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A review of Cambrian megabreccias in the Penguin–Ulverstone area, central northern Tasmania

A report for the *TasExplore* Project

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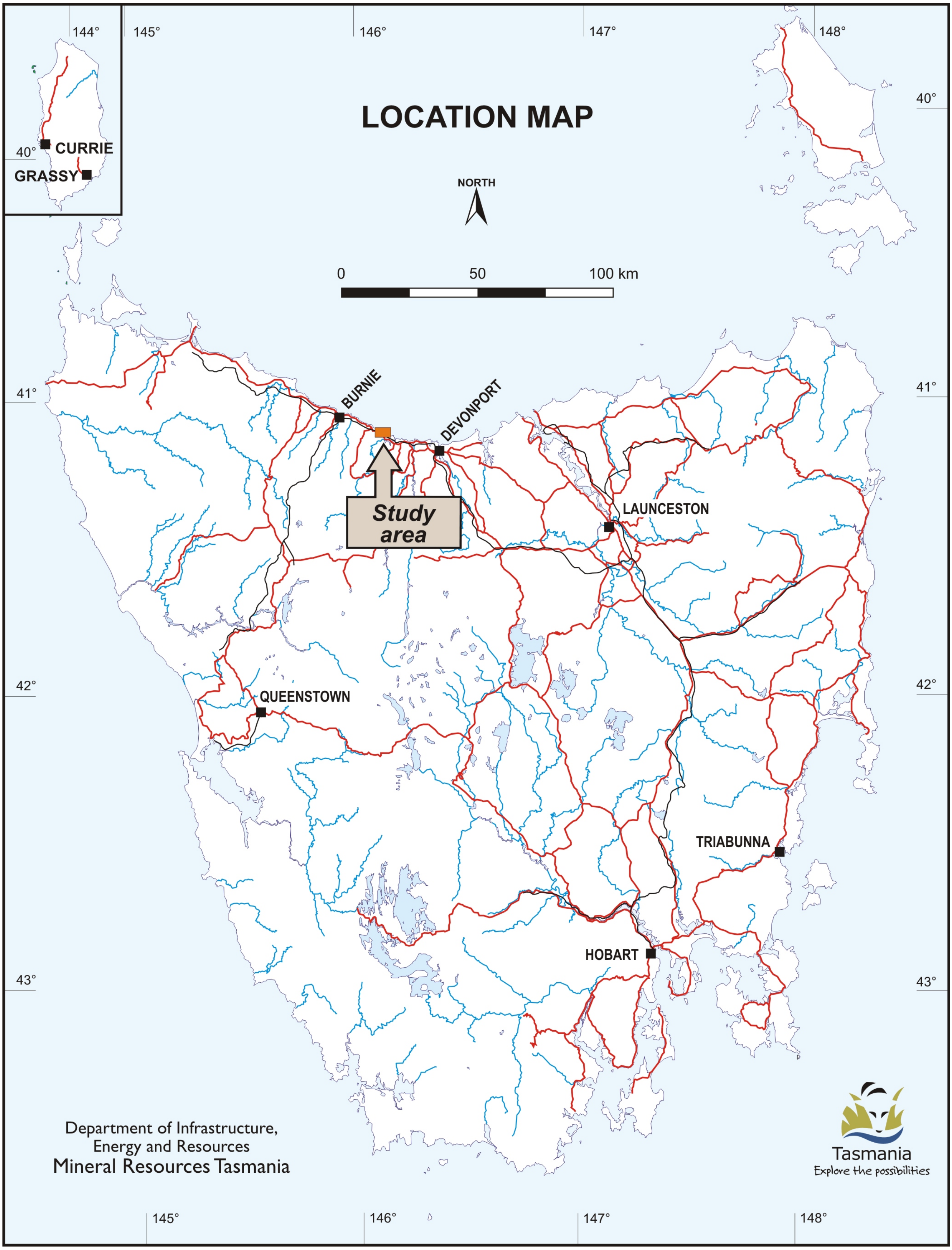

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Introduction

The first major phase of geological fieldwork for Mineral Resources Tasmania's *TasExplore* Project was targeted on an upgrade of the 1:25 000 scale digital geological map coverage of the pre-Carboniferous rocks of the Penguin–Sheffield–Gog Range area in central northern Tasmania. The main priority in this exercise was re-examination of the economically important Middle to Late Cambrian Mt Read Volcanics correlates and associated sequences in the area, with an aim to improve map coverage, unit correlations and associated interpretations to a standard closer to that achieved in the previous (1986–1990) Mt Read Volcanics Project in the Dundas Trough area of western Tasmania.

Within this brief, one suite of rocks in the area which has always stood out as atypical comprises a number of occurrences of variably deformed Cambrian coarse (boulder grade) blocky breccias, which are well exposed within extensive strip outcrops orientated mostly across strike on the Bass Strait coast between Penguin and Ulverstone. Most of these unusual rocks had been previously well documented and mapped in great detail (by plane table methods) during specialist studies associated with the first-generation regional geological mapping of the surrounding region (Burns, 1963, 1964). What was less clear at the start of *TasExplore* was precisely how the genesis of these deposits fits in with what is now known about western Tasmanian Cambrian structural history, encapsulated in the multi-phase Tyennan Orogeny (Turner *et al*., 1998; Stacey and Berry, 2004; Berry *et al*., 2007).

As previous detailed geological maps of the breccias existed in all but one case, the approach taken to the problem in most cases was not to remap. Instead the previous maps were field-checked in detail and adjusted where judged necessary, key lithologies were sampled and key outcrop features re-examined, documented and photographed. The previous maps lack reference grids, and one approach which proved useful was to scan and georeference the maps in desktop GIS prior to the work so that a current metric grid could be superimposed (and included on revised detailed maps). This enabled use of the relatively high accuracy of modern handheld GPS units to pinpoint (and remap if required) key outcrop features in the field.

In documenting these rocks, Burns (1964) made a distinction between 'megabreccias' and 'chaos', the former term describing relatively unsheared and unfoliated very coarse breccias which are not directly associated with fault zones, and the latter describing highly sheared and foliated but otherwise similar breccias which occur in the immediate footwalls of major thrust faults (the Westbank and Ulverstone faults). Burns (1964) saw a connection between the two types, correlating the Westbank Chaos (in the footwall of the Westbank Fault) with the Beecraft Megabreccia, based on similarities in block composition. Recent university research (Berry and Gray, 2001; Foster *et al*., 2005) has indicated a polyphase movement history for the Westbank and Ulverstone faults and similar structures in the area, with at least two phases of Cambrian compressional movement associated with the Tyennan Orogeny, possibly followed by a further phase of Devonian compressional movement. Fieldwork for this report has reinforced a number of significant compositional, structural and textural differences between the two classes of breccia. The 'chaos' class of Burns (1964) is essentially foliated tectonic mélanges with structural histories probably starting with the first phase of the Tyennan Orogeny in the Early Cambrian, while the 'megabreccias' have a primarily sedimentary (although tectonically influenced) origin and appear to be associated with the Middle–Late Cambrian extensional phase of the Tyennan Orogeny (Stacey and Berry, 2004). The discussion below is subdivided accordingly.

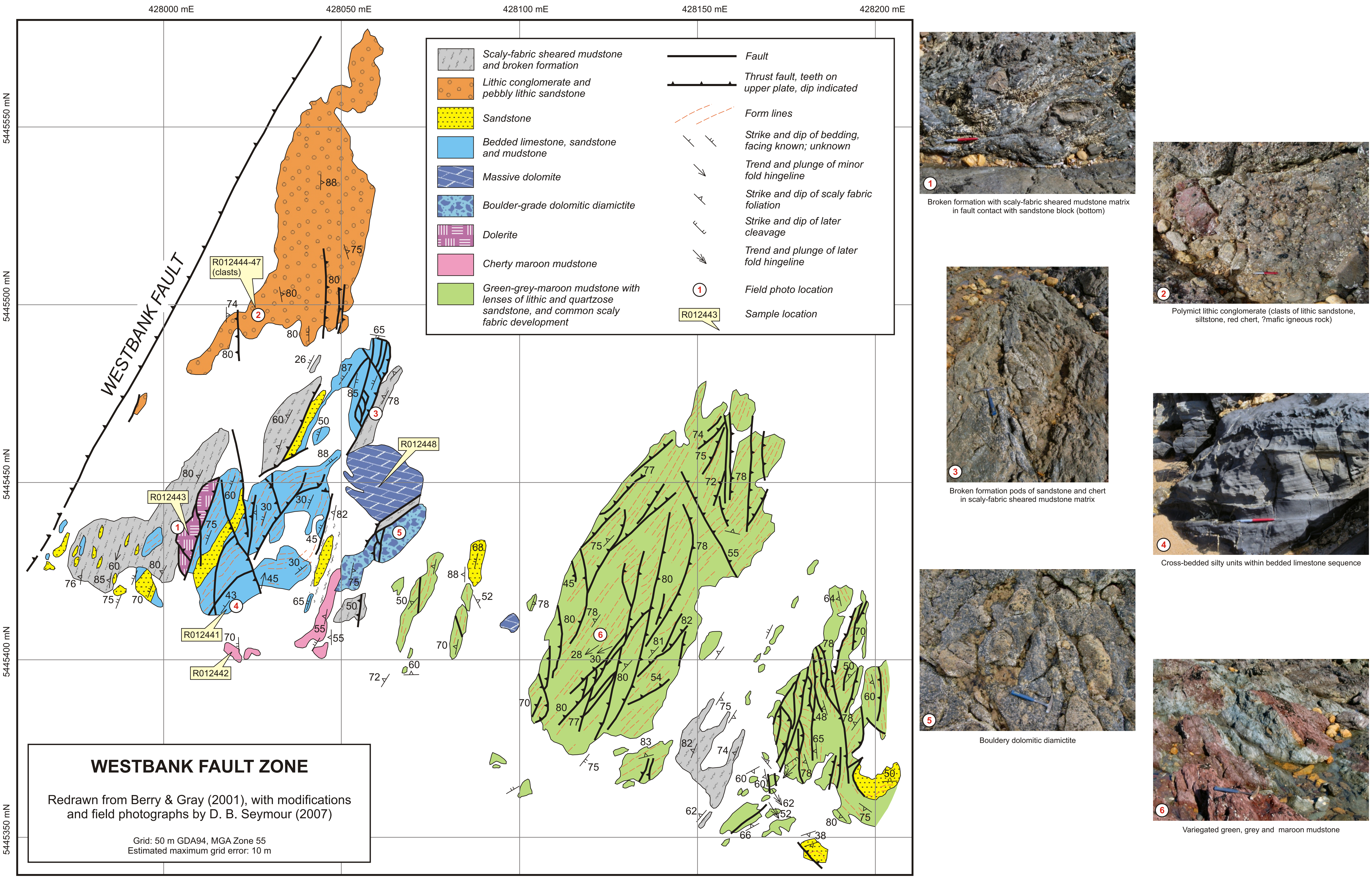
All grid references in the text (and map grids) are GDA94 datum and are MGA co-ordinates in Zone 55, quoted in the form xxxxxx/yyyyyyy, where the first six numbers are metres east and the last seven numbers are metres north.

Tectonic mélanges (?Early–Middle Cambrian)

Westbank Fault Zone

Burns (1964) introduced the term Westbank Chaos as a structural term for "….an assemblage of sheared Cambrian rocks on the footwall of the Westbank Fault….", east of Goat Island in the vicinity of 428085/5445435 (fig. 1). On its western side the chaos is in contact with the Ulverstone Metamorphics at a west-dipping thrust fault, while on the eastern side it is in contact with the Burnie Formation at what Burns inferred to be an unconformity but has since been re-interpreted as another west-dipping thrust fault (Berry and Gray, 2001). The whole of the Westbank Chaos between these two faults is referred to in recent interpretations as the Westbank Fault Zone (Berry and Gray, 2001; Foster *et al*., 2005). A detailed lithological map of the zone was produced by Burns (1963), while an updated map published in Berry and Gray (2001) omitted some of the outcrops closest to low water mark but showed greater structural detail and indicated that the blocks in the complex reside in a matrix of sheared scaly-fabric mudstone and broken formation. The brief re-examination of the Westbank Fault Zone outcrops reported here uses the Berry and Gray (2001) map as a basis with minor alterations (fig. 1).

