

**A review and interpretation of the Lower
Palaeozoic geology of the Que River–Sheffield
area, with particular reference to the Cambrian
volcanic sequences**

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Maps

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Summary

This report summarises and synthesises the geology of the Lower Palaeozoic rocks of the Beulah–Sheffield–St Valentines Peak–Que River area, with particular emphasis on correlation of the Cambrian volcanic sequences to the better known units in western Tasmania. A new compilation map of the geology at a scale of 1:100 000, and maps of aeromagnetism and radiometrics at the same scale, have been prepared.

- The Mt Read Volcanics belt and associated Cambrian sedimentary sequences continue unbroken into the Sheffield area, with a more-or-less smooth swing in trend from N-S to E-W, following the arcuate margin of the Tyennan region. The Cambrian ‘trough’ expands in width (N-S), and has an inverted V-shape. Major blocks of allochthonous Early Cambrian rocks, the Barrington Chert and Motton Spilite, underlie parts of the trough, and also occur at the poorly defined western margin.
- A complex sequence of Middle Cambrian Mt Read volcanic and volcano-sedimentary rocks is present, much of it poorly known. The sequence is unconformably overlapped by Late Cambrian–Ordovician siliciclastic rocks showing derivation from both Precambrian quartzite and allochthonous chert sources. Ordovician limestone is preserved in a series of large Devonian synclinal structures, most with a core of Siluro-Devonian sandstone.
- Two major Devonian granite bodies intrude the margins of the basin at Housetop and Dolcoath, the latter only just reaching the surface and having a large westerly extension in the subsurface. Both granites are associated with skarn-type tin-tungsten deposits hosted in Moina Sandstone and Gordon Limestone, and the Dolcoath Granite has an outer zone of Ag-Pb-Zn-Au-Cu deposits, including the rich Ag-Pb deposits of the Round Hill district.
- Granodioritic intrusive rocks at Beulah, previously interpreted as the Devonian ‘Beulah granite’, are now known to be Cambrian andesitic bodies, and recent mapping has clarified their extent. Company mapping has shown that another group of similar bodies is present at Native Track Tier.
- Forming the southern part of the Mt Read belt is a zone of felsic quartz-phyric volcanic and volcanoclastic rocks associated with large intrusive quartz-feldspar-biotite porphyry bodies fringing the Tyennan region. These rocks are clearly correlates of the Eastern Quartz-Phyric Sequence (EQPS) of the Mt Murchison–Lake Selina area. They host a large sericite-pyrite hydrothermal alteration zone in the Bell Mount–Cethana area known as the Cethana Pyrite Zone.
- Immediately north of this, along the front of the Fossey Mountains chain, is a zone rich in andesitic volcanic rocks, volcanoclastic breccia and crystal-rich volcanoclastic sandstone and conglomerate, extending through Winterbrook, Staverton, Gowrie Park, Paradise and Beulah. Most of these rocks have been assigned to the Tyndall Group, on the basis of Tyndall-age fossils at Paradise and abundant ‘Tyndall-like’ breccias and sandstones. The large mass of andesite and breccia at Beulah may be the same age, but has enigmatic relationships with the adjacent sedimentary rocks and may be slightly older.
- Another area of Tyndall Group correlates is present at Native Track Tier, and contains diagnostic fossils and typical Tyndall-type breccias. Tyndall Group time correlates are also present at St Valentines Peak, where the sequence is notably finer grained than normal and lacks any andesitic component.
- An extensive sequence of mixed volcanoclastic and non-volcanic sandstone, siltstone and shale, with scattered felsic to andesitic lavas and intrusive rocks, occupies the main central part of the trough from Loongana Range through Nietta, Castra, Barrington and Beulah to the Weegen area. This sequence overlies ‘basement’ rocks, probably interfingers with the EQPS, and is correlated with the Western Volcano-Sedimentary Sequence (WVSS) of the West Coast. No diagnostic fossils are known, and it is likely that younger rocks (Tyndall Group and Owen Group equivalents) have been included in some areas. Siliciclastic conglomerates, virtually identical to those of the Owen Group, occur in the sequence in several areas.
- Five bodies of Cambrian granite have been recognised, three in the Dove River area and two small bodies intruding EQPS near Cethana.
- Altered mafic tholeiitic rocks of uncertain affinities, mostly intruding WVSS, occur at Mt Tor, Wilmot and Gog Range. The body at Wilmot is strongly magnetic, and, although largely buried beneath Moina Sandstone, appears to be responsible for a large aeromagnetic anomaly in the area.
- The Late Cambrian Owen Group siliciclastic sequence of the West Coast Range continues on to the Black Bluff Range but thins to zero in the Moina area, where only the shallow-marine Moina Sandstone (of Middle Ordovician age) separates the Middle Cambrian rocks from the overlying Ordovician limestone. It is in this area, where the sub-Moina Sandstone siliciclastic wedge is missing, that the Dolcoath Granite body surfaces, and

where there is maximum development of granite-related mineral deposits in the calcareous Moina–Gordon host rocks.

- Most of the known productive mineral deposits in the area are related to the Devonian granites, and have been reviewed elsewhere. Four groups of Cambrian deposits/prospects can be recognised:
 - (i) gold and base metal occurrences related to the large felsic intrusive bodies, such as Fire Tower, Star of the West, Ten Mile Hill, Carters, Speeler Creek;
 - (ii) prospects within the Cethana Pyrite Zone, a large alteration system somewhat analogous in size and stratigraphy to Mt Lyell and Henty, with a potential exhalative zone associated with the base of the nearby Tyndall Group. Although only minor base metals have so far been intersected, there is a possibility of an association with the nearby Devonian Round Hill Ag-Pb deposits, which may have involved remobilisation of Cambrian sulphides;
 - (iii) Pb-Zn-Cu-Ag prospects hosted mainly within WVSS rocks in the Barrington–Castra–Nietta area, with links to andesitic intrusive rocks in some cases and a suggestion of exhalative mineralisation in some cases, e.g. Lake Barrington, McPhersons, Preston Silver, Barrington (Alma), Loyetea South and Crosby Creek. Several of these have given Cambrian lead isotope signatures. Such occurrences suggest that buried VHMS deposits, and other types of mineralisation, could be present in this large area of Cambrian rocks where our knowledge of the geology is woefully inadequate;
 - (iv) Pb-Zn-Ag-Cu-Ba prospects in mainly andesitic rocks of the Tyndall Group in the Mt Roland–Gowrie Park–Staverton area, possibly including the Beulah Barite prospect. Their presence in a range of Tyndall Group lithologies suggests mineralising systems continued operating later in the history of this area than on the West Coast. The well-known prospective horizon around the base of the Tyndall Group is widely represented around Sheffield and Cethana, but has had little if any specific exploration.
- The enigmatic negative gravity anomaly in the Sheffield–Barrington–Nietta area, previously attributed to the Beulah ‘granite’ (Cambrian microgranodiorite), is discussed. A Devonian granite source seems unlikely because of lack of expected mineralisation/alteration effects. Cambrian granodioritic bodies seen outcropping at either end of the zone are likely to be too dense to be responsible, but an unexposed more felsic or ‘granitic’ variant is a contender. The allochthonous Barrington Chert bodies, which probably underlie much of the trough in this area, are a possible source.

Introduction

Present study and previous mapping

This report, and the associated maps, represent the third phase of a project within the Western Tasmanian Regional Minerals Program (WTRMP) to update the geology of the Mt Read Volcanics belt using new geophysical data obtained for the WTRMP and new geological data from other available sources (Corbett, 2002*b*, 2003). A new 1:100 000 scale geological compilation map of the Que River–Sheffield area has been prepared (Map 1), and maps of aeromagnetism and radiometrics at the same scale are available from Mineral Resources Tasmania (Maps 2, 3).

There have been few attempts to integrate the Cambrian geology of northwest Tasmania into the stratigraphic scheme established for western Tasmania (e.g. Corbett and McNeill, 1988), largely because of the lack of recent mapping. The original 1:63,360 scale Sheffield geological map sheet was mapped in 1959 (Jennings *et al.*, 1959), the Middlesex sheet in 1958 (Jennings and Burns, 1958), the Mackintosh sheet in 1966 (Barton *et al.*, 1966), and the

St Valentines sheet in 1986 (Baillie *et al.*, 1986), as shown in the source diagram for Map 1. Although the mapping was done by highly competent people, the stratigraphic framework and knowledge of volcanic facies and relationships which underpins recent work on the volcanic belt was not then available.

The situation was improved somewhat when mapping for the Mt Read Volcanics Project was extended into the Black Bluff, Winterbrook and Moina areas in the late 1980's (MRVP Maps 7, 8, 9; Vicary and Pemberton, 1988; Pemberton and Vicary, 1988, 1989), but this project did not extend into the main Sheffield area. Some preliminary re-mapping for the Sheffield 1:50 000 scale sheet was done in the early 1990's, but was suspended until mapping for the new 1:25 000 scale digital series maps commenced in the late 1990's. The Wilmot and Cethana sheets were published in 1999 (McClenaghan and Green, 1999*a, b*), and the Gog sheet in 2001 (McClenaghan *et al.*, 2001). The Sheffield 1:25 000 scale sheet has also been largely re-mapped in recent times, and is being compiled by

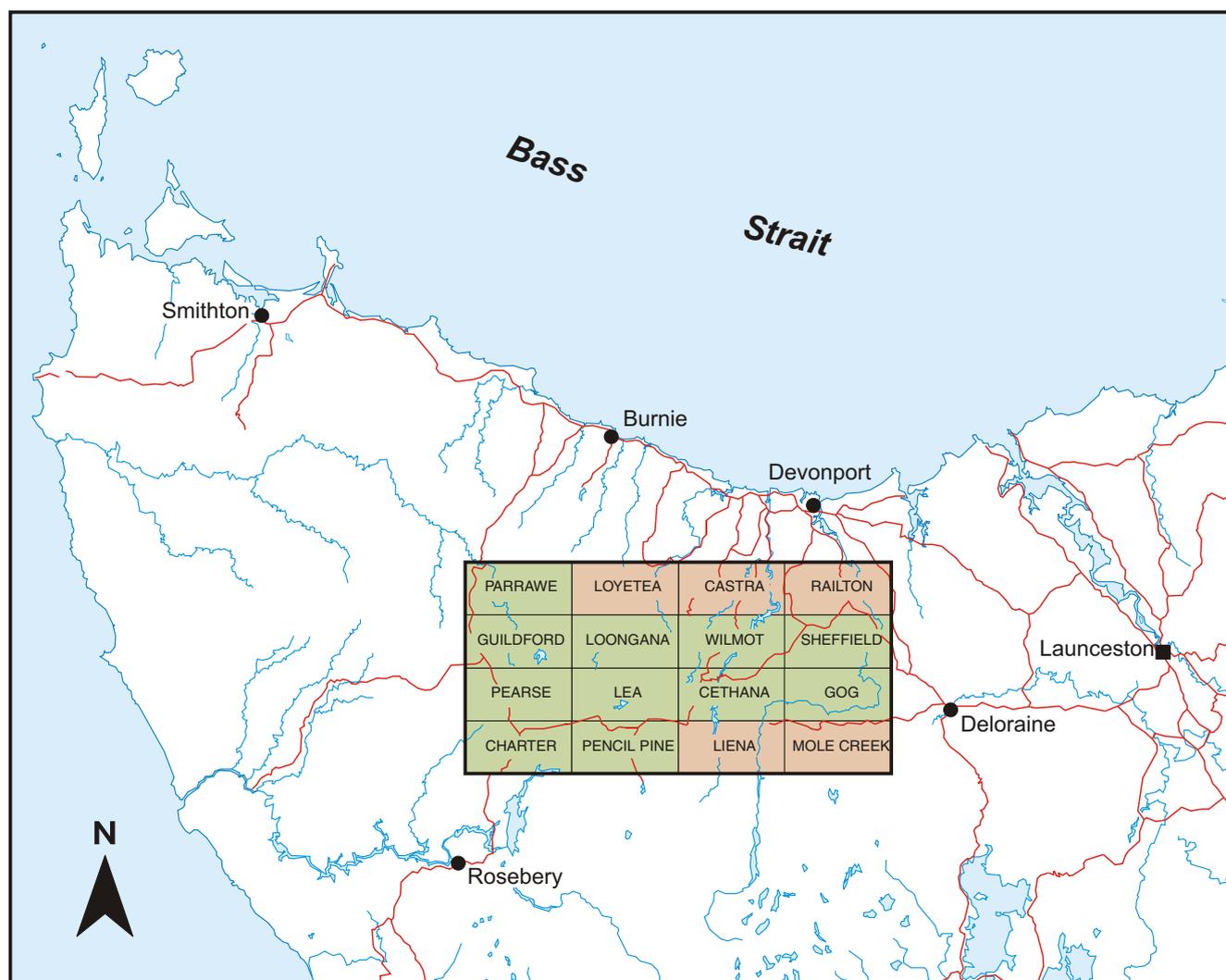


Figure 1

Northwest Tasmania showing location of mapped area. Available 1:25 000 scale map sheets within the mapped area are shown in green, maps in progress are shown in brown.

M. P. McClenaghan at the time of writing. The sheets for Loongana, Lea and Pencil Pine were published in 1996, mainly from existing sources with minimal re-mapping, and the Parrawe, Guildford and Pearse sheets in 2001, after compilation from existing sources.

