Maronghi Creek beds, Yarraman Block, SE Qld: Petrography, provenance and microstructure

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Introduction

The Yarraman Block - comprising the Sugarloaf Metamorphics, the Maronghi Creek beds and later intrusives - has been consistently inferred or broadly assumed to be part of the accretionary wedge associated with the New England Fold Belt (Korsch *et al.* 2009 and reference within, Willey 1998). The nature, provenance and structure of the Maronghi Creek beds (MCB) are described and discussed, allowing development of a model for the origin of the MCB within the context of the New England Fold Belt.

The pre-Permian Maronghi Creek beds (MCB *senso stricto* = MCB Elements A-C of Willey (1998)) has been studied in an area (Fig. 1) roughly 20 km by 20 km in the southernmost Yarraman Block. The nature of and relationship to other younger units are discussed elsewhere (Willey 1998,1999).

The MCB is a broken formation dominated by poorly sorted, massive, subangular arenites, with lutites, and rare granule conglomerates, all deposited from turbidites, with interbedded acid shard fall tuffs. Minor cherts and very localised altered pillow basalts also occur. Bedding is rarely preserved, and structures suggest emplacement in an accretionary wedge most probably of Devonian-Carboniferous age (Willey 1998). The MCB is cut by hornblende microdiorite intrusions with radiometric dates of 296 Ma and 291 Ma (Willey 1998). The MCB and Hb-microdiorites suffered repeated fracturing, veining and cataclastic or mylonitic deformation. The MCB show no burial metamorphic or greenschist facies assemblages, possibly reflecting protolith composition, and have a regional planar fabric dipping ~70° to ~250 °.

The most accessible area of the MCB includes outcrop of a faulted inlier of simply deformed ?Early Permian rocks – the MCB-Element D (Willey 1998,1999). These were included in the definition of the MCB (Cranfield and Schwarzbock 1974), and because of accessibility, their nature dominated the description of the MCB. They are not present in the Maronghi Creek transect, the 'type section' of the MCB.

Study method

This study involved over 350 thin sections representing the sedimentary MCB (N=207), MCB shard tuffs (N=28), hornfelses (N=30), and Hb-microdiorites (N=95). Hornfelses were excluded from the study.

Qualitative study was conducted first to determine the types of grains and fragments present. The pervasive structural protolith fragmentation rendered conventional petrographic methods impractical. Therefore, proportions of components were obtained by averaging estimates from 8 to 10 fields of view using percentage comparison diagrams. Microstructure was studied under a stereoscope, checking detail with a petrological microscope and annotating observations on digitised enlargements (~7 X) and high-resolution enlargements (~20X) of the slide. The enlargements were a convenient format for comparison.

Provenance

Striking features of MCB detrital material are the absence of metamorphic detritus (L_m) and polyminerallic quartz (Q_p), the virtually exclusive presence of unstrained Q_m, and the lack of mafics and opaques. The samples plotted on Q_mFL_t (effectively a QFL) diagram (Fig. 2) fall in the magmatic arc and recycled orogen fields, however, the discussion below precludes a recycled orogen source.