The large blocks in the Westbank Fault Zone are up to 110 m in length, and comprise a variety of rock types including mottled green-grey-maroon mudstone with lenses of sandstone; massive crystalline dolomite; boulder-grade dolomitic diamictite; maroon-red cherty mudstone; bedded limestone with interbedded sandstone and mudstone; lithic sandstone; dolerite; and polymict lithic conglomerate with interbedded pebbly lithic sandstone (fig. 1). Burns (1964) attempted to determine a stratigraphic succession of these lithologies, although it is clear from the revised map in Berry and Gray (2001), and confirmed by re-examination of outcrops for this report, that the various rock types are commonly in fault relationship with each other and so any apparent succession may be stratigraphically meaningless. The dolomitic diamictite consists of matrix-supported sub-rounded boulders of



1 Broken formation with scaly-fabric sheared mudstone matrix in fault contact with sandstone block (bottom)

2 Polymict lithic conglomerate (clasts of lithic sandstone, siltstone, red chert, ?mafic igneous rock)

3 Broken formation pods of sandstone and chert in scaly-fabric sheared mudstone matrix

4 Cross-bedded silty units within bedded limestone sequence

5 Bouldery dolomitic diamictite

6 Variegated green, grey and maroon mudstone

Figure 1

massive dolomite up to 0.5 m in size in a matrix of dark grey mudstone; it is an unusual lithology which bears a striking resemblance to the Julius River Member of the late Neoproterozoic Black River Dolomite, part of the Togari Group in the Smithton region of northwestern Tasmania (Everard *et al*., 2007). The clast population of the polymict lithic conglomerate which forms the dominant component of the most westerly block includes lithic sandstone (common), carbonate-altered maroon or grey siltstone, carbonate-chlorite altered dolerite, and red chert. The "keratophyre" clasts noted by Burns (1964) and the "volcanic clasts" noted on the Berry and Gray (2001) map were not re-confirmed, unless they refer to the uncommon altered dolerite clasts. The lithic sandstone clasts internally have a clast population of strained quartz (common), feldspar, basalt, quartzite and other metamorphic rocks, and a possible felsic volcanic or intrusive rock. The mafic igneous clastic component (albeit fairly minor) in this block suggests some compositional similarity with the Kanunnah Subgroup of the Togari Group (Everard *et al*., 2007), but the overall match is equivocal.

The various blocks are set in a 'matrix' of highly sheared mudstone with a scaly-fabric shear foliation which anastomoses on all scales (down to thin-section level, as shown in Burns, 1963). This 'matrix' contains smaller blocks and cuspate or sigmoidal pods of sandstone, mudstone, carbonate rocks and other lithologies which in places are numerous and resemble 'broken formation' (outcrop photographs 1 and 3, fig. 1) (Berry and Gray, 2001). The nature of the 'matrix', together with the polymict composition of the large blocks, gives the overall composition and fabric of the Westbank Fault Zone many of the characteristics of mélange (Raymond, 1984). The suggestion that the blocks in the Westbank Fault Zone are derived from Togari Group correlates (Berry and Gray, 2001; Foster *et al*., 2005), while still equivocal is consistent with the presence of dolomite and other carbonate rocks, a dolomitic diamictite very similar to the Julius River Member, and a conglomerate with mafic igneous clasts (although these are only a minor component here).

Lodders Point mélange

In the Penguin–Ulverstone sector of the Bass Strait coast, perhaps the only significant occurrence of 'megabreccia' that was not mapped in detail by Burns (1964) forms a 190 m wide contact zone of coarse blocky mélange between near-coherent outcrop areas of Barrington Chert and Motton Spilite immediately west of Lodders Point (fig. 2). A detailed (1:285 scale) sketch map of the western part of the mélange zone was included in a B.Sc. (Hons.) thesis by Sproule (1994), but while giving a good impression of the structural style of the mélange does not show accurate relative internal dimensions. A previously unpublished structural map by D. R. Gray, covering the mélange zone and a tract of the Barrington Chert east of it, appeared in an excursion guide by Berry and Holm (2001), but is somewhat too broad in scale (1:2860) to adequately show the detailed internal relationships in the mélange itself. Consequently an attempt was made for this report to remap the mélange zone in detail, with some structural detail in the coherent Barrington Chert to the east adopted from the map in Berry and Holm (2001) (fig. 2).

The Lodders Point mélange appears to be approximately stratabound between the Barrington Chert to the east and the Motton Spilite to the west (fig. 2). Bedding dips are generally moderate to steep westward within the coherent Barrington Chert and within larger blocks in the mélange, while a single determination of westward facing comes from flame structures at the upper contact of a unit of red cherty mudstone (merging into jasper in part) at the base of the Motton Spilite section west of the mélange (locality 1, fig. 2). The approximate dip-corrected thickness of the mélange is a little over 180 metres. Blocks in the Lodders Point mélange range in size from sub-metre scale to over 60 m in length, and appear to be largely derived from 'local' lithologies (fig. 2). Block compositions include basaltic lava identical to the nearby Motton Spilite; bedded chert identical to the nearby Barrington Chert; a coarse bouldery basaltic volcaniclastic unit which may represent a subaqueous pillow breccia associated with the Motton Spilite; thin bedded green to maroon mudstone similar to the rock type forming some of the largest blocks in the Westbank Fault Zone (fig. 1; see below); and a distinctive black siliceous shale identical with the lithology forming two large blocks of uncertain origin (but with possibly unfaulted contacts) within the Motton Spilite just east of the Beecraft Megabreccia (fig. 3).

The large blocks are set in a 'matrix' of blocky sheared mudstone with scaly-fabric shear foliation, very similar to the 'matrix' of the Westbank Fault Zone. This contains smaller angular chert blocks on all scales, and in some places elongate cuspate to sigmoidal pods (ductile boudins?) of sandstone, which give the impression of having been incompletely lithified at the commencement of deformation (locality 8, fig. 2).

All of the block boundaries within the mélange are faults, most commonly steep west-dipping or northwest-dipping thrust faults; the only non-faulted boundaries are between grey-green and maroon variants within the large mudstone block, and between the main body of Motton Spilite west of the mélange and the red chert-mudstone at its base. There are examples of fault-bounded blocks of altered basalt partially enclosed by chert, and of fault-bounded blocks of chert partially enclosed by coarse basaltic volcaniclastic rocks. A recurrent feature of several of the chert blocks in the central part of the mélange is the presence of 'rootless', southward-plunging, tight reclined folds in bedding (e.g. localities 6 and 9, fig. 2). These folds have no axial planar foliation, but their consistency in style and orientation is perhaps inconsistent with an origin as chaotic soft-sedimentary slump folds. Instead, they may have formed during an early phase of tectonic deformation involving east-west compression which initiated when the rocks were still incompletely lithified. They may also be related to larger scale early tight to isoclinal recumbent folds recorded in the Barrington Chert at several inland localities (e.g. the northern and southwestern flanks of Sullocks Hill, and near 424785/5444825 in a quarry north of Hays Creek; Vicary *et al*., 2008). The mélange is also transected by a number of steep dextral wrench faults and

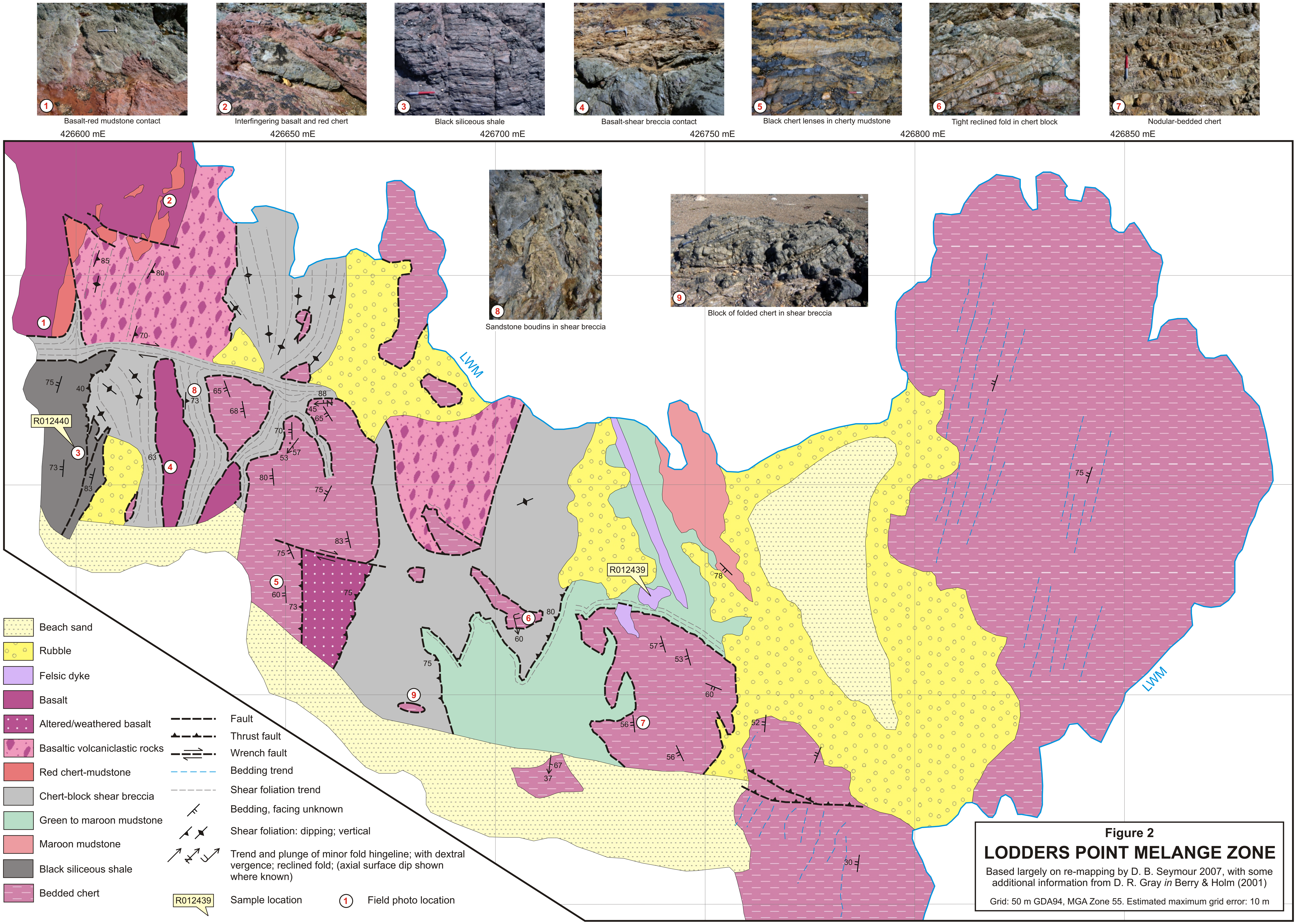


Figure 2

LODDERS POINT MELANGE ZONE

Based largely on re-mapping by D. B. Seymour 2007, with some additional information from D. R. Gray *in* Berry & Holm (2001)

Grid: 50 m GDA94, MGA Zone 55. Estimated maximum grid error: 10 m ductile shear zones trending a little south of east. Local structural relationships suggest these may be coeval with development of the scaly-fabric shear foliation, implying that they are early structures. They also show a lack of strike continuity consistent with an origin as transfer zones or lateral ramps associated with thrust faulting during an episode of east-west compression — but perhaps an early (Early Cambrian?) movement, rather than a later (Late Cambrian or Devonian) phase of east-directed thrusting.

Discussion

Possibly the best match for the Westbank Fault Zone assemblage as a whole is the Ragged Basin Complex in the Lake Gordon area of southwest Tasmania. This is an extensively disrupted (broken formation) assemblage or mélange of lithic sandstone (with mixed mafic-volcaniclastic and metamorphic derivation), chert, red mudstone, mafic volcanic and shallow intrusive rocks, and dolostone (Turner, 1989; Seymour and Calver, 1995; Calver *et al*., 2007). In some places the Ragged Basin Complex shows the same distinctive anastomosing 'scaly' shear fabric which is prominent in the 'matrix' of the Westbank Fault Zone (Turner, 1989). It has been interpreted as an allochthonous assemblage structurally emplaced in the late Early Cambrian (e.g. Corbett, 1995), although the mafic volcanic rocks in the complex show within-plate, probably continental geochemical signatures (Calver *et al*., 2007), and so do not share the oceanic geochemical affinities of the Early Cambrian ultramafic-mafic complexes which are more generally accepted as allochthonous (Crawford and Berry, 1992).

