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Evolution of a Cambrian active continental margin: The Delamerian–Lachlan connection in southeastern Australia from a zircon perspective

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ABSTRACT

The Early Palaeozoic Ross–Delamerian orogenic belt is considered to have formed as an active margin facing the palaeo-Pacific Ocean with some island arc collisions, as in Tasmania (Australia) and Northern Victoria Land (Antarctica), followed by terminal deformation and cessation of active convergence. On the Cambrian eastern margin of Australia adjacent to the Delamerian Fold Belt, island arc and backarc basin crust was formed and is now preserved in the Lachlan Fold Belt and is consistent with a spatial link between the Delamerian and Lachlan orogens. The Delamerian–Lachlan connection is tested with new zircon data. Metamorphic zircons from a basic eclogite sample from the Franklin Metamorphic Complex in the Tyennan region of central Tasmania have rare earth element signatures showing that eclogite metamorphism occurred at ~510 Ma, consistent with island arc–passive margin collision during the Delamerian(−Tyennan) Orogeny. U–Pb ages of detrital zircons have been determined from two samples of Ordovician sandstones in the Lachlan Fold Belt at Melville Point (south coast of New South Wales) and the Howqua River (western Tabberabbera Zone of eastern Victoria). These rocks were chosen because they are the first major clastic influx at the base of the Ordovician 'Bengal-fan' scale turbidite pile. The samples show the same prominent peaks as previously found elsewhere (600–500 Ma Pacific-Gondwana and the 1300–1000 Ma Grenville–Gondwana signatures) reflecting supercontinent formation. We highlight the presence of ~500 Ma non-rounded, simple zircons indicating clastic input most likely from igneous rocks formed during the Delamerian and Ross Orogenies. We consider that the most probable source of the Ordovician turbidites was in East Antarctica adjacent to the Ross Orogen rather than reflecting long distance transport from the Transgondwanan Supermountain (i.e. East African Orogen). Together with other provenance indicators such as detrital mica ages, this is a confirmation of the Delamerian–Lachlan connection.

1. Introduction

An issue with wider implications for the development of the East Gondwana Pacific margin is the relationship between the Lachlan and Delamerian fold belts in southeastern Australia (Cawood, 2005; Foster et al., 2005; Squire and Wilson, 2005; Cayley, 2011). The long-held opinion has been that these two orogenic belts developed adjacent to each other with the Delamerian Fold Belt formed by Neoproterozoic continental rifting followed by orogenesis involving collision and convergent margin tectonism in the Delamerian(−Tyennan) Orogeny, whereas the Lachlan Fold Belt developed with Cambrian oceanic island arc and backarc basement followed by widespread Ordovician turbidite deposition and island arc development (Cas, 1983; Powell, 1984; Glen, 2005). The source of the Ordovician turbidites is clearly continental, as indicated by the quartz-rich nature of sandstones in the succession. Some authors infer derivation of the sandstones from the Delamerian mountain chain (Turner et al., 1996; Fergusson and Tye, 1999), whilst others argue for a more distant source in the East African Orogen at the junction of West and East Gondwana (Fig. 1) (the Gondwana Supermountain of Squire et al., 2006; Williams and Pulford, 2008). The East African Orogen has been considered a significant source for early Palaeozoic sedimentary units in Gondwana including North Africa and adjacent parts of the Middle East (Fig. 1) (Squire et al., 2006; Meinhold et al., 2013) and may also have been a source for late Cambrian to earliest Ordovician sedimentary rocks along the Tethyan margin of north India (Cawood et al., 2007). It has also been argued that many of the early Palaeozoic units of the Lachlan Fold Belt are allochthonous and have been transported by hundreds of kilometres or more along strike-slip faults (Willman et al., 2002; Glen, 2005; Glen et al., 2009).

