believed to represent local "basement" unrelated to CPg_2, in an inlier or roof pendant.

On the basis of available data, we are unable to judge whether the material described above belongs to the Anakie Inlier or Lolworth - Ravenswood Block, or both/neither. However, the observations are taken as confirmation that there was spatial continuity, and perhaps some degree of temporal equivalence, between rocks making up the main "basement" elements (or element, if original relationships were sufficiently close) prior to accumulation of the northern Drummond Basin sequence.

Precambrian zircon grains, up to slightly more than 2500 Ma old according to their U-Pb isotopes, recovered from several Palaeozoic rocks in different parts of the map area (as discussed further by Black 1994, and Appendix 2) are of uncertain, possibly composite, provenance.

Dated (whole-rock plus biotite Rb-Sr) Peak John Well Granite from west-northwest of Peak John Well (sample 88502866, grid reference 8356-370047) has a strontium isotope initial ratio of 0.7253. This high value could be indicative of "old" (i.e. Proterozoic) crust as source material for this mesocratic and biotite-only, somewhat potassic, component of the unit.

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DRUMMOND BASIN

Olgers (1972) subdivided the Drummond Basin sequence into three tectono-stratigraphic sub-sequences ("cycles") separated by hiatuses. The same tectono-stratigraphic framework has been used since, most recently by Hutton et al. (1991) and Johnson & Henderson (1991). The validity of this "layer-cake" approach is unclear, especially in view of the probable syn-depositional extensional deformation and structures, and the potentially complex interfingering and/or diachronous clastic sedimentary facies relationships. All such settings probably require a comprehensive re-evaluation of their "classical" (i.e. 1970s or older) stratigraphic and structural frameworks in the light of current concepts.

Most of the stratigraphic units discussed below belong to Olgers' (1972) "conventional" Cycle 1. The Scartwater Formation accumulated in "conventional" Cycle 2, and the Star of Hope Formation in Cycle 3.

Mount Wyatt Formation, Dum (*Dum of Oversby et al. 1991*)

The Mount Wyatt Formation was named by Olgers (1972) from Mount Wyatt, 15 km northwest of "Conway" homestead itself. The formation is of Late Devonian age. In its rather limited regional distribution, the Mount Wyatt Formation consists mainly of lithic sandstone, siltstone, shaly mudstone, conglomerate and chert. Volcanic and sedimentary rocks to the south of the Sellheim River, which were originally placed in an un-named unit (Malone et al. 1966), and later assigned to the upper Mount Wyatt Formation (Olgers 1972), are now considered to be Bimurra Volcanics (below). The Mount Wyatt Formation is unique in being the only unit in the Drummond Basin sequence that contains marine fossils (in its lower part), and which can be considered to be well-dated palaeontologically. At least 1500 m of the formation have been estimated to occur in the type area (Olgers 1972). However, we believe that probably no more than about 500 m occur anywhere in the area (including the type area).

The Mount Wyatt Formation in the southwest and southeast is made up of varying proportions of the sedimentary rock types which characterise it regionally. In localities where mudstones predominate, differentiation of the unit from Ukalunda Beds arbitrarily follows previous mapping.

The restricted distribution of the Mount Wyatt Formation is probably mainly a consequence of unconformable relationships with overlying Drummond Basin units. Specifically, in the south substantial instability, with uplift and erosion of at least partly subjacent (rather than laterally equivalent, as argued below) Mount Wyatt Formation, may well have accompanied the extrusion of the Bimurra Volcanics.

Bimurra Volcanics (Undivided), DCb, and Un-Named Subunits, DCb_1 to DCb_3 *(part DCv, $DCv_{(S)}$, $DCv_{(A)}$, $DCv_{(B)}$, $DCv_{(I)}$, Dcv_{di}, Cv_{la} of Oversby et al. 1991)*

The formation-rank Bimurra Volcanics were named by Hutton et al. (1991) from Bimurra (gold) Prospect, about 10 km south-southwest of "Conway" homestead (in the Mount Coolon 1:100 000 Sheet area). The nominated type section of the formation (Hutton et al. 1991, p. 22) extends from "Conway" southwards to Conway Creek " . . . . just north of Bungobine Creek [*sic*] . . . ." (this should read Bungobine Peak according to L.J. Hutton, personal communication 1992).

The Bimurra Volcanics consist of a folded sequence of lavas and tuffs, with local minor sedimentary rocks. The formation is believed to be at least 3500 m to 4000 m thick in and around its type section. The sequence consists of a lower interval of andesitic rocks, overlain by an interval in which trachyandesitic to trachytic lava and tuff are interbedded with minor rhyolitic lava and tuff, passing gradationally upwards into predominantly rhyolitic rocks with sedimentary interbeds.

The type Bimurra Volcanics were thought by Hutton et al. (1991) to underlie and/or to be laterally equivalent to the lowermost part of the Mount Wyatt Formation (and thus, by implication, to be of Late Devonian age). However, abundant plant fossils have been obtained from siliceous rocks in both the southeastern Glendon and adjacent Mount Coolon 1:100 000 Sheet areas (Wobegong and Durah Creek occurrences respectively - cf. Ewers et al. 1993). Among the fossils is a form identified by Dr L.N. Morris (as credited in White et al. 1989, p. 722) as *Oxroadia gracilis*. The type material of this species (from a loose block at the foot of sea cliffs in Scotland!) is believed, from its matrix and position relative to *in situ* stratigraphy, to be of Tournaisian (early Early Carboniferous) age (Alvin 1965). In common with other researchers (White et al. 1989; Hutton et al. 1991, Ewers et al. 1993), we regard the fossiliferous siliceous rocks as genuine palaeo-sinters - chemical sedimentary components of the Bimurra Volcanics sequence formed contemporaneously with accumulation of that sequence. Thus, in the absence of information to the contrary (e.g. an age other than Tournaisian indicated for Australian *Oxroadia gracilis*), we assume that the Bimurra Volcanics sequence is at least in part of Early Carboniferous age, younger than the demonstrably Late Devonian portion (and probably the whole) of the Mount Wyatt Formation. Observations (mostly by S.R.L.) to the north and west of "Conway" suggest that the Bimurra Volcanics there overlie the Ukalunda Beds with variably angular unconformity.

Volcanic-dominated Drummond Basin sequences farther north (mainly in the northwestern map area) are assigned either to the Stones Creek Volcanics (see below), or to a currently un-named interval, probably lying within the Star of Hope Formation (see also below), rather than to the Bimurra Volcanics. Although the sequences have some similarities to each other, we consider that the differentiation of the Bimurra Volcanics from the northern units is justifiable on the grounds of non-continuity between them; each probably emanated from its own geographically separate eruptive centre or group of centres.

The Bimurra Volcanics sequences in the vicinity of "Conway" homestead, and at other localities in the southeastern part of the study area, contain a heterogeneous assemblage of mostly intermediate extrusive, with subordinate sedimentary, rocks up to a tentative estimate of 3500 m thick. Probable small-volume ignimbrites occur in the unit. Volcaniclastic conglomerate intervals are common (the sedimentological characteristics of these and most other rudaceous rocks in volcanic-dominated units have not been studied in detail; reworking may have been minimal. At least some could be primary pyroclastic rocks containing "milled" pebbles and cobbles).

Locally, the southeastern Bimurra Volcanics are dominated by sedimentary rather than extrusive rocks, although the latter are nowhere entirely lacking. Such sedimentary rock-dominated occurrences are placed in a discrete subunit, DCb_1 ($DCv_{(S)}$ of Oversby et al. 1991), which consists mainly of interbedded purple, grey and red siltstones (locally muddy), and very fine- to medium-grained volcaniclastic sandstone. Volcanic-clast "conglomerates" are a minor component.

Different ignimbrite types ($DCv_{(I)}$, DCv_{di} of Oversby et al. 1991) in the Bimurra Volcanics are now all assigned to subunit DCb_3. They consist of: a purple, moderately crystal- poor, lithic-clast-poor, originally thoroughly welded, probably dacitic rock containing white feldspar and rare quartz, but without fiamme; and a buff, pale green or mauve, crystal-poor to moderately crystal-poor, lithic-clast-poor to moderately clast-poor, originally thoroughly welded dacitic(?) rock with characteristic dark green fiamme. Both rock types may be parts of a single ignimbrite sheet (cooling unit rather than flow unit?); both are overlain by a volcaniclastic conglomerate (not differentiated on the map). This conglomerate contains subangular to rounded pebbles to small boulders (up to 30 cm in maximum dimension) of both ignimbrite types, plus porphyritic andesite (see also below), with rare granite and sedimentary(?) siltstone. The conglomerate also contains at least two blocks of laminated sedimentary mudstone more than 10 m in maximum dimension, which suggests proximity to an eruptive centre and/or caldera wall. Bedding orientations within both blocks are variable, indicating folding and/or partial fragmentation with sub-block rotation at the time of incorporation into the host conglomerate.

Andesite ($DCv_{(A)}$ of Oversby et al. 1991), included in the southeastern Bimurra Volcanics as part of subunit DCb_2, is dark green and contains 10% to 25% plagioclase phenocrysts. It is locally (auto)brecciated, and assumed to be fundamentally extrusive, although some unrecognised intrusive equivalents may also be present. Assumed extrusive basalt ($DCv_{(B)}$ of Oversby et al. 1991) occurs in or close to some southeastern outcrop areas of the Bimurra Volcanics, and is also placed in subunit DCb_2.

Undated rhyolites in and adjacent to some southeastern outcrop areas of the Bimurra Volcanics (most notably at the Battery Hill and Blue Gum Prospects, nos 6 and 14 respectively on the map) are included in intrusive Coastal Ranges Igneous Province unit CPr_1, in part tentatively. While their geometry leads us to believe that the rhyolite bodies are intrusive, we do not rule out the possibility of an extrusive component in them. Nor do we exclude the possibility that they are manifestations of Bimurra Volcanics magmatism.

Farther west, in the south-centre, rocks tentatively assigned to the Bimurra Volcanics crop out sporadically near "Old Hidden Valley" homestead (previous DCv), and in the vicinity of Havilah Hill (previous Cv_{1a}). At this group of localities, aphyric and porphyritic, locally (auto?)brecciated, extrusive(?) andesites, which have been hornfelsed and quartz-veined near "Old Hidden Valley", are most simply interpreted as outcrops of small structural blocks bounded by faults and intrusive contacts with post-Bulgonunna Volcanic Group granitoid (CPg_2). However, the very limited nature of occurrences, and apparent random mixing with a variety of Bulgonunna Volcanic Group and other rock types in the vicinity of Havilah Hill, suggest that at least some of these outcrops of possible Bimurra Volcanics could actually represent individual very large clasts in a Bulgonunna volcanics-related megabreccia.

Sedimentary rocks tentatively assigned to Stones Creek Volcanics in a northern tributary of Five Mile Creek to the west-northwest of Peak John Well are somewhat similar to, but apparently not so deformed as, adjacent Ukalunda Beds; the rocks contain a volcaniclastic component. This occurrence is about 10 km north-northwest, and 6 km northeast, of definite and tentative Bimurra Volcanics, at the junction of the Sellheim River and Isabella Creek, and near "Old Hidden Valley". The rocks could be a distal representative of the Bimurra Volcanics; however, the closest Bimurra Volcanics are predominantly andesitic (subunit DCb_2), rather than sedimentary, rocks.

Volcanic rocks that occur along middle Oaky Creek and upper Frederick Creek, and their tributaries, in the central-eastern part of the map area (DCv of Oversby et al. 1991) are now tentatively assigned to undivided Bimurra Volcanics (DCb). This assignment is made mainly on the basis that they contain similar rock types to Bimurra Volcanics around "Conway" homestead. However, the stratigraphic position of the rocks is very loosely constrained; they are overlain by Permian Lizzie Creek Volcanics, as can be demonstrated unambiguously at several localities, but other contacts are with intrusive rocks (mostly CPg_{10} granitoids - below) of uncertain age/s, or are faults. The sequence has no exposed base. The nearest outcrops of definite Bimurra Volcanics are about 25 km to the southwest of these Oaky Creek - Frederick Creek exposures. However, the latter volcanics are clearly compositionally distinct from any in nearby Bulgonunna Volcanic Group representatives, and no definite Stones Creek Volcanics or Star of Hope Formation volcanics are any closer than the Bimurra Volcanics. Conceivably, the rocks could represent a discrete volcanic-dominated Drummond Basin, or even North Queensland Igneous Province (below), sequence with no precise equivalents elsewhere in the study area. Thus, the assignment to the Bimurra Volcanics must be regarded as provisional.

Exposure of the probable Bimurra Volcanics in the Oaky and Frederick Creek drainages is very good. The sequence is texturally diverse, but dominated by intermediate-composition rocks. Primary volcanics include: dark blue and dark green feldspar-phyric andesitic lava; feldspar crystal-rich, lithic clast-rich, welded dacitic ignimbrite with black wispy fiamme;

grey, crystal-poor, fine-grained welded dacitic ignimbrite with attenuated fiamme; dark blue, aphyric and fine-grained, basaltic(?) lava(?); and pale, sparsely feldspar-phyric, flow-laminated and spherulitic, felsic (rhyolitic?) lava. Coarse clastic rocks are relatively abundant. They are: dark blue, massive, clast- to matrix-supported polymictic volcanic pebble to cobble conglomerate with feldspathic sandstone matrix; dark bluish-green, polymictic volcanic lithic breccia with conspicuous basalt blocks, sparse relic pumice clasts, and feldspar-crystal-rich matrix; and khaki, massive, pebbly tuffaceous mudstone. The paucity of bedding data precludes a thickness estimate more precise than several tens of metres (two hundred metres possible maximum).

The bulk of the Bimurra Volcanics may have accumulated in a 20 km-wide depocentre, which trended north into the map area from about 20 km north of Mount Coolon (Hutton et al. 1991). Current outcrop areas are delimited eastwards and northwards by faults, suggesting that the postulated depocentre may have been a partial graben (Hutton et al. 1991).

Geochemical data from a small number and limited range of Bimurra Volcanics sedimentary rocks in and south of the area have been presented by Ewers et al. (1992 Table 1 except samples 8750 0082 to -0086, which are "Earlscliffe" association Bulgonunna volcanics). The more extensive petrographic and oxygen, sulphur, and carbon isotope data presented are all from altered or otherwise specially selected material in gold prospects. Hutton et al. (1991) report that the Bimurra Volcanics in the Mount Coolon 1:100 000 Sheet area are all extremely altered. Compositions range from andesitic to rhyolitic, with most material being rhyolitic. The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Bimurra Volcanics (their unit V78) rocks are mafics and I-types, unfractionated, reduced to oxidised, and low- to high-potassium (based on four unpublished AGSO analyses of rocks collected by D.W.).

Rocks assigned to the Bimurra Volcanics occur at all of the known epithermal-type gold prospects in the southeastern Burdekin Falls Dam - "Conway area (nos 6 - 8, 14, 30, and 36 on map), in adjacent Mount Coolon 1:100 000 Sheet area prospects (including Bimurra itself), and probably at Wirralie Mine. The deposits are discussed at greater length below, under "Metalliferous Mineral deposits and Economic Potential".

Saint Anns Formation, DCa (*DCa, DCa_i of Oversby et al. 1991*)

The Saint Anns Formation (the name as originally published, although commonly written St Anns subsequently) was named by Olgers (1970) from a homestead about 50 km southwest of "Conway". The formation is stated to be about 2100 m thick in its type area; it is believed to be of Late Devonian to Early Carboniferous age. Regionally, the Saint Anns Formation consists of conglomerate, lithic sandstone, mudstone, and limestone. Volcanic rocks are minor, except in the "Saint Anns" homestead area itself, where the pyroclastic Llanarth Volcanic Member (Olgers 1972) is developed.

A very approximate maximum of about 500 m of the Saint Anns Formation is estimated to occur in the map area. In addition to the sedimentary rock types which characterise it regionally the formation in the southwest also contains thin (about 3 m) ignimbrites (DCa_i of Oversby et al. 1991) and possible lava of limited preserved extent. These volcanics crop out on the central-west flank of the Pyramid Range, and 6.5 km west-southwest of the southern end of the range. Ignimbrite in the Pyramid Range is very pale grey and nonwelded. At the second locality it is pale buff and green, welded but altered or weathered, apparently very crystal-poor (macroscopically detectable crystals are "kaolinised" feldspars up to about 2 mm across), and contains scattered angular lithic clasts to 25 mm across. It is underlain by about 3 m of generally similar, but "flow" banded, rock which may be lava. This extrusive component of the Saint Anns Formation in the southwest could conceivably represent a tongue of the Stones Creek Volcanics.

The restricted distribution of the Saint Anns Formation in the map area may be at least in part a consequence of it having been uplifted and eroded by Stones Creek Volcanics activity in the northern half of the area.

Silver has been won from the Saint Anns Formation at the New Years Gift Mine (no 27 on the map).

Stones Creek Volcanics (Undivided), DCs, and Un-Named Subunits, DCs_1 to DCs_4 *(part DCv, DCv_s, DCv_a, part DCv_i, DCv_r of Oversby et al, 1991)*

The formation-rank Stones Creek Volcanics (new name) are named from Stones Creek, in the northwestern part of the study area. The type section of the formation lies between 4 km and 8 km northeast of "Glenroy" outstation (Appendix 1).

The Stones Creek Volcanics sequence is estimated to be up to at least 500 m thick. A maximum thickness in the order of 2000 m may be attained locally, although this is probably a function of unseen structural complications rather than stratigraphic superposition. Andesite from the formation 15 km north-northeast of Burdekin Falls Dam has given a pooled (from only two grains) mean U-Pb zircon age of approximately 357 Ma (Black 1994, Appendix 2).

Previous workers (Clarke & Paine 1970, Olgers 1972) recognised and delineated, but did not name, a formation-rank Drummond Basin unit (D/Cv) in the north made up of volcanic and sedimentary rocks which were believed to be of Late Devonian and/or Early Carboniferous age, equivalent to the upper part of the Saint Anns Formation and the Silver Hills Volcanics (Olgers 1972). Plant fossils were reported from the unit at two localities near "Cranbourne" homestead, about 20 km west of Burdekin Falls Dam, in the extreme northwest. The homestead, and possibly both localities, are now covered by Lake Dalrymple. We have not reviewed the original collections; however, the lack of *Leptophloeum australe* among the flora as identified by M.E. White (in Olgers 1972 p. 74) may be indicative of an Early (but not earliest) Carboniferous, rather than Devonian, age.

Rocks (previous D/Cv) considered by us to belong to the Stones Creek Volcanics extend to the western side of Lake Dalrymple, opposite the site of "Cranbourne". Additionally, previous investigations indicate the occurrence of the same, or a similar, unit about 20 km farther to the west-northwest.

Rocks assigned to the Stones Creek Volcanics in the northwest occur in an arcuate outcrop belt extending from the Burdekin River, near its junctions with Stones Creek and Packhorse Creek, northwest to the middle reaches of Glenroy Creek. From there the belt strikes southwest to the western shore of Lake Dalrymple, near the drowned confluence of the Burdekin and Suttor Rivers. In these northwestern occurrences, the formation unconformably overlies, or is in faulted contact with the Mount Windsor Volcanics (see above). It is mainly overlain with apparent conformity by Scartwater Formation. In places it is overlain by the Star of Hope Formation, possibly with slight angular unconformity; however, most contacts with that unit have been faulted. Rocks assigned to the Bulgonunna Volcanic Group overlie the Stones Creek Volcanics unconformably at several localities, although the relationships are demonstrably angular only to the east of Limey Dam (9 km northeast of "Glenroy" outstation), and on the western side of Lake Dalrymple.

The northwestern Stones Creek Volcanics consist predominantly of massive dacitic(?) to (most abundantly) andesitic rocks (DCs_2; DCv_a of Oversby et al. 1991); these are probable lavas, although unrecognisable cogenetic intrusive components may be present. They are accompanied by massive to bedded fragmental (probably mainly or entirely pyroclastic) rocks. Mostly coarse-grained mixed pyroclastic-epiclastic, with medium- to coarse-arenaceous epiclastic, rocks (DCs_1) are also quantitatively important. Rhyolitic ignimbrite and lava (DCs_4), the latter with a probable undifferentiated intrusive component, plus quartz-bearing arenites and finer-grained pyroclastic and epiclastic rocks are notable rare constituents of the main part of the formation.

Probable lavas are concentrated in two, or possibly three, main parts of the northwestern Stones Creek Volcanics, presumably proximal to extrusive centres. Away from these concentrations there is a general lateral and upward gradation into massive fragmental rocks. These eventually grade distally into bedded pyroclastic-epiclastic and epiclastic rocks which become progressively finer-grained and more mature as they interfinger or intergrade with units assigned to the Scartwater and Star of Hope Formations.

The principal development of massive and fragmental dacitic(?) to andesitic rocks in the northwestern Stones Creek Volcanics is in the area bounded by Glenroy Creek in the west, Pebble Creek in the east, Stones Creek in the south, and the outcrop edge of the Mount Windsor Volcanics to the north (the Stones Creek Volcanics' type section - see Appendix 1 - is in the northwestern part of this development). The most conspicuous rock type in the area is massive, moderately to intensely altered, porphyritic augite and hornblende-augite andesite lava(?). This grades locally, particularly westwards and southwestwards (up-sequence), into agglomerates and breccias. Minor volumes of dacite, and rare lithic clast-bearing, crystal-rich, andesitic ignimbrite (and/or welded andesitic breccia - cf. Sparks et al. 1993), are intercalated with the massive andesites. Towards the Mount Windsor Volcanics, unbedded andesitic lithic breccia and lapilli tuff, crystal-lithic ash tuff, and very immature (presumably proximal) pebbly feldspar-lithic arenite to arenaceous rudite made up essentially of andesitic detritus, are intercalated with intervals of massive andesite.

To the east (laterally), and up-sequence, massive andesite by itself gives way to an apparent thickness of about 2500 m (although thickness estimation here is difficult because of patchy outcrop and uncertain structural details) of interbedded massive andesite, andesitic agglomerate and breccia, lithic clast-rich dacitic ignimbrite, andesitic crystal-lithic tuff, feldspar-lithic arenite(?) and rare rhyolitic lava(?). The feldspar-lithic arenite(?) is mid greenish-grey to dark grey, generally well-bedded (locally graded), and is made up essentially of andesite fragments and plagioclase crystals, with rare augite crystals. It is commonly difficult to distinguish between it and the andesitic crystal-lithic tuff in outcrops, and the two end-member rock types appear to grade imperceptibly into each other.

Massive andesite, and andesitic agglomerate/pyroclastic breccia, with intercalated beds of andesitic lapilli to ash tuff and andesite-derived arenite and conglomerate, (described above) extend approximately along strike in the northwestern part of the study area, southeastwards to Packhorse and Stones Creeks. Here, the sequence is much more variable, and parts of it have been repeated and cut out by faults. However, the general succession (reference sections in Stones Creek and on the western bank of Packhorse Creek - Appendix 1) can be inferred to consist of (from bottom to top): andesitic ignimbrite and lava(?) interbedded with andesitic agglomerate/breccia and tuffs (and possibly coarse-grained, very proximal, andesite-derived, epiclastic sedimentary rocks); dacitic ignimbrite; massive andesite; unbedded andesitic rudite and andesitic ignimbrite(?); well-bedded andesitic lithic lapilli and crystal-lithic ash tuffs; and possible andesite-derived epiclastic arenite and rudite.

An interval of massive andesite and andesitic breccia/agglomerate, totalling about 1000 m thick, also extends west to Glenroy Creek. A thinner (a few hundred metres at most) interval makes up the lowermost part of the formation northwestwards to the edge of Stuart Pocket. In both instances there is a progressive northwestward decrease in the volumes of: initially lavas(?), as they interfinger with, and are overlain by, andesitic pyroclastic rocks; and then both lavas(?) and pyroclastic rocks, as they in turn interfinger with, and are overlain by, a variety of epiclastic sedimentary rocks. The pyroclastic rocks include: poorly-sorted andesitic lithic-crystal to crystal-lithic tuff and breccia, which locally (notably to the east of Glenroy Creek, 7.9 km north-northeast of "Glenroy" outstation) contain small lapilli (2 mm) to large blocks (500 mm maximum) of vesicular andesite; andesitic lithic lapilli tuffs and small-lapillus to medium-block (200 mm) breccias; lithic clast-rich and moderately crystal-poor to lithic-poor but crystal-rich dacitic ignimbrite; lithic clast-poor and (small) crystal-poor rhyolitic to dacitic ignimbrite; and thin (up to 15 cm) intervals of rhyolitic fine-ash (dust) tuff, some of which is silicified.

Stratigraphically concordant intervals, up to several metres thick (and thought to represent lava flows), of sparsely porphyritic, flow-banded and commonly brecciated, rhyolite, and of variably porphyritic dacite, occur sporadically throughout the Stones Creek Volcanics to the north and northeast of "Glenroy" outstation.

The uppermost Stones Creek Volcanics near Glenroy Creek, 3.5 km northeast of "Glenroy" outstation, is marked by an approximately 10 m to 15 m thick sheet of lithic clast-poor, moderately crystal-poor, originally nonwelded, rhyolitic ignimbrite.

The epiclastic rocks in the Stones Creek Volcanics are lithic to quartz-feldspar arenite, pebbly arenite, lithic conglomerate, siltstone, and rare mudstone. Additionally, in the vicinity of Stuart Pocket area, "chert" (at least some of which may be silicified fine ash tuff) and jasper occur in local beds up to a few centimetres thick, and in lenses up to 10 cm thick and 1 m to 2 m long. Quartz-rich arenites are exceptional. The only known two examples are: a variety made up mainly of subangular to angular granite-derived quartz plus feldspar grains near Stuart Pocket; and one containing augite, quartz, and lithic (rhyolite to andesite, phyllite, and granite) grains which crops out to the west of Glenroy Creek, 7.7 km north of "Glenroy" outstation. Both of these occurrences are near the base of the local Stones Creek Volcanics. Lenses of algal(?) limestone up to about 20 cm thick by 1m long occur in lower Stones Creek Volcanics in the vicinity of Stuart Pocket, and in middle and upper parts of the formation on the eastern side of Glenroy Creek.

On the western side of Glenroy Creek, and near Stones Creek to the north of "Glenroy" outstation, Stones Creek Volcanics of the type discussed above include: lithic clast-poor to lithic-rich and crystal-rich dacitic ignimbrite; lithic-feldspar arenite and/or andesitic lithic-crystal ash tuff; andesitic lithic ash tuff; fine-grained lithic to lithic-crystal lapilli tuff; and, near the top of the formation, porphyritic andesitic lava. The rocks are very patchily exposed, being largely obscured by rhyolites and rhyolitic ignimbrite. The rhyolites mostly make up concordant bodies. Some could belong to the Stones Creek Volcanics; however, others (e.g. 1.2 km north-northwest of "Glenroy" outstation) are demonstrably continuous with subhorizontal intrusive sheets, whose upper surfaces are exposed and which clearly cut across fragmental rocks believed to overlie the Stones Creek Volcanics. On this basis, all are treated as Carboniferous and/or Permian intrusive rocks. The rhyolitic ignimbrites are regarded as belonging to the lower rhyolite-dominated ("Locharwood") association of the Bulgonunna Volcanic Group (see below).

The proportion of extrusive andesite in the Stones Creek Volcanics increases markedly farther to the southwest. Near the Ravenswood - Burdekin Falls Dam road, and extending to the western side of Mount Graham Creek, the lower and upper parts of the formation are dominated by massive porphyritic andesite. Rudite, with mostly andesitic clasts but also containing rhyolitic ones, and lithic clast-rich dacitic ignimbrite, are minor components of the upper part of the formation. The middle part of the formation here consists of up to 900 m of interbedded andesitic lava and pyroclastic rocks, and andesitic to polymictic (andesite, dacite, and rhyolite clastic material) arenite to rudite. These rocks give way west-southwestwards to massive andesite, and an apparently concordant wedge of predominantly rhyolitic rocks, differentiated as subunit DCs_4. This rhyolitic wedge may be of composite intrusive and extrusive origin. The total thickness of the Stones Creek Volcanics here is estimated to be about 3000 m.

Farther west in the northwestern part of the study area, between Mount Graham Creek and the shore of Lake Dalrymple, the Stones Creek Volcanics sequence begins with poorly exposed andesitic fragmental rocks and their sedimentary derivatives. These are overlain by up to 300 m of intensely altered and pyritised moderately lithic clast-rich and crystal-rich dacitic to andesitic ignimbrite. This western sequence is separated from the predominantly andesitic Stones Creek Volcanics to the east by a (presumably major) fault.

The sequence assigned to the Stones Creek Volcanics on the western side of Lake Dalrymple is at least 1000 m thick. It consists of porphyritic andesite and andesitic fragmental rocks, accompanied by lithic clast-poor, crystal-rich, dacitic to andesitic ignimbrite. The andesitic fragmental rocks include: medium to coarse-grained lithic lapilli tuffs; matrix-supported breccia containing angular clasts up to 30 cm in maximum dimension; bedded medium to coarse ash, with rare fine-ash, crystal-lithic tuffs; and thin-bedded quartz-feldspar arenite.

The best exposures of rocks assigned to the Stones Creek Volcanics (undivided - DCs), albeit tentatively, in the northeast occur along middle Desmond Creek, and to the west of the junction of Desmond and Sandalwood Creeks, in the middle and upper reaches of a western tributary of the latter. In the Sandalwood Creek tributary occurrence, a package dominated by andesitic volcanics overlies tentative Ukalunda Beds with presumed unconformity, and is also probably unconformably overlain by Bulgonunna Volcanic Group ("Locharwood" association) ignimbrite of composite unit Cub_{21} (below). The andesitic volcanics consist of: dark bluish-green, massive to poorly banded, feldspar-phyric, medium-fine, lava; and dark to very dark bluish-grey, moderately feldspar-phyric, medium-grained lava. The thickness of the andesitic sequence is uncertain because of a paucity of bedding determinations; it is probably no more than a couple of hundred metres, and more likely in the order of several tens of metres.

Possible outcrop-scale megaclasts of Stones Creek Volcanics andesites occur in the northeast, to the south of the Burdekin River in the vicinity of its junction with Glendon Creek. The outcrop area was included in DCv by Oversby et al. (1991). However, it is now considered more likely to represent disrupted but non-transported "basement" and/or a minimally-transported megabreccia related to a centre of activity of the Bulgonunna Volcanic Group's "Smedley" association. The occurrence is accordingly discussed more fully below as a volcaniclastic Bulgonunna Volcanic Group "sediment" (sCub). Dark bluish-green, massive to locally flow- laminated and auto(?)brecciated, at least partly feldspar-phyric, andesitic lava/s comprise the main outcrops examined. Texturally similar rocks occur as more probable megablocks, and as smaller (pebble to boulder size) clasts, in immediately overlying dacitic ignimbrite. Stones Creek Volcanics andesitic lava(?), and possible Stones Creek Volcanics (or Bulgonunna Volcanic Group) breccia, are also represented nearby in the xenolith population of a granitoid (CPg_{10}) exposed in Glendon Creek downstream from (north of) its junction with Gap Creek.

Sporadic small fault slices and blocks of andesitic and other volcanics, with local sedimentary rocks occur in the northeast along and adjacent to the Burdekin River about 7 km southwest of the mouth of Glendon Creek. The rocks were included in DCv by Oversby et al. (1991). They are now assigned to the Star of Hope Formation volcanics (below).

The best development of rocks assigned with a high degree of confidence to the Stones Creek Volcanics in the southwest occurs along the middle reaches of Bell Creek, to the east of the new "Myall Creek" homestead and about 3 km north of the House and Kitchen hills. Another good section occurs along the upper reaches of the creek, about 6 km northwest of the Sunbeam Mine (no 11 on the map). Rocks tentatively assigned to the unit are also inferred (from airphoto signatures along strike from the middle Bell Creek rocks, although separated from those by a minimum of about 2.5 km of Tertiary Sellheim Formation cover and probable Easter Granodiorite) to crop out discontinuously for up to about 10 km to the northeast and east-northeast of middle Bell Creek.

The Stones Creek Volcanics along middle Bell Creek are overlain with apparent slight angular unconformity by rocks assigned to the Star of Hope Formation. Southwestwards along strike, the volcanics are replaced by the Scartwater Formation, although stratigraphic continuity between the two formations is obscured by faults and intrusions in the zone of probable gradation and/or interfingering. Along middle Bell Creek itself, most components of the Stones Creek Volcanics are separated by strike-parallel to slightly oblique high-angle faults, some of which contain rhyolite dykes.

To the northeast and east-northeast of middle Bell Creek, photo-interpreted occurrences of the Stones Creek Volcanics are overlain by, and in faulted contact with, rocks assigned to the Star of Hope Formation. Locally, relationships between the two formations may be interfingering; if this is the case, any unconformable relationships elsewhere must represent only local and transient disruptions, and the hypothesis of Drummond Basin-wide tectono-sedimentary cyclicity (Olgers, 1972) is compromised. A variety of intrusive rocks also occurs to the northeast and east-northeast of middle Bell Creek. Farther (about 10 km) east, near Peak John Well (northeast), sedimentary rocks tentatively assigned to Ukalunda Beds may contain a tuffaceous component. This, and their apparent lack of a cleavage, suggests that they could be distal Stones Creek or Bimurra Volcanics (their geographical position renders either alternative possible).

In upper Bell Creek, the Stones Creek Volcanics are in faulted contact with rocks tentatively assigned to the Star of Hope Formation, and are overlain with angular unconformity by the Locharwood Rhyolite (Bulgonunna Volcanic Group).

The lower part of the Stones Creek Volcanics in middle Bell Creek is dominated by massive to well-stratified (laminated and thin bedded) andesitic pyroclastic and resedimented(?) rocks (DCs_2; DCv_a of Oversby et al. 1991) whose thickness between House and Kitchen Granite in the south and intrusive rhyolite to the north may be as much as 1600 m (assuming that there has been no substantial repetition or deletion of section on the several strike-parallel fractures/intrusions which cut it). Clastic material ranges from coarse silt (uncommonly) to large cobble size (maximum observed 150 mm), but is mostly in the medium sand to very large pebble range. Macroscopic andesitic clasts are mid to dark green and locally dark grey, aphyric and subangular to rounded; they are locally accompanied by a variable proportion of feldspar fragments. Massive to poorly and diffusely stratified rocks characterise the lower quarter of the exposed interval, with the better stratified ones being more common higher up; the two parts of the interval are separated by sporadic small rhyolite bodies which may have been intruded along a minor(?) strike-parallel fault.

Andesitic rocks adjacent to intrusive rhyolite in the middle Bell Creek sequence are locally silicified, pale grey in colour, and contain disseminated pyrite.

To the east-northeast of middle Bell Creek, photo-interpreted andesitic rocks occur as lensoidal intervals which occupy both the lower and upper parts of the possible Stones Creek Volcanics. Each of these interpreted lenses interfingers vertically and laterally with a sedimentary rock-dominated (below) middle interval of the formation.

The andesitic lower part of the Stones Creek Volcanics in middle Bell Creek is overlain by an interval dominated by clastic sedimentary rocks, and designated DCs_1 (DCv_s of Oversby et al. 1991). The interval consists of mid buff, thick-bedded and locally tabular cross-laminated, medium-grained feldspar-lithic sandstone to fine conglomerate interbedded with pale to mid green, medium-bedded and locally planar-laminated, medium to coarse-grained mudstone and siltstone. The sandstone locally contains angular "rip-up" clasts of siltstone. These dominant sedimentary rocks are associated with minor mid green, sparsely amygdaloidal but aphyric, andesite and feldspar crystal-poor dacitic(?) welded ignimbrites. The interval is estimated to have a minimum preserved thickness of about 500 m.

In the upper Bell Creek sequence, the exposed part of this sedimentary interval is at least 450 m thick. It is dominated by mainly pale greenish-buff, medium-bedded, fine- to coarse-grained quartz-feldspar sandstone which commonly has a silica cement. This rock locally contains scattered subangular to rounded pebbles and cobbles of pale purple dacitic(?) ignimbrite and/or lava containing feldspar crystals/phenocrysts. The sandstone is accompanied by rare fine- to coarse-grained (up to small-boulder) conglomerate.

In the middle and upper Bell Creek sequences, a sheet of crystal-poor to moderately crystal-rich welded dacitic(? - or quartz-free rhyolitic) ignimbrite makes up subunit DCs_3 ($DCvr_i$ of Oversby et al. 1991) in the upper part of the Stones Creek Volcanics. The sheet has an estimated minimum thickness of up to 200 m (middle Bell Creek), and 700 m (upper Bell Creek). In middle Bell Creek the sheet is cut out locally below the Star of Hope formation. The ignimbrite is characteristically mid buff to dark grey in colour, and contains white to buff or pale orangey-red feldspar crystals between 0.5 mm and 5 mm (mostly about 1mm) across, with rare subangular to rounded lithic clasts, some of which may be andesitic, to 40 mm. Fiamme are mostly small, and variably attenuated. Extremely attenuated fiamme in the middle part of the interval as preserved in upper Bell Creek are also contorted, presumably as a consequence of post-depositional rheomorphic flow. The presence or absence of an ignimbrite to the northeast and east-northeast of middle Bell Creek cannot be resolved unequivocally from airphoto signatures.

The preserved thickness of, and presence of common extremely attenuated and locally contorted fiamme in, the Bell Creek ignimbrite suggests that the rock there is closer to its original eruptive centre/s than in any other area of preservation. However, no coarse lithic clast-bearing facies is known.

Rocks tentatively regarded as Stones Creek Volcanics (subunit DCs_1), occur in the central part of the study area. These are pale greenish-grey siliceous mudstone and volcaniclastic sandstone. The rocks are poorly exposed in a northern tributary of Five Mile Creek about 5 km west-northwest of Peak John Well; the occurrence (tentative DCv of Oversby et al. 1991) is about 20 km due east of definite DCs_1 and other Stones Creek Volcanics in Bell Creek. These possible Stones Creek Volcanics dip moderately steeply to the northwest, and have steep (faulted?) contacts with the Ukalunda Beds and the south-dipping Locharwood Rhyolite ("Locharwood" association, Bulgonunna Volcanic Group), to the southeast and northwest respectively. They could be Ukalunda Beds, but are not cleaved (as are adjacent definite Ukalunda Beds). They could also be distal Bimurra Volcanics, although the closest (about 10 km south-southeast) definite representatives of that unit are andesitic rocks of subunit DCb_2.

We interpret the Stones Creek Volcanics as essentially the result of eruptions from at least one, and possibly several, palaeotopographically positive stratovolcano-like centre/s of predominantly andesitic composition. Active erosion and reworking of material derived from the growing extrusive pile/s were coeval with eruptive activity. Clastic detritus from other provenances was introduced only very rarely in recognisable concentrations.

Regionally, the supposed Early Carboniferous Scartwater Formation may be largely, if not entirely, a predominantly epiclastic (and thus distal, relative to extrusive activity) time-equivalent of part (upper?) or all of the Stones Creek Volcanics. The same applies to the Star of Hope Formation, even more so because of the substantial volcanic subunit which the formation is now perceived to contain in the map area.

The generally highly-oxidised composition of extrusive rocks, the presence of possible ignimbrites (and/or welded breccias) and bedded (airfall?) tuffs, the extreme immaturity of intercalated epiclastic sedimentary rocks, and the terrestrial plant fossils recorded from rocks assigned to the formation, are consistent with subaerial and/or very shallow subaqueous (e.g. fluviatile) environment/s of deposition. The occurrence at some localities of algal(?) limestone, mudstone, and chert may indicate the presence of standing water, at least transiently. The nature of the alteration, which has many characteristics in common with spilitisation, suggests that marine surface water, or groundwater of comparable salinity, reacted with the rocks during or soon after extrusive activity.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that the Stones Creek Volcanics (their unit V71) rocks are I-type, unfractionated, reduced to strongly oxidised, and medium- to high-potassium (based on nine unpublished AGSO analyses of rocks collected by D.E.M.). A major rock type in the formation is porphyritic (with phenocrysts of plagioclase, augite, and orthopyroxene) two-pyroxene, high-silica andesite with or without hornblende. Chemically, the rock has similarities to medium to high-K calc-alkaline or arc andesite (e.g. Gill 1981). However, alteration has variably, but always extensively, produced modifications; most conspicuously, CaO, Na_2O, K_2O, Ba, Rb, and Sr range from very depleted to very enriched. The rock invariably contains a sericite + chlorite + calcite + albite + epidote or prehnite alteration assemblage; tremolite-actinolite is present in some occurrences. Alteration ranges from moderate (plagioclase and orthopyroxene partly affected, augite not affected) to extreme (all primary minerals completely pseudomorphed). In some areas, particularly around Limey Dam (9 km northeast of "Glenroy" outstation, in the northwest), there is evidence for a later, lower-temperature, alteration which produced mainly sericite and/or clay(s), and hematite. Analysed specimens of andesite, dacite and rhyolite from the Stones Creek Volcanics in the northwest, have a strong degree of chemical coherence, and are probably all related by fractionation.

The Stones Creek Volcanics are not known to contain any mineral deposits. However, the unit has several features which make it a potentially favourable locus for epithermal gold mineralisation, comparable to the Bimurra Volcanics. Additionally, a unit which may be at an equivalent stratigraphic level to the Stones Creek Volcanics, although probably from an independent eruptive centre, is represented by the rocks which are host to the gold deposit at Pajingo Mine.These aspects are discussed further below under "Metalliferous Mineral Deposits and Economic Potential".

Supposedly Late Devonian to Early Carboniferous Silver Hills Volcanics (Veevers et al. 1964, Olgers 1972) are not recognised in the Burdekin Falls Dam - "Conway" area, although rocks in the southern Mount Coolon 1:100 000 Sheet area have been assigned to the formation (Hutton et al. 1991). However, we are unwilling to use the name for sequences discussed above as Stones Creek Volcanics and Bimurra Volcanics, even though both are volcanic-bearing units of appropriate general age. This is because of our belief that the stratigraphic nomenclature applied to these rocks should, to be fully informative and useful, emphasise that each major sequence probably originated from its own eruptive centre or group of centres. Potentially important details of original relationships could be blurred by use of a single name, particularly one carried over a considerable geographical distance. The name Silver Hills Volcanics has been used so far afield from its type area, near Anakie in the southern Drummond Basin, as to suggest that multiple sources must have been involved in the development of the unit. We suggest that the name as currently used has been considerably over-extended.

In the particular context of this study, a significant incentive to attempt detailed differentiation of volcanic-dominated units arises from the possibility that eruptive centres would tend to be preferred loci of recurrent synvolcanic structural instability, focussing of fluid flow, and mineral precipitation.

A sequence currently assigned to the Silver Hills Volcanics at "Verbena", 15 km southeast of Mount Coolon, contains lensoidal sinter intervals (Cunneen & Sillitoe 1989). Fragments of an unidentified lycopod of Devonian to Early Carboniferous age (J.F. Rigby, quoted in Cunneen & Sillitoe 1989 p. 137) occur in these sinters.

Scartwater Formation, Clc (*Clc of Oversby et al. 1991*)

The name Scartwater Formation, used by Olgers (1972) after de Bretizel (quoted in Olgers, p. 31), is derived from "Scartwater", about 55 km west-southwest of "Conway". The unit is of probable Early Carboniferous age.

Regionally, the Scartwater Formation is dominated by quartz sandstone and mudstone interbedded in variable proportions. Limestone, conglomerate and lithic sandstone are subordinate components. Tuff at several stratigraphic levels is locally conspicuous throughout the formation. The formation is about 1200 m thick in its type area.

In the map area, approximately 800 m (cf. 300 m in Olgers 1972) of rocks assigned to the Scartwater Formation crop out in a northern belt extending from near the Stones Creek - Glenroy Creek junction, west-southwest to Lake Dalrymple opposite the drowned Burdekin - Suttor Rivers junction. Although a maximum thickness of about 1200 m is suggested locally by outcrop width, there may be repetition of sequence because of structural complications such as the locally observed medium-scale intrafolial folds. Stratigraphically, the Scartwater Formation overlies the Stones Creek Volcanics with apparent conformity; it is overlain, again with apparent conformity, by rocks assigned to the Star of Hope Formation, and unconformably by various constituents of the Bulgonunna Volcanic Group.

The northwestern development of the Scartwater Formation is thickest to the east of Glenroy Creek, and decreases (to about 450 m or less) west-southwestwards. In addition to the regionally distributed rock types, the formation in the area is notable for a variable, locally substantial, content of tuffaceous arenites and siltstones, as well as: andesitic to dacitic crystal, crystal-lithic, and lapilli tuffs of various grain-sizes; pyroclastic breccia(?); and several thin (up to 10 m) and impersistent dacitic, rhyolitic to dacitic, and rhyolitic ignimbrite sheets. Andesitic feldspar-lithic arenites and rudites may be epiclastic and/or mixed epiclastic-pyroclastic. Probable purely epiclastic conglomerate is a minor constituent. Most of these rocks are similar to ones in the Stones Creek Volcanics. Those parts of the formation containing a substantial volcanic component tend to be somewhat coarser-grained overall than epiclastic parts, and contain fewer depositional structures, such as cross-beds (low-angle, generally planar) and normally graded beds. In the area around "Glenroy" outstation, on either side of Stones Creek, small clasts possibly derived from the Mount Windsor Volcanics (similar to ones common in the Stones Creek Volcanics adjacent to Stuart Pocket) are known from one level in the lower part of the Scartwater Formation.

Two southwestern outcrop belts of the Scartwater Formation strike southwest across the Sellheim River to the west of the House and Kitchen hills and Pyramid Range. Here, the formation appears to overlie Saint Anns Formation conformably; it is again overlain with apparent conformity by the Star of Hope Formation. The southwestern Scartwater Formation may have, at least in part, a laterally interfingering relationship with local Stones Creek Volcanics. The similarity of at least part of the volcanic component in the northwestern Scartwater Formation to rocks of the Stones Creek Volcanics is also consistent with there being a degree of interfingering, and a diachronous boundary, between the two units.

The similarity of at least part of the extrusive component in the northwestern Scartwater Formation to Stones Creek Volcanics material, and the tendency for this component to increase with proximity to the latter formation both vertically and laterally, suggests that the two units intergrade (vertically) and interfinger (laterally) to some degree. This is consistent with indications of a lateral stratigraphic relationship between the two formations in the southwest (Bell Creek area; see above under Stones Creek Volcanics). Thus, at a regional scale, the contact between the Stones Creek Volcanics and the Scartwater Formation seems to be diachronous, possibly extending from Upper Devonian into Lower Carboniferous Stages.

The Scartwater Formation is not as restricted in its distribution in the study area as the Mount Wyatt and Saint Anns Formation are. This suggests that any unconformity at the base of the Star of Hope Formation volcanics in the north does not substantially affect Scartwater rocks (which in turn is consistent with a possibility - below - that the volcanics may not actually be sufficiently high in the stratigraphic sequence to be in Star of Hope Formation "proper", i.e. Early Carboniferous age).

<u>Mount Hall Formation</u> (not shown on the map)

Previous workers (Olgers 1972, Paine & Cameron 1972, Paine et al. 1974) delineated tongues of the Mount Hall Formation between the Scartwater and Star of Hope Formations extending into the western Burdekin Falls Dam - "Conway" area near "Mount McConnell" homestead and Mount McConnell hill. We have not examined the relevant section near the homestead in sufficient detail to confirm whether or not the Mount Hall Formation can be recognised there (although airphoto interpretation suggests that its approximate position coincides with a fault). However, we have not identified it at any location elsewhere in the study area where the stratigraphic contact zone between the Scartwater and Star of Hope Formations is currently exposed.

Star of Hope Formation (Undivided), Cls, and Un-Named Volcanic Subunits, Cls_1 to Cls_4
(Cls, Cs, Csv, Cls_i, Cld, Cr, part DCv_i of Oversby et al. 1991)

The Star of Hope Formation was also named by de Bretizel (quoted by Olgers 1972 p. 39); the type area is in the southern Drummond Basin, about 70 km west of Clermont. The unit is believed to be of Early Carboniferous age.

The Star of Hope Formation has been regarded as a useful stratigraphic marker throughout the entire Drummond Basin on the basis of containing "varicoloured sediments and volcanics which can be easily distinguished" (Olgers 1972 p.39) from the rocks in subjacent and suprajacent units. The objectivity of this distinction may be questionable, however, because the formation is evidently very variable at both regional and local scales. Dominant lithologies and associations in different areas include quartzose sandstone and conglomerate, volcaniclastic sandstone with tuff, and interbedded quartz-pebble conglomerate and tuff. Regionally, the Star of Hope Formation has previously (Olgers, 1972) been estimated to be up to 1800 m thick. However, in the map area thicknesses of up to about 2 000 m may be present.

We postulate the existence of an important volcanic-dominated interval (un-named subunits Cls_1 to Cls_4), estimated to be up to approximately 1000 m thick, within the Star of Hope Formation to the north of the Burdekin River. These probable Star of Hope Formation volcanics are tentatively recognised from limited occurrences as far south as middle Coopers Creek and upper Glendon Creek.

In the northwest rocks assigned to the Star of Hope Formation crop out from near the Stones Creek - Glenroy Creek junction south to the Burdekin River, and west-southwest to Lake Dalrymple. The formation also occupies an extensive area to the southwest of Burdekin Falls Dam, and several areas between the dam and the upper part of Bell Creek. The formation overlies the Scartwater Formation with apparent conformity in the north, and both the Scartwater Formation and Stones Creek Volcanics in the middle Bell Creek area. In this last area, stratigraphic relationships between the formation and subjacent rocks (most conspicuously the Stones Creek Volcanics) vary from interfingering to slightly discordant. To the southwest and south of Burdekin Falls Dam, various occurrences of the Star of Hope Formation are overlain with marked angular unconformity by components of the Bulgonunna Volcanic Group (most importantly: Collins Creek Rhyolite, Locharwood Rhyolite, Smedley Dacite and Arundel Rhyolite).

What appears to be the lowermost part of the Star of Hope Formation in the northwest (eastern part), where it is faulted against the Stones Creek Volcanics, consists of at least 400 m of an undivided assemblage of massive to thin-bedded feldspar-lithic arenite, pebbly arenite, rudite and mudstone (all composed dominantly of very immature andesitic material), andesitic fine lithic-lapilli and crystal-lithic ash tuffs, and thin (up to 1 m or 2 m) nonwelded andesitic to rhyolitic ignimbrites; minor quartz-feldspar to feldspar-quartz and rare dacitic to rhyolitic lava, also occur. Many of these rock types are broadly similar to ones in the Stones Creek Volcanics, although thinner-bedded, and contain abundant sedimentary structures such as cross- and graded-bedding, and ripple marks. Probable raindrop impressions were observed in planar-laminated mudstone at one locality near the northern bank of the Burdekin River 7 km northeast of Burdekin Falls Dam (grid reference 8356-176221). Conformably (or paraconformably) above this apparently lowermost assemblage of rocks is an interval, up to about 400 m thick, of dark bluish-grey to brownish-grey massive welded, apparently dacitic (macroscopic quartz markedly subsidiary to feldspar), ignimbrite; the entire interval is differentiated as Cls_2. The interval consists of approximately six ignimbrite flow units, some of which are separated by thin intercalations of locally pebbly coarse siltite to coarse arenite. The ignimbrites are locally very similar in hand specimen appearance to some nearby quartz-bearing varieties of the Smedley Dacite (Bulgonunna Volcanic Group - below), to the extent that it has not always been possible to confidently assign all stratigraphically isolated and/or structurally compromised ignimbrite occurrences in and adjacent to the Burdekin River. The ignimbrites diverge, thin, and eventually die out, towards the west-northwest; they are progressively replaced by a facies of the undivided Star of Hope Formation (Cls) dominated by epiclastic and nonwelded pyroclastic rocks. Each of the Cls_2 ignimbrite flow units grades upwards from lithic clast-rich and crystal-poor (verging on moderately crystal-poor) rock types to lithic-poor or -free and crystal-rich ones. Lithic clasts also decrease in size upwards, from about 5cm to about 1cm, while squashed pumice "fiamme" increase from about 3 cm to about 12 cm in length. Lithic clasts are predominantly fine-grained (i.e. extrusive or very high-level intrusive), and range from andesite to rhyolite. The ignimbrites are moderately to intensely altered (to hematite $\pm$ clay(s) $\pm$ sericite $\pm$ chlorite $\pm$ epidote) throughout; the hematite and clay(s) appear to overprint the propylitic-type alteration. This ignimbrite-dominated interval is overlain by up to 30 m of another undivided (Cls) assemblage of rocks similar to the one below it. This assemblage in turn is succeeded by: (a) about 50 m of undivided coarser, more quartz-feldspar-rich, sedimentary rocks (still in Cls); and (b) a succession dominated by rhyolitic tuffs, ignimbrites and lavas (assigned to Cls_1).

The lower part of the Star of Hope Formation to the south of "Glenroy" outstation (here entirely undivided - Cls) is also dominated by volcaniclastic sedimentary and pyroclastic rocks. However, the proportion and average grainsize of epiclastic rocks increases progressively to the west. Gritty to pebbly coarse arenites and granule to pebble conglomerates, containing clasts up to 20 cm diameter, become increasingly common westwards, and also upwards at least to the level of the ignimbrite-dominated subunit (Cls_2), which appears to have been faulted out of the section. Finer-grained rocks, including rhyolitic (and scarce dacitic to andesitic) tuffs, feldspar-lithic arenites, silty and clayey mudstones, predominate above the probable Cls_2 ignimbrite level. Rhyolitic to dacitic ignimbrites, andesitic volcanic breccia, andesitic lithic-lapilli tuff (?), and a variety of andesite-derived feldspar-lithic arenites and pebbly arenites, are present in the undivided (Cls) sequence immediately below rhyolitic extrusive rocks assigned to subunit Cls_1. However, conglomerate is rare throughout this section. Fossils of indeterminate plant fragments are common in some of the arenites, and in one rhyolitic (nonwelded lithic clast-poor, crystal-rich, ignimbrite?) bed. The upper undivided (Cls) Star of Hope Formation significantly changes character from east to west to the southeast and south of "Glenroy" outstation. An upper Cls outlier resting on Cls_2, and the sequence immediately beneath Cls_1, about 7 km southeast of the outstation, contain substantial pebbly components (notably polymictic pebble conglomerate and pebbly arenite). These rocks are generally coarser, and are noticeably more quartzose, than lower Cls (i.e. sub-Cls_2) rocks farther to the northeast and north in the same sections.

Exposures of the Star of Hope Formation near the main Ravenswood - Burdekin Falls Dam road are poor. Outcropping rocks in the undivided (Cls) part include lithic, feldspar-lithic, and quartz-lithic arenites and pebbly arenites (lithic component predominantly andesite- derived), siltite and lutite, and possible andesitic vitric-lithic ash tuff. Massive andesitic to basaltic lavas(?) in the middle part of the sequence, which probably represent a local eruptive centre, crop out on both sides of the road approximately 3 km northeast of Mount Graham. An additional notable feature in the vicinity is the appearance of quartzose arenites near the base of the formation, particularly near the edge of Lake Dalrymple. In the vicinity (east) of Mount Graham, moderately porphyritic olivine(?)-(two?) pyroxene basalt makes up a wedge-shaped (in plan) concordant body within the Star of Hope Formation sequence about 300 m above its base, at and just below the contact between a lower Cls interval and overlying subunit Cls_1. This body is tentatively included within subunit Cls_3. However, the rock type is sufficiently similar to Tertiary basalt lava (Tb) elsewhere in the Burdekin Falls Dam - "Conway" area to suggest that it could be of that age. Its lateral impersistence, and an apparent slight discordance of its base locally, are consistent with this alternative interpretation. Approximately 8 km east of Mount Graham and 3 km north of Burdekin Falls Dam, subunit Cls_1 is overlain by an interval made up of a series of thin sheets of rhyolite; this interval makes up subunit Cls_4. The rhyolites are sparsely porphyritic, variably flow-laminated, locally autobrecciated (mainly in the lowermost and uppermost parts of the interval), and locally spherulitic (lowermost part). Rhyolite sheets are separated by minor intercalations of rare arenite and crystal tuff. The sheets are interpreted to be mostly lava flows, although intrusive equivalents are probably also present in the interval. A thin nonwelded, moderately lithic clast-rich and very small-crystal-poor rhyolitic ignimbrite also occurs in the lowermost part of the interval in its western outcrops. Subunit Cls_4 has a maximum preserved thickness of a few tens of metres; it evidently represents another local magmatic centre, but whether or not it is a lateral equivalent of Cls_1 and/or Cls_2 ignimbrites is not entirely clear.

Only very limited occurrences of the Star of Hope Formation (all undivided - Cls) are (tentatively) recognised in the northeast. The principal occurrences are sedimentary rocks on the northwestern, southwestern and southern edges of the granitoid plutons centred on "Glendon", between about 3 km and 6 km from the homestead. In addition, strongly deformed, not notably volcaniclastic, mudstone and sandstone (not differentiated on the map) are known within a narrow north-northeast-trending strip of Bulgonunna Volcanic Group rocks ("Smedley" association, composite unit Cub_{27}), between a fault to the west and a porphyritic very fine-grained granite (CPg_2) intrusion to the east, 4.5 km west of "Glendon". These deformed sedimentary rocks could belong to the Star of Hope Formation rather than the "Smedley" association. At its southern end, the entire strip of rocks is interpreted (from field traversing) to stratigraphically overlie, on a steeply west-northwest-dipping contact, a dacitic ignimbrite of debateable affiliation (below). About 1 km farther to the south-southwest, this ignimbrite is interpreted (from airphoto interpretation) to stratigraphically overlie, on a gently northeast-dipping contact, the northeasternmost Star of Hope Formation (undivided - Cls). Hornfelsed mudstone, sparse basaltic lavas, and possibly rare dacitic ignimbrites, about 6 km south-southeast of "Glendon" are also tentatively assigned to the Star of Hope Formation (undivided - Cls). This occurrence of the formation has a faulted contact in the northeast with dacitic ignimbrite of the Bulgonunna Volcanic Group (probably "Earlscliffe" association; unit Cub_1). A further 4 km to the south is definite Star of Hope Formation (undivided) in the uppermost reaches of Glendon Creek; here, the formation is dominated by blue, well bedded to laminated, mudstone with excellent symmetrical ripple marks.

Dacitic(?) ignimbrite, or ignimbrites, associated with the Star of Hope Formation to the southwest and south of "Glendon" is, or are, sufficiently similar to each other that both occurrences were correlated with the same Bulgonunna volcanics unit by Oversby et al. (1991; unit Cvi_4). This equates with "Smedley" association unit Cub_{26} of the current scheme. In view of available U-Pb isotopic data (see Black 1994, Appendix 2), which are consistent with a pre-"Smedley" association age for the Collins Creek Rhyolite rather than the reverse, this correlation is now considered to be unsupportable for at least the ignimbrite to the south of "Glendon", which is tentatively assigned to composite "Earlscliffe" association grouping Cub_1. From "known" stratigraphic relationships, and from a comparison of rock types (including consideration of the amount of observed variability within individual units), the other rock could also belong to Cub_1, to ignimbritic subunit Cls_2 of the Star of Hope Formation volcanics, or to a "Smedley" association unit (specifically Cub_{26}, as preferred by the field researcher, J.M.). The third option introduces a problem (minor, in view of, for instance, the sharp westward overstepping of the nearby Arundel Rhyolite from the Smedley Dacite onto unassigned Star of Hope Formation) of non-deposition or erosion of "Earlscliffe" and "Locharwood" association rocks at the locality. On balance, the ignimbrite is included (tentatively) in Cub_1.