The re-mapping of the Wilmot, Cethana, Gog and Sheffield 1:25 000 scale geological map sheets represents a very significant advance in the understanding of this important area of Cambrian rocks, but a large area of critical geology north of this remains too poorly known. In particular, the Castra, Loyetea and Railton sheets cover extensive areas of Mt Read Volcanics rocks of considerable economic and strategic significance. The area lies near the boundary of the original Devonport and Sheffield map sheets, where rocks of the 'Fossey Mountains trough' merge with those of the 'Dial Range trough', and where published accounts of the Cambrian geology are somewhat confusing and conflicting (Jennings, 1979; Burns, 1964). It is also the area underlain by a possible granitic body of uncertain age (Leaman, 2003), which could be related to undiscovered mineral deposits. There would seem to be a strong case for thorough re-mapping of these sheets, and the adjacent sheets to the north covering the Dial Range trough, to clarify this critical part of Tasmania's geology and properly assess its considerable economic potential.

Four weeks of field work was done by the author for this project, comprising one week visiting outcrops and discussing possible correlations in the Sheffield-Beulah-Wilmot-Cethana area with MRT and industry geologists (April, 2002), two weeks mapping of problem areas around Sheffield with M. McClenaghan (February, 2003), and one week of reconnaissance mapping in the Loyetea-Leven Canyon-Nietta area (March, 2003).

The compilation map (Map 1) includes a number of features recognised and reported on by R. A. Poltock (2002) during a program of ground checking of WTRMP geophysical data, including a new outcrop of Proterozoic Burnie Formation rocks near Companion Hill, and a new area of outcrop of a mafic igneous rock at Wilmot. A number of other modifications have been made to such things as Tertiary basalt boundaries to accord with the new geophysical data. Some recent company mapping has also been utilised, particularly by RGC Exploration (Vicary, 1994, 1995) in the Loyetea-Nietta area, and Auriongold (Callaghan, 2002) in the Gog Range-Fire Tower area. The outline of the Cethana Pyrite Zone has been compiled from mapping by W. Herrmann for Noranda (*in* Jones, 1989) and D. Hicks (1989; included in Close and Reid, 1997).

Time constraints have not permitted a complete review of the exploration history and mineralisation prospects in the area, and this aspect is dealt with only in summary.

Major elements of the geology

The Cambrian 'Dundas trough' and Mt Read Volcanics belt swing from a N-S trend into an E-W orientation in the Sheffield area, before disappearing under younger rocks to the east. The main Cambrian trough expands considerably in width in a N-S direction at this 'big bend', and links to the narrow 'Dial Range trough' just north of the area under consideration.

The following major geological elements are present in the area:

- (1) Proterozoic rocks forming three areas of 'basement' to the trough. The largest is the northern margin of the Tyennan Region, of Mesoproterozoic schist, quartzite and phyllite. A smaller block of dolomitic schist and quartzite, surrounded by post-Cambrian rocks, is present to the northeast of the trough at Railton. A small area of Neoproterozoic quartzwacke belonging to the Oonah/Burnie Formation correlates is present in the western part of the area around Guildford and Hampshire.
- (2) Several blocks of Early Cambrian allochthonous Cleveland-Waratah Association rocks, including the 'Barrington Chert' and 'Motton Spilite', form 'basement' in the central part of the trough in the Sheffield-Preston area, and are also exposed in the Parrawe area to the west.
- (3) The main trough is largely occupied by Middle Cambrian post-collisional volcanic and volcano-sedimentary sequences of the Mt Read Volcanics belt. The trough is shaped like an inverted 'v', bounded by the Tyennan Region to the south, and by Neoproterozoic and allochthonous rocks to the west and east.
- (4) Late Cambrian to Ordovician siliciclastic sequences of conglomerate and sandstone are widespread across the area, and include correlates of the Late Cambrian Owen Group on Black Bluff Range, the Roland Conglomerate along strike at Mt Roland, and the extensive shallow marine shelf deposit of Ordovician Moina Sandstone across most of the area. The siliciclastic rocks are regionally unconformable on the underlying Middle Cambrian rocks.
- (5) Ordovician Gordon Group limestone and small remnants of Siluro-Devonian sandstone occur in a series of large Tabberabberan synclinal structures.
- (6) Two significant bodies of Devonian granite, the Housetop and Dolcoath granites, crop out in the northern and south-central parts of the area, and are associated with numerous mineral prospects.
- (7) Flat-lying and block-faulted Carboniferous-Permian-Triassic sedimentary rocks, and associated Jurassic dolerite intrusions, blanket most of the older rocks in the eastern part of the area. The sequence is exposed along the scarp of the Great Western Tiers, and includes a thick (300 m) upper dolerite sill and a possible thin lower sill

forming small outliers in the Mole Creek area (Jennings, 1963). Coal deposits in the Permo-Triassic beds have been widely exploited and drilled in the Mersey River–Railton area.

- (8) A widespread sequence of Tertiary basalt flows lies unconformably across all older rocks, and represents the remnant of a partly eroded Tertiary plateau. The basalt has infilled a previous system of river valleys and gorges, and is associated with lake sediments, river gravels and deep leads in many places. Much of the basalt has been cultivated as farmland.

Acknowledgements

The author is pleased to acknowledge the co-operation and helpfulness of MRT and industry personnel in this

project. Dr Geoff Green supervised and directed the overall project, and provided enthusiastic support. Dr Marcus McClenaghan gave freely of his time and knowledge of the Sheffield area, and participated in a number of joint field trips and many useful discussions. The petrological and geochemical data freely shared have been vital to the project. Drs David Seymour and David Green have also freely shared their knowledge of the area, and offered many useful suggestions. Dr Bob Richardson kindly supplied the geophysical images, and Joanne Bowerman produced the geological map, with able assistance from Chris Meech and Ken Bird. Mike Vicary and Tim Callaghan from AurionGold gave freely of information on the Fire Tower prospect and other areas, and Greg Ebsworth of CODES provided helpful information and discussions on Native Track Tier and other areas.

Proterozoic rocks

The northern margin of the Tyennan Region comprises a multiply-folded and metamorphosed sequence of phyllite, quartzite and schist. The rocks east of Fleece Creek include a significant proportion of garnet-grade rocks, and have been included in the 'Mersey River Metamorphic Complex' by Meffre *et al.* (2000). They consider this complex to possibly represent equivalents of the Neoproterozoic rift-related sequences elsewhere (i.e. Oonah Formation, Success Creek Group, Crimson Creek Formation) metamorphosed in the Middle–Late Cambrian Tyennan Orogeny, a proposal which appears to require further testing against field data.

The Tyennan rocks are overlain unconformably by the Middle Cambrian sequence on an exposed contact between Back Peak and the Forth River. East of this, the contact is overlapped by, and appears to be faulted against, Ordovician rocks at the Mersey River (D. B.

Seymour, pers. comm.), and further east is overlapped by the Permo-Triassic sequence.

The isolated inlier of Proterozoic-type rocks northeast of Railton has been described as consisting mostly of quartzite and quartz-sericite schist, and correlated with the Tyennan rocks (Jennings, 1979). Some recent work has shown that most of the rocks are somewhat dolomitic, i.e. quartz-dolomite schist, raising the possibility of them being correlates of the Neoproterozoic rift sequences (e.g. Togari Group and Smithton Dolomite; D. Hartney and R. Berry, pers. comm., 2003).

Quartzwacke-mudstone sequences correlated with the Oonah and Burnie formations crop out west of Companion Hill and near Guildford. The latter are possibly part of an elongate zone of these rocks, largely concealed by Tertiary basalt, extending through the Waratah area from the Coldstream River to the south.

Early Cambrian allochthonous sequences

Several outcrop areas of a greywacke-mudstone-chert-basalt sequence in the Guildford–Hellyer River area are a continuation of the belt of Cleveland–Waratah Association rocks in the Luina area. Descriptions are given in Seymour (1989). In the Fossey Mountains trough, two units previously regarded as part of the Cambrian sequence (the 'Barrington Chert' and 'Motton Spilite' of Jennings, 1979 and Burns, 1964) are now regarded as being allochthonous basement lithologies introduced during a major collisional event in about the early Middle Cambrian (Seymour and Calver, 1995).

The 'Barrington Chert' is the name given to sequences of laminated to massive black to grey chert with minor interbedded greywacke, siltstone and chert breccia, occurring in a number of areas from just west of Sheffield to the coast near Penguin. The largest area is between Barrington and Paloona, where at least

1000 m thickness of chert is considered to be present (Jennings, 1979), although some structural thickening seems likely. No evidence for silicification of a carbonate precursor rock has been described, and the chert appears to be a primary ocean-floor deposit. Similar chert is interbedded with basalts of the 'Motton Spilite' in places, and is present in most of the allochthonous units around Tasmania (e.g. the Ragged Basin Complex at Adamsfield, the Mainwaring Group at Mainwaring River). The chert is quarried for road metal in many places.

The Middle Cambrian sequences overlying the chert contain chert-rich conglomerate in many places (e.g. 'Gog Range Greywacke' and Sprent Formation of Jennings, 1979), and the chert is also a prominent component in some of the Late Cambrian siliclastic conglomerates in the area (Burns, 1964). Thus the chert bodies or allochthonous blocks must have projected as

ridges through the complete Middle Cambrian sequence in at least some areas, suggesting that the presently visible ridges are only the tops of much larger bodies perhaps forming a large part of the trough 'basement'.

The 'Motton Spilite' is represented on the map by a small patch near Preston, which is the southern end of a large body extending through the Dial Range trough, where it is interleaved with Barrington Chert. Pillowed

and massive basaltic lavas are present, typically chlorite-epidote-altered, with intercalated breccias, sandstone, mudstone and chert (Burns, 1964; Jennings, 1979). Chemical and petrological data indicate Ocean Floor Basalt affinities (Hashimoto *et al.*, 1981; Seymour and Calver, 1995) as for the Cleveland-Waratah Association. Clasts of the basalt occur in the overlying Middle Cambrian rocks in places (e.g. Sprent Formation; Jennings, 1979).

Middle Cambrian volcanic-sedimentary sequences — Mt Read Volcanics and Correlates

INTRODUCTION

A complex and variable volcanic-sedimentary sequence, much disrupted by faulting and polyphase folding, and concealed beneath basalt cover over large areas, occupies the 'Fossey Mountains trough'. Establishing a stratigraphy within such a sequence is inherently difficult, even where there is good recent mapping, and hence considerable uncertainties are attached to the present interpretation.

In a regional sense, there is a general variation from quartz-phyric felsic volcanic rocks and porphyries in the southern part of the area, fringing the Tyennan Region, through a zone rich in andesitic volcanic rocks and associated volcanoclastic breccia and sandstone along the front of the Fossey Mountains, to a broad zone dominated by mixed volcanoclastic and non-volcanic sedimentary rocks occupying the main central part of the trough. Coarser volcanoclastic rocks, with some associated andesitic to felsic lavas and intrusive rocks, form a lateral zone to the west, probably continuing into the Dial Range trough.

Early workers struggled with the complexity and variation, and developed a simplified stratigraphic-lithological terminology to make mapping possible. Most of the coherent felsic volcanic rocks and intrusive quartz porphyries were mapped as 'Minnow Keratophyre', wherever they occurred, the extensive greywacke-mudstone sequences were mapped as 'Gog Range Greywacke', and the andesites were referred to as 'Beulah Formation' (Jennings *et al.*, 1959). This system at least allowed maps to be drawn, but the terms have limited usefulness now and are being phased out.

One of the more enduring and unfortunate legacies from the early work has been the misconception of a Devonian Beulah 'granite'. The granular to porphyritic-textured andesitic intrusive rocks at Beulah, with plagioclase, k-feldspar, quartz, pyroxene, hornblende and biotite, were described as fine-grained granite and micro-granodiorite, and presumed to be of Devonian age (despite the Cambrian-type sericite-chlorite-epidote alteration) by Jennings *et al.* (1959) and Jennings (1979). The granite was not included in the regional granite dating program of McDougall and Leggo (1965), and hence the mis-identification has persisted for over 40 years on

geological maps (e.g. Calver *et al.*, 1995; Seymour and Calver, 1995), and in geophysical interpretations (e.g. Leaman and Richardson, 1989). Geological work by Aberfoyle Exploration in the late 1980's recognised that the intrusive rocks were probably related to the nearby Beulah andesites (Rand, 1990; Wallace, 1991), and zircon dating later confirmed a Late Cambrian-Early Ordovician age (Black *et al.*, 1997). A gravity low extending from the Beulah area to the Barrington-Castra area was attributed to this 'granite' by Leaman and Richardson (1989), but has recently been reinterpreted as being due to a non-exposed granite-like rock of uncertain age by Leaman (2003). Somewhat similar andesitic intrusive rocks, with monzonitic-dioritic features, have recently been mapped in the Native Track Tier-Nietta area (Vicary, 1994, 1995; Virgoe, 1990), and are tentatively correlated herein with the Beulah microgranodiorite.

FOSSIL HORIZONS

The paucity of known fossiliferous horizons has been another major problem for stratigraphers in the region. Prior to the 1970's, the only Cambrian fossils known from around Sheffield were in a boulder of greywacke in the Mersey River at Dynans Bridge near Weegenia (Map 1), with trilobites of possible Late Cambrian age (Jennings, 1979), possibly from the 'Gog Range Greywacke' but possibly also from Owen Group rocks; and some poorly preserved small brachiopods and dendroids in siltstone in the Don River east of Barrington, for which Banks (in Burns, 1957a) suggested a Late Cambrian age. The latter beds were designated 'Gog Range Greywacke' by Jennings *et al.* (1959), and are located between outcrops of the 'Bott Conglomerate'.

In the Dial Range area, fossils of Middle and late Middle Cambrian age were known in the Isandula Road and Leven Gorge areas, just north of the current map boundary (Burns, 1964). The older sequence (Burns' 'Cateena Group') lies along strike from rocks designated as Western Volcano-Sedimentary Sequence herein, and the younger sequence (Burns' 'Radfords Creek Group') is considered to be a Tyndall Group equivalent.