These interpretations can be tested by analysis and compilation of provenance data including palaeocurrents, sedimentary petrology, and isotopic data including zircon and mica ages of detrital components (Cas, 1983; Ireland et al., 1998; Fergusson and Tye, 1999; Fergusson and Fanning, 2002; Squire et al., 2006; Williams and Pulford, 2008). Detrital zircon ages have been widely used to indicate provenance and for the Ordovician quartzose turbidites the detrital zircon age spectra are seemingly uniform with most ages in the ranges 600–500 Ma and

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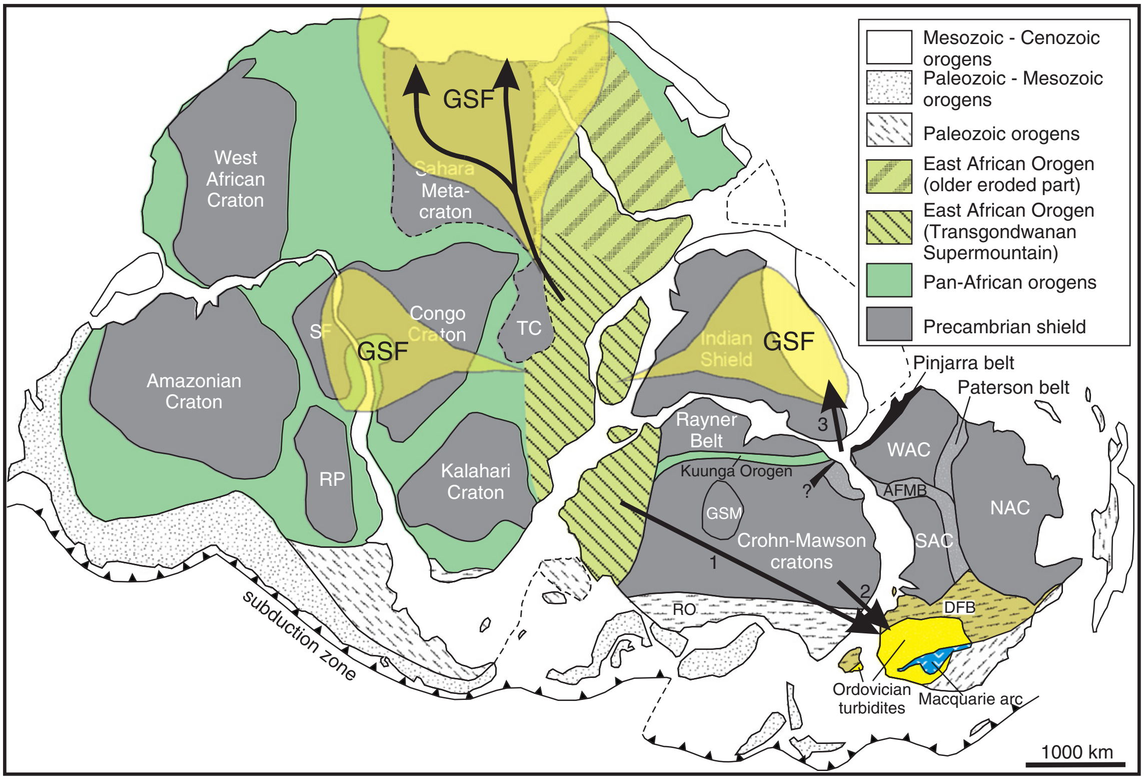

Fig. 1. Gondwana reconstruction after de Wit et al. (1988) with modifications after Myers et al. (1996), Squire et al. (2006), Gray et al. (2008), Boger (2011) and Meinhold et al. (2013). Major cratonic units are highlighted in East Gondwana and with subdivisions of Australia and East Antarctica from Myers et al. (1996) and Boger (2011) respectively. Gondwana super-fan (GFS) and black arrows showing sediment movement pattern in north Africa from Squire et al. (2006). Black arrows show sediment transport path required if Ordovician turbidites in the Lachlan Fold Belt of southeast Australia were derived from the East African Orogen (1) as suggested by Squire et al. (2006) and Williams and Pulford (2008) and shorter sediment transport route from East Antarctica (2). Path 3 provides an alternative source for early Palaeozoic sandstones on the Tethyan margin of India that may have been derived from the East African Orogen. The Lachlan Fold Belt in southeast Australia is divided into the Ordovician turbidite succession and the Ordovician Macquarie Arc. The Crohn–Mawson cratons are an amalgam of Precambrian and early Palaeozoic units largely concealed beneath the East Antarctic ice sheet; alternative representations of these units are given by Boger (2011) and Veever and Saeed (2011). Abbreviations: AFMB—Albany-Fraser-Musgrave belt, DFB—Delamerian Fold Belt, GSF—Gondwanan super-fan, GSM—Gamburtsev Subglacial Mountains, NAC—North Australian Craton, RO—Ros Orogen, RP—Río de la Plata Craton, SAC—South Australian Craton, SF—São Francisco Craton, TC—Tanzania Craton, WAC—West Australian Craton.

