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Towards understanding the early Gondwanan margin in southeastern Australia

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ABSTRACT

This review synthesizes the Proterozoic and early Paleozoic geology of Tasmania, Bass Strait and western and central Victoria. We examine the many different conflicting hypotheses that have been proposed to solve the paradoxical relationships between Tasmanian geology and that of mainland Australia, most notably the prevalence of Proterozoic basement of western and central Tasmania, while immediately across Bass Strait evidence of Proterozoic rocks is much more cryptic. We conclude that the Selwyn block model is the most satisfactory hypothesis to date, since it fits best with the obvious patterns in the magnetic and gravity data. This model proposes that the central Victorian Melbourne Zone is underlain by the northern extension of thin Tasmanian Proterozoic and Cambrian crust under Bass Strait, and that the Silurian to Middle Devonian Melbourne Zone was shortened along a décollement during the Tabberabberan Orogeny. The Ordovician rocks of eastern Tasmania correlate more closely with the Tabberabbera Zone than the Melbourne Zone in Victoria; however the Silurian and Devonian correlations are less certain. Major unresolved issues are the origins of the Proterozoic and Early Cambrian lithostratigraphic packages, tectonic models for their assembly during the Tyennan Orogeny, and how these models fit with those for mainland Australia.

1. Introduction

Understanding the relationships in Gondwana between Australia and Antarctica cannot be solved without an understanding of how the geology of Tasmania fits into the eastern margin of the supercontinent. Tasmania is often ignored, for example by Flöttmann et al. (1998), Betts et al. (2002) and Veevers (2007). Those who choose to include Tasmania in post-Rodinian reconstructions are challenged by the wide variety of incompatible and conflicting interpretations of Tasmania's relationships with the rest of the eastern Gondwana margin. One reason for these disparate interpretations is that major changes take place either beneath Bass Strait, a 300 km wide stretch of water separating Victoria and Tasmania, or under the Cretaceous and Cenozoic Gippsland and Otway basins that dominate Victorian exposures in the Bass Strait region.

The geology of Victoria and Tasmania are along strike from each other, and an Upper Cambrian to Lower Ordovician paleomagnetic pole reported by Li et al. (1997) places northwestern Tasmania within a few hundred kilometers of its present position with respect to the Australian mainland. Despite this, there are several fundamental differences that are difficult to reconcile. The oldest Tasmanian rocks known are the Mesoproterozoic meta-turbidites on King Island, and Proterozoic rocks are ubiquitous in northwestern Tasmania (Burrett and Martin, 1989; Seymour et al., 2007; Berry et al., 2008). By contrast, in Victoria, just 80 km north of King Island, there are no Proterozoic rocks known to crop out (Crawford et al., 2003) (Fig. 1). The Tasmanian Ordovician and Silurian rocks in the western and central parts are mostly terrestrial or marginal marine, while across Bass Strait the coeval Victorian Paleozoic rocks are largely deep marine turbidites (Burrett and Martin, 1989; VandenBerg et al., 2000; Crawford et al., 2003). In Tasmania, the dominant Cambrian deformational and thermal event, the Tyennan Orogeny, took place from about 515 to 505 Ma, with less significant early events at about 520 Ma and later events extending to about 490 Ma (Berry et al., 2007). In Victoria and South Australia, the broadly contemporaneous Delamerian deformation was initiated as far back as 545 Ma, while the peak metamorphism is generally younger than 505 Ma (Morand et al., 2004; Miller et al., 2005; Foden et al., 2006; Turner et al., 2009). In Tasmania, the Tyennan metamorphism formed both blueschist and eclogite facies rocks, while in Victoria and southeastern South Australia the Delamerian metamorphism is typically of a moderate to high temperature–low pressure style, although intermediate pressure rocks formed along the Moyston Fault (Preiss, 1995; Meffre et al., 2000; Cayley et al., 2002; Phillips et al., 2002; Morand et al., 2004). In Tasmania, Crawford and Berry (1992) argued that the Cambrian subduction system was east dipping, while in Victoria and Antarctica, north and south of Tasmania, the geological record suggests a west-dipping subduction system (Finn et al., 1999; Miller et al., 2005).