In the west-central part of the map area, on the southern to eastern side of Lake Dalrymple, the undivided Star of Hope Formation is significantly more quartzose than in the north; in addition, it contains a greater rudite component. Overall, the facies consists of fine to very coarse lithic-quartz arenites (with cross-bedding in places), polymictic pebble to cobble conglomerate, lithic-rich siltstone, dark mudstone (commonly with abundant plant debris), rhyolitic fine ash tuff, rhyolitic lava, andesitic(?) crystal (feldspar)-lithic to crystal (feldspar) tuffs and rare dacitic(?) ignimbrite. The proportion of conglomerate in the upper part of the formation increases progressively southwestwards towards "Myall Creek" homestead, while the lower part continues as an intricately heterogeneous assemblage of andesite- and dacite-derived feldspar-lithic to lithic-quartz lutites to arenites, and rhyolitic to andesitic pyroclastic rocks. Subunit Cls_1 consists of rhyolitic tuffs, various epiclastic arenites and rudites, minor rhyolitic lava, rare siltite, and (in its uppermost part) rhyolitic ignimbrite in a total preserved thickness of about 160 m (east) to at least 500 m (west). The tuffs are predominantly very fine- to fine-grained, and vitric; they contain up to 5% lithic clasts up to 3 cm in maximum dimension, and up to 10%

feldspar and quartz crystal fragments up to 1 mm or 2 mm across. Some of the tuffs are entirely vitric (and commonly silicified, with a porcellanous appearance locally), while others contain accretionary lapilli up to 7 mm or 8 mm in diameter. The epiclastic arenites and rudites are predominantly feldspar-lithic, and thin to medium planar-bedded; approximately half overall are rudites or pebbly arenites. Rudites are concentrated in the lower half of the subunit, and increase in abundance relative to arenites from east to west. A tuffaceous component is probably present in up to a third (by volume) of the epiclastic rocks. A large proportion of the lithic detritus is rhyolitic, although quartz fragments are scarce. Sedimentary structures appear to be rare, the only example observed being of low-angle planar cross-bedding sets up to 1m thick (in very coarse-grained gritty to pebbly arenite, separated from overlying massive polymictic pebble conglomerate by a possible scour-and-fill surface). Ignimbrites in these outcrops of subunit Cls_1 are nonwelded to poorly welded, and range from lithic clast-poor and crystal-rich to very lithic-rich and crystal-poor. Lithic clasts range in size up to 3 cm long, and are mostly rhyolitic, although dacitic to andesitic types are also present. Pumice clasts are rarely apparent, and invariably small (up to 1 cm in maximum dimension).

In the northeast, rocks (DCv of Oversby et al. 1991) assigned to the Star of Hope Formation volcanics occur in sporadic small fault slices and blocks along and adjacent to the Burdekin River between about 6 km and 8 km southwest of the mouth of Glendon Creek. These occurrences are approximately along strike from both the Star of Hope Formation volcanics and the Stones Creek Volcanics, in less disrupted sequences preserved to the north of the river. They are assigned to the former in preference to the latter, because they are more directly in line, and west of, the Stones Creek Volcanics south of the Burdekin River, near the mouth of Glendon Creek; none of their individual rock types is particularly indicative of Star of Hope Formation volcanics in preference to the Stones Creek Volcanics, however. One well-exposed occurrence in the bed of the river 8.3 km southwest of Glendon Creek consists of intensely fractured, dark blue, massive andesite and andesitic breccia (Cls_3). Two other fault blocks (but only one of them large enough to show on the map), to the east of the river about 2 km farther east, include bluish-grey, laminated to thin-bedded, siliceous mudstone in addition to andesitic volcaniclastic rocks (Cls_1).

Along and adjacent to Bell Creek (southwest), rocks assigned to the Star of Hope Formation consist of pale pinkish-buff to mid green medium to thick-bedded and locally crudely laminated, pebbly to small-cobbly, medium-grained quartz-feldspar-lithic and feldspar-lithic sandstone to fine-grained conglomerate. These rocks are associated with minor pale greenish-grey, locally laminated, fine-grained lithic(?) sandstone, and mid green, medium bedded, siltstone. No volcanic rocks have been seen.

Provisionally, we consider the volcanic-dominated interval made up of subunits 1 to 4 in the northwestern and southwestern parts of the map area to be a member of the Star of Hope Formation. The interval appears to decrease in thickness westwards, and it may be ultimately lensoidal. From the northwest, there is a northward and westward decrease in the importance of welded ignimbrites within it. In part this may be due to a local(?)

disconformable contact with the overlying undivided rocks of the Star of Hope Formation, but it also confirms that the main eruptive centre/s which operated during accumulation of the interval lay in the east or southeast.

Lack of age control on appropriate rocks forces us to assume that the volcanic-dominated interval, and undivided rocks enclosing it, have essentially the same age as that reported for the formation regionally (supported by palaeomagnetic data acquired during our investigation - see Klootwijk et al. 1993, Appendix 3), i.e. Early Carboniferous. The interval is probably younger than the adjacent Stones Creek Volcanics. However, structural complexity at critical contacts prevent us from completely ruling out the possibility that it represents a tongue of the Stones Creek Volcanics extending laterally and/or upwards into the Star of Hope Formation. If this could be demonstrated unequivocally, it would indicate that the Star of Hope Formation (and thus potentially all other lithological assemblages currently treated as "layer-cake" stratigraphic units in the northern Drummond Basin sequence) is a diachronous and/or recurrent entity.

In view of these uncertainties regarding original relationships, and to emphasise the important implications which resolution of them would have for Drummond Basin stratigraphy, we have refrained from formally naming the volcanic-rich interval within the Star of Hope Formation.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that these volcanic rocks (their unit V74) are mafics and I-types, unfractionated, oxidised to strongly oxidised, and low- to medium-potassium (based on five unpublished AGSO analyses of rocks collected by D.E.M.).

Although the Star of Hope Formation volcanics are not known to have been mineralised, we believe that the rocks must be regarded as prospective. This aspect is discussed further below ("Metalliferous Mineral Deposits and Economic Potential").

NORTH QUEENSLAND IGNEOUS PROVINCE

AGSO's North Queensland Igneous Province is almost exactly equivalent to the Coastal Ranges Igneous Province of Henderson (1980), and precisely equivalent to the "North Queensland volcanic and plutonic province" of Day & others (1983). The Bulgonunna Volcanic Field of Oversby & others (1980) and its near-synonym, the so-called Bulgonunna Province of Hutton & others (1991), are those palaeogeographic (extrusive) and present-day (intrusive plus extrusive) subprovince-rank parts respectively of the North Queensland Igneous Province in and adjacent to the study area.

BULGONUNNA VOLCANIC GROUP

The Bulgonunna Volcanics were named from Bulgonunna Creek and Peak, and originally defined as a formation-rank unit by Malone et al. (1964). The nominated type section is along Bulgonunna Creek, from the Mount Coolon - Collinsville road crossing in the eastern Mount Coolon 1:100 000 Sheet area to "the vicinity of" Bulgonunna Peak (Byerwen 1:100 000 Sheet area). The name was extended northwards beyond "Conway" into the Burdekin Falls area by Paine et al. (1974); this expansion of the perceived distribution of the formation resulted in incorporation of a greater compositional range of extrusive rock types than the predominant rhyolites of the Mount Coolon area. The formation was raised to group rank by Hutton et al. (1991), concurrent with the introduction of (in ascending order) the Bobby Dazzler Rhyolite, Locharwood Rhyolite and Pinang Rhyolite as formal constituent formations in the Mount Coolon area.

The preserved Bulgonunna Volcanic Group represents the core and main remnant of the postulated Bulgonunna Volcanic Field of Oversby et al. (1980). As preserved, the group is of Late Carboniferous to Early Permian age.

The Locharwood Rhyolite (below) is the most extensive single unit recognised in the Bulgonunna Volcanic Group. It underlies wide areas in the Mount Coolon and Byerwen 1:100 000 Sheet areas (Hutton et al. 1991), as well as in the Burdekin Falls - "Conway" area. Although there is no continuity between the main southern and northern occurrences of Locharwood Rhyolite, rocks from the two areas have the same isotopic age (below). In addition, the unit is sufficiently distinctive in its field characteristics for the separate occurrences to be confidently equated. The Locharwood Rhyolite provides the key to correlation of the Bulgonunna group throughout the entire Burdekin Falls Dam - "Conway" - Mount Coolon district.

At various stages during this investigation, interpretations of field relationships have led us to the opinion that dacitic ignimbrites now included in the Bulgonunna Volcanic Group belonged to a different, older, sequence (previous Cv - "Smedley" association), with only rhyolite-dominated sequences (previous Cb) being Bulgonunna volcanics "proper". In view of the zircon U-Pb "control ages" (i.e. isotope geochronological data obtained from critical units, and pivotal to our current perception of stratigraphic relationships within the group) obtained, and in the absence of clearly contradictory field data, we must now consider this opinion to be unsupportable. We are forced to concur with previous workers in recognising that the overall Bulgonunna Volcanic Group sequence is compositionally heterogeneous. In this respect, the sequence is unusual among the late Palaeozoic ignimbrite-dominated units elsewhere in northeastern Queensland, which are overwhelmingly rhyolitic. At face value, the few isotopic dates also indicate that relationships between rhyolite-dominated and mixed rhyolite-dacite (dacite generally dominant) rock associations are not a straightforward matter of a single representative of the former overlying one of the latter. Available data are mostly consistent with the presence of two of each type of association, which alternate through the cumulative sequence. These may have been a degree of interfingering between some, or all, of the associations which cannot now be clearly demonstrated. However, the lack of critical field relationships and paucity of high-resolution geochronological data prevent us from confirming this. In particular, we have no geochronological or palaeomagnetic control from definite representatives of the oldest postulated association (lower rhyolite-dacite, or "Earlscliffe"). The one isotopic date which could relate to the association (from sample 89302132 in the southeast, see Appendix 2) is identical to one from the supposedly younger "Smedley" association. This must mean either that there are far-flung "Smedley" association outliers below and between "Earlscliffe" association ones in the southeast, or that the concept of two temporally distinct rhyolite-dacite associations is wrong. In the interests of maximising consistency while minimising confusion, the former is assumed throughout ensuing discussion, as on the map. However, precise knowledge of the numbers of associations involved, and of the relationships between them, would obviously be desirable because they have an important bearing on the way that the stratigraphic and structural evolution of the Bulgonunna Volcanic Group as a whole are interpreted. For this reason we have preferred to continue the provisional treatment of associations as informal packages, rather than introduce a formalised subgroup nomenclature which may prove to be inappropriate. Our (pseudo- or actual) stratigraphic-type associations should not be confused with the volcanic "facies associations" of Cas & Wright (1988).

Rocks annotated sCub do not make up a single stratigraphic unit. Rather, they occur as repetitive associations in intervals (which are commonly lensoidal) within and/or between many of the formation-rank units in the Bulgonunna Volcanic Group. Rocks so annotated also lie below the ignimbrite-dominated Bulgonunna volcanics sequence in the southwestern part of the study area. The sCub associations consist entirely of, or are dominated by, rocks of broadly sedimentary aspect. Some occurrences, most notably the one below ignimbrites in the southwest noted above, are epiclastic, but the majority are pyroclastic and mixed pyroclastic- epiclastic types. Some of the rocks, while being composed of volcaniclastic material, are of uncertain origin/s. In detail, most occurrences of sCub are composite, with each containing its own proportions of individual rock types; a few occurrences contain single rock types. No stratigraphically meaningful pattern has been detected.

Composite units Cub_8, Cub_{21} and Cub_{27} are made up of undivided groupings of Bulgonunna Volcanic Group rocks which are not sufficiently distinctive to be stratigraphically positioned, and/or are out of their original stratigraphic context (e.g. in isolated fault blocks).

Limitations of available data render the stratigraphy of formation-rank units, most particularly those of the "Locharwood" association, very provisional. In many cases, local inconsistencies in relationships between units as currently recognised have produced partial reversals of the nominal stratigraphy. Such reversals become most conspicuous where numerically ordered un-named units are involved in adjacent or nearby sequences. This probably represents, at least in part, a real repetition of certain characteristic rock types. Such repetition could be due to a "layer-cake" style of stratigraphy. However, in view of the complexity inherent in any volcanic environment, it seems more likely to be a reflection of intricate lateral intertonguing of units, disrupted and obscured by faulting.

LOWER RHYOLITE - DACITE ("EARLSCLIFFE") ASSOCIATION

The Earlscliffe Dacite and associated rhyolitic and dacitic rocks, which lie directly on sub-Bulgonunna units, are inferred to constitute a lower rhyolite-dacite association of the Bulgonunna Volcanic Group in the southeast with an estimated maximum aggregate thickness of about 450 m. It must be emphasised here, however, that that there are no geochronological or palaeomagnetic data available from "Earlscliffe" association rocks which would "prove" (or otherwise) their inferred low stratigraphic position. On the contrary, it could be argued that the "Smedley" association date from an isolated occurrence of dacitic andesite lava to the north of "Conway" homestead (sample 893021320; see Black, 1994, Appendix 2; also "Dacitic Andesite Lava" in "Smedley" association text, below), close to extensive ignimbrite remnants assigned only to the "Earlscliffe" association, "proves" that the two associations are not fundamentally different, stratigraphically. Additional work to more objectively define the position of the "Earlscliffe" association, and thus confirm (or otherwise) currently preferred interpretations of the structure and evolution of the Bulgonunna Volcanic Group as a whole, would obviously be desirable.

These southeastern "Earlscliffe" association rocks connect discontinuously northwards with ones assigned to the same association which are preserved in a complex belt of fault slices and blocks extending west-southwest for about 20 km from Reginald Peak to north of "Ukalunda", in the south-central to southwestern parts of the study area. In the southwest, a varied assemblage of rocks assigned to the "Earlscliffe" association is locally overlain stratigraphically by the Pyramid Rhyolite and/or the Locharwood Rhyolite of the lower rhyolite-dominated association. Representatives of the "Earlscliffe" association are nowhere known to be in definite stratigraphic contact with rocks in the inferred upper rhyolite-dacite ("Smedley") association. However, it must be noted in this respect that an important mineralogical characteristic of most "Earlscliffe" association ignimbrites, the dominance of macroscopic feldspar crystals and fragments over quartz, is unfortunately shared with many "Smedley" association rocks. This commonly makes it impossible to differentiate members of the two associations with any confidence.

Ignimbrites that probably belong to the "Earlscliffe" association are sporadically distributed in the northeast. Their designation is based primarily on stratigraphic position beneath recognisable components of the "Locharwood" association.

The rhyolite-dacite association which is well developed in the southeast directly overlies Drummond Basin rocks. Consequently, it is regarded as being in a sub-Locharwood Rhyolite position. At Mount Landsborough it is close to (about 3 km minimum), though structurally separated from, rocks assigned to the lower rhyolite-dacite association preserved between Havilah Hill and Reginald Peak. Dacitic ignimbrite in this southeast association is similar to that in the upper rhyolite-dacite association of the northwest, characterised by the Smedley Dacite. However, these similarities are not judged sufficient to override other indications that we are dealing with the same (or another) lower association as that in the southwest.

The "Earlscliffe" association in the southeast occurs in two settings. Between Mount Landsborough and the Sellheim River the association is represented by a thick and varied sequence confined within a concentric fracture/intrusion system. Farther east, the association is represented by only the upper part of the Mount Landsborough sequence, plus two units (the Bobby Dazzler Rhyolite and Cub_7) not seen at Mount Landsborough, and faulting follows a simpler linear pattern.

A flow-banded dacite (Cx of Oversby et al. 1991) occurs in and on both sides of the Sellheim River about 1.5 km east-southeast of the summit of Mount Landsborough. The rock occupies the eastern three-quarters of a lensoidal body, up to about 40 m thick, between the Mount Wyatt Formation and the base of "Earlscliffe" association ignimbrite (Cub_1 - below). This body appears to be effectively concordant with respect to the base of the ignimbrite. The flow-banded dacite could be a lava making up the lowermost part of the local extrusive sequence. However, it has not been differentiated here from apparently pre-"Earlscliffe" association, gabbro (Cgm of Oversby et al. 1991) which makes up the western quarter of the same body. The entire body is included in intrusive grouping CPm (below).

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that “Earlscliffe” association (the dominant component of their unit V72) rocks are probably I-types, unfractionated, oxidised to strongly oxidised, and medium- to high-potassium (based on seventeen unpublished AGSO analyses).

<u>Volcaniclastic Rocks, sCub</u> *(Cvt, Cvs of Oversby et al. 1991)*

The lowermost exposed part of the best-preserved "Earlscliffe" association sequence, between Mount Landsborough and the Sellheim River, in the southeast, is represented by crystal- and lithic-rich fine ash to lapilli tuffs (Cvt of Oversby et al. 1991) and fine epiclastic(?) sandstones to fine conglomerates (previous Cvs) in a series of small fault-bounded blocks and slices within the western part of the concentric fracture/intrusion system. These locally (opposite Sunbeam Mine - no. 11 on map) well exposed rocks have only been studied briefly, so that their potentially complex origins and significance (cf. McPhie 1993, McPhie et al. 1993) cannot be fully evaluated.

Nonwelded, commonly stratified, probable pyroclastic rocks (previous Cvt) placed in the "Earlscliffe" association, occur in structurally complex small outcrop areas in the southwest, near the Sunbeam Mine. They also occur in a less complex setting about 2 km farther north. These rocks are typically pale-coloured, although containing only a low proportion of macroscopic quartz. However, their content of microcrystalline groundmass quartz suggests that they are compositionally rhyolitic.

Among the regularly thin- to medium-stratified nonwelded rocks adjacent to the Sunbeam Mine are beds about 30 cm thick which contain fiamme. These particular fiamme probably resulted from coeval diagenesis and burial-compaction (cf. Branney & Sparks 1990). Judging from the regular planar stratification of the rocks adjacent to the Sunbeam Mine, they were probably deposited by pyroclastic airfalls. Lack of soft-sediment deformation features attributable to dewatering suggests that the material accumulated subaerially.

Un-Named Unit Cub_1 *(part Cvi, part Cvi_4, Cv_{ir}, part Cbv, part rh_2 of Oversby et al. 1991)*

A minimum of 100 m of the lower part of the southeastern "Earlscliffe" association sequence between Mount Landsborough and the Sellheim River consists of a mixture of small- to moderate-volume ignimbrite flows and probable lavas plus intrusive bodies. The rocks are mostly quartz-poor rhyolites.

Ignimbrites in this part of the sequence are mid to dark purplish-buff contain about 5% white to pale buff feldspar with slightly subsidiary quartz crystals most commonly to about 2 mm across. The rocks typically contain angular to rounded lithic clasts (pale to mid buff aphyric rhyolite, dark greyish-buff very crystal-poor welded rhyolitic ignimbrite with quartz and feldspar, grey dacitic ignimbrite, and rare dark brownish-green aphyric and porphyritic andesite or basalt); the clasts are mainly moderately abundant to very abundant, and range from 10 mm to 750 mm across. The largest clast sizes occur in the lowermost ignimbrites. Fiamme are typically small- to medium-sized, and weather recessively. Dips of eutaxitic foliations are variable in azimuth, although mostly gentle to moderate.

Ignimbrites in this interval grade with decreased quartz crystal contents in the upper 30 m or 40 m into the Earlscliffe Dacite ($Cube_3$) which caps Mount Landsborough (below). The upper part of the interval also locally contains flow-banded, quartz-free and clast-poor, rhyolite which may be extrusive.

The most northerly occurrences of probable "Earlscliffe" association rocks, tentatively placed in composite grouping Cub_1, are located in the northeast, about 5 km west, 2 km southwest, and 3.5 km south-southeast of the junction of Sandalwood and Desmond Creeks. These occurrences were included in groupings Cvi and Cbv by Oversby et al.

(1991). Dark purple to black, fine, moderately crystal-poor (dominant euhedral feldspar, minor quartz, trace pseudomorphed ferromagnesian phase) dacitic ignimbrite occurs above probable Stones Creek Volcanics (undivided - DCs) to the west and south-southeast of the Sandalwood-Desmond Creek junction, and below ignimbrites of the "Locharwood" association (Collins Creek Rhyolite, Cubc, to the southwest of the creek junction; Cub_{15} to the west) in sections that appear to be stratigraphically intact. The ignimbrite has a very well developed "streaky" eutaxitic foliation defined by extremely attenuated fiamme. Lithic clasts are very sparse, and less than 2 cm across. In outcrop, the ignimbrite closely resembles a lava; however, pumice and groundmass shard pseudomorphs are well preserved and conspicuous in thin section.

It is noteworthy that spatially associated dacitic ignimbrite which is well exposed in Sandalwood Creek about, 4 km south-southwest of the Desmond Creek junction, and which directly overlies undivided Stones Creek Volcanics between about 1 km and 3 km to the northeast, is more likely to be Smedley Dacite (below) than an "Earlscliffe" association rock.

Farther south in the central-east thoroughly hornfelsed dacitic ignimbrite/s and volcaniclastic rocks (Cvi of Oversby et al. 1991) occur in a small (0.75 km x 1.25 km) west-northwest-trending outcrop area, now completely surrounded by intrusive rocks (CPg_{10}) and presumably originally a fault block, 4 km south-southwest of "Glendon". These hornfelsed rocks are also tentatively included in "Earlscliffe" association unit Cub_1. Ignimbrite is bluish-grey, moderately crystal-rich (feldspar more abundant than quartz), and contains scattered lithic clasts 2 cm to 3 cm across; volcaniclastic rocks are pale bluish grey, diffusely stratified, siltite and arenite with local pebble rudite, of indeterminate origin. More probable Cub_1 ignimbrite occurrences lie about 1 km to the east-southeast and about 2 km to the west-northwest of the above outcrop area (about 5 km south-southeast and 6 km southwest of "Glendon" homestead respectively), along the present structural and probably original stratigraphic strike. The eastern occurrence has been examined in a (north-flowing) western tributary of lower Collins Creek, the western one in a western tributary of middle Glendon Creek. The rocks were assigned to unit Cvi_4 (tentatively, in the case of the ones exposed in the Collins Creek tributary) by Oversby et al. (1991). In the Collins Creek tributary section, about 200 m of dark purple, "streaky" foliated, euhedral feldspar-bearing ignimbrite is overlain northeastwards by the Collins Creek Rhyolite; in the southwest it is in fault contact with mainly bedded sedimentary rocks tentatively assigned to the Star of Hope Formation. This purple ignimbrite thus occupies the same sub-"Locharwood" association stratigraphic position as the very similar lava-like ignimbrite farther north. In the Glendon Creek tributary occurrence, the ignimbrite is involved in an intricately faulted and intruded north-northeast-trending belt; however, it appears to stratigraphically overlie undivided Star of Hope Formation, and it may underlie rocks included in composite "Smedley" association unit Cub_{27}.

Beyond the southeastern end of its outcrop area, the probable northeastern "Earlscliffe" association ignimbrite may be represented southwards across faults for an additional 2 km by rocks tentatively assigned to composite unit Cvi by Oversby et al. (1991). Adjacent to (east of) this, a northerly-elongated body mapped as intrusive rhyolite (CPr_3; rh of Oversby et al. 1991) is made up in part of material (not delineated separately on the map) which is also very similar to, and could represent, the purple lava-like "Earlscliffe" association ignimbrite.

Earlscliffe Dacite?, ?Cube *(Cv_{d}) of Oversby et al. 1991)*

A dark grey and dark purplish-grey crystal-rich, commonly lithic-rich, dacitic ignimbrite containing subsidiary but conspicuous hornblende preserved in the southeast, in an area of about 100 km^2 to the east of "Conway" (Glendon and adjacent parts of Mount Coolon 1:100 000 Sheet areas), may be a facies or flow unit variant of the Earlscliffe Dacite at Mount Landsborough. This rock occurs in a near-horizontal sheet, lying with apparent angular unconformity on the Bimurra Volcanics. Hornblende-bearing dacitic ignimbrite also occurs in fault blocks between Mount Landsborough and upper Rosetta Creek.

Earlscliffe Dacite, $Cube_1$, $Cube_2$, $Cube_3$ *(Cvi_{fl}, Cvi_{fq}, Cvi_f, respectively, of Oversby et al. 1991)*

The upper 150 m at least of the southeastern "Earlscliffe" association sequence at Mount Landsborough consists of the type occurrence of Earlscliffe Dacite. This is a sheet of mainly mid buff to dark grey and dark purplish grey, originally thoroughly welded, dacitic ignimbrite which appears to lack hornblende. The sheet is probably made up of multiple flow units. The most common rock type is moderately crystal-rich to crystal-rich, and clast-rich. White and pink to pale buff feldspar (15% to 30%, to 2.5 mm across) is the dominant crystal component; rare (maximum 3%) quartz to 1.5 mm across (mostly smaller) occurs at a few levels. Lithic clasts are mainly subangular, and up to 60mm across (mostly 10 mm to 40 mm). Fiamme and/or a more diffuse eutaxitic foliation are developed locally; some of the fiamme are distinctly attenuated. On Mount Landsborough, dips of eutaxitic foliation are variable in azimuth, and locally very steep (to 85°).

East of Mount Landsborough, in the southeast, $Cube_3$ is the most widespread rock type assigned to the Earlscliffe Dacite. Here it is a dark grey crystal-rich to very crystal-rich, originally thoroughly welded, dacitic ignimbrite similar to the dominant rock in the unit at Mount Landsborough (the lower part of the Mount Landsborough sequence is either not represented, or has only very minor development). Crystals (25% to 55%), mostly of white feldspar, are up to 2 mm across; quartz is absent to rare (maximum 3%), although only moderately rare (5% to 7%) in a local variant ($Cube_2$, previous Cvi_{fq}) notable for containing conspicuous macroscopic (0.5 mm to 1.5 mm across) quartz. This variant appears to occupy a stratigraphically median position, but could also be a lateral facies of $Cube_3$ to some degree. Subsidiary biotite occurs locally. The rock is typically very clast-poor and fiamme-free. However, a moderately lithic clast-rich to lithic-rich (15% to 30%) rock ($Cube_1$, previous Cvi_{fl}), apparently a stratigraphically high variant (and lateral facies?) of $Cube_3$, occurs in upper Ten Mile Creek (mainly Collinsville 1:100 000 Sheet area). This variant is susceptible to weathering, when it becomes pale green to buff in colour; this feature suggests a less than thorough degree of welding, perhaps because clast-rich parts of the original pyroclastic flow were cooled significantly by the entrained material. Pyrite is characteristically developed in the unit adjacent to granitoids.

Bobby Dazzler Rhyolite, Cubb *($Cubi_a$ of Oversby et al. 1991)*

The Bobby Dazzler Rhyolite was named by Hutton et al. (1991) from Bobby Dazzler Creek, an eastern tributary of Rosetta Creek which it joins 5 km north-northeast of "Conway". No type section was nominated by them; a provisional type reference section for the present study area has been established in the vicinity of Whitestone Peak, about 10 km east of "Conway" homestead (Appendix 1). On the basis of incomplete sections, the unit has been stated (Hutton et al. 1991) to be probably no more than 200 m thick; about 30 m is estimated to occur in the Burdekin Falls Dam - "Conway" area reference section.

The Bobby Dazzler Rhyolite extends into the southeast from the south, where it may underlie the Locharwood Rhyolite (Hutton et al. 1991). To the east of "Conway", the formation overlies hornblende-bearing welded dacitic ignimbrite assigned to possible Earlscliffe Dacite (?Cube, above). For these reasons, and because of the known and suspected dacitic natures of its underlying and overlying associates, the Bobby Dazzler Rhyolite is included in this discussion of the lower dacite-rhyolite association of the Bulgonunna Volcanic Group. However, it may be part of a sequence which was extruded from the Mount Coolon area, rather than from Mount Landsborough, and so should be regarded as belonging to a potentially separate stratigraphic entity.

The Bobby Dazzler Rhyolite in the southeast consists of a homogeneous moderately crystal-rich, moderately lithic clast-rich, originally thoroughly welded, rhyolitic ignimbrite. The rock is pale grey when fresh, brown and buff when weathered. It contains 15% to 25% crystals of quartz, feldspar and biotite from 0.5 mm to 2.5 mm in maximum dimension, and up to 15% conspicuous volcanic lithic clasts between 20 mm and 30 mm in maximum dimension. Fiamme are rare.

Un-Named Unit Cub_7 *($Cubi_1$ of Oversby et al. 1991)*

In the southeast the Bobby Dazzler Rhyolite is overlain with apparent conformity by buff, moderately lithic-rich to lithic-rich (15% to 30%), moderately crystal-rich (slightly less than 10% to about 20% pink feldspar, with subsidiary biotite and rare quartz) probably rhyolitic welded ignimbrite which is invariably altered to some degree and so of uncertain original composition. Some of the apparent clasts may be siliceous pseudomorphs of poorly expanded and/or unflattened pumice fragments.

Part(?) of Un-Named Unit CPr_2 *(rh_2 of Oversby et al. 1991)*

While unit CPr_2 in the southeast is believed to incorporate rocks which are mostly of very high-level intrusive origin (and discussed more fully under that heading - below), finer-grained components, with ambiguous or structurally disrupted stratigraphic relationships, could be lavas belonging to the "Earlscliffe" association.

Un-Named Unit Cub_8 *(part Cvi, Cvi_r, Cvi_d, Cvl_r, Cvl_d of Oversby et al. 1991)*

Nonwelded rhyolitic ignimbrite (previous Cvi_r) believed to belong to the "Earlscliffe" association is known from a small outcrop area in the southwest, about 5 km north of "Ukalunda" homestead. Here, the rock is intensely fractured to brecciated and appears to have been mildly hornfelsed, presumably by the adjacent House and Kitchen Granite. The rock contains small, moderately attenuated, fiamme; it is overlain discordantly by the Pyramid Rhyolite. The contact with the Pyramid Rhyolite has evidently been structurally modified to some extent, but could originally have been an unconformity.

In the southwest, other occurrences of welded rhyolitic ignimbrite placed in the "Earlscliffe" association occur to the west and north of the Sunbeam Mine. In this area, the rocks locally overlie nonwelded pyroclastic rocks (sCub - above), and are overlain by the Locharwood Rhyolite.

Flow-banded dacite of probable extrusive origin (previous Cvl_d) is associated with inferred (on a basis of groundmass grainsize) intrusive equivalents (previous mg_2, where mapped separately) in the southwest (to the north-northeast of "Ukalunda" homestead, and in the vicinity of the Sunbeam Mine), and between western tributaries of upper Percy Douglas Creek and Reginald Peak, in the south-central part of the study area. These rocks are commonly overlain by the Locharwood Rhyolite, and, locally, by the Pyramid Rhyolite. To the north of the Sunbeam Mine the inferred intrusive equivalents may also be overlain locally by pre-Locharwood nonwelded pyroclastic (sCub - above) rocks which also belong to the "Earlscliffe" association.

In the central-eastern part of the study area, ignimbrites (tentative Cvi of Oversby et al. 1991) that may belong to the "Earlscliffe" association are known only from very limited exposures between Oaky Creek and lower Birralee Creek. They are tentatively regarded as part of grouping Cub_8. Stratigraphically, these occurrences are very poorly constrained, but are overlain by Permian Lizzie Creek Volcanics. They are faulted against intermediate volcanics, tentatively regarded as undivided Bimurra Volcanics. However, the rocks are feldspar-dominant and quartz-poor, and moderately close to (about 8 km north of) definite Earlscliffe Dacite (subunit $Cube_2$).

Discussion

The thick, and in detail stratigraphically intricate, Mount Landsborough sequence of "Earlscliffe" association rocks (sCub, Cub_1, and part [$Cube_3$] Earlscliffe Dacite) probably overlies its own extrusive centre/s, according to thicknesses and the localisation of clast-rich ignimbrites, particularly in the lower part of the sequence.

Lava assigned, tentatively in part, to "Earlscliffe" association grouping Cub_8 (above), along with related(?) high-level intrusive rocks (CPr_2-type), in the southwest and south-centre indicate that extrusion was also centred there.

The Bobby Dazzler Rhyolite and unit Cub_7 elsewhere in the southeast probably originated from the northern Mount Coolon 1:100 000 Sheet area, according to their distributions; on this basis, it could be argued that they do not properly belong to the "Earlscliffe" association.

LOWER RHYOLITE-DOMINATED ("LOCHARWOOD") ASSOCIATION

Ignimbrites belonging to the lower rhyolite-dominated ("Locharwood") association are present in all areas of preserved Bulgonunna Volcanic Group except the centre-west and southeast; they are dominant in the southwest, most of the centre, and a large portion of the northeast. Only one possible example of the "Smedley" association stratigraphically overlying the "Locharwood" association is known; it is in a structurally complex belt in the Burdekin River, downstream of the dam (northeast). There, steeply-dipping purple quartz-bearing ignimbrite of uncertain composition crops out (poorly) below gently-dipping "Smedley" association conglomerate. The ignimbrite is not delineated separately on the map from unit Cub_{22} ("Smedley" association). While the ignimbrite is most simply interpreted as a rhyolitic component of that association, it may actually be a non-distinctive "Locharwood" association rock.

The most confidently established relationships among "Locharwood" association units are, from direct field observations:

(i) south-centre- Locharwood Rhyolite overlying Pyramid Rhyolite, in an eastern tributary of upper Bell Creek 7.5 km north of the Sunbeam Mine;

(ii) northeast- Locharwood Rhyolite overlying Collins Creek Rhyolite, in northeastern tributaries of upper Gap Creek;

(iii) northeast- unit Cub_{15} overlying Cub_{12}, 7.5 km south of the Burdekin River weir (about 2 km east of the river);

(iv) northeast- unit Cub_{12} overlying poorly exposed and locally tentative Locharwood Rhyolite, in the vicinity of (c);

(v) northwest- unit Cub_{19} overlying tentative Locharwood Rhyolite, in northeastern tributaries of middle Bull Creek; and overlain by unit Cub_{20}, in the watershed between eastern tributaries of upper Bull Creek and adjacent minor western to northwestern tributaries of the Burdekin River, to the west and southwest of Burdekin River weir.

A somewhat more equivocal outcrop, but potentially more significant in suggesting repetition of at least one ignimbrite rock type which may be due to original stratigraphic intertonguing relationships, is:

(vi) northeastern unit Cub_{14} overlying a lens of Cub_{13}, with the pair both underlain and overlain by Cub_{15}, 4.5 km southeast of the weir (1.5 km east of the river), according to eutaxitic foliation dips and the mapped trace of the lower Cub_{15}/Cub_{13}/Cub_{14} contact in the southeast, although contrary to the trace of the Cub_{14}/upper Cub_{15} contact to the northwest.

The aggregate thickness of preserved "Locharwood" association units in the map area is estimated to be about 7500 m. However, no individual development of the association ever contained a full complement of units, so that this thickness is only meaningful in being broadly indicative of a cumulative magma volume.

The principal occurrences of "Locharwood" association rocks in the northeast lie between "Smedley" association outcrops to the west, and a large expanse of granitoid plutons to the north and east. The intricacy of the internal ignimbrite stratigraphy, the number of mappable sheets, and probably the aggregate thickness represented, all increase from south to north. The sequence in the south is dominated by the two most extensive ignimbrite sheets in the entire study area - the Collins Creek Rhyolite (Cubc) and the Locharwood Rhyolite (Cub_1). The ignimbrite sequence in the north has been unravelled in part, with varying degrees of confidence, from the displaced remnants of sheets in fault blocks and slices. A locally intricate stratigraphic framework has been revealed. As now perceived, this framework is made up of six, in part repetitious, ignimbrite types assigned to the units Collins Creek Rhyolite (Cubc), Locharwood Rhyolite (Cub_1), and un-named units Cub_{12}, Cub_{13}, Cub_{14} and Cub_{15}. The lack of a Cub_{16} is due to the transference of Locharwood Rhyolite from that level to its present position as evaluation and re-evaluation of data proceeded.

Three of the major "Locharwood" association ignimbrite remnants in the northwest (Cub_{10}, Cub_{19}, and Cub_{20}) are seen nowhere else in the study area. Similarly, the Pyramid Rhyolite, one of the main "Locharwood" association ignimbrite units preserved in the southwest and south-centre, is not known in any other part of the study area.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that "Locharwood" association (their unit V73) rocks are I-types, unfractionated, oxidised to strongly oxidised, and high-potassium (based on seven unpublished AGSO analyses, mostly from Locharwood Rhyolite).

Epiclastic and Volcaniclastic Rocks, sCub *(Cbs of Oversby et al. 1991)*

In the southwest, poorly bedded and sorted, coarse, locally small-pebbly to large-cobbly, medium olive-green lithic-feldspar sandstone, together with fine to very coarse conglomerate and probable rare planar- and cross-laminated siliceous fine to coarse siltstone grading into pebbly medium feldspar-lithic sandstone, is exposed around most of the northern, southern, and western periphery of the Pyramid Range.

These rocks lie unconformably on the Saint Anns Formation, and appear to have accumulated on a slightly irregular palaeotopographic surface; they are not known from any other part of the study area. The sedimentary interval is placed provisionally in the lowermost "Locharwood" association because of its spatial association with the Pyramid Rhyolite and apparent intra-Bulgonunna age (below).

Clasts in the sedimentary rocks are well-rounded, and consist of: lithic-feldspathic sandstone/s; pale grey "chert" with finely disseminated pyrite; fine green siltstone; ignimbrites, including conspicuously large clasts of a pale buff to grey one containing 20% quartz and feldspar crystals mostly to 1 mm across (a few to 3 mm) in approximately equal proportions.

This partly volcaniclastic sedimentary interval is overlain, conformably or disconformably, by the Pyramid Rhyolite, the lowest recognised extrusive part of the "Locharwood" association. Original relationships of the sedimentary rocks to other Bulgonunna volcanics are no longer preserved. However, the size and types of volcanic clasts in the unit suggest that it incorporates debris from some nearby unit or association which was apparently rhyolitic, i.e. probably Bulgonunna Volcanic Group, and not necessarily "Earlscliffe" association.

The lowermost Pyramid Rhyolite about 2 km north of Reginald Peak, in the south-central part of the study area, contains apparent lenses up to about 3 m thick of unsorted and unstratified pebble- to small boulder-conglomerate. This material is not differentiated from the Pyramid Rhyolite on the map. Crystal-poor (quartz plus feldspar and feldspar alone) rhyolitic ignimbrites, again of unknown provenance, comprise the well-rounded conglomerate clasts. Conglomerate is accompanied at least locally by pale buff to medium buff-grey, very fine- to fine-grained volcaniclastic arenite displaying low-angle cross laminae and thin to medium-thickness planar beds. Comparable clastic material is not known from the Pyramid Rhyolite preserved in a series of interlocking fault blocks between 1 km and 2.6 km to the southwest of Reginald Peak. With one possible (photo-interpreted) local exception, the main Pyramid Rhyolite ignimbrite rests directly on sub-Pyramid rocks.

A crystal-poor and pumiceous, locally lithic clast-rich (matrix-supported) pyroclastic rock with flattened pumice fragments included in sCub crops out among a swarm of southwest-trending CPr_3 (below) dykes in the northeast, approximately mid-way between the Burdekin River and middle Sandalwood Creek (grid reference 8356 - 344260 and vicinity). The rock apparently occurs as a lens within the Collins Creek Rhyolite. However, the proportion of feldspar crystals is much greater than that of quartz, suggesting that it had an origin independent of, or modified from, the quartz-rich ignimbrite making up that formation. Lensoidal bodies of volcaniclastic rocks (laminated and thin-bedded, locally pumiceous, lutites and arenites, with sporadic lithic-granule rudite, possibly representing minimally reworked pyroclastic material) up to a few tens of metres thick are also moderately common higher in the "Locharwood" association sequence between the Burdekin River and middle Sandalwood Creek. Stratigraphically, they occur in the Cub_{12} through Cub_{15} interval.

Pyramid Rhyolite, Cubp *(Cb_{IIa}, Cb_{IIb} of Oversby et al. 1991)*

The Pyramid Rhyolite is named from, and best developed in, the Pyramid Range in the southwest, where its type section occurs (Appendix 1). The formation extends as a recognisable entity, via discontinuous outcrop areas, for about 15 km eastwards to near Reginald Peak (south-centre). The formation consists of lower nonwelded and upper welded parts, with the latter being dominant and characteristic. The nonwelded part of the unit does not occur everywhere.

The characteristic upper part of the Pyramid Rhyolite consists of medium purple or pale red to purplish-brown moderately crystal-rich to (occasionally) crystal-rich welded ignimbrite with fiamme (previous Cb_{IIb}) in an apparent single cooling unit and possible single flow unit. Crystals are 0.5 mm to 3 mm in maximum dimension; both quartz and feldspar are present in approximately equal proportions. The rock also contains up to about 3% biotite, mostly pseudomorphed by iron oxides, in flakes up to 0.5mm long. Fiamme are eroded and outcrops are distinctively pockmarked by small elongate cavities as a consequence. This ignimbrite is rich in lithic clasts in the area of upper Percy Douglas Creek.

A subsidiary part of the Pyramid Rhyolite exposed in the Pyramid Range consists of very pale greenish-grey to pale buff, commonly "chalky", moderately crystal-rich, nonwelded or very poorly welded ignimbrite (previous Cb_{IIa}) containing less than 1% biotite flakes. It underlies the main part of the unit, and may represent a discrete eruptive event. This part of the Pyramid Rhyolite has been recognised at a few localities beyond the Pyramid Range, most notably to the north of Reginald Peak. However, its distribution appears to be sporadic and irregular.

About 3 m of flow-banded rhyolite containing approximately 7% feldspar and subsidiary quartz phenocrysts up to about 2 mm across occurs rarely in the northern Pyramid Range between the base of the Pyramid Rhyolite and underlying epiclastic sedimentary. This rock may represent a lava of the rhyolite-dominated association, rather than a concordant intrusion.

On the northeastern side of the Sellheim River, about 4 km north-northeast of "Ukalunda" homestead, about 30 m of southeasterly-dipping (10^{o}) ignimbrite assigned to the main part of the Pyramid Rhyolite overlies tentative "Earlscliffe" association unit Cub_8 ignimbrite which also dips to the southeast, but at 65^{o}. Although the contact has evidently been structurally modified (a sill-like CPr_3 body, which could be an apophyse of House and Kitchen Granite, follows it), originally it may have been an angular unconformity. To the southeast, the Pyramid Rhyolite is in fault contact with the Locharwood Rhyolite.

In the west-centre and south-centre the main ignimbrite sheet of the Pyramid Rhyolite occurs in structurally intricate settings straddling and to the north of upper Bell Creek, and in the vicinity (southwest and north) of Reginald Peak. The upper Bell Creek outcrops are locally moderately rich to rich in angular lithic clasts up to 6 cm across. Abundant lithic clasts are also known from the Reginald Peak occurrences (in which both ignimbrites are represented), but less commonly.

In the Pyramid Range, the Pyramid Rhyolite is estimated to be approximately 100 m thick; of this, the lower part of the unit accounts for about 30 m. To the north of the Sunbeam Mine on the other hand, the main part of the unit may be as much as 400 m thick (although there could be some repetition on unrecognised strike-parallel faults). Faulted remnants up to about 100 m thick are preserved in the vicinity of Reginald Peak.

The Pyramid Rhyolite ignimbrites cut out beneath the Locharwood Rhyolite along the western part of the Sunbeam Mine fault zone in such a way as to suggest that the zone underwent syn-depositional oblique-slip (east side down).

Un-Named Unit Cub_{10} *(Cb of Oversby et al. 1991)*

Unit Cub_{10} is recognised only in the northwest; it crops out from near the junction of Stones and Glenroy Creeks, 4.5 km east of "Glenroy" outstation, to the head of Packhorse Creek, 9 km east-northeast of the outstation. The unit consists of very dark grey, moderately crystal-rich to crystal-rich and lithic clast-poor to moderately clast-rich welded rhyolitic ignimbrite containing biotite and hornblende. It is at least 100 m thick (top not preserved).

Rocks of unit Cub_{10} occur as a single faulted sheet, probably representing a single cooling unit. This unconformably overlies the Stones Creek Volcanics and the Scartwater Formation, suggesting that the unit is the lowest one in the local Bulgonunna Volcanic Group sequence. However, it is not in stratigraphic contact with any other part of the group; it is treated as a "Locharwood" association component because of its rhyolitic nature and its proximity to other representatives of the association. The closest other representative, the Collins Creek Rhyolite, occurs 2 km to the east-southeast. Unfortunately, because of extensive faulting and igneous intrusion, it is unknown whether or not this occurrence of the Collins Creek Rhyolite overlies Cub_{10} ignimbrite. Certainly, it rests on subunit DCs_1 of the Stones Creek Volcanics in a single small "window" less then 1 km south of middle Bull Creek, but this relationship may be atypical. The most likely alternative possibility, that Cub_{10} belongs to the "Arundel" association, lacks credibility because the unit is nowhere known to overlie "Locharwood" association rocks.

Collins Creek Rhyolite, Cubc *(Cbg, Cb_1 of Oversby et al. 1991)*

The Collins Creek Rhyolite is named from Collins Creek, south of "Glendon" homestead in the northeastern part of the study area. The type section of the formation occurs, in two parts, in and adjacent to middle Collins Creek and upper Gap Creek (Appendix 1).

The Collins Creek Rhyolite typically consists of dark to very dark bluish-grey, crystal-rich to very crystal-rich and lithic clast-free to lithic-poor, moderately massive, thoroughly welded rhyolitic ignimbrite. Abundant and conspicuous, equant embayed quartz grains up to 7 mm (mostly 5 mm) in diameter, are especially characteristic. Weathered surfaces commonly have a very rough texture imparted by protruding quartz grains. Feldspar crystals and fragments are smaller (1 mm to 2 mm), though more abundant, than quartz. Biotite flakes up to 3 mm long are also conspicuous; these are semi-diagnostic of the Collins Creek Rhyolite in the northwest because of their relative abundance in the unit compared to other ignimbrites in the area. Hornblende and biotite occur in minor amounts in the northeast and centre. The quartz plus sanidine/orthoclase plus sodic plagioclase plus biotite crystal content of the rock ranges up to 45%. Lithic clasts are up to 5 cm across locally in the northwest (near the possible base of the unit), although mostly less than 2 cm. Lapillus-size (4 mm to 32 mm) lithic clasts are typically present in the northeast and centre, although usually not abundant. In many cases the primary vitroclastic matrix has been recrystallised to granophyre. In the northeast and centre, pumice relics (fiamme) are slightly darker blue, and less crystal-rich, though coarser than the groundmass; they are usually inconspicous, but are locally easily seen on river pavements. The Collins Creek Rhyolite is estimated to be at least 200 m thick in and adjacent to its type section.

In the northwest, the Collins Creek Rhyolite crops out in the area between Packhorse Creek and Bull Creek, and along the northern side of the Burdekin River east from Bull Creek; the unit extends across the river to the south of the weir. The Collins Creek Rhyolite overlies the Stones Creek Volcanics with angular unconformity, and is overlain with probable paraconformity (disconformity?) by the Locharwood Rhyolite (Cubl - below). The Collins Creek Rhyolite is for the most part only slightly altered in the northwest, to propylitic assemblages of sericite, epidote, chlorite, "leucoxene", and prehnite(?). More intense alteration occurs along fractures and shears, e.g. in Bull Creek, 1.1 km northwest of its debouchement into the Burdekin River, near a significant faults (in terms of probable amount of dip-slip displacement on it). Crystals in general, and quartz, become generally more abundant upwards in the unit. The abundance of lithic clasts decreases upwards from the base of the unit, then increases again at a level in the upper(?) part (e.g. in Bull Creek 1.6 km west-northwest of its junction with the Burdekin River). However, lithic clasts are rare or absent immediately below and a few metres above this level. Clast types include andesite, dacite, rhyolite, trachyte(?), siltstone and mudstone. Pumice clasts up to 10 cm long are conspicuous in places, mainly near the base of the unit in the west, and in Bull Creek 1.6 km west-northwest of its mouth. Pumice near the base is oxidised, and deep reddish-brown in colour. The distribution of lithic clasts and pumice indicates the presence of at least two flow units. Thickness is uncertain because of the paucity of dip information; it is at least 250 m, and may be as great as 750 m.

Some outstanding exposures of the Collins Creek Rhyolite in the northeast occur along the upper reaches of Gap Creek and on the high plateau to the south of Charlie Creek, as far as Peak John Well, in the south-central part of the study area. The stratigraphic base of the formation is exposed only in and beside a southern tributary of lower Collins Creek 5 km south-southeast of "Glendon" homestead, where it overlies feldspar-bearing ignimbrite tentatively assigned to unit Cub_1 of the "Earlscliffe" association. Here, the Collins Creek Rhyolite is massive and no dip was determined; however, the trace of the contact suggests a moderate inclination to the northeast. The "Earlscliffe" association (?) ignimbrite dips very steeply to the northeast. On this basis, there appears to be an angular discordance between the two sequences. Nearby (Collins Creek at grid reference 8356 - 255108), the lower Collins Creek Rhyolite is particularly rich in clasts of purple "Earlscliffe" association-type dacitic ignimbrite.

The Collins Creek Rhyolite ignimbrite sheet in the northeast is not known to contain mappable internal textural variations which might reflect individual flow units. However, a presumably lenticular interval, less than 10 m thick, of stratified volcaniclastic (pumiceous and crystal-rich) "sediment" is known from within the formation in the upper reaches of an un- named southeastern tributary of the Burdekin River 8 km southwest of the junction of Sandalwood and Desmond Creeks. This suggests that at least two flow units make up the sheet. Flow unit boundaries at other localities must be very subtle, requiring more detailed examination than was possible in this study to pinpoint and trace.

Locharwood Rhyolite, Cubl *(Cb_L, Cb_l, Cb_{IIIa}, Cb_{IIIb} of Oversby et al. 1991)*

The Locharwood Rhyolite was originally mapped and named in the Mount Coolon area (Hutton et al. 1991), although no specific type area or section has yet been nominated. Pending rectification of this omission, a provisional type section to the north of “Ukalunda” homestead is offered by us (Appendix 1). The main rock type assigned to the formation in the Mount Coolon and Byerwen 1:100 000 Sheet areas is dark grey, buff- to white-weathering, moderately crystal-rich to crystal-rich densely welded rhyolitic ignimbrite with well-developed eutaxitic foliation. The rock contains 10% to mainly 15% but locally reaching 25% quartz, alkali feldspar, and plagioclase, with accessory biotite crystals. Well-defined fiamme, commonly consisting of chlorite and/or sericite, are ubiquitous. Up to 80 m of the formation are exposed locally.

A zircon U-Pb control age of approximately 305 Ma has been given by the type Locharwood Rhyolite 18 km east-southeast of Bulgonunna Peak in the Byerwen 1:100 000 Sheet area (Black 1994; Appendix 2).

Supplementary sections illustrative of the Locharwood Rhyolite as it is developed in the map area occur in the northwest (northeast of lower Bull Creek), centre (west-northwest of Peak John Well), and southwest (west and north of the Sunbeam Mine, and northeast of "Ukalunda" homestead provisional type) (Appendix 1). The main part of the unit in its section near "Ukalunda" has yielded a zircon U-Pb date essentially identical to the one, noted above, from the type-area Locharwood Rhyolite (Black 1994; Appendix 2).

In the map area, rocks assigned to the formation are preserved semi-continuously from the hills overlooking "Ukalunda" homestead, eastwards to the limits of the southwestern part of the study area. The formation continues without interruption into the centre and northeast, and can also be recognised in the northwest. It is the only Bulgonunna Volcanic Group unit common to both the Burdekin Falls Dam - "Conway" and Mount Coolon areas, thus providing an important datum for correlation not only within the group, but also between the two areas.

The Locharwood Rhyolite in the map area was originally placed at stratigraphic level 16 in the ordering of Bulgonunna Volcanic Group units. However, while that remains a possibility, it became evident at a fairly advanced stage of map and text compilation that a revised position between the Collins Creek Rhyolite (original level 11) and Cub_{12} is more consistent with available data. Unit notations involving numbers have not been altered to reflect this revision because of the probability of introducing errors and significant confusion to map and text.

Rocks (previous Cb_1) in the Bull Creek - old Burdekin River Weir area (northwest), which are equated with the Locharwood Rhyolite in its main exposures farther south, overlie the Collins Creek Rhyolite (Cubc - above), probably paraconformably (disconformably?). The rocks are paraconformably overlain by Cub_{19}. They are at least 160 m, and probably close to 200 m, thick near Bull Creek. The Locharwood Rhyolite in this area consists of pale to mid grey or pinkish-grey, poorly welded (in lowest-exposed parts) to welded, moderately crystal-rich rhyolitic ignimbrite. The rock is characterised by conspicuous pink K-feldspar crystals 1 mm to 3 mm long, and pink to red, moderately to extremely attenuated, fiamme; eutaxitic foliation is generally very well developed. An additional, but not ubiquitous, characteristic is the visibility at hand specimen scale of abundant pseudomorphs of extremely flattened and wispy groundmass glass shards. Quartz crystal fragments are not as abundant, nor as conspicuous, as in sub- and suprajacent units (Cubc and Cub_{19}). The lowermost part of the ignimbrite sheet (apparently a single cooling unit, but possibly multiple flow units) is a lithic-rich interval up to 15 m thick. Clasts range up to 25 cm across and include rhyolitic ignimbrite and rhyolite. Clasts are present sporadically up to 60 m above the clast-rich interval, most notably in a zone about 50 m to 60 m above the base of the sheet. This latter zone contains lithic clasts up to about 1 cm across, and pumice fragments up to 7 cm x 1.5 cm; it may be at, or close to, the base of a second flow unit. The Locharwood Rhyolite is moderately (propylitically) altered to chlorite, sericite, epidote and calcite.

In the northeastern and central parts of the study area, the Locharwood Rhyolite (Cb_L of Oversby et al. 1991) conformably overlies the Collins Creek Rhyolite. The relationship is confidently established from exposures in both northern and southern tributaries of uppermost Gap Creek. The formation extends east and north from the vicinity of upper Gap Creek around the periphery of the large, half-moon-shaped, stock of "Billy-can Creek" granite (CPgb) that intrudes it. The formation also occurs in the complexly faulted and intruded area to the north of the Billy-can Creek stock, where it is apparently overlain by Cub_{12}; it extends almost as far as the Burdekin River. In the vicinity of Mount Constance, it is overlain by Cub_{17} (an occurrence of Cub_{12} on the southeastern side of the mountain is in high-angle fault contact with both the Locharwood Rhyolite and Cub_{17}; it may have been displaced laterally on a concealed low-angle fault. To the southwest of the mountain, about 5 km north-northeast of "Old Hidden Valley" homestead, the Locharwood Rhyolite is apparently overlain by a local development of rhyolitic lava placed in composite unit Cub_{21}. Good sections of Locharwood Rhyolite occur in tributaries of Gap Creek, beginning at the contact with Collins Creek Rhyolite, e.g. in southern tributaries 5.4 and 6.3 km northwest of Peak John Well, and continuing south-southwest for 2 km to 3 km to the contact with the Cub_{21} lava. In upper Gap Creek, the Locharwood Rhyolite is about 1500 m thick.

The Locharwood Rhyolite is extensively exposed on the plateau north of Willie Moore and Two Mile Creeks, to the northeast of "Ukalunda" homestead in the southwest. Here, the bulk of the formation (Cb_{IIIb} of Oversby et al. 1991) consists of medium grey, moderately crystal-rich, welded ignimbrite with fiamme. Crystals are 0.5 mm to 3 mm in maximum dimension; quartz and feldspar crystals occur in approximately equal proportions. The feldspar crystals are white to medium orangey-red. The rock also contains less than 1% biotite, mostly pseudomorphed by chlorite, in flakes up to 0.5 mm long. Fiamme in this occurrence are atypical, being mostly medium grey and small; they weather neutrally and are thereby inconspicuous. No lithic clast-rich facies is known to be exposed. The unit displays crude rectangular columnar jointing.

In the Sunbeam Mine area, and eastwards as far as the junction between Isabella, Mary and Five Mile Creeks (central study area), the main Locharwood Rhyolite is mainly medium buff in colour, with the majority of feldspar crystals and fiamme being pale to medium orangey-red; joints are very much more closely-spaced than in the westernmost outcrops. The rock contains about 1% biotite, partly replaced by iron oxides, in flakes up to 1 mm long. Again, no clast-rich representatives of this part of the unit are known.

The westernmost and more easterly variants of Locharwood Rhyolite in the southwest appear to intergrade laterally and vertically in the Sunbeam Mine area. The differences between them might reflect compaction-welding and devitrification-recrystallisation variations concomitant with a westward increase in thickness.

A minor, lower part of the Locharwood Rhyolite in the southwest (previous Cb_{IIIa}), is made up of very pale grey, nonwelded or very poorly welded and commonly "chalky", rhyolitic ignimbrite similar to the lower part of the Pyramid Rhyolite. This subunit is only locally exposed.

The Locharwood Rhyolite to the north of "Ukalunda" has an estimated thickness of 650 m. Farther east, to the north of the Sunbeam Mine, up to about 400 m of the unit occur; of this thickness, locally up to 30 m consists of the lower nonwelded part.

The Locharwood Rhyolite in and adjacent to an east-northeast-striking fault zone about 5 km north of Peak John Well has been silicified, contains disseminated pyrite and scattered coarse specularite, and is locally distinctly "gossanous"; these features are developed most conspicuously in a 1 km-long tract to the northwest of the well.

Un-Named Unit Cub_{12} *(Cb_3 of Oversby et al. 1991)*

In the northeast, unit Cub_{12} consists of pale purple, cream, or pink, moderately crystal-poor (quartz equal to feldspar) rhyolitic ignimbrite with delicate relic pumice wisps and scattered (commonly brick red) lithic fragments less than 4 cm across. The eutaxitic foliation defined by relic pumice is typically well-defined. Another important characteristic is the "chalky" dull appearance of the rock, even though matrix shard pseudomorphs indicate that it was originally welded (the "chalky" appearance is more commonly associated with nonwelded rocks). The principal occurrence of Cub_{12} lies between the Burdekin River and middle Sandalwood Creek, where it overlies the Locharwood Rhyolite. However, unit Cub_{12} directly overlies the Collins Creek Rhyolite in western tributaries of lower to middle Sandalwood Creek about 9 km southeast of the Burdekin River weir. Unit Cub_{12} is overlain by, and locally separated from, unit Cub_{15} by thin lenses of bedded volcaniclastic "sedimentary" rocks (sCub). Unit Cub_{12} itself also includes a thin-bedded sedimentary lens (too limited to show on the map) 4.1 km southwest of the junction of Sandalwood and Desmond Creeks, and is evidently made up of at least two flow units. The thickness of Cub_{12} in the northeast is about 900 m.