Another possible candidate for correlation with the Westbank Fault Zone is the Port Sorell Formation, some 37 km further east on the north coast, where it is in east-dipping thrust fault contact with the ?Neoproterozoic Badger Head Group to the east and overlain by younger cover rocks to the west. The Port Sorell Formation consists predominantly of shale with interbedded siltstone and sandstone, and significant units of chert, dolostone, mafic-volcaniclastic sandstone, conglomerate, dolerite, basalt and rhyolite (Calver and Reed, 2001; Reed *et al*., 2002). Most of the formation is not a true mélange, as the various lithologies are generally not strongly mixed structurally at outcrop scale and mapped units can be followed along strike for kilometres (Calver and Reed, 2001). Broadly bedding-conformable zones of mélange are present and so stratigraphic order has probably not been preserved (Calver and Reed, 2001). Microfossils in the cherts are identical to those in cherts from the Togari Group, and the basalts have a within-plate, continental trace-element geochemical signature, like those from the Ragged Basin Complex and the Togari Group (Reed *et al*., 2002).

The Lodders Point mélange is similar in structural and morphological characteristics to the Westbank Fault Zone, but differs in that more of the blocks are composed of lithologies similar to the adjacent rock units (Barrington Chert and Motton Spilite) which structurally enclose the mélange. Common to both assemblages are the scaly-fabric sheared mudstone matrix and indications that the first major compressional deformation started when the rocks were still incompletely lithified.

Further inland, the Barrington Chert and Motton Spilite form a conformable succession (Burns, 1964; Vicary, 2006) which has previously been correlated with autochthonous upper Proterozoic successions in western Tasmania (Brown, 1989; Berry and Gray, 2001; Berry and Holm, 2001). However the Barrington Chert contains siliceous sponge spicules of probable Cambrian age, while the cherts of the mid-Cryogenian Black River Dolomite contain vase-shaped microfossils (Saito *et al*., 1988). The Barrington Chert is typically well-bedded and/or finely laminated, consistent with an origin as 'primary' deep-water chert, whereas silicified derivatives of the upper Proterozoic dolomites typically preserve a range of shallow marine sedimentary structures and textures (Everard *et al*., 2007). The most recent review of the geochemistry of the Motton Spilite shows that it has a MORB geochemical signature (Calver and Everard, in press), unlike the within-plate signatures of the upper Neoproterozoic basalts. Together with the common fault contacts of the two formations with adjacent units, the weight of evidence is in favour of them being allochthons emplaced during the Early Cambrian collision/obduction phase of the Tyennan Orogeny (Stacey and Berry, 2004). As the Lodders Point mélange seems to represent a major strata-parallel early shear zone which developed when the rocks were still perhaps incompletely lithified, it may be that its formation coincided with the first effects of collision-generated compression at the onset of the Tyennan Orogeny.

Sedimentary megabreccias (?Middle–Late Cambrian)

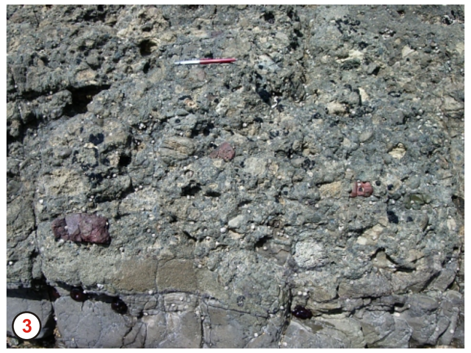
Beecraft Megabreccia

The term Beecraft Megabreccia was introduced by Burns (1964) for an assemblage of very coarse blocky clastic rocks exposed on the Bass Strait coast at Penguin between 422720/5448045 and 423600/5447935. The detailed map by Burns (1964) has been re-assessed in fieldwork for this report and found to be generally accurate, although the nature of some contacts and lithological identifications have been revised, some lithological distinctions have been amalgamated and some additions made (fig. 3). At the western end of the outcrop the unit is in contact with sandstone of the early Neoproterozoic Burnie Formation (referred to by Burns as Rocky Cape Group, which at the time included the Burnie Formation), and at the eastern end it is in contact with the ?Early Cambrian Motton Spilite. Both of these contacts are interpreted in this report as faults, although the nature of the western contact (which Burns described as a steep unconformity) has been a subject of debate and is reviewed in detail below.

The dominant clastic components of the Beecraft Megabreccia (basalt *cf.* Motton Spilite, and chert) are similar to those of conglomerate of the Middle–?Late Cambrian Sprent Formation (Vicary, 2006), with which it has been correlated (Vicary *et al*., 2008). Attempts were made in this study to address the question of whether some of the 'chert' component of the megabreccia may be derived from

Shearing at fault contact between Burnie Formation and Beecraft Megabreccia (view to E)

Bedding in Beecraft Megabreccia oblique to fault contact with Burnie Formation (view to N)



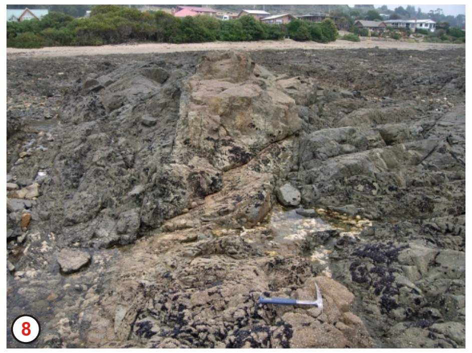
Lithic conglomerate in Beecraft Megabreccia

Large chert block within lithic conglomerate/breccia, Beecraft Megabreccia

Block of bedded chert within chert breccia unit, Beecraft Megabreccia

Possible shaft remnant, Penguin Mine

Dextral shear indicators in fault zone



Felsic dyke intruding lithic conglomerate/breccia of the Beecraft Megabreccia

Fault contact between lithic conglomerate/breccia (L) and its contact-hornfelsed equivalent (R)

Block of jasper within lithic conglomerate/breccia of the Beecraft Megabreccia

Pillow lava within the Motton Spilite

Pods of jasper filling voids within basalt lava sequence of the Motton Spilite (423958mE 5447819mN, east of this map area)

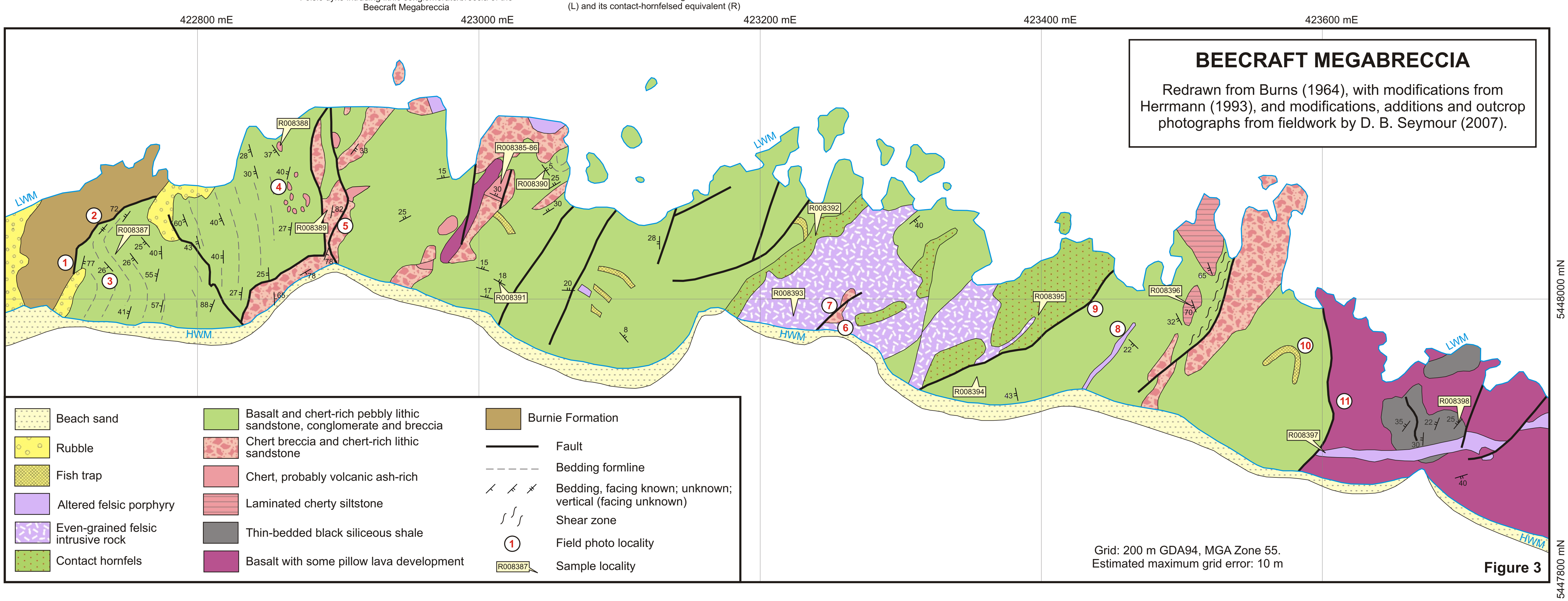


Figure 3

fine-grained volcanic ash-rich rocks associated with the Mt Read Volcanics, rather than from the ?Early Cambrian Barrington Chert — which if so would imply distal influence of the Mt Read volcanism in the Dial Range Trough.

The Beecraft Megabreccia is intruded by a small stock of even-grained sphene-bearing felsic intrusive rock and probably related dykes and small bodies of altered felsic porphyry (fig. 3, fig. 5*g,h*), which are collectively believed to be related to the Lobster Creek Porphyry (late Middle or early Late Cambrian, 500 4 Ma U-Pb zircon, Black *et al.*, 1997).

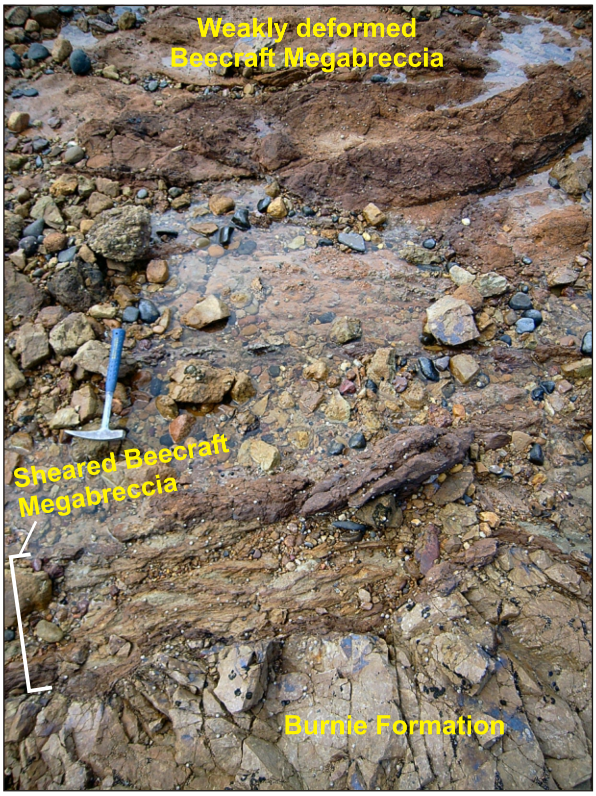
The western contact of the megabreccia was re-examined in detail in this study, and a number of key outcrops are illustrated in Figure 4. In part of the exposed contact closest to high water mark, the eastern limit of Burnie Formation sandstone is marked by a 100 mm thick layer of what appears to be pebble conglomerate (fig. 4*b*). While not specifically described by Burns (1964), this is commonly interpreted by modern observers as a basal conglomerate of the megabreccia sequence. Balanced against this is the field observation that the centimetre-scale 'pebbles' in the layer are dominantly composed of vein quartz, rather than of Burnie Formation sandstone. Furthermore, the layer gives the impression of being developed within the Burnie Formation sandstone rather than forming part of the adjacent megabreccia sequence, which is less resistant to erosion and shows negative relative relief (fig. 4*b*). This suggests the possibility that the 'pebble' layer is actually a form of crackle breccia initiated at the onset of movement on a fault. Further evidence for a fault contact is found nearby, where a discretely-bounded 300 mm thick zone of well-developed shear foliation is present within the megabreccia sequence adjacent to and parallel with the contact with the Burnie Formation (fig. 4*a*). The megabreccia shows little evidence of penetrative deformation outside this discrete zone. Further towards low water mark (locality 2, fig. 3), a relationship where bedding in the megabreccia converges obliquely on the contact (fig. 4*c*) could, in isolation, be interpreted as sedimentary onlap — however broader relationships suggest that sedimentary facing in the megabreccia is towards the contact here (see below) which is more consistent with a fault relationship. Close nearby, and even though the contact itself shows considerable local relief, a zone of discrete anastomosing shear surfaces generally parallel to the contact can be seen extending some 1.5 m out into the megabreccia sequence but not beyond (fig. 4*d*), which lends further weight to a fault interpretation.