Two discoveries of fossils of Tyndall Group age (late Middle Cambrian) in 1989 have greatly assisted

correlations in the area. These were at Native Track Tier by Baillie (*in Seymour, 1989*), and at Paradise by S. Rand, A. Crawford and the author (described by J. B. Jago, pers. comm., 1989). Fossils of similar age had previously been discovered at St Valentines Peak by G. Pike in 1963, and described by Jago *et al.* (1977).

While most of the areas now designated as Tyndall Group have some fossil control, there is still much uncertainty about the age and affinities of the other major sequences in the area.

DESIGNATIONS AND PROBLEM AREAS

1. The generally quartz-phyric felsic volcanic sequence extending through Stormont, Lorinna, Bell Mount and the Cethana area is considered to be the along-strike continuation of the **Eastern Quartz-Phyric Sequence** (EQPS) from the Mt Murchison-Lake Selina area (Corbett, 2002*a, b*). The large Bonds Range Porphyry body provides a strong link from the Murchison-Mackintosh area, and appears to be continuous at least to Lorinna, where it equates to the Bull Creek porphyry of Jennings and Burns (1958).

The large body of intrusive, and possibly partly extrusive, felsic porphyry at Gog Range – the original ‘Minnow Keratophyre’ – is in part more felsic than the Bonds Range body, but is probably related. Its association with voluminous pumice-rich deposits (McClenaghan *et al.*, 2001) suggests a sub-volcanic relationship. This zone along the face of the Gog Range may be where the EQPS interfingers with the Western Volcano-Sedimentary Sequence.

The zone of quartz-phyric and/or feldspar-phyric rhyolitic-dacitic lavas and associated volcanoclastic rocks extending between Mt Roland and Erriba (McClenaghan and Green, 1999*a, b*) has been problematic to assign. It could be considered an extension of the EQPS, but on the basis of its apparent interfingering with units considered to be Tyndall Group correlates, it has been assigned to that group.

2. The regionally extensive greywacke-mudstone sequences, mapped mostly as ‘Gog Range Greywacke’ by Jennings *et al.* (1959), have mostly been assigned to the **Western Volcano-Sedimentary Sequence** (WVSS), as they generally match the diverse lithologies of this sequence (particularly the mixture of volcanic and non-volcanic units), they appear to be along strike from WVSS rocks in the Mt Tor area, and they rest directly on ‘basement’ rocks of the trough in places. Because of the lack of fossils, there is considerable uncertainty about the age of this sequence in some areas, and it is quite possible that some equivalents of the Tyndall Group have been included. One such area is between the Wilmot River and Claytons Rivulet (Map 1), where Burns’ (1957*a, b*) descriptions of coarse volcanoclastic breccias suggest a zone of Tyndall Group.

Siliceous Owen-type conglomerate at the Dasher River southeast of Sheffield and near Barrington (the ‘Bott Conglomerate’ of Jennings *et al.*, 1959) has been included in the WVSS. Some doubt remains about the Barrington unit because of its apparent close association with Owen Group (Dial) conglomerate just to the north and the presence nearby of fossils of possible Late Cambrian age, which could indicate that it may be part of a Late Cambrian marine Owen Group sequence.

In the Native Track Tier area, an inferred boundary has been drawn between a volcanoclastic sequence correlated with the WVSS, and Tyndall Group correlates to the northwest. The boundary coincides, in part, with some lenses of siliciclastic conglomerate, and a large andesitic intrusive body (Vicary, 1994, 1995), but no boundary has actually been identified and there is scope for revision in this area of rather poor outcrop.

3. The **Central Volcanic Complex** (CVC), which is a broad zone of dominantly feldspar ± quartz-phyric volcanic and volcanoclastic rocks dominating much of the Mt Read belt between South Darwin Peak and Mt Block (Corbett, 2002*a*), apparently disappears beneath younger rocks near Mt Charter (Map 1). It has not been recognised as such north of this. Some poorly exposed feldspar-phyric lavas with spherulitic textures, which have been mapped around Mt Jacob in the Winterbrook area (Pemberton and Vicary, 1989), are similar to CVC lavas in the Darwin-Lyell area, but appear to be lenses in a generally quartz-feldspar-phyric sequence correlated with the EQPS. It should be noted that typical CVC-type feldspar-phyric lavas are scattered through the EQPS in the type area around Mt Murchison (Corbett, 2002*b*). Other lateral equivalents of the CVC may be represented by zones of pumice-rich rocks in the lower parts of the EQPS and WVSS.
4. Several major areas have been designated as **Tyndall Group** correlates. Those at Native Track Tier and St Valentines Peak are relatively straightforward because of the presence of definitive fossils, although the rock sequence at St Valentines Peak is not really typical of Tyndall Group sequences elsewhere. Fossils at Paradise also indicate that Tyndall Group correlates are present, and some widespread distinctive ‘Tyndall-type’ volcanoclastic breccias have been used to define the limits of the group in this area. The large body of andesitic lavas at Dasher River appears to be within the Tyndall Group in this case, although it is not differentiated from other andesites on the map.

The zone of Tyndall Group correlates has been extended westwards from Mt Roland through Staverton to the Wilmot River, mainly on the basis of the presence of andesite-rich volcanoclastic breccia and sandstone. From here it connects with the somewhat similar sequence of volcanoclastic

conglomerate and sandstone, with intercalations of felsic to andesitic lava, at Winterbrook, which sequence was correlated with the Tyndall Group by Pemberton and Vicary (1989). The presence of common granite clasts in this sequence (observations by the author and G. Ebsworth) supports the Tyndall Group correlation, although there are no known fossil horizons. The porphyry intrusive bodies in the sequence are typically flow-banded and lacking in ferromagnesian phenocrysts, suggesting they are feeder bodies for the felsic lavas rather than bodies of Bonds Range-type porphyry.

5. **Andesite bodies** in the area have not been given specific stratigraphic designations, but appear to range through pre-Tyndall and Tyndall Group positions. The large body of Beulah andesites has confusing and apparently variable relationships with the adjacent WVSS – the sedimentary rocks appear to dip away from, and overlie, the andesite along the southern margin at Lower Beulah, but to dip under, and be older than, the andesite at the northwest margin of the body. An interfingering relationship with the sedimentary rocks at the basal part of the andesitic sequence perhaps best explains these features. The time relationship between the andesitic intrusive rocks (Beulah 'granite') and the large quartz-feldspar porphyry intrusive at Paradise ('Minnow Keratophyre') has not been clearly resolved, although the presence of a small andesite body within the porphyry at Gog Range (McClenaghan *et al.*, 2001), and the slightly younger age (493 ± 4 Ma vs 500 ± 6 Ma) recorded for the Beulah 'granite' by Black *et al.* (1997), suggest that the andesitic intrusive rocks may be slightly younger. This supports the suggestion herein that they represent feeders for the adjacent Dasher River andesites of the Tyndall Group.

EASTERN QUARTZ-PHYRIC SEQUENCE AND CORRELATES

This sequence has a discontinuous basal unit of siliciclastic sandstone and conglomerate in the Back Peak area, correlated with the Sticht Range Beds, resting unconformably on Precambrian basement (Vicary and Pemberton, 1988). Overlying this is a sequence of pumiceous rocks and vitric-crystal sandstone, referred to as the Back Peak Beds (Vicary and Pemberton, 1988), followed by the 2–3 km wide body of Bonds Range Porphyry. Numerous intercalations or xenoliths of volcanoclastic rocks mapped near the eastern margin of this body suggest a shallow intrusive to partly extrusive character.

Similar quartz-feldspar-phyric volcanoclastic rocks are exposed in the Lake Cethana–Lorinna area (Pemberton and Vicary, 1989; McClenaghan and Green, 1999b) adjacent to the porphyry body, and in the Five Mile Rise area near the Dove Granite body. The term 'Lorinna Greywacke' was used by Jennings and Burns (1958) and Jennings (1963) for rocks in the

latter area, which from their description includes a basal representative of the Sticht Range Beds.

A rather non-descript sequence of dominantly quartz-feldspar-phyric volcanoclastic rocks with associated felsic lavas and porphyries, extending through Bell Mount and Cethana to the foothills of Mt Claude, is also considered to be EQPS. It includes some feldspar-phyric lavas in the Mt Jacob area (Pemberton and Vicary, 1989) which are reminiscent of CVC lavas elsewhere. The sequence is intruded by two small altered granitic bodies near Cethana (McClenaghan and Green, 1999b), and includes a wide zone of sericite-pyrite alteration referred to as the Cethana Pyrite Zone, with some associated minor base metal mineralisation (Map 1). This zone represents the largest VHMS-type alteration zone in the area, and has been fairly intensively prospected and drilled (e.g. Jones, 1989; Close and Reid, 1997). The stratigraphic situation, with a hangingwall of Tyndall Group rocks just to the north, is reminiscent of that at Mt Lyell and Henty.

Three windows of pumice-rich volcanic and volcanoclastic rocks are exposed through the Owen Group cover (Vicary and Pemberton, 1988) on the southern part of the Black Bluff Range. The rocks include quartz-feldspar-phyric volcanoclastic conglomerate, and probable welded ignimbrite. Pemberton *et al.* (1991) suggested they might represent proximal equivalents of a welded tuff in the Tyndall Group on the Cradle Mountain Link Road, and of pumice-rich mass-flow breccias in the upper part of the Southwell Subgroup (of the WVSS) in the same area.

The relationships of the EQPS correlates to other sequences are difficult to establish. Lateral equivalence to the WVSS seems likely, as both sequences overlie basement rocks to the basin, and contain siliciclastic units derived from that basement. The zone of interbedded pumice-rich rocks and sedimentary rocks along the face of the Gog Range possibly represents the interfingering boundary between the two sequences. In the Cethana area, and in the Wilmot River area, there is a suggestion from a few bedding readings that the sequence faces north and is overlain by the Tyndall Group correlates.

WESTERN VOLCANO-SEDIMENTARY SEQUENCE AND CORRELATES (WVSS)

This mixed sequence of volcano-sedimentary and sedimentary rocks, with scattered felsic to andesitic lavas and intrusive rocks, is widespread in the central part of the basin. The stratigraphy is well established in the **Que River–Mt Tor area**, where the overall sequence has been termed the 'Mt Charter Group' (Corbett, 1992). This comprises basal vitric-rich siltstone and sandstone (Black Harry Beds), followed by micaceous-siliciclastic Precambrian-derived sandstone and shale (Animal Creek Greywacke), black shale with fossils (Que River Shale), a large lens of andesite and basalt, with a middle unit of dacitic lavas

and breccias (Que–Hellyer Volcanics), and an upper sequence of quartz-feldspar-phyric and pumice-rich mass-flow volcanoclastic sandstone and breccia with minor felsic lavas (Southwell Subgroup). Fossils have been recovered from shallow-water limestone clasts in a mass-flow unit in the Southwell Subgroup, and are of Middle Cambrian age, slightly older than the Tyndall Group faunas (Jago and McNeill, 1997).

The vitric-rich lower part (Black Harry Beds) has correlates in the **Two Hummocks area**, and a correlate of the micaceous Animal Creek Greywacke lies in a NNE-trending syncline along the Leven River. The faulted eastern boundary of this zone is a possible continuation of the Henty Fault (Pemberton *et al.*, 1991).

The continuation of the andesitic-basaltic rocks of the Que–Hellyer Volcanics has been drilled under the Tertiary basalt cover north of the Cradle Mountain Link Road (Pemberton *et al.*, 1991), indicating that the unit has a strike length of at least twenty kilometres. It has an across-strike width of only about 5 km, and where not present there is a clean passage from Animal Creek Greywacke into Que River Shale. A genetic relationship between the elongate andesite body and the adjacent Henty Fault seems likely, and there are similarities to the relationship between andesites further south (e.g. Sterling Valley, Anthony Road, Comstock) and the Henty and Great Lyell Faults (Corbett, 2002a).

This well defined stratigraphy has not been traced or recognised in the main part of the Fossey Mountains trough. In the **Loongana Range area**, a non-descript sequence rich in quartz-feldspar-phyric volcanoclastic sandstone, with lenses of siliciclastic conglomerate and bodies of andesitic intrusive rock, appears to dip largely southwards (Vicary, 1994, 1995), while in the **Nietta–Upper Castra area**, pumice-rich and vitric-rich sandstone and mudstone are intercalated with micaceous siltstone and scattered felsic lavas and intrusive rocks. A zone of strong pyrite-sericite alteration in quartz-phyric volcanic and intrusive rocks on the Castra–Nietta road is known as the Castra prospect. In the **Preston area**, probable basal conglomerate of the ‘Sprent Formation’ overlies a tongue of Motton Spilite (Jennings *et al.*, 1959), but there is some uncertainty as to whether this conglomerate might be basal Tyndall Group.

The extensive sequences in the **Central Castra–Wilmot River area** are known only from Burns’ (1957a, b) descriptions, in which he divided the sequence into some twenty formations, most of which were incorporated into the ‘Gog Range Formation’ by Jennings *et al.* (1959), and some into the Barrington Chert. Much of the sequence appears to consist of the usual micaceous siltstone and greywacke mixed with vitric-rich siltstone. Several units of ‘keratophyre’ lava – probably andesite – are recorded from the western side of the Wilmot River around 5 428 000 mN, and an adjacent area around Groove Creek is described as consisting of coarse volcanic breccias which may be

Tyndall Group correlates, and are shown as such on Map 1.

McClenaghan and Green (1999a) described the sequence in the **Wilmot–Narrawa–Lake Barrington area** as massive to bedded greywacke, pebble conglomerate and laminated siltstone, generally non-volcanic but with minor interbeds of volcanoclastic sandstone, ‘tuff’ and felsic lava. A unit of siliciclastic pebble conglomerate with quartzite and chert clasts occurs in the upper part of the sequence at Lake Barrington, and outlines a broad southwest-plunging anticlinal structure. This is probably the same conglomerate unit mapped as an outlier of Roland Conglomerate near the Wilmot Road just north of Wilmot by Jennings *et al.* (1959).