The only other occurrence of rocks assigned to unit Cub_{12} in the study area is in the south-centre, in a small outcrop area, probably surrounded by steep faults (in part occupied by CPg_2 and an apophyse of CPg_{10}), on the southeastern flank of Mount Constance. Here, the unit has been structurally juxtaposed against the Locharwood Rhyolite and Cub_{17}. Probably less than 100 m of the unit are preserved.

Un-Named Unit Cub_{13} *(Cb5 of Oversby et al. 1991)*

In the northeast, unit Cub_{13} occurs 4.5 km southeast of the old Burdekin River weir (1.5 km east of the river); it consists of very pale green, fine, crystal-poor (subequal quartz and feldspar) pumiceous rhyolitic ignimbrite, with characteristically "chalky" fresh surfaces and smooth weathered surfaces. Lithic clasts are locally abundant. Relic pumice clasts, less than 2 cm long, are darker green than the groundmass. Unit Cub_{13} forms a lens below unit Cub_{14}, and is underlain by lower Cub_{15}. Units Cub_{13} and Cub_{14} together possibly represent an intercalation within, or an intertonguing into, unit Cub_{15} (i.e. Cub_{15} appears to both underlie and overlie the pair).

The maximum thickness of Cub_{13} in the northeast is a few tens of metres. It is not known from any other part of the Burdekin Falls Dam - "Conway" area.

Un-Named Unit Cub_{14} *(Cb6 of Oversby et al. 1991)*

Unit Cub_{14}, recognised only in the northeast, is made up of well jointed dark purplish-buff and purplish-grey to blue, fine-medium, moderately crystal-rich, ignimbrite. The rock is especially characterised by its euhedral feldspar crystals averaging 2 mm long, and well developed eutaxitic foliation defined by thoroughly flattened relic pumice clasts; it is also characteristically strongly jointed. The rock appears to lack quartz crystals and may be geochemically close to dacite. Lithic clasts are generally spae and small (1 cm to 2 cm). The unit is restricted to the highest parts of the hills between the Burdekin River and Sandalwood Creek, where it overlies unit Cub_{13} and lower Cub_{15}. Unit Cub_{14} is about 250 m thick.

Un-Named Unit Cub_{15} *(part Cb_4 of Oversby et al. 1991)*

In part, rocks assigned to unit Cub_{15} may be the highest ignimbrites within the northeastern "Locharwood" association; they crop out between the Burdekin River and Sandalwood Creek. The rock is dark blue, coarse, crystal-rich (feldspar equal to or greater than quartz, each much greater than hornblende and biotite where present) rhyolitic ignimbrite, and contains coarsely porphyritic relic pumice lenses. The ignimbrite is texturally very similar to the Collins Creek Rhyolite. In particular, it has the same coarse (5 mm) embayed quartz crystals. The only conspicuous (but not invariable) difference between them is the greater abundance, variety and size of lithic clasts in Cub_{15} compared with the Collins Creek Rhyolite. Whether or not the two units are related as lateral and/or vertical variants (tongues?) representing a single eruptive event remains problematical. Rocks of unit Cub_{15} probably underlie and apparently also overlie units Cub_{13} plus Cub_{14}, suggesting that the last two together make up an intercalation within, or a tongue into, Cub_{15}. In the northeast, Cub_{15} is about 800 m thick.

Hornfelsed rocks tentatively assigned to unit Cub_{15} occur in the north-central part of the study area, in a southeast-trending screen separating granitoids ("Billy-can Creek" granite, CPgb, mainly in the southwest, and CPg_{10}, mainly in the northeast) between the upper reaches of Billy-can and Sandalwood Creeks. These rocks appear (from mapped traces of contacts and two determinations of eutaxitic foliation dips) to be underlain at separate localities by tentative Collins Creek Rhyolite and by the Locharwood Rhyolite. Again, this is suggestive of intertonguing or other vertical and lateral stratigraphic complexities involving "Locharwood" association units. However, the data currently available are equivocal, as the contacts from which relationships have been, in part, interpreted are not entirely free of structural complications.

Un-Named Unit Cub_{17} *(part Cb_4 of Oversby et al. 1991)*

Unit Cub_{17} occurs only in a series of mainly fault-bounded blocks in upper Teatree Creek, to the southwest (tentatively) and east-northeast of Mount Constance, and (tentatively) 5 km southeast of the mountain, in the south-central part of the study area; it probably rests directly on Locharwood Rhyolite. The unit is very similar to upper and lower Cub_{15} farther north (above), and is associated structurally with rocks assigned to unit Cub_{12}. Unit Cub_{17} may be a lateral equivalent of lower or upper parts (or both combined) of unit Cub_{15} farther north. The minimum thickness of Cub_{17} is about 1000 m.

Un-Named Unit Cub_{18} *(Cb_8 of Oversby et al. 1991)*

Unit Cub_{18} is recognised (in part tentatively) only in a group of fault blocks traversed by the Burdekin River about 5 km south of the weir, in the northeast. It consists of pale to (mainly) dark purple, medium, moderately crystal-rich (quartz about equal to feldspar, each much greater than biotite) rhyolitic ignimbrite with well-developed foliation defined by relic pumice lenses. The feldspars are commonly pink or orange, and brick-red lapillus-size lithic clasts are locally conspicuous. There is some variation in crystal abundance and size (2 mm to 3 mm). The overall rock type is not readily matched with any of the other ignimbrites in the northeastern "Locharwood" association (although, of the ignimbrites occurring in the vicinity, it most resembles Locharwood Rhyolite itself). The unit completely lacks stratigraphic context, and its true position within the aggregate "Locharwood" association sequence is thus not known. Moderate to steep dips of Cub_{18} in its outcrop area imply that a minimum thickness of a few hundred metres of the ignimbrite is preserved.

Un-Named Unit Cub_{19} *(Cbm of Oversby et al. 1991)*

Unit Cub_{19} has only been recognised in the northwest. The unit is composed of dark grey, welded, crystal-rich verging on very crystal-rich and lithic clast-poor (clasts mostly rhyolite less than 2 cm in diameter) rhyolitic ignimbrite which is slightly to moderately altered to chlorite, epidote and sericite. The unit is probably a single cooling unit containing multiple flows. Unit Cub_{19} overlies Locharwood Rhyolite, probably paraconformably, in the area between Bull Creek and the vicinity of the Burdekin River weir; it is overlain, conformably or paraconformably, by unit Cub_{20}.

Unit Cub_{19} has a minimum thickness of 300 m; depending on the overall dip assumed (dips of "fiamme" are up to 70° northwestwards near the Burdekin weir, decreasing to about 15° or 20° eastwards in the west) this may be increased to up to 750 m in the west, and 1500 m in the east.

Un-Named Unit Cub_{20} *(Cbn of Oversby et al. 1991)*

Rocks assigned to un-named unit Cub_{20} are restricted to the northwestern part of the map area, cropping out in an elevated and rugged tract of country to the west and southwest of the Burdekin Gorge weir. The unit consists of medium to very dark grey, welded and massive, moderately to very crystal-rich and lithic clast-free to lithic-poor (subangular to subrounded clasts, predominantly of andesite and rhyolite, up to 3 cm across) rhyolitic ignimbrite. Dark altered pumice "fiamme", ranging up to 5 cm x 2 cm, are common. The rocks appear to represent a single cooling unit which is probably made up of several flows; they are slightly to moderately altered to propylitic to potassic assemblages of sericite + chlorite ± (generally +) biotite ± quartz ± epidote ± calcite.

Unit Cub_{20} paraconformably or conformably overlies Cub_{19}, and is intruded by a dyke and plug-like body of andesite (CPm). The current thickness (top not preserved) of the unit is difficult to estimate because of uncertain dip; it is at least 200 m, and may be as much as 1500 m. The rocks form a half-basin, with moderate (about 40°) to steep (about 70°) northerly to northwesterly dips.

Un-Named Unit Cub_{21} *(Cbv, Cbi, Cbl_r of Oversby et al. 1991)*

Rocks assigned to unit Cub_{21} (mostly Cbv plus Cbi of Oversby et al. 1991), which is a composite grouping, occur in the northwest, northeast, and south-centre. They comprise a number of isolated outcrop areas of various, flat-lying (predominantly), ignimbrite rock types that could not confidently be placed in any other of the volcanic units. They are treated as components of the "Locharwood" association solely on the basis of proximity to better defined parts of that association, rather than on any more objective grounds.

In the northwest, rocks included in this grouping mostly stratigraphically overlie Lolworth-Ravenswood Block and Drummond Basin units (including Stones Creek Volcanics). In the northeast, ignimbrites placed in the grouping overlie probable Ukalunda Beds and tentative Stones Creek Volcanics; locally, separate occurrences are directly overlain conformably by Collins Creek Rhyolite, and by unit Cub_{15}. These last two observations demonstrate the distinct possibility that not all Cub_{21} ignimbrites are of precisely the same age.

In the northwest, the most common rock type included in unit Cub_{21} is nonwelded to poorly welded, moderately crystal-poor to crystal-rich and variably lithic clast-bearing, rhyolitic ignimbrite. This rock is everywhere moderately to intensely altered. Minor intercalated rock types include rhyolitic lava(?) and rhyolitic tuff.

The most extensive outcrop area of rocks assigned to Cub_{21} in the northwest is on the western side of Lake Dalrymple, in the area of Coppershow Creek about 10 km west-northwest of Mount Graham. The rocks reappear in the vicinity of The Twins, farther to the northeast. The predominant rock type is moderately crystal-rich to crystal-rich and lithic clast-poor to moderately lithic-poor, rhyolitic ignimbrite. It is intercalated with flow-laminated, sparsely porphyritic, rhyolite in the northeast, and overlain 1 km south of the debouchement of Coppershow Creek into Lake Dalrymple by a few metres of rhyolitic very fine ash tuff. The ignimbrite is intensely altered to: sericite; combinations of chlorite, sericite and calcite or of sericite, clay and hematite/goethite; alunite and quartz (south of the debouchement of Coppershow Creek); or sericite, quartz, hematite, and anthophyllite (on a hill, accompanied by extensive breccia, 2 km north of the debouchement of Coppershow Creek).

Two small outliers of Cub_{21} at Mount Graham consist of about 10 m of intensely sericitised, moderately crystal-rich to crystal-rich and lithic clast-poor to moderately lithics-poor, rhyolitic ignimbrite underlain by about 1 m of laminated fine crystal tuff.

A small (less than 1 km^2) outlier on the western side of the sealed road 12 km north-northwest of Mount Graham consists of grey, welded and massive, crystal-rich and lithic clast-poor, biotite-hornblende rhyolitic ignimbrite which resembles rocks immediately east and south of Limey Dam (below).

In the Limey Dam area (northwest), the ignimbrite ranges from lithic clast-poor to very lithic-rich; clasts are andesite and dacite. The rock is moderately to extremely altered to calcite + sericite + chlorite ± epidote ± hematite. Thickness ranges up to 20 m. The ignimbrite is intercalated with, and merges laterally into, massive rhyolitic lava. Rhyolitic ignimbrite on the northern side of Stones Creek, 7 km northwest of "Glenroy" outstation similarly interfingers with rhyolitic lava, which makes up "Breccia Hill" to the east. This rock is lithic clast-rich (rhyolite and very rare granite clasts up to 25 cm across). Thickness is very variable, up to 50 m. Similar ignimbrite in small outliers on the southern side of Stones Creek contains blocks of flow-laminated rhyolite up to 1 m across. Outliers of Cub_{21} on a ridge to the east and south of Limey Dam consist of dark to very dark grey, moderately crystal-rich to crystal-rich and lithic clast-poor to lithic-rich, rhyolitic ignimbrite up to about 200 m thick. The lowermost part of the ignimbrite is lithic clast-rich (andesite and rhyolite clasts up to 10 cm across, increasing to 15 cm to 20 cm southwestwards in an eastern tributary of Glenroy Creek, 3.3 km northeast of the Glenroy - Stones Creek junction, where pumice fragments are up to 30 cm long). Abundance and size of lithic clasts, and size of pumice "fiamme", decrease upwards and northwards, while crystal content increases. Nonwelded to poorly welded, and/or fine-grained (i.e.small-crystal-bearing), ignimbrite is present in the uppermost (southern) exposures. The rocks are moderately to extremely altered to propylitic assemblages (chlorite + sericite + calcite ± epidote). Rocks near the base of the unit in a gully 3.2km northeast of the junction of Stones and Glenroy Creeks also contain up to 5% pyrite. In the north and east, close to granitoid unit CPg_3, the ignimbrite is variably hornfelsed, and minerals such as biotite and blue-green hornblende are present.

At least some of these northwestern rocks assigned to "Locharwood" association unit Cub_{21} could well be of similar ages to Smedley Dacite and/or Arundel Rhyolite (below), or even outflow facies of the main part of the latter formation. However, these possibilities cannot usefully be considered further without more data.

Rocks assigned to Cub_{21} in the northeast are ignimbrites lacking distinctive primary features (including hornfelsed ignimbrites), or ignimbrite occurrences out of stratigraphic context, or a combination of both. They are mostly of limited extent.

In the south-centre, a unit of flow-banded rhyolite (Cbl_r of Oversby et al. 1991) is provisionally included in the Cub_{21} grouping. The unit crops out at higher elevations than Locharwood Rhyolite in hills to the west of upper Mary Creek (north of "Old Hidden Valley" homestead). Contacts between the two units appear to alternate locally from concordant and possibly stratigraphic to discordant and probably faulted and/or intrusive. The rhyolite is interpreted to represent a mainly extrusive lava lens of originally limited areal extent, stratigraphically overlying Locharwood Rhyolite; an intergradational intrusive component may also be present, but cannot be differentiated without further study. The precise stratigraphic equivalent of the lava in terms of "Locharwood" association or other ignimbrite units is not known because none directly overlies it, nor are the stratigraphic top of the Locharwood Rhyolite or any supra-Locharwood rocks preserved closer than the vicinity of Mount Constance. Inclusion of the lava in the "Locharwood" rather than "Arundel" association is based solely on its spatial juxtaposition with Locharwood Rhyolite.

To the south, closer to "Old Hidden Valley", bodies of mainly (entirely?) intrusive rhyolite and microgranite (rh_1 and mg_1 of Oversby et al. 1991 - now CPr_1) cutting Locharwood Rhyolite are common. These rocks may represent deeper "roots" of the lava unit.

Rocks assigned to unit Cub_{21} are dominant at the Mount Robin (gold) Mine and Prospect (nos 3 and 4 on the map), and at the Limey Dam (gold) Prospect (no 1).

Discussion

The total thickness of the "Locharwood" association in the northeast and north-centre, where it is most extensively preserved, can only be estimated roughly. Estimates are very dependent on measured dips of foliations defined by flattened relic pumice (fiamme) in ignimbrites. At best, these measurements can then be converted into thickness estimates only by assuming that they give a fair, albeit imprecise, indication of the true dip of the relevant ignimbrite, and by further assuming that dips so derived are indicative of subsurface geometries of the relevant ignimbrite body as a whole, i.e. the ignimbrite sheet has tabular, rather than some other, form. However, eutaxitic foliations are not always present, or accurately measurable (Collins Creek Rhyolite is one of the most difficult to deal with in these respects, because it only rarely exhibits a foliation which is sufficiently conspicuous and well defined to measure with confidence). Very few of the main ignimbrite sheets have basal and top stratigraphic surfaces intact and exposed, and accessible in a single undisturbed section. In most cases, only one of the surfaces is in an original state, the other being a fault plane or, commonly, an intrusive contact. However, allowing for all of the limitations of our field data, a summation of the estimated thicknesses of each of the six main northeastern and north-central "Locharwood" association ignimbrites gives a cumulative thickness for the association there of approximately 7500 m. Of this, more than half is made up of Collins Creek Rhyolite and Locharwood Rhyolite. In the northeast, Collins Creek and Locharwood Rhyolites are probably 4000 m and 2000 m thick, respectively. Farther south, in the north-centre, those two units combined are probably more than 6000 m thick; addition of preserved Cub_{15}(?) may take the total thickness to 6500 m. Added to these thickness estimates, those of units restricted to the northwest (${Cub}_{10}$, Cub_{19}, Cub_{20}) and to the southwest (Pyramid Rhyolite) give a cumulative total in excess of 7000 m for the association.

The cumulative total thickness of the "Locharwood" association has no real relevance in terms of (lesser) thicknesses attained by its local developments. However, local estimates in the order of 6000 m even for the two main units in the association seem excessive to the point of unreality. It is suspected that unrecognised structural complications, such as repetition of essentially identical ignimbrite slices along bedding-parallel faults (perhaps very early post-depositional, and thus welded and extremely subtle), have doubled or tripled original stratigraphic thicknesses.

Pyramid Rhyolite was probably extruded from the vicinity of upper Bell Creek, rather than the Pyramid Range, according to the localisation of clast-rich ignimbrite there. However, the unit has its maximum preserved representation in the Pyramid Range, as does immediately subjacent sCub. The thickness distributions may reflect pre- to syn-extrusion uplift in the Pyramid Rhyolite's souce area. According solely to its overall distribution and thickness, Locharwood Rhyolite can be inferred to have been mainly extruded from the Mount Coolon area (cf. Law 1988), with subsidiary activity in the central and/or northeastern part/s of the Burdekin Falls Dam - "Conway" area. The non-occurrence of the unit between the Mount Coolon and Burdekin Falls Dam - "Conway" areas suggests that there were separate extrusive centres although they must have tapped essentially the same magma chamber. Alternatively, by analogy with the Pyramid Rhyolite situation (above), it may be the Locharwood Rhyolite's zone of non-occurrence that actually marks its main extrusive centre/s. This would be consistent with the fact that no lag-fall facies of the Locharwood Rhyolite is known in the northeast. Other "Locharwood" association ignimbrites may have been extruded from the northeast, according to thicknesses and localisation of clast-rich types; however, once again no actual lag-fall representatives are known.

UPPER RHYOLITE-DACITE ("SMEDLEY") ASSOCIATION

Smedley Dacite and its associates are preserved in the northwest and northeast. On the basis of an isotopic date of approximately 297 Ma from Smedley Dacite at Burdekin Falls Dam (Black 1994; Appendix 2), this mixed rhyolite-dacite association is believed to be younger than Locharwood Rhyolite and its associates. The rocks are thus provisionally interpreted to constitute a second rhyolite-dacite association similar to, but with a distinctly higher stratigraphic position than the sequence containing Earlscliffe Dacite in the southwest. However, there are no field relationships known to us which unequivocally confirm this interpretation of the geochronological data. It should be noted that, in fact, geomagnetic data (Klootwijk et al. 1993; Appendix 2) possibly contradict the geochronology.

Dark blue to green, crystal-rich (feldspar more abundant than quartz, each much more abundant than hornblende), variably lithic clast-rich dacitic ignimbrites dominate the "Smedley" association. The association's northwestern sequence, and its extension across the Burdekin River into the northeastern part of the study area, also contains quartz crystal-rich rhyolitic ignimbrite sheets. Initially, these caused considerable confusion because they were regarded as associates of the Locharwood Rhyolite.

The correlation between northwestern and northeastern "Smedley" association occurrences hinges on the belief, which is not contradicted by any of the available data, that there is a single Smedley Dacite ignimbrite sheet. This sheet is widely distributed and easily recognised, and provides the only marker interval within the association. In our view, Smedley Dacite is distinguished by common, though not ubiquitous, dark greenish or bluish-grey fiamme and lithic clasts containing large (5 mm to 1 cm in maximum dimension) subhedral to near-euhedral white feldspars. It is primarily on the basis of distinctive enclave content that rocks originally assigned to northeastern unit Cvi_3 by Oversby et al. (1991) are now, in general, regarded as being the same as Smedley Dacite (Cvd or "dam ignimbrite" of Oversby et al. 1991). A previous correlation (Oversby et al. 1991) between northeastern unit Cvi_3 and northwestern sub-"dam ignimbrite" unit Cvc, mainly on the basis of comparable levels within local sequences, is not now considered supportable. Assuming the validity of the current Smedley Dacite concept and correlation, additional appreciation of the stratigraphic framework of the "Smedley" association has been derived from four main sets of relationships:

(i) northwestern Smedley Dacite (Cubs) extending northeastwards from the rock pavement below the Burdekin Falls Dam wall onto the construction settlement plateau, underlain on the southeastern side of the plateau and northeastern bank of the Burdekin River by (in descending order) units Cub_{24}, Cub_{23}, and Cub_{22}. Cub_{24} at this locality is overlain locally on the northern side of the plateau by a faulted remnant of volcaniclastic "sediment" too small to show at 1:100 000 scale;

(ii) northwestern unit Cub_{23} at the east-northeastern end of the construction settlement plateau overlain by Cub_{24}, and underlain by coarsely rudaceous sCub;

(iii) northeastern unit Cub_{22} with an apparent intercalation of pebbly to cobbly rudite and feldspar-rich arenite (sCub), overlain successively by units Cub_{24} and Smedley Dacite (Cubs), between the eastern side of the Burdekin River, 2.3 km east- northeast of Burdekin Falls Dam, and the local limit of exposure 1.5 km to the east-southeast, near the top of a spur. In a separate small structural block underlying the next spur northwards, unit Cub_{24} contains a lens of fine-grained volcaniclastic "sediments" (sCub);

(iv) northeastern unit Cub_{26} overlying Smedley Dacite in the next major coherent structural block to the east of (iii).

In the first three of the above situations, stratigraphic relationships inferred in and beside the Burdekin River, involving lower-exposed parts of the "Smedley" association, are tentative. This is because of the possibility that significant faults remain unrecognised adjacent to the intricately disrupted belt along the river. However, there appear to be real stratigraphic differences in the "Smedley" association on either side of the fault zone occupied by the river; these differences are outlined and discussed further below.

In the northwestern part of the study area, the "Smedley" association is best exposed in an intricately faulted belt along the bed and northern/western bank of the Burdekin River at Burdekin Falls Dam (particularly on the rock pavement below the dam wall, and in cuttings beside the main access road for about 1 km from the northeastern abutment of the dam), and as far as about 5 km downstream of the dam (east-southeast, then north-northeast). It is moderately well exposed on the top and northwestern side of the small plateau on which the dam construction settlement was situated, but only poorly exposed in the northeast-trending valley beyond (northwest of) the plateau.

In the northeast, "Smedley" association rocks are well represented in two adjoining, structurally separated, domains, and are also known in a third domain of mostly poor outcrops, viz.:

(I) locally excellent exposures in the bed and southern/eastern bank of the Burdekin River paralleling the best northwestern exposures continuous with good exposures in less structurally compromised sections immediately south and southeast of the river;

(II) low-relief hills drained by the lowermost reaches of Glendon and Charlie Creeks, immediately south and southeast of the Burdekin River, and to the north of "Glendon"; the best exposures occur along the southern bank of the river, beginning 1 km upstream (west-northwest) of the mouth of Glendon Creek;

(III) isolated and very minor outcrops (of unassigned rocks all included in composite grouping Cub_{27}) in an apophyse extending for about 5 km northeast from the eastern limit of (II).

From excellent exposures (including road cuttings) at the southwestern abutment of Burdekin Falls Dam, and moderate exposures in hills to the south of the Burdekin River, Smedley Dacite of the "Smedley" association continues with mostly moderate exposure for about 4 km southwest across lower and middle Coopers Creek, in the central-west of the study area.

Our best understanding of the stratigraphic framework of the "Smedley" association in the northeast is derived entirely from relationships (iii) and (iv) discussed above; these are known only from domain (I), and to that extent our understanding is inadequate. No firm internal stratigraphy has been confidently established from "Smedley" association outcrops of domains (II) and (III) because of poorly constrained structural complications combined with the absence of shared stratigraphic "markers" (none of the ignimbrites is particularly distinctive, and all are included in unit Cub_{27})

Coarse to very coarse conglomerate cropping out in the Burdekin River of domain (I) opposite the construction village plateau is underlain by coarse breccia. This breccia may be the same as the one which occurs in the fault zone at the southern edge of domain (II).

The overall southeasterly-dipping section of "Smedley" association rocks preserved in the fault blocks and slices of northeastern domain (I) may have a stratigraphic thickness in the order of 1200 m. Thicknesses in the generally north- and south-dipping domains (II) and (III) respectively, in which neither stratigraphic base nor top are known, cannot be estimated with any certainty, but it is probably at least the maximum amount of local topographic relief in (II) (about 150 m). The domain (II) sequence could actually be about 1000 m thick. However, the distinct possibility that abundant unrecognised faults repeat and/or eliminate substantial parts of the sequence makes this estimate tentative.

The cumulative preserved thickness of "Smedley" association rocks in the whole of the Burdekin Falls Dam - Conway area may be about 2000 m.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that "Smedley" association (their units V75 and V76) rocks are I-types, unfractionated, oxidised, and medium- to high-potassium (based on four unpublished AGSO analyses).

Volcaniclastic Rocks, sCub (*Cvs of Oversby et al. 1991*)

One occurrence of pebbly siltite to arenite, too small to show at 1:100 000 scale, is known from the northwestern "Smedley" association. It crops out beside a fault 2.4 km northeast of Burdekin Falls Dam, near the top of the northern edge of the construction village plateau, and appears to overlie unit Cub_{24}.

An interval of volcaniclastic sedimentary rocks, overlain and apparently underlain by ignimbrite assigned to Cub_{22} in the lower "Smedley" association, occurs in sporadic, locally excellent, exposures in the bed and on the southwestern bank of the Burdekin River of the northeast's domain (I) from about 2 km to 5 km downstream (east-southeast to north-northeast) of Burdekin Falls Dam. Thicknesses appear to be between 10 m and more than 30 m. The rock types represented are: pale grey, fine-grained and well-sorted, lithofeldspathic-quartz arenite; purple, gritty to pebbly, tuffaceous(?) feldspatholithic-quartz arenite containing scattered pumice fragments and altered glass shards; massive, large-cobbly (to 15 cm, and clast-supported), very coarse-grained quartzofeldspathic arenite; and massive, pebbly to bouldery and clast-supported, rudite. Coarse to very coarse rudites (breccia overlain by a minimum of 30 m of internally massive, though with crude preferred orientation of some "flat" clasts, poorly-sorted, clast-supported pebble to cobble conglomerate) crop out in the bed and on the eastern bank of the river opposite the eastern end of the plateau on which the dam construction village was situated.

The rocks are overstepped onto by disconformably overlapping ignimbrite sheets of either unit Cub_{22} in the upstream half of the outcrop belt, or units Cub_{23} (west) and Cub_{24} (east) farther from the dam.

Two apparently lensoidal volcaniclastic sedimentary intervals, up to about 30 m thick, occur higher in the "Smedley" association sequence of domain (I). One of these (exposed 4 km east-northeast of Burdekin Falls Dam) probably lies within unit Cub_{24}; it consists of sporadically pebbly silt-size tuff with subordinate sand-size tuff. The other interval (exposed 3 km southeast of the dam) is made up of similar material, and is within or possibly on top of the Smedley Dacite.

In the fault zone making up the southern edge of domain (II), which is about 1 km wide at the Burdekin River but decreases east-southeastwards across lower Glendon Creek, coarse to very coarse polymictic lithic breccia, which apparently has an ignimbritic matrix at least in part, crops out sporadically. Unfortunately, the breccia is totally out of local stratigraphic context, although it can be matched in type with breccia below conglomerate in the domain (I) sequence (above and below). Granitoid (unit CPg_{10} - below) exposed in Glendon Creek downstream (north) of the Gap Creek junction, adjacent to "Smedley" association domain (II), contains numerous and varied xenoliths. These may have been acquired from nearby (subjacent) sCub.

Up to about 170 m of coarse to very coarse lithic breccia, commonly with a dacitic ignimbrite matrix, at the northern edge of northeastern domain (II) is sporadically but extremely well exposed along a stretch of the southern bank of the Burdekin River beginning about 1 km west-northwest of the mouth of Glendon Creek, and extending upstream to about 1 km beyond (south of) a point opposite the mouth of Stones Creek. It is connected with an inlier of disrupted Stones Creek Volcanics to the west of lower Glendon Creek. The breccia along the Burdekin River contains angular to subrounded clasts at least 6 m across. A wide variety of rock types is represented in the clasts, of which three warrant special mention:

(a) pale pink, moderately crystal-rich (quartz about equal to feldspar) ignimbrite with dark pink relic pumice in angular clasts up to 40 cm across. Such clasts are locally abundant (e.g. 1.9 km upstream from Glendon Creek); the rock type is Locharwood Rhyolite, and its occurrence as clasts within the "Smedley" association is consistent with U-Pb isotopic ages (the closest currently outcropping Locharwood Rhyolite is about 5 km away to the northwest);

(b) grey, coarsely porphyritic (feldspar greater than quartz) granitoid of late Palaeozoic aspect as clasts abundant in one breccia interval 1.2 km upstream from Glendon Creek. These clasts are significant in suggesting possible paoaeo-outcrops of sub-Bulgonunna Volcanic Group Carboniferous (or possibly Devonian) granitoids during "Smedley" association volcanism;

(c) Dark green, medium-fine, feldspar-phyric andesite. Blocks of andesite that are totally enclosed in dacitic ignimbrite range up to 6 m across (e.g. 2.1 km upstream from Glendon Creek). In the same outcrop are two even bigger composite clasts, each containing andesite in near-conformable contact with laminated siltstone. In both blocks, bedding in the siltstone and the andesite-siltstone contacts is inclined at high angles to the eutaxitic foliation in the adjacent ignimbritic matrix. In the vicinity of the very large composite andesite-siltstone blocks, there are more extensive outcrop areas of apparently identical andesite and andesitic breccia. These are either *in situ* occurrences of the andesitic lava(?) and autobreccia from which the clasts in the ignimbritic breccia came, or else even bigger clasts. Large andesite clasts are also common farther upstream along the Burdekin River, opposite the mouth of Stones Creek, as well as along Glendon Creek downstream (northwest) of its junction with Charlie Creek. The size of the andesite clasts suggest a local source, or steep transport route, or both. Stratigraphically, the most likely source is Stones Creek Volcanics. At least about 10m of intensely brecciated Stones Creek Volcanics andesitic lavas without an exposed base crops out in an area almost entirely surrounded by dacitic ignimbrites (Cub_{27}), immediately west-southwest of the mouth of Glendon Creek. The rocks are dark bluish-green, commonly massive but locally flow-laminated and autobrecciated(?). Individual outcrops and groups of outcrops in the area are thought to represent disrupted and probably rotated, but not laterally transported, country rock megablocks, which may or may not be separated by ignimbritic material, in a within-vent setting. This disrupted material apparently passes upwards, and possibly laterally, into ignimbrite which contains observable megablocks and smaller (pebble- to boulder-size) clasts of a texturally similar range of andesites.

Granitoid (CPg_{10}) exposed in Glendon Creek between the Gap Creek junction and the southern edge of domain II contains a variety of xenoliths. Some or all of these may have been acquired from local sCub; volcanic breccia xenoliths may represent sCub itself.

Elsewhere in northeastern domain (II), rudite occurs as discrete, very thick and internally massive beds within or between ignimbrite sheets, and is not delineated separately on the map.

Andesite megaclast-bearing rudite/ignimbrite (above) can be traced discontinuously, via a series of fault blocks and slices in the complex Burdekin Gorge Fault Zone at the intersection between northeastern domains (II) and (I), to the eastern bank of the Burdekin River opposite the dam village plateau. Here, it is overlain by massive conglomerate.

Although clastic material in ignimbrites can, in principal, be far-travelled, the very coarse to megaclastic nature and probable local derivation of many of the rudites with ignimbritic matrix in the northeastern "Smedley" association of domains I and II, irrespective of clast roundness, suggests that they represent very proximal lag-fall material (Wright & Walker 1977, Walker 1985). In cases where the matrix of subrounded to rounded pebble- to boulder-size clasts is crystal-rich, ash-poor and pumice-free, volcaniclastic arenite, the rudite is not necessarily a pyroclastic deposit. Some, or all of such occurrences may have originated as subaerial to shallow subaqueous, volcanically-triggered, debris flows or hyperconcentrated flood flows (e.g. Schmitt & Olson 1986, Scott & Vallance 1993), from neighbouring palaeoslopes (fault scarps?).

Thick-bedded massive volcaniclastic conglomerate, with diffusely-bedded, coarse, quartz-feldspar crystal-rich sandstone and minor purple mudstone occur to the west of upper Sandalwood Creek. These sediments are interbedded with "Smedley" association ignimbrites which are placed in Cub_{27} although a variant of Smedley Dacite may also be present.

Dacitic Andesite Lava

Fresh dacitic andesite occurs in a limited outcrop area too small to show even at airphoto scale, among somewhat altered andesitic Bimurra Volcanics (DCb_2 - above) 11 km north of "Conway" homestead and 3 km southeast of the junction of the Sellheim River and Isabella Creek, in the southeastern part of the study area. A sample (89302132) from grid reference 8356-394906 has the thin-section appearance of being a very fine-grained lava; it has yielded a (zircon) U-Pb date identical to the one obtained from Smedley Dacite (Black 1994 and Appendix 2). Our preferred current interpretation of this is that the dacitic andesite represents an outlier of "Smedley" association lava which elsewhere in the southeast underlies, and/or has not been differentiated by us from, "Earlscliffe" association remnants.

Un-Named Unit Cub_{22} (*Cva, Cvi₁ of Oversby et al. 1991*)

Un-named unit Cub_{22} consists of mainly dark blue-grey to greenish-grey to greyish-green, crystal-rich and clast-free to moderately clast-rich welded dacitic ignimbrite. Crystals are 2 mm to 3 mm across; quartz crystals occur in the rock suggesting it verges on rhyolite, but are very subsidiary to feldspars. The rock also contains sparse hornblende consistent with a dacitic composition.

In the northwestern part of the study area, ignimbrite assigned to this unit occurs only in the Burdekin River between 1.7 km and 3.6 km downstream of the dam, and on the adjacent southeastern side of the construction village plateau.

Within the northeast's domain (I), upstream (southwest to west-southwest) along the Burdekin River for about 1.7 km from the lowest point of section (iii), described above, towards Burdekin Falls Dam, up to about 50 m of variable ignimbrite crops out sporadically from the intricate and confusing collage of small fault blocks and slices within the Burdekin Gorge Fault Zone. The ignimbrite is all assigned to unit Cub_{22}. In part, its variability is due to different fracture densities and/or types and degrees of alteration. However, local differences in crystal proportions and/or sizes, and in fiamme and lithic clast contents and characteristics, from those typical of unit Cub_{22} are suggestive of a subsidiary representation of Smedley Dacite and at least one unassigned (unit Cub_{27}) ignimbrite type in 20 m to 30 m exposed thicknesses. An apparently undisturbed stratigraphic contact of gently east-dipping "Smedley" association conglomerate with purple quartz-bearing ignimbrite also occurs in the fault zone. The quartz-bearing ignimbrite is (according to "fiamme") near-vertical and west-northwest-striking; on that basis it could belong to the "Locharwood" association. Such subsidiary occurrences are not indicated on the map because of their small size, scattered nature, and ambiguous significance. Near monomictic lithic-clast conglomerates and breccia/s (both types notated sCub), presumably representing intervals within and above Cub_{22}, also crop out. Ignimbrite locally grades into such breccia. The contact of this faulted collage belt with Smedley Dacite is a northeast-striking high-angle fault.

Un-Named Unit Cub_{23} (*Cvb, Cvi₂ of Oversby et al. 1991*)

Unit Cub_{23} consists almost exclusively of pale to medium grey, nonwelded to poorly welded, crystal-rich verging on very crystal-rich and lithic clast-free to lithic-poor, rhyolitic ignimbrite, apparently in a single flow. Quartz plus sanidine/orthoclase and oligoclase, with (minor) biotite crystal contents range from 25% to 40%; quartz has a similar abundance to that in northwestern Collins Creek Rhyolite (Cubc - above), but the crystals/fragments are not as large, nor as conspicuous at outcrop scale (especially on somewhat weathered surfaces, when the grains stand out in relief), and in hand specimens. Biotite is not as conspicuous at hand specimen scale as in Collins Creek Rhyolite, despite the fact that it is almost as abundant. The crystal content of Cub_{23} ignimbrite tends to increase upwards in the unit, antipathetically with lithic clast content which decreases from about 10% to near zero upwards. Clast types include andesite, rhyolite, and dacite; they range up to 10 cm across. The largest clasts occur in the lowermost part of the dominant ignimbrite rock type. Pumice "fiamme" are mostly smaller than 6 cm x 1 cm, but range up to 15 cm x 3 cm near the base. Alteration (propylitic) is slight to moderate.

In the northwest, unit Cub_{23} crops out along the walls of the Burdekin River gorge downstream of Burdekin Falls Dam. It also occurs in fault slices along the northern side of the small plateau on which the dam construction settlement was sited, between about 1.1 km and 2.6 km northeast of the dam's northern abutment.

The lowermost part of the unit at the northeastern end of the construction village plateau, below the base of the dominant ignimbrite rock type, consists of 1m or so of cross-laminated, fine sand-sized material which is probably represents the base-surge component of the ignimbrite.

Stratigraphically, unit Cub_{23} in the northwest paraconformably overlies Cub_{22} ignimbrite and is overlain (probably also paraconformably) by Cub_{24} ignimbrite. The unit is about 40 m to 50 m thick.

In the northeast, unit Cub_{23} cannot be clearly identified. An interval containing rhyolitic ignimbrite/s occurs on the southeastern side of the Burdekin River beneath Smedley Dacite. However, the interval as a whole is dominated by Cub_{24} rock types (below), with the Cub_{23}-type component being only minor and apparently unsystematically distributed (interbedded?). While the interval may well represent intertonguing of unit Cub_{23} into Cub_{24}, it has been assigned to the latter alone because we have not been able to delineate any Cub_{23} component/s separately.

<u>Un-Named Unit Cub_{24}</u> *(part Cvc, part Cvi3 of Oversby et al. 1991)*

Unit Cub_{24} consists of medium to dark grey, fine-grained 0.5-1 mm crystals, nonwelded to poorly welded, moderately crystal-poor to crystal-rich and lithic clast-free to lithic-poor, rhyolitic ignimbrite. Crystal contents in the ignimbrite range from 5% to 25% (mainly 15% to 20%); the proportion of quartz is less than in Cub_{23}. Lithic clasts (predominantly rhyolite) range up to 5% by volume, and are mostly less than 2 cm across. The rock is slightly altered to chlorite and sericite.

Unit Cub_{24} in the northwest paraconformably overlies Cub_{23} and is similarly overlain by Smedley Dacite (Cubs - below). The unit is about 10 m to 20 m thick.

In the northeast, an interval of rhyolitic ignimbrites below the Smedley Dacite to the southeast of the Burdekin River contains a mixture of Cub_{23} and Cub_{24} rock types, with the latter being dominant, as noted above. The whole interval is provisionally assigned to unit Cub_{24}. It is about 30 m thick.

Smedley Dacite, Cubs (*Cvd = "dam ignimbrite", part Cvc, part Cvi$_3$ of Oversby et al. 1991*)

Smedley Dacite (new name - Appendix 1) consists of mid to dark grey, bluish-grey and purplish-grey, moderately crystal-rich verging on crystal-rich (quartz absent to much less abundant than 1 mm to 3 mm feldspars, sparse pyroxene(?) and hornblende, minor biotite), lithic clast-poor to lithic-rich, welded dacitic ignimbrite. Fiamme and/or lithic clasts with large (1 cm) white feldspars are characteristic, though not ubiquitous and apparently not uniquely diagnostic of the unit.

Smedley Dacite at Burdekin Falls Dam yielded the U-Pb zircon "control" age of approximately 297 Ma (Black 1994; Appendix 2).

There have been substantial disagreements between the northwestern and northeastern field mappers (D.E.M. and J.M.) regarding correlation of some "Smedley" association units across the Burdekin River, and between J.M. and B.S.O. in the equating of previous unit Cvi$_3$ in part with the Smedley Dacite. The first disagreement has probably been sorted out adequately, but it has not been possible to fully resolve the second one on a basis of available data. However, even if Cvi$_3$ represents an ignimbrite sheet separate from Smedley Dacite (as distinct from the other possibility, that it is a rock type within the permissible range of Smedley Dacite internal variability), the indications are that the two must be at about the same stratigraphic level.

Smedley Dacite is the most extensively developed and conspicuous component of the upper rhyolite-dacite association of the Bulgonunna Volcanic Group in the northwest. The unit forms the basement to, and buttresses of, Burdekin Falls Dam, where its type section occurs (Appendix 1); it also crops out spectacularly along the riverbed (although now frequently obscured by overflow from the dam) and gorge walls downstream of the dam. Less impressive, but moderate to good, exposures extend onto the small plateau adjacent to (northeast of) the dam on which the dam construction settlement was sited, and for several kilometres to the southwest of the dam. In the vicinity of Burdekin Falls Dam, a lithic-rich basal horizon is overlain by moderately lithic-poor to moderately lithic-rich ignimbrite in which there is a gradual increase in abundance, but decrease in size, of clasts upwards. Higher up, this progression in clast abundance is repeated, and then interrupted abruptly about 240 m above the base of the ignimbrite by a 5 m-thick lithic concentration (ground-lag) interval. This interval contains more than 60% clasts up to 20 cm in diameter. Clast abundance and size then decrease upwards more regularly to the stratigraphically highest exposed ignimbrite. Pumice "fiamme", most evident at stratigraphically high levels, also show a general upwards decrease in size; they are about 40 cm long just above the ground-lag, and 4 cm to 5 cm long at the upper limit of exposure. Outcrops in the construction village site area are of medium-fine, moderately crystal- and lithic clast-rich, ignimbrite, with lithic clasts of generally less than 1.5 cm across. Clast types are: porphyritic andesite, including a vesicular variety making up irregular, subangular to subrounded, clasts that appear to have been plastic when the ignimbrite was deposited; several textural varieties of rhyolite; and fine-grained siliceous (silicified ?) sedimentary rocks or tuffs(?). A characteristic of the ignimbrite in some places (e.g. the road cutting on the southern side of the dam) is a patchy devitrification texture in which dark-coloured, relatively less devitrified, remnants of the ignimbrite strongly resemble lithic clasts. Alteration in Smedley Dacite is typically slight to moderate, and propylitic (a chlorite, calcite, and sericite, with sporadic epidote, assemblage). The crystal content of Smedley Dacite ranges from 5% to about 15%. Crystals and fragments consist of plagioclase (altered andesine), and almost invariably altered (chlorite + opaque grains $\pm$ calcite) hornblende and clino(?)pyroxene. Most of this material is 0.5 mm to 2.5 mm in maximum dimension.

In the northeast, Smedley Dacite extends without substantial interruption from a northeast-striking faulted contact with rocks assigned to Cub_{22} and sCub in the bed and banks of the Burdekin River, and from hills to the south of the river, via the rock pavement below the wall of Burdekin Falls Dam, southwestwards across lower and middle Coopers Creek to underlie Arundel Rhyolite with angular unconformity in the central-west. Within domain (I), upstream (southwest to west-southwest) along the Burdekin River for about 1.7 km from the lowest point of section (iii) (above), some of the ignimbrite cropping out within the Burdekin Gorge Fault Zone, shown as Cub_{22} on the map, may be Smedley Dacite. East-southeast-dipping rocks assigned to the unit in the northeast crop out on the main ridge west of middle to lower Glendon Creek, opposite "Glendon" homestead, in association with Cub_{26} ignimbrite. In addition, blue dacitic ignimbrite, which is tentatively assigned to the Smedley Dacite mainly on the basis of containing porphyritic pumice pseudomorphs, is well exposed in Sandalwood Creek, 3.7 km south-southwest of its junction with Desmond Creek. At the exposed stratigraphic edge of its outcrop area, about 3 km to the northeast of Sandalwood Creek, this ignimbrite overlies individual Stones Creek Volcanics (DCs) directly. "Earlscliffe" (tentative) and "Locharwood" association rocks are faulted against the northwestern edge of this possible Smedley Dacite outcrop area, even though absent immediately subjacent to it, at least at its northeastern edge. Minor tentative representatives of the "Earlscliffe" association (Cub_1) also occur about 2 km farther east. Smedley dacite in the northeast to central-west has a minimum thickness of 100 m.

Un-Named Unit Cub_{26} *(Cvi$_4$ of Oversby et al. 1991)*

Unit Cub_{26} consists of very dark bluish-grey, moderately crystal-rich, welded dacitic ignimbrite; crystals (feldspar only) average 2 mm to 3 mm across. Diffuse attenuated "fiamme" are characteristic.

Ignimbrite of this unit is known only from the main ridge west of Glendon Creek, opposite "Glendon" homestead. Here, it crops out east of Smedley Dacite. Unit Cub_{26} is mainly faulted against, but also locally apparently overlies, the Smedley Dacite; its minimum thickness (top not preserved) is probably in the order of 50 m.

Un-Named Unit Cub_{27} (*Cv, Cvx, Cve, Cvi, part Cbi of Oversby et al. 1991*)

This unit accommodates a miscellany of mainly dark-coloured, feldspar-rich and probably dacitic, welded ignimbrites. Spatial relationships suggest that the rocks belong to the "Smedley" association, but they are not otherwise more precisely assignable. This is because they are not individually of diagnostic ignimbrite types, and/or are not in determinable stratigraphic context (or are in ambigous context). The unit could represent any, or several, stratigraphic interval/s within the "Smedley" association, including the entire thickness locally. At least some of the rocks in the unit could belong to other associations (including the stratigraphically higher "Arundel" association, as noted in appropriate cases below).

In the northwest, a possibly fault-bounded body of volcanogenic rocks on the southwestern side of the Stones Creek/Burdekin River junction is exposed mainly in scattered "whaleback"-like outcrops and pavements. These reveal porphyritic andesite and andesitic ignimbrite, with minor nonwelded, quartz-poor, rhyolitic ignimbrite (or tuff), and rhyolite breccia. Rare exposures of andesite breccia occur in intervening areas. The rocks are included in unit Cub_{27}. It is likely that the entire assemblage represents a body of extremely coarse, dominantly andesitic, volcanic breccia. However, details of its nature, geometry, and origin/s are obscure.

An east-northeast-trending fault wedge 1 km north of Burdekin Falls Dam consists of thin interbeds of: very dark grey, sparsely porphyritic, rhyolite; very fine rhyolitic lithic-crystal-vitric ash tuff; very fine nonwelded, moderately crystal-poor and lithic clast-poor, rhyolitic ignimbrite; altered pyroxene dacite; and minor mudstone to siltstone. This assemblage is also included in unit Cub_{27}.

In the northeast, rocks included in unit Cub_{27} crop out in a large area of fault slices and blocks extending from the vicinity of Burdekin Falls Dam to northeast of lower Charlie Creek (just west of middle Sandalwood Creek). Some of the dacitic ignimbrites in the northern and eastern parts of domain (I), particularly those occurring in fault blocks and slices at the approaches to domain (II), as well as all of the ignimbrites (again dacitic, but commonly clast-rich) in domains (II) and (III), cannot currently be placed in the "Smedley" association's stratigraphic framework with any confidence. They have, of necessity, all been included in composite unit Cub_{27}.

In domain (II), and to a lesser extent in (III), separate dacitic ignimbrite flows are commonly delineated by basal coarse lithic clast breccias. Such breccias attain an extreme level of development in domain (II), to the extent that an ignimbritic groundmass is typically minimal. In this case, angular to subrounded clasts, including exceptionally large ones locally, are concentrated in an interval gradationally below more average dacitic ignimbrite. The ignimbritic matrix is essentially identical to the bulk of the succeeding part of the sheet. In general terms, these lithic-rich intervals can be compared with layer 2bL in a "standard ignimbrite flow unit" (Sparks et al. 1973), or with a ground-lag deposit (Froggatt 1981, Walker et al. 1981).

One particularly spectacular, but potentially misleading, outcrop of dacitic Cub_{27} ignimbrite occurs in Glendon Creek, 5 km north-northeast of "Glendon" homestead (domain II). Superficially, this rock appears to be particularly rich in dark, equant lithic clasts from 1cm to 3 cm across. However, these "clasts" are actually spherulites that have nucleated on crystals and a minor proportion only (relative to that suggested by spherulite size and density) are lithic fragments.

An isolated occurrence of ignimbrites included in Cub_{27}, with sediment (sCub) interbeds lies about 3 km northeast of northeastern domain III, to the west of upper Sandalwood Creek. One ignimbrite type is purple, crystal-rich (feldspar more abundant than quartz) and lithic clast-rich. Another ignimbrite type here is blue, and medium-crystal-rich (with feldspar much more abundant than quartz); conspicuous porphyritic relic pumice suggests that this rock could be Smedley Dacite (tentatively recognised by itself, and delineated on the map, from an occurrence of apparently the same ignimbrite between about 1 km and 3 km farther east).

Flat-lying hilltop remnants of ignimbrite tentatively included in Cub_{27} apparently overlie gently (15^{o} to 20^{o}) southeast-dipping "Smedley" association dacitic ignimbrite/s (also Cub_{27}) in domain III of the northeastern study area. The remnants lie to the north of Charlie Creek, between 3.3 km and 5.8 km northeast of the junction of Charlie and Glendon Creeks. They consist of pale purplish-grey, medium crystal-rich (quartz more abundant than feldspar; subsidiary biotite), locally lithic clast-rich (clasts less than 3 cm across), welded rhyolitic ignimbrite which in places contains conspicuous relic pumice lenticles. A thickness of less than 40 m is preserved (no top). This rhyolitic ignimbrite could either be a component of the "Smedley" association, as suggested by its spatial proximity to dacitic Cub_{27} ignimbrite/s, or a representative (outflow facies?) of the "Arundel" association. However, the rock has no characteristics which distinguish Arundel Rhyolite.

Opposite the domain (II)/(III) boundary, about 7 km south-southeast of the ignimbrite remnants to the north of Charlie Creek discussed above, and approximately 7.7 km southeast of the junction of Charlie Creek and Glendon Creek, are two additional small hilltop remnants of rhyolitic ignimbrite about 10 m thick. Again, these are tentatively included in unit Cub_{27}. These remnants are flat-lying, and consist of very dark to dark grey and brown, moderately crystal-rich (crystals and fragments less than 1 mm across; quartz more abundant than feldspar, subsidiary biotite) welded rock. The ignimbrite appears to overlie the contact between Collins Creek Rhyolite (Cubc) and porphyritic intrusive rhyolite (CPr_2) unconformably; the precise time of emplacement of this occurrence of CPr_2 is not known. The ignimbrite does not seem to be interposed as a discrete unit between Collins Creek Rhyolite and overlying Locharwood Rhyolite about 5 km south of this hilltop occurrence, suggesting that it does not belong to the "Locharwood" association. However, it does not extend far enough east to also overlap onto Locharwood Rhyolite across the local faulted and intruded (by CPr_3) contact with Collins Creek Rhyolite, which an ignimbrite of "Arundel" association age would do. Taking the limitations of these observations into account, there is again a possibility that the rhyolitic ignimbrite is a local, non-distinctive, (outflow facies?) representative of the "Arundel" association rather than being part of the "Smedley" association.

Discussion

The high proportion of coarse to very coarse, probable lag-fall and ground-lag, clastic material in the "Smedley" association in domains (I) and (II) implies proximity to source/s. One good candidate for a vent site can be identified immediately west of lower Glendon Creek. The presence of coarse probable sedimentary rocks in the association, combined with stratigraphic complexity in the vicinity of, and detailed stratigraphic contrasts across, the Burdekin River (i.e between the northwest and domain (I) of the northeast), suggest that a precursor of the Burdekin Gorge Fault Zone was active at the time of "Smedley" association volcanism. Thickness variations indicate that the fault zone and its immediate surroundings had overall negative palaeotopographic expression. The known and inferred absence of "Earlscliffe" and "Locharwood" association representatives from directly below the "Smedley" association between Coopers Creek and Sandalwood-Desmond Creeks suggests that the negative feature succeeded what had earlier been a northeast-striking belt of uplift and erosion. The possible significance of these conclusions are explored further under "Structure and Tectonics".

UPPER RHYOLITE-DOMINATED ("ARUNDEL") ASSOCIATION

The upper rhyolite-dominated association recognised in the study area contains only one formation, Arundel Rhyolite, of apparently limited preserved extent in the central-west. The "Arundel" association sequence lacks a stratigraphic top. Its maximum preserved thickness is very uncertain because the geometry of the main body could be funnel-like. An estimated thickness of about 500 m occurs in peripheral parts of the body, but the thickness could be considerably greater in the centre.

A minor (less than 1 km^2) outlier of the main outcrop area of the Arundel Rhyolite occurs on the eastern side of Coopers Creek, about 5 km south-southeast of Burdekin Falls Dam. Arundel Rhyolite is also recognised tentatively to the west of the main outcrop area, on Mount McConnell, and about 7 km south-southwest of "Myall Creek".

A scattering of rhyolitic ignimbrites in the northwest (assigned to "Locharwood" association units Cub_{10} and Cub_{21}) and the northeast ("Smedley" association unit Cub_{27}) could possibly belong to the "Arundel" association. However, none is a "typical" Arundel Rhyolite type. Each has been adequately discussed above, and they will not be considered further.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that "Arundel" association (their unit V77) rocks are I-types, unfractionated, oxidised, and high-potassium (based on six unpublished AGSO analyses, mostly from the main Arundel Rhyolite ignimbrite, $Cuba_2$).

Arundel Rhyolite

The formation-rank Arundel Rhyolite is named from Arundel Holding. It is mainly preserved in a hilly plateau to the west of Coopers Creek and northeast of "Myall Creek" homestead, where un-named lower and upper subunits of member rank can be distinguished. The formation's type section lies in the southern part of the plateau (Appendix 1). Minor remnants of Arundel Rhyolite have also been recognised on the eastern side of Coopers Creek, tentatively on the middle slopes of Mount McConnel, and (also tentatively) to the south-southwest of "Myall Creek" homestead. Arundel Rhyolite overlies Drummond Basin rocks and Smedley Dacite with conspicuous unconformity. A sample (89503028) of the main ignimbrite (upper subunit - $Cuba_2$) has given a U-Pb (zircon) isotopic age of approximately 293 Ma (Black, 1994; Appendix 2).

Un-Named Subunit $Cuba_1$ (*Cby_1 of Oversby et al. 1991*)

The lower member-rank subunit of the Arundel Rhyolite, $Cuba_1$, is dominated by medium grey to buff, moderately crystal-poor to crystal-rich (mainly moderately crystal-rich), predominantly welded but commonly nonwelded locally, rhyolitic ignimbrites. The ignimbrites make up a heterogeneous section of multiple flow and cooling units. The thickness of subunit $Cuba_1$ increases from between zero and a few metres in the northeastern part of the main outcrop area to at least 250 m (possibly up to 440 m) in the southwest.

Some of the welded ignimbrites have well-developed eutaxitic foliation. Crystals are 1 mm to 2 mm across; quartz is commonly subsidiary to K-feldspar plus plagioclase, or absent; biotite (mainly chloritised) is minor. Crystal contents range from about 10% in the northeast to about 25% in the southwest. The rocks are mostly lithic clast-rich, although some moderately clast-rich, others (rarely) are clast-poor. Lithic clast abundance of individual ignimbrites is directly correlated with the thickness of the subunit as a whole; it varies from 10% to 20% in the northeastern corner of the main outcrop area to 25% to 50% in the southwest. Clast size also shows a general southwestward increase - most are less than 5 cm across in the northeast, while larger (up to 40 cm) clasts are common in the southwest. Clast types reflect to some degree the underlying or neighbouring bedrock geology, implying local source/s for the pyroclastic flows in which they were incorporated. Smedley Dacite is the predominant clast type in the northern and northeastern parts of the outcrop area, where $Cuba_1$ ignimbrite locally (e.g. grid reference 8356-114143) overlies 0.5 m of rudite composed of subrounded pebbles of Smedley Dacite. Farther to the southwest, dacitic ignimbrite clasts give way to a polymictic clast assemblage dominated by rhyolite, rhyolitic ignimbrite and phyllite.

Flow-banded rhyolite, assumed to be lava, is a minor component of subunit $Cuba_1$ at the southwestern extremity of the main outcrop area.

The rocks of subunit $Cuba_1$ are generally moderately altered to propylitic assemblages (combinations of sericite, chlorite, and calcite), and are commonly overprinted by hematite-clay alteration and/or weathering.

$Cuba_l$ in the main outcrop area overlies Smedley Dacite and Star of Hope Formation, and overlaps the boundary between those two units. The contact is an angular unconformity. However, it is probably a structural detachment at some localities. Smedley Dacite exposed for about 10 m below the contact at the northeastern edge of the main outcrop area, in gullies draining into Coopers Creek, is intensely fractured to brecciated, and reddened ("weathered"). The breccia may be a stratigraphic interval of sedimentary origin (e.g. talus). However, it has more of the aspect of a fault breccia, particularly in view of its gradational outcrop relationship with fractured Smedley Dacite. The relationship between lower Arundel Rhyolite and the Star of Hope Formation is also seen clearly in two exposures on the northeastern side of the main outcrop area. At the southwestern corner of the main outcrop area, about 12.5 km east-southeast of "Myall Creek" homestead, $Cuba_l$ rests on a very irregular surface developed on cross-laminated, ripple-marked, micaceous siltstone to fine sandstone, and pinnacles and/or detached blocks of laminated siltstone protrude into/occur within the ignimbrite in places. Farther (1.5 km) to the northeast there is a knife-sharp, acute-angle contact between finely cross-laminated to thinly cross-bedded quartzose sandstone and the overlying ignimbrite. These may be unmodified stratigraphic contacts.

Up to about 10 m of rocks assigned to lower Arundel Rhyolite crop out discontinuously beneath the upper subunit in an outlier of the main outcrop area immediately east of Coopers Creek. These are: mottled and streaky dark brownish-grey and dark reddish-brown, moderately crystal-rich welded ignimbrite containing white feldspar, plus slightly subsidiary quartz crystals up to about 1.5 mm across, and locally abundant angular clasts of feldspar-phyric rhyolite (CPr_2-type - below) up to 8 cm in maximum dimension; dark grey, diffusely bedded, volcaniclastic (feldspar-quartz-lithic) coarse siltite to arenite. Details of the relationships between the rocks are obscured by a discordant to concordant intrusive body made up of rhyolite identical (at least superficially) to that occurring as clasts in the welded ignimbrite. The rocks lie on Star of Hope Formation and Stones Creek Volcanics sediments (DCs_l).