The westernmost 170 m of the Beecraft Megabreccia outcrop consistently dips and faces towards the western contact at an average of about 40° (fig. 3), equivalent to about 110 m of exposed stratigraphic thickness (albeit interrupted halfway by a minor fault). Bedding steepens to almost vertical close to the contact but local sedimentary facing is indeterminate at this point. Definite sedimentary facings recorded further away from the contact in this study (fig. 3), in combination with bedding traces shown on the Burns (1964) map, suggest that the megabreccia sequence may still face west at the contact, which again supports a fault. Even if the facing direction reverses due to crossing a fold axis close to the contact, there is clearly insufficient room to accommodate 110 m of section on the east-facing fold limb. It seems likely that this contact is a preserved half-graben growth fault which was active during the whole deposition of this western part of the megabreccia sequence, with a final movement just post-dating close of deposition (and perhaps a later compressional re-activation as well). In this scenario, the westerly dip of this part of the sequence may have been at least partly generated by rotation due to progressive syn-depositional movement on the growth fault. This is consistent with the statement by Burns (1964, p.158) that the Beecraft Megabreccia "…abuts against Precambrian basement on the west side of the trough…". If this interpretation is correct, the contact could be viewed as a type of 'growth-fault unconformity' with sediment accumulating against a progressively moving half-graben fault with one or more final post-sedimentation movements to give the current appearance, now correctly mapped as a fault contact (Vicary *et al.*, 2008).

The eastern contact of the megabreccia against the Motton Spilite is also interpreted here as a fault, based on an observed fault contact dipping west at 80° near 423605/5447960, and on the apparent truncation of a post-megabreccia felsic dyke at the contact (fig. 3). The megabreccia for some 60 m west of the contact is massive with little sign of bedding, and commonly contains blocks up to several metres in diameter of basalt and chert (including red jasper, a lithology which seems to be intimately associated with the Motton Spilite), suggesting that the fault may have been active during sedimentation.

A number of additional faults and fault contacts have been recognised within the megabreccia sequence and have been added to the revised map (fig. 3). A major point of note is that the only substantial occurrences of cleavage or ductile shear foliation in the megabreccia are adjacent to some of the faults; the unit lacks the widespread development of scaly-fabric foliation in the matrix which is a prominent feature of the tectonic mélanges described above, and is fundamentally a sedimentary breccia rather than a structurally-generated breccia.

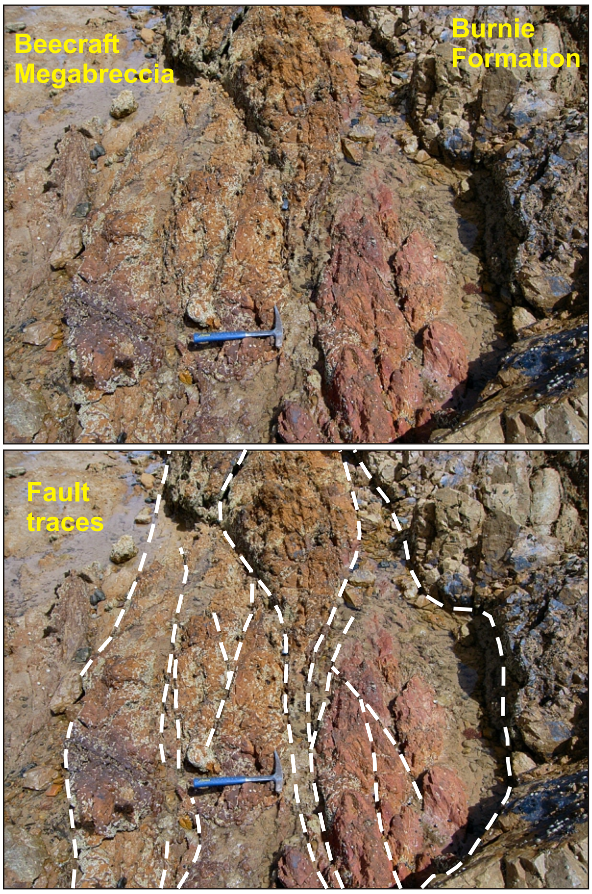
The dominant component of the Beecraft Megabreccia sequence is a coarse clastic unit which varies from a distinctly bedded and commonly graded polymict lithic wacke conglomerate with interbedded lithic sandstone (e.g. locality 3, fig. 3), to massive disorganised polymict lithic breccia. All of these lithologies have a similar clastic composition, dominantly basalt, mafic intrusive rocks (or coarse basalt), and chert which also forms large blocks up to over five metres in length scattered irregularly through the sequence. The first two clast types have an obvious source in the Motton Spilite, but the chert may have multiple origins. Chert clasts and blocks comprise three lithotypes: thin bedded light to dark grey chert (possibly derived from the Barrington Chert); massive to distinctly laminated buff or pink chert with a glassy appearance and tendency to conchoidal fracture (similar in appearance to ash-rich fine-grained volcaniclastic rocks of Mt Read Volcanics association); and red jasper, which is a rock type spatially (and probably genetically) associated with the Motton Spilite.



(a) zone of shearing in the megabreccia adjacent to the contact

(b) 'pebble layer' at the contact

(c) bedding in the megabreccia converging on the contact



(d) zone of anastomosing shears within megabreccia adjacent to the contact

Figure 4

Outcrop photographs of the contact between the Beecraft Megabreccia and sandstone of the Burnie Formation.

Burns (1964) mapped compositional variations within the polymict lithic conglomerate-wacke-breccia facies, particularly between 423010/5448035 and 423215/5448035, distinguishing parts that were richer in mafic volcanic detritus. Re-examination of outcrops and collection of extra structural data has indicated that the boundaries on Burns' (1964) map transect bedding at high angles, and so if the compositional variation is real it is not stratigraphically controlled (Burns stated that the boundaries were not easy to define and were somewhat generalised on his map). Petrographic comparison of samples collected in this study from the two variants indicates no major compositional or textural differences, so the boundaries have not been maintained on the revised map included here (fig. 3).

Further east, adjacent to the margins of the felsic intrusive stock, a unit shown as 'welded spilitic tuff' on Burns' map has also proven to show no significant petrographic differences from samples of the nearby 'normal' lithic wacke conglomerate-breccia sequence. Nonetheless, there are visible differences in outcrop, the 'welded spilitic tuff' being significantly darker and more erosion-resistant than the other unit (locality 9, fig. 3). Analysed samples show no significant differences in major element geochemistry between the two rock types, but trace elements show elevated Sr, Zn, Pb and Cu values in the 'welded spilitic tuff' (samples R008395, R008392, Table 1) compared to the 'normal' lithic wacke conglomerate-breccia (sample R008394, Table 1). The interpretation of Herrmann (1993) that the differences are due to alteration in proximity to the felsic intrusive is followed here.

The other main component of the Beecraft Megabreccia consists of virtually monomict chert breccia and megabreccia with some interbedded, graded chert-rich pebbly lithic sandstone. This facies, which Burns (1964) interpreted as 'exotic' or allochthonous (i.e. olistoliths), occurs in three main, partially fault-bounded zones distributed at intervals through the megabreccia outcrop (fig. 3). Where bedding is present, both bedding orientation and facing direction may be at odds with the adjacent 'background' polymict lithicwacke facies (e.g. in the westernmost chert breccia zone centred on 422895/5448058). Of the three chert clast types mentioned above, the bedded chert (*cf.* Barrington Chert) and massive to laminated pink chert are also present in this facies, but perhaps not the jasper. Intimately associated with the chert breccia zones are a number of occurrences of very large blocks (some more than 50 m long) of basalt, chert and laminated cherty siltstone (fig. 3).

A number of chert blocks from the megabreccia succession were sampled to compare compositions and textures, and to assess the possibility of felsic volcaniclastic input in the detritus. A 13 24 m block of laminated glassy chert at 423010/5448080 in one of the three main zones of monomict chert breccia was assessed in the field to be a possible candidate for volcanogenic origin. One of the two samples collected shows what might have originally been small (0.5 mm) feldspar crystal clasts now pseudomorphed by very fine-grained sericite (fig. 5*a*), but there are probably other explanations. Both samples contain scattered small (50–100 m) unstrained subhedral quartz clasts which show common triangular cross sections (fig. 5*b,c*), suggestive of sections through bipyramidal grains of volcanic beta-quartz. Another sample (R008388) is from a 7 4.5 m block of buff-coloured chert in a roughly stratabound zone of similar blocks within the polymict conglomerate-breccia facies just west of the westernmost zone of monomict chert breccia (fig. 3). At high magnification in thin section, the matrix of this sample shows arcuate and cuspate sub-50 m shapes which suggest the presence of relict volcanic glass shards (fig. 5*d*).

In major element geochemistry the two chert samples show a reasonable degree of similarity with each other, and they also show similarities with the felsic plug (sample R008393) intruding the centre of the Beecraft Megabreccia and a possibly related felsic dyke (sample R008397) intruding the Motton Spilite immediately east of the megabreccia (fig. 3, Table 1). The two cherts are higher in silica than the plug, and would classify as dacites in volcanic geochemistry terms; compared to the intrusive rocks the cherts also show somewhat lower MgO and Na_2O, and higher K_2O (Table 1). Trace elements show that the cherts have elevated Rb, As and Pb, and substantially elevated Zn and Ba levels, compared to the two intrusive rocks (Table 1).

Despite the petrographic and major element indications, trace element geochemistry of the two cherts described above does not support their derivation from volcanic ash-rich units associated with the Mt Read Volcanics (Appendix 1). One of the two samples does show a significantly elevated CO_2 content (Table 1), which may suggest that its original source was a primary carbonate sedimentary rock.

Chert blocks with definite non-volcanogenic characteristics are also present in the sequence. Sample R008396 comes from one of two blocks (the larger at least 60 m long) in the vicinity of the easternmost zone of monomict chert breccia (fig. 3) and is a thin bedded plane-laminated cherty siltstone of apparently non-volcanic, clastic origin (fig. 5e). It may have originally formed part of the Barrington Chert. East of the eastern contact of the megabreccia, two large (up to 60 m) 'chert' blocks within the Motton Spilite are composed of thin bedded, fissile black siliceous shale. A thin section of sample R008398 from one of the blocks shows prominent plane lamination, and 2 mm thick layers rich in silt-grade clastic quartz in a general background of dark siliceous shale with elongate ovoid objects of unknown origin flattened into the lamination (fig. 5*f*). This lithology is similar to that comprising some of the chert blocks in the Lodders Point mélange, and is probably an Early Cambrian unit associated with the Barrington Chert–Motton Spilite association.

Teatree Point Megabreccia

Burns (1964) used the term Teatree Point Megabreccia for a 225 m wide exposure of blocky coarse-grained clastic rocks in contact with the Motton Spilite to its east and west, between 424170/5447810 and 424385/5447775, just west of Tea Tree Point (fig. 6). The megabreccia consists of blocky, commonly graded, lithic wacke conglomerate and breccia, sand-grade lithic wacke and siltstone. The sequence dips and faces away from the eastern contact with the

Table 1

Major and trace element analyses for representative samples from the Ulverstone–Penguin area

Major elements (%)

Reg. No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	CO_2	H_2O^+	Total	L.O.I.	Description
R008385	63.27	0.76	11.57	1.04	2.30	0.19	2.15	4.10	0.21	5.21	0.16	0.09	5.60	2.19	98.84	7.54	Chert blocks,
R008388	66.90	0.86	12.55	7.02	0.80	0.06	1.64	0.07	0.25	4.75	0.09	0.00	0.20	3.52	98.70	3.63	Beecraft Megabreccia
R008394	55.60	1.14	12.00	1.75	6.60	0.13	5.98	5.69	3.37	1.21	0.11	0.02	2.30	3.69	99.61	5.26	'Typical' Beecraft Megabreccia
R008395	58.80	0.96	12.39	2.78	3.70	0.15	6.02	6.60	4.35	0.72	0.17	0.06	0.30	2.78	99.77	2.67	Beecraft Megabreccia
R008392	54.07	1.10	12.29	3.57	5.10	0.22	7.63	7.97	4.74	0.33	0.11	0.01	0.20	2.24	99.58	1.88	altered adjacent to felsic stock
R008393	63.03	0.49	14.54	0.87	2.60	0.10	4.21	4.96	4.48	0.78	0.05	0.02	0.80	2.32	99.23	2.83	Felsic stock intruding Beecraft MB
R008397	65.41	0.58	15.17	2.66	4.40	0.04	3.25	0.17	0.20	3.35	0.10	0.00	0.10	4.15	99.57	3.76	Felsic dyke intruding Motton Spillite
R012439	61.43	0.62	17.29	1.14	6.40	0.04	2.49	0.18	5.35	0.94	0.15	0.01	0.40	3.42	99.85	3.11	Felsic dyke, Lodders Point
R012442	70.94	0.59	12.80	4.53	1.00	0.08	1.75	0.17	0.90	3.78	0.10	0.00	0.10	2.81	99.54	2.80	Cherty mst., Westbank Fault Zone