The WVSS correlates crop out as a narrow southeast-trending belt about three kilometres wide in the **Beulah–Gog Range–Weegen area**. Micaceous siltstone and sandstone are the dominant lithologies, with lesser volcanoclastic sandstone (usually quartz-feldspar-phyric) and siliciclastic conglomerate (McClenaghan *et al.*, 2001). A major zone of siliciclastic pebble conglomerate with interbedded sandstone and minor siltstone occurs in the Dasher River southeast of Sheffield (around 449 000 mE, 5 415 000 mN). The beds dip and face southwest, opposite to that of the adjacent Roland Conglomerate, which the rocks closely resemble. The conglomerate becomes interbedded with micaceous sandstone and siltstone to the south, suggesting it is part of the WVSS. Pumice-rich volcanoclastic sandstone and breccia become abundant and dominant in the area adjacent to the large quartz-feldspar porphyry body fronting the Gog Range, where the beds are folded into a broad E-W trending syncline (McClenaghan *et al.*, 2001).

TYNDALL GROUP CORRELATES

Introduction

The Tyndall Group was originally defined from outcrops in the Lynchford, Lyell Comstock and Tyndall Range (Anthony Road) areas as the younger, volcanoclastic-rich part of the Mt Read sequence, overlying WVSS, EQPS and CVC rocks (Corbett *et al.*, 1974). Characteristic lithologies were volcanoclastic breccia with andesitic-basaltic clasts in the lower part, crystal-rich volcanoclastic sandstone with pink and green colour stripes due to albite-rich and chlorite-rich bands (‘Comstock Tuff’) in the middle part, and an upper sequence of volcanoclastic conglomerate. Minor felsic to andesitic lavas, and rare welded ignimbrites, were also present.

Further mapping showed well-developed Tyndall Group sequences on the Cradle Mountain Link Road (Komyschan, 1986; Corbett and Komyschan, 1989; Pemberton and Vicary, 1988; Vicary and Pemberton, 1988; Pemberton *et al.*, 1991), and in the Silver Falls–Que River area, west of the Murchison Highway (McKibben, 1993; Poltock, 1994; Buxton, 1997; Corbett, 2002a).

Detailed descriptions and formal definitions of the group were given by White and McPhie (1996), who defined a lower breccia-rich *Lynchford Member* (of the *Comstock Formation*), a middle unit dominated by crystal-rich sandstone with a welded tuff near the top (*Mt Julia Member*), and an upper unit of volcanoclastic conglomerate (*Zig Zag Hill Formation*). A more simple terminology involving *Lower*, *Middle* and *Upper Tyndall* was used for the three main units by Corbett (2001a, b).

The importance of the base of the Tyndall Group as a locus for hydrothermal activity and mineralisation in the Lyell–Comstock–Henty area has long been recognised (Corbett, 1986, 1992; Callaghan, 2001), and recent work has shown that the exhalative upper part of the huge Mt Lyell alteration system is hosted within the lower part of the Tyndall Group at Lyell Comstock (Corbett, 2001a, b). Knowledge of the location of Tyndall Group correlates, and particularly of the basal parts, could therefore be of potential economic significance.

As previously noted, Tyndall Group correlates are relatively common in the Sheffield area, with major sequences present at St Valentines Peak, Native Track Tier, Winterbrook, and the Cethana–Mt Roland–Paradise area.

Cradle Mountain Link Road–Mt Tor area

The Tyndall Group sequence on the Cradle Mountain Link Road (Pemberton *et al.*, 1991) comprises four units:

- a basal lensoidal unit of interbedded micaceous siltstone, siliciclastic sandstone and siliciclastic pebble/cobble conglomerate (with quartzite clasts up to boulder grade), up to 200 m thick;
- a lower unit of crystal-rich (quartz, feldspar) volcanoclastic sandstone, with clasts of andesite, felsic porphyry, and rare massive sulphide, interbedded with siltstone, minor welded tuff and rare andesite lava;
- a unit of fossiliferous yellow siltstone and volcanoclastic sandstone, with a rich trilobite fauna of latest Middle Cambrian age (J. B. Jago, pers. comm., 1991; Laurie *et al.*, 1995); and
- a thick upper unit (at least 600 m) of volcanoclastic cobble/boulder conglomerate, with clasts of andesite, felsic lava, Bonds Range-type porphyry, and minor quartzite.

Only the upper volcanoclastic conglomerate unit is present in the Mt Cattley–Mt Tor area, and is of the order of 600 m thick at Mt Tor.

St Valentines Peak area

An anticlinal sequence of Tyndall Group correlates is present between St Valentines Peak and Companion Hill, and has been described by Jago *et al.* (1975) and Seymour (1989). Much of the sequence has been

affected by contact metamorphism related to the nearby Housatop Granite, and appears as siliceous and banded hornfels. Fossils of late Middle Cambrian age occur in a poorly exposed siltstone-dominated sequence which passes up into cherty sandstone and siltstone overlain by a welded tuff about 100 m thick. Above this are several hundred metres of striped, laminated and massive silty hornfels, followed by cherty siltstone with a few fossils and some conglomeratic bands. Unconformably above this is the basal chert-rich conglomerate of the Owen Group.

The overall sequence is not typical of the Tyndall Group elsewhere, in that it lacks the usually abundant volcanoclastic sandstone, breccia and conglomerate, and any of the andesitic to felsic lavas. The only possible link to the Cradle Mountain Link Road sequence is the welded tuff, which seems somewhat out of place in this generally fine-grained marine sequence. It may be that the St Valentines Peak sequence was deposited further offshore and away from the basin-margin environments and proximal volcanic sources represented by the coarser Tyndall Group sequences to the east.

Native Track Tier area

This area of logging roads and plantation forests south of Loyetea Peak has some excellent exposures of crystal-rich volcanoclastic sandstone, breccia and conglomerate, forming tor-like outcrops typical of the Tyndall Group elsewhere. Some descriptions have been given by Baillie (*in* Seymour, 1989) and Vicary (1994). Much of the sequence in the eastern part of the area dips and faces north, but the overall stratigraphic arrangement is uncertain. Fossils discovered in siltstone bands at two localities by Baillie (*in* Seymour, 1989) are of latest Middle Cambrian age, with a number of the same species as at Cradle Mountain Link Road and St Valentines Peak.

The breccias contain abundant clasts of andesitic to dacitic lavas in a feldspar-rich matrix, with distinctive patchy pink and green alteration in places. Also present are numerous bodies of feldspar-hornblende-phyric dacitic to andesitic igneous rocks. Many of these are flow-banded and some are vesicular, suggesting they are lava flows, but some are probably intrusive (Seymour, 1989; Vicary, 1994).

A somewhat arbitrary boundary, largely following that of Vicary (1994), has been drawn between this sequence and a slightly different sequence of mainly volcanoclastic rocks, with andesitic intrusive bodies, to the southeast, the latter being tentatively correlated with the WVSS.

Winterbrook area

A thick sequence (over 1000 m) dominated by volcanoclastic conglomerate and sandstone is exposed at Winterbrook between the Black Bluff Range and Loongana, and has been mapped by Pemberton and Vicary (1989). The sequence is folded into a broad ENE-trending syncline, with much of the south flank

obscured by scree, and has an unconformable relationship with overlying Owen Group rocks. A number of thin units of andesitic lava, and several bodies of felsic quartz-feldspar-phyric lava or flow rock, are present. Several of the latter have vitriclastic textures in places, and are probably welded tuffs. Units mapped as quartz-feldspar-biotite-phyric crystal tuff are also present.

The conglomerate is typically pebble-cobble grade, with clasts predominantly of quartz-feldspar-phyric volcanic rocks but also including andesite, granite and quartzite. Some units are predominantly andesitic in composition. Several intrusive bodies of flow-banded quartz-feldspar porphyry are present in the northern part of the area, and may be shallow sub-volcanic bodies related to the felsic lavas.

A zircon date of 500 ± 7 Ma has been obtained from a felsic lava unit in the central part of the Winterbrook area (Black *et al.*, 1997).

The Winterbrook sequence is quite strongly magnetic, which tends to support the Tyndall Group correlation. The volcanoclastic conglomerates are similar to those of the Mt Cattle–Mt Tor area, but the much thicker sequence at Winterbrook indicates a deeper, larger and more complex basin. The two-fold subdivision of the Tyndall Group in western areas into a lower sequence dominated by syn-eruptive crystal-rich sandstone with minor lavas and welded tuff, and an upper sequence dominated by post-eruptive volcanoclastic conglomerate (White and McPhie, 1996), is not evident here. Instead, there seems to be a rather unusual mixture of primary flows and syn-eruptive units in a ‘matrix’ of post-eruptive erosional detritus.

Staverton–Mt Roland–Paradise area

This very large area of Tyndall Group correlates covers some 80 km², and includes large areas of andesitic volcanic rocks around the Dasher River, and a large belt of felsic lavas through the Staverton area. The overall sequence may be broadly synclinal, although there is much disruption by faulting and uncertainties due to poor exposure and lack of bedding.

A generalised stratigraphy can be established for the lower part of the group in the Roland–Staverton area, where a south-dipping basal unit of volcanoclastic breccia and sandstone, of the order of 700 m thick, overlies a greywacke-mudstone sequence correlated with the WVSS in the Holmes Road area (McClenaghan and Green, 1999a). The volcanoclastic rocks are crystal-rich, with abundant feldspar and pyroxene crystals, and are very like Tyndall Group breccias from the Queenstown and Cradle Mountain Link Road areas. They appear to have an overall andesitic composition. Clasts of brown andesite and pink quartz-phyric lava are evident. A ‘marker’ unit of siliciclastic pebble-cobble conglomerate, of the order of 100 m thick, with abundant quartzite clasts and clasts of felsic lava, occurs within this lower sequence, and has been mapped for some seven kilometres to the east. It may not be the same conglomerate as that within the

WVSS at nearby Lake Barrington, which is somewhat lower in the sequence.

Similar volcanoclastic breccias, with abundant feldspar and pyroxene crystals and clasts of andesitic to felsic lava, occur on the south side of the belt of Tyndall Group correlates in the Cethana–Gowrie Park area (McClenaghan and Green, 1999b).

Andesitic lavas and breccias overlie the volcanoclastic rocks and form a three kilometre-wide zone extending across the Dasher River valley and up the slopes of Mt Roland, where there is extensive cover by siliceous scree. The andesites are typically plagioclase-pyroxene-phyric, with some units also carrying biotite phenocrysts. Brecciated facies are abundant. Preliminary geochemical work by M. P. McClenaghan (pers. comm.) indicates that they are typical calc-alkaline andesites with affinities to Suite I of Crawford *et al.* (1992). There is a close spatial and compositional relationship with the adjacent granodioritic andesitic intrusive rocks (feldspar-pyroxene-hornblende-biotite porphyry) of the Beulah ‘granite’, one body of which is in contact with the andesite at Paradise (recent mapping by M. P. McClenaghan), suggesting that these bodies represent feeders for the andesites.

At the southeast margin of the Tyndall Group zone, under the cliffs on the east flank of Mt Roland, there are large outcrops of thick-bedded cobble-grade volcanoclastic conglomerate, with sparse interbeds of volcanoclastic sandstone. Bedding dips northeast, and the sequence seems to represent the basal facies of the group. Clasts include andesitic and felsic lava, quartzite, and rounded hematite clasts to 80 mm across. Further north, around Belstone Road, are similar Tyndall-like outcrops of volcanoclastic conglomerate and sandstone, with clasts up to 300 mm of andesite and other volcanic rocks in a crystal-rich (quartz, feldspar, biotite) sandy matrix. Some of the clasts are notably epidote-altered. These volcanoclastic rocks pass up into feldspar-pyroxene-phyric andesite above Belstone Road (McClenaghan *et al.*, 2001).

A sequence of interbedded grey-fawn micaceous siltstone, volcanoclastic and siliciclastic sandstone, pumiceous quartz-phyric flow rocks, and feldspar-biotite-hornblende-phyric andesite, occurs in the central part of the zone just west of Paradise. The author collected fossils of early Tyndall Group age from the siltstone in 1989, after their discovery in thin sections of rocks by A. Crawford for Aberfoyle Exploration (Rand, 1990; J. B. Jago, pers. comm., 1989; Laurie *et al.*, 1995). The sedimentary sequence dips and probably faces southeast, and may be close to the core of the main synclinal structure, but mapping has not fully resolved the relationship with andesite and other rocks in the area. A unit or lens of felsic quartz-phyric pumiceous rocks is exposed on the slopes of Mt Roland to the southwest of the sedimentary rocks (M. P. McClenaghan, pers. comm.). This unit is probably the same as that intersected within an otherwise andesite-dominated sequence in the third of three

diamond-drill holes (Claude Road 1, 2, 3) drilled in the McCoys Road area by the Department of Mines in about 1976 (unpublished report by the author, 1976).

BEULAH ANDESITES

The andesitic lavas and breccias forming the large mass at Beulah (the 'Beulah Formation' of Jennings *et al.*, 1959) are generally similar to those of the Dasher River area, but their age and relationships have not yet been fully determined. The lavas are mostly feldspar-pyroxene (\pm hornblende \pm quartz)-phyric, with only minor biotite-phyric units noted east of Lower Beulah. Minor dacitic (feldspar-phyric) lavas are also present. Epidote alteration and veining are common, and there is considerable barite-carbonate-hematite alteration in the vicinity of the Beulah barite prospect.