Tentative lower Arundel Rhyolite cropping out on the middle slopes of Mount McConnell consists of moderately crystal-rich rhyolitic ignimbrite up to 150 m thick. Near the base of the sequence the rock is nonwelded and lithic clast-poor to moderately clast-rich whereas higher up it is welded and lithic-rich. It overlies Star of Hope Formation, and apparently also a small body of granitoid (CPg_{10}); it is intruded and overlain by rhyolite and rhyolitic breccia (CPr_l), and probably also intruded by a small, flat-roofed, body of granitoid (CPg_{10}).

The lower subunit of the Arundel Rhyolite in the main outcrop area and its outlier represents a series of eruptive episodes separate from that (or those) of the upper subunit. To the extent that both subunits appear to have originated from essentially the same extrusive centre/s, however, the earlier eruptions may be regarded as precursor events.

Un-Named Subunit Cuba$_2$ (*Cby of Oversby et al. 1991*)

The main, upper, part of the Arundel Rhyolite consists of mid grey to mid purplish-, bluish- or greenish-grey, massive, welded rhyolitic ignimbrite making up a probable single cooling unit. It is at least 200 m thick. The rock is moderately crystal-rich verging on crystal-rich; it generally contains 20% to 25% entire and fragmented crystals 1 mm to 3 mm across. The crystal population is broadly similar to that in welded Cuba$_1$ ignimbrites, but unaltered biotite is more common. Quartz crystals are more abundant than feldspars. About 3% fresh biotite (or pseudomorphs composed of chlorite and iron oxides) occurs in flakes up to 0.5 mm long. Lithic clasts are either absent, or sparse and small. Lithic clast types include rhyolite, fine-grained metasedimentary (greenschist-grade) rocks, and an orthopyroxene-bearing dacite similar to ones in Stones Creek Volcanics. The last is taken as confirmation that Stones Creek Volcanics exist at depth in the area, as expected. Clast sizes are mostly 1 cm or less, and rarely up to 3 cm. Positively-weathering (i.e. standing out from the surfaces of outcrops and float) medium to large (ranging in size up to 15 cm x 3 cm) fiamme are characteristic; their average size increases upwards through the subunit. Well-developed polygonal columnar joints are also characteristic. Columnar joints are essentially vertical, while fiamme typically dip at unsystematically variable but steep angles, suggesting significant rheomorphism.

A lens of vitrophyric ignimbrite (i.e. with a non-devitrified groundmass), ranging up to about 2 m thick but of unknown lateral extent, crops out at grid reference 8356-101137, in the northwestern part of the main outcrop area, about 5 km southwest of Burdekin Falls Dam. This consists of crystals (about 20%) of quartz, sanidine, sodic andesine and biotite, and about 5% by volume clasts of dacite and low-grade metasiltstone set in a black, isotropic glass. It is underlain by a few metres of massive, crystal-rich and lithic clast-poor, rhyolitic ignimbrite with abundant hollow (gas cavity?)-centred spheruloids up to 20 cm in diameter.

Alteration in Cuba$_2$ is slight to moderate, and mostly propylitic (sericite + chlorite $\pm$ calcite $\pm$ epidote), but some (mainly in the lowermost parts of the subunit) is similar in style to that observed in Cuba$_1$ (above), with a clay-hematite overprint.

About 50 m of "typical" upper Arundel Rhyolite are preserved above a discontinuously developed lower subunit in the small outlier on the eastern side of Coopers Creek.

A thin (about 10 m?) partial veneer of tentative upper Arundel Rhyolite is represented by a group of outcrop areas about 7 km south-southwest of "Myall Creek" homestead. Most of these outcrop areas are suprajacent to a small, presumably younger, stock of CPr$_1$ rhyolite verging on "elvan"-type microgranite; the ignimbrite of one outcrop area overlies Star of Hope Formation sedimentary rocks. The tentative upper Arundel Rhyolite contains unsystematically steep "fiamme". No associated lower Arundel Rhyolite is known.

Discussion

The distinctly intra-caldera nature of, and indication of extreme rheomorphism in, the upper Arundel Rhyolite are rather unexpected. This is particularly because of the complete lack of a ring fracture-intrusion system around or within the main outcrop area of the unit. Our preliminary conclusion (discussed at greater length under "Structure and Tectonics") is that the main outcrop area underwent synchronous extension and cauldron subsidence of an unusual kind.

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BOWEN BASIN

Lizzie Creek Volcanics, Plz (*Plz of Oversby et al. 1991*)

The Lizzie Creek Volcanics were named from Lizzie Creek, near Eungella, by Malone (1968); previously they had been known as the Lower Bowen Volcanics. Regionally, the formation consists of up to 6000 m of andesitic to basaltic lavas and pyroclastic rocks, with subsidiary clastic sedimentary rocks (probably mostly fluviatile, but also marine near the top of the unit), felsic volcanics (including ignimbrites) and local coal. Geochemically, the igneous rocks are calc-alkaline, and probably continental (Hutton et al. 1991). They represent the postulated Lizzie Creek Volcanic Field of Oversby et al. (1980). The formation overlies older rocks nonconformably, disconformably, or unconformably; it is disconformably to unconformably overlain by the extrusive component of Mount Wickham Rhyolite and by Bowen Basin sediments. Palaeontological and K-Ar isotopic data are consistent with an Early Permian age for most, perhaps all, of the Lizzie Creek Volcanics, with lower parts of the unit possibly being Late Carboniferous. However, a mid-Permian age has also been suggested (Murray 1983), and sparse palaeomagnetic data (Klootwijk et al. 1993; Appendix 3) are consistent with this.

We follow the majority of regional syntheses (e.g. Olgers 1972, Dickins & Malone 1973, Staines & Koppe 1980, Murray 1990) in treating the Lizzie Creek Volcanics as part of the Bowen Basin sequence. However, as discussed further under "Structure and Tectonics", we believe that the unit (and Mount Wickham Rhyolite) could equally well be placed in the North Queensland Igneous Province (cf. Henderson 1980).

The Lizzie Creek Volcanics are restricted to eastern (except extreme southeastern) parts of the map area. Rocks assigned to the formation crop out, generally moderately well, on either side of a low range of hills (made up of tentative Mount Wickham Rhyolite), which trends south-southeast subparallel to the Bowen River from near "Strathbowen" homestead to between Frederick Creek and the lower reaches of Ten Mile Creek. Malone et al. (1966) considered that the rocks to the west of the hills were Tertiary, but this age asignment has not been supported by subsequent workers. We also tentatively recognise very poorly exposed Lizzie Creek Volcanics to the east of Mount Wickham. The Lizzie Creek Volcanics overlie various granitoids of unit CPg_{10} nonconformably, and also overlie probable Bimurra Volcanics, "Earlscliffe" association Bulgonunna Volcanic Group (Earlscliffe Dacite subunit $Cube_3$, and tentative unit Cub_8), and Nostone Creek Granodiorite. The nonconformable contact with CPg_{10} granitoid is well exposed in gullies draining into Birralee Creek, near its junction with Oaky Creek, and to the southeast of lower Ten Mile Creek. At Mount Wickham, and also to the south-southeast, Lizzie Creek Volcanics are partly intruded and partly overlain with probable angular unconformity by intrusive and extrusive components respectively of the Mount Wickham Rhyolite. The formation is also overlain, and overlapped, disconformably by Collinsville Coal Measures. Although subparallel to, and partly disrupted by, exposed faults, the current western margin of the Lizzie Creek Volcanics is stratigraphic, and not fault-controlled (cf. Paine et al. 1974, p. 40).

The Lizzie Creek Volcanics sequence in the map area presumably belongs to the informal "Mt Toussaint" volcanic member (Clare 1990). Poor outcrop quality has inhibited finer internal subdivision. As exposed, the sequence is dominated by lavas, of which the most common is blue, fine-grained and locally amygdaloidal, basalt. This basaltic lava is locally associated with minor, poorly-sorted and non-bedded, monomictic basaltic (auto?)breccia. Pale purple, vesicular and feldspar-phyric, trachytic(?) lava was noted to the south of middle Frederick Creek. Minor dark greyish-blue, fine-grained and crystal (feldspar)-poor, welded andesitic(?) ignimbrite crops out 2.5 km due east of the junction of Goldbeetle and Glenmore Creeks. Rhyolitic ignimbrite rich in quartz and feldspar crystals occurs with sedimentary rocks in tentative Lizzie Creek Volcanics to the southeast of Mount Wickham. Sedimentary rocks are not commonly exposed; the exposed ones are principally very thick bedded and homogeneous polymictic conglomerate. Sedimentary material immediately above the nonconformable contact with CPg_{10} in gullies beside Birralee Creek, near its junction with Oaky Creek, consists of locally derived quartzo-feldspathic sandstone, and conglomerate that contains granite clasts. Feldspatho-lithic sandstone occurs to the southeast of Mount Wickham.

Petrographically, Lizzie Creek Volcanics basalt is sparsely to abundantly plagioclase-phyric. The mineral occurs in laths less than 1 mm long which contain scattered, weakly titaniferous, clinopyroxenes. Groundmass material consists of feldspar, abundant opaque grains, and green biotite. Altered olivine crystals about 0.5 mm across are present in some rocks (e.g. at grid reference 8456-707994).

A maximum of about 250 m of Lizzie Creek Volcanics is probably present in the study area. The unit thins southwards, and is locally overlapped by Collinsville Coal Measures. It is completely absent at Parrot Creek, in the extreme southeast, where Collinsville Coal Measures lie directly on Earlscliffe Dacite ($Cube_3$), Bobby Dazzler Rhyolite, and granitoids (CPg_2, CPg_{10}).

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that the Lizzie Creek Volcanics (their unit V70) rocks are mafics plus I-types, unfractionated, oxidised to strongly oxidised, and high-potassium (based on twenty eight analyses, including five unpublished AGSO ones). The analysed rocks resemble calc-alkaline basalts. They have the high La/Nb ratios (3.0 to 5.0) typical of oceanic island arc or continental margin settings, and are enriched in large-ion lithophile elements to about fifty times above primordial mantle contents. Moderate TiO_2 levels are in keeping with their obvious continental, rather than oceanic, setting.

Part of Mount Wickham Rhyolite, Pw (*PRr of Oversby et al. 1991*)

The Mount Wickham Rhyolite is a CPr_1-type (below) formation, distinctive by virtue of its stratigraphic-structural setting. The unit was named (Paine et al. 1974) from Mount Wickham, to the north of the Bowen River in the extreme northeast. Its nominated type occurrence is Mount Herbert (evidently an intrusive plug), 40 km northwest of Collinsville (Paine et al. 1974). Mount Wickham Rhyolite has conventionally been credited with a

Permo-Triassic age on the basis of an Rb-Sr total-rock age of 230 ± 15 Ma ("old" constants) from a suite of geographically dispersed samples, included three from about 5 km north of Mount Wickham itself (Webb & McDougall 1968, Paine et al. 1974), i.e. Late Triassic. We see no reason to regard Mount Wickham Rhyolite in the study area as being other than slightly younger than Lizzie Creek Volcanics, i.e. probably mid-Permian.

The name has previously been most commonly applied to that group of fine-grained felsic rocks which occurs both in intrusive bodies (dykes to stocks) and as lavas, cutting and overlying the Lizzie Creek Volcanics throughout the northwestern Bowen Basin. None of the rocks involved seems to be particularly distinctive in its own right. Some previous investigators have used the name even farther afield (e.g. Mount McConnell - Paine & Cameron 1972, Paine et al. 1974). We consider that this is too far removed from the source of the name to be appropriate and that it is unlikely that the rocks belong to the same unit. We (re)define the unit more restrictively, and nominate Mount Wickham itself as its type occurrence (Appendix 1). Extension of the name much beyond this without some particularly good justification seems indefensible; non-distinctive rhyolites were intruded and extruded recurrently throughout the entire magmatic history of northeastern Australia, cf. discussion (above) of units CPr_1, CPr_2, and CPr_3. This history was particularly long in the Burdekin Falls Dam - "Conway" area. We do tentatively assign rhyolites concentrated along the Millaroo Fault Zone, along strike (south-southeast) from Mount Wickham, to the unit.

A Permian age is equally, if not more likely, for the unit as here redefined than the Permo-Triassic one conventionally quoted. It would be consistent with the local stratigraphic position of extrusive Mount Wickham Rhyolite above the Lizzie Creek Volcanics (absence below the Collinsville Coal Measures farther east and south may only be a function of the viscous nature, i.e. restricted areal distribution away from source/s, of rhyolitic lavas). The rocks to the south-southeast of Mount Wickham were regarded by Malone et al. (1966) as Tertiary; this has not subsequently been supported.

Mount Wickham is made up of moderately massive, though well-jointed, "white" (mainly very pale buff), moderately abundantly quartz-phyric, rhyolite. Staining by iron oxides/hydroxides (after sulphides?) is a common feature, especially along joint surfaces. Cliff-forming rhyolite below the main summit of the mountain appears to occur in gently eastward-dipping sheets. A pair of west-northwest-striking rhyolite dykes, which are presumed to be related to the main mass of the unit, occur to the north. Mount Wickham Rhyolite is in contact with CPg_{10} granitoid to the southwest of the mountain. Elsewhere, the unit is in contact with tentative Lizzie Creek Volcanics. The massive nature of the rocks at Mount Wickham, together with moderately porphyritic texture and lack of flow-bands, suggest that they could be mainly intrusive. However, unfaulted contacts with subjacent rocks have map traces which indicate that they are gently inclined (a fault can be inferred only in the southeast). This, and the apparent subdivision into sheets, are consistent both with the body being an extrusive lava pile, and a multiple sill- or laccolith-like intrusion; it is not possible to nominate either option as the preferred one on a basis of available data. We are inclined to suspect that, in reality, the body may be a composite intrusive-extrusive feature in which origins of components cannot be differentiated because of subtle and intricate intergradations between intrusives and extrusives.

Rocks tentatively identified as Mount Wickham Rhyolite crop out in a range of low hills that run south-southeast from "Strathbowen" homestead in the north, to about 3 km beyond middle Frederick Creek, on the western side of the Bowen River. An aggregate thickness of 150 m to 200 m of cliff-forming rhyolite is preserved in sheet-like bodies. Rhyolite is sparsely feldspar- and/or quartz-phyric, and commonly spherulitic. Most of the sheets contain intricately folded flow bands in zones which grade into autobreccia lenses, and commonly display polygonal columnar joints perpendicular to upper and lower surfaces. They are overall gently east-dipping; this contrasts with the apparently more intricate structure of subjacent Lizzie Creek Volcanics. Sheets are accompanied locally by steep dyke- and plug-like bodies of identical rhyolite. The stepped profiles of many of the hills reflect the presence of multiple rhyolite sheets, each one of which is up to a few tens of metres thick. A few of the sheets (e.g. 3.5 km south-southeast of the junction of Goldbeetle and Glenmore Creeks) are known to be separated by thin lenticular intervals of pumiceous and lithic-pebble conglomerate, and tuffaceous sandstone. In such instances, at least one, probably both, of the rhyolite sheets can be safely assumed to be a lava flow (as distinct from a sill), with unconformable relationships to Lizzie Creek Volcanics. Collectively, flows and sills may both be represented among the sheets.

The contact between one sheet of possible Mount Wickham Rhyolite and the underlying Lizzie Creek Volcanics is well exposed at grid reference 8456-596201, 3 km south-southeast of the junction of Goldbeetle and Glenmore Creeks. Lizzie Creek Volcanics basalt is directly overlain by a probable flow-foot autobreccia made up of blocks of black vitrophyre and varicoloured devitrified rhyolite. Unbrecciated vitrophyre and pale buff rhyolite succeed the breccia upwards. The dimensions (about 23 km long, 1 km to 3 km wide) of this belt of possible Mount Wickham Rhyolite are suggestive of rhyolite emplacement via a linear conduit system. The paucity of steeply discordant intrusive bodies in the belt, and lack of any other nearby source/s for such a large volume (almost 10 km^3, as preserved) of felsic material, suggest that the system has not been exhumed from among sheeted rhyolites, assuming near-surface steepness of conduit/s (this assumption may not be valid however as discussed further below under "Millaroo Fault Zone" in “Structure and Tectonics”).

In their GIS compilation, Champion & Heinemann (1993, 1994) suggest that Mount Wickham Rhyolite (their unit 225, which includes the tentative correlatives) rocks are I-types; however, no analyses are available to back this up, nor to characterise the rocks further.

<u>Collinsville Coal Measures, Plc</u> (*Plc of Oversby et al. 1991*)

The Collinsville Coal Measures overlie Earlscliffe Dacite ($Cube_3$) and Bobby Dazzler Rhyolite of the Bulgonunna Volcanic Group "Earlscliffe" association, CPg_{10} granite, and Lizzie Creek Volcanics in the extreme central-eastern to southeastern Burdekin Falls Dam

- "Conway" area. Contacts are either unconformable or nonconformable (or possibly disconformable in the case of Lizzie Creek Volcanics). This, a formation-rank unit in the Back Creek Group (Dickins & Malone 1973, Staines & Koppe 1980), occupies the structural Collinsville Shelf sector of the palaeotectonic/depositional Clermont Stable Block (Staines & Koppe 1980). The formation was named from Collinsville (Reid 1924), which lies 70 km east of Burdekin Falls Dam, and about the same distance northeast of "Conway" homestead. No type section as such has been nominated, although the unit is extremely well known (e.g. Webb & Crapp 1960) as a result of exploratory drilling and mining for coal.

Regionally, the Collinsville Coal Measures consist of lower and upper intervals of mainly fluviatile and paralic (deltaic?) sandstones and conglomerates plus coal seams, with minor siltstone and carbonaceous mudstone. These coal-bearing intervals are separated by marine sandstone (Glendoo Sandstone Member). Somewhat equivocal palaeontological data suggest that the formation is probably of mid-Permian age. It is up to about 250 m thick.

Polymictic pebble to cobble conglomerate with sporadic breccia, containing locally-derived clasts, together with lithic sandstones and siltstones, make up the Collinsville Coal Measures as exposed in the study area. The rocks are reported to be cut by "many small intermediate sills and dykes" (Malone et al. 1966, p. 35).

CAINOZOIC

Suttor Formation, Ts (*Ts, Tu, T, Mz, (w) of Oversby et al. 1991*)

Following previous workers, all probable Tertiary sedimentary rocks in the map area are assigned to the Suttor Formation, named from the Suttor River. The type area of the formation lies to the southeast, near "Cerito" in the Byerwen 1:100 000 Sheet area (Malone et al. 1964, Hutton et al. 1991). The formation is most widespread in the southern part of the study area.

The Suttor Formation is characterised by "white" (very pale grey to very pale buff), clayey, medium- to very coarse-grained and commonly pebbly, quartz sandstone and sandy mudstone; oil shale has been reported from Rutherfords Table, 15 km west-northwest of "Conway" (Levingston 1956).

Some areas delineated on the map as Suttor Formation are intensely and deeply weathered bedrock rather than representatives of the unit proper. The weathering presumably took place in pre-Suttor Formation, Mesozoic and/or Cainozoic, time/s.

Gold has been won intermittently (until at least 1987) from a deep lead-type deposit in Suttor Formation at Rutherfords Table (no 33 on the map).

Tertiary Basalt, Tb (*Tb of Oversby et al. 1991*)

Mount Dalrymple and a hill about 6 km farther west (11 km west-southwest of "Pyramid" homestead), in the southwest are capped by fresh, presumably Tertiary, basalt above elevations of about 365 m and 310 m respectively. None occurs on The Pyramid (summit at 360 m). It is not entirely clear whether the two occurrences represent intrusive plugs, or outliers of lava; a combination of both is distinctly possible at each locality. In both cases the basalt is dark greyish-green, and blocky to slabby. Both occurrences unconformably overlie Saint Anns Formation. To the west of each basalt cap are sedimentary rocks assigned to the Suttor Formation; these are at least locally sheared and intensely silicified at Mount Dalrymple.

Unconsolidated Alluvium, Colluvium, and Soil, Cz (*Qha, Qa, Cz, Czs, (r) of Oversby et al. 1991*)

Mappable alluvium, colluvium, and soil in the Burdekin Falls Dam - "Conway" area occurs mainly in and adjacent to the main channels of the Burdekin, Bowen, and Sellheim Rivers. Extensive, but probably thin, soil on Lizzie Creek Volcanics and Collinsville Coal Measures, in the extreme east, has been omitted from the map.

Small-scale alluvial gold workings are known from the Burdekin River, about 3 km east-northeast of Burdekin Falls Dam (no 5 on the map), from Isabella Creek near its junction with the Sellheim River (no 7), and from gullies (including "Mutton Gully", no 32) on the northern side of that river to the east of Rutherfords Table.

INTRUSIVE ROCKS

LOLWORTH - RAVENSWOOD BLOCK

Ravenswood Granodiorite Complex

Rocks of the Ravenswood Granodiorite Complex (Wyatt et al. 1970) are restricted to the northwestern part of the map area. Two subunits have been discriminated. The rocks are emplaced into Cape River Metamorphics and the Mount Windsor Volcanics, and in their turn are intruded by a limited variety of late Palaeozoic rocks (mainly CPm and CPr_3 types), predominantly in dykes. Outliers of Bulgonunna Volcanic Group ignimbrite/s (Cub_{21}) overlie the Ravenswood granodiorite rocks.

The GIS compilation of Champion & Heinemann (1993, 1994) suggests that most Ravenswood complex rocks in the Burdekin Falls Dam - "Conway" area belong to their unit 95, and are I-types, unfractionated, reduced to oxidised, and medium- to high-potassium (based on eighteen analyses, including twelve unpublished AGSO ones).

Un-Named Subunit ODg_1 (*ODr of Oversby et al. 1991*)

This is the most extensive, more mafic, and probably older of the two Ravenswood granodiorite subunits recognised in the study area. In general, it is exposed in sparse, generally deeply-weathered outcrops to the north of the drowned junction of the Burdekin and Suttor Rivers, mainly to the east of Lake Dalrymple but also extending to the western side around Fern Creek (extreme northwestern corner), to the west of its companion subunit.

Subunit ODg_1 consists of medium grey to pinkish-grey, medium-fine (1 mm to 2 mm) inequigranular to weakly porphyritic (i.e. phenocrysts poorly-developed and small), hornblende-biotite and biotite-hornblende granodiorite grading to tonalite. Quartz and potassium-feldspar commonly occur in coarse graphic intergrowths. In some places, the rock contains hornblende phenocrysts up to 1 cm long. Allanite is a conspicuous accessory mineral locally. The subunit is cut by numerous dykes of comagmatic(?) porphyritic hornblende-biotite dacite and microgranodiorite, as well as by veins and dykes of presumably unrelated aplites. A subsidiary eastern stock tentatively assigned to ODg_1 is made up of grey, weakly plagioclase-phyric, hornblende-biotite granodiorite which has undergone a moderate degree of propylitic (sericite + chlorite + calcite + epidote) alteration.

Four chemical analyses have been obtained from occurrences of this unit in the vicinity of Range View homestead, outside the study area approximately 30 km north-northwest of Burdekin Falls Dam. No substantial chemical differences between ODg_1 and other northern granitoids (mainly assigned to unit CPg_{10}) have been detected, even though ODg_1 is, slightly more mafic than the others.

Un-Named Subunit ODg_2 (*ODa of Oversby et al. 1991*)

The bulk of this subunit consists of pink, relatively felsic (in comparison with ODg_1 rocks), medium- to coarse-grained and weakly porphyritic, biotite granite which grades locally into biotite microgranite. Miarolitic cavities are common in the granite.

Rocks of subunit ODg_2 crop out on the western side of Lake Dalrymple, as well as (tentatively) to the east of the lake, 15 km northwest of Burdekin Falls Dam.

The presence of miarolitic cavities in the bulk of subunit ODg_2 is suggestive of emplacement depths shallower than about 2.5 km or 3 km, and hints at a possible mid rather than early Palaeozoic age.

NORTH QUEENSLAND IGNEOUS PROVINCE

In the northeastern and central-eastern Burdekin Falls Dam - "Conway" area late Palaeozoic intrusive rocks crop out in an area comparable in size to that occupied by the Bulgonunna Volcanic Group and other extrusive rocks. Numerous separate intrusive bodies occur in the stock to batholith size range; added to these are abundant dykes and plugs. Collectively, the rocks show an enormous spectrum of textural variations. With a few exceptions, noted below, neither the relative nor absolute ages of individual intrusions are precisely known. The vast majority of granitoid stocks and batholiths are known, or can be reasonably inferred, to postdate the Bulgonunna Volcanic Group; they antedate late plugs, dyke swarms and the Lizzie Creek Volcanics. Pre-Bulgonunna granitoid stocks-batholiths seem to be rare. A moderate number of felsic rocks (including "elvan"-type CPr_1 - below) in dykes, plugs and stocks can be inferred to be broadly syn-Bulgonunna on the basis of their subvolcanic aspect. Final emplacement of some intrusive rocks, in addition to Mount Wickham Rhyolite, may have been penecontemporaneous with early development of the now-adjacent (and possibly in part originally overstepping and superjacent) Bowen Basin.

Most of the medium- to coarse-grained late Palaeozoic granitoids are biotite- and hornblende-bearing, with feldspar contents ranging from K-feldspar plus subequal plagioclase to plagioclase-dominant. Some rocks are quartz-poor, and fall into the quartz monzonite and quartz monzodiorite fields.

As discussed further below under sections dealing with CPg_2, CPg_{10}, CPr_1, CPr_2, CPr_3, and CPm rocks, a few of the plutons in the northeast contain mixtures of different components. Intrusive heterogeneity is also very commonly manifested in the northeast by concentrations of microgranitoid enclaves in a coarser-grained or otherwise texturally distinct host. Although all enclave types at any one exposure tend to be similar, a limited range of textural variants is typically present. Enclaves are locally concentrated to the extent where only narrow (centimetre-scale) seams of the host separate them. Specific enclave occurrences are detailed below under discussions dealing with their hosts ("Billy-can Creek" granite, CPg_2, CPg_{10}). Small-scale intrusive heterogeneity has not developed so markedly in other parts of the study area.

Only a summary of the major, or more distinctive, characteristics of the intrusive rocks is presented here, pending fuller investigations of stock- to batholith-scale granitoids.

<u>House and Kitchen Granite, Cgh</u> (*Clg_{mgh} = "House and Kitchen granite" of Oversby et al. 1991*)

The House and Kitchen Granite, named from the House and Kitchen, a pair of hills about 12km north-northwest of "Ukalunda" homestead, occurs in the southwest. The granite crops out between Bell Creek and the Sellheim River, in an irregular ovoid area of about 60 km^2, shown as Bulgonunna Volcanics in previous 1:250 000 mapping. The type area of the unit lies to the south-southeast of the House and Kitchen hills (Appendix 1). The granite cuts up to at least the stratigraphic level of Scartwater Formation, and is overlain unconformably by Locharwood Rhyolite ("Locharwood" association, Bulgonunna Volcanic Group). Its relationship to rocks tentatively assigned to the "Earlscliffe" association, which underlie the rhyolite-dominated assemblage in the area, is somewhat uncertain, although available evidence suggests that the granite is younger, i.e. it was emplaced in the interval between accumulation of the local "Earlscliffe" and "Locharwood" association sequences.

The House and Kitchen Granite is typically mid-pink to pale red, equigranular to sparsely porphyritic, microgranite to (predominantly) very fine-grained granite of "aplitic" aspect. Biotite occurs locally. Where the rock is porphyritic, feldpar phenocrysts tend to be consistently larger and more conspicuous than those of quartz. The granite commonly contains miarolitic cavities.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that House and Kitchen Granite (their unit 231) rocks are I-types, unfractionated, strongly oxidised, and high-potassium (based on one upublished AGSO analysis). The unit is one of the most felsic ones in the study area; the single analysis shows very low femic elements (magnesium, iron, titanium, vanadium, chromium, nickel), but rather high rare earths and high field strength elements.

<u>Peak John Well Granite, Cgp</u> (*part Clg of Oversby et al. 1991*)

This is a moderately well characterised unit made up of two irregular occurrences of biotite-bearing granite (mainly) to subsidiary granodiorite in the central-south. The rocks are judged to be early (relative to the majority of North Queensland Igneous Province intrusive rocks in the study area) on the basis of isotopic (Rb-Sr biotite and total-rock) dates of 324$\pm$3 Ma and 328$\pm$3 Ma (unpublished AMDEL Report G 8037/89 and A.W. Webb, personal communication 1990, respectively) from the same sample of biotite granodiorite (sample 88502866) at the type locality of the unit, 2.1 km west-northwest of Peak John Well (grid reference 8356-370047 - see Appendix 1). The high strontium isotope initial ratio (0.7253) in this rock implies an old crustal source and/or an even greater age than the oldest of the two dates above.

Several bodies of Cgp between Peak John Well (including the isotopically dated rock - above) and Peak John, 5 km to the south-southwest, consist of very pale grey, locally "white", somewhat potassic, biotite-only granites. Exposures range from poor in low-lying country for mafic phases, to excellent in hilly tracts for more felsic rocks. Individual bodies display a range of textures and grain sizes, from marginal very fine verging on microgranular porphyritic, through coarse (grains larger than 5 mm) mesocratic granite, to leucogranite; the dated rock is mesocratic and medium-equigranular biotite granite. The rocks have been deformed and slightly recrystallised. East of Peak John Well, the unit consists of pale pink to cream, medium- to coarse-equigranular, biotite granite probably in fault contact with Bulgonunna Volcanic Group rocks (Locharwood Rhyolite and Cub_{17}).

The compilation of Champion & Heinemann (1993, 1994) indicates that Peak John Well Granite (their unit 232) rocks are typical I-types, unfractionated, oxidised, and high-potassium (based on six unpublished AGSO analyses). The rocks have no especially distinctive geochemical features; barium, rubidium, and strontium contents indicate that alkali feldspar fractionation has been minimal.

<u>"Billy-can Creek" Granite, CPgb</u> (*part* Cug_{mg} *of Oversby et al. 1991*)

This unit is informal because the geographical component of the name provisionally reserved by us was subsequently required for use elsewhere in Queensland (C. Brown, personal communication, 1992). The unit consists of a pink porphyritic microgranite to very fine granite CPg_2 rock type; it is distinctive in making up a relatively large (with respect to other CPg_2 occurrences), half moon-shaped (convex to the southwest), stock of about 60 km^2 exposed area in the central-west. The stock crops out on a high plateau drained by Billy-can Creek and upper Brawl Creek. It cuts Locharwood Rhyolite, and is immediately west of (cut by ?) the main stock of CPg_{10} granitoids (below).

Abundant microgranitoid enclaves in "Billy-can Creek" granite are exposed in a western tributary of upper Brawl Creek at grid reference 8356-410152.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that "Billy-can Creek" granite (their unit 485) rocks are I-types; however, lack of analyses makes further characterisation impossible.

<u>Joe-De-Little Granite, CPgj</u> (Clg_j = *"Joe de Little granite" of Oversby et al. 1991*)

The Joe-De-Little Granite occurs as an elongate series of bodies in the southwest, extending in a southwesterly direction between The Pyramid and the Percy Douglas Range; it extends into the Mount Coolon 1:100 000 Sheet area.

The most common rock type assigned to Joe-De-Little Granite is a pale to mid-, locally pinkish, grey, fine- to medium-grained (about 1 mm) hornblende-biotite granite; granodiorite predominates in some areas, such as adjacent to the Sellheim River. The most mafic variety has a colour index of about 25, with roughly equal abundances of hornblende and biotite. Hornblende is pale green; it is commonly cored by clinopyroxene, less commonly by orthopyroxene. In the most felsic rocks (approximately 70% SiO_2), hornblende is absent, and the colour index is about 7.

A sample of the most common, type-locality (grid reference 8356-212898 - see Appendix 1), variety of Joe-De-Little Granite, a hornblende-biotite granite with a colour index of 12 was dated by the Rb-Sr method via a biotite plus whole-rock isochron. The age obtained was 301$\pm$3 Ma, with initial strontium isotope ratio of 0.7074 (unpublished AMDEL Report G 8037/89).

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Joe-De-Little Granite (their unit 238) rocks are I-types, unfractionated, oxidised, and high-potassium (based on seven unpublished AGSO analyses). The granite is one of a group of hornblende-bearing granites and granodiorites from the southern part of the study area which have very comparable chamical characteristics. Others in the group are Sunbeam Granodiorite, Percy Douglas Granodiorite, Roscow Granite, and Nostone Creek Granodiorite (below).

Percy Douglas Granodiorite, CPgp (*Clg_p = "Percy Douglas granodiorite" of Oversby et al. 1991*)

The Percy Douglas Granodiorite underlies much of the valley drained by Percy Douglas Creek between the Percy Douglas range and Mount Wyatt, in the southwest and central-south. Outcrops are generally sparse, although some very good rock pavement exposures can be found in creeks, as at the ford across Percy Douglas Creek at grid reference 8356-252892, which is nominated as the type section (Appendix 1).

Typical Percy Douglas Granodiorite is a pale to mid-grey, fine- to medium-grained (1 mm), hornblende-biotite granodiorite with a colour index of 25. It is very similar to the more mafic parts of Joe-De-Little Granite. Microgranite enclaves are common in Percy Douglas Granodiorite.

Biotite and hornblende are present in approximately equal amounts in Percy Douglas Granodiorite. The hornblende is pale green, and commonly cored by clinopyroxene or actinolite pseudomorphs of pyroxene. Plagioclase has quite calcic (An50 to An60) cores. Potassium feldspar is relatively rare; some samples are almost petrographic tonalites.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Percy Douglas Granodiorite (their unit 235) rocks are I-types, unfractionated, oxidised, and medium- to high-potassium (based on three unpublished AGSO analyses). Compared to hornblende-bearing rocks of equivalent silica content in other southern plutons, Percy

Douglas Granodiorite is rather low in Na_2O, P_2O_5, and Zr. Compositional variation in the unit is not as great as in the Joe-De-Little Granite (above).

Percy Douglas Granodiorite has been exploited in the Mount Wyatt Goldfield. It yielded gold and copper ores at the Amanda (no 10 on map), Big Lode (34), and Top of the Hill (35) Mines, and in the "Copper Contact Zone" (with Ukalunda Beds) worked at the Big Hope (23) Mine.

<u>Roscow Granite</u> (*Clg_{ra}, Clg_r = "Roscow granite" of Oversby et al. 1991*)

A composite granodiorite and granite unit restricted to the central-south. Roscow Granite crops out, generally quite well, in a single north-northwest-elongated stock of about 25 km^2 extending for nearly 8 km from the southern foot of Mount Landsborough to the southern foot of Mount Tindale. According to the map trace of the contact, Roscow Granite may be overlain nonconformably by Bulgonunna Volcanic Group ("Earlscliffe" association, unit Cub1) rocks. Roscow Granite has been divided into two member-equivalent subunits, $CPgr_1$ (mafic) and $CPgr_2$ (felsic),

<u>Un-Named Subunit $CPgr_1$</u> (*Clg_r of Oversby et al. 1991*)

The mafic, older, one of the Roscow granite subunits is predominantly dark grey equigranular (0.5 mm to 1 mm) granodiorite, with a colour index of about 25. The subunit makes up a peripheral western to southern to eastern sector, and a central-northern part, of the Roscow Granite pluton. Near the margins of the subunit locally, as at grid reference 8356-347810, quartz monzodiorite occurs.

Granodioritic to monzodioritic Roscow Granite of subunit $CPgr_1$ is the most mafic of several granitoid in the southern part of the study area. Amphibole in the rock is almost entirely secondary after pyroxene; clinopyroxene is moderately abundant, especially in the quartz monzodiorite. Orthopyroxene is also present locally, and probably much of the secondary amphibole is cummingtonite after orthopyroxene. Despite the mafic character of $CPgr_1$ rocks, potassium feldspar is more common in them than in Percy Douglas Granodiorite (above).

<u>Un-Named Subunit $CPgr_2$</u> (*Clg_{ra} of Oversby et al. 1991*)

Felsic rocks of subunit $CPgr_2$ make up an irregularly arcuate marginal northwestern to internal south-central to marginal northeastern sector of the Roscow Granite pluton. This subunit commonly contains pink, sugary-textured "aplitic" granite, or pink medium-grained granite with low colour index (3 to 5). Granite of subunit $CPgr_2$ can be seen cutting $CPgr_1$ granodiorite in the bed of the Sellheim River at grid reference 8356-339862. The granite is moderately pyritic in places, particularly around grid reference 8356-342817.

The $CPgr_2$ granite commonly has a graphic texture. It is free of amphibole for the most part, although some fine-grained "aplitic" varieties contain scattered crystals (xenocrysts?) of the mineral, along with more common calcic plagioclase; these crystals are believed to have been derived from the granodioritic subunit.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Roscow Granite (their unit 234) rocks are I-types, unfractionated, oxidised, and high-potassium (based on seven unpublished AGSO analyses). Compared to other granodiorites from the southern part of the study area, $CPgr_1$ rocks have slightly higher K_2O and Zr. In all other geochemical aspects, the rocks can be grouped with the other southern granodiorites, as well as the granites, as a coherent suite. The Roscow Granite pluton seems to have developed its mafic margin and more felsic core by crystal fractionation processes. An observed gap in composition between granodiorite and granite could have developed by convective fractionation within the original magma chamber, with mafic cumulates separating at the walls of the chamber and more felsic derivative liquids escaping laterally and vertically from the cumulates (cf. Wyborn & Chappell, 1986).

Stuart Pocket Granite, CPgs (*Cgs = "Stuart Pocket granite" of Oversby et al. 1991*)

Stuart Pocket Granite is the coarse biotite granite restricted to an isolated 10 km^2 stock topographically defined by Stuart Pocket, in the northwestern part of the study area (Appendix 1).

Stuart Pocket Granite crops out on the eastern side of Glenroy Creek, 10 km north-northeast of "Glenroy" outstation. It cuts Seventy Mile Range Group rocks (including Mount Windsor Volcanics), and is also in contact with Stones Creek Volcanics. The unit consists of orangey-pink to buff, coarse-medium- to coarse-equigranular, granite. The rock has been pervasively and intensely altered to an epidote + muscovite/sericite + calcite(?) assemblage, and greisenised locally. Extensive deformation (shearing and/or recrystallisation) are evident, particularly at the margins of the pluton.

Stuart Pocket Granite is significantly more deformed than most other granitoids in the area. Clastic sedimentary rocks in adjacent Stones Creek Volcanics are not obviously hornfelsed, and contain detritus that could have been derived from the granite. These observations indicate that the contact between Stuart Pocket Granite and Stones Creek Volcanics could be a nonconformity, and suggest that the age of the granite could actually be significantly older than the late Palaeozoic one which we provisionally assign to it.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Stuart Pocket Granite (their unit 219) rocks are probably I-types; however, lack of analyses makes further characterisation impossible.

Sunbeam Granodiorite, CPgu (*Clg$_{ms}$ = "Sunbeam granodiorite", Clgm of Oversby et al. 1991*)

`Sunbeam Granodiorite is named from the Sunbeam Mine (no 11 on the map), 10 km east-northeast of "Ukalunda" homestead; the type area is at and adjacent to the mine itself (Appendix 1). As currently recognised, the unit occurs exclusively in the southwest. Sunbeam Granodiorite extends as a semi-continuous medium-size irregular body from the Sunbeam Mine for 5 km southwest and 7 km west-northwest to the Sellheim River north of "Ukalunda".

Sunbeam Granodiorite consists of dark to very dark (and characteristically slightly greenish) grey, fine- to medium-grained granite to granodiorite. The rock contains about 30% biotite with accessory to subsidiary hornblende (both commonly partly to wholly pseudomorphed by chlorite).

Sunbeam Granodiorite cuts rocks assigned to the Ukalunda Beds, Mount Wyatt Formation, and (tentatively) Saint Anns Formation. It is in apparent intrusive contact with Joe-De-Little Granite (above) between 1.3 km and 3.5 km southwest of the Sunbeam Mine, but age relationships are uncertain; the map trace of the contact suggests that Sunbeam Granodiorite is the older of the two units. The granodiorite is cut (rarely) by irregular small bodies of a fine-grained granitoid, which may represent a felsic differentiate, or could possibly be a phase of the Joe-De-Little Granite. Sunbeam Granodiorite is also in structural (faults with sporadic dykes) contact with mainly Locharwood Rhyolite ("Locharwood" association, Bulgonunna Volcanic Group), but also locally with rocks tentatively placed in the "Earlscliffe" association.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Sunbeam Granodiorite (their unit 240) rocks are I-types, unfractionated, oxidised, and high-potassium (based on three unpublished AGSO analyses). Sunbeam Granodiorite is part of the same geochemical suite as the other granodiorites in the southern part of the study area.

Sunbeam Granodiorite acts as host to most of the silver and/or gold deposits (nos 11-13 and 15-22 on the map) which formed the basis of the Ukalunda Silver Field. Some of the deposits are still periodically exploited on a small scale; the Sunbeam Mine was active at the time of our investigations in 1987 and 1988, and the Walhalla Mine site (22) showed signs of fairly recent activity.

Un-Named Unit CPg$_1$ (*Clg$_{po}$, Clg$_{mg}$ of Oversby et al. 1991*)

Rocks notated CPg$_1$ in the south-central and southeastern parts of the study area are porphyritic microgranites to (dominantly) fine-grained granites. The rocks are superficially identical to some varieties of House and Kitchen Granite and may be the same age. However, because of geographical separation, there is no justification for assigning them to the named unit.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPg_1 (their "Ten Mile Creek" microgranite, unit 446) rocks are I-type, unfractionated, oxidised, and medium-potassium (based on two unpublished AGSO analyses).

Un-Named Unit CPg_2 *(Cga, Cgp, Cug_{po}, part Cug_{mg} of Oversby et al. 1991)*

This unit is made up of various, commonly "aplitic", microgranitoids and (predominantly) fine-grained granitoids. A unifying feature of the grouping is the broadly subvolcanic aspect of the rocks involved; they occur in large dyke-like bodies and various-sized stocks that cut or are otherwise spatial intimates of the Bulgonunna Volcanic Group. One of the main rock types included is pinkish-buff to grey massive microgranite to very fine granite that contains moderately abundant, evenly distributed, large quartz, feldspar and biotite phenocrysts in variable relative proportions. The other main rock type is broadly similar in colour, but finer-grained ($\leq$1 mm); it may be either equigranular or contain a small percentage of quartz, feldspar, and/or biotite phenocrysts. Miarolitic cavities lined with quartz, K-feldspar and muscovite, and irregular patches of quartz-feldspar pegmatite, are moderately common.

In the northwest, rock assigned to CPg_2 is pink to red, sparsely porphyritic with small phenocrysts, fine-grained to "aplitic", biotite granite. This granite makes up an irregularly-shaped pluton that crops out along the Burdekin River, 13 km northwest of Burdekin Falls Dam. The rock has intruded Bulgonunna Volcanic Group rocks (Collins Creek Rhyolite, Cub_{21}, Cub_{27}).

A small (1.5 km x up to 1 km) irregular dyke-like (northern part) to stock-like (south) pluton of CPg_2 occurs in the northwest, 16.5 km northeast of the Dam. It contains abundantly porphyritic, medium-coarse-grained, biotite microgranite, with large phenocrysts, cutting Collins Creek Rhyolite. The rock is marginally flow-banded.

Another small (3.3 km x up to 0.5 km) northwestern, inflated-dyke-like (north) to stock-like (south) body of biotite microgranite occurs on the eastern side of lower Packhorse Creek. This has intruded Stones Creek Volcanics and Collins Creek Rhyolite. The rock is pale grey to pink or orange, moderately to abundantly porphyritic, and medium-fine- to medium-grained; it grades northwards into a porphyritic rhyolite marginal(?) variant. In places, the microgranite is brecciated, and intensely "gossanous" (limonite-flooded).

Irregular, but generally north-elongated and commonly interconnecting, bodies of CPg_2 extend from middle Charlie Creek (northeast) to middle Gap Greek (north-centre) and the vicinity of "Old Hidden Valley" homestead (centre). To the south of "Glendon" homestead (northeast) a contact between CPg_2 porphyritic microgranite and medium to coarse granitoid (CPg_{10} - below) is exposed in an eastern tributary of the main creek 7.6 km due south of the homestead. The contact zone shows structural and magmatic interleaving/banding which suggest that a mafic dyke, and then CPg_{10} granitoid, were emplaced before porphyritic CPg_2 microgranite. This microgranite makes up a roughly north-striking dyke, nearly 5 km long and up to 400 m wide, separating CPg_{10} (east) from CPg_8 (west).

Pink aphyric microgranite of CPg_2 type is intimately mixed with (dominant) granite included in unit CPg_{10} between middle Gap Creek and middle Collins Creek, approximately 8 km southeast of "Glendon" homestead. In this case, age relationships between the two rock types are unclear.

In the southeastern part of the study area, a series of dyke-like bodies amalgamating locally into stocks around Ten Mile Creek have been assigned to CPg_2. A granitic body that cuts Earlscliffe Dacite in the Perch Creek area has also been included in the unit. The more mafic parts of these geometrically variable intrusions are tonalitic, commonly porphyritic in plagioclase and hornblende, and less commonly quartz. Primary hornblende in these rocks distinguishes them from ones in other southern granodioritic units, which contain amphibole pseudomorphs of original pyroxene.

Enclaves of dark bluish-grey, fine to medium equigranular, locally biotite- and/or hornblende-bearing, microgranitoid of CPg_2 type are common in local concentrations within texturally different hosts in the northeast. These enclaves are of irregular to rounded form, and up to 2 m in maximum dimension. Concentrations of microgranitoid enclaves within CPg_2 itself are exposed in: a western tributary of upper Glenella Creek, 7 km east-northeast of Peak John Well (grid reference 8356-456060), where the host is a microgranite with sparse quartz phenocrysts; upper Gap Creek, 8 km southeast of "Glendon" homestead (grid reference 8356-284102), where the host is a pink biotite microgranite and some enclaves contain acicular hornblende crystals; and an eastern tributary of upper Sandalwood Creek, 5.7 km south-southeast of the Desmond Creek junction (grid reference 8356-411258), where the host is a pale pink microgranite.

Enclaves of CPg_2-type microgranitoid in CPg_{10} granitoids about 7 km south-southwest and about 5 km south-southeast of "Glendon" homestead have fine-grained (chilled?) margins.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPg_2 (their "Heidelberg complex", unit 228) rocks are probably I-types and unfractionated; however, lack of analyses at the time of GIS compilation inhibited further characterisation. Two unpublished AGSO analyses which have subsequently become available confirm that the rocks are I-types and unfractionated, and also reduced and low-potassium; they form a discrete group of low-potassium, high-Na_2O (greater than 4%) granitoids, along with Easter Granodiorite (below). CPg_2 granodiorite is high in Al_2O_3, P_2O_5, and Sr, and low in MgO, K_2O, Rb, Th, Ni, and Cr compared to other southern granodiorites.

Un-Named Unit CPg_3 (*Cug_1 of Oversby et al. 1991*)

Unit CPg_3 consists of biotite granite; it is recognised only in the northern part of the map area.

A sample (88302138), probably from the unit, obtained at grid reference 8357-246432, 3 km north of the study area, yielded an Rb-Sr biotite plus whole-rock age of 297$\pm$3 Ma (unpublished AMDEL Report G 8037/89), with initial strontium isotope ratio of 0.7078.

In the northwest, CPg_3 is the main component of a body of batholithic dimensions that extends north beyond the study area for many kilometres, and which may include other intrusive units. In the study area, the rock is pink, medium-fine- to coarse-equigranular, and leucocratic in part. It contains sporadic rounded microgranodioritic enclaves, is locally miarolitic, and is cut in places by veins and dykes up to 2 m wide of pink to brown aplite. Unit CPg_3 has intruded and at least locally hornfelsed Stones Creek Volcanics and Bulgonunna Volcanic Group rocks (Collins Creek Rhyolite, Locharwood Rhyolite, Cub_{19}, Cub_{20} and Cub_{21}). Rocks of unit Cub_{21} to the east and southeast of Limey Dam are the most notably hornfelsed.

In the northeast, CPg_3 is very poorly exposed in middle Sandy Creek. The unit is represented by pink, medium-equigranular, felsic granite.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPg_3 (their "Pine Creek" granite, unit 220) rocks, mostly collected to the north of the study area, are I-types, unfractionated, oxidised, and high-potassium (based on four unpublished AGSO analyses). Geochemically, rocks in the unit appear to be virtually indistinguishable from northeastern unit CPg_{10} ones.

<u>Un-Named Unit CPg_4</u> (*Cug_2 of Oversby et al. 1991*)

Unit CPg_4 consists of hornblende-biotite granite. The unit is recognised only in the northeast where it is very poorly exposed on the eastern side of the Burdekin River, opposite the old weir. The rock is pink, and fine- to medium-equigranular.

The GIS compilation of Champion & Heinemann (1993, 1994) suggests that CPg_4 (their "Bull Creek" granite, unit 221) rocks are I-types, and unfractionated; however, lack of analyses preclude further characterisation.

<u>Un-Named Unit CPg_5</u> (*Cug_3 of Oversby et al. 1991*)

This unit is also made up of hornblende-biotite granite. It crops out very poorly only in the northeast between about 1 km and 2 km south-southeast of the old Burdekin River weir. It is speckled mid grey, and fine- to medium-equigranular; hornblende is characteristically acicular.

<u>Un-Named Unit CPg_6</u> (*Cug_4 of Oversby et al. 1991*)

This is another hornblende-bearing biotite granite unit restricted to the northeast; it is very poorly exposed in western tributaries of middle and upper Sandy Creek. The rock is bluish- grey, and medium- to coarse-equigranular.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPg_6 (their "Packhorse Creek" granite, unit 222) rocks are I-types, unfractionated, strongly oxidised, and high-potassium (based on one unpublished AGSO analysis).

Un-Named Unit CPg_7 (*Cug_h, Cug_5, Cug_x of Oversby et al. 1991*)

Unit CPg_7 consists of porphyritic biotite- and/or hornblende-bearing granite.

On the western side of the Burdekin River downstream from the old weir (northwest), rock assigned to unit CPg_7 (Cug_5 of Oversby et al. 1991) is coarse-grained and biotite-bearing; it is moderately porphyritic, with K-feldspar phenocrysts up to 1.5 cm long. The rock occurs to the south of miarolitic CPg_3 biotite granite, and could represent a deeper-level variant of that unit.

In the northeast, occurrences of granite assigned to unit CPg_7 are very poorly exposed between the old Burdekin River weir and middle Sandy Creek, between about 1.5 km and 3 km southeast of the weir, and in lower Sandy Creek. The rocks are pale pink, medium- to coarse-grained; they are biotite-bearing, and contain tabular K-feldspar phenocrysts.

Rocks assigned to this unit also occur in a medium-sized southeastern stock traversed by the middle reaches of Bobby Dazzler Creek, to the northeast of "Conway" homestead. Granite here contains biotite only, although epidote in it may be after hornblende; it has a grain size of approximately 1mm.

The GIS compilation of Champion & Heinemann (1993, 1994) shows that northern CPg_7 (their "Blue St [*sic*] Creek" granite, unit 236) rocks are I-types, unfractionated, oxidised, and medium- to high-potassium (based on two unpublished AGSO analyses). A more recent analysis from the southeastern stock indicates similar characteristics.

Un-Named Unit CPg_8 (*Clg_c of Oversby et al. 1991*)

Characteristically, unit CPg_8 is made up of pink coarse-grained biotite granite identical in hand-specimen to the well-known Elizabeth Creek-type granites of the Mount Surprise - Herberton - Mount Garnet district to the north.

An area of about 14 km^2 between middle Bell Creek and the House and Kitchen hills in the southwest is underlain by poorly exposed granite assigned to this un-named unit. The rock has intruded units assigned to Stones Creek Volcanics in the north. It is cut to the east by younger Easter Granodiorite (Plge - below). To the south, it is in contact with House and Kitchen Granite, but relative ages of the two units are unknown. In the western part of its outcrop area, the CPg_8 biotite granite appears to have been intruded by a body (probably plug-like overall, although with a near-horizontal outer/lower contact with the granite locally) of moderately abundantly quartz-feldspar-phyric rhyolite (CPr_1 - below). This rhyolite is tentatively correlated with the post-Bulgonunna "elvan"-type microgranite ring-dyke around the Pyramid Range area, and this correlation is the justification for the pre-Bulgonunna ("Locharwood" association) age preferred for this granite.

The un-named biotite granite is pink, coarsely equigranular, and contains about 3% biotite; feldspars have invariably been "kaolinised" to some degree. Aplite veins and sills occur locally. It is conceivable that the pre-Bulgonunna "aplitic" House and Kitchen Granite is merely a late-stage "roof" phase of this biotite granite.

Between the "Glendon" homestead access road and the middle to upper reaches of the creek which flows past the homestead, 5 km to 11 km south-southwest of the homestead, CPg_8 granite is pale pink, felsic, and very coarse-equigranular to porphyritic.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPg_8 (their, "Bell Creek" granite, unit 229) rocks are I-types, unfractionated, oxidised, and high-potassium (based on one unpublished AGSO analysis).

<u>Un-Named Unit CPg_9</u> (*CPg of Oversby et al. 1991*)

Unit CPg_9 is restricted to a single broadly arcuate (convex to north), approximately west-trending, stock 5 km long and up to 1 km wide in the northwestern part of the study area. The stock is exposed on the northern side of Lake Dalrymple between 2km north-northeast and slightly more than 4km west-northwest of the northern abutment of Burdekin Falls Dam. It is made up of moderately porphyritic fine biotite granite which cuts probable Star of Hope Formation volcanic rocks. The granite is in faulted contact with "Smedley" association (Bulgonunna Volcanic Group) unit Cub_{27}.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPg_9 (their "Coopers Creek" granite, unit 246) rocks are probably I-types, and less probably unfractionated (no analyses available).

<u>Un-Named Unit CPg_{10}</u> (*Cug, part Clg of Oversby et al. 1991*)

This is an undivided grouping of diverse granitoids (biotite-, biotite plus hornblende-, and hornblende-bearing granites; hornblende granodiorites) which either cannot be otherwise assigned, or which occur in parts of the study area (particularly the east) where it has not been possible for us to map the various rock types because of insufficient observations and non-distinctive airphoto signatures.

Granodiorite (sample 88302208) included in grouping CPg_{10} has yielded an Rb-Sr (whole-rock plus biotite) age of 293 ± 3 Ma with initial strontium isotope ration of 0.7052 (unpublished AMDEL Report G 8037/89) from a site 1.2 km north of "Glendon" homestead (grid reference 8356-235171).

The most extensive (about 650 km^2) single concentration of granitoids included in this grouping extends from beyond the northeasternmost corner of the Burdekin Falls Dam - "Conway" area to middle Glenella and upper Smoko Creeks, in the central-east. Observations illustrative of the composite and locally very variable nature of the unit include: in upper Sandalwood Creek and along Brawl Creek - pale and mid pink, medium- to coarse- equigranular, biotite granite; middle and lower Glenella Creek, east of the Collinsville road - pale pinkish-grey, quartz-feldspar-phyric microgranite with biotite and subsidiary hornblende; Glenmore Creek, upstream (southwest) of Goldbeetle Creek junction - bluish-grey, medium-equigranular biotite-hornblende quartz monzonite and pink, coarsely quartz-feldspar-phyric microgranite; middle and lower Smoko Creek and middle Oakey Creek, south and southeast respectively of "Heidelberg" homestead - pinkish-grey, coarse, feldspar-phyric biotite granitoid, plus pink, medium-equigranular granitoid with conspicuous acicular hornblende, and pink, fine- to medium-equigranular hornblende-biotite granitoid with locally (e.g. 6.5 km southeast of "Heidelberg") abundant microgranitoid enclaves.

The predominant rock assigned to "unit " CPg_{10} in the northeastern part of the study area is biotite granite. However, rocks which appear to be compositionally distinct, and to make up discrete plutons (although their boundaries cannot be delineated from available ground information or airphoto interpretation) occur in two areas. In the vicinity of Brawl Creek, CPg_{10}-type granite is more sodic than average; this occurrence may alternatively be a representative of composite unit CPg_2, although hornblende is absent from it. Around Goldbeetle Creek the rocks are more mafic and richer in hornblende than average; they resemble ones at and adjacent to "Glendon" homestead.

A dyke-like body extending west-southwest for 7 km from the main eastern CPg_{10} stock crosses middle Sandalwood Creek 4.5 km south of the Desmond Creek junction. The western 2 km of this body contains a mixture of CPr_1- and (dominant) CPr_2-type microgranitoids (the whole body shown as the latter on the map), with granite enclaves; these different rocks may all represent marginal mineralogical and textural variants of the local CPg_{10}.

Farther west, in the north-centre 8 km south of "Glendon" homestead, poorly exposed pale pink and buff, medium- to coarse-equigranular, quartz-rich granitoid assigned to CPg_{10} includes hornblende-biotite granite. Several phases are present, partly separated by gabbroic (i.e. CPm-type - below) material. The mafic phase in the vicinity of "Glendon" is a granodiorite with mostly equant hornblende, and colour index of 20. The more felsic phase lies west of the CPm-type material, and is distinguished by needle-like hornblendes. Hornblende-bearing rocks included in unit CPg_{10} contain mostly primary grains of that mineral, with only rare actinolite cores after pyroxene. The rocks are thus probably derived from more water-rich magmas than pyroxene-bearing Roscow Granite (granodiorite subunit $CPgr_1$), Percy Douglas Granodiorite, and Joe-De-Little Granite (above) in the southern part of the study area. About 8km south of "Glendon" homestead, poorly exposed pale pink and buff, medium- to coarse-equigranular, quartz-rich granitoid assigned to CPg_{10} is cut by a local swarm of rhyolite and microgranite (CPr_3) dykes. The western contact of this granitoid with a porphyritic microgranite (CPg_2) making up a wide, south-trending dyke, shows large-scale compositional and textural banding. This banding (or perhaps more correctly, structural-magmatic interleaving) evidently involves a sheared mafic dyke and porphyritic marginal phases of the granitoid. It is excellently exposed at grid reference 8356-234083, in a side creek 7.6 km due south of "Glendon". At and around "Glendon" itself, unit CPg_{10} is represented by bluish-grey, medium-equigranular mafic biotite-hornblende granodiorite; this is the rock which has been isotopically dated (above).

In the north-central CPg_{10} outcrop area, between Gap Creek and Collins Creek, about 8 km southeast of "Glendon" homestead, equigranular granitoid and microgranite (CPg_2-type - above) are intimately mixed. In a western tributary of Collins Creek, 5 km south-southeast of "Glendon", as well as about 7 km south-southwest of the homestead, margins of CPg_2-type microgranitoid enclaves appear to have been chilled against their CPg_{10} granitoid host. About 6 km southwest of "Glendon", CPg_{10} granitoid is intimately mixed with diorite (CPm - below). At this locality two different phases of CPg_{10} are separated by CPm-type material, implying that (here at least) unit CPm rocks are older than unit CPg_{10} ones. Other notable concentrations of (predominantly microgranitoid) enclaves in the north-central CPg_{10} outcrop area have been noted at: upper Gap Creek (grid references 8356-290096, 8356-293100), where the host is weathered buff microgranitoid to granitoid; weir on upper Gap Creek (grid reference 8356-285096), where the host is felsic equigranular microgranitoid to coarse granitoid, and enclaves are up to 2 m across; upper Collins Creek (grid reference 8356-261087), where the host is pinkish-grey, fine- to medium- equigranular biotite granitoid, and enclaves contain hornblende needles and appear to have chilled margins; and east of the creek south of "Glendon" (grid reference 8356-239086), where the host is a pink equigranular felsic granitoid.