Trace elements (ppm except S)

Reg. No.	Th	Sr	Rb	Y	Zr	Nb	Cr	V	Sc	Co	As	Ga	Zn	Cu	Ni	Pb	S %	Nd	Ce	La	Ba
R008385	bdl	51	120	36	105	10	150	230	23	bdl	25	16	3200	91	30	590	0.6	20	57	28	1400
R008388	bdl	49	170	30	115	12	430	380	21	32	46	16	2200	95	125	120	0.1	bdl	bdl	bdl	1950
R008394	bdl	79	29	24	68	6	390	350	40	27	bdl	16	63	9	105	bdl	0.0	bdl	bdl	bdl	220
R008395	bdl	240	23	20	63	bdl	330	270	36	21	bdl	14	390	250	77	71	1.3	bdl	bdl	bdl	260
R008392	bdl	155	8	23	60	4	540	350	42	28	bdl	17	220	720	115	100	0.3	bdl	bdl	bdl	210
R008393	bdl	320	26	19	140	6	58	145	27	bdl	bdl	18	860	280	16	320	0.7	bdl	28	bdl	220
R008397	bdl	25	110	21	135	8	59	210	27	21	bdl	18	48	21	18	bdl	0.0	21	57	27	320
R012439	bdl	27	34	28	140	9	7	110	22	13	bdl	19	54	15	26	bdl	0.0	23	55	23	58
R012442	21	37	170	20	120	15	58	78	12	14	bdl	19	54	10	56	bdl	0.0	27	89	36	220

Elements below detection limits for all samples: U, Mo, Bi, W, Sn

Detection limits (ppm):

Th	Sr	U	Rb	Y	Zr	Nb	Mo	Cr	V	Sc	Co	As	Bi	Ga	Zn	W	Cu	Ni	Sn	Pb	Nd	Ce	La	Ba
10	5	10	5	5	5	3	5	5	5	9	8	20	5	5	5	10	5	5	9	10	20	28	20	23

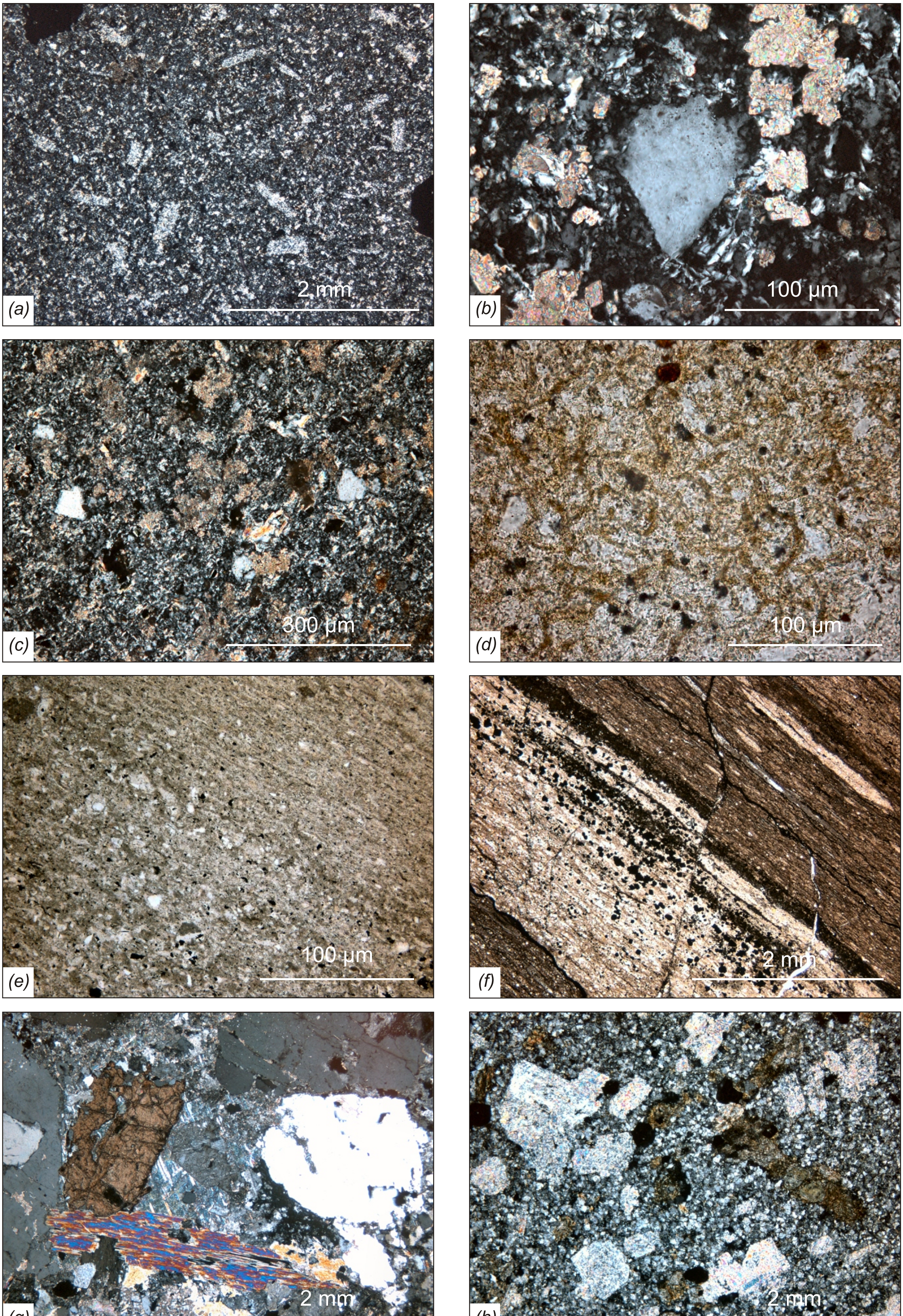

(a)
2 mm
(b)
100 µm
(c)
300 µm
(d)
100 µm
(e)
100 µm
(f)
2 mm
(g)
2 mm
(h)
2 mm

Figure 5

Photomicrographs of chert blocks within the Beecraft Megabreccia and Motton Spilite, and of felsic intrusive rocks post-dating the megabreccia: (a) chert block sample R008385 showing possible feldspar crystal clasts now pseudomorphed by sericite; (b) and (c) chert block samples R008385 and R008386 showing possible volcanic beta-quartz crystal clasts and carbonate alteration; (d) chert block sample R008388 showing possible relict volcanic glass shard shapes in matrix; (e) chert block sample R008396 comprising ?non-volcaniclastic plane-laminated cherty siltstone; (f) chert block sample R008398 from the Motton Spilite comprising thin bedded black siliceous shale; (g) sample R008393, even-grained felsic stock intruding Beecraft Megabreccia; (h) sample R008397, porphyritic felsic dyke intruding Beecraft Megabreccia.

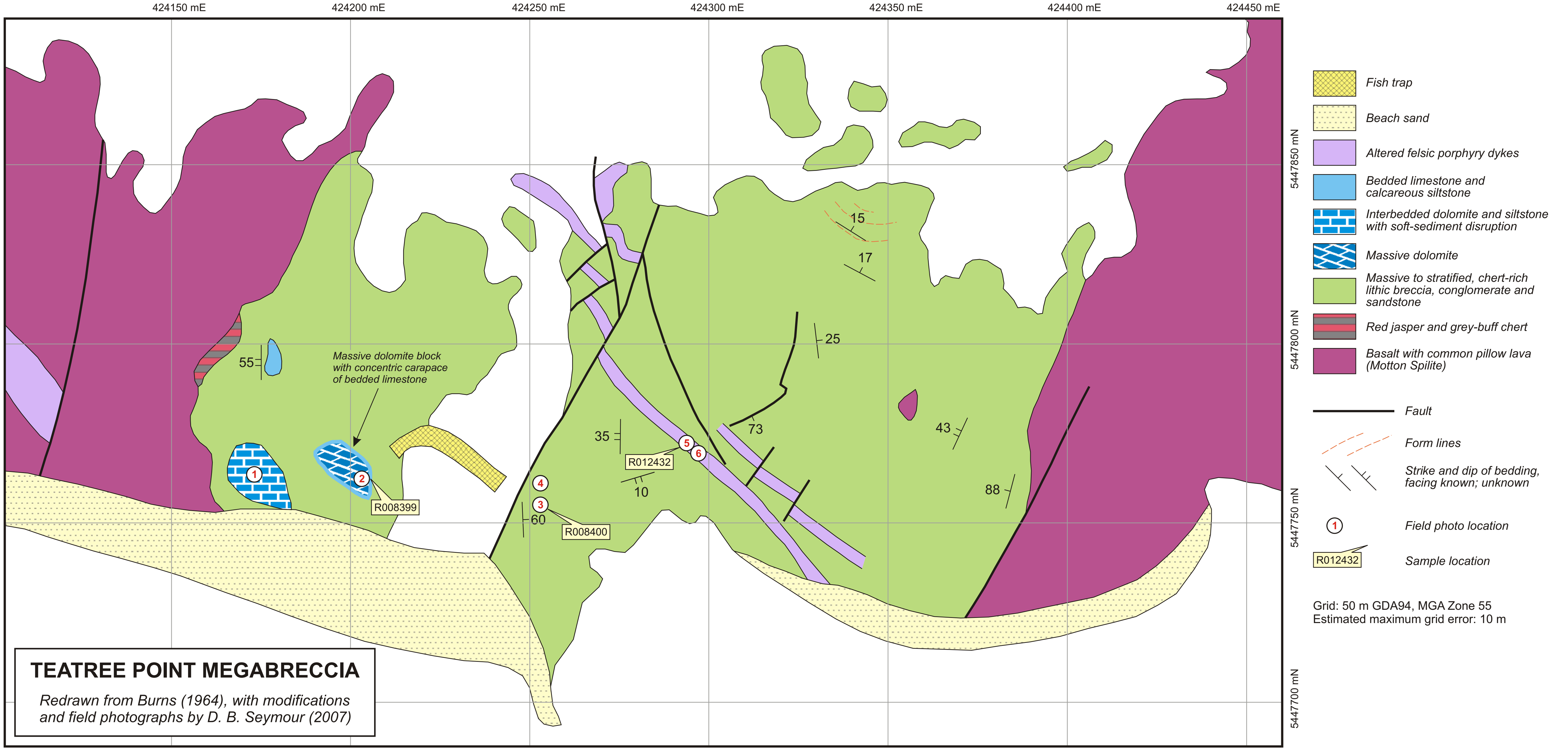
Motton Spilite, interpreted by Burns (1964) as an erosional contact, a conclusion supported here by observation of an apparent transitional basaltic conglomerate at the contact in the vicinity of 424395/5447800 (fig. 6). The western contact was described as faulted by Burns (1964), but this could not be reconfirmed here. Scant bedding observations in the megabreccia dip towards the contact, and a large ?block of red jasper and grey-buff chert resides apparently at the contact (fig. 6). If Burns (1964) is correct, the overall structure of the megabreccia may be a half-graben (*cf.* the western part of the Beecraft Megabreccia), with an erosional unconformity at the eastern contact and a preserved growth fault at the western contact. As with the Beecraft Megabreccia, the Teatree Point Megabreccia is intruded by altered felsic porphyry dykes (plagioclase-phyric here), and these are offset on a set of later NE-trending faults (fig. 6). Bedding observations are more common in the megabreccia sequence east of the most prominent of these faults, and suggest that this part of the sequence may be occupying a syncline (fig. 6), although bedding orientations are somewhat chaotic in part of the outcrop. The structural architecture is less clear west of this fault.