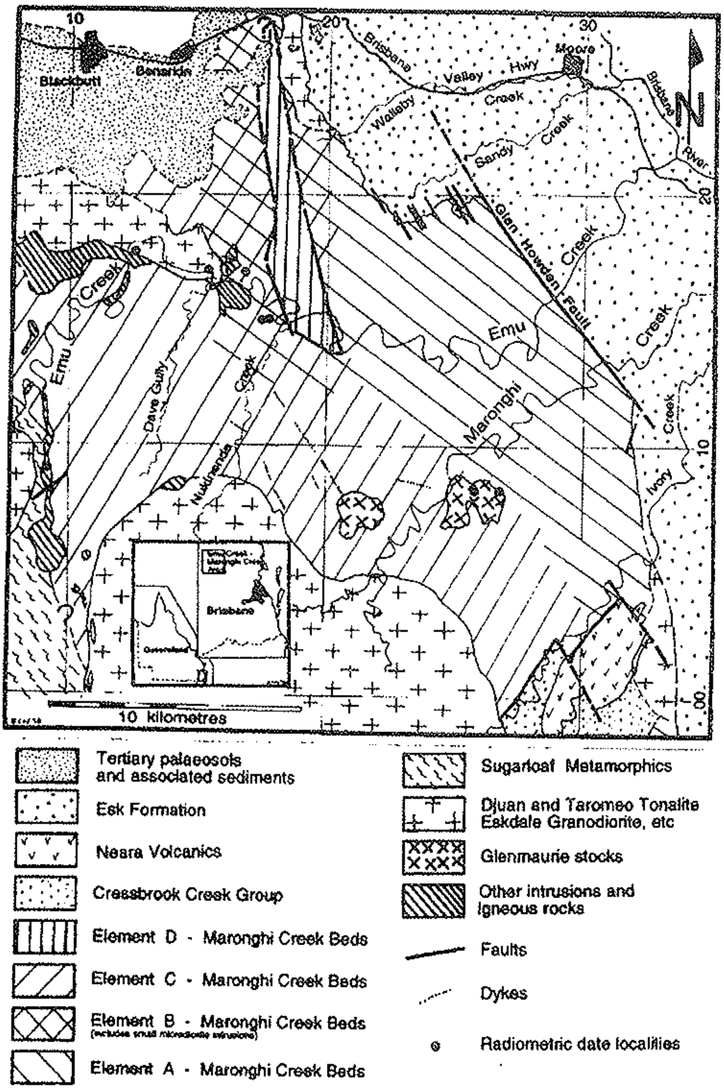


Fig. 1 Location map and geological map of the Maronghi Creek beds study area.

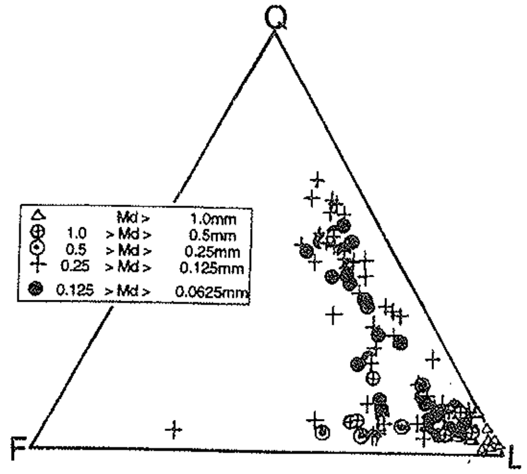


Fig. 2 (above) Q_mFL_t (effectively a QFL) diagram for MCB arenites.

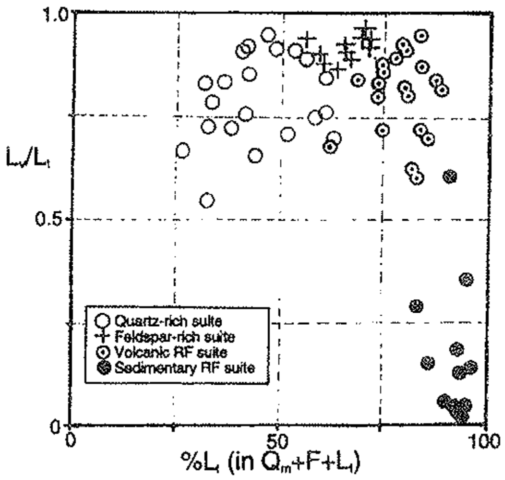


Fig. 3 (below) Plot of L_v/L_t against % of L_t in Q_m+F+L_t for MCB arenites.

Because of the absence of L_m, the $L_mL_vL_s$ is difficult to show graphically because of the very crowded L_v-L_s axis. A $L_mL_vL_s$ plot: shows no L_m with 41% of samples with greater than 80% L_v; 37% with 60-80% L_v; 5% with 20-60% L_v; and 17% with less than 20% L_v. This reflects the two sediment sources:

(a) a dominant *rhyodacitic volcanic* source -

Quartz: monomineralic, unstrained and occasionally embayed.

Feldspars: oligoclase, orthoclase (sometimes microperthitic) and microcline.

Clasts: felsic eutaxitic, devitrified glass, or porphyry (with no mafics), very rare granophyre.

Rare tourmaline and zircon and *no* mafics or opaques, and

(b) an *intraformational sediment* source

Mud/mudstone and silt/siltstone, and some sand/arenite clasts from the rhyodacitic source.

Very rare chert clasts found chiefly in coarser-grained samples indicate a third minor source.

