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The metamorphic sole of the western Tasmanian ophiolite: New insights into the Cambrian tectonic setting of the Gondwana Pacific margin

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ABSTRACT

The Cambrian Ross–Delamerian Orogeny records the first phase of accretional tectonics along the eastern margin of Gondwana following breakup of the supercontinent Rodinia. Western Tasmania represents a key area for understanding the Cambrian tectonic setting of the eastern margin of Gondwana as it is one of the few places where a Tethyan-type ophiolite is preserved and contains the only known exposures of a sub-ophiolitic metamorphic sole associated with the Ross–Delamerian Orogen. This paper presents an integrated study of the field, petrographic, geochemical, and metamorphic characteristics of the metamorphic sole to the western Tasmanian ophiolite. The structurally highest levels of the metamorphic sole consist of granulite–upper amphibolite facies metacumulates and metagabbros. A transition to amphibolite and epidote–amphibolite facies conditions is recorded by metadolerites and metabasalts towards the base of the metamorphic sole. Kinematic indicators in mylonitic amphibolites suggest the metamorphic sole formed in an east-dipping subduction zone located to the east of the Proterozoic continental crust of Tasmania. Major and trace element whole rock and relict igneous spinel geochemistry indicates that the protoliths to the metamorphic sole formed at a back arc basin spreading centre. Our new data supports a model in which east-dipping subduction in Tasmania was driven by collapse of a back arc basin developed above an earlier west-dipping subduction zone outboard of the eastern margin of Gondwana. The proposed model may help to resolve a controversy related to apparent along-strike variations in subduction zone polarity during the Ross-Delamerian Orogeny and suggests a complex geodynamic setting had developed along the eastern margin of Gondwana by the Middle Cambrian. This study highlights the importance of considering the role of multiple subduction zones in generating metamorphic soles and emplacing ophiolites, which are key events associated with the construction of many orogenic belts worldwide.

1. Introduction

Understanding how large fragments of oceanic lithosphere (ophiolites) are emplaced onto continental margins is critical to unravelling the complex tectonic evolution of many orogenic belts. Tethyan-type ophiolites are relatively intact ophiolites that have been emplaced onto continental margins or arc terranes (Moores and Macgregor, 1972). The emplacement of Tethyan-type ophiolites represent important periods in the evolution of orogenic systems that provide key insights into the wider geodynamic setting of orogenesis and the processes by which orogenic belts are constructed.

At the base of many Tethyan-type ophiolites are thin sheets of high-grade, highly deformed metamorphic rocks known as metamorphic soles (e.g. Williams and Smyth, 1973; Jamieson, 1986). Metamorphic soles are thought to form at the subduction zone interface where material from the down-going plate is "welded" onto the hot mantle section of the overriding plate (e.g. Boudier et al., 1988; Hacker and Gnos, 1997). Many metamorphic soles preserve pressure conditions corresponding to depths that far exceed the thickness of the overlying ophiolite, implying significant exhumation of the metamorphic sole prior to ophiolite emplacement (e.g. Wakabayashi and Dilek, 2003; Van Hinsbergen et al., 2015). As metamorphic soles represent the first material accreted to the base of the upper plate and are an integral part of many obducted ophiolite complexes, they represent a unique record of the history of an ophiolite from subduction initiation to emplacement.

The late Neoproterozoic–early Paleozoic Ross–Delamerian Orogen of East Antarctica and southeast Australia records the earliest stages of convergent tectonics along the eastern margin of Gondwana following breakup of the supercontinent Rodinia (e.g. Cawood, 2005; Boger, 2011). Tethyan-type ophiolites emplaced during the Ross–Delamerian Orogeny are rare (Spaggiari et al., 2003), with the best-preserved example exposed in western Tasmania (southeast Australia, Fig. 1). The significance of Cambrian orogenesis in Tasmania (Tyennan Orogeny) in the context of the Ross–Delamerian Orogeny has long been

