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Stratigraphic signature of the late Palaeozoic Ice Age in the Parmeener Supergroup of Tasmania, SE Australia, and inter-regional comparisons

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ABSTRACT

Recent research in eastern Australia has established that rather than being a single, long-lived epoch, the late Palaeozoic Ice Age comprised a series of glacial intervals each 1–8 million years in duration, separated by non-glacial intervals of comparable duration. In order to test whether the glacial events recognized in New South Wales and Queensland have broader extent, we conducted a reappraisal of the Parmeener Supergroup of Tasmania, southeast Australia. A facies analysis of the Pennsylvanian to Permian section was carried out, allowing rationalization of the succession into four recurrent facies associations: a) glacigenic facies association, restricted to the basal Pennsylvanian/earliest Permian Wynyard Formation and correlatives, b) glacially/cold climate-influenced to open marine shelf facies association, which accounts for large parts of the Permian succession, c) deltaic facies association, which specifically describes the Lower Permian "Lower Freshwater Sequence" interval, and d) fluvial to estuarine facies association, which specifically addresses the Upper Permian Cygnet Coal Measures and correlatives. Indicators of sediment accumulation under glacial influence and cold climate are restricted to four discrete stratigraphic intervals, all of which indicate that glaciation was temperate in nature. The lowermost of these, incorporating the basal Wynyard Formation and its correlatives, and overlying Woody Island Formation, shows evidence of proximal glacial influence (subglacial, grounding-line fan and ?fjordal facies), and is likely a composite of one or more Pennsylvanian glacial event(s) and an earliest Permian (Asselian) glacial. The second, of late Sakmarian to early Artinskian age, comprises an initial more proximal ice-influenced section and an overlying more distal ice-influenced interval. The third (Kungurian to Roadian) and fourth (Capitanian) intervals are both distal glacimarine records. The four intervals are of comparable age to glacials P1–P4, respectively, recognized in New South Wales and Queensland (notwithstanding apparent discrepancies of <2 million years in age), and display similar facies characteristics and vertical contrasts to those intervals. Accordingly, it is concluded that the late Palaeozoic stratigraphy of Tasmania preserves a glacial/cold climate record correlatable to that of mainland eastern Australia, lending support to the hypothesis that these events were widespread across this portion of Gondwana.

1. Introduction

Until recently, the late Palaeozoic Ice Age was thought to have been a single, protracted Icehouse interval some 60–70 million years in duration, with some waxing and waning of ice centers across Gondwana (Veevers and Powell, 1987; Crowell, 1999). Increasingly, however, this view is being supplanted by the concept of a multi-phase Ice Age characterized by several, shorter (1–10 m.y.) glacial intervals separated by non-glacial intervals of comparable duration (Isbell et al., 2003; Fielding et al., 2008a, b, c). Eight such, discrete glacial intervals have been recognized by Fielding et al. (2008a) from the stratigraphic record in eastern Australia (New South Wales and Queensland). Each of these intervals contains sedimentological and other evidence for glacial ice presence either in the depositional basin or in the immediate hinterland to the basin, and each can be correlated in time, within the limitations imposed by current geochronological resolution, over wide areas. The intervening intervals display no evidence whatsoever of glacial conditions, and are thus regarded not as "interglacials" but as longer intervals of time during which climate was more temperate, similar perhaps to the mid-Miocene Climatic Optimum of the Neogene (Holbourn et al., 2004; Zachos et al., 2008).

The issue of whether glacial events or intervals recognized in any particular part of the world were global in extent, or rather more restricted in influence, remains to be satisfactorily resolved (Fielding et al., 2008c). Intuitively, and by analogy with the better-known and

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more highly-resolved Neogene Icehouse, it seems unlikely that all late Palaeozoic glaciations were synchronous globally. Rather, the stratigraphic record, particularly in far-field regions where the main consequence of glaciations was a product of glacioeustatic sea-level fluctuations, is likely to have been a mosaic of effects from asynchronous events at different times in different areas. As more highly resolved stratigraphic records from Gondwana become available, it may become possible to assess whether or which glacial events were indeed synchronous.

As an initial test of the hypothesis that Permian glacial events in eastern Australia are of broader extent, a study of the Carboniferous to Permian Parmeener Supergroup of the Tasmania Basin was undertaken (Fig. 1). In the present paper, we report the results of that investigation. The Carboniferous to Permian stratigraphy was examined at a number of surface outcrops and in selected drillcores held at the Tasmania Department of Mineral Resources facility in Mornington, Hobart. Sections were described and interpreted in terms of depositional environment. Evidence for glacial influence, ice rafting and cold climate was carefully noted, and discrete intervals with glacial/cold climate indicators (Table 1 of Fielding et al., 2008a) were recognized. Correlations were then drawn between this record and the stratigraphic framework of Fielding et al. (2008a) from New South Wales and Queensland.

Age control is derived entirely from biostratigraphic data. The most widely used scheme for determining relative age is the marine macroinvertebrate zonation of Clarke and Farmer (1976), which has been correlated in detail to similar schemes for the eastern Australian mainland and to the Australian late Palaeozoic palynostratigraphic zonation (Reid et al., in press Fig. 5). At this time, no absolute ages are available for the Parmeener Supergroup, rendering relative age determinations somewhat tentative.