The arenites show a continuum with four suites (Fig. 3): (a) *feldspar-rich* suite; (b) *volcanolithic-rich* suite; (c) a coarse *reworked sediment clast-rich* suite; and (d) a subrounded to rounded *quartz-rich* suite suggesting prior residence in a high-energy environment. The shard tuffs have a rhyodacitic source. Distributions of the arenite suites and tuffs show no ghost stratigraphy, reflecting possible tectonic mixing.

Quartzes have (a) an overwhelming volcanic origin and (b) a maximum size of 0.4-0.65mm regardless of the greater grainsize of other components (lithic fragments (Fig. 4) and feldspar grains (Fig. 5)) or sample mean grainsize (Fig. 6). The homogeneity of the quartzes suggests a restricted source for the material.

Comparison with other petrographic studies of New England Fold Belt accretionary wedge units indicates closest similarity to petrofacies A and B of the Coramba beds, in the Coffs Harbour Block (Korsch 1981) because of absence of mafics; however, andesitic clasts present in these petrofacies have not been observed in the MCB. To date the provenance of the Maronghi Creek beds remains distinctive and unique.

Fig. 4 Plot of maximum size of VRFs against maximum size of quartz grains in individual slides of MCB arenites.

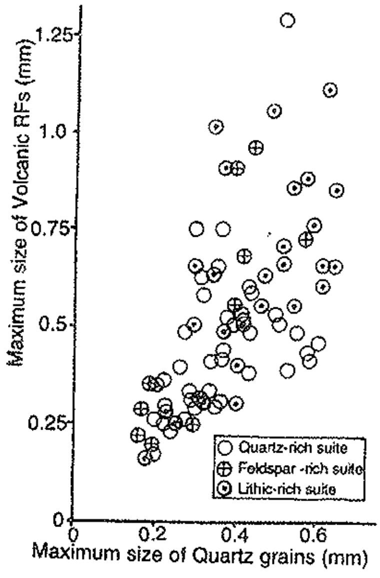


Fig. 5 Plot of maximum size of feldspar against maximum size of quartz grains in individual slides of MCB arenites.

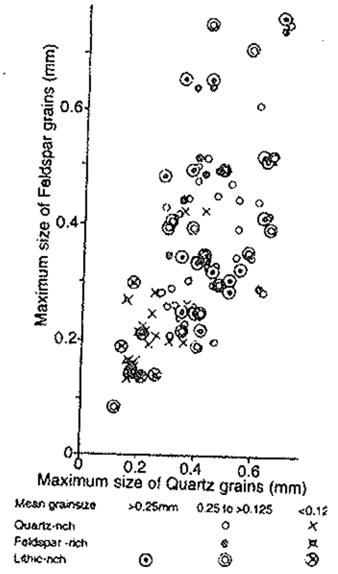
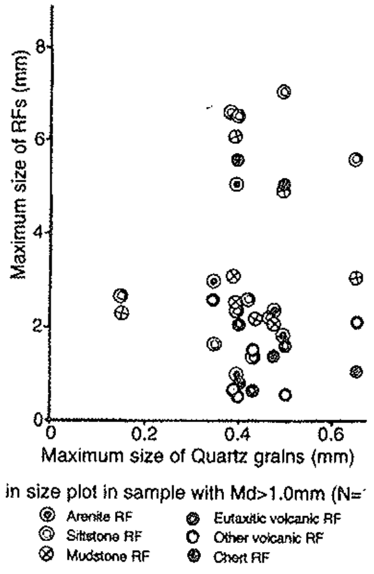


Fig. 6 Plot of maximum size of RFs against maximum size of quartz grains in individual slides of MCB arenites.



Microstructure (see Fig. 7-20)

Complex sequences of diverse fractures, sharp and diffuse veins and cataclastic or mylonitic deformation are typical of over 93% of the MCB and Hb-microdiorites slides. The style of this deformation can be seen not only in thin-section, but also in hand specimen and outcrop and thus shows fractal nature. That so many sections show these features is significant as few samples were selected for structural study, and because of the small area (mostly 30mmx20mm) actually studied. Interpretation of these microstructures is constrained by the similar appearance of structures formed in unconsolidated sediments and those formed in more competent materials. Any interpretation has to take note of the apparently brittle behaviour of even water-rich argillaceous sediments when under compression (see Maltman 1994 and reference therein).