This paper describes the geology of Victoria and Tasmania and outlines the various, often conflicting, hypotheses invoked to try to resolve the paradoxical relationships outlined above. We will outline the geological, magnetic, gravity and seismic data, much of which

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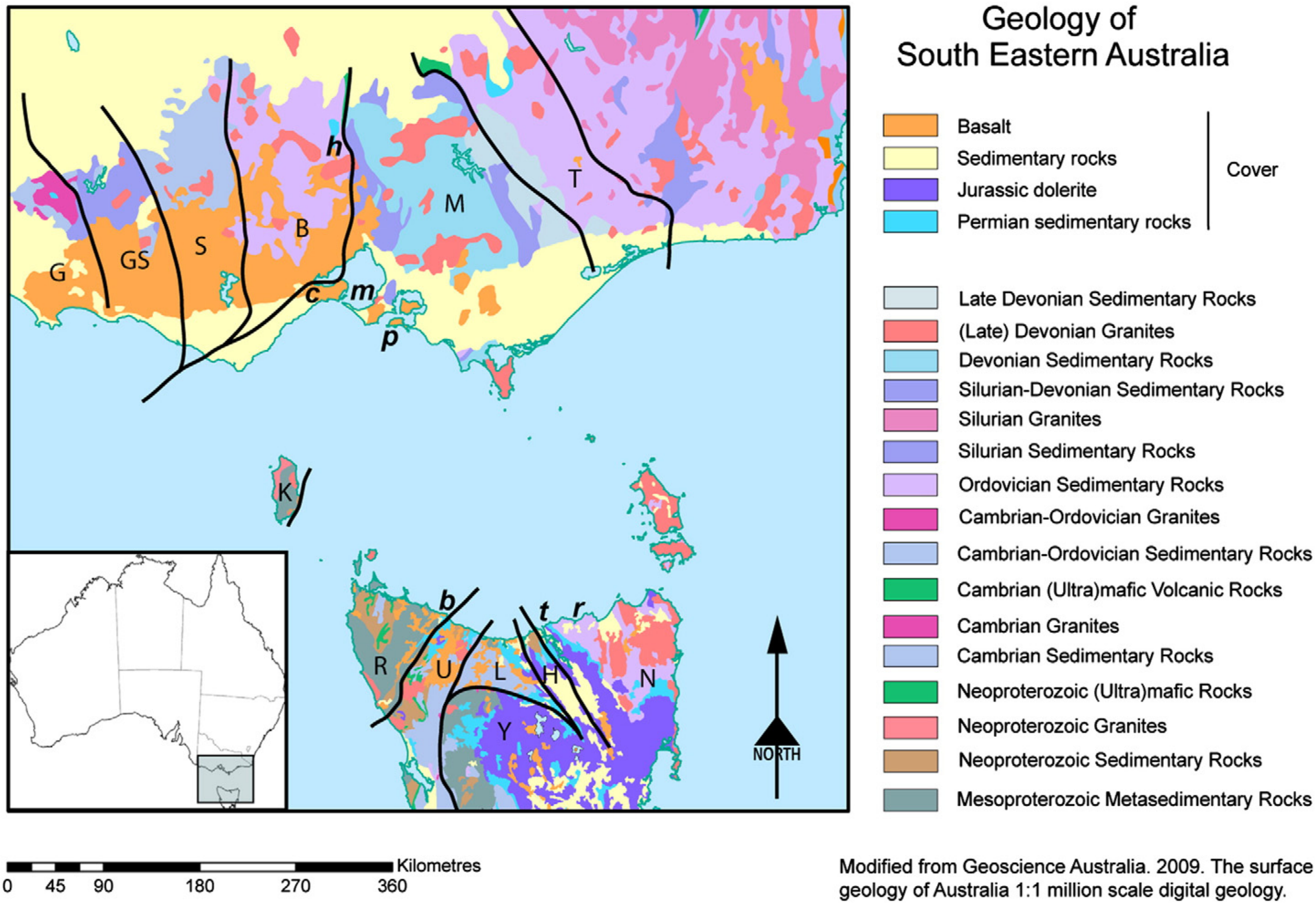