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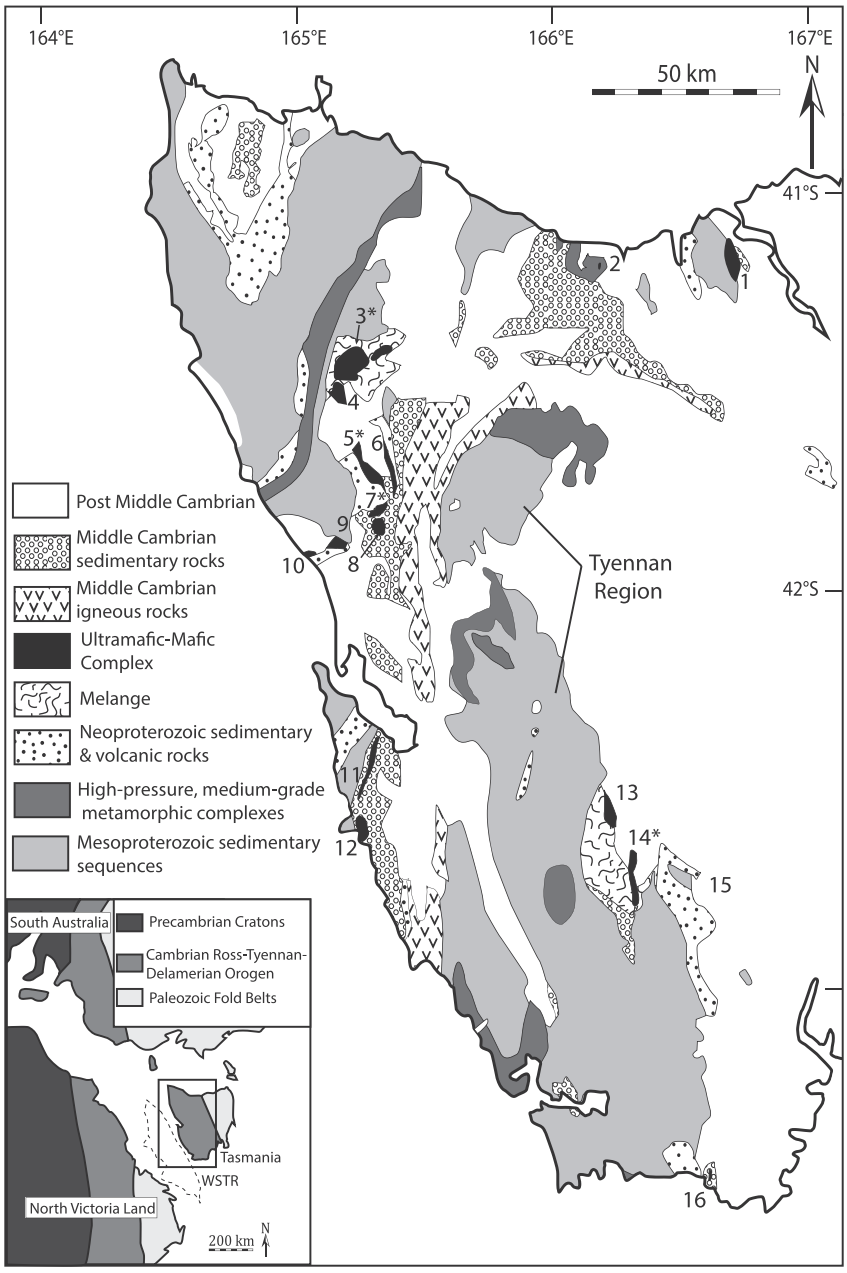

Fig. 1. Distribution of pre-Late Cambrian rocks in Tasmania, modified after Meffre et al. (2000) and Berry et al. (2007). Inset shows inferred position of Tasmania within the Ross–Delamerian Orogen; dashed outline of the inferred Cambrian position of the Western South Tasman Rise (WSTR) is from Royer and Rollet (1997). Locations of mafic-ultramafic Complexes representing remnants of the western Tasmania ophiolite are modified from Brown (1989). Mafic-ultramafic complexes where metamorphic sole is exposed are marked with an asterisk. 1-Andersons Creek, 2- Forth Metamorphic complex, 3- Heazlewood River complex*, 4-Mt. Stewart, 5-Wilson River*, 6-Huskisson River, 7- Serpentine Hill*, 8-Dundas, 9-McIvors Hill, 10- Trial Harbour, 11- Noddy Creek, 12-Spero Bay, 13-Boyes River, 14-Adamsfield-Gordon River Road*, 15-Styx River area, and 16-Rocky Boat Harbour.

problematic due to evidence for east-dipping subduction in Tasmania being synchronous with west-dipping subduction beneath the margin of Gondwana to the north (southeast Australia) and south (East Antarctica). The polarity of subduction along various segments of the Ross–Delamerian Orogen is still debated (e.g. Crawford et al., 2003; Cayley, 2011; Gibson et al., 2011; Rocchi et al., 2011) as it has important implications for understanding the Cambrian tectonic history of eastern Gondwana and subsequent orogenic events along the margin (e.g. Cayley, 2011; Moresi et al., 2014).

Mylonitic amphibolites outcropping beneath the western Tasmanian ophiolite have previously been interpreted as a metamorphic sole (Rubenach, 1973; Berry, 1989) but until now have not been studied in detail. These amphibolites represent the only known metamorphic sole associated with the Ross–Delamerian Orogeny. The metamorphic sole preserves important clues into the processes controlling the emplacement of the western Tasmanian ophiolite and hence has the potential to provide unique insights into the tectonic setting of the eastern margin of Gondwana during the early Cambrian.

This paper presents an integrated study of the field, microstructural, geochemical, and metamorphic characteristics of the metamorphic sole of the western Tasmanian ophiolite. The new data set supports a detailed assessment of the protoliths to the metamorphic sole rocks and allows us to reconstruct the complex structural and metamorphic history associated with the assembly of a metamorphic sole. Our findings provide new insights into the geodynamic setting of the eastern margin of Gondwana during the Cambrian that may help to resolve the apparent along strike variability in subduction zone polarity during the Ross–Delamerian Orogeny.

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