1300–1000 Ma. Similar spectra have also been widely found in early Palaeozoic sandstones throughout Gondwana (Veevers, 2000; Squire et al., 2006; Cawood et al., 2007; Williams and Pulford, 2008; Meinhold et al., 2013). In syntheses of global zircon ages these age ranges are associated with supercontinent formation. The 1300–1000 Ma range for granitoid ages and detrital zircons is associated with formation of Rodinia whereas the 600–500 Ma range reflects the final part of the Pan-African Orogeny during Gondwana assembly (Rino et al., 2008; Condie et al., 2009; Voice et al., 2011). Differences occur between detrital and igneous ages within continents; for example, no significant igneous peaks occur in Antarctica and Australia in the range 1500–1000 Ma whereas a large detrital peak is at 1060 Ma in Antarctica and at 1200 Ma in Australia (Condie et al., 2009, p. 237). How these are interpreted has important implications for provenance assessments. Thus does the absence of 1300–1000 Ma igneous ages in Antarctica reflect a sampling bias due to cover or is a distant source implied by the large detrital peak at 1060 Ma? Using detrital ages of zircons and other geochemical and isotopic data from sediment and sedimentary rocks it has been concluded that much of interior East Antarctica consists of an amalgam of Grenville and older cratons in a matrix of Pan-African fold belts (Veever and Saeed, 2008, 2011).

We examine the connection between these orogenic belts by acquiring chemical and isotopic data from zircons in three widely spaced samples. The first sample is a ~510 Ma (Black et al., 1997) eclogite from the Franklin Metamorphic Complex of Tasmania and the other two samples are of sandstones from the base of the Ordovician turbidites of the Lachlan Fold Belt at the Howqua River of eastern Victoria and Melville Point on the south coast of New South Wales (Fig. 2). The study of the Tasmanian eclogite was undertaken to confirm if its zircons grew during collision-related eclogite facies metamorphism or whether they formed in some other event unrelated to high-pressure metamorphism. Although metamorphism at ~510 Ma has been shown by chemical U–Th–Pb monazite dating to be widespread in Tasmania (Berry et al., 2005) and therefore part of the Delamerian(—Tyennan) Orogeny, it has been assumed rather than demonstrated that the ~510 Ma SHRIMP U–Pb zircon age on eclogite in the Franklin Metamorphic Complex reflects the timing of high-pressure metamorphism. We have therefore undertaken rare earth element (REE) analysis of these zircons to see if they have a low HREE abundance and no negative Eu anomaly signature that is diagnostic of zircons grown during eclogite facies metamorphism (Rubatto, 2002). The study of the Ordovician turbidite samples was designed to provide a better constraint on the initiation and provenance of the extensive East Gondwana turbidite fan (Fergusson and Tye, 1999; Williams and Pulford, 2008). This was done by selecting the least mature Ordovician sandstones that occur at the base of the succession in the Howqua River in eastern Victoria and at Melville Point on the south coast of New South Wales. These samples are most likely to reflect the source in the earliest Ordovician, during the final phases of the Delamerian Orogeny (Foden et al., 2006).

2. Geological setting

2.1. Tasmanides of southeast Australia

The Tasmanides of southeast Australia consist of the inner Delamerian Fold Belt occurring in southeastern South Australia, western Victoria and