At grid reference 8356-243193, in Glendon Creek 0.5 km north of its junction with Gap Creek (northeastern study area), pink porphyritic CPg_{10} granite contains a northwest-elongated megablock of flow-banded CPr_3 rhyolite. The megablock is about 20 m wide and at least 80 m long; it is surrounded by smaller rhyolite xenoliths. Other xenolith-rich occurrences of CPg_{10} granitoids are known from Glendon Creek, for several hundred metres downstream (north) from its junction with Gap Creek. There, a pink, medium-equigrained to sparsely porphyritic, granitoid host contains xenoliths of: schistose and dark grey metasedimentary "basement" (possible Anakie Metamorphics - above); dark blue feldspar-phyric lava (probable Stones Creek Volcanics); dark bluish-grey welded ignimbrite (probable "Earlscliffe" and/or "Smedley" association Bulgonunna Volcanic Group); grey volcanic breccia (probably either Stones Creek Volcanics or a volcaniclastic rock [sCub] from the "Smedley" association - above), and; pink flow-banded rhyolite (CPr_3). Individual xenoliths range from one or a few centimetres to several tens of metres in maximum dimension; they show no indication of sorting, and no preferred alignments are evident. The granitoid hosting these xenoliths has intruded a pale grey, medium- to coarse-equigranular, granitoid (which is also included in grouping CPg_{10}); the chilled margin of the former, which truncates a microgranitoid enclave in the latter, can be seen in Glendon Creek. It may be significant that this occurrence of notably xenolith-rich CPg_{10} is adjacent to clast-rich ignimbrites and coarse to very coarse volcaniclastic material in the "Smedley" association of the Bulgonunna Volcanic Group.

In the northwest rocks included in unit CPg_{10} crop out as three small stocks. The rocks are variably porphyritic, very fine- to fine- equigrained ("aplitic"), biotite granitoids. One stock crops out beside the main sealed road, 16.5 km northwest of Burdekin Falls Dam. A second stock occurs on the western side of Lake Dalrymple, 16.5 km west of the Dam, and the third occupies the lower northeastern slopes of Mount McConnell. This third stock may be broadly related genetically to nearby (tentative) lower Arundel Rhyolite and unit CPr_1.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that rocks included here in unit Cpg_{10} (their "felsic Strathalbyn batholith", unit 224, and "Perch Creek" granodiorite, unit 226) are I-types, undifferentiated, oxidised, and medium- (unit 226) to high-potassium (unit 224) (based on fifteen unit 224 and one unit 226 unpublished AGSO analyses).

Un-Named Unit CPr_1 *(part Cut, Cur, Cb_{rh}, mg_1, rh_1, po of Oversby et al. 1991)*

Composite unit CPr_1 is a grouping of predominantly high-level (subvolcanic) intrusive rhyolites and microgranites in small to medium-sized dykes, plugs and stocks; many of the rock types are broadly similar to those in other units, such as CPg_2 (above). The local presence of undifferentiable extrusive representatives is strongly suspected. The rocks contain 5% to 20% quartz and feldspar phenocrysts, in the case of "elvan"-type microgranites up to 1 cm or more in maximum dimension. Microgranites also contain up to 5% biotite and/or hornblende.

Like CPg_2 (above), these rocks are commonly spatially associated with Bulgonunna Volcanic Group remnants. However, neither precise ages, nor relationships to specific parts of the Bulgonunna Volcanic Group's stratigraphy, can be inferred for the majority of occurrences. It is likely that the grouping incorporates material emplaced recurrently throughout late Palaeozoic time. In addition, an unknown number of occurrences is likely to have been introduced during each of the magmatic episodes that produced earlier Mount Windsor Volcanics, Stones Creek and Bimurra Volcanics, and Star of Hope Formation volcanics, as well as later Mount Wickham Rhyolite and Lizzie Creek Volcanics.

The most noteworthy occurrence of CPr_1 rocks in the study area is as a discontinuous ovoid ring-dyke structure made up of "elvan"-type microgranite in the southwest; this is discussed further under "Structure and Tectonics" (below).

A large number of small- to medium-sized bodies of CPr_1 occur in the northwest; a few of these are of ambiguous or indeterminate geometries and origin/s. By far the most common rock type is variably flow-banded or -laminated rhyolite which contains up to 10% equant phenocrysts of quartz, K-feldspar (sanidine and/or orthoclase) and plagioclase (oligoclase?). Phenocrysts are generally about 1 mm to 2 mm across, but larger ones (3 mm to 4 mm, and very rarely up to 1 cm) are present locally. Spherulites and amygdales, most of the latter being "drusy" (partly filled with crystalline quartz) are common in places, mainly in the narrower dykes and upper(?) parts of some probably extrusive components of the unit, e.g. in the vicinity of Limey Dam, and to the southwest of the Breccia Hill Prospect (no 2 on the map).

In the area of middle Glenroy Creek and Stuart Pocket, CPr_1 rhyolite mainly occurs as dykes; these locally swell out into, or radiate away from, plug-like (as currently exposed) bodies (Cur of Oversby et al. 1991). Around Limey Dam, rhyolite comprises two plugs (to the southwest and south-southwest) plus possible lava of less than 1 km^2 outcrop area.

Autobreccia and polymictic rhyolite breccia is common on the flanks, and in some cases the "tops" (i.e. at the upper limits of exposure) of some plug-like bodies (e.g. 7 km northeast of "Glenroy" outstation, east of Glenroy Creek; 2.5 km south-southeast of "Glenroy", to the south of Stones Creek; the relatively large [5 km x 2 km] body making up much of "Breccia Hill", between Stones Creek and Glenroy Creek to the north of "Glenroy"; and a much smaller [1 km x 400 m] body close by to the east). The mode of association of these breccias with the plug-like bodies suggests that they are carapace breccias, and that the "plugs" probably breached their roofs and extruded, at least in part, to form surficial exodomes (i.e. lava mounds growing mainly by addition of external flows). The presence of a nonwelded rhyolitic ignimbrite component in and adjacent to some plug-like bodies (northern flank of the one 2.5 km south-southeast of "Glenroy", intercalated with rhyolite breccia and possible lava; western margin of one of a coalesced group traversed by Stones Creek, 7.5 km east of "Glenroy") further supports the suggestion that at least some "plugs" extruded as true palaeotopographic domes. Similarly, rhyolite on the northern side of Stones Creek, part of one of the coalesced bodies traversed by the creek to the east of "Glenroy" (above), locally displays well-developed stratification suggestive of an extrusive origin.

Autobreccia also characterises probable flows, such as those intercalated with nonwelded lithic clast-rich ignimbrite of Bulgonunna Volcanic Group unit Cub_{21} on the western side of the "Breccia Hill" body. In this instance, a direct relationship to the Bulgonunna Volcanic Group is indicated.

To the southwest of "Breccia Hill", CPr_1 rhyolite occurs as steeply-dipping, concordant and near-concordant (with respect to enclosing stratified rocks) dykes with contiguous sub-horizontal lava flows which are brecciated.

Most of the remaining CPr_1 rhyolite in relatively large bodies in the northwest appears to be intrusive at the present level of exposure; however, the bodies could represent palaeotopographic endodomes (i.e. domes which grew by internal addition of intrusive material).

A 7 km-long west-southwest-striking dyke-like apophyse of CPg_{10} (above) in the northeast crosses middle Sandalwood Creek 4.5 km upstream (south) of the Desmond Creek junction. Among the rocks making up the western 2 km of this body, shown on the map as CPr_2, is a dark pinkish-brown, hornblende-rich, quartz-feldspar-phyric microgranite of CPr_1 type.

A group of three sparsely quartz-feldspar-phyric cream and pink CPr_1-type rhyolite bodies occur in the northeast, approximately 6 km southwest of the junction of Sandalwood and

Desmond Creeks. These bodies appear to have essentially horizontal bases, suggesting that they are either flat-lying intrusions or lavas. They rest, at least locally, with marked angular discordance, on substantially different parts of the local Bulgonunna Volcanic Group sequence ("Locharwood" association unit Cub_{12}, and "Smedley" association unit Cub_{27} with volcaniclastic "sedimentary" [sCub] intercalations). If the bodies do represent remnants of a single lava unit, that unit does not "slot" neatly into the Bulgonunna Volcanic Group's stratigraphy as preserved locally, which implies a relationship to the "Arundel" association preserved more than 20 km to the southwest. However, the three occurrences are all assigned to unit CPr_1 for the sake of simplicity.

In the southeast, dykes of CPr_1 microgranite occur in a southwest-trending swarm nearly 7 km long, approximately 10 km northwest of the junction of Nostone and Ten Mile Creeks.

Rhyolite assigned to unit CPr_1 cropping out on the uppermost slopes of Mount McConnell (central-west) is flow-laminated, and extensively (perhaps entirely) brecciated. The rock could represent a lava flow-foot or -front.

Rocks included in grouping CPr_1 occur at the Breccia Hill (no 2 on the map), Blue Gum (14) and Mount Dalrymple (29) gold prospects. Tentative CPr_1 has also been prospected for gold at Battery Hill (6). The unit is probably represented, although apparently dominated by Bulgonunna Volcanic Group ignimbrite/s of unit Cub_{27}, at the Mount Robin Mine (3) and Prospect (4).

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPr_1 (their "Isabella Creek" rhyolite, unit 227) rocks are I-types, unfractionated, oxidised to strongly oxidised, and medium- to high-potassium (based on eleven unpublished AGSO analyses).

Un-Named Unit CPr_2 *(part Cut, mg_2, rh_2, mgd, da of Oversby et al. 1991)*

These rocks contain 5% to 15% feldspar phenocrysts, up to about 1 cm in maximum dimension in a few instances of "elvan"-type microgranodiorite. Compositionally they are probably rhyolites/microgranites, grading to (subsidiary) dacites/microgranodiorites. Like CPr_1 units, CPr_2 intrusives were probably emplaced recurrently throughout late Palaeozoic time, with local components possibly also being related to one or more of the older and younger volcanic-dominated units present in the study area.

In the southeast, unit CPr_2 consists of pink, buff, or cream, sparsely to moderately porphyritic rhyolite to microgranite. The rocks contain 3% to 10% alkali feldspar, with very minor quartz phenocrysts. Some occurrences are flow-banded, but no autobreccia facies is known. At least some CPr_2 rocks in the southeast may be related to "Earlscliffe" association Bulgonunna Volcanic Group.

The western 2 km of a 7 km-long dyke-like body (mainly a CPg_{10} apophyse) in the northeast that crosses middle Sandalwood Creek 4.5 km south of the Desmond Creek junction is locally very heterogeneous, and accordingly included in CPr_2. The most commonly exposed rock type is dark pinkish-brown, hornblende-rich, quartz-feldspar-phyric microgranite of CPr_1 type. It is accompanied at grid reference 8356-368262 (about 3 km west of Sandalwood Creek) by undulatory bands in which grey and pink hornblende- and feldspar-rich (CPr_2-type) microgranites alternate, and which contain irregular pale-coloured CPg_{10} granite enclaves. In this instance, the microgranitoid components may be marginal variants of the CPg_{10} granitoid.

Rhyolites and microgranodiorite of CPr_2 type are developed extensively in the Mount Coolon and Byerwen 1:100 000 Sheet areas. There, they (and CPr_1 constituents) may represent slightly deeper equivalents of the of leucocratic to mesocratic rhyolites and dacites assigned to unit CPr_3.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPr_2 (their "Willie Moore Creek" rhyolite, unit 239) rocks are probably I-types, and less probably unfractionated; better characterisation is not possible because of lack of analyses.

Un-Named Unit CPr_3 (*mg, rh, rh3, f of Oversby et al. 1991*)

This unit incorporates a miscellany of rhyolites and microgranites not assignable to either of the other units. Most are aphyric to very sparsely porphyritic. However, an uncertain number of occurrences of more abundantly feldspar- and quartz-feldspar-phyric rocks, which should more properly be included in units CPr_1 or CPr_2 but which were not visited, or sufficiently well characterised, during the original field research, are also included. This is particularly so in the southeast, and may be the reason why rocks of CPr_3 type appear to be somewhat more common at the structural level exposed there than elsewhere in the study area, or in the Mount Coolon and Byerwen 1:100 000 Sheet areas farther south. Unit CPr_3 also includes a range of undifferentiated rhyolite dykes. The unit was probably emplaced during late Palaeozoic time. However, like its companion units CPr_1 and CPr_2, it may well include older and/or younger material.

In the northeast, cream or pink, aphyric to sparsely quartz- and/or feldspar-phyric, commonly flow-banded and locally columnar-jointed, rhyolites are common. At many localities they are coincident with, or immediately adjacent to, Bulgonunna Volcanic Group rocks. These rhyolites occur mainly as small, steep and discordant dykes and plugs. The most noteworthy occurrences are in a series of dyke swarms; these swarms are discussed further under "Structure and Tectonics". Confirmation that at least some of these northeastern CPr_3-type rhyolites are older than some of the spatially associated granitoids comes from a spectacular exposure in Glendon Creek (grid reference 8356-243193, 700 m north of the Gap Creek junction). At this locality, pink porphyritic and xenolith-rich granite of unit CPg_{10} is host to a large block of flow-banded CPr_3 rhyolite. The block is elongated from northeast to southwest, and is at least 80 m long by 20 m wide in plan view. Adjacent smaller rhyolite clasts in the granite have apparently been detached from the large block.

One northeastern occurrence of CPr_3 forms a northeast-elongated small stock underlying a prominent 1 km-long ridge west of and overlooking Glendon Creek, approximately 7.5 km southwest of "Glendon" homestead. This rhyolite contains scattered lithic clasts up to a few centimetres across, especially near its eastern margin. The rock has been partly altered, and outcrop surfaces and joint planes are now thickly coated with iron oxides.

Several dyke swarms containing a mixture of rhyolite and microgranite types, collectively included in the CPr_3 grouping, occur in the northeast. One of the most extensive of these swarms is subparallel to, and mainly west of, lower and middle Sandalwood Creek from near the junction of the Burdekin and Bowen Rivers. Another extensive swarm trends west-southwest to southwest from the southern side of the Bowen River opposite Mount Wickham, to at least middle Sandalwood Creek (probable continuations can be detected discontinuously for up to 5 km farther to the southwest). Less well developed, locally irregular, swarms occur in the central-east and southeast.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPr_3 (their "Rosetta Creek" rhyolite, unit 233) are probably I-types, and possibly unfractionated; however, there are no analyses to support these conclusions.

Un-Named Unit CPm (*CPi, Cgm, CPd, Cx, m, do, ad, t, mdi of Oversby et al. 1991*)

This composite grouping incorporates mainly melanocratic, dark green to dark blue, dolerites and gabbros. Included rather arbitrarily within it, for the sake of simplicity, are subsidiary andesites, microdiorites, diorites, quartz diorites, quartz-microdiorites and trachytes, as well as a few melanocratic rocks of unknown composition/s. The rocks are predominantly equigranular types. All components of the unit occur as minor bodies, mostly cutting rocks older than the Bulgonunna Volcanic Group. They occur throughout the Burdekin Falls Dam - "Conway" area, but are most common (and in the largest bodies) in the southwest and southeast.

A wide variety of late Palaeozoic, and possibly other, ages and stratigraphic affiliations could well be present within unit CPm (cf. also discussions of units CPr_1, CPr_2, and CPr_3 above). The dated (Late Carboniferous) dacitic andesite from 11km north of "Conway" homestead and 3 km southeast of the junction of the Sellheim River and Isabella Creek (sample 89302132) could be a representative of the unit. However, its lava-like nature in thin-section, and a U-Pb (zircon) age identical to the one from Smedley Dacite (Black 1994; Appendix 2), suggest that it is probably an outlier of the Bulgonunna Volcanic Group's "Smedley" association (above).

Small (mostly 1 km^2 or less outcrop area) bodies of CPm rocks are scattered throughout the northwestern part of the study area. Between about 1 km and 5 km east of Stuart Pocket, near the northern edge of the map, several small bodies of pyroxene-hornblende gabbro cut Mount Windsor Volcanics. One of these occurrences is associated with aphyric augite basalt (also CPm). Bodies of similar gabbro cut the Stones Creek Volcanics about 2 km south of Stuart Pocket. To the northwest, in the tract of country traversed by the main sealed road, is a larger body of (tentative) CPm pyroxene-hornblende gabbro to diorite. In places (generally close to margins), gabbro in this body contains biotite; the pyroxene is usually too altered to be identified, although augite is preserved in some samples.

Very altered (to chlorite), aphanitic and aphyric to sparsely plagioclase-phyric, hornblende(?)-augite andesite occurs in the north. The mode of occurrence is as sporadic dykes up to 10 m wide. Occasional dykes of dacite and dolerite also occur.

In the north-central part of the study area, subparallel, north-striking, mafic (dolerite in at least some instances) dykes occur at "Glendon" homestead, 1 km to the east of the homestead, and another 5 km farther east. Aligned dykes extend along strike for up to almost 6 km. The easternmost occurrence is distinctive in probably containing one, or several, roughly east-striking mafic dyke/s crossing the meridional ones.

In the central-west, lens-like bodies of two-pyroxene diorite to gabbro cut Star of Hope Formation sedimentary rocks at and 500 m north of the northern edge of the main outcrop area of Arundel Rhyolite, 4 km southwest of Burdekin Falls Dam.

Bluish-grey fine to medium equigranular diorite assigned to unit CPm in a small stock on the western side of the main access road to "Glendon" homestead, about 6 km southwest of the homestead, in the northeast, is intimately mixed with granitoid (CPg_{10}) in a zone along and east of the road.

In the southwest a group of dolerite and gabbro bodies cut the Saint Anns and Scartwater Formations north of the ring-dyke of coarsely porphyritic "elvan"-type microgranite (CPr_1) which surrounds the Pyramid Range area, although none is part of the ring-dyke structure proper. Elongate bodies have the same west-southwest strike as the host stratigraphy (subparallel to the long axis of the ring-dyke), and at least one is unusual (unique?) in the study area in that it is probably sill-like.

A dark grey and pink flow-banded dacite crops out in the Sellheim River about 4 km upstream (south-southwest) of its junction with Isabella Creek (2.5 km southeast of the summit of Mount Landsborough), in the southeast. It makes up the eastern three-quarters of a body, the remainder of which is occupied by gabbro 2 km south of Mount Landsborough summit. The gabbro contains phenocrysts of calcic plagioclase and rounded clinopyroxene in a groundmass of plagioclase, actinolite, biotite and opaque minerals; it has the composition of tholeiitic basalt, with high Al_2O_3 and moderate MgO. The gabbro is probably intrusive; it appears to be nonconformably overlain by the Bulgonunna Volcanic Group's ("Earlscliffe" association) Mount Landsborough sequence. The dacitic part of the body is less certainly intrusive; its margins also appear to be concordant relative to the suprajacent "Earlscliffe" association rocks. This suggests a number of possibilities for the origin of the dacite (intrusive in sill-like body, Bimurra Volcanics lava, or lowermost "Earlscliffe" association lava), of which the simplest is that it makes up an intrusive sill-like apophyse from a gabbro plug. Sporadic minor occurrences of equigranular and porphyritic andesites and diorites also occur in the lower part of the "Earlscliffe" association sequence on Mount Landsborough. These are interpreted as intrusions broadly affiliated with the dacite/gabbro body described above.

Analysed CPm rocks range from moderately primitive magnesium-rich, uralite- and two-pyroxene-bearing, gabbros (Isabella Creek vicinity), through uralite- and two-pyroxene-bearing diorites, to quartz diorites and quartz monzonites. Titaniferous magnetite gabbros occur in a cumulate gabbro sequence to the east of Mount Marion, and at Oaky Creek. A plagioclase-rich (anorthositic) gabbro occurs at Ten Mile Creek. The GIS compilation of Champion & Heinemann (1993, 1994) indicates that CPm (their "mafic Strathalbyn batholith", unit 223) rocks are mafics, unfractionated, reduced to oxidised, and low- to high-potassium (based on seventeen unpublished AGSO analyses). With the possible exception of the high-magnesium, low-potassium gabbro at Isabella Creek, CPm gabbros and diorites appear to extend the range of late Palaeozoic granodiorites and quartz monzodiorites to even more mafic compositions. Many of the CPm rocks could be mafic cumulates derived from fundamentally granodioritic magmas. They would thus be better classified as calc-alkaline than as tholeiitic gabbros, despite the fact that some iron enrichment has taken place in titaniferous varieties.

Intrusive Breccia and Tuff, CPx (*agg of Oversby et al. 1991*)

Intrusive pyroclastic material occurs in a 7 km-long, steep dyke which strikes northwest in and beside middle Collins Creek (central Burdekin Falls Dam - "Conway" area). Similar rocks also occur in a probable extension of the main body, about 1 km farther to the southeast.

The pyroclastic material in these bodies consists of: diffusely layered, crystal-rich (with quartz more abundant than feldspar) and locally "pebbly", coarse (sand) tuff (or, accepting an intrusive origin, tuffisite); and massive, poorly sorted, matrix (tuff)-supported lithic breccia (commonly with rounded clasts). Breccia clasts are mostly coarse crystal-rich (subequal quartz and feldspar) rhyolitic ignimbrite; some of these clasts are 1 m in maximum dimension. No pumice, clasts, or matrix shards have been identified in the tuff. Layering in tuff is vertical, or dips steeply east, subparallel to the walls of the dyke.

It is tempting to equate this intrusive pyroclastic material directly with one or other of the local Bulgonunna Volcanic Group ignimbrites. However, not only do the main dyke-like body and its extension cut Collins Creek Rhyolite and Locharwood Rhyolite respectively, but the main body also cuts younger granitoids (CPg_2 and local CPg_{10}). The fracturing and gas-streaming event/s manifested by the body must thus have been related to the emplacement and degassing of even younger material.

Easter Granodiorite, Plge (*$Cugg_b$ = "Bells Creek granodiorite" of Oversby et al. 1991*)

Easter Granodiorite is named from Easter Pastoral Holding, in the central part of the map area. The unit occupies a single, ellipsoidal (5 km x 8 km, elongated northwest), stock of approximately 25 km^2 exposed in an area of subdued relief to the east of middle Bell

Creek. The type area (Appendix 1) lies on the western side of the Burdekin Falls Dam road, 1.4 km northeast of the "Myall Creek" turnoff. Easter Granodiorite intrudes to the stratigraphic level of at least CPg_8; isotopic dates (Appendix 2) from the type area indicate a latest Carboniferous to earliest Permian age.

Easter Granodiorite is an homogeneous, pale grey, fine- to medium-equigranular (grainsize up to 3 mm), hornblende-biotite granodiorite. Magnetite and sphene, indicative of high $f(O_2)$, are ubiquitous accessory minerals.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Easter Granodiorite (their unit 230) rocks are I-types, unfractionated, oxidised, and medium-potassium; Na_2O contents are greater then 4% (based on two unpublished AGSO analyses). The rocks are very similar to hornblende-porphyritic granodiorite assigned to unit CPg_2.

Nostone Creek Granodiorite, Plgn *(Clg_n = "Nostone Creek granodiorite" of Oversby et al. 1991)*

Nostone Creek Granodiorite occurs as an irregularly oblong stock in the southeastern part of the study area, between Nostone Creek and Parrot Creek. The dominant rock type making up Nostone Creek Granodiorite is a mid, slightly pinkish, grey hornblende-biotite granodiorite grading to quartz monzodiorite. Average grain size is approximately 2 mm; colour index is typically 20 to 25. The rock is similar to other granodiorites in the southern part of the study area in that most of the hornblende is secondary after pyroxene, although many of the uralitised pyroxenes are rimmed by greenish-brown primary hornblende. More felsic variants of the unit are also present, particularly in the northern part of the pluton.

Nostone Creek Granodiorite cuts Earlscliffe Dacite ($Cube_3$), and in its turn is cut by sodic hornblende-porphyritic granodiorite and tonalite included in unit CPg_2. A U-Pb isotopic age from type Nostone Creek Granodiorite (Appendix 2) is slightly more suggestive of an earliest Permian age than of a latest Carboniferous one. The moderately straight map contact between the unit and Earlscliffe Dacite along the southern margin of the granodiorite body seems most likely to be a fault. However, clear field evidence for the presence of a fault is absent, despite reasonable exposures at the contact. It may be that the fault is a subtle (diffuse?) ductile structure, initiated and maintained as part of the pluton-ascent process, and affecting in part hot plus incompletely crystallised magma.

The GIS compilation of Champion & Heinemann (1993, 1994) indicates that Nostone Creek Granodiorite (their unit 237) rocks are I-types, unfractionated, oxidised, and high-potassium (based on four unpublished AGSO analyses). Geochemical data from Nostone Creek Granodiorite, along with data from other southern granodiorites, conform to trends on Harker Diagrams. The unit is probably younger than apparently (geochemically) related Joe-De-Little Granite (above). Temporally, Nostone Creek and Easter Granodiorites appear to be comparable; However, the latter is one of a suite of more sodic granodiorite types which includes components of CPg_2 demonstrably younger than (because they cut) the former. Thus, current geochronological techniques appear not sufficiently sensitive to resolve temporal differences between at least some distinct late Palaeozoic intrusive geochemical suites (assuming that they were emplaced in separately timed pulses, rather than recurrently).

Part of Mount Wickham Rhyolite, part Pw (*part PRr, part rh of Oversby et al. 1991*)

Part of the Mount Wickham Rhyolite at Mount Wickham (northeast), and farther south (central-east), is intrusive. This intrusive component is intimately mixed with, and not easily differentiated from, lava flows. The stratigraphic context of the Mount Wickham Rhyolite has been discussed above under “Bowen Basin”; structural aspects are considered below under "Millaroo Fault Zone".

STRUCTURE AND TECTONICS

Introduction

Previously, most tectonic scenarios have treated the mid- to late Palaeozoic evolution of northeastern Queensland, commonly rather cursorilly or only by implication, essentially as a peripheral part of the New England and Yarrol tracts. In these scenarios, "conventional" plate convergence and (westward) subduction, with or without terrane accretion, have been invoked, even for the late Palaeozoic ignimbrite-dominated and cauldron-associated style of volcanism characteristic of northeastern Queensland. Perhaps the most useful analyses were presented by Harrington & Korsch (1985), Murray et al. (1987), and Coney et al. (1990). Oversby (1988) departed from "conventional" wisdom when he interpreted northeastern Queensland's late Palaeozoic magmatism in terms of the membrane tectonics concept of Oxburgh & Turcotte (1974). Magmatism was extensional; extension, or at least tensional instability, was an inescapable geometrical consequence of the rapid drift of Gondwanaland towards and over the rotational South Pole. More recently, Allen (1994) has tied the Bulgonunna Volcanic Group plus associated late Palaeozoic intrusive rocks, and the plutonic Urannah Batholith east of the northern Bowen Basin, together as rifted parts of a single magmatic arc. This Urannah arc excluded Lizzie Creek Volcanics (and Carmila Beds) magmatism; rather, these were linked to early Bowen Basin rifting. Similarly, Stones Creek etc.Volcanics were seen as parts of a spatially coincidental continental (island ?) arc substrate, rather than properly being part of the Urannah arc. In a wider context, an impressive supra-regional synthesis in which late Palaeozoic Australia is explicitly considered as part of Pangaea (coalesced Gondwanaland and Laurussia) has been presented by Veevers et al. (1994). In this, a scenario was developed in which plate collision at 320 Ma was followed by uplift of the Pangaean platform. The first release of self-induced Pangaean heat took place at approximately 300 Ma; this heat weakened a newly cratonised and inherently sensitive eastern Australian fold belt, encouraging the belt to become a stress localiser and guide. Superimposed magmatism was related to anticlockwise rotation of the supercontinent, with development of deep transtensional fractures through the subjacent fold belt crust. Somewhat later, at about 290 Ma, the Pangaean platform subsided in basins through thermal weakening of its crust. Basins were maintained and grew in response to transtension, and subsequently (mid-Permian) to thermal sagging and rifting.

Drummond Basin Structures

Drummond Basin rocks (including Stones Creek Volcanics) throughout the southwest have been folded and probably extensively faulted. Folds are large-scale, upright, moderately open, northeast-trending and conspicuous. Faults are typically less obvious. However, airphoto interpretation suggests that many of the boundaries between major units, mapped as stratigraphic contacts by previous workers (e.g. Olgers 1972), are bedding-parallel to only slightly discordant faults. If this is the case, the currently accepted stratigraphic framework in the northern Drummond Basin, and palaeogeographic-palaeo-tectonic conclusions arising therefrom, may be open to significant reinterpretation.

The present contact between the northern Drummond Basin and the Lolworth-Ravenswood Block in the study area is a structural (faulted) one in part, but mainly a substantial stratigraphic unconformity. However, there is no clear indication from Drummond Basin rocks that they are close to an original depositional "feather edge". The localisation of Star of Hope Formation volcanics near the contact suggests the presence of a series of magma conduits, in Early Carboniferous time.

We have been unable to identify any specifically volcanic-related cauldrons or other structures associated with any of the volcanic-dominated Drummond Basin units in the Burdekin Falls Dam - "Conway" area.

The sub-Bulgonunna distribution of Stones Creek and Bimurra Volcanics, and Star of Hope Formation volcanics, in the study area can be inferred approximately from the trends of associated Drummond Basin units. Specifically, there is probably a concealed connection between these units around the closure of a southwest-plunging anticlinorium at Bell Creek.

We now disagree with the conclusions of a few authors (e.g. Henderson 1980, Oversby et al. 1980 by implication) that Upper Devonian and Lower Carboniferous volcanic components of the Drummond Basin sequence (Bimurra Volcanics, Stones Creek Volcanics, and Star of Hope Formation in the Burdekin Falls Dam - "Conway" area) are representatives of the Coastal Ranges Igneous Province. This is because of the apparent hiatus (probably about 50 Ma) in significant activity between Star of Hope Formation volcanism in the Early Carboniferous and the Late Carboniferous to Early Permian Bulgonunna Volcanic Group and voluminous intrusives.

Bulgonunna Volcanic Group Structures

Throughout the study area, most direct Bulgonunna Volcanic Group dip determinations have been made on eutaxitic foliations in welded ignimbrites, as defined by fiamme; there are very few from well-stratified rocks. To this extent they may not be entirely reliable. However, many are associated with mapped traces of stratigraphic contacts, which help to confirm (or deny, in some cases) their general relationship to sedimentary bedding.

The loci of Bulgonunna volcanics extrusion and accumulation evidently young northwestwards in the map area, from "Earlscliffe" association (southeast), through "Locharwood" association (centre), to "Smedley" and "Arundel" associations (northeast and central-west). This contrasts with the Mount Coolon area, where the progression from Bobby Dazzler Rhyolite ("Earlscliffe" association) to areally dominant Locharwood Rhyolite takes place from north to south. In the northeast there is a marked variation from south to north towards increasing structural, as well as stratigraphic, complexity. No folds are recognisable; deformation has been by brittle block-faulting with concomitant rotation about variably inclined axes.

The disappearance of Bulgonunna Volcanic Group rocks, including entire sequences, over short distances (e.g. especially close to the Burdekin River in the northwest and northeast) may reflect the presence of subjacent palaeotopographic highs (structural horsts?).

"Earlscliffe" Association

The "Earlscliffe" association volcanics in the Mount Landsborough area and east to the Sellheim River have a locally broadly warped but otherwise uncertain geometry. However, the lower part of the sequence consists of thick rhyolitic ignimbrites, with lavas and/or intrusive rocks not seen farther east, suggesting significant downward movement during accumulation. Again, evidence for palaeotopography is lacking. The structure of the southeastern "Earlscliffe" association may have been that of a "trapdoor" caldera, hinged in the east, with eruptive centre/s and locus of maximum subsidence coinciding at Mount Landsborough. Caldera-collapse deposits at Mount Landsborough may be masked by the apparent lag-fall and ground-lag material. The effect of this structure was to almost completely separate the Mount Landsborough sequence from representatives of the association postulated to occur farther to the northwest (Havilah Hill vicinity).

Structural data from the "Earlscliffe" association sequence east of the Sellheim River, in the southeast are sparse. The few available data suggest that present outcrops represent an essentially single block-faulted and locally tilted ignimbrite sheet of uniform thickness.

"Locharwood" Association

Bulgonunna (almost exclusively "Locharwood" association) rocks in the southwest have the overall geometry of partial shallow basins or tilted sheets. A small, conspicuously north-northeast-elongated, basin is defined mainly by Pyramid Rhyolite in the Pyramid Range; to the east, between hills north of "Ukalunda" homestead and the Sunbeam Mine-upper Percy Douglas Creek area, a marginally oversteepened southeast-tilted sheet is defined mainly by Locharwood Rhyolite; farther east, mainly Locharwood Rhyolite again defines a moderately large, apparently east-northeast-elongated basin. The southwest's Pyramid Range basinal structure noted above occurs within a single concentric fracture-intrusion system. The tilted sheet and second basin are circumscribed locally by, and also contain, similar systems. These structures can be regarded as volcanic-related cauldrons which appear to have had only very mild palaeotopographic expression without collapse scarps. Gravity and magnetic features (Appendix 4) in the vicinity of the circumferential fracture/intrusion system are consistent with a graben-like form for the cauldron at depth, bounded by a southern fault downthrown to the northwest, and two northern faults with downthrows to the southeast.

Elongate bodies of an "elvan"-type CPr_1 microgranite extending from the edge of the House and Kitchen pluton and the vicinity of "Pyramid" homestead for about 10 km southwest to Fairview Hill define half of an east-northeast-elongated ovoid ring-dyke around the Pyramid Range cauldron. The eastern half of this structure is probably represented to the south by the complex system of faults and minor bodies of intrusive rhyolite locally verging on microgranite (CPr_1) between "Pyramid" homestead and the Sunbeam Mine; to the north it is probably represented by the fault zone with intrusive rhyolite to microgranite (CPr_1 again) bodies in the middle reaches of Bell Creek (mainly adjacent/external to the northwestern edge of the older House and Kitchen pluton, but also locally within the pluton), plus (possibly) subparallel contacts of CPg_8 granite. No north-eastern closure is evident, probably because of: failure to propagate coherently through older granitoid bodies; obliteration by younger bodies; and/or loss of identity among other westwards-convex ring-type fracture/intrusion systems east of the Sunbeam Mine.

An "elvan" belonging to an apophyse of the ring-dyke intrudes the stratigraphic contact between epiclastic fluviatile rocks and Pyramid Rhyolite at the southern end of the Pyramid Range. The postulated extension of the system between "Pyramid" homestead and the Sunbeam Mine also delimits and has overstepped the tilted sheet containing Locharwood Rhyolite. Quartz-feldspar-phyric rhyolite similar to, although about 8 km north of, the ring-dyke "elvan" intrudes Arundel Rhyolite. These observations indicate that the structure formed at a post-Bulgonunna Volcanic Group magmatic stage, possibly when volcanic rocks continuous with those in the group, but no longer preserved, were being extruded. This age discrepancy between preserved extrusive rocks and major fracture/intrusion systems which seem to be interrelated as parts of cauldron structures is common in northeastern Queensland.

Four zones of curvilinear faults and intrusive contacts occur between about 2 km west of the Sunbeam Mine, in the southwest, and Isabella Creek (central-south), 15 km to the east. Intrusive components of these zones are mostly CPr_1 (including "elvans"), and subsidiary CPg_2. Contacts of some larger granitoid stocks also locally follow the zones (e.g. Percy Douglas Granodiorite about 5 km southeast of Sunbeam Mine). At least some "elvan" bodies, e.g. 3 km northeast of the Sunbeam Mine, probably have flat roofs (incipient bell-jar plutons?). The curvilinear zones are centred on, and decrease in diameter along, an east-northeast-trending axis. The outer three are concave and open to the east; each has undergone some degree of east-side-down faulting. The innermost zone is closed to the east. Contacts between the zones are complex, with unsystematic fault interferences and/or reorientations, so that relative ages cannot be inferred; however, the westernmost zone appears to have displaced the southern arm of the circum-Pyramid Range ring-dyke southwards, suggesting that there is an eastward-younging relationship between at least those two structures. These concentric fracture/intrusion systems may mark the peripheries of nested cauldrons. Rare zones of radial faults and intrusions connect some (up to three locally) curvilinear zones.

In the vicinity of Reginald Peak, a complex but mappable collage of apparent fault slices and blocks of "Earlscliffe" association rocks occurs within the second (counting inwards) curvilinear fault system. Mappable slices and blocks grade down in size to unmappable (at airphoto scale) entities; all may make up a melange of synextrusive collapse megabreccia blocks.

An upper relative age limit for the curvilinear fault systems is provided by microgranite (CPr_1) dykes and elongate stocks emplaced locally into them. The maximum development of such bodies at the present limit of exposure is associated with the inner systems.

In the watershed between Bell and Percy Douglas Creeks, the concentric fracture/intrusion systems described above merge with more linear, overall north-trending, systems. The latter extend into the northeast where they predominate. The third and fourth concentric systems also merge southeastwards with a separate concentric fracture/intrusion system around the possible “Earlscliffe” cauldron between Mount Landsborough and the Sellheim River in the central-south.

Beyond the northeastern end of a composite structural “superblock” made up of “Smedley” association rocks along the Burdekin River and to the southwest of Burdekin Falls Dam it is possible to outline a northeast-trending "corridor" of fault blocks (that preserve the upper units of the local "Locharwood" association sequence at the current level of exposure), flanked to the northwest and southeast by blocks in which the lower parts of the "Locharwood" sequence are exposed. These relationships suggest a diminished northeastern continuation of the "superblock". Contrasts between local "Locharwood" association stratigraphies in individual fault blocks making up the "corridor" suggests that at least some of the faulting there was syn-"Locharwood". Intervals of stratified "sedimentary" rocks are far more common between and within "Locharwood" association ignimbrites here than anywhere else, consistent with the presence of fault-controlled drainage depressions/sediment traps.

The northeast's "Locharwood" association sequence as a whole contains no markedly angular internal discordances, even though not all stratigraphic units occur everywhere. This suggests that unit distributions were influenced by pre-existing palaeotopography features, rather than contemporaneously active structures. In the vicinity of Sandalwood and Desmond Creeks (northeast), local positive pre- to early syn-"Smedley" association palaeotopographic, possibly marking the edge of a "Locharwood" collapse structure, is inferrred from a fault block containing Smedley Dacite directly overlying Stones Creek Volcanics, without intervening older Bulgonunna Volcanic group rocks in and west of Sandalwood Creek. "Earlscliffe" (tentative) and "Locharwood" association representatives occur immediately to the north.

Similarly, “Locharwood” association rocks are totally unknown below Smedley Dacite (or suprajacent Arundel Rhyolite) to the southwest of Burdekin Falls Dam.

In the vicinity of Peak John Well, southeasterly dips of between 25° and 45° occur in “Locharwood” association rocks (mostly Locharwood Rhyolite). The association is delimited by (i.e. on the downthrown side of) a high-angle (at the present level of exposure) northeast-striking fault zone approximately 2 km from the Well. These relationships suggest that the “Locharwood” association rocks have been “reverse-dragged” towards a fault zone which is listric and northwest-dipping at depth.

"Smedley" Association

Much of the course of the Burdekin River between Burdekin Falls and the old weir appears to follow alternating northeast- and northwest-striking fault segments. The thickness distribution of rocks belonging to the association indicates that the fault zone had overall negative palaeotopographic expression during their extrusion. Further, the association's sequence shows every indication of having vented and accumulated along at least part of this complex Burdekin Gorge Fault Zone; of particular significance is the localisation of very coarse rudites within and adjacent to the zone. The fault zone probably represents, and presumably roughly marks, the palaeotopographic wall of a partial collapse caldera.

The Burdekin Gorge Fault Zone marks the northern end of a large, northeast-elongated, bow-tie-shaped, composite structural block of "Smedley" association ignimbrites that has been down-thrown relative to its surroundings. Within the block, Smedley Dacite adjacent to its northern edge (immediately east of the Dam construction settlement site) has been folded (dragged?) into a gentle, west-southwest-trending, synformal structure. A complementary but southwest-trending anticline or antiform extends across Coopers Creek farther south. The structural block is bounded by faults that are among the most clearly defined ones in the northeast. One of these boundary faults, which extends southwestwards from the Burdekin Gorge Fault Zone, and the fold which crosses Coopers Creek, are overlain unconformably by Arundel Rhyolite. This stratigraphic relationship probably indicates the upper age limit of substantial Burdekin Gorge Fault Zone activity, and of partial "Smedley" caldera collapse.

Caldera collapse cannot be inferred to have taken place farther to the east and southeast. Nor can it be inferred in the northwest where "Locharwood" association rocks are still extensively preserved. These observations imply an elongated feature with fault-scarp- or narrow-graben-like form; it may have been part of an incomplete or asymmetrical ("trapdoor") collapse structure, open to the east/southeast. The known and inferred absence of "Earlscliffe" and "Locharwood" association representatives from directly below the "Smedley" association rocks of Coopers Creek, lower Glendon Creek, and Sandalwood-Desmond Creeks suggests that the partial caldera was a successor to an earlier (pre-unit Cub_{22}) northeast-striking linear zone of uplift and erosion.

"Arundel" Association

The main outcrop area of the Arundel Rhyolite defines a northeast-elongated basin. This basinal structure is not associated with either circumferential or internal concentric fracture-intrusion system/s at the present level of exposure, suggesting that it was not produced by foundering of discrete cauldron block/s. There are no known occurrences of landslide or talus breccias, or manifestations of interior fluviatile/lacustrine reworking. Lack of such features is taken to indicate that the basin never properly developed any substantial palaeotopographic expression. However, upper Arundel Rhyolite is of distinctly intra-caldera aspect, and has evidently been intensely, and extensively, rheomorphosed. We provisionally reconcile these observations by postulating that the main outcrop area of Arundel Rhyolite underwent rapid, but not catastrophic, subsidence contemporaneous with eruption/s of the upper part of the unit. The subsidence proceeded, at the levels now exposed at least, by sagging rather than faulting and block collapse. Infilling by pyroclastic flow/s effectively kept pace with the rate of sagging, so that no palaeotopographic depression could develop (cf. Oversby et al. 1980). The processes involved in cauldron sagging may have been similar to ones inferred at the Kumseongsan caldera, South Korea, but reported on only very briefly to date (Branney, quoted in Day 1993 p. 208). No ring-fault occurs around most of the margin of Kumseongsan; dips of subcaldera rocks increase inwards to near vertical. Collapse-related and -associated processes in the caldera were evidently complex; they may have included foundering of material into a large, open, internal vent. An analogous situation can be visualised as being responsible for extreme rheomorphism of ignimbrite basin fill, cf. upper Arundel Rhyolite.

The Arundel Rhyolite on the eastern side of Coopers Creek is an outlier of the main outcrop area; the base of the Arundel Rhyolite as preserved both in the outlier and along the adjacent eastern edge of the main outcrop area lies at a similar elevation (between about 260 m and 280 m). However, a degree of structural control of the localisation of the outlier is evident from associated west-northwest-striking faults and a minor body of CPr_2 rhyolite.

Tentative upper Arundel Rhyolite containing "fiamme" with variable steep dips is apparently suprajacent to, and is cut by, "flat"-roofed CPr_1, to the south-southwest of "Myall Creek" homestead. The extrusive and intrusive association may mark a local vent structure.

The small outlier of Arundel Rhyolite to the east of the northern end of the main outcrop area could mark the site of another vent. A vent site would be consistent with the presence of intrusive rocks there, although is not supported by an absence of coarse clastic material. "Flat" sectors of intrusive rocks may have been intruded or emplaced into stratigraphically-controlled dislocation surfaces.

Late Palaeozoic Dykes and Dyke Swarms

Throughout most of the northeastern part of the map area, the last magmatic event that can be recognised is the intrusion of dykes. These bodies are typically less than 10 m wide, and the vast majority dip at more than 70°. Their distribution ranges from scattered but laterally persistent single bodies, to distinct swarms.

Six separate dyke swarms have been identified on the basis of geographical location, general strike of constituent bodies, and the dominant rock types involved. They are:

(i) immediately west of Sandalwood Creek and the Bowen River. The swarm is 3 km wide, and extends for 18 km; individual dykes strike north. The swarm cuts at least up to the level of CPg_{10} granitoids. Most individual dykes examined consist of dark pinkish-orange, massive, sparsely feldspar- and biotite-phyric microgranites (CPr_2). This rock type and most other components of the dyke swarm are generalised as CPr_3 on the map; only the (few) main CPm dykes are delineated separately;

(ii) beginning on the southern side of the Bowen River opposite Mount Wickham, a 2 km- to 4 km-wide swarm extends for about 15 km southwest to Sandalwood Creek. Concentrations of dykes in line with the swarm occur locally about 3 km and about 5 km farther to the southwest. Dykes cut up to the level of granitoids included in unit Cpg_{10}. The strike of individual dykes in the main swarm changes from slightly north of northeast (030°) at its northeastern end, to northeast in the southwest. The southwestern end just impinges on swarm (i) in Sandalwood Creek, but no cross-cutting individual bodies were seen. The dykes in this northeast-trending swarm are texturally and mineralogically diverse; felsic types are dominant over more mafic types. Observed rock types are: pink, coarsely quartz-phyric, microgranite (CPr_1); brown, quartz-feldspar-hornblende-phyric microgranite (CPr_1); pink aphyric microgranite (CPr_3); pale pink, flow-banded aphyric rhyolite (CPr_3); orange, finely feldspar-phyric, microgranite (CPr_2); dark grey, fine equigranular diorite (CPm). The dykes are all shown as CPr_3 on the map;

(iii) a swarm of north-northeast-striking CPr_3 and (a few) CPm dykes is exposed on the northern side of Charlie Creek, about 7 km north-northeast of "Glendon" homestead, to the southwest of the intersection of swarms (i) and (ii) above. More nearly north-striking groups of CPm dykes (dolerite in at least some instances) occur slightly farther south 1 km and 6 km east of "Glendon" homestead. Aligned segments of dykes extend along strike for up to 6 km. The most easterly occurrence is probably crossed by a series of roughly east-striking CPm dykes;

(iv) a north-trending belt of more dispersed and somewhat irregularly-striking dykes, with an apparent 3 km x 3 km maximum concentration (swarm) exposed in Charlie Creek and an un-named subparallel creek to the northeast. This belt has the same overall trend as swarm (i); the swarm of dykes within it is 9 km west of (i), and contains different rock types, viz: pale pink, very fine, sparsely feldspar-phyric rhyolite (CPr_2); dark bluish-grey, fine to medium, aphyric and feldspar-phyric, dolerite(?) (CPm). The mafic dykes locally cut rhyolite ones. Dykes in the swarm part of the belt are mostly confined to Bulgonunna Volcanic Group ("Smedley" association) unit Cub_{27}. They do not appear to extend north into post-Bulgonunna granitoids. To the south, at least one dyke in the belt is unusual in being cut by a CPg_{10} granitoid;

(v) a swarm of dykes west of Collins Creek/south of "Glendon" is confined almost entirely to CPg_{10} in an equant 2 km x 2 km area. Strikes of individual dykes are slightly variable; northwest is most common. Observed dykes consist of either cream flow-bended aphyric rhyolite, or pink, massive and aphyric, microgranite (both CPr_3);

(vi) a 1 km- to 2 km-wide swarm extends from the drainage divide between Oaky Creek and Frederick Creek for about 13 km south-southwest to opposite the middle reaches of Ten Mile Creek. Individual dykes strike from slightly north to south of northeast (030° to 060°). Most dykes examined are pale buff to pink, fine, massive or flow-banded, aphyric rhyolite (CPr_3) some are quartz- feldspar-phyric microgranite (CPr_1). Mafic dykes (CPm) occur rarely. The dykes cut CPg_{10} granitoids. Some appear to extend into Lizzie Creek Volcanics, but none are known to cut tentative Mount Wickham Rhyolite.

As a notable occurrence, fragmental rocks assigned to intrusive unit CPx crop out in one major dyke-like body, plus a minor one exposed about 1 km along strike to the southeast of it. The major dyke is vertical to steeply northeast-dipping, strikes northwest, and extends continuously in and beside middle Collins Creek for 7 km; it is mainly less than 100 m wide. It and its southeastern extension cut "Locharwood" association Bulgonunna Volcanic Group (Collins Creek and Locharwood Rhyolites respectively), as well as CPg_2 and CPg_{10} granitoids. The northern part of the main dyke has apparently been shifted sinistrally about 100 m along a northeast-striking fault.

Significance of North Queensland Igneous Province Structural Trends

Southeasterly trends of late Palaeozoic fracture/intrusion systems are conspicuous in the southeastern part of the map area, with northerly trends being of secondary importance. Northwesterly trends are absent here, but are seen in the southwest. In the southeast, only one partial concentric fracture/intrusion system is evident. It is delineated by elongated bodies of "elvan"-type microgranite with CPr_1-type rhyolite plugs and minor dykes, plus probably unrelated feldspar-phyric rhyolite (CPr_3) plugs and minor dykes. Some of the intrusions are connected by faults. The system is evident to the north and east (close to the Sellheim River) of Mount Landsborough. It encloses the main preserved sequence of "Earlscliffe" association Bulgonunna volcanics. Its best-developed, northern, component is a major northwest- to west-northwest-trending "elvan" dyke. The northwestern end of the dyke passes west, across a "corridor" of Ukalunda Beds and granitoids, into the merged southern peripheries of the second and third fracture/intrusion systems developed between the Sunbeam Mine and Isabella Creek. The southeastern end of the "elvan" dyke is aligned with a linear fracture/intrusion system delineated mainly by elongate bodies and dyke swarms of CPg_2, accompanied by irregular to elongate bodies of CPr_3 rhyolites. The linear system continues into the Leichhardt Range, where it degenerates and is superseded by large but scattered and irregular CPr_3 bodies.

The northeasterly and east-northeasterly structural trends displayed by Bulgonunna volcanics and associated rocks in the map area may be unique. Elsewhere, both main and subsidiary mid- to Late Carboniferous trends are known or inferred to be northerly to northwesterly. The more easterly trends were tentatively interpreted in terms of extension-related transfer by Oversby (1987).

According to Henley & Adams (1992), gold mineralisation processes at Bimurra and Wirralie were mainly controlled by a reactivated northeast-striking strike-slip fault array which, it was postulated, may have originated(?) as a transfer zone early in the history of the northern Drummond Basin. We agree with this postulate, and extend it to suggest that the northeast to east-northeast-trending fracture/intrusion systems in the study area, and the subparallel mineralised "corridors" apparent throughout this part of northeastern Australia, were extensional transfer and/or accommodation zones during mid- to late Palaeozoic time. The parallelism of Drummond Basin fold and fault trends to these fracture/intrusion systems and "corridors" suggests that the Basin's deformation was, at the least significantly influenced by a set of such features. The main features may have originally separated resistant (to stress propogation) basement blocks from less resistant ones, with the edges of resistant blocks acting as structural bulkheads. The features evidently perturbed local late Palaeozoic magma-induced stress fields to the extent that the trends conspicuous farther north have been subdued.

The Burdekin Gorge Fault Zone which marks the northern edge of the preserved Drummond Basin, and of the thick Bulgonunna volcanics, may have acted as a "master" transfer structure during late Palaeozoic extensional magmatism.

North Queensland Igneous Province/Bowen Basin Interaction ?

The Lizzie Creek Volcanics and Mount Wickham Rhyolite could be early components of the Bowen Basin. It has been variously suggested that the Lizzie Creek Volcanics are: (i) manifestations (together with correlatives such as Camboon Andesite farther south) of a "Camboon Volcanic Arc" (Day et al. 1983 Murray 1983, 1985); (ii) symptomatic of early Bowen Basin subsidence-related "magmatic rifting"; or (iii) representatives of a back-arc basin fill, related to a bimodal dyke swarm which extends from Rockhampton to Cairns as an overprint along the axis of an earlier North Queensland Igneous Province arc (Allen 1993, 1994). Alternatively, and equally legitimately, they and the late Palaeozoic dyke swarms (above) can be perceived as (iv) representatives of a late-stage subprovince of the North Queensland Igneous Province (cf. Henderson 1980, Oversby et al. 1980 by implication). The fourth of the above options would conform to the situation elsewhere in northeastern Australia, where there is currently no alternative but to include Lower Permian volcanic sequences, such as the Agate Creek Volcanics and the bulk of the Featherbed Volcanic Group, in the Igneous Province.

Bowen Basin

The few bedding measurements (dips up to 35°, strikes variable) obtained in the Lizzie Creek Volcanics, mostly in the vicinity of "Strathbowen", may reflect upright short-wavelength and low- to moderate-amplitude folds, whose axial traces strike more westerly than the dominant (north-northwest) Bowen Basin fault- and fold-trend. Dips of 50° (northeast) in sedimentary material above the nonconformable contact with granite (CPg_{10}), in gullies draining into Birralee Creek near its junction with Oaky Creek, probably indicate significant tilting of the contact (as distinct from establishment on a steep palaeoslope), at least locally.

The Lizzie Creek Volcanics sequence in the easternmost part of the study area has evidently been substantially more folded than suprajacent, near-horizontal to gently east-dipping, probable lavas tentatively equated with Mount Wickham Rhyolite, at least locally. No cleavage is evident in Lizzie Creek Volcanics, however, and the structural contrasts observed may reflect local disharmonic deformation, with only minor tectonic significance.

The western margin of the Lizzie Creek Volcanics is not faulted at the present level of exposure. However, the deposition of the unit may have been structurally controlled. In this scenario, syndepositional faults, which are now "blind" or incompletely exposed, would have localised intrusion/extrusion and subsidence in an early magmatic rifting phase of Bowen Basin development (cf. Murray 1990). Similarly, deposition of the Mount Wickham Rhyolite to the south-southeast of Mount Wickham may have been fault-controlled, as discussed at more length below under "Millaroo Fault Zone".

Millaroo Fault Zone

The Millaroo Fault Zone has been identified as a probable continuation of the Palmerville Fault farther north, and the successor to a major structure which played an important part in focussing late Palaeozoic igneous activity in the middle to upper crust (Oversby et al. 1980). Previous mapping suggests that the zone becomes increasingly poorly defined, and eventually undetectable (absent?), from opposite "Strathmore" to near the edge of the Bowen Basin. We have found that there is no continuous south-southeast-trending structure at the present level of exposure anywhere in the eastern Burdekin Falls Dam - "Conway" area, from Mount Wickham southwards. Rather, the fault zone is represented by a complex, diffuse, discontinuous fracture/intrusion system comprising a series of intrusive and probable extrusive rhyolites (tentatively assigned to Mount Wickham Rhyolite), locally bounded and/or connected by short faults which have individually undergone only minor movement. This fracture/intrusion system locally cuts the Lizzie Creek Volcanics. There are no associated mylonitic rocks. The fracture/intrusion system does not impinge on preserved Collinsville Coal Measures; it appears to end on the northwestern side of lower Ten Mile Creek, about 5 km upstream (southwest) of the Bowen River, possibly because it is overlapped and obscured by a stratigraphically high part of the Lizzie Creek Volcanics sequence.

None of these observations necessarily negates the suggestion that a predecessor of the Millaroo Fault Zone was instrumental in focussing medium- to high-level late Palaeozoic magmatism. In fact, the inference that the Bulgonunna volcanics had a major source or sources in the east, the increased area of exposed late Palaeozoic granitoids eastwards, and the localisation of rhyolites in the zone where we have studied it, are all consistent with the suggestion.

The suggestion that the Millaroo Fault Zone is equivalent to, and probably a continuation of, the Palmerville Fault is not supported by its weak surficial expression. However, geophysical data (Appendix 4) indicate that the fault zone could be a more significant structure at depth, forming the local boundary between the Thomson and New England Fold Belts. Significant activity along a precursor to this fault zone may predate the Lizzie Creek Volcanics. The lack of mylonitisation in late Palaeozoic granitoids associated with the fault zone suggests that this precursor may have been active prior to their intrusion and that the granitoids behaved as "stitching plutons". The possibility remains, therefore, that a precursor of the Palmerville Fault-Millaroo Fault Zone existed, and potentially still exists at depth, as a single fault or zone in its own right.

METALLIFEROUS MINERAL DEPOSITS AND ECONOMIC POTENTIAL

Introduction

Initially, small-scale alluvial and hard-rock mining in the Burdekin Falls Dam - "Conway" area was concentrated between the present "Ukalunda" (early spelling variant, Eukalunda - cf. Jack 1889) homestead and vicinity, and Mount Wyatt (Jack 1889, Daintree 1870, de Havelland 1987). The first gold was apparently discovered at Mount Wyatt early in 1867, although copper was already known from the vicinity; the Ukalunda Silver Field (subsequently Sellheim Mineral Field) and Mount Wyatt Goldfield were proclaimed in 1885 (de Havelland 1987). Alluvial gold was obtained mainly from Isabella Creek and other tributaries of the Sellheim River. Many localities were probably not recorded, and are now not easily detected. The underground hard-rock mines typically exploited complex gold $\pm$ silver $\pm$ bismuth $\pm$ arsenic $\pm$ copper, and silver-lead, ores in vein-type deposits.

Somewhat later (post-1913) activity fanned out from Mount Coolon (vein-type gold-silver); this activity included the discovery (in 1928) and exploitation of "reef" gold at Bimurra, to the south of the study area (de Havelland 1987, Hutton et al. 1991).

Alluvial gold has been won since before 1900 (de Havelland 1987) from a "pothole" in the Burdekin River downstream of Burdekin Falls Dam by, at various times, hand digging and washing, dredging, hydraulic sluicing, and mechanical digging and jigging. Palaeoalluvial gold also occurs in the Suttor Formation at Rutherfords Table (Levingston 1953, Olgers 1972, de Havelland 1987).

General mineral exploration interest in the potential for epithermal-type gold occurrences in the northern Drummond Basin was initiated by the discovery of a deposit at Pajingo late in 1983, whose significance became "common knowledge" during 1984. Commercial gold production began at Pajingo late in 1987. It is noteworthy that, at this deposit, " . . . . No previous mining or officially documented exploration had occurred . . . . " (Porter 1990 p. 1483), i.e. its gold presumably escaped detection by conventional dollying and panning, making it one of the few true examples of recent "greenfields" discovery. Industry attention was focussed further when a broadly similar exploitable deposit to that at Pajingo was revealed at Wirralie (mineralisation was discovered in early 1986, mine development started in late 1987, and the first gold was poured in mid 1988). Exploration and evaluation in the district were facilitated by the application of the bulk-leach extractable gold (BLEG; alternatively BCL = bulk cyanide leaching) analytical technique, developed coincidentally in the early 1980s; using the technique, micro-grained gold and very low-level gold anomalies could be detected routinely in, e.g., stream-sediment surveys (i.e. without reliance on "pathfinders"). Exploration by BHP-Utah around "Conway" homestead, which was the springboard for our study, began late in 1984; the most extensively explored of this "Conway" group of prospects have been described briefly by Ewers, Wood, et al. (1993).