As noted previously, the relationship with the adjacent sandstone-siltstone sequence of the WVSS (Gog Range Greywacke) is enigmatic and apparently contradictory, in that the latter beds dip away from, and appear to overlie, the andesites in the southern part of the area, but dip towards, and appear to underlie, the andesites in the northern part. Although the southern contact has been interpreted as a fault at times, drilling and mapping suggest a conformable and possibly interfingering contact (e.g. Rand, 1989; McClenaghan *et al.*, 2001). A possible analogue to this arrangement might be that of the Lynch Creek basalt body at South Queenstown (Corbett, 1979; Corbett *et al.*, 1989), which has a variable relationship to surrounding WVSS beds but appears to have 'punched' up through these beds on the sea floor to build a younger volcanic edifice.

Although there is little published geochemistry, work by exploration companies (particularly Aberfoyle) and preliminary work by M. P. McClenaghan (pers. comm.) shows these andesites to be essentially similar to the Dasher River andesites, and to the Beulah granodiorites, i.e. with general affinities to Que-Hellyer footwall andesites and Suite I of Crawford *et al.* (1992), and lacking the P₂O₅ and LREE-enriched types of the Que-Hellyer hangingwall and Suite III.

CAMBRIAN INTRUSIVE ROCKS

At least four major groups of Cambrian intrusive rocks associated with the volcanic sequences are present in the area, including granite, felsic porphyries, andesitic intrusive rocks, and mafic tholeiitic bodies.

Granites

Five granitic bodies are known, three within Precambrian rocks of the Tyennan region, and two within EQPS correlates in the Cethana area. The three southern bodies are referred to as the **Dove Granite** and its correlatives in the Forth and Mersey rivers. Although Jennings and Burns (1958) and Jennings (1963) considered them to be Devonian, radiometric dating (K-Ar and Rb-Sr on minerals) by McDougall and Leggo (1965) clearly showed a pre-Devonian and

probable Cambrian age for each of the bodies. The spread of K-Ar dates (455–500 Ma) was attributed to argon loss.

Leaman and Richardson (1989) found that the Dove Granite bodies were not recognisable on the regional gravity field, and that magnetic responses differed from body to body. This contrasts with the nearby Devonian Dolcoath Granite, which is associated with a very large negative gravity anomaly.

The two small altered granitic bodies intruding EQPS rocks near Cethana were recognised and mapped by McClenaghan and Green (1999b). They consist of quartz, feldspar and biotite strongly overprinted with sericite-chlorite alteration.

Quartz-feldspar \pm biotite porphyries

The Bonds Range Porphyry has been described by Pemberton *et al.* (1991). It forms a continuous body from Lake Mackintosh to Lea River, a distance of 33 km, and is probably continuous at least to Lake Cethana, another 14 km, making it the largest Cambrian intrusive body known in Tasmania. It clearly intrudes Precambrian rocks in places, indicating that the eastern/southern part of the Mt Read belt was erupted onto Tyennan Precambrian basement. The porphyry is a calc-alkaline rock with dacitic to rhyodacitic composition and general Suite I characteristics (Crawford *et al.*, 1992).

Two large bodies of quartz-feldspar porphyry which intrude WVSS rocks west of Hellyer appear to lack biotite phenocrysts and are slightly more felsic (rhyolitic) in composition (Corbett and Komysan, 1989). Quartz-feldspar porphyries with spherulitic textures and rhyolitic compositions are common in the Cradle Mountain Link Road–Mt Cattley area, and the felsic porphyries of the Winterbrook–Cethana area appear to be of similar type.

The large felsic porphyry bodies of the Gog Range–Paradise area ('Minnow Keratophyre' of Jennings *et al.*, 1959) are mostly quartz-feldspar-phyric, with only minor ferromagnesian phenocrysts, but zones or bodies with common biotite and/or pyroxene phenocrysts are present in places, e.g. off Belstone Road (McClenaghan *et al.*, 2001). Cross-cutting intrusive relationships against WVSS rocks are evident in places, particularly in the northern part of the body, but the close association with volcanoclastic and pumiceous rocks of similar composition in the south suggests that some of the southern part may have been extrusive. A genetic relationship to the voluminous felsic lavas in the Staverton area seems possible.

Andesitic intrusive rocks

The Beulah 'granite' or 'microgranodiorite' is a distinctive rock forming at least five separate bodies around Beulah and Paradise. Most of these are intrusive into WVSS rocks, but a western body recently delineated by M. P. McClenaghan appears to be in contact with Dasher River andesites, suggesting a genetic relationship. The author noted several small,

probably intrusive bodies of biotite-feldspar porphyry, with some similarities to the Beulah microgranodiorite, within the Tyndall Group fossiliferous sequence just west of Paradise.

The microgranodiorites in thin section have granular to porphyritic textures, with the main crystals being biotite, hornblende, plagioclase, orthoclase, and quartz, with variable degrees of chlorite, sericite and epidote alteration. Groundmasses are typically well crystallised and plagioclase rich. Preliminary chemical data (Black *et al.*, 1997; M. P. McClenaghan, pers. comm.) show andesitic compositions with the general characteristics of Suite I of Crawford *et al.* (1992). A zircon date of 493 ± 4 Ma has been obtained from the largest body by Black *et al.* (1997).

Several bodies of a similar porphyritic to granular andesitic intrusive rock, including a large body which extends some seven kilometres, are present in the Native Track Tier-Nietta area, where they intrude WVSS correlates close to the boundary with Tyndall Group rocks (Vicary, 1994, 1995). The largest body has been drilled at the Crosby Creek Prospect, and some smaller bodies in the Tulip Tree Creek-Loongana Range area (Virgoe and Mathison, 1989). Petrological descriptions given by Crawford (*in* Virgoe, 1990) indicate that some of the rocks are medium to coarse-grained and dioritic or monzonitic in character, with plagioclase, quartz, k-feldspar, and altered ferromagnesian crystals. The descriptions suggest rocks similar to the Beulah 'granites', and some trace element values given by Vicary (1994) lend tentative support to this correlation (e.g. similar Ti, V, Hf values).

Three bodies of doleritic rock intruding WVSS rocks in the Que-Hellyer area, known as the Mt Charter dolerites, appear to be related to the Cambrian andesites and basalts in that area (Corbett and Komyschan, 1989). The rocks have basaltic andesite compositions, relatively high Ti/Zr ratios (average 38) and, although rare earths are not available, appear to be related to the Suite III basalts of the Hellyer hangingwall.

Unassigned mafic intrusive rocks

A number of bodies of altered mafic rock with uncertain affinities and relationships are grouped in this category.

A narrow body of 'quartz dolerite' was mapped by Jennings *et al.* (1959) on the western bank of the Forth

River near Wilmot. It was described (Jennings, 1979) as having doleritic texture, with feldspar crystals and altered (chlorite-epidote) ferromagnesian crystals, ragged biotite plates, abundant strongly pleochroic iron ore minerals, and interstitial quartz. A finer-grained, more felsic sample had an interlacing mass of feldspar crystals with hornblende, epidote and chlorite, less common altered ferromagnesian, and magnetite, ilmenite, biotite and interstitial quartz. The alteration was indicative of a Cambrian rock.

The same body was mapped by McClenaghan and Green (1999a) as a 'quartz biotite diorite' and referred to in notes as the 'Lake Barrington diorite'. There is no published chemistry for the rock, but an analysis and some preliminary geochemical plots by M. P. McClenaghan (pers. comm.) indicates that the rock is tholeiitic, with high TiO₂ (1.32%), low MgO (4%), and remarkably high P₂O₅ (0.93%). While the latter might suggest a relationship to the high-P₂O₅ Suite III rocks, the rare earth element values do not indicate significant LREE enrichment.

Subcrop and float of the same rock type were mapped around Wilmot by R. A. Poltock (2002) for a WTRMP field checking program, plus one or more dykes near the Narrawa Road to the west, indicating a potentially large body. Of considerable interest is the fact the rock is strongly magnetic (magnetic susceptibility reading of 66×10^{-3} SI on a hand specimen sample according to M. P. McClenaghan), suggesting that it is probably responsible for the very strong magnetic anomaly over the area around Wilmot (Map 2). Much of the source of this anomaly is apparently buried beneath the cover of Moina Sandstone, and might in part be due to detrital magnetite in the basal conglomerate.

Several other altered mafic intrusive rocks have been described from the Mt Tor area by Pemberton *et al.* (1991), where they mostly intrude WVSS rocks. The largest of these is referred to as the 'Ring Road metadolerite', and is a chlorite-epidote-carbonate-sericite altered ophitic to porphyritic textured tholeiitic rock with plagioclase and pyroxene, and high Ti and Zr values. It is not obviously related to any other groups. The second main body intrudes Tyndall Group conglomerate just to the northeast, and is an intensely epidote-quartz-actinolite altered tholeiite with moderate Ti and Zr values and some similarities to the Tertiary basalts, although the degree of alteration seems to preclude a Tertiary age.

Late Cambrian–Ordovician siliciclastic sequences

INTRODUCTION

The widespread siliciclastic conglomerate-sandstone sequences are regionally unconformable on the underlying Middle Cambrian rocks, and are typically exposed on the flanks of broad Tabberabberan folds. The sequence on the West Coast Range is referred to as the Owen Group, and is mostly of Late Cambrian age. It is continuous onto the Black Bluff Range, where the Upper Owen Sandstone correlates are dominant, but thins rapidly to the east of this and essentially disappears at the Wilmot River. East of this there is only Moina Sandstone, of Ordovician age, until the Roland Conglomerate, which is of Middle and Lower Owen type, appears below the Moina Formation at Cethana. The conglomerate reaches its maximum development at Mt Roland, before wedging out eastwards at the Gog Range.

There is a strong suggestion that the original depositional wedge of Roland Conglomerate may have extended northeastwards across the Paradise–Sheffield area to the Badger Range area near Railton, as there is a significant thickness of similar conglomerate in this area, and an isolated small inlier just north of Paradise suggests original continuity. There is some implication here that the source of detritus for the Roland Conglomerate might have been to the northeast (e.g. the inlier of Precambrian rocks northeast of Railton), at least in part, rather than to the southwest from the Tyennan Region, but further studies are required to establish this.

This question highlights the general issue in this area of the source regions for siliciclastic detritus, as there is evidence for multiple sources, including the allochthonous ‘Barrington Chert’ bodies. The conglomerates of the Dial Range area are largely chert-derived in the lower part and quartzite-derived in the upper part (Burns, 1964), and a similar situation seems to apply at St Valentines Peak. The proportion of chert detritus appears to decrease through the Gunns Plains–Loongana area (Seymour, 1989). Many of the conglomerates below the Moina Sandstone appear to be locally derived, and are generally unfossiliferous and difficult to correlate from area to area. There is a general lack of palaeocurrent data and sedimentological studies on the siliciclastic sequences.

The term ‘Moina Sandstone’ is used for the widespread facies of grey, thick-bedded, gritty sandstone, with locally abundant ‘pipe stem’ burrows and rare marine fossils, which forms the upper part of the siliciclastic sequence in most areas. It is transgressive beyond the limits of the lower units in many areas, to rest on older Cambrian and Precambrian rocks. Brachiopods of Middle Ordovician age have been recovered from the formation at Lorinna, Mole Creek, and Lake Gairdner, and a rich trilobite-brachiopod fauna from near Railton (where the unit has at times been referred to as the ‘Caroline Creek Sandstone’) is also of Middle

Ordovician age (Laurie, 1996). Thus the bulk of the formation, and certainly the upper part, is Middle Ordovician, but considerable diachroneity of the base seems likely. A unit of granule-pebble to pebble-cobble grade conglomerate, typically of local derivation, occurs at the base in many areas (e.g. Pemberton and Vicary, 1988, 1989), and may be difficult to distinguish from older Owen Group units. A disconformable break at the base seems likely in many areas, but this may be difficult to establish because of reworking of underlying beds. The upper part of the formation tends to be somewhat shaly and calcareous, and a separate unit of siltstone can be mapped in some areas. These calcareous beds have been particularly favourable for skarn formation.

The prominence of the Ordovician Moina Sandstone in this area creates a terminology problem when using the Owen Group term. This is because the type Owen Group around Queenstown is separated from the overlying Middle Ordovician sandstone, known as the Pioneer Sandstone or Pioneer Beds, by a period of folding and erosion expressed as the Haulage Unconformity. Recent usage has favoured placing the Pioneer Sandstone in the overlying Gordon Group (e.g. Corbett, 2001*a, b*; 2002*a, b*), because of its close association with the Gordon Limestone sequence and its clear stratigraphic, tectonic and age distinction from the underlying, mostly Late Cambrian, Owen Group. The problem becomes evident away from the West Coast Range, where there is apparent conformity and passage from Owen Group correlates into a major unit of Ordovician sandstone below the Gordon Group limestone (e.g. in southwest and northwest Tasmania). The question arises as to whether the Moina Sandstone should be included in the Gordon Group (as it is more or less equivalent to the Pioneer Sandstone), or be left attached to the underlying group of siliciclastic rocks, as is the case with the Denison Group (defined in the Adamsfield area – Corbett, 1975; Seymour and Calver, 1995).

BLACK BLUFF RANGE AREA

The sequence here was mapped by Vicary and Pemberton (1988) and Pemberton and Vicary (1988, 1989), with descriptions given by Corbett (1990) and Seymour and Calver (1995). A thin lower unit of Jukes-type volcanoclastic conglomerate is present in places, followed by a thin unit of siltstone and sandstone referable to the marine facies, followed by a thin unit of cobble-boulder conglomerate, correlated with the Middle Owen Conglomerate, which wedges out at Black Bluff. A thick sandstone-rich sequence correlated with the Upper Owen Sandstone forms most of the range, and is divided into two members. The lower member has siltstone interbeds and rare marine fossils, while the upper member consists mostly of cross-bedded chert-rich pink sandstone above a basal conglomerate on a transgressive

disconformity surface. The Moina Sandstone sits more or less conformably across the top.