Compositionally the Teatree Point Megabreccia shows some similarities with the Beecraft Megabreccia, but also some important differences. The 'background' lithological association is coarse lithic conglomerate and breccia with interbedded coarse lithic sandstone and minor laminated siltstone. The conglomerate and breccia are rich in chert clasts which are commonly up to 500 mm in diameter, and the different lithologies are commonly in irregular beds or lenses, or large irregular masses which may locally transect the general bedding orientation. Bedding is not always locally consistent, and in some places there is an impression of a significant amount of soft-sediment movement and deformation, reinforced by direct observation of large blocks or masses of slump-folded thin-bedded siltstone within the general conglomerate-breccia-sandstone sequence (e.g. locality 4, fig. 6). These masses were noted by Burns (1964) who termed them "sedimentary rolls and slides" and thought they may have been open cast. Petrographically, a typical coarse lithic sandstone from the sequence (sample R008400 from near the middle of the outcrop, fig. 6) contains clasts of high-purity white microcrystalline chert (probably derived from the Barrington Chert); dark laminated cherty siltstone or siliceous shale (possibly also from the Barrington Chert); an impure very fine-grained sericitic cherty rock which may be felsic-volcaniclastic; and lithic wacke. Surprisingly there is little or no basalt.

Like the Beecraft Megabreccia, the Teatree Point Megabreccia also contains very large blocks of various rock types, which Burns (1964) considered to be "allochthonous lithologies". What particularly distinguishes the blocks in the Tea Tree Point sequence is the presence of limestone and dolomite blocks in the western, less consistently bedded part of the sequence (fig. 6). Here, one 11 m block consists of bedded limestone; another 23 m block comprises interbedded dolomite and siltstone with internal evidence of soft-sediment disruption causing crumpling and brecciation (locality 1, fig. 6); a third 20 m block largely comprises massive crystalline dolomite, but has a continuous outward-dipping concentric shell of dark grey, thin-bedded silty micritic limestone (locality 2, fig. 6). Burns (1964) seems to have noted this feature: "….the bedding in one slab is deformed in conformity with the boundaries of the slab. Indeed, the slab has the form of a rolled-up pod....", and considered it as evidence that the soft-sediment deformation occurred at the time of incorporation of the blocks into the megabreccia. There perhaps also exists the possibility that this block represents a piece of shelf-edge carbonate reef with draping calcareous sediment which has broken off and tumbled down into a continental slope or deep-water environment (or a basin created by an active extensional growth fault?) in which the 'background' coarse clastic sediments were being deposited. As well as the carbonate blocks, the 20 m long mass of red jasper and grey-buff chert at or close to the western contact of the megabreccia is probably a block within the megabreccia sequence, and at least one 10 m block of Motton Spilite occurs in the eastern part of the sequence (fig. 6).

Discussion

Despite their unusual extremely coarse nature, the Beecraft and Teatree Point megabreccias appear to have been primarily generated by sedimentary processes, albeit in an environment that was substantially influenced by coeval active extensional tectonism. This is evidenced by the general lack of pervasive tectonic foliation in the matrix of these units, in contrast to the tectonic mélanges at Lodders Point and in the Westbank Fault Zone. The megabreccias show unconformable relationships with older, Neoproterozoic and Early Cambrian rock units, and in some cases these contacts can be interpreted as preserved growth faults which were active during sedimentation of the megabreccia complexes. A suspicion that some of the large 'chert' blocks in the Beecraft Megabreccia may have been sourced in volcanic ash-rich siltstones associated with the Middle–Late Cambrian Mt Read Volcanics is not supported by trace element geochemistry; however the blocks in question are also unlikely to have been sourced from the

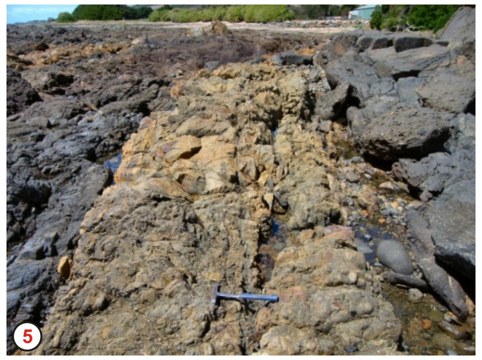


1 Interbedded dolomite and siltstone with soft-sediment disruption, within megabreccia block

2 Megabreccia block comprising massive dolomite (bottom to centre) with concentric carapace of thin bedded grey silty limestone (top)

3 Irregular zone of chaotic chert-rich breccia within lithic conglomerate-breccia-wacke sequence

4 Large block of slump-folded thin bedded siltstone within lithic conglomerate-breccia-wacke sequence



5 Altered felsic dyke intruding Teatree Point Megabreccia

6 Laminated margin of felsic dyke

Figure 6

Barrington Chert. Other features, such as soft-sediment deformation combined with block sliding, and blocks of shallow-water carbonates which appear to have rolled downslope into a deeper marine environment, are consistent with deposition in one or more rapidly developing extensional half-graben basins.

Conclusion

This review has confirmed that the Cambrian blocky megabreccias exposed on the Bass Strait coast between Penguin and Ulverstone comprise two distinct morphological types, which appear to differ in both age of formation and genesis.

The occurrences at Lodders Point and the Westbank Fault Zone are high-strain tectonic mélanges which represent early compressional fault zones in which the strain history may have begun when the rocks were still incompletely lithified. Blocks in the Lodders Point mélange are largely derived from the enclosing allochthonous Early Cambrian Barrington Chert and Motton Spilite, while the Westbank Fault Zone includes components which may be derived from autochthonous late Neoproterozoic Togari Group correlates. Both occurrences share the characteristic of a sheared mudstone matrix with pervasive scaly-fabric foliation reminiscent of Franciscan mélange. These characteristics, together with the apparent lack of Middle–Late Cambrian rock units in their provenance, suggest that the mélanges formed during and as a result of the Early Cambrian to early Middle Cambrian, first compressional phase of the Tyennan Orogeny (Stacey and Berry, 2004).

By contrast, the Beecraft and Teatree Point megabreccias were formed largely by sedimentary processes, but in an active extensional environment during deposition. These megabreccias generally lack structural and textural evidence of major tectonic compression, except close to fault zones which may have been reactivated and partially inverted in later compressional events. Some of their blocks were derived from Early Cambrian allochthonous units, but geochemistry indicates that other sources are unlikely to have included cherty volcanic ash-rich siltstones related to the Mt Read Volcanics. Field evidence indicates the presence of growth faults which formed the western boundaries of rapidly developing half-graben sub-basins, creating depositional slopes which caused substantial block sliding and soft-sediment deformation during deposition of the megabreccias. These unusual deposits appear to represent a particularly graphic expression of the post-collisional, Middle–Late Cambrian extensional phase of the Tyennan Orogeny (Stacey and Berry, 2004).

References

BERRY, R. F.; GRAY, D. R. 2001. The structure of the coastal section from Goat Island to Ulverstone, northwestern Tasmania. *Field Guide Specialist Group in Tectonics and Structural Geology Geological Society of Australia* 10.

BERRY, R. F.; HOLM, O. 2001. The structure of northwestern Tasmania. *Field Guide Specialist Group in Tectonics and Structural Geology Geological Society of Australia* 11.

BERRY, R. F.; CHMIELOWSKI, R. M.; STEELE, D. A.; MEFFRE, S. 2007. Chemical U-Th-Pb monazite dating of the Cambrian Tyennan Orogeny, Tasmania. *Australian Journal of Earth Sciences* 54:757–771.

BLACK, L. P.; SEYMOUR, D. B.; CORBETT, K. D.; *et al.* 1997. Dating Tasmania's oldest geological events. *Record Australian Geological Survey Organisation* 1997/15.

BROWN, A. V. 1989. Eo-Cambrian–Middle Cambrian mafic volcanic rocks, *in:* BURRETT, C. F.; MARTIN, E. L. (ed.). Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:61–69.

BURNS, K. L. 1963. Megabreccias and chaos structure in the Cambrian system of northern Tasmania, *in: Syntaphral Tectonics and Diagenesis: A Symposium.* F1–F14. Geology Department, University of Tasmania : Hobart.

BURNS, K. L. 1964. Geological Atlas 1 Mile Series. Sheet K/55-6-29. Devonport. *Explanatory Report Geological Survey Tasmania.*

CALVER, C. R.; REED, A. R. 2001. Port Sorell Formation, *in:* REED, A. R. Structure and setting of Proterozoic and Palaeozoic rocks in the Tamar region, northern Tasmania. *Field Guide Specialist Group in Tectonics and Structural Geology Geological Society of Australia* 9:91–97.

CALVER, C. R.; FORSYTH, S. M.; EVERARD, J. L. 2007. Explanatory report for the Maydena, Skeleton, Nevada, Weld and Picton geological map sheets. *Explanatory Report 1:25 000 Scale Digital Geological Map Series Mineral Resources Tasmania* 1.

CALVER, C. R.; EVERARD, J. L. In press. Early Cambrian allochthonous sequences, *in:* CORBETT, K. D.; QUILTY, P. G. (ed.). Geological Evolution of Tasmania. *Special Publication Geological Society of Australia.*

CORBETT, K. D. 1995. Stratigraphic mapping, Tyennan connections, Cambrian orogenies, the Arthur Lineament, and the tectonic context of the Mount Read Volcanics. A fresh look at western Tasmania, *in:* COOKE, D. R.; KITTO, P. A. (ed.). Contentious issues in Tasmanian geology. *Abstracts Geological Society of Australia* 39:35–37.

CRAWFORD, A. J.; BERRY, R. F. 1992. Tectonic implications of Late Proterozoic–Early Palaeozoic igneous rock associations in western Tasmania. *Tectonophysics* 214:37–56.

EVERARD, J. L.; SEYMOUR, D. B.; REED, A. R.; MCCLENAGHAN, M. P.; GREEN, D. C.; CALVER, C. R. 2007. Regional geology of the southern Smithton Synclinorium. Explanatory report for the Roger, Sumac and Dempster 1:25 000 scale geological map sheets, far northwestern Tasmania. *Explanatory Report 1:25 000 Scale Digital Geological Map Series Mineral Resources Tasmania* 2.

FOSTER, D. A.; GRAY, D. R.; SPAGGIARI, C. 2005. Timing of subduction and exhumation along the Cambrian East Gondwana margin, and the formation of Paleozoic backarc basins. *Bulletin Geological Society of America* 117:105–116.

HERRMANN, W. 1993. Notes on a geological reconnaissance of the Dial Range EL 9/92, *in:* FITZGERALD, F. G. *EL 9/92 Dial Range, Annual Report July 1992–June 1993*. Pasminco Exploration [TCR93-3447].

RAYMOND, L. A. 1984. Classification of melanges. *Special Paper Geological Society of America* 198:7–20.

REED, A. R.; CALVER, C. R.; BOTTRILL, R. S. 2002. Palaeozoic suturing of eastern and western Tasmania in the west Tamar region: implications for the tectonic evolution of southeast Australia. *Australian Journal of Earth Sciences* 49:809–830.

SAITO, Y.; TIBA, T.; MATSUBARA, S. 1988. Precambrian and Cambrian cherts in northwestern Tasmania. *Bulletin National Science Museum (Tokyo), Series C: Geology and Palaeontology* 14(2):59–70.

SEYMOUR, D. B.; CALVER, C. R. 1995. Explanatory notes for the Time-Space Diagram and Stratotectonic Elements Map of Tasmania. *Record Geological Survey Tasmania* 1995/01.

SPROULE, R. A.1994. *Stratigraphy and geochemistry of the Dial Range Trough, NW Tasmania*. B.Sc. (Hons) thesis, University of Tasmania : Hobart.

STACEY, A. R.; BERRY, R. F. 2004. The structural history of Tasmania: a review for petroleum explorers, *in:* BOULT, P. J.; JOHNS, D. R.; LANG, S. C. (ed.). *Eastern Australasian Basins Symposium II.* Special Publication Petroleum Exploration Society Australia. 151–162.

TURNER, N. J. 1989. The Adamsfield District, *in:* BURRETT, C. F., MARTIN, E. L. (ed.). Geology and Mineral Resources of Tasmania. *Special Publication Geological Society of Australia* 15:168–174.

TURNER, N. J.; BLACK, L. P.; KAMPERMAN, M. 1998. Dating of Neoproterozoic and Cambrian orogenies in Tasmania. *Australian Journal of Earth Sciences* 45:789–806.

VICARY, M. J. 2006. Re-interpretation of geological relationships in the Castra–Kindred area. *Record Geological Survey Tasmania* 2006/01.

VICARY, M. J.; CALVER, C. R.; EVERARD, J. L.; SEYMOUR, D. B. 2008. *Digital Geological Atlas 1:25 000 Series. Sheet 4244. Ulverstone*. Mineral Resources Tasmania.

[22 December 2010]

APPENDIX 1

Lithogeochemistry of selected rock types from the Dial Range–Fossey Mountains trough

The Dial Range–Fossey Mountains trough developed on an imbricate array of older basement elements in the Middle to Late Cambrian. These elements comprise:

(a) low to high grade Proterozoic metasedimentary rocks;

(b) a Neoproterozoic cover sequence containing within plate basalts, carbonate etc.; and

(c) an Early Cambrian allochthonous sequence of MORB-like basalt, chert and some ultramafic units.