Fig. 1. Geology of southeastern Australia showing the major Proterozoic to Lower Paleozoic structural zones and locations mentioned in the text. B marks the Bendigo Zone, H the Badger Head Block, G the Glenelg Zone, GS the Grampians–Stavely Zone, K King Island, L the Sheffield–Ulverstone area, M the Melbourne Zone, N northeast Tasmania, R the Rocky Cape Block, S the Stawell Zone, T the Tabberabbera Zone, U the Burnie area and Y the Tyennan Block. Locations mentioned in the text are *b*, Black River, *c* the Ceres Gabbro, *h*, Heathcote, Kilmore, *m* the Mornington Peninsula, *p* Phillip Island, *i* Piper River and *t*, the Tamar River. The Arthur Lineament forms the boundary between the Rocky Cape Block and the Burnie area.

has been collected or reprocessed since 2000, to evaluate these hypotheses and to conclude which are most likely to be valid.

2. Historical data

2.1. Geology

The oldest rocks known from the region are from the southern tip of King Island, where SHRIMP analyses of zircons showed that the psammitic and pelitic rocks were deposited after 1350 Ma, while monazite dating showed that they were metamorphosed at 1290 ± 20 Ma (Figs. 1 and 2) (Black et al., 2004; Berry et al., 2005). These rocks have no known equivalents on Tasmania or Victoria (Crawford et al., 2003; Calver, 2007). Mapping by Calver (2007) divided the basement of King Island into a western part of amphibolite facies metasedimentary rocks and an eastern part of greenschist to lower amphibolites facies metaturbidites. He believed that the eastern metaturbidites were the high-temperature low-pressure metamorphic equivalents of the western succession (Blackney, 1982; Calver, 2007).

In Tasmania, the Rocky Cape Group of the Rocky Cape Block are the oldest rocks mapped. These rocks are dominantly shallow marine to neritic metaquartzites and associated siltstones. These rocks are exposed in northwestern Tasmania, and the detrital zircons present indicate that the upper parts are younger than 1000 Ma and the lower parts no older than about 1430 Ma (Burrett and Martin, 1989; Black et al., 2004; Everard et al., 2007). Calver et al. (2010) correlated the *Horodyskia Williamsii* 'string of beads' trace fossils present low in the Rocky Cape Group with similar fossils in the Bangemall Basin in W.A., where they are constrained to rocks aged between 1465 and 1700 Ma. The basement to the Rocky Cape Group is not exposed. The age of the earliest deformation is uncertain, but at the eastern edge of the Rocky Cape Block, rocks that may be younger than it are intruded by a granite with an age of 777 ± 7 Ma (Turner et al., 1998; Calver et al., 2010). On northern King Island, Turner et al. (1998) used U/Pb zircon geochronology to document a second metamorphic event, the Wickham Orogeny, that took place at 760 ± 12 Ma.

Several other sequences in western and central Tasmania also contain metasedimentary rocks where the youngest zircon populations range from 1400 to 1450 Ma (Black et al., 2004). All were apparently sourced from the same, probably Laurentian, source (Berry et al., 2001; Burrett and Berry, 2001; Black et al., 2004). Even where younger sources are present, e.g. Badger Head in north central Tasmania(1242 ± 29 Ma) and the Jacob Quartzite further west (1010 ± 45 Ma), the 1400 to 1450 Ma zircons are also present (Black et al., 2004). Chmielowski (2009) found older monazites ranging from 1000 to 1400 Ma, with a peak at 1376 ± 7 Ma; several monazites also had overgrowths that grew at 1220 ± 36 Ma. While these give maximum ages of sedimentation, there are few other constraints. A K/Ar age by Crook (1979) on a dolerite intruded into wet sediments was recalculated by Black et al. (2004) as 711 ± 16 Ma;