An unusual feature of the sequence is the occurrence of sill-like bodies of altered dolerite, about 50 m thick, near the top of the lower sandstone, and of lenses of hematite-chlorite altered basalt and some associated volcanoclastic sandstone, near the top of the upper sandstone member. The dolerite is probably related to the basalts, and is likely to be of Late Cambrian to early Ordovician age. The basalts persist eastwards to the Wilmot River and Mt Jacob. The significance of the mafic rocks is uncertain.

Some palaeocurrent measurements given by Seymour (1989) show currents from the east and south, indicating derivation of much of the detritus from the Tyennan quartzites, although the source of the chert is not clear.

ST VALENTINES PEAK AREA

The siliceous pebble conglomerate forming the crest of St Valentines Peak and Companion Hill is several hundred metres thick, poorly bedded, and dominated by chert clasts in the lower part and quartzite clasts in the upper part (Pike, 1964; Jago *et al.*, 1975; Seymour, 1989). Rare clasts of mafic igneous rock are also reported, and a few examples of imbrication indicating a westerly derivation (Jago *et al.*, 1975). This suggests that the allochthonous chert bodies to the west were a major source.

The overlying Moina Sandstone correlate has been thermally metamorphosed in many areas by the Housetop Granite, and several of the skarns in the area host the Kara Mine scheelite deposit.

MT EVERETT-LOYETEA AREA

A thick sequence of well-bedded grey sandstone and siltstone, with some interbedded granule-pebble conglomerate, overlies a basal conglomerate, and is overlain by Moina Sandstone, in the Mt Everett-Laurel Creek-Loyetea Peak area (Vicary, 1994; Baillie *et al.*, 1986). The sequence appears to be marine, and the author's examination suggests it is a general correlate of the Newton Creek Sandstone and the marine facies of the Owen Group. Vicary (1994) records that some of the sandstones are volcanoclastic or 'ashy'. The basal conglomerate on Native Track Tier consists largely of pebble-cobble conglomerate, with quartzite as the dominant clast type, and some lenses of cross-bedded sandstone (Baillie *in* Seymour, 1989).

The crest of the Loongana Range is very difficult to access. Vicary (1994) described pink chert-bearing granule-pebble conglomerate similar to the Upper Owen correlates on Black Bluff Range. The author examined this sequence near the Leven Canyon at the eastern end of the range, and found the section to be dominated by Moina-type grey sandstone, with vertical burrows in places, passing down into similar pink sandstone with some interbedded units up to five

metres thick of pink granule-pebble conglomerate rich in chert clasts.

MT ROLAND AREA

The Roland Conglomerate is a thick-bedded, pale pink, pebble-cobble to cobble-boulder conglomerate, of the order of 250 m thick, extending through mounts Claude, Vandyke and Roland onto the western part of the Gog Range. Where examined by the author, on the eastern flank of Mt Roland, there are scattered lenses of purplish sandstone up to 300 mm thick, scattered clasts to boulder size (all of quartzite), and some imbrication of tabular clasts. The sequence appears to be of fluvial (braided channel) origin, and resembles the Lower and Middle Owen Conglomerate of the West Coast Range (Corbett, 2001a).

An enigmatic small outlier of Roland-type siliceous pebble-cobble conglomerate, 700 m long × 100 m wide, lies just northwest of Paradise. The unit is surrounded by andesitic rocks, but there are no exposed contacts, and relationships are uncertain. Steeply dipping bedding is evident in several places, and the unit appears to be a genuine outcrop rather than a giant float block of some kind. The body is not obviously sheared or cleaved. The author's suggestion is that it represents the keel of a synclinal structure of conglomerate, developed in a once-continuous belt of such rocks connecting Mt Roland with the Badger Range, most of which was eroded away during a major period of post-Ordovician erosion (e.g. the Carboniferous glaciation). This is not an entirely satisfactory suggestion, as it implies removal of large volumes of hard siliceous materials, leaving virtually no trace.

The distribution of the Roland Conglomerate with respect to the faults in the area is rather puzzling, and raises some interesting questions. Particularly striking is the situation at the Machinery Creek Fault (Claude Creek Fault of Jennings, 1958), a major NW-trending, NE-dipping thrust structure along the southwestern side of Mt Claude (McClenaghan and Green, 1999b; Jennings *et al.*, 1959). A significant thickness of Roland Conglomerate is present on the eastern (upthrown) side of this fault, overlying Cambrian volcanic rocks exposed on Olivers Road, but directly across the fault the Moina Sandstone rests on volcanic rocks with only some basal pebbly beds but no intervening Roland Conglomerate. The question arises as to whether this fault formed an original basin margin to the Roland Conglomerate wedge, and if so, was the source of the conglomerate detritus to the south (Tyennan) or to the northeast?

BADGER RANGE-WEEGENA AREA

A thickness of some 275 m of siliceous conglomerate, overlain by Moina Sandstone, is present along the Badger Range northeast of Sheffield (Jennings, 1979), and on strike ridges extending southeast towards Weegen. The author examined the formation at two locations near the Dasher River southeast of Sheffield,

and also near Dynans Bridge Road five kilometres west of Weegen. The conglomerate is generally similar at all locations, typically consisting of white, thick-bedded to massive pebble-cobble conglomerate, with scattered boulder-size clasts and intercalated sandstone lenses up to 500 mm thick. Clasts are predominantly of quartzite, with some volcanic clasts in the lower part. In general character the conglomerate is similar to the Roland Conglomerate and to the Lower and Middle Owen Formations of the West Coast Range, and a fluvial (braided channel) origin seems most likely.

Exposures along an access track just south of the Dasher River southeast of Sheffield suggest that there is a downward passage from the siliciclastic conglomerate through mixed siliciclastic-volcaniclastic conglomerate to a lower sequence of volcaniclastic conglomerate and sandstone. The latter contains clasts of andesite, felsic volcanic rocks and rare granite to 400 mm. This northeast-dipping volcaniclastic sequence has been tentatively correlated with the Tyndall Group, and has a possible angular unconformable relationship with nearby southeast-dipping siliciclastic conglomerate and sandstone thought to part of the WVSS.

Ordovician Gordon Group limestone and Siluro-Devonian Eldon Group sandstone

The limestone sequences generally overlie the Moina Sandstone conformably and gradationally, and are typically preserved in large Devonian synclinal structures now forming broad valleys. The main areas are as follows:

- The largest area is around Mole Creek and Liena, where two large coalesced synclinal structures plunge gently east and are overlapped by Permian rocks. Eldon Group sandstone occurs in both synclines. Much of the low-lying limestone country is karstic, and much is blanketed by superficial deposits, including widespread dolerite-rich glacial deposits derived from the Great Western Tiers to the south, and gravelly alluvial deposits along the Mersey River (Jennings and Burns, 1958). The limestone is quarried for agricultural purposes at Mole Creek.
- A large NNW-trending syncline in the Railton area is extensively covered by Permian deposits. The Railton limestone deposits are the main source of lime for Cement Australia.
- At Gunns Plains, where the structure is sub-circular but the bedding indicates an E-W fold. Much of the eastern side of the valley is filled with Tertiary basalt.
- At St Valentines Peak, where the structure is N-S orientated and gently south-plunging, and connects with a large area of limestone and Eldon Group rocks largely buried beneath Tertiary basalt in the Talbot Lagoon area.
- The Loongana-Narrawa area, where a fairly narrow east-trending structure sits quite discordantly across the series of NNE-trending structures coming up from the south, and is probably also connected to the basin of Gordon-Eldon Group rocks around Talbot Lagoon.
- The Vale of Belvoir, where a small well-defined syncline trends NNE to NE, in a valley partially filled with Tertiary basalt and lake sediments. A similarly infilled smaller structure, much disrupted by northwest-trending cross faults and affected by the Dolcoath Granite, is present along strike in the Moina-Lake Gairdner area.
- An elongate NNE to NE-trending structure extends from Mt Cattley southwards to Lake Mackintosh. It has Eldon Group sandstone in the core, and is obscured by basalt in the northern part. The western margin of this structure is largely defined by the Henty Fault.

Devonian granites

The two Devonian granite bodies, known as the Housetop and Dolcoath, are important elements in the geology, not least because of the many occurrences of mineralisation and alteration associated with them. Both granites are associated with significant geophysical effects, particularly in the form of large negative gravity anomalies (Leaman and Richardson, 1989, 1992). The approximate roof shapes of the granites have been determined from the gravity data; the approximate one kilometre isobaths on the granite surface are shown on Map 1.

The isobaths show the Dolcoath body to be quite shallow and to extend for some 20 km west to the Black Bluff Range area. The Housetop batholith, by contrast, has relatively steep contacts around its southern end. An in-depth discussion of the granites and their effects is beyond the scope of this report, which is limited to some observations related to the new geological map.

Tin, wolfram, bismuth and gold mineralisation associated with the Dolcoath Granite is concentrated around the Moina–Stormont area, while gold-base metals prospects extend further afield to the Black Bluff and Lorinna areas, and important silver-lead deposits are located east of Cethana in the Round Hill area (Jennings, 1958, 1963; Collins and Williams, 1986; Leaman and Richardson, 1989). Most of the deposits are hosted in the Moina Sandstone or Gordon Limestone.

A number of gold-base metal prospects within Moina Sandstone or Precambrian rocks south of Lorinna (e.g. the Five Mile Rise district) were originally attributed to the Dove Granite (Jennings, 1963), but subsequent dating of this body as Cambrian (McDougall and Leggo, 1965) has required a re-assessment, and most of the prospects are now attributed to the Dolcoath

Granite (Collins and Williams, 1986). Whether this includes the silver-lead vein deposit actually within the Dove Granite at the Devon mine is uncertain.

The apparent concentration of mineralisation and metamorphic effects in the eastern part of the Dolcoath aureole, as opposed to the western half, is quite striking. Metamorphic effects were mapped by Pemberton and Vicary (1989) as far west as the Lea River on the (upthrown) western side of the Kauri Fault, where corundum-bearing silicified 'spines' are present within Cambrian porphyry and felsic volcanic rocks showing granite-related silica-epidote-chlorite alteration. Several gold prospects associated with northwest-trending faults are hosted within Owen Group sandstone in this area (e.g. Golden Cliff, Blacks, Devonport), but the more intense alteration is associated with bismuth-gold-silver mineralisation in Moina Sandstone–Gordon Limestone host rocks further east around Stormont.

A possible reason for the apparent lack of mineralisation in the western part is the presence of an increasing thickness of Owen Group siliciclastic sandstone and conglomerate beneath the more reactive carbonate-bearing Moina and Gordon formations. This sub-Moina siliciclastic wedge thins to virtually zero in the Moina–Cethana area, where most of the mineralisation is evident. It may not be coincidence that the highest part of the roof of this granite body, forming its only surface exposure, is also within this zone which lacks the sub-Moina siliciclastic wedge.

In general, it seems that the Cambrian rocks have not been particularly receptive to this style of mineralisation.

Notes on aeromagnetic features from the WTRMP survey

INTRODUCTION

Several major zones of anomalies are present (Map 2):

- An arcuate arrangement of magnetic ridges following Cambrian volcanic units as they wrap around the Tyennan Region basement in the central south of the area – particularly the Bonds Range Porphyry and Tyndall Group. A number of major fault offsets are apparent in this trend.
- A central E-W zone or ‘basin’ of low magnetics across most of the area, with some relatively localised highs – particularly at Wilmot and Beulah – and a bifurcated ridge in the Dasher River-Paradise area.
- A large northern high associated with the eastern part of the Husetop Granite, falling away to a magnetic low zone over the western half, studded with local highs corresponding to magnetic skarns.
- A second large northern high over Gunns Plains, coinciding partly with Tertiary basalts but also involving older rocks.
- Widespread ‘busy’ magnetics related to the Tertiary basalts, characterised in many places by parallel ridges and troughs presumably reflecting more magnetic and less magnetic (or reversely magnetised?) flows. ‘Holes’ within this pattern in the western area mainly relate to exposures of older rocks, some of which have been investigated and confirmed by Poltock (2002) for the WTRMP.
- Various ridge-like, spot-like and irregular anomalies related to Palaeozoic features, not all of which are readily explained.
- The NNE-trending zone of strong magnetics related to Tyndall Group rocks in the southwest corner of the map, and the adjacent large circular feature probably related to buried ultramafic rocks in the Bulgobac River area, have been discussed in a previous report (Corbett, 2002b)

ANOMALIES ON THE ‘SOUTHERN ARCH’

- A strong NNE-trending positive anomaly coincides with the western margin of the Bonds Range Porphyry near Mt Beecroft, with the source rocks partly concealed beneath the Owen Group. The location suggests a possible relationship to hematite-chlorite-minor magnetite alteration associated with gold mineralisation in the porphyry at Ten Mile Creek, just to the south (Pemberton *et al.*, 1991). Further investigation of such a large anomaly would seem to be warranted.
- A strong positive zone follows the ENE-trending belt of Tyndall Group rocks through the Winterbrook area, and appears to be more or less symmetrical about the central syncline. The dextral

offset on the Kauri Fault is clearly apparent. The zone does not seem to be influenced by the cover of Tertiary basalt at Smiths Plains, but continues into the Wilmot River area. The anomalous zone appears to continue southwest under the Owen Group cover along the Black Bluff Range for nearly ten kilometres.