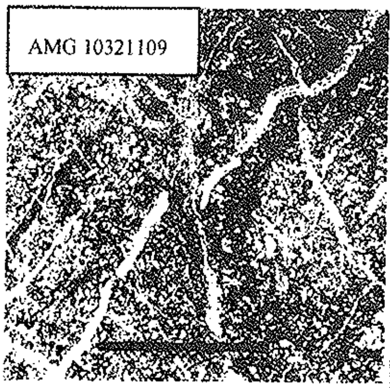
Microstructures display a range of characters depending on (a) nature and condition of the protolith and (b) the sequence of varying stress conditions. Variation occurs along a single structure as it intersects different grains, clasts or earlier structures. These variations result in thin-sections presenting a wide range of microstructure types and sequence of types; at least 10 vein-forming events have been observed in one slide. Veins and other crosscutting structures show varying displacements - mostly small with matching geometry or composition of opposite walls. But the small size of the studied samples makes observation of displacements larger than 30 mm impossible.

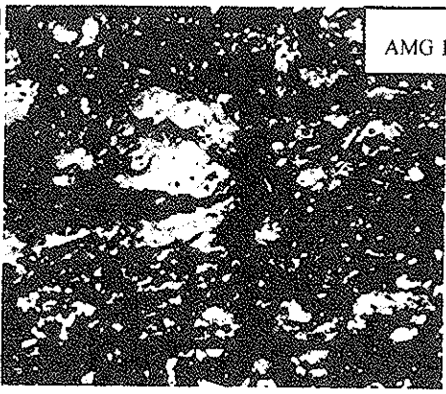
The vein-fill material is not necessarily derived from the immediate vein wall, as often the broken edges of grains can be matched across veins. This suggests that vein-fill is all newly introduced material, and not derived from the immediate vein wall. So vein-fill materials must have a source external to the immediate vicinity of the fill; this applies to quartz, feldspar, calcite and cataclastic/pseudotachylitic fills. In eutaxial veins, vein-fills change in response to wall composition, so the walls nucleate deposition.

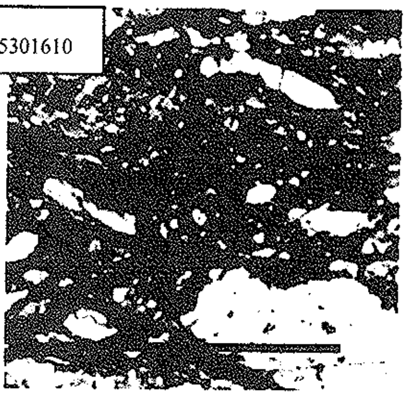
Veins and zones with *diffuse* margins have fills ranging from single grains or groups of grains of the sedimentary protolith to fragments of microdiorite in darker finer-grained materials. These diffuse veins or zones are early structures. Many are typical of dewatering channels; but some may be portions of wider cataclastic zones. Large zones are exposed particularly in the eastern two-thirds of the area. Veins with *sharp* margins are more diverse. The common fill is quartz, feldspar is rarer. Calcite, epidote and chlorite are the usual vein-fill in the microdiorites extending to adjacent sedimentary protoliths. Cataclastic and pseudotachylitic fills also occur widely in arenites and finer grained sedimentary protolith.

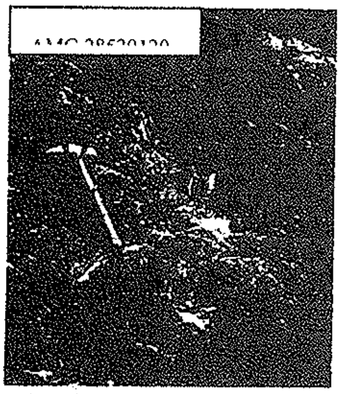
Quartz fills are drusy, eutaxial or crack-seal often with splaying strands, and feldspar fills are drusy, eutaxial or felty, and often associated with tuffaceous protolith. Calcite fills are drusy or felty; epidote fills are typically drusy often lining vein walls with later quartz fill; chlorite fill is rare. Cataclasite veins range from protocataclasites to ultracataclasites with quartz inclusions. Vein-fills, which microscopically are best described as pseudotachylite, are earlier features. Where several sets of veins intersect, later sets may track along pre-existing veins, while cutting obliquely veins of an intervening vein set; this is common with cataclasite and pseudotachylite veins. This would occur if the sets corresponded to conjugate structures.