Prospecting activity in the Burdekin Falls Dam - "Conway" area since our fieldwork ended appears to have moved from "Conway" and its vicinity to concentrate around both "Glendon" and Bell's [*sic*] Creek (Austwhim Resources NL / Austmin Gold NL), and Mount Dalrymple (The Pyramid on the map) (Dalrymple Resources NL, Louthean 1993). Nearby, prospecting at Bimurra (Menzies Gold NL) appears to have been "put on hold" (Louthean 1993), and production at Wirralie (Ross Mining NL, previously Poseidon Gold Ltd, and before that ACM Gold Ltd) was anticipated to cease in the second half of 1993. On the positive side, mining started at Yandan (Ross Mining NL, previously Western Mining Corporation) in mid-1993, with the first gold poured towards the end of the year (Louthean 1993).

Known epithermal-type gold occurrences in the northern Drummond Basin (the immediate rationale for our work and associated studies in the Burdekin Falls Dam - "Conway" area), have many features typical of the adularia-sericite (Heald et al. 1987) or low-sulphidation (White & Hedenquist 1990) subtype. Characteristically, they are low in sulphur (generally less than 2% sulphides, mainly pyrite). Mineralising fluids were generally low-salinity (typically less than 5 wt% NaCl equivalent), and predominantly meteoric. Mineralisation took place at temperatures in the range 200° to $300^{\circ}C$; the fluids boiled at least locally (Ewers et al. 1993). Deposits have been variably but pervasively silicified, and have undergone argillic/phyllic (predominantly sericite and mixed-layer clays) and propylitic alteration. Adularia is present locally. Hydraulically-fractured and brecciated rocks are common associates, while quartz veins are generally banded and chalcedonic. Some of the gold occurrences are notable in having intimately associated hot-spring sinters (i.e. chemical "sediments"); the presence of these sinters virtually proves that the gold was introduced while host rocks were accumulating. Unfortunately, the possibility of an older original age (and source/s) for metal and/or sulphur cannot be ruled out from available data. Isotopic (K-Ar) dates suggest multiple hydrothermal events at many deposits, presumably linked to phases of elevated heat flow. Any or all of these hydrothermal events, with or without mineralisation, could have accompanied one or more of the several recurrent intrusive and/or extrusive episodes which have affected the region.

In the following section, many aspects of mineralisation beyond the boundaries of the Burdekin Falls Dam - "Conway" area will be explored which may not seem directly relevant to the discussion. This is done in the belief that a better appreciation of the study area's potential will be reached through considering it in a context of nearby and overall similar geological settings.

Structural Settings of Known Mineral Deposits

A "universal" theme in the localisation of mineral deposits throughout northeastern Queensland, irrespective of any single investigator's tectonic or metallogenic prejudices, is the use and re-use by mineralising agents of established structures and rock-type contacts. In particular, all known gold deposits have strong structural controls (Laing, 1994). At regional scale, a large proportion of known deposits lies within roughly northeast-trending, and supposedly subequally-spaced (at intervals of 35 km to 40 km), major belts, commonly termed "corridors" (cf. Laing 1994 Figure 1). These belts are delineated locally by discrete faults. Generally, however, they are diffuse structural-metasomatic-magmatic entities up to about 5 km wide and about 200 km long, which are commonly more evident in aeromagnetic imagery (because of characteristic magnetite-destructive alteration - Webster et al. 1989) and in monochrome RC-9 aerial photographs (because of pale siliceous-phyllic-argillic alteration overprints) than in surficial geological data.

In at least the senior author's view, these northeast-trending belts may well represent late Palaeozoic transfer zones. These are envisaged as having separated semi-regional extensional domains which were, collectively, broadly north-trending. Transfer zones served to accomodate variations in styles (geometries) and/or rates of predominantly east - west extension between adjacent domains (cf. Oversby 1983, 1987, Henley & Adams 1992). Fundamental control/s of the belt's northeasterly trend is/are obscure; it may ultimately have been inherited from an early Palaeozoic, or older, set of features in the true regional basement.

Northeast-trending belts which contain mineral deposits identified in and near the Burdekin Falls Dam - "Conway" area (cf. Peters 1987, Morrison 1988; Hartley et al. 1993, Wormald et al. 1993, Laing 1994) are: the Mount Leyshon Corridor (of Morrison 1988) or Mount Leyshon - Tuckers Lineament (Mount Leyshon, Disraeli, Hadleigh Castle, and Reward deposits); the Ravenswood Corridor (Ravenswood and Pajingo deposits); and the Collinsville Corridor (Wirralie, Yandan, Bimurra, and "Conway" area deposits). These corridors/lineaments appear to reflect significant crustal features. Several late Palaeozoic intrusive-extrusive features line up along the Mount Leyshon Corridor, and some (notably the Tuckers Igneous Complex plus un-named associates to the southwest - nos 16 on Figure 3 of Oversby et al. 1980) are conspicuously co-aligned with it. Each northeast-trending corridor is presumably underlain by one (or several semi-connected) granitoid bodies of up to batholithic dimensions (cf. Morrison 1986).

The apparent gap of about 110 km between the Ravenswood and Collinsville Corridors is occupied at 35 km to 40 km "repeat distances" by: (i) the present northwestern to northern edge of the preserved Drummond Basin, plus possibly the Burdekin Falls Dam Fault Zone (of Laing 1994, Figure 1); (ii) the House and Kitchen Granite pluton, with crudely centred volcanic and subvolcanic structures adjacent to the southwest and northeast, plus; (iii) the southwestern extension and main part of the Mount Wyatt - Peak John Well corridor in which "basement" and granitoid units are exposed in a belt between preserved Bulgonunna Volcanic Group sequences. This belt contains the Mount Dalrymple Prospect (no 29 on the map), and Ukalunda- and Mount Wyatt-type mineral deposits (below). One of the northeast-trending belts, the Cork - Ravenswood Corridor, has been identified (from regional aeromagnetics) as a first-order ("master") dextral and south-block-down fault zone, extending into the area of the Mount Leyshon and Ravenswood Corridors from the Mount Isa region, and active from Proterozoic to Permian times (Laing 1994). Although the northeast-trending belts do not usually show displacements in mapped geology and aeromagnetics, a dextral strike-slip component can be detected in a few, such as the Collinsville Corridor (Hutton 1989, Laing 1994). This is incompatible with east-west-directed extension inferred for the Carboniferous of the Georgetown region (cf. Oversby 1983), although that may be irrelevant if the corridors represent transfer zones, with some or all behaving in the same way as transform faults - above. More commonly, displacement vectors revealed during combined magmatic and metasomatic events were evidently variable in space and time. Most significantly in terms of mineral deposit localisation, the belts were evidently broadly extensional domains for significant intervals of time; internal dilation sites were recurrently active in space and time (Laing 1994). Optimum late Palaeozoic dilation sites appear to have been east-striking and/or gently-dipping fractures. Gentle dips may be indicative of high-level crustal settings with low lithostatic pressure, hence a vertical (or at least steep) minimum principal stress inclination. Somewhat less commonly used sites were enclosed by, and subparallel to, the main (second-order) belts themselves (Laing 1994). The main first- and second-order corridors may represent transfer zones, some of considerable original age (e.g. Withnall & Lang 1990, Johnson & Henderson 1991; cf. discussion above under "Structure and Tectonics"). The occurrence of 65% of northeastern Queensland's known gold both in and within 20 km of, the combined Mount Leyshon and Ravenswood (i.e. easternmost Cork - Ravenswood) Corridors (Laing 1994) emphasises the potential and actual economic significance of these features, irrespective of their origin/s.

Within the approximately 6 km-wide Mount Leyshon Corridor, the gold-mineralised Mount Leyshon breccia body itself is located on an east-west-trending contact between metasedimentary Seventy Mile Range Group (Puddler Creek Formation) and Ordovician granite of the Lolworth-Ravenswood Complex (Wormald et al. 1993).

A suite of north- to northwest-trending corridors can also be discerned. These link, and in some instances cross, the main northeast trending corridors, e.g.: the north-northwest Merri Monarch Corridor links Charters Towers with Mount Leyshon, and perhaps with Pajingo (one fault system and some of the trachyandesite dykes at Mount Leyshon also strike to the northwest); and north to northwest corridors have been recognised through Bimurra, the "Conway" area, Mount Coolon, and Wirralie (Laing 1994). In part, this set of corridors coincides with a southeastern extension of the northwest-trending Burdekin River Lineament, which has been traced from near "Glenroy" outstation to beyond the eastern Charters Towers area (Wormald et al. 1993, Figure 1 - note that this is not the same as either the northeast-trending Burdekin River Corridor, or the Burdekin Dam Fault Zone, of Laing 1994 Figure 1). Extrapolated southeastwards without deviation, this Burdekin River Lineament would pass only 10 km east of "Conway" homestead.

The north-northeast- to north-striking Southern Cross Lineament and the northeast to north-northeast-striking Merrilands Lineament coincide with the western and eastern limits respectively of significant Charters Towers mesothermal gold mineralisation (Hartley et al. 1993) (as a geographical reference, the Gregory Developmental Road lies between these features). Extrapolated southwards, both would lie well west (approximately 100 km) of the Burdekin Falls Dam - "Conway"area. The Southern Cross Lineament may have had post-Palaeozoic faulting along at least part of its length (Hartley et al. 1993).

At least some of the structures linking the northeasterly corridors may be related to several of the faults around Charters Towers and in the northern Drummond Basin, as well as to the more conspicuous and major Palmerville and Millaroo Fault Zones. East-trending structures (e.g. Mosgardies Shear Zone, contact between the Lolworth-Ravenswood Block and Drummond Basin) are conspicuous only locally, and have not been extensively commented on in any economic context extending beyond Charters Towers. However, their significance may be substantial, not only in terms of major mineral deposit localisation (mid-Palaeozoic Charters Towers and late Palaeozoic Ravenswood gold deposits both lie within the Mossgardies Shear Zone), but also in terms of tectonic activity throughout Palaeozoic time (cf. Hutton et al. 1994). Conceivably, these features could have been transfer structures during early Palaeozoic time.

Aeromagnetic information (including high-resolution 250 m flight-line spacing, 80 m ground-clearance, data - Irvine & Smith 1990, Ewers et al. 1993) reveals that Mount Coolon, Bimurra, Conway (no 36 on the map), Blue Gum (no 14), and Battery Hill (no 6) epithermal gold prospects, in and south of the southeastern part of the Burdekin Falls Dam - "Conway" area, are all aligned within or beside a north-trending magnetic corridor. That part of the corridor containing Bimurra, Conway, and Blue Gum is diffuse, about 5 km wide, and characterised by a series of magnetically quiet areas. It may be analogous to, although apparently of more limited extent than, the mineralised tract between the Southern Cross and Merrilands Lineaments (above), which lies approximately 150 km to the northwest. More specifically, Conway and Bimurra appear to lie at the intersections of this north-trending corridor with aeromagnetically similar east-northeast-trending features. Of these, one extending west from Bimurra may also contain Wirralie (Ewers et al. 1993 Figure 18). Yandan, Wirralie and Bimurra (and also Pajingo) all appear to be close to east-northeast- and/or northwest-trending magnetic corridors or lineaments (Wood et al. 1990, Ewers et al. 1993 Figure 19). In the majority of instances, these corridors and lineaments do not correspond to specific outcropping faults or other structures.

At a more restricted local scale, three main (one bifurcating), northeast- to east-northeast-striking, fault zones are interpreted to cross the Conway Prospect. Intensely altered, silicified and gold-anomalous subareas within the prospect area are localised along these interpreted fault zones (Ewers et al. 1993 Figures 6 and 7).

On the basis of high-resolution aeromagnetic imagery and field research, Henley & Adams (1992) suggested that the east-northeast-trending feature between Wirralie and Bimurra represents a reactivated northeast-striking strike-slip fault array. It was conjectured that this array may have succeeded a transfer zone, developed early in the history of the northern Drummond Basin. The structure was inferred to have acted as a localiser and conduit for circulating gold-bearing fluids, and/or influenced the distribution of the most favourable volcanic and volcaniclastic host rock types.

Laing (1994, p. 129) has presented a structurally-oriented nine-point "hit-list" as an attempted aid to predictive mineral-deposit exploration throughout northeastern Queensland.

Magmatism and Metallogeny

Northeastern Queensland is perceived by some to have a moderately simple metallogenic history, with two major phases of Palaeozoic gold and base-metal introduction - at about the Siluro-Devonian transition and during Carboniferous and Permian times (e.g. Morrison 1988). These two phases appear to have coincided with times of major change in regional tectonism, which were also times of strong crustal dilation (Laing 1994). This fairly straightforward metallogenic scenario may be somewhat simplistic; exceptions to it, such as the volcanogenic sulphide deposits associated with (and presumably genetically related to) Cambro-Ordovician Mount Windsor Volcanics, are of more than trivial interest.

The metallogenic framework of the Charters Towers district of Hutton et al. (1993) and Hartley et al. (1994) is based mainly on known mineral associations, observed structural settings and interpreted origins. The framework is objective, but has the limitation of only considering known and reasonably well "understood" deposits. In the case of gold mineralisation, Morrison (e.g. 1994) has presented a somewhat more conceptual deposit classification for the Late Devonian to Early Permian ("Kanimblan") time interval. The classification relies on recognition of four broad environments of mineralisation, six detailed deposit styles/sites localised (in part repetitively) within these environments, and three temporally distinct pulses of mineralisation explicitly tied to different stages of tectonic development. Two of the environments (epithermal and porphyry), several styles/sites (hotspring, vein, breccia and possibly skarn), and possibly all three temporal pulses of mineralisation are represented to some degree in the Burdekin Falls Dam - "Conway" area, although cost-effective mining of these deposits is apparently not practicable at present.

By comparison, Stolz (1994) explicitly linked mineral deposits in the Seventy Mile Range Group to subduction-related tectonic settings. Massive sulphide mineralisation in and immediately (stratigraphically) above Mount Windsor Volcanics was placed in a context of continental lithospheric extension, and of " . . . . the onset of back-arc volcanism produced from subduction-modified sub-arc mantle . . . . " (Stolz 1994 p. 19), in an Okinawa Trough-like setting.

The relationship between magmatism and metallogeny in the late Palaeozoic of northeastern Queensland is in the process of being systematically re-evaluated by means of AGSOs "North Queensland Igneous Rocks" Geographic Information Systems (GIS) compilation (Champion & Heinemann 1993, 1994). The compilation currently extends from the Burdekin Falls Dam - "Conway" area to the tip of Cape York Peninsula. Its relevance to economic mineral deposits lies in the conceptual principal that significant mineralisation represents one end-point in a continuum of igneous-geochemical fractionating (including fluid-generating) events. This continuum can result in potentially ore-forming elements being selectively concentrated to high levels, and/or transported at high levels; such levels are far in excess of background igneous ones (cf. Blevin & Chappell 1992, Blevin 1994). Many researchers (e.g. Ishihara 1981, Blevin & Chappell 1992, Candela 1992) have indicated that the oxidation state of granitoids (as well as volcanics and subvolcanic intrusives) is an important parameter in terms of mineralising potential. The oxidation state basically mirrors the magmatic Fe^{3+}/Fe^{2+} ratio. It is reflected in magnetite (oxidised) and ilmenite (reduced) contents, and is best indicated by a rock's magnetic susceptibility. Whole-rock geochemical data from northern Queensland also show a strong association of I-type (most particularly fractionated I-type) granitoids (and other igneous rocks) with mineral associations of potential economic significance (Blevin 1994, Mackenzie et al. 1994). Thus, continually refined geochemical studies, better thermodynamic modelling, and/or other way/s which can further clarify fractionation mechanisms of (and the degrees of fractionation undergone by) granitoids and other igneous suites are of major medium- to long-term importance at a practical, ore-finding, level, as well as being of fundamental long-term petrogenetic significance.

The GIS compilation also highlights and confirms some independently recognised structural associations. Notable among these are: margins of volcanic and volcano-tectonic subsidence structures (cauldrons); major through-going corridors and lineaments; and intersections between subsidence structure margins and corridors/lineaments, between both of these and other geological features such as rock-type contacts with significant rheological contrasts. Regional oxygen-isotope depletions (cf. Ewers et al. 1991, 1993, 1994), with or without easily recognised alteration, probably reflect extensive circulation of meteoric water with mineralising potential. New-generation (400 m and closer line-spacing) aeromagnetic data combined with gamma-ray spectrometry may be used to identify certain types of alteration, highlight structures, and provide at least qualitative indications of prospectivity at regional to local scales (cf. Laing 1994, Mackenzie et al. 1994). The GIS should highlight increasingly subtle relationships as compilation proceeds, with future refinement and manipulation of more varied types of data.

Ore precipitation in response to host rock composition appears not to have been particularly important regionally (e.g. Laing 1994). However, this is still debatable at the individual deposit scale, particularly so in the case of epithermal gold occurrences in and adjacent to the study area.

Descriptions of Known Mineral Deposits and Economic Potential of Map Units

Mount Windsor Volcanics

Although no mineral deposits have been discovered in the Mount Windsor Volcanics of the map area, the formation overall " . . is the most prospective geological province for volcanic-hosted massive sulphide mineralisation in North Queensland. . " (Beams 1993 p. 75). A concentration of known deposits (from west to east - Liontown, Waterloo, Highway, Reward, Handcuff, Trooper Creek, and Sunrise Spur - Beams et al. 1990, Hartley et al. 1993 Figure 4) occurs in and adjacent to an east-trending 35 km outcrop belt of the volcanics. The belt is bisected by the Gregory Developmental Road (to Clermont), about 35 km south of Charters Towers and slightly more than 100 km west-northwest of Burdekin Falls Dam. Another Mount Windsor Volcanics deposit, Thalanga, lies 65 km southwest of Charters Towers. The Thalanga deposit is the most outstanding of those known in Mount Windsor Volcanics. Its outcropping gossan, surrounded by Cainozoic rocks (Campaspe Beds), was discovered in 1975, and the decision to mine was made in 1989 (Gregory et al. 1990). The potential of Mount Windsor Volcanics in the study area thus cannot be dismissed as negligible, particularly because the stratigraphic level preserved appears to be at least locally high (undivided Seventy Mile Range Group rocks associated with the volcanics seem most likely to be overlying Trooper Creek Formation).

The "Volcanogenic Type" gold, zinc, copper, and lead with gold and silver mineral deposits of Hutton et al. (1993), in the Mount Windsor Volcanics include "Footwall" or "Stockwork" and "Stratiform" subtypes (low- and high-sulphide subtypes respectively of Hartley et al. 1994). Thalanga (above), is a "Stratiform"/high-sulphide occurrence. This "Stratiform" subtype apparently represents exhalative syngenetic mineralisation, of the same age (at or about the Cambrian - Ordovician boundary, see Henderson 1983, 1986) as the upper Mount Windsor Volcanics rhyolites and, locally, lowermost Trooper Creek Formation which enclose the deposits (Gregory et al. 1993; Hill, 1994). The Trooper Creek Formation is made up of mainly andesitic and dacitic lavas, and sedimentary rocks. Some rhyolitic tuffs and intervals of "quartz-eye" tuff (probably submarine mass-flow units, see Gregory et al. 1990) were deposited during precipitation of massive sulphides at Thalanga; these rock types also locally cap the massive body. Deposits in the "Stratiform" subtype have as their main sulphides semi-massive to massive pyrite with sphalerite, chalcopyrite and galena; i.e. they are "classic" V(olcanogenic) M(assive) S(ulphide) deposits. Barite, silica, carbonate, chlorite and amphibole are common mullock components. Footwall alteration at Thalanga (extending for approximately 2 km on either side of the outcropping gossan) is in rhyolite; it is characterised by enrichment in MgO, Na_2O, FeS_2, and base-metals, with depletion in CaO and Na_2O (K. Wills unpublished data, quoted in Gregory et al. 1993 p. 97). Strong (10% to 80%) pyrite alteration is associated with silica and sericite development; it passes laterally to moderate (1% to 10%) pyrite associated with sericite, chlorite and carbonate, and patchy to pervasive disseminated sphalerite, galena and chalcopyrite. In the weak (0.5%) pyrite zone, sericite, some talc, minor sphalerite and galena may be associated. Hanging wall alteration (of dacites) at Thalanga is weak; epidote, carbonate, chlorite, actinolite, biotite, and pyrite occur locally. Gold is an accessory mineral; it is usually located within pyrite grains, but is otherwise free. There is a sharp cut-off of massive sulphide mineralisation down-dip (at about 150 m to 300 m depth below present surface) at Thalanga. This cut-off takes place at a north-northeast-striking, originally steep and inferred synvolcanic, fault that has been suggested as the main locus of ore fluids (Gregory et al. 1990, 1993). The along-strike extension of sulphides is represented by pod-like bodies of cherty quartz-magnetite (which extend up into the Trooper Creek Formation) at Thalanga West.

Occurrences of "Footwall" subtype deposits appear to represent the feeder zones of "Stratiform" subtype ones. Potentially mineable occurrences of this subtype (e.g. Highway) are volumetrically small (up to a few tens of m^3) components of low-sulphide stockworks, developed as part of intense "hydrothermal" alteration affecting a cubic kilometre or so of host rock/s. The "ore"-bearing components are zones of intense sericitic alteration; these zones also contain irregular but pervasive patches and veins of silica. Barite, amphibole and chlorite are characteristic associates. The dominant sulphide is most commonly pyrite, in disseminations of typically 2% to 10%, but occasionally up to 29%, by volume. It occurs with minor microveins and blebs of chalcopyrite and sphalerite.

The Reward deposit is somewhat unusual in being not only large and blind, but also pipe-like and transgressive (to local stratigraphy). It consists of a massive pyrite-chalcopyrite body (or, more correctly, series of four bodies), and apparently formed in several stages, syn- and/or post-cleavage, after peak metamorphism. It has been postulated that a Late Cambrian precursor mineral concentration (Beams 1993) was probably remobilised and concentrated into the largest of the bodies now seen - a cleavage-parallel pipe of pyrite carrying copper and gold. An Ordovician timing for the remobilisation is considered likely (Beams 1993; cf. Hartley et al. 1993, Beams et al. 1993). The massive sulphide-bearing pipe has analogues at Cobar (Beams 1993).

The earliest Mount Windsor Volcanics deposits discovered had outcropping gossans which produced marked stream sediment and soil metal anomalies; later discoveries were made on the basis of different geophysical techniques (mainly EM in the case of high-sulphide deposits, IP with low-sulphide ones; aeromagnetics have not yet been an orefinder at the prospect scale), with initial prospect selection being made on a conceptual basis centred on the identification of key stratigraphic units/packages, plus alteration (mainly feldspar-destructive) indicators. All large outcropping occurrences have probably been found. The most recent, blind, searches have used RAB geochemistry as an important tool. In the absence of more obvious or predictable indicators, future blind searches are likely to involve geophysical techniques which can "see" through deep, oxidised and conductive cover, and/or extensive pattern drilling (Beams 1993).

Ukalunda Beds

Vein-type deposits formerly exploited on a small scale in the Ukalunda Beds of the Burdekin Falls Dam - "Conway" area have yielded: gold from the Leichhardt Vale (no 9 on the map), Big Hope (no 23), Southern Cross (no 24), and Golden Ridge (no 25) mines (with arsenic minerals at most deposits, and copper at nos 9 and 25). Silver has been won (probably ultimately from argentiferous galena) at the Birthday Gift Mine (no 26); and copper from the Margaretta Mine (no 31). The Big Hope Mine exploited the so-called "Copper Contact Zone" (de Havelland 1987), developed along the contact of Ukalunda Beds with Percy Douglas Granodiorite between Mount Wyatt and Mount William Philpott. The small-vein style of deposits, similarity of mineral assemblages (particularly the gold-arsenic one), and geographical proximity, suggest a relationship between these Ukalunda Beds deposits and mineralisation in the Sunbeam Granodiorite extending north and northeast of "Ukalunda" itself. Morrison (e.g. 1994 Table 1) has suggested explicitly that occurrences in the vicinity of Mount Wyatt are porphyry-related gold deposits of skarn style and of mid-Carboniferous (330 Ma to 295 Ma) age.

The location of the Salopia (gold) Mine (no 28) shown on the map is based mainly on the position of mullock heaps visible on aerial photographs. The location was not visited by us; it appears to be in a tract of Ukalunda Beds. The position of the Salopia Mine is shown by Golding & Wilson (1984 Figure 3) to be approximately 2 km east-northeast of our location, but again in a tract of Ukalunda Beds (we could see no aerial photographic evidence of a mine site in Golding & Wilson's location), However, granodiorite samples were collected at the mine, or nearby, by Golding & Wilson (1984 Table 2); these presumably represent a small body or apophyse of Joe-De-Little Granite (if the mine is at the location identified by us) or Percy Douglas Granodiorite (if it is at the alternative localition). Quartz (one sample only) from Salopia gold-arsenic "ore" has yielded an ^{18}O value of +14.9 ‰ SMOW (Golding & Wilson 1984). This is consistent with mineralisation by a magmatically-derived hydrothermal fluid, rather than by a prediminantly meteoric one as in the otherwise similar deposits hosted by Sunbeam Granodiorite, discussed below. Thus, while the two deposit groups may be related, they apparently differ in at least one detail.

As noted by Ewers Wood et al. (1993), a prospected lead- and zinc-bearing skarn (no 37 on the map) occurs at "Mount David", about 2 km south of the BHP Blue Gum Prospect (no 14). Indications of prospecting activity are somewhat scattered; however, the mineralised skarn is in a Ukalunda Beds' limestone lense. The age of skarn formation is not known, although it may be related to the intrusion of unit CPr_2 rhyolite, which crops out nearby.

Bimurra Volcanics

Rocks assigned to the Bimurra Volcanics host all of the known epithermal-type gold in the group of BHP prospects in the Burdekin Falls Dam - "Conway" area (nos 6 to 8 inclusive, and 14 on the map), in adjacent parts of the Mount Coolon 1:100 000 Sheet area (Durah Creek, Bimurra, Hill 273, and Eaglefield Prospects - Ewers et al. 1993 Figure 2), and probably also at the Wirralie Mine. Although initial prospecting interest centred on the gold at Bimurra worked by "old-timers" in the late 1920s and '30s, it was an orientation stream-sediment geochemical survey, and application of the BLEG analytical technique, which were instrumental in locating the other previously undetected and potentially more significant prospects.

Battery Hill (no 6 on the map), Isabella (no 8), Blue Gum (no 14), Bobby Dazzler (no 30), and Conway (no 36) epithermal gold prospects occur in the Burdekin Falls Dam - "Conway" area. Gold occurs in belts of locally vuggy, finely crystalline to comb-textured quartz veins (in places, colloform-banded chalcedony veins and veinlets, locally hematitic [typically fracture-related, uncommonly pervasive, and rarely associated with epidotic alteration at Conway]) and hydrothermal breccias, in altered Bimurra Volcanics host rocks. Within the 15 km^2 area of the Conway Prospect, several anomalous subareas (Wobegong, Mill Hill, Bustard Egg Hill, Big Sinter Hill, Split Hill, Quartz Reef Hill and Red Flag Hill - Ewers et al. 1993 Figure 2) are marked by intense silicification reflected in topographic highs. Dykes (passing into sills and/or lavas locally) of quartz trachyte, syenite, and rhyolite in Bimurra Volcanics host rocks (massive trachyte, rhyolitic to andesitic lavas and volcaniclastic sedimentary rocks - Ewers et al. 1993 Figure 4) appear to have been genetically associated with veining by quartz throughout the Conway Prospect. They are also spatially associated with surficially precipitated sinters within an epiclastic interval to the southwest of the Wobegong subarea. Quartz-veining was followed (at Blue Gum, possibly Conway) by at least two generations of calcite $\pm$ zeolite, chlorite, epidote, prehnite and opaque mineral veins. At Conway, calcite/zeolites occur as narrow veinlets filling tension fractures. Calcite veinlets are almost invariably late; in rare instances, bladed calcite has been totally replaced by quartz pseudomorphs. Disruption of individual late-stage calcite grains at Blue Gum indicates that some degree of deformation also took place after the veining. Locally at Blue Gum, this late vein mineralogy is patchily distributed in host rocks, and has the aspect of a retrograde skarn assemblage (cf. Mount David Prospect, no 37 on map). Hydrothermal alteration extends for up to several km^2 in surface area (Blue Gum); it is marked by variable but pervasive, fracture-controlled, silicification (essentially a fine-grained quartz replacement of chalcedony). Argillic/phyllic assemblages (mainly sericite and mixed-layer illite/smectite) are weakly to very strongly developed in host rocks; they appear to have overprinted a weak and pervasive (regional ?) propylitic assemblage at least locally. Secondary K-feldspar alteration, minor kaolinite, alunite, pyrophyllite and jarosite have also been recognised at the Conway Prospect. Some clay alteration has probably been produced by Mesozoic(?) and Cainozoic weathering. Minor sulphides present are trace pyrite in disseminations (typically within intensely silicified breccia fragments, and along selvages of quartz and calcite veins at Conway) and rare veinlets $\pm$ rare disseminated pyrrhotite (partly pseudomorphed by marcasite), chalcopyrite (also in rare veinlets at Isabella), sphalerite, and arsenopyrite, also occur (Battery Hill, Isabella, Blue Gum), accompanied by galena (Blue Gum) with rare chalcocite and bornite (Blue Gum, Conway). Native gold (Blue Gum, Conway) and electrum (Conway) occur as isolated micro-grains up to 200 microns across, associated with quartz veins and silica-rich zones. Naumannite (Ag_2Se) has also been tentatively identified from Conway Prospect (Wood et al. 1990).

A feature of the Conway Prospect (and also conspicuous at the Durah Creek and Hill 273 Prospects, and tentatively at Bimurra) is the presence of sinters interbedded with volcaniclastic sedimentary rocks, particularly in five outcrop areas aligned along a northeasterly trend near the Wobegong gold anomaly (White et al. 1989, Ewers et al. 1993 Figure 3). These are less than 2 m thick, and up to only several hundred m^2 in individual outcrop area. They dip shallowly to the southwest, in concordance with host rocks. The Conway sinters contain plant fossils. (the probable Early Carboniferous form *Oxroadia gracilis* - White et al. 1989). Barely detectable gold occurs in the Hill 273 sinter.

Along with Durah Creek, Bimurra and Eaglefield to the south (see Ewers et al. 1993 Figure 2), Blue Gum Prospect is notable in that substantial bodies of rhyolite have been affected by sericitic alteration and/or silicification associated with the gold mineralisation. The geometry of the feldspar-phyric bodies at Blue Gum indicates that they are more likely to be CPr_2 intrusives than lavas in the Bimurra Volcanics sequence (with the implication that at least some of the Blue Gum gold was remobilised at a late stage); minimum K-Ar ages (Ewers et al. 1993 Table 7) from Blue Gum sericite are Late Carboniferous, consistent with this interpretation.

In the adjacent part of the Mount Coolon 1:100 000 Sheet area, Durah Creek and Bimurra Prospects lie due south of "Conway" homestead, and east-northeast of Wirralie Mine; Hill 273 and Eaglefield Prospects are east-southeast of Mount Coolon (cf. Ewers et al. 1992, Figure 2). The Bimurra alteration system extends through an area of more than 10 km^2; at least two generations of banded chalcedonic silica ± sulphide veins occur. At Eaglefield Prospect, gold and silver values are accompanied by minor mercury; the higher gold values (maximum 1.3 ppm) invariably correlate with elevated pyrite contents, up to an estimated 5% by volume.

Field relationships and other features suggest that the hydrothermal-mineralisation system at Conway Prospect is exposed in an oblique west-dipping section; the Red Flag Hill area represents the deepest and hottest part revealed. Suspected sinters in the Big Sinter Hill area could be juxtaposed against high-temperature (approximately 250°C) quartz veins, either because a single hydrothermal system was both long-lived and being concurrently eroded throughout its lifetime, or because independent systems exploited the same structures at different times (overprinting of one hydrothermal system by a younger one has been tentatively documented at Bimurra, see Wood et al. 1990).

Sericites from "Conway" area prospects have given a moderately wide and apparently unsystematic range of K-Ar ages, which must be regarded as minima, from 342±15 Ma at Conway (mid Early Carboniferous) to 283±3 Ma at Bimurra (earliest Permian) (Ewers et al. 1992 Table 7, Perkins & Walshe quoted in Ewers et al. 1993 p. 24).

Andesitic and basaltic components of the Bimurra Volcanics may have been a source of the gold, and of sulphur for its transport (cf. Seward 1973). However, this has not yet been unequivocally demonstrated (Ewers et al. 1993). The low CO_2 content of fluids apparently involved with mineralisation at Conway may indicate that the system was incapable of producing a really major deposit (cf. Hedenquist & Henley 1985).

The Wirralie deposit lies approximately 13 km southwest of "Conway" homestead (and 40 km north-northwest of Mount Coolon. According to Fellows & Hammond (1990), the deposit is hosted by Mount Wyatt Formation, exposed in an inlier surrounded by Tertiary Suttor Formation. However, the deposit-bearing sequence consists of volcaniclastic sedimentary rocks (tuffaceous mudstones to cobble conglomerates) with subordinate interbedded lapilli and crystal tuffs (Fellows & Hammond 1990), suggesting that the rocks are more likely to represent the sediment-dominated subunit of the Bimurra Volcanics than the Mount Wyatt Formation. Some beds in the sequence contain pyritic clasts and possible sinters.

Ore-grade gold at Wirralie is supergene; it occurs in a crudely conformable (with respect to enclosing oxidised strata) tabular body dipping gently to the northwest. Host rocks are cut by a network of several generations of quartz-chalcedony and quartz-matrix breccia veins, which vary from several millimetres to several metres wide. Angular-clast breccias of silicified wall rocks set in quartz matrix occur adjacent to some of the thicker veins. Colloform banding and cavity-filling silica textures are common; bladed quartz replacement of anhydrite and/or gypsum is also notable. The gold has an elemental gold:silver ratio of about 4:1. It occurs in hematite and goethite, along quartz grain boundaries and in relic pyrite. Arsenic, antimony, and mercury concentrations vary considerably. Host rocks are rich in illite (with interlayered smectite) and kaolinite. Ore-grade gold also occurs locally within laterally adjacent Suttor Formation.

Below the oxidised zone at Wirralie, pyrite (generally arsenical) is the dominant sulphide; marcasite is common, particularly in higher-grade gold zones. Most gold (elemental gold:silver ratio 3.5:1) appears to occur within the pyrite, although it is also known as rare grains in vein quartz. Quartz, illite, sericite, minor adularia and accessory anatase are the dominant alteration minerals. Below the gold blanket, host rocks have been altered to a green colour (possibly due to celadonite). Overprinting this green alteration is "white clay", occurring as a replacement of feldspars, in veins, and as fracture-coatings. Some of this "white clay" below the base of oxidation may be hypogene; that above is probably entirely supergene. Disseminated and fracture-controlled iron carbonate appears about 20 m below the highest-grade gold zone, while calcite appears at greater depth.

The assumed Upper Devonian to lowermost Carboniferous species *Lepidodendron mansfieldense* M'Coy has been recovered from a locality in the inlier, Mc81F, close to the mineable part of the Wirralie deposit (M.E. White in Olgers 1972 p. 75 and Figure A plus Plate D)

Saint Anns Formation

Saint Anns Formation appears to have been the host of a small vein-type silver (from argentiferous galena) deposit worked at the New Years Gift Mine (no 27 on map). This deposit was presumably related to other Ukalunda gold and silver occurrences, mostly hosted by Sunbeam Granodiorite, and discussed under that heading below.

Farther afield (approximately 50 km southwest of "Conway"), the Yandan gold deposit occurs in tuffaceous sedimentary rocks of the informal "Yandan host unit", believed to be part of the Saint Anns Formation (Johnston 1994). The deposit is of low-sulphidation (adularia-sericite) epithermal type. Gold is disseminated; it most commonly occurs within altered matrix, and in cavities, associated with early quartz-adularia-illite-pyrite±bladed carbonate, graphite and chalcopyrite. The gold-bearing alteration grades laterally into an outer low-rank illite-mixed-layer clay-celadonite assemblage, and at depth passes into a propylitic chlorite-illite-carbonate-silica assemblage. Late "alteration" (weathering?) kaolin-hematite-jarosite-hydrated iron oxides also occurs. Highest gold grades are associated with more porous, and presumably optimally permeable, rock types within an overall east-trending, blanket-like, "Yandan feeder zone". Production of gold from the Yandan deposit was recently scheduled to start late in 1993 (Louthean 1993).

The Scartwater - Mount Hope epithermal gold prospects, approximately 50 km west-southwest of "Conway", may also be in "Yandan" (Saint Anns Formation?) volcanics.

Stones Creek Volcanics

Andesitic components of the Stones Creek Volcanics in the middle Bell Creek sequence have been silicified (and are pale grey in colour), and locally contain disseminated pyrite, adjacent to intrusive rhyolite bodies. Elsewhere in the Burdekin Falls dam - "Conway" area, the formation is not known to show any indications of mineralisation. However, at Pajingo, approximately 75 km west-northwest of Burdekin Falls Dam (53 km south-southeast Charters Towers), opposite the drowned site of "Cranbourne" homestead, gold occurs in an andesitic host sequence very like Stones Creek Volcanics. This host sequence has been postulated variously to belong to D/Cv, to the combined Star of Hope and Raymond Formations (Clarke & Paine 1970, Olgers 1972), and, by the current generation of mine geologists, to the Saint Anns Formation (Porter 1990). This most recent correlation is not particularly convincing. Previously-recognised Saint Anns Formation volcanics (Llanarth Volcanic Member) are overwhelmingly felsic. In its predominantly andesitic nature, the unit at Pajingo is most unlike Saint Anns Formation; it has similarities with, but is certainly not identical to, Star of Hope Formation volcanics. If the Pajingo host is not actual Stones Creek Volcanics, it may well be a laterally equivalent, related unit.

The Pajingo deposit consists of volcanic-hosted epithermal quartz vein systems/complexes dominated economically by the so-called Scott Lode. It has many features in common with the adularia-sericite epithermal subtype, and has been interpreted to have formed at 300 m to 500 m below the Early Carboniferous palaeosurface (Porter 1990). The Scott Lode is hosted by andesitic (mainly) lavas, tuffs, and volcaniclastic rocks (plus chloritised subvolcanic intrusive rocks), intercalated with variable sandstones and siltstones. The volcanic rock-dominated part of the sequence makes up the hanging wall. Scott Lode is boomerang-shaped (concave to the north-northwest), and steeply south-dipping. The lode consists of a quartz vein complex measuring 560 m along strike, by 23 m in maximum workable width (1.0 gm/tonne gold cutoff), tapering to 4 m widths at each end. It is subparallel to, and lies within the central sector of the 2500 m-long east-northeast-striking Janet 'A' Vein, which is interpreted to be occupying, and filling, a dilational fault zone. Although the Janet 'A' Vein-Scott Lode complex is economically most important at Pajingo, northwest-trending but otherwise similar vein systems are dominant.

Silica-sealed hydrothermal breccia is common in localised zones marginal to, and farther out from, the vein components at the hanging- and footwall edges of Scott Lode. Veins consist mainly of clear to milky, and locally reddish-brown, chalcedonic and microcrystalline silica; this vein silica displays a variety of cavity-filling textures (including some indicating replacement of bladed carbonate); limonite and hematite occur in bands and "dusty" disseminations. Indications of multiple brecciation and reprecipitation of silica, interpreted to indicate recurrent hydraulic fracturing and silica sealing, are ubiquitous in vein and matrix material. Gold occurs "free" mainly as electrum, associated with native gold; some native silver also occurs. Several generations of gold are evidently represented. High gold grades (more than 60 gm/tonne gold) are in multiply-brecciated sites, which contain both matrix gold and gold-quartz veins. The highest grades (more than 2 000 gm /tonne gold) occur in very fine-grained aggregates forming late veinlets, crustiform bands, and clots enclosed by quartz; the aggregates are often spatially close to iron oxides. In general, mercury, arsenic, antimony, barium and possibly fluorine in veins increase with increasing distance away from the Scott Lode, while copper, lead and zinc decrease; the second group of elements tends to increase with depth in the lode. Tellurium, thorium, bismuth and tungsten occur in only low to trace quantities in the lode. Molybdenum and manganese are variable, and are not diagnostic of position.

Gold-associated alteration at Pajingo consists of a series referred to as phyllic and neutral argillic (Porter 1990). Alteration mineral assemblages are silica and illite (phyllic), and interlayered illite-smectite (neutral argillic). Kaolinite (dickite) is regarded as a hypogene phase, and carbonate is seen as the last manifestation of alteration. These pale grey-, pale green-, and cream-coloured assemblages are generally overprinted by red, brown, and orangey-brown ankerite or dolomite, and siderite. Adularia occurs as rare narrow selvages and fillings of deep veinlets, as well as local late infill within lattice quartz in some outcropping veins. Illite and kaolinite pseudomorphs after adularia also occur within quartz.

K-Ar dating of alteration sericite (illite) associated with gold in the Scott Lode has yielded a 330 ± 10 Ma age (Etminan 1989, Porter 1990), suggesting late Early Carboniferous (minimum) precipitation of associated gold.

On a conceptual basis, there are a number of factors which could make the Stones Creek Volcanics a potentially favourable locus for epithermal gold mineralisation, comparable to the Bimurra Volcanics. The most important of these would be: (1) proximal volcano-structural setting; an environment of high, focussed heat and fluid flux; (2) accumulation under probable subaerial but fluviatile conditions, with abundant groundwater; (3) an original high porosity and, probably, permeability; and (4) the oxidised composition of the bulk of the unit, in large part a function of chemical fractionation of precursor magmas.

The predominantly highly oxidised compositions of andesitic rocks in the formation would indicate that a potential gold source was combined with an environment suitable for hydrothermal fluid circulation and metal scavenging. High porosity and permeability are probable because of the substantial proportions of fragmental and vesicular rocks in the unit; lapilli tuffs and clast-supported breccias would be particularly porous and permeable. There is evidence for a compositional continuum between low-silica andesite and rhyolite, providing opportunity for the evolution of a metal-enriched magmatic fluid. Near-surface fluid cooling, by heat exchange with host materials and/or by mixing with "cold" meteoric water, could have initiated gold precipitation. The indication of late, relatively low-temperature, alteration suggests that epithermal-type fluids circulated after the propylitic/spilitic alteration episode. If so, the abundant carbonate present would have rendered the andesitic rocks even more reactive and favourable for the precipitation of any circulating gold.

Star of Hope Formation volcanics

The Bimurra and Stones Creek Volcanics also share many characteristics with volcanic rocks which are provisionally assigned to the Star of Hope Formation in the Burdekin Falls Dam - "Conway" area. The presence of lesser andesitic rocks (which may have played an important part in gold mineralisation - above) in this volcanic interval suggest a somewhat reduced prospectivity from that of the other two units.

Bulgonunna Volcanic Group

Silicified Locharwood Rhyolite occurs within and alongside an approximately 1 km-long segment of an east-northeast-striking fault zone, 5 km northwest of Peak John Well. The silicified ignimbrite contains disseminated pyrite and scattered patches of coarse specularite on joint surfaces. The occurrence has undoubtably attracted the attention of prospectors, although it shows no sign of having been intensively tested. This silicified and pyritic ignimbrite lies (approximately 9 km east of) an apparent dyke of intrusive tuff and breccia (CPx); the silicified/pyritised fault zone and the apparent dyke have nearly orthogonal strikes (east-northeast and northwest respectively). As noted further below, tuff dykes are locally important gold hosts at Mount Leyshon. An elongate small stock of CPr_3-type rhyolite approximately 7 km west-southwest of the northwestern end of the CPx body, west of Glendon Creek and 7.5 km southwest of "Glendon" homestead, is intensely "ironstained" and partially "kaolinised". The structural connection between these occurrences is not clear at the present level of exposure.

Rocks assigned to unit Cub_{21} of the Bulgonunna Volcanic Group ("Locharwood" association) are dominant at Hunter Resources' Limey Dam (gold) Prospect (no 1 on the map), and at the Mount Robin (gold) Mine and Prospect (nos 3 and 4). Intrusive rocks of unit CPr_1 probably also occur at Mount Robin; it is not known whether there is one preferred host for mineral occurrences there. Intense alteration at and around the Mount Robin Prospect occurs in an irregularly north-northwest-elongated area of approximately 1 km^2, with east- and west-directed apophyses and subsidiary patches, suggesting control by two (conjugate?) sets of joints.

Evaluation of the mineral deposit potential within and beneath major remnants of Bulgonunna Volcanic Group rocks is hampered by lack of information on subsurface geometries and structures. This problem is common to all substantial remnants of ignimbrite-dominated sequences in northeastern Australia, all but one (Croydon Volcanic Group) of which are Carboniferous and/or Permian in age. At present none can be regarded as having totally negligible economic potential. The problem will not be alleviated unless and until high-resolution seismic reflection traverses become part of the routine prospecting strategy applied to such sequences.

Lizzie Creek Volcanics and Mount Wickham Rhyolite

The Mount Wickham Rhyolite at Mount Wickham is commonly "ironstained", especially along joint surfaces; however, it never assumes a "gossanous" aspect. Apart from this, no indications of any unusual mineral occurrences or conspicuously intense alteration are known from the Mount Wickham Rhyolite or Lizzie Creek Volcanics in the study area even though the former marks the course of the Millaroo Fault Zone. This is somewhat surprising, because the Millaroo Fault Zone presumably could, potentially, have acted as a conduit for hydrothermal fluids to at least the same extent as it evidently did for viscous rhyolitic magma. Additionally, the Lizzie Creek Volcanics sequence, with or without the overlying Collinsville Coal Measures, would presumably not have been lacking in meteoric and/or connate water.

Joe-De-Little Granite

The location of the Salopia (gold) Mine (no 28 on the map, and discussed under Ukalunda Beds) is somewhat uncertain. Its productive workings could have been in either the Joe-De-Little Granite or the Percy Douglas Granodiorite (below).

Percy Douglas Granodiorite

The Percy Douglas Granodiorite has been host to copper with gold at the Amanda (no 10 on the map), Big Lode (no 34), and Top of the Hill (no 35) Mines, and in the "Copper Contact Zone" at the contact of the granodiorite with Ukalunda Beds, approximately 1.5 km southeast of Mount Wyatt (exploited at the Big Hope Mine, no 23).

Sunbeam Granodiorite

The Sunbeam Granodiorite has hosted all of the productive veins of complex gold-bismuth and argentiferous galena ores which formed the basis of the old Ukalunda Silver Field, except those worked at mines 26, 27 and 28 (Birthday Gift - see Ukalunda Beds, New Years Gift - see Saint Anns Formation, and Salopia - see Ukalunda Beds, respectively) on the map (Jack 1889, Golding & Wilson 1984, de Havelland 1987). The veins are small quartz-filled fissure- and breccia zone-fillings; host rocks are intensely fractured and propylitised (Golding & Wilson 1984). Although hosted by Sunbeam Granodiorite, deposits almost all occur close to the faulted contact with Bulgonunna Volcanic Group (mainly Locharwood Rhyolite) rocks. Many deposits are in intimate spatial association with rhyolite (CPr_1-type) dykes and plugs, suggesting that they essentially occupy a broad fracture/intrusion system peripheral to the Bulgonunna Volcanic Group. The further implication is that mineralisation took place during, or shortly after, interrelated Bulgonunna volcanics extrusive and structural activity. Some of the deposits may still be capable of small-scale exploitation; the Sunbeam (no 11) was being worked as a medium-size opencut (production unknown) during our investigations in 1987 and 1988, while the Walhalla Mine site (22) showed signs of recent activity.

Golding & Wilson (1984) saw the structural setting, spatial proximity of the deposits to Bulgonunna Volcanic Group ignimbrites, the complex mineralogies of the deposits, and the type of associated alteration, as being suggestive of an epithermal origin. The ^{18}O-depletion (relative to "normal" igneous rocks) of sampled "ore", vein material, and/or wall rocks from the Sunbeam, as well as "Pinnacles" (of Golding & Wilson 1984 Table 2, possibly a misprint for Pyramid, no 15 on the map, cf. Golding & Wilson's Figure 3), Daisy (no 16), Big Pyrite (no 18), Carrington (no 19), Golden Mantle (no 21), and Walhalla (no 22), deposits (the Salopia, no 28, also contributed "ore" and wall rock samples) is consistent with a component of meteoric water in the hydrothermal fluid responsible for the alteration and/or mineralisation. Except at the Salopia, the oxygen isotope values recorded from (eleven) vein quartz samples, with a mean of approximately +7.0 $^{o}/oo$ SMOW, are consistent with ore fluids containing a significant proportion of meteoric water (Golding & Wilson 1984). Perhaps more significantly, ^{18}O in 8 "microadamellite" (i.e. CPr_1-type microgranite) wall rock samples from Daisy, Big Pyrite, Carrington and Golden Mantle, has a depleted mean of approximately +2.5 $^{o}/oo$, and ignimbrite and tuff adjacent to the Sunbeam deposit (three samples) are also depleted, with a mean of approximately +2.0 $^{o}/oo$. In contrast, granodiorite hosting the "Pinnacles" deposit may have a "normal" igneous ^{18}O content (+8.3 $^{o}/oo$, based on one sample only). By comparison, extrusive rocks as a whole in the study area show regional (at least 1500 km^2 area) depletion, ranging from -8.2 $^{o}/oo$ to +0.4 $^{o}/oo$, while intrusive rocks (granites to gabbros) are mostly "normal", cf. the granodiorite at "Pinnacles" (e.g. Ewers et al. 1994). It is thus not now clear whether the ^{18}O depletions associated with the Ukalunda Silver Field are cogenetic with, and specific to, its deposits, or whether they fall within the background depletion signature. Available data indicate close similarities between Ukalunda Silver Field and "Ravenswood Type" (specifically "Sunset"-style veins) deposits, and imply a comparable (late Palaeozoic) age.

Un-Named Units CPr_1, CPr_2, CPr_3, and CPx

Brecciated and altered rhyolite, commonly with intrusive tuff and breccia (CPr_1) has been investigated for gold at Hunter Resources' "Breccia Hill" Prospect (no 2 on the map). Variably "gossanous" CPr_1 microgranite on the northeastern flanks of Mount Dalrymple (The Pyramid), about 5 km west of "Pyramid" homestead, has been prospected intermittently (no 29 on the map). The most recent activity appears to have shown that the occurrence falls within a 30 km-long, northeast-trending, diffusely gold-mineralised belt containing at least two ("Gettysberg" and "Marrakesh") economically interesting vein/stockwork/breccia systems " . . . . with associated volcanics and subvolcanic intrusions . . . . " (Louthean 1993 p. 131); maximum gold grades reportedly coincide with chloritic and pyritic breccia. The belt, interpreted as a fault zone, probably coincides with the northeastern boundary of the southwestern to central sectors of the Mount Wyatt - Peak John Well Corridor and its southwestern extension past "Pyramid" homestead towards 13 Mile Dam.

Tentative CPr_1 rocks (with andesitic Bimurra Volcanics and Ukalunda Beds) have been prospected for epithermal gold by BHP at Battery Hill Prospect (no 6). A body of CPr_2 approximately 4 km farther south and apparently in the same north-trending fracture/intrusion system occurs (again with andesitic Bimurra Volcanics and Ukalunda Beds) in the Blue Gum Prospect (14). Equivalent rocks are probably present, although apparently dominated by Bulgonunna Volcanic Group ignimbrite/s of unit Cub_{27}, at the Mount Robin (gold) Mine (no 3) and Prospect (no 4).

Farther afield, the Mount Leyshon deposit (Paull et al. 1990) lies approximately 100 km northwest of Burdekin Falls Dam. The deposit is (with Kidston, cf. Baker & Tullemans 1990) " . . . . one of two world class breccia hosted gold deposits in north Queensland . . . . " (Wormald et al. 1993 p. 62). Mount Leyshon has been responsible for more than half of the approximately 45 tonnes of gold produced to date from the Charters Towers region (Hutton et al. 1993); it is currently producing more than 11 tonnes per year, plus a substantial amount of silver (Toutounji 1993, pp. 60-61), and is expected to continue production into the next Century. Mount Leyshon is the most outstanding example of a group of "Mount Leyshon Type" mesothermal breccia-hosted (of Hutton et al. 1993, Hartley et al. 1994), or porphyry-related (Morrison et al. 1988), gold-silver deposits.

The Mount Leyshon gold deposit itself occurs in a body formed by multiphase (six currently discriminated) igneous intrusion and brecciation events. The breccia has an intrusive magmatic-hydrothermal nature (cf. Sillitoe 1985). Although some possible volcanic rocks are known, the body is not now perceived to be "largely extrusive", as was previously thought (Wormald et al. 1993). In plan, the Mount Leyshon body is roughly circular, but elongataed northeastwards; its average diameter is 1.6 km (Orr 1994). In the third dimension, it is crudely pipe-like. The Mount Leyshon intrusion/breccia body is dominated by the so-called Main Pipe. Near its western (Fenian Granite) wall, the Main Pipe in turn is host to a subsidiary, 400 m by 300 m (in plan), similarly pipe-like, body of breccia (Mount Leyshon Breccia) which is a major source of ore. Trachyandesite dykes postdate brecciation, alteration, and mineralisation. Important local structural controls on sites of brecciation and mineralisation were evidently provided by the dilationally reactivated west-striking contact between the Cambrian Puddler Creek Formation (lower Seventy Mile Range Group) rocks and the Fenian Granite, of Ordovician age (Wormald et al. 1993). Dilation may have been a transtensional response to dextral strike-slip movement along the Mount Leyshon Corridor as a whole. Assay plans of the Mount Leyshon deposit also indicate west-, northwest- and northeast-trending controls on the distribution and geometries of zones of highest-grade.

There is no evidence that Mount Leyshon Breccia broke through to the palaeosurface in any significant way, although the Main Pipe is thought to have probably vented to at least some extent (Orr 1994). Breccia is typically clast-supported and matrix-poor; clasts are mostly of basement material. Two broad stages of hydrothermal activity are evident: (1) an early stage, in the late part of which a quartz-molybdenite-basemetal stockwork developed; (2) a later stage, during which gold in economic amounts was introduced in the northwestern part of the structure. Most (about 80%) economic gold occurs in the Mount Leyshon Breccia. It is carried by a near-vertical northern ore shoot, and a 55° south-southwest-dipping southern one; once again, these ore shoots have pipe-like geometries (Orr 1994). In addition, gold occurs in altered porphyritic intrusives (Wormald et al. 1993). Specifically, a plug-like body of "Mine Porphyry" contributes about 15% of ore (Orr 1994). Gold is mainly free (electrum is minor). It is disseminated in the breccia and in "Mine Porphyry", and also occurs in uncommon relatively high-grade quartz-sulphide (90% pyrite with chalcopyrite, sphalerite, and galena, plus minor complex bismuth sulphides and molybdenite) vein stockworks. Localisation of ore shoots was evidently controlled by channelling of mineralising fluids along the optimally porous and permeable

Mount Leyshon Breccia, and influenced locally by "ponding" of fluids at structural, intrusive and facies-controlled contacts between permeable and less permeable/impermeable breccias and other rock types. Associated alteration assemblages are largely sericite-pyrite (phyllic), or biotite (potassic), with pervasive chlorite-carbonate-anatase (propylitic). Intense alteration has locally produced rocks with a misleading pseudo-fragmental aspect. Precipitation of disseminated gold apparently accompanied replacement of breccia matrix by chlorite-pyrite-quartz, and cavity filling by crystalline quartz, carbonate, sulphides, sulphosalts, chlorite, and gypsum. Most gold occurs in cavity fillings and in quartz-sulphide stockwork veins; 84% is spatially associated with the complex bismuth sulphides (Paull et al. 1990). It has been recognised that there were at least three main phases of gold introduction and precipitation, along with pyrite and other base-metal sulphides, at temperatures decreasing from 450° C (or slightly less) to 300° C. All three recognisable mineralisation phases may have been condensed into a late period in the evolution of the structure as a whole. However, although the age of the Mount Leyshon deposit seems well established in general terms (below), precise timings of individual events within the total spectrum of intrusion and brecciation, and of episodes of gold mineralisation and alteration, are uncertain (Wormald et al. 1993). Thus, possible direct and indirect genetic interrelationships between mineralisation and other types of processes cannot be evaluated.

Fragments of tuffisite, and a complex set of later tuffisite "ring-"dykes (cut by porphyries of Phase IV - Wormald et al. 1993, Orr 1994), both occur at Mount Leyshon. This tuffisite is comparable to material in our unit CPx, which likewise appears to occur in a dyke-like intrusive body. At Mount Leyshon, the tuffisite dykes are localised at and near the margin of the Mount Leyshon Breccia. Tuffisite breccia fragments and tuffisite dykes show textural similarities suggesting a comparable origin (Wormald et al. 1993). Alteration and locally abundant gold within tuffisite suggest that the dykes were important conduits for mineralising fluids, at least temporarily.

The age of mineralisation at Mount Leyshon is most likely Early Permian (approximately 280 Ma - Carr et al. 1988), on the basis of only one K-Ar date from alteration sericite plus Pb-isotope studies. A dominant magmatic ore fluid can be inferred (Paull et al. 1990, Hartley et al. 1993).

Mount Wright (9.5 km northwest of Ravenswood, approximately 75 km northwest of Burdekin Falls Dam) marks the outcrop of a vertically-dipping gold-bearing breccia (with clasts of rhyolite, granite and subordinate andesite) pipe. Gold occurs "free" with sulphides (marcasite, pyrite, minor sphalerite, arsenopyrite, chalcopyrite), siderite, and minor quartz as breccia infill (Henderson 1993, Green et al. 1994). Alteration is sericitic. Although Mount Wright lies within the Mount Leyshon Corridor, there is no obvious single fault or lineament (airphoto or aeromagnetic) which ties Mount Leyshon and Mount Wright more directly to each other (Hartley et al. 1994).