Intrabasinal Middle to Late Cambrian sedimentary rocks have chemical compositions which reflect derivation from varying proportions of the older basement elements. In addition, active volcanism during basin development during the Middle to Late Cambrian has added an additional younger intermediate to felsic source.

A limited number of chemical analyses are available for the Middle to Late Cambrian sedimentary rocks and basement elements from the Dial Range–Fossey Mountains trough (Table 2).

On a primitive mantle normalised spider plot, the Motton Spilite defines a very flat trend indicative of MORB-like compositions (fig. 7*a*). In contrast the Gog Range Greywacke is notably enriched in Th and LREE and depleted in Nb, P and Ti (fig. 7*b*). This reflects derivation from a predominantly crustal source. High Cr and Ni contents reflect an additional ultramafic component. Other rocks from the Dial Range–Fossey Mountains trough which are largely derived from a crustal source include the Barrington Chert and associated mudstone facies (fig. 7*c,d*), clasts from the Beecraft Megabreccia (fig. 7*g*) and a cherty mudstone from the Westbank Fault Zone (fig. 7*h*).

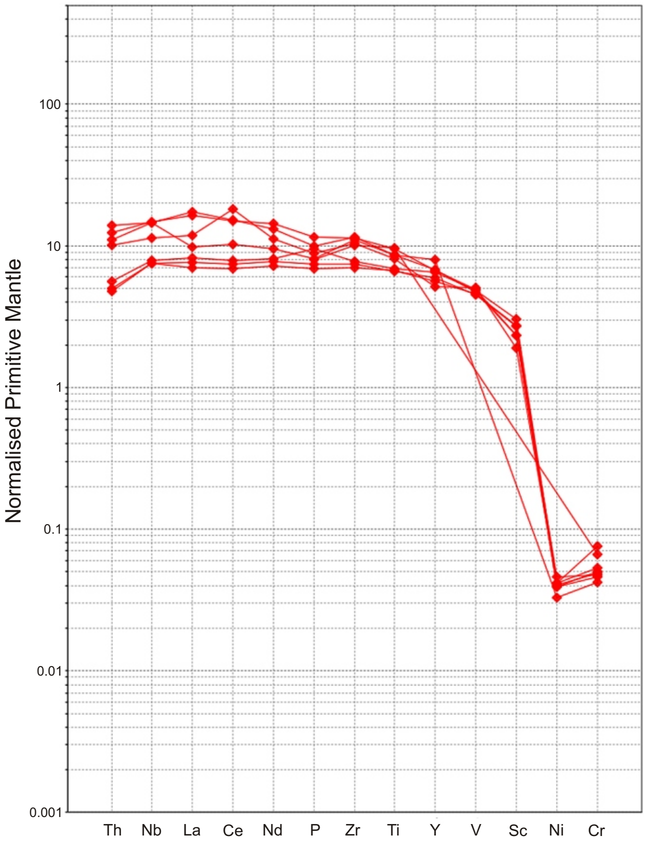
The Beecraft Megabreccia defines a relatively flat pattern which largely reflects derivation from the locally sourced Motton Spilite (fig. 7*e*). In contrast, the more distal Sprent Conglomerate has enriched Th and LREE contents and variable Nb, P and Ti depletions (fig. 7*f*), which reflect variable mixing between Early Cambrian Barrington Chertl and Motton Spilite sources. Both the Beecraft Megabreccia and Sprent Conglomerate have enriched Cr and Ni contents due to mixing with an additional ultramafic source (fig. 7*e,f*). Minor carbonate clasts, which are present in both the Beecraft Megabreccia and the Sprent Conglomerate, reflect Neoproterozoic sources.

The two main geochemical subgroups of the Mt Read Volcanics in central northern Tasmania are shown in Figures 7*i* and 7*j*. Both suites display enriched Th and LREE contents and depletion in Nb, P and Ti, indicative of crustal or subduction-modified lithospheric mantle sources. The Lobster Creek Porphyry ranges from andesitic to rhyolitic in composition and is transitional between Suite 2 and Suite 1 due to fractionation.

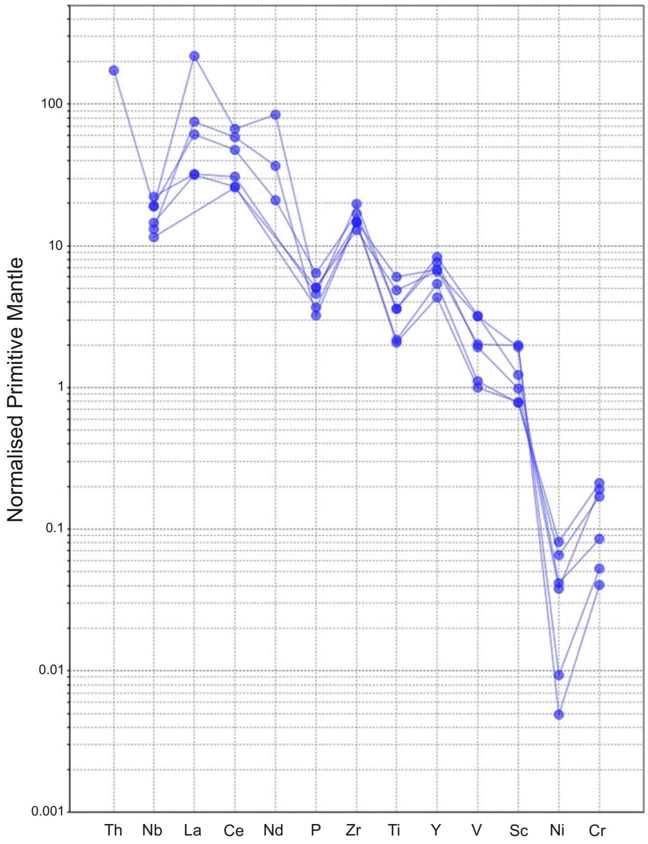
Figure 7*k* displays a series of XY plots highlighting some of the main geochemical features. On most plots the Beecraft Megabreccia and Sprent Conglomerate plot on an apparent mixing trend between end members defined by the Motton Spilite and Barrington Chert. The influence of an additional ultramafic source for the Beecraft Megabreccia and Sprent Conglomerate is evident on the SiO_2 v Cr plot. All four plots in Figure 7*k* show that two blocky chert clasts collected from the Beecraft Megabreccia, and which were suspected to have a felsic volcanogenic origin, have compositions lying outside the field of representative Mt Read Volcanics samples from central northern Tasmania. The Gog Range Greywacke typically has lower Ti/Zr and higher Al_2O_3/TiO_2 and higher Zr contents than the Sprent Conglomerate, reflecting a change to metamorphosed siliceous source rocks. Variable Cr contents of the Gog Range Greywacke reflect mixing with ultramafic detritus.

In general, the Gog Range Greywacke, the 'cherty' clasts from the Beecraft Megabreccia, the cherty mudstone from the Westbank Fault Zone and the mudstone facies of the Barrington Chert define a unique subset largely reflecting derivation from crustal sources. It is unclear if this source is of Proterozoic or Early Cambrian age. With the exception of the 'cherty' clasts from the Beecraft Megabreccia, these units also contain a significant component derived from an ultramafic source. The clasts also have anomalous K_2O, As, Cu, Pb and Zn contents, suggesting that bulk rock chemistry has been modified by hydrothermal alteration. The timing of the alteration event is unclear.

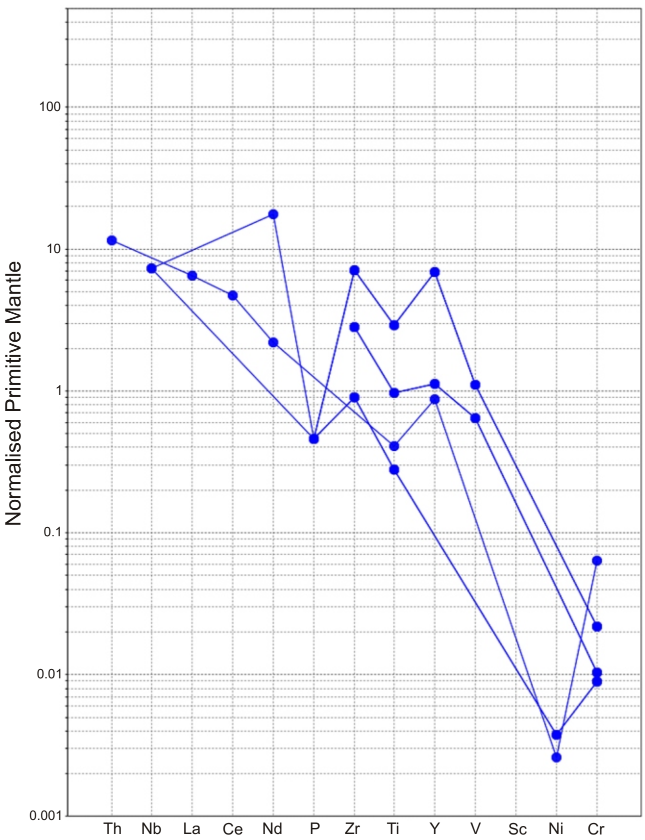
The Mt Read Volcanics typically display a well defined subgroup with typically lower Ti/Zr and Cr and higher Al_2O_3/TiO_2 and possible Zr than all other units (fig. 7*k*), suggesting a unique source composition and that it is not a major source in the sedimentary facies of the Dial Range–Fossey Mountain Trough, although minor Mt Read Volcanic derived components are locally present.



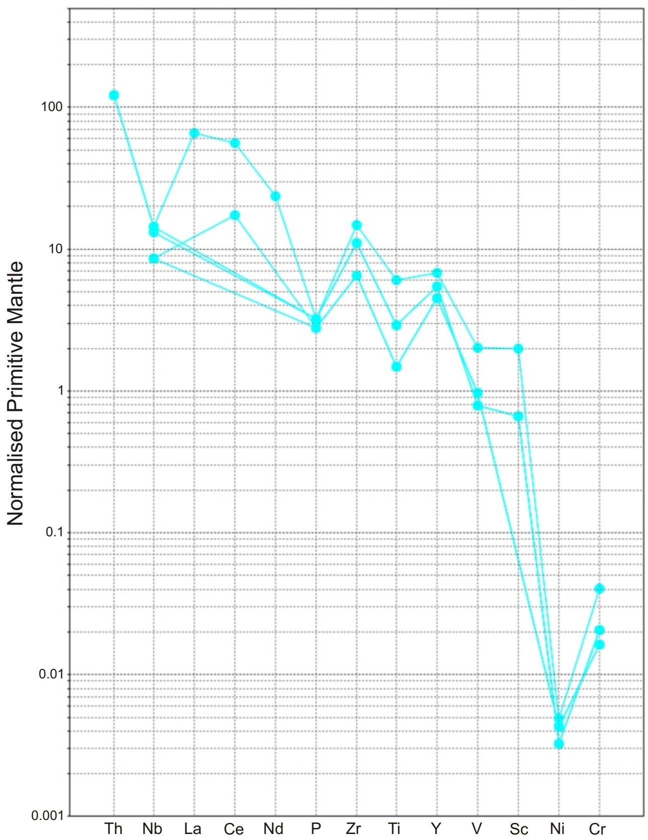
(a) Motton Spilite



(b) Gog Range Greywacke



(c) Barrington Chert



(d) Barrington Chert mudstone

Figure 7*(a–d)*

Trace element geochemistry plots of representative Cambrian rock units from central northern Tasmania