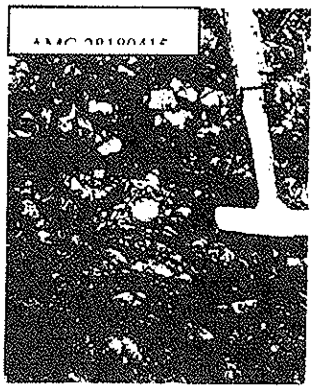
Comparison of annotated blow-ups provides a valuable record of different styles of deformation and data on issues such as strain partitioning and sequences of deformation. Diversity is a dominant feature, as rarely do two views provide clear parallel development. However, the comparison does allow some general remarks (number in brackets is the number of blow-ups displaying the nature described). Coarser-grained rocks rich in sediment (mud and silt) clasts show factured protolith with fractures cutting clasts (N=3). Arenites show greatest diversity: *cataclasites* with or without earlier or later at times anastomosing shears or veins or zones of aligned grains (N=36); *foliated cataclasites* with or without early or later veins (N=19); and *mylonites* with or without early or later veins, especially in the western third of the area (N=6). Finer-grained protoliths show blocky foliated cataclasites with early veins (N=6) to mylonites in the west (N=3). Shard tuffs show blocky foliated cataclasites with early veins cutting the blocks and vein fragments amongst the cataclastic material, particularly with thinner tuff layers (N=6); and in massive tuff layers (*i.e.* the bars of *enigmatic quartz-rich rocks* of Willey 1998, p.51) essentially cataclasites (N=5). The Hb-microdiorite protolith are: either multiveined and fractured (N=6), or cataclasites with early and late veins (N=5) in the east and centre; mylonitic cataclasites in the central-west of the area (N=5), and mylonites typical of the western third of area (N=4). The arenite and fine-grained protolith generally show a westward increase in strain; but the microdiorites, clearly the weakest rocks, best display the increase in strain westwards.

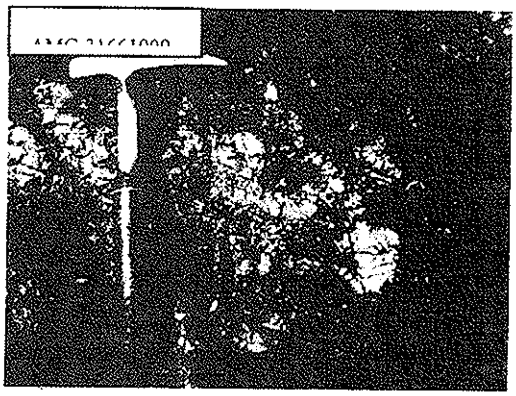


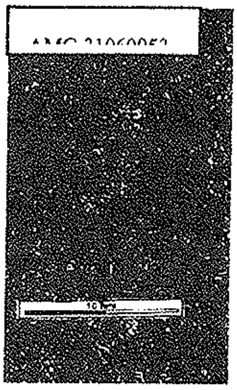


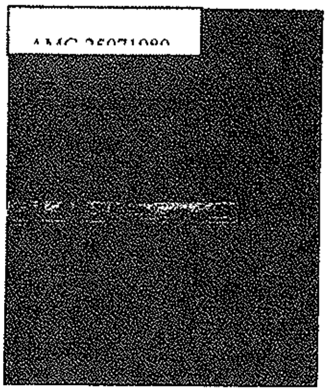












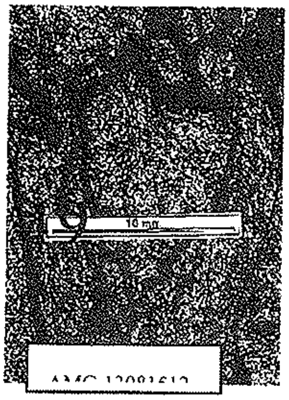


Fig. 7 Veined arenite. Figs. 8 and 9. Lutite polycataclasite. Fig. 10. Melange exposure.

Fig. 11 Cataclasite exposure. Fig. 12 Cataclasite, in Maronghi Creek transect.

Figs. 13-15 Arenites: Multi-veined, Veined cataclasite and Cataclasite respectively.

Fig 16 Tuff: veined blocky cataclasite. Fig. 17-20. Microdiorites: Veined and fractured, Cataclasite, Mylonitic cataclasite, and Mylonite respectively. Scale bar 10mm.

Discussion

This study permits development of a preliminary model for the origin of the Maronghi Creek beds using the model for the northern part of the New England Fold Belt proposed by Day *et al.* (1978); this involves a westward dipping subduction zone, and assumes the Yarraman Block to be part of the accretionary wedge.