At Mount Canton (approximately 20 km south of Ravenswood and 50 km northwest of Burdekin Falls Dam) a gold-bearing ring-dyke breccia occurs along the margin of a 6 km-diameter sub circular (in plan) late Palaeozoic centred igneous "complex". This centred igneous structure contains fragmental, porphyritic and fine-grained intrusive (and possibly extrusive) rhyolitic to dacitic rocks; it is truncated by younger granite. The occurrence has many porphyry-style features (cf Morrison 1988), although it has a different geological setting and brecciation style (Harmsworth 1994). Breccia typically contains subangular to rounded fragments of the various porphyritic and fine-grained igneous rocks associated with the "complex", along with intensely fractured and sheared Ordovician granite, sedimentary rocks and volcanics. The matrix is made up of " . . . . juvenile glass shards, crystals or rock flour, or any combination of these . . . . " (Harmsworth 1994 p. 38); it is essentially nonporous and impermeable. A core of intrusive ignimbrite and "vesiculated" flow-banded rhyolite in the Mount Canton breccia (Harmsworth 1994) suggests that venting to the palaeosurface may have taken place. Breccia occurs with intrusive components of the structure in swarms of inward-dipping (70^{o} to 80^{o}) cone-sheet-like dykes which strike northeast and north, and are separated by (although at least locally grading into/away from, in the case of the breccia) a screen of "basement". Mineralised breccia has been pervasively altered (probably in three pulses) to silica-sericite-chlorite-pyrite±carbonate (calcite)/ankerite(?); pyrite, pyrrhotite, chalcopyrite, sphalerite, galena, bismuth-silver, and gold mineralisation with calcite is fracture-filling, lesser replaceive, and limited breccia open-space-filling, and is associated with silica-sericite-chlorite±epidote alteration. The most intense alteration occurs in a country-rock milled breccia facies; highest gold grades are in the same milled breccia, particularly in association with prominent fractures and zones of shearing (Harmsworth 1994). Barren calcite is late. Gold is "free", or in an electrum with bismuth; there is no clear association between gold and any of the basemetal sulphides. Mineralisation occurs mainly in microfractures and small shears (perhaps formed by cooling, contraction, and settling-in of the structure), which evidently provided only limited porosity and permeability.

The Mount Canton centred igneous structure lies along an east-northeasterly or northeasterly trend with the broadly comparable Three Sisters, Camp Oven Mountain and Rangeview structures (Harmsworth 1994 Figure 1, cf. Oversby et al. 1980 Figure 3). This 40 km-long grouping of structures occurs southeast of the Ravenswood Corridor and may mark the edge, or a subsidiary part, of that major feature.

Other Late Palaeozoic Mineralisation

An example of what might be buried/concealed beneath (and/or within) late Palaeozoic ignimbrite-dominated sequences is the vein-type mesothermal gold/silver deposit at Ravenswood (Hutton et al. 1993, Hartley et al. 1994). This deposit, 60 km northwest of Burdekin Falls Dam, is of late Palaeozoic age.

The Ravenswood deposit (exemplifying the "Ravenswood Type" of Hutton et al. 1993) is made up of multiphase, quartz-sulphide (1% to 50% , mainly pyrite, sphalerite, chalcopyrite, arsenopyrite, and pyrrhotite, see Green et al. 1994) veins containing complex copper-molybdenum, copper-arsenic, copper-lead-zinc, and bismuth-arsenic-antimony-tellurium-silver element associations (Hartley et al. 1989). Total gold output from Ravenswood to mid-1993 (including alluvial and eluvial production in the early period 1868-72) was slightly more than 30 million gm (Henderson 1993, Green et al.

1994). Veins range from a few centimetres to a few metres wide, and are typically very high-grade (30 to 100 gm/per tonne gold, see Green et al. 1994). In a broader context, Ravenswood may ultimately be related to "Porphyry Style" deposits (Morrison 1988), with the "Ravenswood Type" marking a moderately high to high crustal level. Granitoids usually host "Ravenswood Type", and the deposits seem to be almost invariably associated spatially with mafic (or at least melanocratic) dykes.

At Ravenswood itself, auriferous quartz-sulphide-dominated fracture-infillings in fine- and medium-grained tonalitic components of the Ravenswood Granodiorite Complex have yielded more than 80% of gold produced to date. The large and conspicuous Buck Reef is now the single most important source of ore, although effectively barren to earlier generations of miners. It is the main component of a group of internally fissured and brecciated shear-zone structures (Green et al. 1994). The Buck Reef has a strike length of 2 km, with widths of less than 1 m to greater than 10 m (Henderson 1993); ore shoots are 4 m to 40 m wide, with typical gold grades of 2 gm to 3 gm per tonne (Green et al. 1994). Associated "Sunset" style (of Green et al. 1994) veins are simpler pipe- or sheet-like dilational fissure features (Neindorf et al. 1989); most previous gold production came from this class of structure. Veins of the "Sunset" style cut the Buck Reef and related structures (Green et al. 1994). Quartz-growth shapes in the "Sunset" veins, and in dilated and brecciated sections of "Buck Reef"-style structures, are variable, although cockscomb crystal aggregates (cavity-filling) are typical. Biotite (chlorite)-altered and/or replaced "shear" sections of "Buck Reef" structures have also been mineralised. This style has internal and marginal alteration assemblages typified by a sericite- and chlorite-rich core surrounded by a biotitic halo; patches of sericite, pyrite and silica, also occur. Veins of the "Sunset" style are rimmed by narrow selvages of sericitic-rich alteration material, grading outwards into host granitoid containing chloritised ferromagnesian minerals.

At Ravenswood, the mineralisation has been dated (K-Ar, two samples of sericite from gold-associated alteration) at 310$\pm$3 Ma to 296$\pm$2 Ma (Neindorf et al. 1989, 1993), i.e. Late Carboniferous. Carr et al. (1988) reported Pb-isotopic ages in the 260 Ma to 245 Ma range, i.e. mid- to latest Permian, from veins in the Ravenswood area.

Undated but possibly late Palaeozoic gold-bearing veins (collectively making up the main "Puddler Creek Type" deposit - below), broadly similar in style, mineralogy, and element associations to the Sunset Type ones at Ravenswood, occur on the flanks of Mount Leyshon. Comparable late Palaeozoic (or possibly younger) deposits are also known in and adjacent to the Carboniferous and/or Permian intrusive-extrusive structures (e.g. Mount Cornishman) in the Mount Leyshon Corridor farther to the northeast (Hartley et al. 1994). To the same extent, individual components of the Sunbeam Granodiorite deposit group near "Ukalunda" (above) are reminiscent of small "Sunset" type veins.

The Puddler Creek Formation (a metasedimentary rock unit, composed mainly of craton-derived material, making up the lower Seventy Mile Range Group and overlain by Mount Windsor Volcanics) south of Mount Leyshon hosts mesothermal "Puddler Creek Type" gold and silver deposits (Hutton et al. 1993, Hartley et al. 1994). A group of east-southeast-striking and steeply south-dipping auriferous quartz veins containing minor carbonate and pyrite comprise these deposits. Veins also cut members of a mafic (microdiorite) dyke swarm which intrudes the sequence (Hutton et al. 1993, Hartley et al. 1994). These dykes are younger than at least one Ordovician granitoid (Fenian Granite), and are probably late Palaeozoic(?). Worked vein widths are less than 1 m, but one line of work (Welcome, Welcome West) extends for more than 1 km. No significant alteration is evident. However, a group of similarly hosted auriferous quartz vein deposits in a group to the south of Ravenswood have limited alteration selvages. It has been conjectured that "Puddler Creek Type" veins may be related to "Charters Towers Type", deposits because they are "not dissimilar" (Hutton et al. 1993), despite having conspicuously lower sulphide contents, and ". . . . there appears to be a spatial relationship with the Trieste-Brookville area (Charters Towers type) suggesting a common mineralising event . . . ." (Hartley et al. 1994 p.9). However, these observations have not yet been supported by any less subjective data. In contradiction is the spatial association of "Puddler Creek Type" deposits with Mount Leyshon, and the distinct possibility that the mafic dykes cut by "Puddler Creek" veins at Mount Leyshon there are of similar late Palaeozoic age to mineralisation there. A "Puddler Creek Type" vein occurrence has been recognised near the late Palaeozoic Ravenswood deposit. These contradictory data combine with broad similarities in deposit style, mineralogy, and element associations, between "Puddler Creek Type" and "Ravenswood Type" deposits, to suggest that the two types may well be penecontemporaneous and genetically related.

Suttor Formation

Gold has been won intermittently from conglomerates in palaeochannels in the Suttor Formation at Rutherfords Table (no 33 on the map) (Olgers 1972, de Havelland 1987), where the formation overlies the Percy Douglas Granodiorite. Although palaeodrainage directions appear to be west and north, the provenance of the clastic gold (small rounded and pitted flakes and scales, mostly up to 2 mm in maximum dimension - Levingston 1953, Olgers 1972) is not known. Wire gold has also been recorded, suggesting supergene mobilisation and reprecipitation. The Rutherfords Table deposit was being exploited on a small to medium scale in 1987.

Cainozoic Alluvium

Gold has been won from Recent alluvium in the Burdekin River (no 5 on the map), about 3 km east-northeast of Burdekin Falls Dam (de Havelland 1987). It is also known from Isabella Creek near its junction with the Sellheim River (no 7), and from gullies (including "Mutton Gully" - no 32) on the northern side of that river to the east of Rutherfords Table (de Havelland 1987). Workings may originally have been more widespread in the study area in the 1880s, particularly in the central-south and southeast, than is now apparent.

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APPENDIX I: New, Revised, and Refined Formal Stratigraphic Units

1: Stones Creek Volcanics (*new formation*)

The Stones Creek Volcanics, in the Drummond Basin sequence, are named from Stones Creek, a northern tributary of the Burdekin River which it joins 10 km northeast of Burdekin Falls Dam. The type section of the formation is along or close to the track between "Glenroy" outstation and Stuart Pocket, from grid reference 8356-154332 (unconformable lower contact with the Mount Windsor Volcanics) for about 4 km nearly due south to grid reference 8356-150293 (conformable upper contact with Scartwater Formation). The Stones Creek Volcanics sequence is about 2800 m thick in its type section.

Supplementary sections of the Stones Creek Volcanics in the vicinity of the type section occur in Stones Creek between grid references 8356-172255 and 8356-192248, and on the western bank of Packhorse Creek at and in the vicinity of grid reference 8356-217253. The Stones Creek supplementary section contains about 1000 m of well exposed andesitic fragmental (pyroclastic with minor epiclastic) rocks; the Packhorse Creek supplementary section includes excellently exposed andesitic ignimbrite. In middle Bell Creek farther south, the Stones Creek Volcanics are exposed in a locally faulted and intruded reference section, 1.7 km long and almost due south-trending, between the top of the formation (overlain by Star of Hope Formation) at grid reference 8356-104045 near the "Myall Creek" access road, and the edge of a small stock of un-named Elizabeth Creek-type granite (CPg_8) at grid reference 8356-105026. The Stones Creek Volcanics sequence in this section contains (in descending stratigraphic order, as encountered in the section) a sheet of rhyolitic ignimbrite, sedimentary rocks (mostly sandstones, in part volcaniclastic), and massive to well-bedded fragmental andesites.

The formation is underlain by the Saint Anns Formation, overlain by the Scartwater Formation, and locally interfingers with both. On the basis of this stratigraphic position and palaeobotanical evidence (in particular, the lack of *Leptophloeum australe*), an Early Carboniferous, though not earliest Carboniferous, age is preferred for the Stones Creek Volcanics sequence.

2: Bulgonunna Volcanic Group

The formation-rank Bulgonunna Volcanics as originally defined by Malone et al. (1964) were raised to group rank, and renamed accordingly, by Hutton et al. (1991). The re-ranking/renaming, and the adjustment in definition following on by implication, have been adopted throughout this study.

2a: Earlscliffe Dacite (*new formation in Bulgonunna Volcanic Group*)

Named from the Parish of Earlscliffe, in the southeastern part of the study area, the Earlscliffe Dacite consists of grey, and locally green to buff, welded rhyolitic ignimbrite/s. The type section, in a very clast-poor and virtually quartz-free variant ($Cube_3$), lies on Mount Landsborough. It extends from the apparently conformable contact of the formation with lower "Earlscliffe" association ignimbrite (Cub_1) exposed on a spur between gullies leading to a western tributary of the Sellheim River at grid reference 8356-347897, west-northwest via Mount Landsborough summit (grid reference 8356-342898) for 1.7 km to a faulted contact with Cub_1 at grid reference 8356-331899. No stratigraphic top is preserved. The Earlscliffe Dacite is approximately 150 m thick in its type section.

A reference section embracing correlatives (in part tentative) of the formation at Mount Landsborough, plus the variably clast-rich and quartz-bearing probable variants ($Cube_1$, $Cube_2$), extends roughly southwest for approximately 4 km along a sinuous branch of the main western tributary of Ten Mile Creek, approximately 25 km northeast of "Conway" homestead. The section commences at the junction with the main tributary at grid reference 8356-576988, in an ignimbrite essentially the same as type Earlscliffe Dacite on Mount Landsborough. From there it passes, at grid reference 8356-570984, apparently gradationally downwards into a more clast-rich variety. This persists to grid reference 8356-566978, where an apparently overlying ignimbrite similar to the one at the commencement of the section, but somewhat more clast-rich, re-occurs. At grid reference 8356-560971 the gradational contact with a quartz-bearing dacitic ignimbrite is reached; this ignimbrite may be at a higher stratigraphic level than the preceding one. The section ends at the edge of an irregular small stock of probably intrusive rhyolite at grid reference 8356-557964.

Circumstantial evidence suggests that the Earlscliffe Dacite is older than the Locharwood Rhyolite, and thus of approximately early Late Carboniferous age. However, this evaluation of the evidence remains to be confirmed by isotopic geochronology or other means.

2b: Bobby Dazzler Rhyolite (*provisional type/reference section*)

The Bobby Dazzler Rhyolite consists of grey to buff, welded, rhyolitic ignimbrite. A reference section (the provisional type section, pending possible formal nomination of a better one by Hutton and co-workers) for the Bobby Dazzler Rhyolite in the Burdekin Falls Dam - "Conway" area occurs in the vicinity of Whitestone Peak, about 10 km east of "Conway" homestead. The section begins at a faulted contact with possible Earlscliffe Dacite in a southern tributary of Bobby Dazzler Creek at grid reference 8356-496812, and proceeds southeast along the tributary for approximately 1.8 km to an irregular but apparently stratigraphic contact with an un-named "Earlscliffe" association ignimbrite (Cub_7). The section probably crosses a fault at grid reference 8356-497811.

Approximately 400 m southwest of the beginning point of the reference section, towards the next gully, a 400 m length of north-northwest-striking stratigraphic contact between Bobby Dazzler Rhyolite (above) and Earlscliffe Dacite? (?Cube) may be preserved. The Bobby Dazzler Rhyolite is approximately 30 m thick in the reference section.

Field relationships to the south of "Conway" suggest that the Bobby Dazzler Rhyolite underlies the Locharwood Rhyolite; to the east of "Conway" it overlies tentative Earlscliffe Dacite, but is overlain by an un-named rhyolitic ignimbrite (Cub_7) of uncertain stratigraphic affinity. The weight of available evidence suggests that the formation has an age close to that of the Earlscliffe Dacite, i.e. approximately early Late Carboniferous.

2c: Pyramid Rhyolite (*new formation in Bulgonunna Volcanic Group*)

The Pyramid Rhyolite consists mainly of purple, welded, rhyolitic ignimbrites. It is named from the Pyramid Range, on the western side of the Sellheim River opposite "Ukalunda" and "Pyramid" homesteads; its type section is in the southern part of the range. The section extends from the base of the formation (which unconformably overlies the Saint Anns Formation in this area) at grid reference 8356-093862 for 250 m up slope to the local limit of exposure at grid reference 8356-097861. The top of the lower nonwelded and "chalky" part of the formation (which here apparently grades into the main upper welded part) occurs approximately at grid reference 8356-094861. Lower Pyramid Rhyolite in the type section is 30 m thick; the upper part is estimated to be about 70 m thick.

A supplementary section of thicker Pyramid Rhyolite in the northwestern Pyramid Range extends from its base at grid reference 8356-105910 up slopes and benches for 800 m to the local limit of exposure at grid reference 8356-108903. In this area, the ignimbrite (conformably?) overlies un-named late Palaeozoic conglomerate and rhyolite (probably lava), which in their turn unconformably overlie the Saint Anns Formation. In the section, the top of the approximately 20 m-thick lower part of the unit occurs at grid reference 8356-105909.

A second supplementary section of the formation, illustrating a clast-rich facies of its (main) upper welded part, is in an eastern tributary of upper Bell Creek to the north of the Sunbeam Mine. This section extends from a fault and local lower limit of exposure at grid reference 8356-205986 for about 300 m downstream to a discordant (unconformable and possibly slightly faulted) contact with overlying Locharwood Rhyolite (the main welded part) at grid reference 8356-203986.

The Pyramid Rhyolite is believed to have been in stratigraphic contact with underlying tentative "Earlscliffe" association ignimbrite Cub_8, and to have originally underlain isotopically dated (approximately mid-Late Carboniferous) Locharwood Rhyolite. In the absence of definitive data, the age of the formation is assumed to be the same as that of the Locharwood Rhyolite.

2d: Collins Creek Rhyolite (*new formation in Bulgonunna Volcanic Group*)

The Collins Creek Rhyolite consists of grey, welded, rhyolitic ignimbrite characterised especially by a high proportion of large (5 mm) quartz crystals. The formation is named from Collins Creek, an eastern tributary of Glendon Creek which it joins at "Glendon" homestead.

Because of faults and numerous intrusive bodies, the type section of the Collins Creek Rhyolite is in two separate parts. The western, stratigraphically lower, part begins at the base of the unit (contact with tentative "Earlscliffe" association ignimbrite) exposed in a southern tributary of Collins Creek at grid reference 8356-244110. It extends downstream (north) along the tributary for 850 m to Collins Creek, and then down (north-northwest and northwest) and beside the creek approximately along strike for 1.1 km to the mouth of a southwestern tributary at grid reference 8356-241126, where the unit is cut by intrusive rhyolite and microgranite. This end-point may not be far above the base of the Collins Creek Rhyolite sheet. The eastern portion of the type section recommences about mid-way through the Collins Creek Rhyolite sheet, at the junction of Gap Creek and a northeastern tributary (grid reference 8356-328088). The section extends northeast up the somewhat tortuous tributary for slightly more than 1.6 km to grid reference 8356-337103. From there the final segment of the section ascends a subsidiary gully north-northwest for 600 m to the contact between the Collins Creek Rhyolite and the overlying Locharwood Rhyolite (grid reference 8356-336107). In the type section and its vicinity, the Collins Creek Rhyolite is at least 200 m thick.

A supplementary section of Collins Creek Rhyolite displays the contact between the unit and the underlying sediment-dominated Stones Creek Volcanics on the northwestern slope of a spur to the south of lower Bull Creek at grid reference 8356-227283. From there the section extends southeast for 250 m over the crest of the spur to a gully at grid reference 8356-229282, then down the gully to Bull Creek at grid reference 8356-234284. It continues in and beside Bull Creek downstream (roughly southeast) for approximately 4 km to grid reference 8356-259265, then slightly west of north, up a spur, for 550 m to the base of the Locharwood Rhyolite at grid reference 8356-258271. Minor internal faults are crossed at grid references 8356-229282 (and followed for 200 m along a linear section of gully), 8356-234284 and 8356-257263.

The Collins Creek Rhyolite overlies tentative "Earlscliffe" association ignimbrite, apparently with angular unconformity. The formation is overlain, probably para-conformably (disconformably?) by the approximately mid-Late Carboniferous Locharwood Rhyolite; the two formations are assumed to be of essentially the same age.

2e: Locharwood Rhyolite (*provisional type and supplementary sections*)

The Locharwood Rhyolite is dominated by buff to grey, welded, rhyolitic ignimbrite. A provisional type section of the formation (pending formal nomination of a more appropriate type section or locality farther south, where the formation was originally recognised and named, by Hutton and co-workers) lies to the northeast of "Ukalunda" homestead. It extends from the contact between the formation and the House and Kitchen Granite at grid reference 8356-162930, for 400 m downstream along an un-named creek to a tributary at grid reference 8356-158927, and then for 150 m up this tributary to a moderately extensive irregular rock pavement (and geochronological sample site - below and Appendix 2) at the top of a series of low waterfalls, at grid reference 8356-157929.

To the north, a supplementary section in the formation to the northeast of lower Bull Creek extends from the lower contact of the unit with the Collins Creek Rhyolite at grid reference 8356-258271, northeast up a spur for 500 m onto the crest of a ridge and possible local limit of exposure at grid reference 8356-262276; the section crosses a minor fault (no displacement of the formation's base is detectable at airphoto scale) at grid reference 8356-259272.

A second supplementary section is situated to the west-northwest of Peak John Well. It extends from a probable faulted contact with Bulgonunna Volcanic Group unit Cub_{17} at grid reference 8356-367055, north-northeast and then north-northwest up a gully for 1.7 km to the local limit of exposure on the crest of a ridge at grid reference 8356-363069.

A third supplementary section of the Locharwood Rhyolite lies to the west of the Sunbeam Mine. It extends from the base of the formation (here underlain by rhyolitic ignimbrite tentatively placed in the "Earlscliffe" association) at grid reference 8356-203924, west-northwest uphill for 400 m to the local limit of exposure at grid reference 8356-199925.

Another supplementary section in the vicinity of the Sunbeam Mine extends from the contact between the unit and probable dacitic lava assigned to the "Earlscliffe" association at grid reference 8356-227931, west-northwest uphill for 400 m again to the local limit of exposure at grid reference 8356-234932.

Zircon U-Pb data from the Locharwood Rhyolite in the provisional type section indicate that the rocks here are almost certainly of exactly the same mid-Late Carboniferous age (approximately 305 Ma) as "type" Locharwood Rhyolite from the Mount Coolon area (Black, 1994; Appendix 2).

2f: Smedley Dacite (*new formation in Bulgonunna Volcanic Group*)

The Smedley Dacite is a grey, welded, dacitic ignimbrite named from the Parish of Smedley, in the west-central part of the study area. Its type section is in the approximately 600 m-long road cutting on the northwestern side of the Burdekin River and downstream of Burdekin Falls Dam between grid references 8356-148171 and 8356-153167. The Smedley Dacite is at least 90 m thick in and near its type section.

Supplementary sections of the Smedley Dacite occur 1 km northeast and about 4 km south-southwest of Burdekin Falls Dam. The former extends from the probably slightly unconformable base of the formation, which lies on an un-named welded rhyolitic ignimbrite belonging to the same "Smedley" dacite-rhyolite association, in a steep gully at grid reference 8356-157180, up slopes for about 550 m south to the local upper limit of exposure (and minor topographic summit) at grid reference 8356-157175.

The second supplementary section extends from the lower limit of exposure in the bed of Coopers Creek at grid reference 8356-138132, up a minor gully for about 300 m to the unconformable base of the lower interval of the Arundel Rhyolite (upper rhyolite-dominated association) at grid reference 8356-136132.

The Smedley Dacite is probably of very earliest Early Permian age, on a basis of zircon U-Pb geochronology (Black 1994; Appendix 2).

2g: Arundel Rhyolite (*new formation in Bulgonunna Volcanic Group*)

The Arundel Rhyolite is made up of rhyolitic ignimbrites. The formation is named from the Parish of Arundel, in the west-central part of the Burdekin Falls Dam - "Conway" area. The type section of the Arundel Rhyolite lies at the southwestern corner of the plateau between the new "Myall Creek" homestead and Coopers Creek, in an un-named eastern tributary of Cockatoo Creek. The base of the formation (here underlain unconformably by the Star of Hope Formation) occurs at grid reference 8356-068106. From there the section extends for 600 m southeast and south-southwest up a gully and slope to a ridge crest at grid reference 8356-058100. The contact between the lower and upper un-named member-rank subunits is at grid reference 8356-069105, in the type section.

Heterogeneous lower Arundel Rhyolite (Cub_1 on the map) ignimbrite in the unit's type section is 250 m thick; at least 200 m, possibly considerably more, of preserved upper Arundel Rhyolite ($Cuba_2$ on the map - grey welded rhyolitic ignimbrite) occur in and adjacent to the section. The original stratigraphic top of the formation has been removed by erosion.

Supplementary sections of the Arundel Rhyolite occur at the southwestern and northeastern corners of the "Myall Creek" - Coopers Creek plateau. The first of these, in a northern tributary of Myall Creek, has two parts; it commences at the base of the formation (unconformably overlying the Star of Hope Formation) at grid reference 8356-059079. From there the section extends for 300 m up a gully and power line track to the Tertiary Suttor Formation at grid reference 8356-062080. It recommences at grid reference 8356-065083 and extends for an additional 500 m uphill to a ridge crest at grid reference 8356-069085. The contact between the lower and upper subunits of the formation is concealed by the Suttor Formation.

The second supplementary section of the Arundel Rhyolite extends for 400 m from the head of a minor gully and up slopes on the western side of Coopers Creek between grid reference 8356-136132 (unconformable lower contact with the Smedley Dacite of the "Smedley" rhyolite-dacite association) to the local limit of exposure at grid reference

8356-132130. The top of the lower subunit is at grid reference 9356-135132 in this section.

The Arundel Rhyolite has given a zircon U-Pb isotopic age indicating that its age is probably early Early Permian (Black 1994; Appendix 2).

3: Mount Wickham Rhyolite (*revised formation*)

The Mount Wickham Rhyolite of Paine et al. (1974) is here revised to contain only the rhyolite sequence at Mount Wickham. The sequence probably partly consists of intrusive material, which is likely to be cogenetic and continuous with any extrusive component.

The type section of the restricted unit lies about 800 m southeast of Mount Wickham summit; it extends from the unit's contact with granitoid at grid reference 8356-462393, for 900 m north- northeast to the local limit of exposure at grid reference 8356-464402. The proportions of extrusive and intrusive rocks in the section are not known. About 200 m of exposed Mount Wickham Rhyolite are present on the mountain.

The relationships of the Mount Wickham Rhyolite, as redefined, to the Lizzie Creek Volcanics, and to other parts of the local Bowen Basin sequence, are not known. The precise age of the unit is also not known. It is thought most likely to be Permian; an age extension for the redefined unit into the Triassic Period cannot be justified.

Assuming that extrusive rocks occur at Mount Wickham (which is currently not proven), the entity bearing the name Mount Wickham Rhyolite can be regarded as being effectively a formation. If future studies indicate that this entity consists entirely of intrusive material, a further revision of the unit will be necessary.

4: House and Kitchen Granite (*new formation-equivalent unit*)

The House and Kitchen Granite consists of mid-pink to pale red, fine-grained, aphyric to sparsely porphyritic, "aplitic" granite. The unit occurs in a crudely circular, medium-sized (about 80 km^2) stock between Bell Creek and the Sellheim River. It is named from the House and Kitchen, a pair of butte-like hills (of the overlying Suttor Formation) at grid references 8356-098997 (house) and 8356-098007 (kitchen), between middle Bell Creek and the Sellheim River.

The type area of the unit is at and around grid reference 8356-099991, 0.8 km south-southeast of the summit of the House.

The House and Kitchen granite intrudes to the level of the Stones Creek Volcanics-Scartwater Formation. It is overlain nonconformably by (tentative and undated) "Earlscliffe" association Bulgonunna Volcanic Group, and by isotopically dated (Late Carboniferous) Locharwood Rhyolite.

5: Peak John Well Granite (*new formation-equivalent unit*)

The Peak John Well Granite consists of biotite-only granite and lesser granodiorite. It occurs in two (almost three) irregular but variably east-northeast- to northeast-elongated bodies extending from approximately 2 km north-northwest of Peak John Well to beyond the upper Sellheim River, a maximum of 10 km south-southwest of the Well. The unit is named from Peak John Well.

Type Peak John Well Granite consists of very pale grey, medium- to coarse-equigrained, biotite granite in good exposures at and in the vicinity of grid reference 8356-392030, on both sides of a track 1.4 km south-southeast of Peak John Well, and approximately 0.5 km northwest of Mount Magnus. Excellent exposures of a more felsic, "white", phase of similar grain size also occur on Mount Magnus itself; the boundary between this phase and type Peak John Well Granite is at a break of slope about 100 m southeast of the track.

A Rb-Sr whole-rock plus biotite age of 324.0±3.0 Ma, revised to 328.0+3.0 Ma (unpublished AMDEL Report G 8037/89 and A.W. Webb personal communication 1990, respectively), the latter with an initial strontium isotopic ratio of 0.7253, has been given by a sample (88502866) of granodioritic Peak John Well granite from grid reference 8356-370047, 2.1 km west-northwest of Peak John Well. This is the only geochronological evidence for mid-Carboniferous magmatism in the Burdekin Falls Dam - "Conway" area. The high initial strontium isotopic ratio implies an old (i.e. Proterozoic) crustal source and/or an age even older than approximately 330 Ma for the rock.

6: Joe-De-Little Granite (*new formation-equivalent unit*)

This unit consists mainly of pale to mid-grey to pinkish-grey, fine- to medium-equigranular, hornblende-biotite granite. Granodiorite occurs locally; the most mafic rock noted contains approximately equal proportions of hornblende and biotite. The Joe-De-Little Granite crops out in a pair of irregular bodies extending southwest from 1.5 km north of Mount Joe-De-Little, in the Percy Douglas Range about 9 km east-northeast of "Pyramid" homestead, to the southern edge of the study area, and for an unknown distance (probably more than 5 km) beyond. The name is derived from Mount Joe-De-Little.

The type Joe-De-Little Granite crops out as tors on the north side of the "Pyramid" road 700 m west-southwest of the summit of Mount Joe-De-Little and 3 km southwest of the Sunbeam Mine (at and around grid reference 8356-212898).

A sample (88302105) of the dominant hornblende-biotite granite variant of Joe-De-Little Granite from the unit's type area has given a Rb-Sr whole-rock plus biotite age of 301.0±3.0 Ma (unpublished AMDEL Report G 8037/89). However, the unit appears to be overlain nonconformably by tentative Locharwood Rhyolite (Bulgonunna Volcanic Group) beside Two Mile Creek in the vicinity of grid reference 8356-192907. If these relationships, and the identification of the Locharwood Rhyolite, are correct, then the Joe-

De-Little Granite's Rb-Sr age is low (i.e. it should be older than approximately 305 Ma - early or mid-Late Carboniferous). The Joe-De-Little Granite is in mainly faulted contact with the Sunbeam Granodiorite; the map trace of an intrusive contact between the two granitoids is ambiguous in terms of interpreting relative ages of the pair.

7: Percy Douglas Granodiorite (*new formation-equivalent unit*)

This unit typically consists of pale to mid-grey, fine- to medium-equigranular, hornblende-biotite granodiorite, very similar to more mafic variants of the Joe-De-Little Granite. Microgranitoid enclaves are common in the unit. The Percy Douglas Granodiorite makes up an irregularly elongated stock extending south-southwest and southwest from the southern side of Reginald Peak for about 20 km to the southern edge of the study area, and probably for at least an additional 5 km beyond.

The unit is named from Percy Douglas Creek, which has its headwaters to the north of "Old Hidden Valley" homestead and joins the Sellheim River opposite "New Hidden Valley" homestead. Tors on the southern bank of the Sellheim River immediately east of the main road causeway (at and in the vicinity of grid reference 8356-238793) comprise the type occurrence of the unit.

The Percy Douglas Granodiorite in the study area intrudes no higher than Mount Wyatt Formation; it is faulted against tentative Bimurra Volcanics and "Locharwood" association Bulgonunna Volcanic Group. It is one of several hornblende-bearing granitoid units in the southern part of the study area, but is geochemically distinctive. The Percy Douglas Granodiorite is assumed to be of Late Carboniferous age.

8: Roscow Granite (*new formation-equivalent unit*)

The Roscow Granite is a composite unit. It contains an older (and generally peripheral) un-named subunit ($CPgr_1$) of dark grey, fine- to medium-equigranular, granodiorite to quartz monzodiorite, and a younger (generally central) subunit ($CPgr_2$) made up of pink, very fine saccharoidal-textured, "aplitic" granite or medium-equigranular granite. A coarse graphic texture is common in the granite. Roscow Granite crops out in a single 25 km^2, south-southeast-trending ovoid, stock which extends from about 1.5 km south of the summit of Mount Landsborough to 1 km south-southeast of Mount Tindale.

The Roscow Granite is named from Mount Roscow, 5.5 km north-northwest of "Conway" homestead. Outcrops of melagranodiorite (subunit $CPgr_1$) on the southern side of the Sellheim River 3.8 km west-northwest of the summit of Mount Roscow (grid reference 8356-320845) constitute the type Roscow Granite. The bed of the Sellheim River at grid reference 8356-339862 (3.0 km northwest of Mount Roscow) provides a reference locality for the granite subunit $CPgr_2$; at this locality the granite can be observed cutting granodiorite.

The Roscow Granite probably intrudes the "Earlscliffe" association of the Bulgonunna Volcanic Group. Despite some slight differences, the granodioritic subunit can be grouped geochemically with other late Palaeozoic granodiorites (and hornblende-bearing granites) from the southern part of the study area as a single suite. The Roscow Granite is thus assumed to be of approximately the same Late Carboniferous age as the Joe-De-Little Granite and the other southern granitoids.

<u>9: Stuart Pocket Granite</u> (*new formation-equivalent unit*)

The Stuart Pocket Granite consists of orangey-pink to buff, coarsely equigranular, biotite granite. It crops out in a small (about 10 km^2), irregular northeast-elongated ovoid stock to the west of middle Glenroy Creek, 11 km north-northeast of "Glenroy" outstation.

The unit is named from Stuart Pocket, which is a topographical feature coinciding with the position of the granite stock. The type area is in lower Six Mile Creek, at and around grid reference 8357-145387; access is difficult. A more accessible supplementary occurrence of the Stuart Pocket Granite is on a track between Stuart Pocket and Six Mile Creek, at and around grid reference 8357-156363. Outcrops are of limited extent, and the rock is very altered (weathered?).

The Stuart Pocket Granite as currently exposed apparently cuts the Stones Creek Volcanics; the granite is thought most likely to be of Carboniferous or Permian age. However, Stones Creek Volcanics sedimentary rocks adjacent to the granite are not obviously hornfelsed, and they contain clastic material that could have come from the granite. Additionally, the granite is significantly more deformed than most associated granitoids. A mid-Palaeozoic or older age is thus not ruled out.

<u>10: Sunbeam Granodiorite</u> (*new formation-equivalent unit*)

The Sunbeam Granodiorite consists of dark, slightly greenish, grey, fine- to medium-equigranular, hornblende-biotite granodiorite. The unit is named from the Sunbeam Mine, located at grid reference 8356-223925, 10 km east-northeast of "Ukalunda" homestead. It extends from around the mine to the eastern side of the Sellheim River at the mouth of Willie Moore Creek (1.5 km north of "Ukalunda" homestead).

The type area of the unit is in, and immediately south of, the deep box-shaped opencut that represents the most recent reworking of the Sunbeam Mine.

Exposures of the Sunbeam Granodiorite which are as good as those at the mine (and less liable to concealment by opencut collapse and/or disturbance by future mining) exist along Two Mile Creek, 3 km to the southwest (at and close to grid reference 8356-196913), and in the area of the old Pyramid Mine, 2 km north-northeast of "Ukalunda" (at and around grid reference 8356- 134906). These two areas are accordingly nominated as supplements to the type.

The Sunbeam granodiorite intrudes to the level of tentative Saint Anns Formation; it is commonly faulted against Bulgonunna Volcanic Group rocks, but also appears to be overlain nonconformably by tentative Locharwood Rhyolite in the vicinity of grid reference 8356-192907, beside Two Mile Creek. Age relationships between the Sunbeam Granodiorite and the adjacent Joe-De-Little Granite are not known, but the two units are assumed to be of broadly similar, mid-Late Carboniferous age.

11: Easter Granodiorite (*new formation-equivalent unit*)

The Easter Granodiorite consists of pale grey, fine- to medium-equigranular, hornblende-biotite granodiorite verging on tonalite, containing ubiquitous accessory magnetite and sphene. The unit is named from Easter Pastoral Holding, in the central part of the Burdekin Falls Dam - "Conway" area.

The type occurrences (where the rock is an homogeneous felsic granodiorite) crop out in pavements and shelves between the Burdekin Falls Dam road and a northern tributary of middle Bell Creek on the western side of the road, 1.5 km northeast of the turnoff to "Myall Creek" homestead.

A sample of Easter Granodiorite from the unit's type area has given a U-Pb zircon age of approximately 290 Ma, i.e. Early Permian (Black 1994 and Appendix 2).

12: Nostone Creek Granodiorite (*new formation-equivalent unit*)

This unit consists of pale to mid-, slightly pinkish, grey, medium-equigranular hornblende-biotite granodiorite grading to quartz monzodiorite; it occurs in a crudely hook- shaped, west-northwest-trending, small stock about 9 km long, approximately 5 km south of the junction of Nostone Creek with Ten Mile Creek. Nostone Creek Granodiorite is named from the former creek.

The type locality (where the rock type is melagranodiorite) is on a low rise to the south of a track at grid reference 8356-655932. Nostone Creek Granodiorite at the type locality has yielded a U-Pb age from contained zircon of approximately 290 Ma (Black 1994; Appendix 2). This is younger than the Late Carboniferous age indicated (by Rb-Sr isotopic data) for Joe-De-Little Granite, which appears to be geochemically related.

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APPENDIX 2: U-Pb Zircon Geochronology, by L.P. Black

Introduction

This Appendix summarises important aspects of a specialist geochronological investigation undertaken specifically in support of the Burdekin Falls Dam - "Conway" area study. All zircon analyses were obtained from the Australian National University's (Research School of Earth Sciences) Sensitive High-Resolution Ion-MicroProbe (SHRIMP) facility. This instrument, and its SHRIMP II successor, are particularly useful for the selective analysis of parts of individual zircon grains, thereby avoiding metamict or cracked material which might well not have preserved closed U-Th-Pb systematics since original crystallisation. The instruments also permit the separate analysis of cores and rims within single grains. Fuller details of the data summarised here appear in Black (1994).

Although zircons of hydrothermal origin and potentially anomalous age have been recognised at times, there is no evidence to suggest that they occur in any of the rocks (even the altered Stones Creek Volcanics samples, discussed below) analysed during this investigation. With a few exceptions, which can be attributed to inheritance, ages obtained from the various analyses are firmly believed by this author to represent times of crystallisation/deposition of the rocks involved. In the case of ignimbrites (and other extrusive rocks), it could be argued that zircon crystallisation may have begun pre-eruptively, in high (crustal)-level magma chamber sources. However, in most cases the time interval between any such early crystallisation and final incorporation of material into the surficial stratigraphic record would be trivial, i.e. thousands, rather than millions, of years at most. Any significant exceptions would be detectable by SHRIMP.

In common with this and other SHRIMP studies, ^{208}Pb correction for common Pb produces a slightly normally discordant mean value for the isotopic data array (Black 1994 Figure 3), although this is not obvious from the errors associated with individual analyses. As this effect would lead to the calculation of slightly excessive ^{206}Pb/^{238}U ages, the ^{207}Pb common Pb correction technique (which assumes that data points are concordant) has been used throughout this investigation to derive ages for all Palaeozoic grains. Precambrian grains have been ^{204}Pb-corrected because some showed evidence of disturbed U-Th-Pb systematics.

Initial ^{87}Sr/^{86}Sr compositions for a selection of the analysed samples (Black 1994 Table 2) are all similar, even though low relative to "average" felsic rocks. Values of 0.7046 and 0.7044 for the two granitoid samples 88302095 (Easter Granodiorite - below) and 89302108 (Nostone Creek Granodiorite - below), respectively, are indistinguishable from each other.

Precambrian Basement Material

Two (of only four) zircon grains from Stones Creek Volcanics sample 89503064 (below) gave approximately 1550 Ma ages. These grains are distinctly darker than the others from the sample, presumably because of enhanced radiation damage to their crystal lattices as a result of conspicuously high uranium contents and considerably older ages (Black, 1994, Table 1). The age of these obviously restitic or xenocrystic zircons is the same as most (and possibly all) of the Precambrian igneous and metamorphic activity within the Georgetown Inlier to the north of the Burdekin Falls Dam - "Conway" area (Black & McCulloch 1990).

Three of the four zircon grains recovered from the other Stones Creek Volcanics sample, 88503023, collected by D.E.M. at grid reference 8356-118329, 6.5 km north of "Glenroy" outstation (and 5.5 km north-northwest of Burdekin Falls Dam) appear to have an age a little greater than 2500 Ma (Black 1994 Table 1 and Figure 10). The nearest geological "terrain" with components likely to be temporally comparable is the one exposed in the Georgetown Inlier (Black & McCulloch 1984, 1990, but see Page et al. 1984 for a discussion of why rocks of such a great age may not necessarily occur there). The remaining 88503023 grain yielded an unusual (for northern Queensland) 700 Ma age.

Three of the zircon grains analysed from sample 89302132 (unit CPm) are of Precambrian age. One of these, and an isotopically concordant grain from the Bulgonunna Volcanic Group's Arundel Rhyolite sample 89503028 (below), reveal the presence of local 1800 Ma crustal components. This age has not yet been reported from the Georgetown Inlier; the nearest known outcrops of comparable antiquity occur farther west, in the Bottletree and Argylla Formations of the Mount Isa Inlier (Page 1983). Interestingly, old grains in 89302132 cannot be distinguished morphologically from younger ones. Thus, although the dominant young population contains some anhedral and some approximately equant and multifaceted grains, relatively simple euhedral forms are not exclusive to it. The Precambrian and younger generations might, however, be separable on geochemical grounds; Precambrian zircons appear to have low Th/U (Black 1994, Table 1).

At least some of the Precambrian zircon grains detected during this geochronological research could therefore have been derived from either the Georgetown Inlier, or from rocks of similar age below local Drummond Basin and North Queensland Igneous Province cover (such as, presumably, Anakie Inlier and/or Lolworth-Ravenswood Block components). Geochronological knowledge of the more northerly Yambo Inlier is currently (1994) so limited that its role as a source of old zircon grains cannot be assessed. However, many of the mid- and late Palaeozoic granitoids of the Coen Inlier contain xenocrystic grains with a similar Precambrian age range to the one revealed in this study.

Stones Creek Volcanics

Samples 89503064 and 88503023 were collected (by D.E.M) as representative Stones Creek Volcanics. The first of these is an intensely altered dacitic to andesitic ignimbrite, while the other is a very altered dacite or andesite (probably lava).

Sample 89503064, from grid reference 8356-174311, 7.5 km northeast of "Glenroy" outstation (and 15.0 km north-northeast of Burdekin Falls Dam) yielded only four grains of subhedral to euhedral zircon (Black, 1994, Figure 10). Two of the grains are U-rich, and Precambrian. The two low-U grains (they also have considerably higher Th/U than their associates) from 89503064 are apparently coeval (Black 1994 Table 1), and yield a pooled mean age of 357 Ma. There is an inherent danger in deriving a mean age from such a small number of analyses. In addition, as neither of the two grains is euhedral, it cannot be guaranteed that they crystallised directly from their host rock; it is possible that they were derived from an older source, like their more obviously inherited Precambrian companions. Nonetheless, 357 Ma is consistent with the latest Devonian or earliest Carboniferous age ascribed to the Stones Creek Volcanics on the basis of plant fossils. The most up-to-date estimate for the base of the Carboniferous is 353.2±4.0 Ma (Claoue-Long et al. 1992).

A degree of support for the reality of a Devonian-Carboniferous igneous event is provided by a single 356 Ma-old zircon from "Smedley" association lava sample 89302132 (below), which is about 50 Ma older than the main population in that rock. However, the argument that the two grains in question from sample 89503064 need not be strictly syn-magmatic with their Stones Creek Volcanics host is not necessarily diminished.

These results from the Stones Creek Volcanics show that it will be difficult to obtain a convincing age from the unit. The formation is evidently exceedingly poor, perhaps even entirely lacking, in syn-magmatic zircons.

Locharwood Rhyolite

Sample 88502032 is from "type" Locharwood Rhyolite at grid reference 8455-715376 18 km east-southeast of Bulgonunna Peak; it was collected by S.R.L. during the phase of earlier (1985-86) Geological Survey of Queensland work centred on Mount Coolon.

The rock is very similar to sample 88503170 (below) from the Burdekin Falls Dam - "Conway" area. Included zircons are also morphologically comparable to those in 88503170, except that cores are not as common, and there is a larger range of elongation ratios (up to about 5:1). All but one of the nineteen analysed grains conform to a statistically ideal population in terms of $^{206}Pb/^{238}U$ (Black 1994 Figure 4). The exception is neither morphologically nor geochemically distinctive; its isotopic individuality is considered to be a consequence of analytical conditions, and data from it have been withdrawn entirely from further consideration. The preferred age of the sample, derived from the remaining eighteen zircon grains, is 304.7±6.2 Ma.

Sample 88503170, a welded rhyolitic ignimbrite from 5.0 km northeast of "Ukalunda" homestead (grid reference 8356-157929) collected by B.S.O., is representative of the main ignimbrite sheet preserved on the plateau to the north of the homestead. It was identified as a likely direct correlative of Locharwood Rhyolite at an early stage of the study, on the basis of hand specimen- and outcrop-scale similarities.

Zircons from this sample preserve typically igneous forms, with simple prismatic and pyramidal faces, and length to breadth ratios averaging about 3:1. Foreign inclusions and zircon cores are quite common; pronounced zonation was not observed. A total of twenty-two analyses was made, on twenty-one different grains. One of the analysed zircon grains had an extremely aberrant isotopic composition. Removal of this highly distinctive grain plus two other analyses from further consideration produces an array of nineteen data points in which observed error does not exceed expected error, and which conforms to a single $^{206}Pb/^{238}U$ composition. This is strong evidence that the age of 304.7±4.0 Ma derived from the sample is geologically meaningful, and documents the time of ignimbrite deposition. The age obtained is identical to that from the "type" Locharwood Rhyolite (above).

<u>Smedley Dacite</u>

Welded Smedley Dacite ignimbrite (sample 88502031) was collected by J.M. from the rock pavement at the foot of Burdekin Falls Dam (grid reference 8356-45169). In common with Locharwood Rhyolite (above) and Arundel Rhyolite (below) samples, zircons in this rock mostly have simple prismatic and pyramidal faces, and commonly contain inclusions. Although core and overgrowth relationships were observed in some samples, it was not possible to detect a significant age difference between the two phases. Two zircon grains produced isotopic outliers (Black 1994, Figure 6). The remaining twenty-one analyses yield a ^{207}Pb-corrected $^{206}Pb/^{238}U$ age of 297.3±4.8 Ma, which again is believed to represent the time of ignimbrite deposition. This Smedley Dacite age is inconsistent with a previous stratigraphic model (McPhie et al. 1990) in which a heterogeneous dacitic ignimbrite-bearing volcanic unit (Cv) lay below rhyolitic ignimbrite-dominated Bulgonunna Volcanics "proper" (Cb).

"<u>Smedley" Association Lava</u>

Sample 89302132 is a dacitic andesite (probably lava, or possibly a very high-level intrusive) from 11.2 km north of "Conway" homestead (grid reference 8356-394906). The sample was collected (by D.W.) in the belief that it represented an unusual case of unaltered Bimurra Volcanics, and would thus potentially date that unit. A total of thirty-one zircon grains was analysed.

The main population of twenty-seven zircons from this sample (Black 1994 Figure 7) is clearly isotopically isolated from four older grains (three Precambrian and one Palaeozoic, discussed above under Precambrian "Basement" Material and Stones Creek Volcanics respectively), even though no obvious morphological criteria serve to distinguish between different generations. There are no statistical outliers among the main twenty-seven, which yield an age of 297.4±3.9 Ma. This age is identical to the one from the Smedley Dacite leading inescapably to the conclusion that sample 89302132 represents a southeastern outlier of "Smedley" association, rather than Bimurra Volcanics or (another possibility considered at one stage) a CPm intrusive. Unfortunately, its spatial (and thus temporal) relationship to nearby "Earlscliffe" association rocks is not known.

Arundel Rhyolite

Sample 89503028, a representative of the Arundel Rhyolite from grid reference 8356-101137 5.3 km southwest of Burdekin Falls Dam, was collected by D.E.M. It contains zircon grains of generally similar morphology to the ones in Locharwood Rhyolite sample 88503170, except that they are mostly somewhat smaller (averaging only about 50 microns across). Unlike those in most of the analysed rocks, the zircons in this sample yielded a pooled array of concordant ^{208}Pb-corrected data (Black 1994, Figure 5). Nevertheless, to maintain consistency of detail, ^{207}Pb-corrected data were once again used for $^{206}Pb/^{238}U$ age calculations. Of fourteen analyses made, all conform to an ideal statistical grouping which yields an age of 293.5±5.6 Ma. In conjunction with other Bulgonunna Volcanic Group ages, this date from the Arundel Rhyolite indicates the probability of two late Palaeozoic rhyolitic ignimbrite-dominated sequences, rather than a single one as postulated previously (McPhie et al. 1990).

Although referred loosely to the Late Carboniferous, Bulgonunna Volcanic Group activity appears to have straddled the Carboniferous - Permian boundary, which is placed at 298 Ma in the AGSO Timescale (Jones et al. 1995).

Easter Granodiorite

Sample 88302095 of the Easter Granodiorite was collected (by D.W.) from the type locality to the west of the Burdekin Falls Dam road, between the road and a northern tributary of middle Bell Creek, 1.5 km northeast of the turnoff to the new "Myall Creek" homestead (grid reference 8356-167041). At the time of collection, this "Bells [*sic*] Creek" granodiorite (as it was then informally named, see Oversby et al. 1991) was a presumed representative of the youngest granitoid intrusives in the study area (McPhie et al. 1990). Although its particular field relationshps are not definitive, sodic granitoids have been seen elsewhere to intrude both the Bulgonunna Volcanic Group and K-rich granitoids similar to Nostone Creek Granodiorite (below).

Zircons in the Easter Granodiorite are morphologically similar to those in the Nostone Creek Granodiorite (below), except that they are on average only about half of their grain size, apparently contain no cores, and are not as commonly zoned. The latter feature can be equated with generally lower U and Th contents (Black 1994 Table 1). As in the case of sampled Nostone Creek Granodiorite, the isotopic data from Easter Granodiorite show a noticeable undercorrection for common Pb if the ^{208}Pb technique is used (Black 1994 Figure 9). One analysis, in particular, is well displaced to the right of concordia.

Nevertheless, irrespective of common Pb correction technique, the data define statistically tight $^{206}Pb/^{238}U$ age groupings, with ^{207}Pb-corrected data yielding an age of 289.6±6.1 Ma for the emplacement of this granitoid.

Nostone Creek Granodiorite

Sample 89302108, a quartz monzodiorite phase of the relatively K-rich Nostone Creek Granodiorite, was collected by D.W. from the type locality at grid reference 8456-655932, approximately 30 km northeast of "Conway" homestead. On the basis of field relationships and geochemical criteria, the unit was thought at the time to represent one of a suite of pre-Bulgonunna Group granitoids in the study area (Mc Phie et al. 1990).

The zircon fraction in Nostone Creek Granodiorite is of coarser grain size than that in the sampled Bulgonunna Volcanic Group; they are commonly 100 to 200 microns across. Many of the analysed grains are now broken, but those which are not have mostly first-order prismatic faces and bipyramidal terminations. Inclusions and generally rounded cores are common. Zonation is often evident, particularly at the margins of grains. As shown in Figure 8 of Black (1994), the ^{208}Pb method has produced more undercorrection of the common Pb component than was the case for Locharwood Rhyolite, Smedley Dacite, "Smedley" association lava, Arundel Rhyolite, or Nostone Creek Granodiorite samples. The main point of the data array clearly plots below concordia. The bias in $^{206}Pb/^{238}U$ age from this effect is minimised by the use of ^{207}Pb correction, which yields an emplacement age for the unit of 289.3±5.9 Ma. It is important to note that all of the nineteen individual analyses have indistinguishable ages, regardless of the type of zircon they represent, e.g. zoned or homogeneous, core or rim.

The dates obtained from the Easter Granodiorite and the Nostone Creek Granodiorite suggest that it will not be possible to neatly "pigeonhole" granitoids in the Burdekin Falls Dam - "Conway" area on the basis of their whole-rock geochemistry.

APPENDIX 3: Palaeomagnetism, by C.T. Klootwijk, J.W. Giddings and P. Percival

Introduction

This Appendix summarises the main results from a reconnaissance palaeomagnetic investigation of upper Palaeozoic rocks undertaken in the Burdekin Falls Dam - "Conway" area, northeastern Queensland. The investigation was initiated in 1987 as a contribution to the regional geological study; it focussed on: (1) elucidating and dating the magnetic evolution of the Bulgonunna Volcanic Group; (2) independently checking bedding inclination of ignimbrites, and providing information on timing of deformation; (3) indicating transport directions of ignimbrites, and thus potentially pinpointing their eruptive centres, using the technique of magnetic fabric analysis (cf. LaMarche & Froggatt 1993); and (4) providing control on the orientation of major fault planes, also from magnetic fabric analysis. The investigation was also designed to produce data relevant to longer-term palaeomagnetic research goals, namely: (5) determination of the palaeolatitude history during the large-scale Carboniferous movement of eastern Gondwana; (6) comparison with results from the Carboniferous and Permian volcanic tract of the Tamworth belt (New South Wales), and control on possible oroclinal deformation of the southern New England Orogen; and (7) further delineation and dating of the Late Carboniferous to Early Permian phase of pervasive magnetic overprinting throughout Australia and Pangaea. Only those aspects, (1) to (4), directly concerned with the Burdekin Falls Dam - "Conway" area's geology, are dealt with here. A more comprehensive reporting of the investigation, including full details of sample treatment and analytical techniques, and results pertaining to the broader regional goals, can be found in Klootwijk et al. (1993).

Samples for investigation were collected with a portable drilling machine as standard cores of 2.5 cm diameter and about 10 cm length; they were oriented with both a magnetic and a solar compass. Field samples were subsequently sliced into 2.2 cm-long specimens. Initially, "bedding" at sample sites was determined mainly from fiamme orientations in ignimbrites, and/or mapped stratigraphic contacts; in a few cases, bedding information could be obtained from adjacent sedimentary rocks. The remanence results are from pilot specimens, obtained through standard thermal and alternating electric field techniques and their analysis; more comprehensive bulk demagnetisation studies are in progress. The data and interpretations summarised here, therefore, have to be treated as provisional.

Thermal and alternating field demagnetisation studies have revealed the pervasive presence of a steep downward, southerly, magnetisation component of reverse "Kiaman" polarity. The pole positions documented here for primary and "Kiaman" magnetisations have important implications for the shape of the late Palaeozoic apparent polar wander path (APWP) for Australia and Gondwana, for the evolution of the Tasmanides, for the evolution of the Gondwana-Laurussia (i.e. Siberian Craton) contact, and for the formation of Pangaea. The "Kiaman" reverse overprint had not previously been fully dated. Our new palaeomagnetic results, in conjunction with SHRIMP U-Pb zircon ages obtained in a parallel investigation (Black 1994 and Appendix 2), especially those from the Pyramid and

Arundel Rhyolites, are therefore of potentially great importance. Results from another, more recent, palaeomagnetic study in the Bulgonunna volcanic field known to have been made by the CSIRO rockmagnetic group (Lackie et al. 1992) have not been made publicly available.

Temporal interpretation of remanence directions determined in this investigation has been made mainly through comparison of the remanence's pole positions with preferred APWPs for Australia (Idnurm 1985, Klootwijk & Giddings 1988a, 1988b). It must be emphasised that pole positions for the few primary magnetisations detected in this investigation area are not supportive of the hitherto better-publicised late Palaeozoic APWP advocated by Schmidt and co-workers (Schmidt et al. 1990, Li et al. 1990, Powell et al. 1990).

In general, two main components of remanent magnetisation could be identified and interpreted in a geologically meaningful way. These were: (i) a soft component, C1 (see Klootwijk et al. 1993 Table 2), sometimes distinguishable into a softer sub-component ($C1_l$) and a slightly harder sub-component ($C1_h$), with a direction close to the present local field direction, the anticipated normal- or reverse-polarity Tertiary field direction, or the expected late Cretaceous to early Tertiary field direction; and (ii) a hard to very hard sub-component, $C2_h$, with a steeply downward and generally southern direction, which is close to the expected Late Carboniferous to Early Permian direction for the study area. Thermal demagnetisation generally showed that isolation of sub-component $C2_h$ was preceded by breakdown of a slightly softer and (site-wise) less coherent sub-component ($C2_l$) which had a comparable inclination to, and a declination close to but distinct from, the harder component (see Klootwijk et al. 1993 Tables 3A and 3B). In cases with no directional variation, the Late Carboniferous/Early Permian component has been identified simply as C2. In the Star of Hope Formation volcanics, another magnetisation component can be identified in general terms as: (iii) C3.

The C1 components show a somewhat elongated distribution of pole positions (Klootwijk et al. 1993 Table 2 and Figure 10A). Pole positions derived for the components are, variously: (i) close to the late Tertiary part of Idnurm's (1985) APWP; (ii) close to the present-day magnetic South Pole; and (iii) close to the late Cretaceous/early Tertiary part of Idnurm's (1985) APWP. Positions (i) and (ii) may represent overprints of late Tertiary and Recent ages respectively, and of viscous origin in the case of (ii). Position (iii) may indicate the effects of weathering, as observed in the Eromanga Basin (Idnurm & Senior, 1978), or spreading in the Coral Sea - Tasman Sea region (Weissel & Hayes 1977, Weissel & Watts 1979, Veevers 1984, Veevers et al. 1991). The latter could conceivably have involved continued, or rejuvenated, activity of hydrothermal systems that may have already been in existence during Carboniferous time.

Magnetic fabric results are from representative rocks only, and no further fabric analysis is planned for the present sample collection. Fabrics generally show a low anisotropy of susceptibility of around 1% to 2%, characterised by oblate susceptibility ellipsoids with more pronounced foliation patterns than lineations. Lineation features show some consistency, but the data are too limited to firmly establish details of flow-directions, or to home-in confidently on specific eruptive centres.

Star of Hope Formation volcanics

The volcanics assigned to the Star of Hope Formation were sampled at related sites (BFBH) approximately 4.5 km northeast of Burdekin Falls Dam, beside the track from the Burdekin River to "Glenroy" outstation. There, 30 samples were obtained from lithic clast-rich ignimbrite exposed in "whaleback" outcrops at grid reference 8356-67212, and the same clast-rich ignimbrite exposed in a gully approximately 250 m to 400 m to the south (grid reference 8356-66208) yielded an additional 30 samples.

Magnetisation is complex. The two main components are: a soft Recent component, C1, eliminated at 100°C to 250°C and at 10 mT; and C2, containing two southerly and steep downward sub-components, $C2_l$ and $C2_h$. The first, and softer, of these sub-components is a magnetite-based one eliminated at about 540° C and occasionally at 10 mT to 20 mT. The harder sub-component, $C2_h$, is a hematite-based one eliminated between 580°C and 680°C, and between 20 mT and 100 mT. Three lesser C3 components (see Klootwijk et al. 1993, Tables 4 and 5) are distinguishable as: a normal polarity northerly sub-component of equatorial inclination and of presumed primary origin, with a rather variable blocking temperature range mainly below the Curie Point of magnetite (approximately 580°C); a reverse polarity Recent or Tertiary sub-component which is eliminated at the high end of the magnetite range, between the softer $C2_l$ sub-component and the harder $C2_h$ one (between 550°C and 570°C, and occasionally up to 630°C); and scanty occurrence of northwesterly and moderate upward sub-components, generally of a very soft nature but also with occurrences of a much harder nature, eliminated at 100°C and at 10 mT.