2. Geological setting

During the Pennsylvanian and Early Permian, Tasmania lay within the southern polar circle, according to published palaeomagnetic data and their interpretation (e.g., Li and Powell, 2001; Fig. 2). Portions of the Parmeener Supergroup have been interpreted for many years as having been laid down under the influence of glacial ice (Banks, 1980; Clarke, 1989; Reid et al., in press). While the evidence for glaciation is not substantially disputed, the timing and character of glaciation have never been fully established, and so detailed comparisons with events on the southeastern Australian mainland cannot be made.

The Parmeener Supergroup was accumulated in the Tasmania Basin, an intracratonic basin that was active during the Pennsylvanian to Late Triassic, and one of a number of sedimentary basins developed along the Panthalassan margin of Gondwanaland (Veevers et al., 1994). The confinement of Pennsylvanian to end-Sakmarian glacigenic formations to deep structural lows, and abrupt lateral facies and thickness changes onto marginal structural highs, suggests that these units formed under a period of extensional subsidence in a series of grabens or half-grabens separated by uplifted, block-faulted horsts (Figs. 9 and 10 of Reid et al., in press). Some of these structural lows may have been further deepened by glacial scouring associated with mountain or outlet glacier activity, while the highs may have served as glacial centers (Banks and Clarke, 1987; Hand, 1993). The upper half of the Permian section appears unconfined by previous structural topography, and displays a more sheet-like geometry in cross-section. The mainly Triassic Upper Parmeener Supergroup appears to lie unconformably over the Permian section. The uppermost part of the Supergroup comprises coal-bearing strata of Late Triassic (Carnian–Norian) age that may also be in unconformable contact with earlier Triassic sediments.

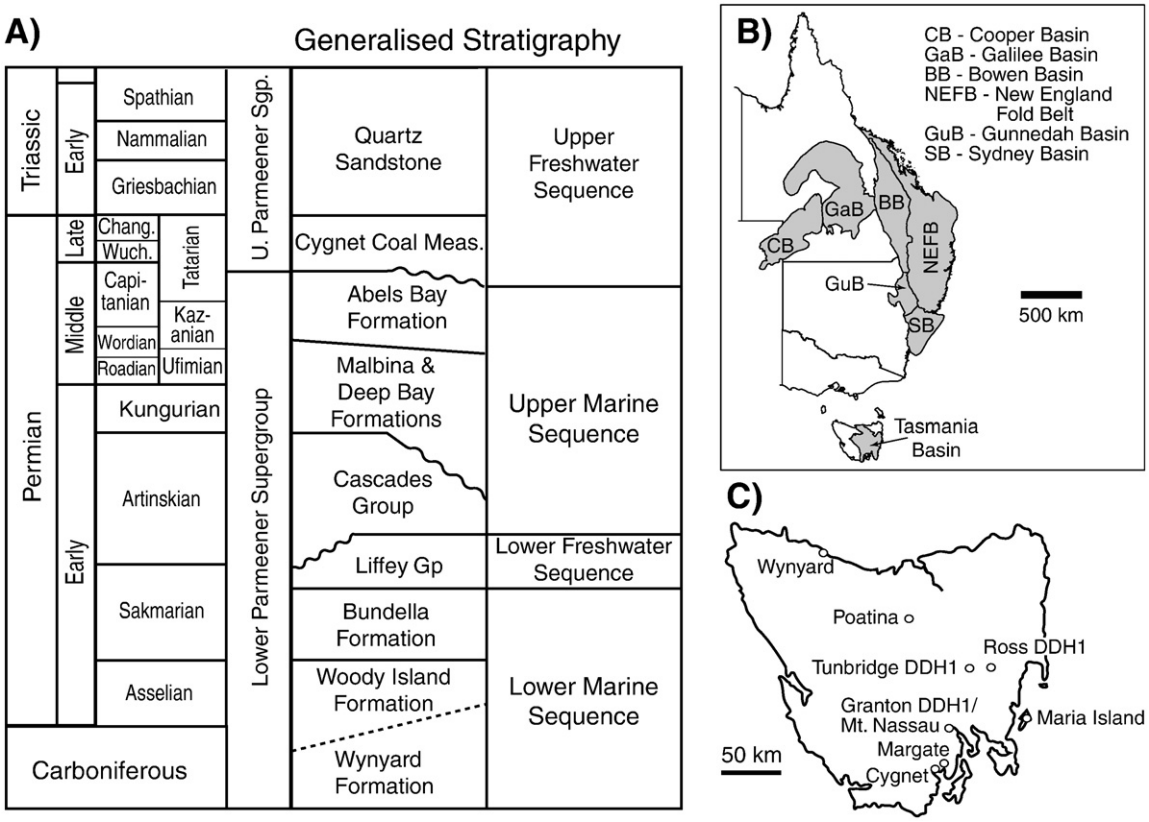

Fig. 1. Generalized stratigraphic column and nomenclature for the Carboniferous to Triassic Parmeener Supergroup of Tasmania (from Reid et al., in press), and map showing the context of the Tasmania Basin in eastern Australia.