- A four kilometre long magnetic ridge follows a tributary of the Lea River just west of Lake Gairdner, and is paralleled by a longer trough of low values coinciding with the zone of skarn development. Small spot anomalies associated with the Moina tin-tungsten skarns are apparent.
- The Dolcoath Granite body forms a distinct magnetic low. The spot high just to the northeast probably corresponds to the Cethana power station, while a ridge and trough pattern to the southwest follows the strike of the Cambrian rocks. A large magnetic high ridging along the southern end of the Bismuth Creek Fault at Lorinna suggests mineralisation related to the fault, with Moina Sandstone and Gordon Limestone host rocks nearby. The size of this anomaly seems to indicate a skarn partially buried under Tertiary basalt just east of the lake.
- An unusual spot high associated with Gordon Limestone beside the Mersey River south of Liena is close to the Croesus Cave, but has no obvious explanation.

CENTRAL ‘BASIN’ ZONE

- A large east-west orientated anomaly at Wilmot is rather unexpected, as most of the area is underlain by Moina Sandstone and the WVSS, neither of which is particularly magnetic. As noted previously, an altered mafic intrusive rock with strong magnetic susceptibility has been mapped on the shore of Lake Barrington (McClenaghan and Green, 1999a), and more recently just northeast of Wilmot by Poltock (2002). This is almost certainly the source of the anomaly, but the age, affinities and significance of the rock type remain frustratingly unclear. The obvious sinistral dislocation of the two parts of this anomaly suggests a major north-south fault, as also noted by Poltock (2002), although no fault has been mapped here.
- A second major anomaly coincides in part with the body of Beulah andesite, but the eastern half of the anomaly lies over younger rocks such as Permian, Jurassic dolerite and Roland Conglomerate. There is a strong suggestion here of a major buried intrusive complex, probably related to the andesites but lying almost along the line of the Roland Conglomerate. It might be speculated whether an intrusive complex similar to that at Wilmot could be present.

- A complex double anomaly corresponds to the area of Tyndall Group–Dasher River andesites around Paradise. The two zones are possibly symmetrical about a synclinal axis, and suggest stratigraphic equivalence of the magnetic andesites. A similar magnetic feature on the western side of Mt Roland suggests that these andesites relate to those on the eastern flank. The apparent northwards continuation of this anomaly zone through Sheffield township area appears to be mainly due to Tertiary basalts, but some stronger anomalies near Sheffield and at Nook may relate to Cambrian sources.
- A narrow ridge of high magnetics along the north flank of the Loongana Range is puzzling. Its trend suggests it is either related to the basal conglomerate of the Owen Group correlates – perhaps a zone rich in detrital magnetite – or to some sort of east-west dyke structure, perhaps related to the Tertiary basalts.
- Another positive feature overlaps the Owen Group–Cambrian contact just west of Nietta, but appears to be related to Tertiary basalt and could indicate that the basalt is more extensive than mapped in this area.

CENTRAL NORTHERN ANOMALIES

- The anomaly associated with the eastern part of the Housetop Granite extends away from the granite margin and over Late Cambrian Owen Group rocks around Loyetee Peak. Alteration associated with the granite, or a detrital magnetite-bearing unit in the siliciclastic rocks, may contribute to this anomaly but a deeper source seems likely.
- Two skarn-like anomalies over Tertiary basalt just west of the Guildford Road suggest metamorphosed Gordon Group limestone beneath the basalt in this area (see also Poltock, 2002), cut off by a major NNE-trending fault.
- The anomaly over Tyndall Group rocks between St Valentines Peak and Companion Hill appears to extend over Tertiary basalt to the southwest, and is probably related to contact metamorphism. A sharp N-S magnetic ridge on the east flank of St Valentines Peak seems to coincide with the base of the Moina Sandstone.
- The large anomaly at Gunns Plains is puzzling. It lies over Tertiary basalt in part, but also extends across the Gordon Group limestone of the valley floor. There is no apparent relationship to the Motton Spilite, which crops out east of the anomaly. A deep source beneath Cambrian rocks which outcrop beneath the Owen Group siliciclastic rocks just north of the map sheet seems likely. It is of interest to note that Jago *et al.* (1977) have described and dated (480 ± 18 Ma) a 48 m wide dyke of doleritic rock intruding Tyndall Group correlates in this area.

OTHER FEATURES RELATED TO PALAEOZOIC ROCKS

- A spot anomaly at the northern end of the Tyndall Group belt on the western side of Mt Tor coincides with a small body of altered mafic rock, as previously described. There may be some relationship between this body and the larger magnetic body at Wilmot. Surprisingly, a larger body of somewhat similar mafic intrusive rock just to the west (the 'Ring Road metadolerite') has only a weak magnetic signature.
- A major anomaly at the eastern margin of the sheet, at the eastern end of the Gog Range, coincides with a mapped lens of basaltic lavas and breccias (McClenaghan *et al.*, 2001). A subtended weaker anomaly to the southwest suggests an extension of these rocks under the Moina Sandstone of the Gog Range. The small area of highly altered basaltic rock on the Union Bridge Road is not associated with any magnetic anomaly.

Notes on the radiometric image

- The radiometric image (Map 3) provides a clear and useful contrast between those rock types with low radiometric response, particularly the Tertiary basalts and the Owen–Moina siliciclastic rocks, and lithologies with significant response, such as the Cambrian volcanic sequences, the Devonian granites, and the Precambrian rocks. Thus small windows of older rocks within the large basalt-covered western area may be clearly visible, and a number of these have been investigated and confirmed by R. A. Poltock (2002). Perhaps surprisingly, the highly siliceous Barrington Chert bodies have a modest response, much stronger than the Owen siliciclastic rocks.
- The zones of strongest radiometric response are the Housetop Granite, Dolcoath Granite, the Precambrian schists of the Tyennan Region, and the Bonds Range Porphyry and its extensions.
- Other strong zones are produced by the volcanic sequences, including the EQPS (particularly in the Bell Mount–Cethana area), the WVSS in most areas (particularly Loongana–Nietta–Lower Wilmot), and the Tyndall Group correlates, which give a strong to patchy response. A contrast is apparent at Native Track Tier between the strong and fairly uniform response of the WVSS correlates to the southeast, and the patchy response of the Tyndall Group correlates to the northwest.
- The andesites of the Dasher River give a generally strong response except where concealed by siliceous scree from Mt Roland. This is in contrast to the relatively poor response of the andesites around the Que River mine. The Beulah andesites have a patchy response, with a relatively strong zone in the south around the Beulah barite area, but a poor response on the higher ground in the northern part of the body (perhaps due to deeper weathering?).
- A narrow zone of strong radiometrics follows the Union Bridge Road down the south flank of the Gog Range. This is unexpected, as mapping suggests that the area consists of siliceous talus covering Moina Sandstone and Gordon Group limestone (McClenaghan *et al.*, 2001). The response suggests that there are probably Cambrian rocks here, and further investigation seems warranted.
- A line of spot anomalies along Dempster Creek, a tributary of the Leven River three kilometres south of Mt Everett, indicates bedrock exposure beneath Tertiary basalt. This is assumed to be Gordon Group limestone pending field checking.

Comments on mineralisation and related features

Time constraints have not allowed for a complete review of mineralisation in this large and complex area, and the following comments are of a preliminary nature. Descriptions of the mineral deposits and prospects in the area are contained in Collins (*in* Jennings, 1979), Jennings (1963) and Seymour (1989). A considerable diversity of mineral deposits is present, of which the great majority of significant deposits are related to the Devonian granite bodies.

- The Dolcoath Granite has been particularly productive, with an inner zone of tin-tungsten-bismuth-molybdenite deposits, and an outer zone of silver-lead-gold-copper-zinc deposits. The largest producing mines have been the Shepherd and Murphy (Moina) mine (tungsten-tin-bismuth) and the Round Hill silver-lead mines (Jennings, 1958). The Moina Sandstone and basal part of the Gordon Limestone have been the favoured hosts, with some relatively minor mineralisation in the Cambrian volcanic rocks. Most of the mineral deposits are contained within the interpreted outline of the one kilometre isobath of the granite (Map 1), except in the area south of Lorinna.
- A strong magnetic high east of Lake Cethana, off the southeast end of the Bismuth Creek Fault, probably represents an unexplored magnetic skarn buried or partly buried under Tertiary basalt.

- Skarn-type scheelite-magnetite deposits related to the Housetop Granite are being mined in the Kara area, with prospects around St Valentines Peak and Loyetea. Two magnetic highs west of Companion Hill suggest buried skarns beneath Tertiary basalt.

PROBABLE CAMBRIAN MINERALISATION

Deposits and prospects considered to be related to the Cambrian volcanism and igneous activity, with a possible Devonian overprint in some cases, occur in a belt extending from Lower Beulah through Mt Roland, Staverton, Barrington, Castra and Nietta to Native Track Tier (see Map 1), and probably link to other such deposits in the Two Hummocks–Que River area. Some are prospects and old mines discovered by prospectors in the 19th century, while most of the remainder were discovered in the 1970's and 1980's after regional stream sediment surveys by Asarco and CRAE. A summary of the main prospects is given below.

Beulah Barite

Barite veins and minor Pb, Zn, Cu in sericite-carbonate-hematite altered andesites. Some 635 t of barite was mined here by the Electrolytic Zinc Company in 1911–1920. Recent drilling has been undertaken by CRAE and Aberfoyle. Lead isotopes

suggest a Cambrian age (Collins *in* Jennings, 1979; Rand and Noonan, 1989).

Star of the West

Old gold workings following quartz veins within and at the contact of a large felsic porphyry body intruding WVSS. Also some alluvial gold in the nearby Minnow River (Collins *in* Jennings, 1979).

Fire Tower Prospect

A recent discovery from follow-up of a 1970's stream survey. Gold in stockwork quartz-carbonate veining in sericite-carbonate-silica altered felsic volcanoclastic rocks close to quartz-feldspar-biotite porphyry intrusive rocks. Some associated As, W, Co, Cu, Pb and Zn (Jones, 1991; MacDonald, 1993; Callaghan, 2002).

Stonebridge Prospect

Barite veins and gossan development with minor base metals in andesitic and felsic volcanic rocks near Paradise (Rand and Noonan, 1989).

Mt Roland Silver-Lead, Atkinsons, Mt Roland

Several old prospects with barite and minor Ag-Pb-Zn-Cu in stockwork veins and disseminations in sericite-carbonate altered andesitic breccias (Weber, 1983; Hicks and Richardson, 1991).

East Cethana, West Cethana, Cethana Pyrite Zone

Recently discovered low-grade Pb-Zn-pyrite mineralisation in an extensive zone of sericite-chlorite-carbonate-quartz alteration in felsic volcanic rocks correlated with EQPS. Drilling by CRAE and Plutonic. Lead isotopes indicate a Cambrian age, with some Devonian overprint possible. Interpreted as possible footwall alteration zone to exhalative position at or near contact with adjacent Tyndall Group volcanoclastic sequence (Jones, 1989; Close and Reid, 1997). Only minor sulphides so far intersected.

Days Road Prospect

Minor Pb-Zn in altered dacitic volcanic rocks.

Staverton Prospect

Recent discovery of disseminated and vein-hosted Pb-Zn in sericite-chlorite-pyrite-altered dacitic volcanic rocks. Was drilled by Plutonic in 1993. Suggestion of Devonian overprint of calcite-chlorite-pyrite-tourmaline alteration (Close and Reid, 1997).

Lake Barrington Prospect

Recent discovery of low-grade Cu-Ag-Pb-Zn mineralisation as disseminations and a possible thin massive sulphide band (Purvis, 1981) in sericite-quartz-carbonate-pyrite altered tuffaceous siltstone and sandstone of WVSS. Drilled by CRAE in 1981-1982 (Close and Reid, 1997).

Barrington (Alma) Mine

Barite and Cu sulphides associated with quartz-siderite veins in slate and sandstone of WVSS

('Gog Range Greywacke') at Lake Palooa. Twelvetrees (1906) records production of some 457 kg of copper ore (Collins, *in* Jennings, 1979). The Devonport adit is located just upstream. The nearby Lucas and Perrys lode is a silver-bearing gossanous formation in slate of the Barrington Chert (Twelvetrees, 1909).

McPhersons Mine

Cu-Pb-Zn-Ba hosted in WVSS rocks in East Gawler River. Few details available, but sampled by Pasminco in 1989, with lead isotopes indicating a Cambrian age (Virgoe, 1990).

Preston Silver Mine

Pb-Zn-Ag-pyrite mineralisation as thin films and irregular slugs in siltstone and sandstone of WVSS close to faulted contact with Owen Group siliciclastic rocks (Collins, *in* Jennings, 1979). Lead isotopes indicate a Cambrian age (Virgoe, 1990).

Castra Road Prospect

Zone of strong pyrite development and minor barite in sericite-silica altered quartz porphyry and volcanoclastic rocks on Castra Road towards Nietta (Virgoe and Mathison, 1989).

Crosby Creek Prospect

Recent discovery of low-level disseminated Pb-Zn-Cu mineralisation in tuffaceous shale of WVSS close to contact with andesitic-dioritic intrusive body. Drilling by CRAE in 1975. Lead isotopes indicate a Cambrian age (Virgoe, 1990; Vicary, 1994).

Loyetea South (Tulip Tree Creek) Prospect

Pb-Zn-Cu in stream sediment and soil anomalies associated with strong sericite alteration in tuffaceous sediments of WVSS. Two drill holes by CRAE in 1975 over soil-IP anomalies produced no significant mineralisation. Lead isotopes indicate Cambrian age (Virgoe, 1990; Vicary, 1994).

Loyetea North Prospect

Similar stream and soil Pb anomalies and some IP anomalies in volcanoclastic Tyndall Group rocks, but no associated alteration (Virgoe, 1990; Vicary, 1994).

Challenger 2 Prospect

Similar stream and soil Pb-Zn anomalies (Buckland, 1977; Vicary, 1994).