A minimum volume of 80 km^3 (given topographic relief of 400 m, area of 400 km^2, and allowing 50% for non-MCB units) of volcanogenic material occurs in the MCB in the study area. Any eruption would have generated much more to deliver this volume to the area alone. Also its homogeneity suggests that it arose from one eruptive phase and thus delivered over a short time span. To achieve volume and homogeneity, an eruption similar in size to that of Toba, San Juan or Dundee (see McPhie 1988) would have to be considered. In the case of the MCB, the source would be an eruptive event in the Connors-Auburn Arc (the magmatic arc of the northern New England Fold Belt). In Late Carboniferous reconstructions, Fergusson and Leitch (1993, Fig 1(b)) speculatively place the Yarraman Block east of the Auburn Arc, and Korsch *et al.* (2009, Fig. 9) place the Yarraman Block east of the Connors Arc.

Part of this debris was deposited in a trench floored by ocean floor cherts and basalts, which was incorporated as the MCB in the accretionary wedge of the Yarraman Block. To reach the trench, the debris would have crossed the existing forearc basin and accretionary wedge. A mature accretionary wedge with emergent upper (older) elements would provide the coarse non-volcanic lithic and non-sediment clast contribution to the MCB. An emergent accretionary wedge would also provide a barrier, ponding some volcanic debris in shallow marine environments in the forearc basin generating the mineralogically and texturally mature quartz-rich arenite suite. During transfer to the trench, pulses of air-borne tuffs from a similar volcanic source were introduced directly to the trench.

The accretionary process would choke, as it attempted to subduct this volume of cold trench sediments. Rapid deposition would generate a sediment pile, with little time to achieve grain-grain coherence, allowing the observed tectonic mixing and dewatering features. There would be little time for heat transfer, thus the lack of metamorphism. Sibson (1983) showed that conditions for mylonite formation lie in the greenschist facies, a metamorphic grade not attained by the MCB. Nevertheless, confining pressure from accumulated overburden and subduction would render the sediment coherent and thus subject to brittle behaviour for the observed facturing, veining and cataclastic and mylonitic deformation (see Maltman 1994).

However, the pervasive and repeated nature of the deformation in the MBC must rest in a cause outside that associated with incorporation into a subduction complex. Numerous examples of rocks with similar deformation to that in the MCB have been reported. Many are in faults cutting rocks with higher metamorphic grade than those in the MCB, or with no indication of fault zone width. Two wide fault zones associated with greenschist facies rocks are from the Appalachians - the Towaliga fault (Georgia (Hadizadeh *et al.* 1991)) and the Norumbega Fault Zone (particular in eastern Maine, where metamorphic grades are low (Ludman *et al.* 1999)); they are 4-8km and 30-40km wide respectively; both are wrench faults.

Subsequent developments in the area are the incorporation of the 15 km x2 km fault-bounded ?Early Permian Element D and the halfgrabens of Element E, with faults trending roughly 150^0-330^0 (Willey 1998). This is the general trend of the MCB's regional planar fabric and of the faults associated with the generation and deformation of the Mid Triassic Esk Trough (Willey 2000), and the direction of major dextral transform movement in the Latest Carboniferous-Earliest Permian on the Gogango-Baryugil Fault to generate the Texas-Coffs Harbour double-orocline (Murray *et al.* 1987). The study area lies on the line of the Gogango-Baryugil Fault, and movements on it may be responsible for the deformation experiences by the MCB.

Concluding remark

The similar protolith of the non-intrusive units of the Yarraman Block - the MCB and the Sugarloaf Metamorphics – has given rise to the idea that the latter is simply a higher metamorphic grade representative of the MCB (Cranfield *et al.* 1976). Contacts between these units occur in areas of poor exposure. The Sugarloaf Metamorphics shows greenschist to amphibolite facies with a deformation history involving S_1 parallel to S_0, followed by a phase of tight to isoclinal folding and later buckling (see reference in Willey 1998). These features are not seen in the MCB, nor does the Sugarloaf Metamorphics show any MCB deformational features. It is possible that the two units formed at different times under different tectonic regimes and brought together by faults - faulting which may be related to the generation of the late Triassic transtensional Tarong Basin. In the west of the study area, the MCB-Sugarloaf Metamorphics contact appears to be a fault, marked by phyllitic slates with no affinity to either unit, partly obscured by the meridional elongate 'Flagstone Creek Granodiorite' of Willey 1999).

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