Uniformly-dipping bedding at the Star of Hope Formation volcanics' sample sites does not permit a fold test being applied to the C2 components of magnetisation. Sub-component $C2_h$ can be interpreted almost unambiguously as being of secondary acquisition, because component C3's equatorial direction is consistent with the most likely age of the rocks, i.e. it is probably primary. A fold test comparison of the two C2 sub-components from the Star of Hope Formation volcanics and the Smedley Dacite is not particularly informative with respect to possible closeness, or otherwise, of ages (Klootwijk et al. 1993 Table 10). There is slightly better agreement between the *in situ* Smedley Dacite and bedding-corrected Star of Hope Formation volcanics results than there is between *in situ* Smedley Dacite and comparable *in situ* Star of Hope Formation (Klootwijk et al. 1993 Figure 11A4), which is more suggestive of a distinct age difference. However, the Star of Hope Formation's C2 components may have been acquired as a Late Cretaceous/Early Tertiary overprint related to emplacement of a nearby (approximately 70 m north in the case of the samples from grid reference 8356-167212) plug of intrusive basalt (Tb on the map). The occurrence of C2 in both magnetite and hematite phases suggests a (thermo-) chemical origin, possibly related to hydrothermal activity.

At least some C3 components in the Star of Hope Formation volcanics appear to represent equatorial directions of Early Carboniferous origin (Klootwijk et al. 1993, Figure 11A5). Others are overprints which are: (i) ill-defined, but which after correction for bedding fall on the mid-Carboniferous part of the preferred APWP path (Klootwijk 1988, Klootwijk & Giddings 1988a, 1988b, Klootwijk et al. 1993 Figure 11A5); (ii) probably reverse polarity overprints of Tertiary or Recent origin; and/or (iii) isolated (site-wise) consistent, but spurious, directions for which no clear interpretation can be presented at this stage. Occasionally, softer and harder C3 sub-components ($C3_l$ and $C3_h$ respectively) can be differentiated. Early Carboniferous acquisition of primary C3 would accord with the age conventionally given to the Star of Hope Formation on palaeobotanical grounds (Olgers 1972), and helps to indicate that these volcanic rocks are more logically included in that formation than in the Stones Creek Volcanics. Type (i) C3 component could possibly be related to hydrothermal events triggered by the Australia-wide "Kanimblan" orogenic event. In its turn, this event may have been triggered by large-scale latitudinal movement of eastern Gondwana.

Comparison of Remanence Results from the Star of Hope Formation volcanics and Silver Hills Volcanics

Pole positions for the primary magnetisation components in the Star of Hope Formation volcanics and in the Silver Hills Volcanics of sites ASDA to ASDD in the southern Drummond Basin (location 17 of Klootwijk et al. 1993, Figure 2D) are far apart, with the difference mainly in divergent declinations (Klootwijk et al. 1993, Figure 11D). Assuming the absence of substantial differential movement between the two units subsequent to acquisition of the magnetisation, stratigraphic relationships between them can be constrained by comparision of their pole positions with the preferred APWPs of Klootwijk & Giddings (1988a, 1988b). The comparison suggests that the Star of Hope Formation volcanics are slightly younger than the Silver Hills Volcanics, i.e. Early to mid(?)-Carboniferous versus Late Devonian and/or Early Carboniferous respectively (Klootwijk et al. 1993 Figures 9B and 12). This is consistent with previous palaeontological conclusions regarding the ages of both these formations (e.g. Olgers 1972).

In contrast, comparison of the same data with the APWP of Schmidt et al. (1990), Li et al. (1990) and Powell et al. (1990) would lead to the otherwise-unsupported conclusions that: (i) both sets of volcanic rocks are of Early to Late Devonian age; and (ii) the Silver Hills Volcanics are younger than the Star of Hope Formation volcanics.

Pyramid Rhyolite

The Pyramid Rhyolite was sampled in the northwestern and northeastern parts of the Pyramid Range, approximately 3 km and 0.5 km northwest of "Ukalunda" homestead (grid references 8356-104909 and 8356-123893 respectively). At the former location (BFBB), nine sites yielded 72 samples over a 70 m stratigraphic interval, extending from a "vesicular" (= recessively-weathering fiamme) lowermost part to the local limit of exposure of the main welded part of the formation. At the second location (BFBC), nine sites (also 72 samples) were sampled over a 90 m stratigraphic interval to the local limit of exposure. Of these sites, the two lower ones were in nonwelded ignimbrite, with the remainder in the main welded part of the formation.

Samples from BFBB sites contain two main palaeomagnetic components: (i) a subdued soft Late Cretaceous/Early Tertiary component, C1, generally removed at 200°C; and (ii) a predominant hard southwesterly to westerly and downward Late Carboniferous/Early Permian component, $C2_h$, removed at 560°C to 680°C. There is a great-circle streaking of directions between C1 and $C2_h$. AF-demagnetisation does not separate C1 as an entity, but $C2_h$ is eliminated between mainly 40 mT and 100 mT. Samples from BFBC also contain two main components: (i) a rather subdued soft Late Cretaceous/Early Tertiary component, C1, generally removed at 100°C to 300°C; and (ii) a predominant hard southwesterly and very steep downward Late Carboniferous/Early Permian sub-component, $C2_h$, removed at 550°C to 670°C. AF-demagnetisation is only occasionally successful in the separation of C1 at 10 mT, and in the elimination of $C2_h$ over a wide range of fields up to 100 mT.

Pole positions for the $C2_h$ sub-component from both sampling locations cross-over during correction for bedding, and show a negative McFadden (1990) fold test (Klootwijk et al. 1993, Figures 11A2 and 11A3 and Table 10). These observations are consistent with acquisition during local cauldron/caldera subsidence, involving "sagging" of the sequence into a structure of basinal form, at the time of ignimbrite extrusion. The observations would also be consistent with magnetisation during regional tectonic folding, but there is no good geological evidence for any such folding during the appropriate late Palaeozoic time interval. A softer $C2_l$ sub-component from both sampling locations, which was probably acquired somewhat later in the subsidence process, shows even more marked cross-over (Klootwijk et al. 1993 Figure 11A3), as is to be expected.

The BFBC sites showed a particularly interesting development of magnetic fabric (K_{min} axes) patterns in ascending from the lowermost to the uppermost site in the massive main ignimbrite sheet. Upwards through the upper part of the sheet, the magnetic fabric plane progressively approaches the observed eutaxitic foliation, with virtually exact agreement between both at the top site (Klootwijk et al. 1993 Figure 7A5). This is to be expected in a single cooling unit whose hot and plastic interior is capable of undergoing subtle rheomorphic movements at the same time as the higher part (and the lower one also, to a lesser extent) is cooler and more brittle. The uppermost BFBC site also displayed an insignificant (less than 1%) magnetic lineation (Klootwijk et al. 1993, Figure 7A5), from which no reliable flow-direction conclusions can be drawn.

Unit Cub_{17}

This unit consists of welded rhyolitic ignimbrite. The unit is believed to be associated stratigraphically with (probably overlies) the Locharwood Rhyolite, but it has been at least mildly hornfelsed by the intrusion of Carboniferous/Permian CPg_2 and CPg_{10} granitoids. The rock was sampled at four sites, AFBH to AFBK), approximately 5 km east-southeast of Mount Constance (grid reference 8356-460083); porphyritic microgranite to fine granite, CPg_2, occurs approximately 150 m south of the sites, while CPg_{10} granite/granodiorite is only about 500 m to the east. The sites were situated at separate stratigraphic levels within the unit; 40 samples were recovered.

The main remanence magnetisation apparent in Unit Cub_{17} samples is a southerly and steep downward Late Carboniferous/Early Permian sub-component, $C2_h$, eliminated at 570° C to 630° C and generally between 20 mT to 100 mT. Results suggest a greater dispersion of magnetisation directions after correction for bedding (Klootwijk et al. 1993 Table 3B), although there are insufficient pilot demagnetisation data for a proper fold test. In this instance, the component may have been acquired during post-extrusional granitoid emplacement and hornfelsing. A minor C1 overprint in Cub_{17} samples gives a geomagnetic South pole position close to the present-day one.

Magnetic fabric patterns were consistent in some Cub_{17} samples. The planar structures indicated by poles to these axes do not relate to any of the observed bedding indications, and could conceivably reflect hornfelsing.

<u>Smedley Dacite</u>

The Smedley Dacite was sampled in an extensive section at Burdekin Falls Dam, and in a limited section in Coopers Creek, approximately 3.5 km farther to the south-southwest (grid references 8356-145170 to 8356-140159, and grid reference 8356-139131, respectively). At the Dam, ten sites (AFBA to AFBG and BFBD) across the riverbed rock pavement below the Dam wall and up the adjacent southern road cutting as far as the local limit of exposure, yielded a total of 100 samples. In the Coopers Creek section, 20 samples were obtained from two sites (BFBE) in upper Smedley Dacite directly below the Arundel Rhyolite sites BFBA (below).

Sites AFBA to AFBG and BFBD at Burdekin Falls Dam contain two main magnetisations: (i) a soft Late Cretaceous/Early Tertiary field component, C1, eliminated at 150°C to 250°C and at 10 mT; and (ii) a very predominant coherent southerly and very steep downward Late Carboniferous/Early Permian sub-component, $C2_h$, eliminated at 600°C to 630°C and between 10 mT to 100 mT. Smedley Dacite at Coopers Creek contains one predominant magnetisation sub-component only: a southerly and steep downward one, $C2_h$, eliminated at 550°C to 630°C and between 15 mT to 100 mT.

The C1 components in the Smedley Dacite have pole positions close to the Late Cretaceous/Early Tertiary part of the APWP of Idnurm (1985), and close to the present-day South magnetic pole (Klootwijk et al. 1993 Figure 10A and Table 2).

Sub-components $C2_h$ and $C2_l$ from the Smedley Dacite at both Burdekin Falls Dam and Coopers Creek clearly disperse after unfolding (Klootwijk et al. 1993 Figure 11A4). Results of McFadden's (1990) fold test are probably, but not definitely, negative (Klootwijk et al. 1993 Table 10). Conventionally, dispersal after unfolding would be taken to indicate secondary, post-tectonic folding, acquisition of C2. The tilt-corrected pole positions for $C2_l$ from both sets of samples show the greatest separation, consistent with the sub-component having been acquired after $C2_h$ during a later phase of the same continuing deformation.

Taken in isolation, these data would indicate that the Smedley Dacite was part of the northern Drummond Basin sequence (along with, e.g., Stones Creek Volcanics and Star of Hope Formation volcanics), and participated in the region-wide tectonic folding of that sequence during (probably) Early Carboniferous time. A pre-Pyramid Rhyolite age would thus be implied for the dacite because the Pyramid Rhyolite appears, from the palaeomagnetic results alone, to have been involved in cauldron/caldera "sagging", but not in true tectonic folding (which it must perforce have been if it was older than tectonically folded Smedley Dacite). However, a pre-Pyramid/Locharwood Rhyolite age for the Smedley Dacite is contra-indicated by U-Pb geochronology of both that unit, and the Locharwood Rhyolite (Black 1994 and Appendix 2). In an indirect way, a pre-Pyramid/Locharwood age is also not supported by magnetic fabric results from the Smedley Dacite and Arundel Rhyolite associated together at Coopers Creek (below). On balance, it seems unlikely that Smedley Dacite ever participated in true tectonic folding. Acquisition of magnetisation sub-component $C2_h$ at different locations, by the dacite at least and presumably by other rocks also, is not amenable to the (palaeomagnetically) simplest explanation, and may not necessarily have been due to one straightforward or regionally uniform process.

Consistent magnetic fabric (K_{min}-axes) patterns were encountered throughout the Smedley Dacite at Burdekin Falls Dam (Klootwijk et al. 1993 Figure 7A1). The planar surfaces defined by these patterns seem to relate to a probable nearby fault, rather than to undisturbed "bedding", and thus are most likely secondary. The degree of magnetic foliation increases from a distal 1% to 2%, to a more proximal 4% (Klootwijk et al. 1993 Table 6) approaching the substantial northeast-striking fault zone mapped directly to the north of the sample sites, and extrapolated beneath Lake Dalrymple 0.5 km to the west. The presence of this probable secondary fabric provides circumstantial support for the late (i.e. post-tectonic folding) acquisition of component C2 at the dam. Magnetic fabric results from the Coopers Creek sites are not so easily explained. The location lies on the tentative extension of another northeast-striking fault, extending southwest from the Burdekin River, and moderately close to (approximately 2 km east of) a north-trending one. While samples from the overlying Arundel Rhyolite showed signs of an obviously acquired $C2_h$ fabric (below), the Smedley Dacite samples, perversely, did not. This observation is not supportive of the case for a secondary, and late, acquisition of sub-component $C2_h$ by the unit.

Arundel Rhyolite

The Arundel Rhyolite was sampled on northeastern and southwestern parts of the plateau between Coopers Creek and "Myall Creek" homestead. Sites were located on a spur of the plateau immediately west of Coopers Creek, approximately 3.5 km south-southwest of

Burdekin Falls Dam (between grid references 8356-35132 and 8356-32132), and near a powerline track to the north of "Myall Creek" access road, 5 km east-southeast of the homestead (grid references 8356-063089 and 8356-060086). Seven sites (BFBA) at the Coopers Creek location yielded 56 samples through the upper 40 m of exposure of the approximately 70 m-thick main welded and rheomorphosed ignimbrite in the formation. To the southwest, at grid reference 8356-060086, 24 samples came from three sites (BFBG) in an approximately 20 m stratigraphic interval in the lower clast-rich ignimbrite of the formation, while 32 samples were collected from four sites (BFBF) nearby (grid reference 8356-063089), in the lower part of the overlying main welded and rheomorphosed ignimbrite sheet.

The sites at Coopers Creek show well-determined remanence component directions, but with rather dispersed directional groupings possibly caused by lightning strikes. Two main magnetisations can be identified, although neither one is prominent: (i) a rather hard Recent field component, C1, which is eliminated in a few samples at 400°C to 500°C, but cannot be separated during AF-demagnetisation treatment; and (ii) a very steep westerly sub-component, $C2_h$, which only AF treatment between 20 mT and 100 mT was successful in separating out. Samples of the welded ignimbrite to the southwest (BFBF sites) contain two main remanence components: (i) a rather subdued soft Recent field component, C1, eliminated at 200°C to 300°C, and in very low AF fields up to 10 mT; and (ii) a more pronounced southwesterly and very steep downward sub-component, $C2_h$, which generally disappears around 630°C and between 20 mT to 100 mT. There is great-circle streaking between plots of C1 and $C2_h$ in these BFBF samples. The clast-rich lower ignimbrite in the southwest (BFBG sites) contains two components: (i) a rather prominent but soft Recent field magnetisation, C1, generally removed at 150°C to 250°C and at 10 mT to 20 mT; and (ii) a southwesterly and steep downward sub-component, $C2_h$, generally eliminated at 540°C to 630°C and between 20 mT to 100 mT. Slight great-circle streaking occurs between C1 and $C2_h$ points.

As in the Pyramid Rhyolite (above), pole positions for the $C2_h$ sub-component in all sampled locations of Arundel Rhyolite cross-over during correction for bedding, and show a negative fold test (Klootwijk et al. 1993 Figure 11A2 and Table 10). Again, this is consistent with acquisition of the magnetisation during synvolcanic cauldron/caldera "sagging".

The C1 sub-components in the Arundel Rhyolite have pole positions close to the Late Cretaceous/Early Tertiary and Late Tertiary parts of the APWP of Idnurm (1985), and close to the present-day geomagnetic South Pole position (Klootwijk et al. 1993, Figure 10A and Table 2).

Consistent magnetic fabric patterns were detected throughout the Arundel Rhyolite. Samples from one of the sites above Coopers Creek (BFBA) showed good correlation between planar surfaces defined by the magnetic fabric and local eutaxitic foliation defined by fiamme (Klootwijk et al. 1993 Figure 7A2). These BFBA samples also showed obvious signs of an acquired $C2_h$ fabric, unlike ones from subjacent Smedley Dacite (above). A single site here showed an insignificant (less than 1%) magnetic lineation. At the southwestern (BFBF) sites, very good agreement was obtained between the magnetic fabric pattern and top surfaces of well-developed columnar-jointed blocks showing variable, moderately-dipping to very steep, fiamme (Klootwijk et al. 1993 Figure 7A4). In this instance, columnar jointing is probably a good indirect indicator of the whole-unit dip (the columns would be approximately perpendicular to it, and thus cross-joints would be subparallel); fiamme orientations in this evidently rheomorphosed ignimbrite would have absolutely no validity as overall "bedding" indicators. The four BFBF sites show an instructive magnetic lineation pattern. Two sites have a pronounced magnetic lineation, close to 2%, whereas the other two show a far less well-developed lineation. Corrected to the palaeo-horizontal, the pronounced K_{max}-axes for the former two sites strike east-northeast to west-southwest, suggesting that this was the axis (not azimuth) of ignimbrite flow. Since the eruptive centre/s of the Arundel Rhyolite was/were probably located beneath the present main outcrop area of the unit, and is/are concealed by it (there being no known candidates exposed along its edges or in sub-Arundel rocks beyond it), and the BFBF sample sites lie in a near-peripheral southwestern position, a flow direction from the east-northeast towards the west-southwest can be inferred to have been more likely than the reverse.

Lizzie Creek Volcanics

The Lizzie Creek Volcanics were sampled cursorily near "Strathmore" homestead and to the northwest of Collinsville (grid references 8456-655330 and 8456-844309, respectively). Neither of these locations is within the Burdekin Falls Dam - "Conway" study area; however, the information obtained is directly relevant to western parts of the formation which are just inside the map area. At sites AFLA and AFLB, near "Strathmore", 20 samples were obtained from two thin and rather poorly welded pyroclastic (ignimbrite?) beds. To the northwest of Collinsville (sites AFLC and AFLD), a further 20 samples came from the welded central part (AFLC) of an ignimbrite, and from approximately 5 m stratigraphically higher (AFLD) in the less welded upper part of the same coarsely clast-rich ignimbrite.

The Lizzie Creek Volcanics samples contain two main magnetisation components: (i) a soft Recent field component, C1, eliminated at $200^{\circ}C$ to $300^{\circ}C$, and in some samples at 10 mT; and (ii) a hard very steep downward and southerly sub-component, $C2_h$, eliminated at $580^{\circ}C$ to $680^{\circ}C$, and in sites AFLC and AFLD between 20 mT and 100 mT. There is also a sporadically-present (iii) reverse polarity Recent sub-component, $C1_l$, eliminated between $200^{\circ}C$ and $650^{\circ}C$.

Pole positions for C1 remanence are grouped at the present-day geomagnetic South pole (AFLA and AFLB sites), and about the pole position for the Late Cretaceous overprint (AFLC - AFLD sites) (Klootwijk et al. 1993 Table 2 and Figures 8 and 10C).

Based on limited results, the mean direction of C2 magnetisation for the four sites in the Lizzie Creek Volcanics shows some dispersion after correction for bedding (Klootwijk et al. 1993 Figure 11C). However, pending bulk demagnetisation studies, this result does not warrant any firm conclusion regarding the origin of $C2_h$. Tentatively, a secondary origin seems the most likely for it in view of the increase in dispersion after correction for bedding. However, a primary origin cannot be ruled out. The pole positions lie close to the mid-Permian segment of the APWP (Klootwijk et al. 1993 Figures 9B, 11C and 12). This supports the age suggested for the formation by Murray (1983), rather than the Early Permian one preferred by the majority of other previous workers. Any improved palaeontological control on the age of the Lizzie Creek Volcanics could provide important additional constraints on the time of acquisition of component C2 by the unit.

Unit CPg_{10}

Granitoids were sampled at two sites (10 samples each) approximately 5 km and 4 km southwest of "Glendon" homestead (grid references 8356-200136 and 8356-203143 respectively). The first of these sites, AFGA, was in coarse-grained granodiorite cut by a dolerite dyke near the sampling site. The second site, AFGB, sampled coarse granodiorite containing large dioritic xenoliths. Field relationships indicate that the AFGA granodiorite (or one like it) cuts a dacitic ignimbrite (Cub_{26}) stratigraphically associated with Smedley Dacite.

Two main remanence magnetisations occur in AFGA and AFGB samples: (i) a soft component, C1, eliminated at about 200°C and at 10 mT, mainly present at site AFGB; and (ii) a harder southeasterly (!) and steep downward sub-component, $C2_h$, eliminated between 560°C to 640°C and at 20 mT to 100 mT. Site AFGA alone shows: (iii) a soft northerly to easterly and very steep upward component, more-or-less antipodal to $C2_h$, which is eliminated at 250°C and at 20 mT.

The significance of component C1 seems obscure. It lies off the Late Tertiary part of Idnurm's (1985) APWP, and away from the present-day magnetic South pole. (Klootwijk et al. 1993 Figure 10A and Table 2).

Discussion

In general, there was gratifying agreement between palaeomagnetic data and the SHRIMP U-Pb zircon geochronology (Black 1994 and Appendix 2), in those instances where the two could be compared directly. The single outstanding exception occurred in the case of the Smedley Dacite (above). It would clearly be desirable if possible reasons for a significant discrepancy in results from the two data sets, explored at length in Klootwijk et al. (1993), could be investigated further. It may be that the U-Pb zircon isotopic systems are not absolutely closed in all circumstances.

APPENDIX 4: Geophysics by P. Wellman

Data sources

This interpretation of geophysical data from the Burdekin Falls Dam - "Conway" area relies on the analyses of previously-released gravity and magnetic maps. The gravity map used incorporates all known data; importantly, it contains the results of a 1987 BMR survey, with observations at 2 km intervals along roads. The magnetic maps are from the BMR regional aeromagnetic survey (1982 and 1983) of the Charters Towers and Bowen 1:250 000 Sheet areas, with 1.5 km flight-line spacing.

Regional Setting

In its regional setting, the Burdekin Falls Dam - "Conway" area lies at the junction of major tectonic provinces. The map shows the extent of major tectonic elements defined from outcrop geology; "basement" domains inferred from geophysical data by Murray et al. (1989) and Wellman (unpublished) are roughly coincident with these provinces. The northwestern corner of the study area contains the southeastern part of the Lolworth-Ravenswood Block, which displays easterly geophysical trends. The remainder of the western three-quarters of the area falls within the northern Anakie Inlier and Drummond Basin; trends are northeasterly. The eastern quarter of the area contains rocks of the northwestern Bowen Basin, and the margin of the New England Orogen, both of which have north-northwesterly trends. In the central third of this eastern portion of the study area, deformation associated with the margins of the Bowen Basin and New England Orogen has superimposed north-northwesterly trends on northeasterly (Anakie Inlier - Drummond Basin) trends.

Gravity Anomalies

The main gravity feature is a low in the central part of the study area. This is believed to be of composite origin, with components due to low-density late Palaeozoic volcanic rocks and low-density late Palaeozoic granitoids, plus the low density of the entire crust at the margin of the Thomson Orogen relative to that of the New England Orogen.

Gravity in the northeastern part of the study area is dominated by two northwest-trending gradients. The strongest, and straightest, of these coincides with the surficial Millaroo Fault Zone, which is likely to form the boundary between the Thompson and New England Orogens locally. The other gradient may be due to a northwest-striking change in rock types beneath CPg_{10} granitoids. This gradient is not linear, so the boundary (if that is what is represented) is probably not a high-angle fault.

Much of the study area is dominated by northeastern gravity trends of the Anakie Inlier and Drummond Basin. Gravity highs coincide with anticlinal folds in interbedded sedimentary and volcanic rocks, and gravity lows mark synclines, probable late Palaeozoic ignimbrite-related subsidence structures and late Palaeozoic granitoids.

In the southwestern part of the study area, a major mapped volcanic downwarp (defined by the Pyramid Rhyolite) is surrounded in part by fault swarms and a partial ring-dyke. Northeast-trending gravity gradients (plus magnetic features - below) lie along the margins of this downwarp.

Magnetic Anomalies

The magnetic anomalies in the Burdekin Falls Dam - "Conway" area are moderately variable because of the range in magnetic properties of their sedimentary, volcanic and intrusive sources. In general terms, late Palaeozoic volcanic rocks are more magnetic than older sedimentary and volcanic ones. However, no single stratigraphic unit or interval has a magnetic signature distinctive enough to be useful as a mapping tool.

Near the northeastern edge of the study area, a northwest-trending shallow magnetic trough, 10 km wide, is roughly centred on the Millaroo Fault Zone. The anomaly may be due to demagnetisation of rocks at depth along this major (judging from the geophysical evidence) boundary. In the southwest, gravity features (above) coincide with magnetic gradients plus local short-wavelength and high-amplitude magnetic anomalies along the margins of the Pyramid Range downwarp. These gravity and magnetic data are consistent with the downwarp being within a continuous structural "corridor", which is graben-like at depth and bounded by three main northeast-trending faults - a southern one with downthrow to the northwest, and two northern faults with downthrows to the southeast.

REFERENCES

Allen, C.M., 1993, Bimodal dyke swarm in costal [*sic*] Queensland: the end of the Carboniferous - Permian arc (abstract). *International Association of Volcanology and Chemistry of the Earth's Interior, 1993 General Assembly, Abstracts*, 2.

Allen, C.M., 1994, The Urannah Arc of central coastal Queensland, Australia: a rifted continental marginal system (abstract). *Geological Society of America Abstracts with Programs*, 26, A-368.

Alvin, K.L., 1965, A new fertile Lycopod from the Lower Carboniferous of Scotland. *Palaeontology*, 8, 281-293.

Baker, E.M. & Tullemans, F.J., 1990, 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, 1461-1465.

Bates, R.L. & Jackson, J.A., 1980, *Glossary of geology (second edition)*. American Geological Institute, Falls Church Virginia.

Beams, S.D., Laurie, J.P. & O'Neill, D.M. 1990, Reward polymetallic sulphide 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, 1539-1543.

Beams, S.D., 1993, Polymetallic massive sulphide exploration case histories, Mt Windsor volcanic belt, North Queensland. *In* Henderson, R.A. (editor), Guide to the economic geology of the Charters Towers region, northeastern Queensland. *Geological Society of Australia, Queensland Division 1993 Field Conference Guidebook*, 75-79.

Beams, S.D., Laing, W.P. & O'Neill, D.M., 1993, The exploration history and geology of the polymetallic Reward deposit, Mt Windsor volcanic belt, North Queensland. *In* Henderson, R.A. (editor), Guide to the economic geology of the Charters Towers region, northeastern Queensland. *Geological Society of Australia Queensland Division, 1993 Field Conference Guidebook*, 81-91.

Black, L.P., 1994, U-Pb zircon ion-microprobe ages from the northern Drummond Basin, northeastern Queensland. *Australian Geological Survey Organisation Record* 1994/34.

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, Isotopic evidence for the dependence of recurrent felsic magmatism on new crust formation: an example from the Georgetown region of northeastern Australia. *Geochimica et Cosmochimica Acta*, 54, 183-196.

Black, L., Mackenzie, D., Oversby, B. & McPhie, J., 1990, Setting of epithermal gold mineralisation in the northern Drummond Basin further refined. *BMR Research Newsletter*, 12, 14-15.

Blevin, P.L., 1994, Identification of favourable exploration/resource areas in eastern Australia using magma compositions (abstract). *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 137-140.

Blevin, P.L. & Chappell, B.W., 1992, The role of magma sources, oxidation states and fractionation in determining the granite metallogeny of eastern Australia. *Royal Society of Edinburgh Transactions, Earth Sciences*, 83, 305-316.

Bock, H., Otto, B., Enever, J.R. & Crawford, G., 1986, *Burdekin Falls Dam: report on rock stress measurements, 1985 - 1986*. James Cook University of North Queensland Civil Systems Engineering Department, Townsville.

Bosworth, W., 1985, Geometry of propogating continental rifts. *Nature*, 36, 625-627.

Branney, M.J. & Sparks, R.S.J., 1990, Fiamme formed by diagenesis and burial-compaction in soils and subaqueous sediments. *Journal of the Geological Society* 147, 919-922.

Burton, N. & Lawson, T., 1988, Engineering Geology of the Burdekin Falls Dam, north Queensland (abstract). *Geological Society of Australia Abstracts*, 21, 76-77.

Candela, P.A., 1992, Controls on ore metal ratios in granite-related ore systems: an experimental and computational approach. *Royal Society of Edinburgh Transactions, Earth Sciences*, 83, 317-326.

Carr, G.R., Dean, J.A. & Morrison, G.W., 1988, Lead isotopes as an exploration technique and an aid in genetic modelling for gold deposits in northeast Queensland (abstract). *Geological Society of Australia Abstracts*, 22, 265-271.

Cas, R.A.F. & Wright, J.V., 1988, *Volcanic Successions - Modern and Ancient (Second Edition)*. Unwin Hyman, London.

Champion, D.C. & Heinemann, M.A., 1993, Igneous rocks of North Queensland, western sheet (1: 50 000 scale map). *Australian Geological Survey Organisation, Canberra.*

Champion, D.C. & Heinemann, M.A., 1994, Igneous rocks of northern Queensland: 1:50 000 map and GIS explanatory notes. *Australian Geological Survey Organisation Record* 1994/11.

Clare, R.C., 1990, Overview of Collinsville geology. Bowen Basin Symposium 1990 Proceedings. *Geological Society of Australia, Queensland Division*, 275-283.

Clarke, D.E. & Paine, A.G.L., 1970, Charters Towers, Queensland, 1:250 000 Geological Series. *Bureau of Mineral Resources Australia Explanatory Notes* SF/55-2.

Claoué-Long, J.C., Jones, P.J., Roberts, J & Maxwell, S., 1992 - The numerical age of the Devonian-Carboniferous boundary. *Geological Magazine*, 129, 281-291.

Coney, P.J., Edwards, A., Hine, R., Morrison, F. & Windrum, D., 1990, The regional tectonics of the Tasman orogenic system, eastern Australia. *Journal of Structural Geology*, 12, 519-543.

CSIRO, 1967, Lands of the Nogoa - Belyando area, Queensland. *Commonwealth Scientific and Industrial Research Organisation, Australia, Australia Land Research Series*, 18.

Cunneen, R. & Sillitoe, R.H., 1989, Paleozoic hot spring sinter in the Drummond Basin, Queensland, Australia. *Economic Geology*, 84, 135-142.

Daintree, R., 1870, Report from Mr. Daintree, late Government Geologist, Northern Queensland, on the Ravenswood, Mt. Wyatt and Cape River Gold Fields. *Queensland Legislative Assembly Votes and Proceedings*, 1870 3rd Session.

Davis, B.K. & Henderson, R.A., 1994, Syn-rift magmatic assemblages of the Drummond Basin (abstract). *In* Davis, R.A. & Henderson, R.A. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 103-104.

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

Day, S.J., 1993, Conference report: the structural evolution and mechanics of volcanoes and subvolcanic intrusions. *Journal of the Geological Society* 150, 207-208.

De Caritat, P, & Braun, J., 1992, Cyclic development of sedimentary basins at convergent plate margins - 1. Structural and tectonothermal evolution of some Gondwana basins of eastern Australia. *Journal of Geodynamics*, 16, 241-282.

De Havelland, D.W., 1987, *Gold and ghosts. Vol. 3, Queensland central and southern districts*. Hesperian Press, Carlisle/Victoria Park W.A.

Department of Primary Industries and Energy, 1989, New maps extend potential for former gold mining towns. *Primary Resource* 89/07, 19-23.

Dickins, J.M. & Malone, E.J., 1973, Geology of the Bowen Basin, Queensland. *Bureau of Mineral Resource, Australia Bulletin* 130.

Dietrich, R.V., Dutro, J.T., Jr & Foose, R.M. (Compilers), 1982, *A.G.I. data sheets (second edition)*. American Geological Institute, Falls Church, Virginia.

Etminan, H., 1989, Project 150.01: Gold mineralisation in north Queensland and its magmatic and tectonic setting. *BMR 1989 Yearbook*, 8.

Ewers, G., 1989, Recognising sinters in epithermal gold deposits. *BMR Research Newsletter*, 11, 5-6.

Ewers, G., 1990a, Epithermal sinters: a low-cost exploration tool. *BMR Research Newsletter*, 12, unpaginated supplement.

Ewers, G.R., 1990b, The isotopic recognition of sinters in epithermal gold deposits (abstract). *Bureau of Mineral Resources Australia Record* 1990/95, 17-18.

Ewers, G.R., 1991, Oxygen isotopes and the recognition of siliceous sinters in epithermal ore deposits. *Economic Geology*, 86, 173-178.

Ewers, G.R. & Hoffman, C.F., 1992, Sample, fluid inclusion, stable isotope, and geochronological data for epithermal gold prospects in the northern Drummond Basin. *Bureau of Mineral Resources Australia Record* 1992/21.

Ewers, G.R., Mackenzie, D.E., Cruikshank, B.I., Wyborn, D. & Andrew, A.S., 1993, Regional oxygen isotope patterns and their implications for epithermal gold exploration (abstract). *International Association of Volcanology and Chemistry of the Earth's Interior 1993 General Assembly Abstracts*, 31.

Ewers, G., Mackenzie, D., McPhie, J., Oversby, B., Wyborn, D. & Law, S., 1989, New mapping extends Drummond Basin gold potential. *BMR Research Newsletter*, 10, 1-4.

Ewers, G., Mackenzie, D., Oversby, B. & Wyborn, D., 1991, Regional oxygen-isotope patterns - implications for epithermal gold exploration. *BMR Research Newsletter*, 14, 1-2.

Ewers, G.R., Mackenzie, D.E., Wyborn, D., Oversby, B.S., McPhie, J. & Andrew, A.S., 1994, Regional ^{18}O depletions in igneous rocks from the northern Drummond Basin, Queensland, Australia, and their implications for epithermal gold mineralization. *Economic Geology*, 89, 662-673.

Ewers, G.R., Wood, D.G., Tedder, I.J., Haas, L. & Hoffman, F., 1993, Epithermal gold mineralisation in the northern Drummond Basin. *Bureau of Mineral Resources Australia Record* 1992/72.

Ewers, G.R., Wood, D.G., Tedder, I.J., White, N.C. & Hoffman, C.F., 1990, Epithermal gold prospects in the Conway area, northern Drummond Basin, Queensland. *Pacific Rim 90 Congress Proceedings*, II, 357-362.

Fellows, M.L. & Hammond, J.M., 1990, Wirralie gold deposit. *In* Hughes, F.E. (editor), *Geology and mineral deposits of Australia and Papua New Guinea*. Australasian Institute of Mining and Metallurgy Monograph 14, 1489-1492.

Froggatt, P.C., 1981, Stratigraphy and nature of Taupo Pumice Formation. *New Zealand Journal of Geology and Geophysics*, 24, 231-248.

Geological Society of Australia, 1971, *Tectonic map of Australia and New Guinea 1:5 000 000 scale*. Sydney.

Geological Survey of Queensland, 1975, *Queensland Geology, 1:2500 000 scale*., Brisbane.

Gill, J.B., 1981, *Orogenic andesites and plate tectonics*. Springer-Verlag, New York.

Golding, S.D. & Wilson, A.F., 1984, Stable isotope relationships in epithermal gold deposits, Queensland. *Australasian Institute of Mining and Metallurgy, Perth and Kalgoorlie Branches 1984 Regional Conference*, 1-9.

Green, C.J., Harvey, K.J. & McIntosh, D.C., 1994, Recent developments at Ravenswood (abstract). *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 27-28.

Gregory, P.W., Hartley, J.S. & Wills, K.J.A., 1990, Thalanga zinc-lead-copper-silver 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, 1527-1537.

Gregory, P.W., Hartley, J.S. & Wills, K.J.A., 1993, The Thalanga masive sulphide deposit. *In* Henderson, R.A. (editor), Guide to the economic geology of the Charters Towers region, northeastern Queensland. *Geological Society of Australia, Queensland Division 1993 Field Conference Guidebook*, 93-98.

Harmsworth, W.R., 1994, The Mt Canton ring dyke breccia - a host to porphyry-style mineralisation in the Charters Towers district. *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50 37-46.

Harrington, H.J. & Korsch, R.J., 1985, Tectonic model for the Devonian to middle Permian of the New England Orogen. *Australian Journal of Earth Sciences*, 32, 163-179.

Hartley, J.S., Peters, S.G. & Beams, S.D., 1989, Current developments in Charters Towers geology and gold mineralisation. *NQ Gold '89 Conference Proceedings*, 7-14.

Hartley, J.S., Peters, S. & Beams, S.D., 1993, Geological context and concepts of mineralisation in the Charters Towers region. *In* Henderson, R.A. (editor), Guide to economic geology of the Charters Towers region, northeastern Queensland. *Geological Society of Australia, Queensland Division 1993 Field Conference Guidebook*, 49-59.

Hartley, J.S., Hutton, L.J. & Rienks, I.P., 1994, Metallogenesis in the Charters Towers Province. *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and matallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50 7-11.

Heald, P., Foley, N.K. & Hayba, D.O., 1987, Comparative anatomy of volcanic-hosted epithermal deposits. *Economic Geology*, 82, 1-26.

Hedenquist, J.W. & Henley, R.W., 1985, The importance of CO_2 on freezing point measurements of fluid inclusions: evidence from active geothermal systems and implications for epithermal ore deposition. *Economic Geology*, 80, 1379-1406.

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, 1-26.

Henderson, R. A., 1983, Early Ordovician faunas from the Mount Windsor Subprovince, northeastern Queensland. *Association of Australasian Palaeontologists Memoir* 1, 145-175.

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. (editor), 1993, Guide to the economic geology of the Charters Towers region, northeastern Queensland. Itinerary and descriptions - Ravenswood, Mt Leyshon, Mt Windsor Volcanics, Thalanga. *Geological Society of Australia, Queensland Division 1993 Field Conference Guidebook*, 103-105, 111-126.

Henley, R.W. & Adams, D.P.M., 1992, Strike-slip fault reactivation as a control on epithermal vein-style gold mineralization. *Geology*, 20, 443-446.

Hill, A.P., 1993, Synchronous felsic volcanism and sea-floor base-metel sulphide mineralisation at East Thalanga, north Queensland, Australia (abstract). *International Association of Volcanology and Chemistry of the Earth's Interior, 1993 General Assembly Abstracts*, 48.

Hill, D. & Denmead, A.K. (editors), 1960, *The Geology of Queensland.* Geological Society of Australia, 7.

Hutton, L.J., 1989, A stratigraphic and tectonic model for the Drummond Basin and its relationship to gold mineralization. *NQ Gold '89 Conference Proceedings*, 31-40.

Hutton, L. J., Grimes, K. G., Law, S. R. & McLennan, T. P. T., 1991, Geology of the Mount Coolon 1:250 000 Sheet area. *Queensland Department of Resource Industries Record* 1991/19.

Hutton, L.J., Hartley, J.S. & Rienks, I.P., 1993, Geology of the Charters Towers region. *In* Henderson, R.A. (editor), Guide to the economic geology of the Charters Towers region, northeastern Queensland. *Geological Society of Australia, Queensland Division 1993 Field Conference Guidebook*, 1-12.

Hutton, L.J., Rienks, I.P., Tenison Woods, K., Hartley, J.S. & Crouch, S.B.S., 1994, A geochemically and structurally based reinterpretation of the Ravenswood Batholith, north Queensland (abstract). *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 3-5.

Idnurm, M. & Senior, B.R., 1978, Palaeomagnetic ages of Late Cretaceous and Tertiary weathered profiles in the Eromanga Basin, Queensland. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 24, 263-277.

Irvine, R.J. & Smith, M.J., 1990, Geophysical exploration for epithermal gold deposits. *Journal of Geochemical Exploration*, 36, 375-412.

Ishihara, S., 1981, The granitoid series and mineralization. *In* Skinner, B.J. (editor), *Economic Geology 75th anniversary volume*. The Economic Geology Publishing Co., El Paso, 458-484.

Jack, R.L., 1889, Report on the Sellheim silver mines and surrounding district. *Geological Survey of Queensland, Publication* 57.

Jensen, H.I., 1921, The geology and mineral resources of the Carnarvon district. *Queensland Government Mining Journal*, 22, 401-407.

Johnson, S.E. & Henderson, R.A., 1991, Tectonic development of the Drummond Basin, eastern Australia: backarc extension and inversion in a late Palaeozoic active margin setting. *Basin Research*, 3, 197-213.

Johnston, M.D., 1994, Mineralisation style and controls: Yandan mine area (abstract). *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny:

northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 105.

Jones, P.J., Burger, D., Chaproniere, G.C.H., Claoue-Long, J.C., Dickins, J.M., Foster, C.B., Laurie, J., Nicoll, R.S., Shafik, S., Shergold, J.H., Strusz, D.L., Truswell, E.M. & Young, G.C. (compilers), 1995. *AGSO Phanerozoic timescale 1995*. Australian Geological Survey Organisation, Canberra.

Kirkegaard, A.G., 1974, Structural elements of the northern part of the Tasman geosyncline. *In* Denmead, A.K., Tweedale, G.W. & Wilson, A.F. (editors), *The Tasman geosyncline - a symposium*. Geological Society of Australia, Queensland Division, 47-62.

Klootwijk, C.T., 1988, Palaeomagnetism. *In* Finlayson, D.M. (editor), Eromanga-Brisbane geoscience transect: position papers presented in February, 1988. *Bureau of Mineral Resources Australia Record* 1988/10, 25-30.

Klootwijk, C. & Giddings, J., 1988a, An alternative APWP for the middle to late Palaeozoic of Australia - implications for terrane movements in the Tasman fold belt (abstract). *Geological Society of Australia Abstracts*, 21, 219-220.

Klootwijk, C.T. & Giddings, J.W., 1988b, Project 9330.05: palaeomagnetism-tectonics and reconstructions. *In* Wolf, K.H., (editor), BMR 88 - Yearbook of the Bureau of Mineral Resources, Geology and Geophysics, 1 July 1987 to 30 June 1988. *Australian Government Publishing Service, Canberra*, 132-133.

Klootwijk, C., Giddings, J.W. & Percival, P., 1993, Palaeomagnetic reconnaissance of upper Palaeozoic volcanics, northeastern Queensland. *Australian Geological Survey Organisation Record* 1993/36.

Lackie, M.A., Clark, D.A. & French, D.H., 1992, Palaeomagnetic reconnaissance of upper Palaeozoic volcanics, northeastern Queensland. *Australian Geological Survey Organisation Record* 1993/36.

Laing, W.P., 1994, Palaeozoic structural framework and regional plumbing system of northeastern Queensland (abstract). *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 125-132.

LaMarche, G. & Froggatt, P.C., 1993, New eruptive vents for the Whakamaru Ignimbrite (Taupo Volcanic Zone) identified from magnetic fabric study. *New Zealand Journal of Geology and Geophysics*, 36, 213-222.

Law, S.R., 1988, The Bulgonunna Volcanics - a Carboniferous ignimbritic cauldron complex in central Queensland (abstract). *Geological Society of Australia Abstracts*, 21, 238.

Law, S., Mackenzie, D., McPhie, J., Oversby, B., Wellman, P. & Wyborn, D., 1989, Geological setting of gold mineralisation in the northern Drummond Basin: significance of the Bulgonunna Volcanics (abstract). *NQ Gold '89 Conferenc, Proceedings*, 47-50.

Leichhardt, L., 1847 (not dated), *Journal of an Overland Expedition in Australia*. T. & W. Boone, London (facsimile edition, Doubleday, Sydney).

LeMaitre, R.W. (editor), 1989, *A classification of igneous rocks and glossary of terms*. Blackwell, Oxford.

Levingston, K.R., 1953, Ukalunda Gold Mining Syndicate, Ukalunda. *Queensland Government Mining Journal*, 54, 819-823.

Levingston, K.R., 1956 - Oil shale occurrences, Ukalunda. *Queensland Government Mining Journal*, 57, 137-138.

Levingston, K.R., 1981, Geological evolution and economic geology of the Burdekin River region, Queensland. *Bureau of Mineral Resources Australia Bulletin* 208.

Li, Z.X., Powell, C.M., Thrupp, G.A. & Schmidt, P.W., 1990, Australian Palaeozoic palaeomagnetism and tectonics - II. A revised apparent polar wander path and palaeogeography. *Journal of Structural Geology*, 12, 567-575.

Lister, G.S., Etheridge, M.A. & Symonds, P.A., 1986, Detachment faulting and the evolution of passive continental margins. *Geology*, 14, 246-250.

Louthean, R. (editor), 1993, Register of Australian mining 1993/94. *Resource Information Unit Ltd, Subiaco W.A.*

Mackenzie, D.E., Champion, D.C. & AGSO-GSQ Project Team, 1994, Permian-Carboniferous magmatism and metallogeny in north Queensland - a new perspective (abstract). *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 67-68.

Malone, E.J., 1968, Mount Coolon, Qld - 1:250 000 Geological Series. *Bureau of Mineral Resource, Australia Explanatory Notes* SF/55-7.

Malone, E.J., Corbett, D.W.P. & Jensen, A.R., 1964, Geology of the Mt Coolon 1:250 000 Sheet area. *Bureau of Mineral Resources Australia Report* 64.

Malone, E.J., Jensen, A.R. & Gregory, C.M., 1966, Geology of the southern half of the Bowen 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources Australia Report* 100.

McFadden, P.L., 1990, A new fold test for palaeomagnetic studies. *Geophysical Journal International*, 103, 163-169.

McPhie, J., 1993, Tuff problems (abstract). *International Association of Volcanology and Chemistry of the Earth's Interior, 1993 General Assembly Abstracts*, 72.

McPhie, J., Black, L.P., Law, S.R., Mackenzie, D.E., Oversby, B.S. & Wyborn, D., 1990, Distribution, character and setting of mineralised Palaeozoic volcanic sequences, Burdekin Falls region, northeastern Queensland. *Pacific Rim 90 Congress Proceedings*, II, 465-471.

McPhie, J., Doyle, M. & Allen, R., 1993, *Volcanic Textures*. University of Tasmania Centre for Ore Deposit and Exploration Studies Key Centre, Hobart.

Morrison, G.W., 1986, Geology and mineralisation of the Mount Leyshon diatreme. *University of Queensland, Department of Geology Paper*.

Morrison, G.W., 1988, Palaeozoic gold deposits of northeast Queensland (abstract). *Geological Society of Australia Abstracts*, 22, 91-101.

Morrison, G.W., Andrew, A. & Teale, G., 1988, Origin of gold mineralisation in the Mount Leyshon diatreme (abstract). *Geological Society of Australia Abstracts*, 22, 116-120.

Morrison, G., 1994, Late Palaeozoic metallogeny in northeastern Queensland (abstract). *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 133-135.

Murray, C.G., 1983, Permian geology of Queensland, *In* Permian Geology of Queensland. *Geological Society of Australia, Queensland Division, Brisbane*, 1-32.

Murray, C.G., 1985, Tectonic setting of the Bowen Basin. *Geological Society of Australia Abstracts*, 17, 5-16.

Murray, C.G., 1990, Tectonic evolution and metallogenesis of the Bowen Basin. *Bowen Basin Symposium 1990, Proceeding*, 201-212.

Murray, C.G. & Kirkegaard, A.G., 1978, The Thomson Orogen of the Tasman Orogenic Zone. *In* Scheibner, E. (editor), The Phanerozoic structure of Australia and variations in tectonic style. *Tectonophysics*, 48, 299-325.

Murray, C.G., Fergusson, C.L., Flood, P.G., Whitaker, W.G. & Korsch, R.J., 1987, Plate tectonic model for the Carboniferous evolution of the New England Fold Belt. *Australian Journal of Earth Sciences*, 34, 213-236.

Murray, C.G., Scheibner, E. & Walker, R.N., 1989, Regional geological interpretation of a digital coloured residual Bouguer gravity image of eastern Australia with a wavelength cut-off of 250 km. *Australian Journal of Earth Sciences*, 36, 423-449.

Neindorf, L., Dennis, R., Palmer, G. & Clark, A., 1989, Ravenswood gold mine, an experience of rapid exploration, development and production. *NQ Gold '89 Conference, Proceedings*, 115-125.

Neindorf, L., Dennis, R., Palmer, G. & Clark, A., 1993, Ravenswood gold mine, an experience of rapid exploration, development and production. *In* Henderson, R.A. (editor), Guide to the economic geology of the Charters Towers region, northeastern Queensland. *Geological Society of Australia, Queensland Division, 1993 Field Conference Guidebook*, 33-47.

Olgers, F., 1970, Buchanan, Qld - 1:250 000 Geological Series. *Bureau of Mineral Resources Australia Explanatory Notes* SF/55-6.

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

Orr, T.H., 1994, The Mt Leyshon gold mine: geology and mineralisation. *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 29-35.

Oversby, B., 1983, Local and regional tectonic-structural controls of late Palaeozoic cratonic volcanism in northeastern Australia (abstract). *Geological Society of Australia Abstracts*, 9, 112-113.

Oversby, B.S., 1987, Extensional and intrusive-extrusive structural interactions in the late Palaeozoic of northeastern Queensland (abstract). *Bureau of Mineral Resources Australia Record* 1987/51, 231-236.

Oversby, B., 1988, Late Palaeozoic magmatism in northeastern Queensland - incipient rifting at a passive margin of Gondwanaland ? (abstract). *Geological Society of Australia Abstracts*, 21, 307-308.

Oversby, B., 1995, Late Palaeozoic magmatism in north Queensland: recent new perspective expanded by transfer-structure hypothesis. *AGSO Research Newsletter*, 22, 11-12.

Oversby, B.S., Black, L.P. & Sheraton, J.W., 1980, Late Palaeozoic continental volcanism in northeastern Queensland. *In* Henderson, R.A. & Stephenson, P.J. (editors), *The geology and geophysics of northeastern Australia.* Geological Society of Australia, Queensland Division, 247-286.

Oversby, B.S., Ewers, G.R., Mackenzie, D.E., McPhie, J., Wyborn, D., Law, S. & Black, L.P, 1990, Volcanic setting of epithermal gold mineralisation in the northern Drummond Basin, Queensland (abstract). *Geological Society of Australia Abstracts,* 25, 36.

Oversby, B.S., Mackenzie, D.E., McPhie, J., Law, S.R. & Wyborn, D., 1991, Catalogue of field compilation sheets of late Palaeozoic ignimbrites and associated rocks in the Burdekin Falls Dam - "Conway" area (Glendon and adjacent parts of Ravenswood, Strathalbyn, Harvest Home, and Collinsville 1:100 000 Sheet areas), northeastern Queensland. *Bureau of Mineral Resources Australia Record* 1991/28.

Oxburgh, E.R. & Turcotte, D.L., 1974, Membrane tectonics and the East African Rift. *Earth and Planetary Science Letters*, 22, 133-140.

Page, R.W., 1983 - Timing of superposed volcanism in the Proterozoic Mount Isa Inlier, Australia. *Precambrian Research*, 21, 223-245.

Page, R.W., McCulloch, M.T. & Black, L.P., 1984, Isotopic record of major Precambrian events in Australia. *27th International Geological Congress Proceedings*, 5, 25-72.

Paine, A.G.L. & Cameron, R.L., 1972, Bowen, Qld - 1:250 000 Geological Series. *Bureau of Mineral Resources Australia Explanatory Notes* SF/55-3.

Paine, A.G.L., Clarke, D.E. & Gregory, C.M., 1974, Geology of the northern half of the Bowen 1:250 000 Sheet area, Queensland (with additions to the geology of the southern half). *Bureau of Mineral Resources Australia Report* 145.

Palmer, A.R. (compiler), 1983, The Decade of North American Geology 1983 geologic time scale. *Geology*, 11, 503-504.

Paull, P.L., Hodkinson, I.P., Morrison, G.W. & Teale, G.S., 1990, Mount Leyshon gold 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, 1471-1481.

Peters, G., 1987, Geology and lode controls of the Charters Towers goldfield, northeastern Queensland. *James Cook University of North Queensland, EGRU Contribution* 19.

Porter, R.G., 1988 The Pajingo gold mine. *In* Morrison, G.W. (editor) Bicentennial Gold 88 excursion guidebook, epithermal and porphyry style gold deposits in north Queensland. *James Cook University of North Queensland, EGRU Contribution* 29, 23-34.

Porter, R.R.G., 1990, Pajingo gold 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, 1483-1487.

Queensland Department of Mapping and Surveying, 1978, *Glendon, Sheet 8356-42, edition 1. (Queensland 1:25 000 Series topographic map).* Department of Mapping and Surveying, Brisbane.

Reid, J.H., 1924, Geology of the Bowen River coalfield. *Geological Survey of Queensland Publication* 276, 1-107.

Russo, R., Richardson, J.K. & Allen, P.H., 1985, Design of the Burdekin Falls Dam. *Institute of Engineers Transactions*, 27, 362-370.

Schmidt, J.G., Horton, B.K. & Brown, C.L., 1993, Influence of transverse structures on sedimentation in continental extensional basins: examples from the eastern Great Basin (abstract). *Geological Society of America Abstracts with Programs*, 25, 143.

Schmidt, J.G. & Olson, T.J., 1986, Hyperconcentrated flood-flow deposition of coarse-grained sediment on temperate, semi-arid to humid alluvial fans (abstract). *Geological Society of America Abstracts with Programs*, 18, 741.

Scott, K.M. & Vallance, J.W., 1993, Hyperconcentrated flows in volcanic settings (abstract). *International Association of Volcanology and Chemistry of the Earth's Interior, 1993 General Assembly Abstracts*, 97.

Seward, T.M.,1973, Thiocomplexes of gold and the transport of gold in hydrothermal ore solutions. *Geochimica et Cosmochimica Acta*, 48, 121-134.

Sillitoe, R.H., 1985, Ore-related breccias in volcanoplutonic arcs. *Economic Geology*, 80, 1467-1514.

Sparks, R.S.J., Self, S. & Walker, G.P.L., 1973, Products of ignimbrite eruptions. *Geology*, 1, 115-118.

Sparks, R.S.J., Stasiuk, M.V., Gardeweg, M. & Swanson, D.A., 1993, Welded breccias in andesite lavas. *Journal of the Geological Society*, 150, 897-902.

Staines, H.R.E, & Koppe, W.H., 1980, The geology of the north Bowen Basin. *In* Henderson, R.A. & Stephenson, P.J. (editors), *The geology and geophysics of northeastern Australia.* Geological Society of Australia, Queensland Division, 279-298.

Stephenson, P.J. & Griffin, T.G., 1976, Cainozoic volcanicity of north Queensland. *XXV International Geological Congress, Field Excursion 7A Handbook.*

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, 349-374.

Stolz, A.J., 1994, Geochemistry and Nd isotope character of the Mt Windsor Volcanics: implications for the tectonic setting of Cambro-Ordovician VHMS mineralisation (abstract). *In* Henderson, R.A. & Davis, B.K. (editors), New developments in geology and metallogeny: northern Tasman orogenic zone. *James Cook University of North Queensland, EGRU Contribution* 50, 13-16.

Sutherland, F.L., 1991, Cainozoic volcanism, eastern Australia: a predictive model based on migration over multiple "hotspot" magma sources. *In* Williams, M.A.J., De Dekker, P. & Kershaw, A.P. (editors), The Cainozoic in Australia: a re-appraisal of the evidence. *Geological Society of Australia Special Publication*, 18, 15-43.

Toutouji, M. (editor), 1993, *Gold producers handbook 1993*. Australian Stock Exchange Ltd, Sydney.

Veevers, J.J., Mollan, R.G., Olgers, F. & Kirkegaard, A.G., 1964, The geology of the Emerald 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources Australia Report* 68.

Veevers, J.J., Clare, A. & Wopfner, H., 1994, Neocratonic magmatic-sedimentary basins of post-Variscan Europe and post-Kanimblan eastern Australia generated by right-lateral transtension of Permo-Carboniferous Pangaea. *Basin Research*, 6, 141-157.

Walker, G.P.L., 1985, Origin of coarse lithic breccias near ignimbrite vents. *Journal of Volcanology and Geothermal Research*, 25, 157-171.

Walker, G.P.L., Self, S. & Froggatt, P.C., 1981, The ground layer of the Taupo ignimbrite: a striking example of sedimentation from a pyroclastic flow. *Journal of Volcanology and Geothermal Research*, 10, 1-11.

Webb, A.W. & McDougall, I., 1968, The geochronology of the igneous rocks of eastern Queensland. *Journal of the Geological Society of Australia*, 15, 313-346.

Webb, E.A. & Crapp, C.E., 1960, The geology of the Collinsville Coal Measures. *Australasian Institute of Mining and Metallurgy Proceedings*, 193, 23-88.

Webster, S.S., Henley, R. & Harris, L., 1989, High resolution airborne geophysics for epithermal gold exploration in northeastern Queensland. *NQ Gold '89 Conference Proceedings*, 41-46.

White, N.C., Wood, D.G. & Lee, M.C., 1989, Epithermal sinters of Paleozoic age in North Queensland, Australia. *Geology*, 17, 718-722.

White, N.C. & Hedenquist, J.W., 1990, Epithermal environments and styles of mineralisation: variations and their causes, and guidelines for exploration. *In* Hedenquist, J.W., White, N.C. & Siddeley, G. (editors), Epithermal gold mineralization of the circum-

Pacific: geology, geochemistry, origin and exploration. *Journal of Geochemical Exploration*, 36, 445-474.

Withnall, I.W. & Lang, S.C., 1990, Tectonic history of the Palaeozoic Broken River Province, north Queensland. *Pacific Rim 90 Congress Proceedings*, II, 315-323.

Wohl, E.E., 1992, Bedrock benches and boulder bars: floods in the Burdekin gorge of Australia. *Geological Society of America Bulletin,* 104, 770-778.

Wood, D.G., Porter, R.G. & White, N.C., 1990, Geological features of some Paleozoic epithermal gold occurrences in northeastern Queensland, Australia. *Journal of Geochemical Exploration*, 36, 413-444.

Wormald, P.J., Orr, T.O.H. & Hodgkinson, I.P., 1993, The Mount Leyshon gold mine (NE Queensland), an intrusive breccia and igneous complex. *In* Henderson, R.A. (editor), Guide to the economic geology of the Charters Towers region, northeastern Queensland. *Geological Society of Australia, Queensland Divisio, 1993 Field Conference Guidebook*, 61-74.

Wright, J.V. & Walker, G.P.L., 1977, The ignimbrite source problem: significance of a co-ignimbrite lag-fall deposit. *Geology*, 5, 729-732.

Wyatt, D.H., Paine, A.G.L., Clarke, D.E. & Harding, R.R., 1970, Geology of the Townsville 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources Australia Report* 127.

Wyborn, D. & Chappell, B.W., 1986, The petrogenetic significance of chemically related plutonic and volcanic rock units. *Geological Magazine*, 123, 619-628.