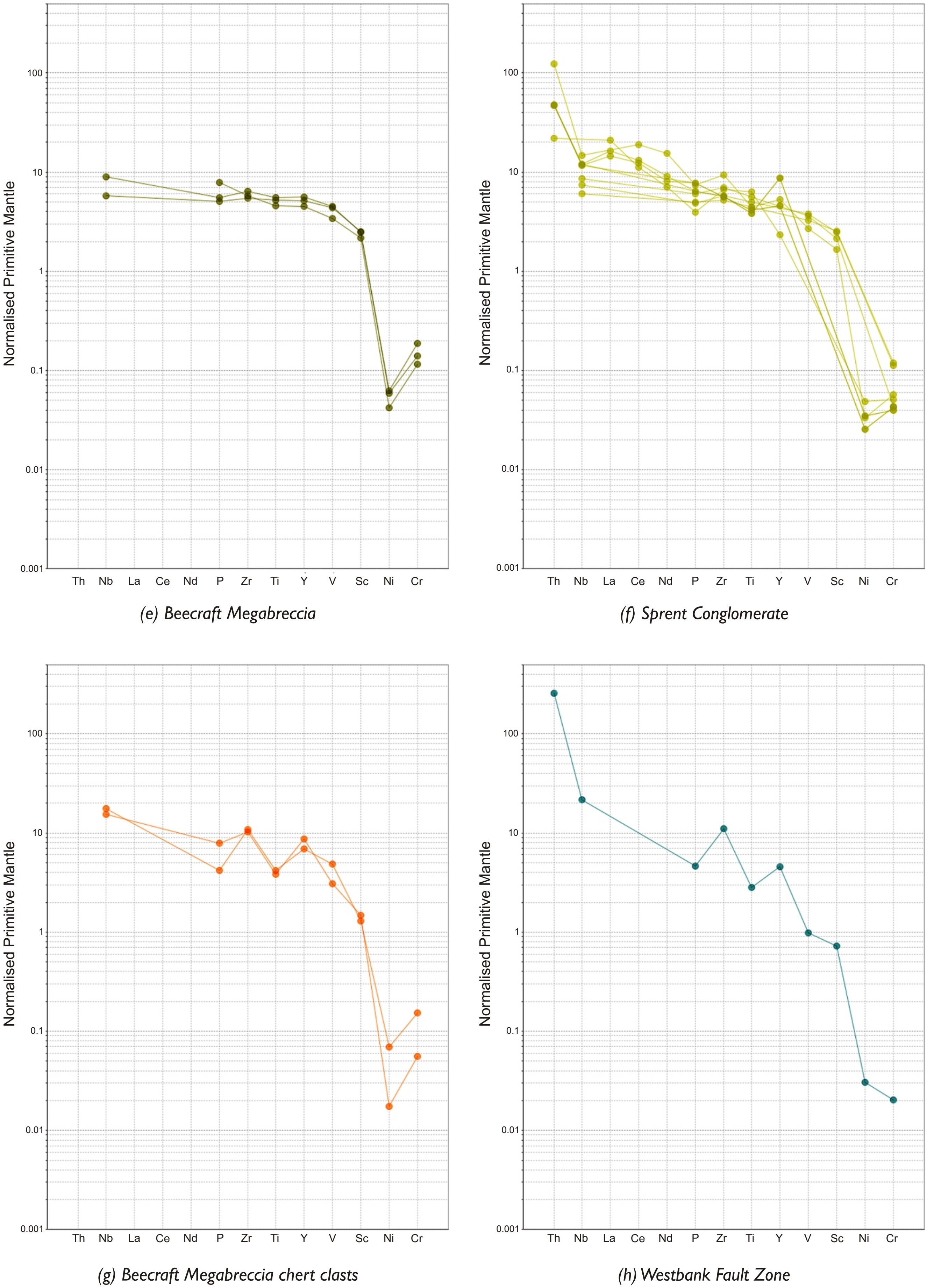
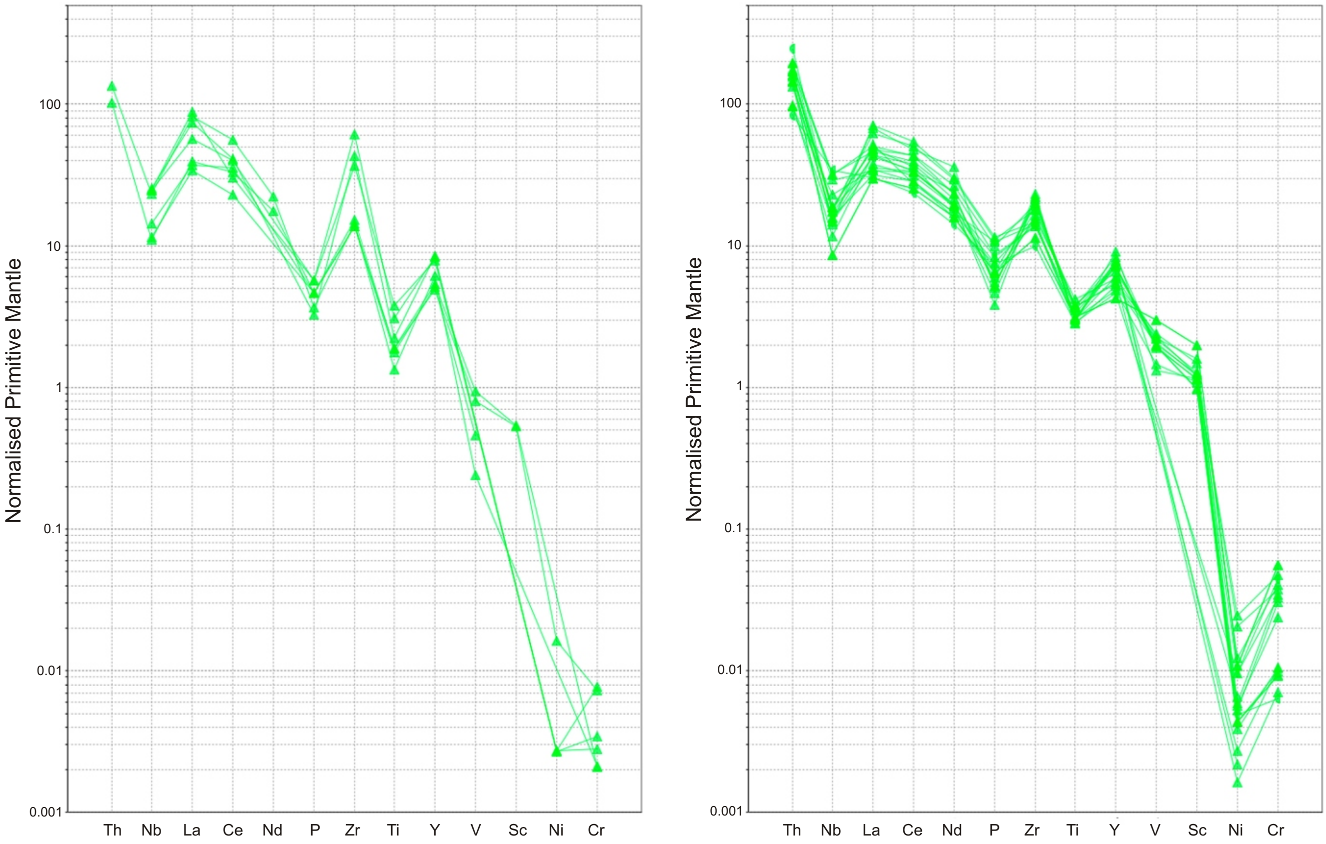


Figure 7*(e–h)*

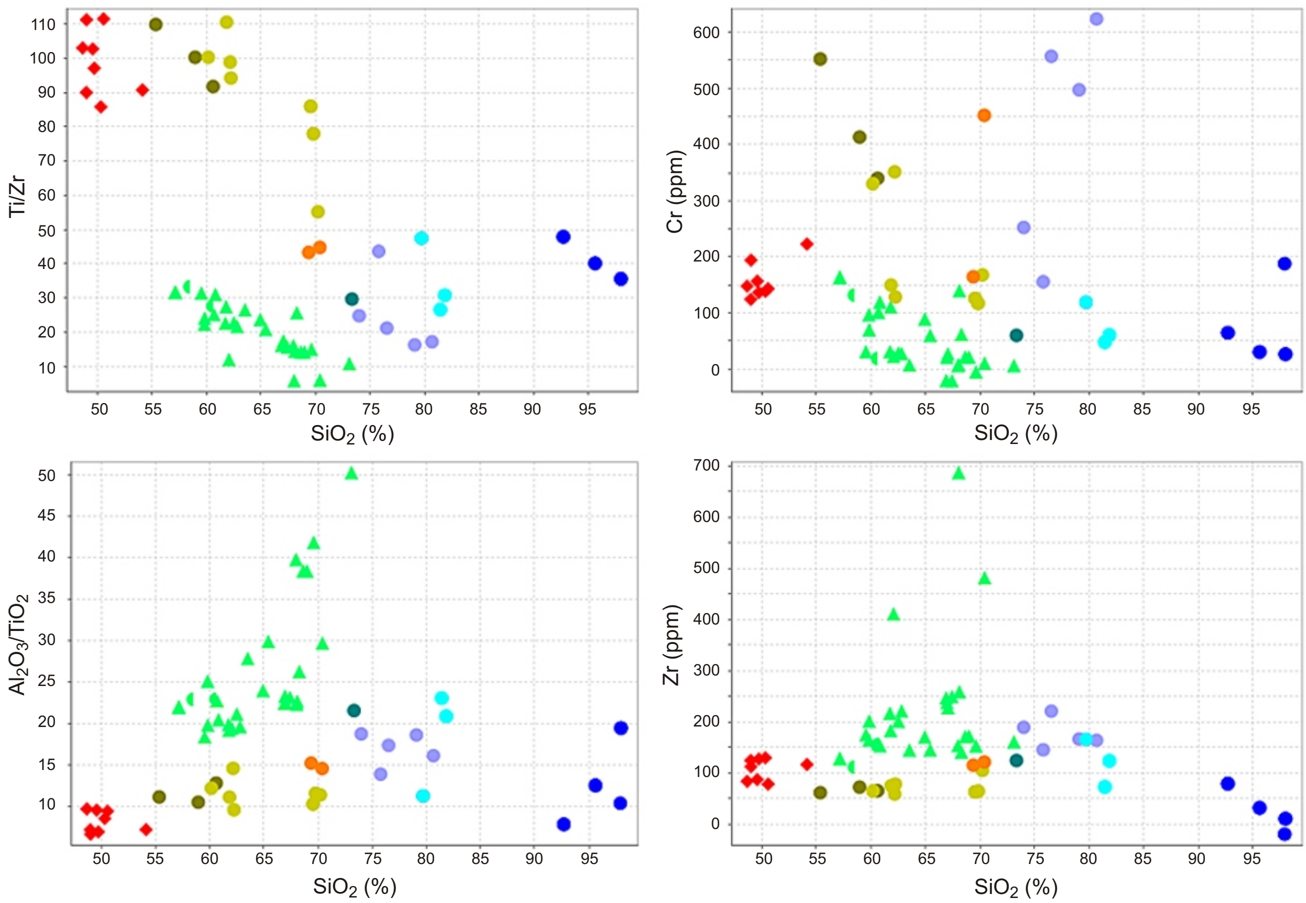
Trace element geochemistry plots of representative Cambrian rock units from central northern Tasmania



(i) MRV Central North Suite 1 *(j) MRV Central North Suite 2*

Figure 7 *(i–j)*

Trace element geochemistry plots of representative Cambrian rock units from central northern Tasmania



Legend:

Red	Motton Spilite
Dark khaki	Beecraft Megabreccia
Light khaki	Sprent Conglomerate
Dark blue	Barrington Chert
Light blue	Barrington Chert mudstone facies
Orange	Cherty clasts from Beecraft Megabreccia
Grey blue	Gog Range Greywacke
Dark green	Cherty mudstone, Westbank Fault Zone
Bright green	Representative samples of Mt Read Volcanics in central northern Tasmania (including Lobster Creek Porphyry)

Figure 7 *(k)*

Trace element geochemistry plots of representative Cambrian rock units from central northern Tasmania

Table 2

Major chemical features of selected geological units from the Dial Range–Fossey Mountains Trough

	Barrington Chert	Barrington Chert mudstone	Motton Spillite	Beecraft Megabreccia	Sprent Conglomerate	Beecraft Megabreccia Clasts	Gog Range Greywacke	Westbank Fault Zone siltstone	Mount Read Volcanics
SiO_2	92–98	79–82	48–54	55–61	60–70	69–70	75–81	73.3	57–73
Al_2O_3	1–5	7–15	12–14	12–13	9–13	12–13	7–15	13.2	13–18
TiO_2	0.06–0.21	0.3–0.6	1.4–2.1	1–1.2	0.8–1.4	0.8–0.9	0.4–1.4	0.6	0.3–1.1
K_2O	0.14–0.67	0.8–1.6	0.2–1.4	0.3–1.3	0.5–1.7	5–6	1.4–4.3	3.9	0.5–4.8
Cr	26–188	48–119	124–223	340–553	117–351	164–452	119–624	60	<164
Zr	16–79	72–165	78–130	61–72	58–104	115–121	164–221	124	111–688
Ti/Zr	35–48	26–47	85–112	92–110	55–100	43–45	16–47	29.6	6–33
Al_2O_3/TiO_2	8–20	11–23	6–10	10–13	9–15	14–15	11–19	21.6	14–50