Mt Jacob Prospect

A 1970's discovery by Comalco of Pb-Zn-Cu sulphides in dacitic lavas under Mt Jacob at Winterbrook, with some carbonate rocks suggestive of a possible exhalative zone (Vicary, 1995). Drilling by Comalco in 1978 on soil-IP anomalies intersected siderite-sphalerite-galena-quartz stockwork mineralisation with up to 1.3% Pb and 1% Zn. Lead isotope value of 18.407 is intermediate between Cambrian and Devonian groups (Vicary, 1995).

SUMMARY OF CAMBRIAN PROSPECTS

The Cambrian prospects may be grouped into four main types:

- Prospects associated with the large felsic intrusive bodies (i.e. 'Minnow Keratophyre', Bonds Range Porphyry). These include gold shows such as the Fire Tower prospect and Star of the West mine, the Ten Mile Hill prospect south of Black Bluff Range, and probably the Bonds Peak gold prospect. Several Pb-Zn prospects are located at the eastern margin of the Bonds Range Porphyry south of Lake Lea, and have characteristics suggesting Cambrian porphyry-related early mineralisation overprinted by later, probably, Devonian, phases (Pemberton *et al.*, 1991).
- Prospects associated with the seven kilometre long Cethana Pyrite Zone, easily the largest hydrothermal alteration zone in the area and comparable with Mt Lyell and Rosebery in this regard. The suggestion that it represents a footwall position relative to a possible exhalative horizon at or near the contact with overlying Tyndall Group rocks is clearly analogous to the situation at Mt Lyell and Henty. The westerly continuation of the zone may be represented by the Mt Jacob Prospect, and the Bell Mountain Alluvial gold prospect probably also has its derivation in the continuation of the zone. Although only low-level Pb-Zn mineralisation has been intersected to date, it should be noted that there is a close spatial association with the rich Ag-Pb deposits of the Round Hill district, less than one kilometre to the south. There may be a possibility that some of this mineralisation was derived by remobilisation of Cambrian sulphides – the lead isotope evidence appears to be inconclusive (e.g. Vicary, 1995).
- Pb-Zn-Cu ± Ag prospects hosted within tuffaceous shale and sandstone of the WVSS, with faint suggestions of exhalative mineralisation in some cases, and links to andesitic intrusive rocks in some cases, e.g. Lake Barrington prospect, McPhersons mine, Preston Silver mine, Barrington (Alma) mine, Loyetee South, Loyetee North, and Challenger 2. The Crosby Creek prospect is clearly related to the adjacent andesitic intrusive rock, and suggests that such intrusive rocks might have acted as both metal sources and heat engines to potentially produce VHMS-type deposits. Large areas of the WVSS around the interpreted 'granitic' intrusive in the Nietta-Castra-Barrington area would seem to be prospective for buried VHMS deposits, or other types of mineralisation, from such a source, but knowledge of the geology of these areas is insufficient at present to properly assess this potential.
- Pb-Zn-Ag-Cu-Ba prospects in andesitic or dacitic rocks interpreted herein as Tyndall Group correlates. These include the Staverton and Days Road prospects, and the series of prospects around the flanks of Mt Roland to the Stonebridge barite prospect at Paradise. The Beulah barite prospect has similarities to this group, although it may be in slightly older rocks. It also has similarities to the Mt Charter barite prospect near Que River. The presence of a number of base metal prospects hosted within Tyndall Group rocks suggests that mineralising systems may have continued operating later in the history of this area than on the West Coast, where most activity is hosted within the lower parts of the Group. The known prospective horizon around the base of the Tyndall Group is widely represented in the Sheffield-Cethana area, but appears to have had little if any specific investigation.

Comments on the Beulah–Barrington–Nietta gravity anomaly

The irregular gravity low which extends between the Sheffield–Beulah area and the Nietta area was originally attributed to the Beulah ‘granite’ body, assumed to be Devonian, but has since been reinterpreted to reflect a granite-like mass reaching to within about one kilometre of the surface (Leaman, 2003). The actual intrusive rocks at Beulah are granodioritic bodies related to the Cambrian andesites, and are associated with positive Bouguer anomalies reflecting their surface outcrop and relatively dense nature.

Leaman (2003) suggests the following characteristics for the rock mass responsible for the negative gravity anomaly:

- (1) implied density 2.62–2.63;
- (2) a large ‘pluton-like’ body is present;
- (3) the character of the anomaly is different from that of the other granite-induced anomalies;
- (4) the ‘arms’ of the body appear to intrude segments of the Cambrian sequences;
- (5) the ‘plutons’ appear to form a general basement for the volcano-sedimentary sequences, and may not intrude them;
- (6) the ‘pluton’ is more restricted than previously thought, but the overall boomerang shape is confirmed; and
- (7) the anomaly is better defined in the Nietta–Lower Barrington area than in the Sheffield area.

The following suggestions are made arising from this review of the geology in the area:

- The nature and distribution of mineral occurrences in the area, the presence of galena with Cambrian-type lead isotope signatures at Crosby Creek, Preston silver mine and McPhersons mine (Virgoe, 1990), and the apparent lack of any mapped metamorphic effects around the anomaly area, are all negative indicators for a Devonian granite being responsible for the anomaly.
- The presence of two zones of Cambrian granodioritic-monzonitic intrusive rocks at either end of the anomaly belt seems highly coincidental, but may be just that, as these rocks would seem to be too dense to be involved. A less dense, more felsic or ‘granitic’ variant or relative is a distinct possibility.

The major bodies of highly siliceous Barrington Chert occur close to, or within, the anomaly area. The exposed ridges of these rocks are almost certainly attached to much larger allochthonous bodies at depth, and probably form much of the ‘basement’ to the volcano-sedimentary sequences. They could therefore constitute major features in the gravity field if their density is slightly different from that of the younger sequences. The density of Barrington Chert is not known to the author, but that for quartz is about 2.65, and is somewhat lower for cryptocrystalline varieties according to Dana (1958).

The uncertainty involved in trying to interpret this anomaly highlights again the inadequacy of the information and detail available for the Cambrian sequences in the Nietta–Castra–Barrington area, and further emphasises the need for quality mapping in the area.

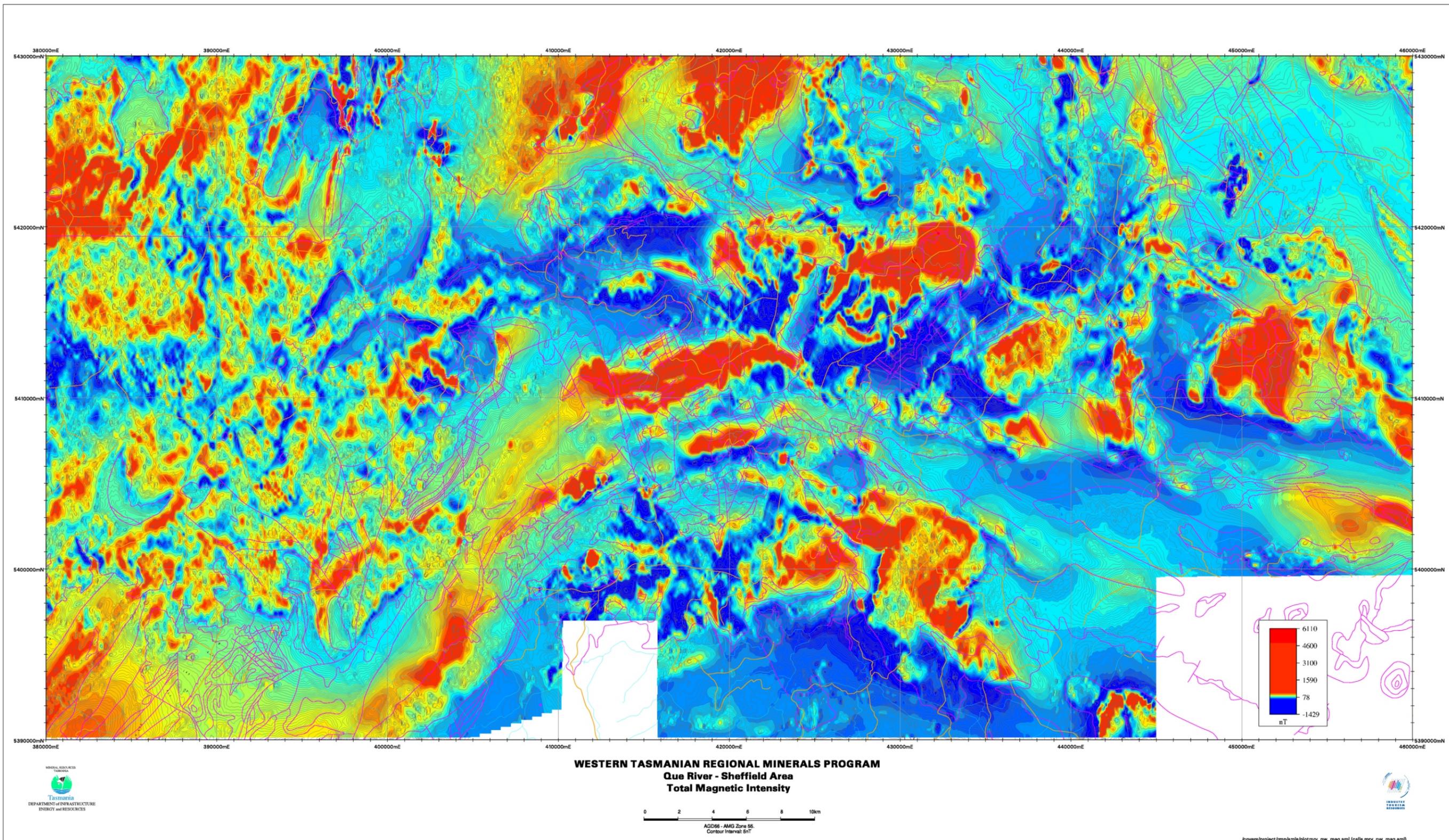
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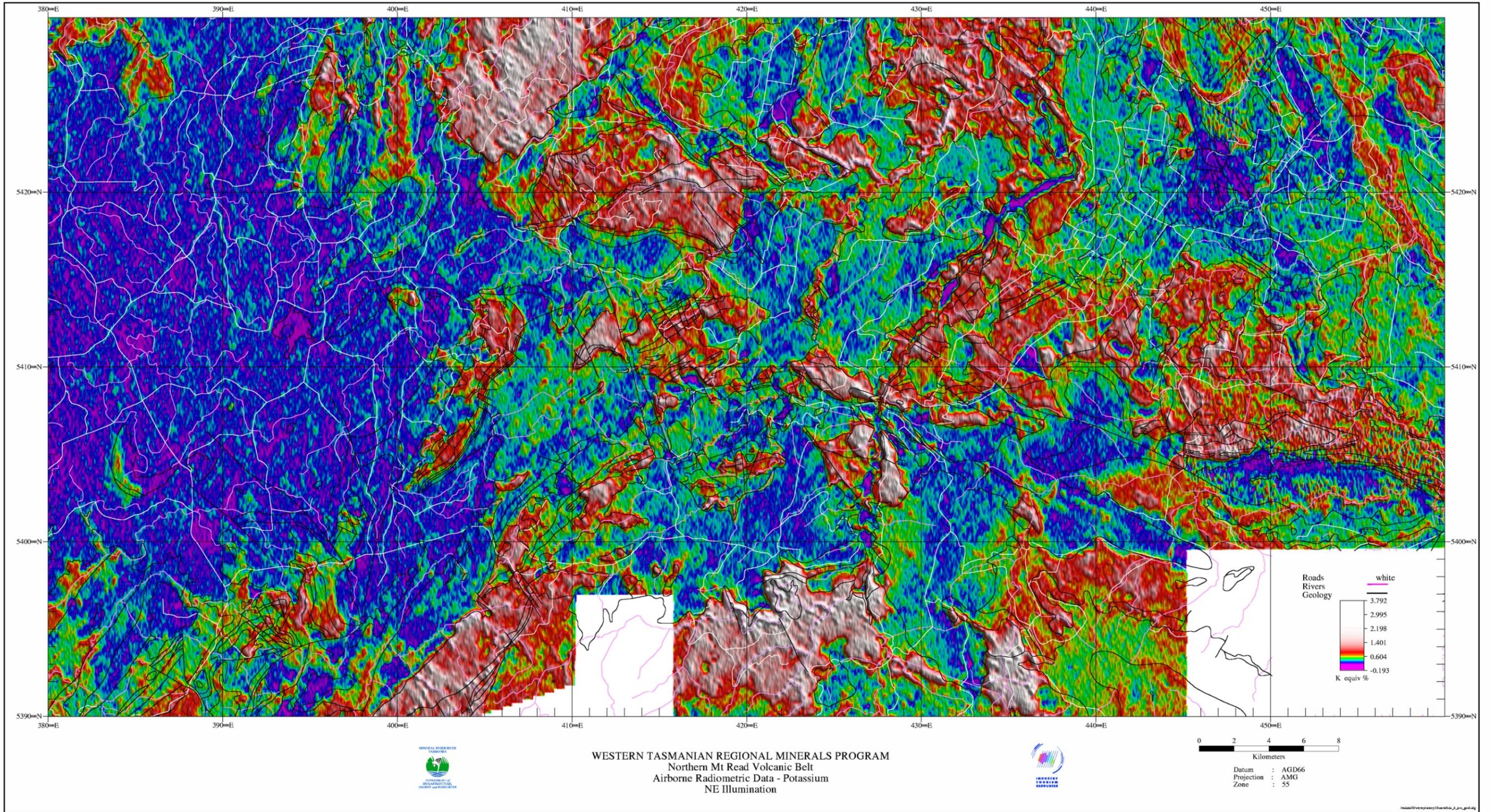
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[30 April 2003]



Map 2



Map 3