Neoproterozoic glacigene successions, western Officer Basin, Western Australia

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Abstract

Neoproterozoic glacigene deposits in the Officer Basin are present within the Lupton and Boondawari Formations, but to date, their age and correlation have been uncertain. The Lupton Formation type section has been revised and is thinner than previously described. New evidence from Empress 1 and 1A drillcore, including the identification of a 'cap dolomite', isotope chemostratigraphy, and stromatolite biostratigraphy, indicates a Marinoan age (approximately 600 Ma) for the Lupton Formation and that it correlates with the Boondawari Formation. As a consequence of these new results, glacigene strata of the Officer Basin can now be correlated with similar units elsewhere in Australia.

KEYWORDS: Neoproterozoic, stratigraphy, glacial sediments, diamictite, Officer Basin, Lupton Formation, Boondawari Formation.

Introduction

Neoproterozoic glacigene successions in Australia are regarded as significant marker horizons for chronostratigraphic correlation (Preiss et al., 1978). Two main glacial intervals were recognized in the Neoproterozoic of the Centralian Superbasin and Adelaide Rift Complex: the Sturtian glaciation and the Marinoan glaciation, with ages estimated at 700–690 Ma and 605–595 Ma respectively (Walter et al., in press).

Despite numerous descriptions of Neoproterozoic glacigene successions in the Officer Basin (Fig. 1), the age and correlation of these widely scattered units remains uncertain. Four western Officer Basin formations were originally ascribed a glacial origin (Jackson and van de Graaff, 1981; Williams, 1992): the Lefroy, Lupton, Turkey Hill, and Boondawari Formations. Of these, only the Boondawari and Lupton Formations (Fig. 2) are demonstrably Neoproterozoic glacigene deposits.

The type section of the Lupton Formation (Lowry et al., 1972; Jackson and van de Graaff, 1981; Cockbain and Hocking, 1989) at Lupton Hills (latitude 26°31'S, longitude 128°01'E; Fig. 1) was remeasured in 1998 (COP 98/3, Fig. 3). A synclinal axis was recognized in outcrop, reducing the measured thickness of the unit from 240 to 69 m. Here, the Lupton Formation contains coarse-grained diamictite with rare striated pebbles, confirming a glacigene origin. The Neoproterozoic Lupton Formation was probably folded during the Petermann Ranges Orogeny.

Because of poor outcrop, the Boondawari Formation (Williams and Tyler, 1991; Williams, 1992; Walter et al., 1995) is divided between three type areas. The stratigraphically lowest part is diamictite (latitude 23°31'32"S, longitude 121°29'57"E); the second area consists of a diamictite with overlying coarse-grained sandstone (latitude 24°17'57"S, longitude 122°16'19"E); and the third area comprises a lutite and carbonate succession (latitude 23°34'56"S, longitude 121°38'25"E).

Diamond corehole GSWA Empress 1 and 1A (Fig. 1) penetrated 197 m of glacigene diamictite and an overlying 30 m-thick sandstone, separated by an approximately 50 cm-thick dolomitic horizon. The diamictite was initially assigned to the '?Lupton Formation' and the upper 30 m to an 'unnamed unit' (Stevens and Apak, 1999). The uncertainty about its correlation arose because the core interval is commonly finer grained than the type section. However, based on lithostratigraphic and facies comparisons, the diamictite is here correlated with the Lupton Formation (Fig. 2). From biostratigraphy and isotope chemostratigraphy, the overlying dolomitic horizon is correlated with the Marinoan 'cap dolomite' found elsewhere in the Centralian Superbasin and Adelaide Rift Complex.

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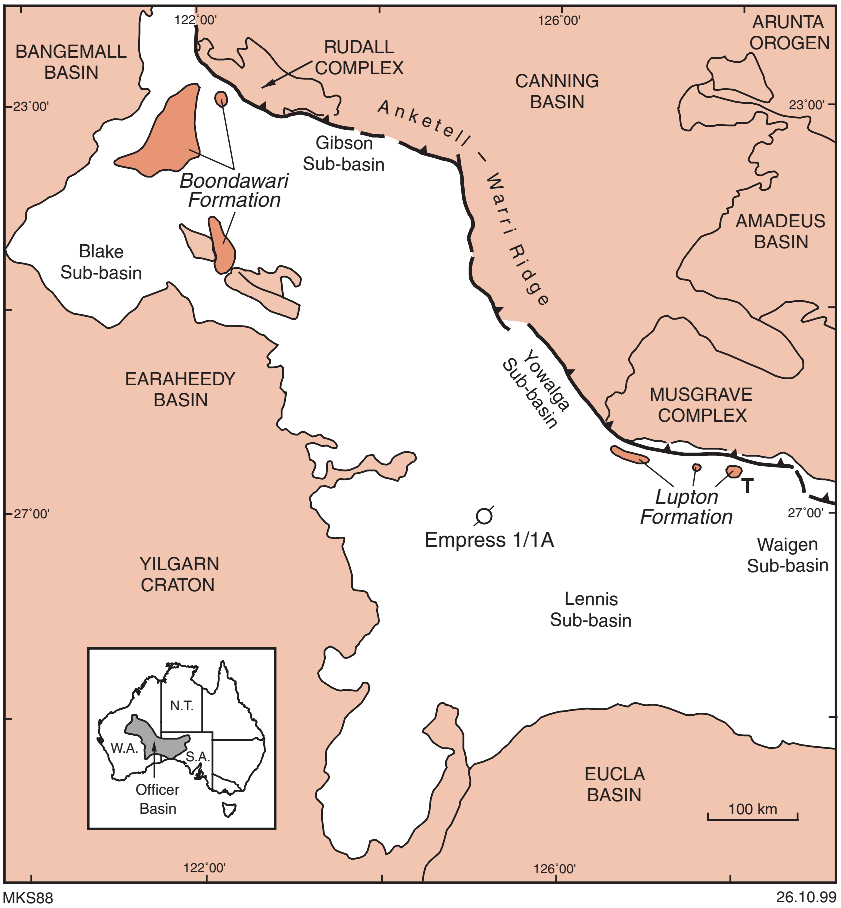

Figure 1. Location of outcrops of Neoproterozoic glacigene rocks and Empress 1 and 1A in the western Officer Basin. T = type section of the Lupton Formation and measured section COP 98/3 (see Figure 3)

Description of glacigene units of the Officer Basin

The Lupton Formation outcrops at Lupton Hills, near Ainslie Gorge (latitude 26°14'S, longitude 126°38'E), and elsewhere along the southern edge of the Musgrave Complex (Fig. 1). At Lupton Hills, the remeasured type section consists of a lower unit of massive, very poorly sorted pebble to boulder conglomerate, and overlying interbedded conglomerate, sandstone, and siltstone (Fig. 3). Outcrops elsewhere consist mostly of fine-grained diamictite with scattered large boulders, and interbeds of fine-grained, well-bedded sandstone and coarse-grained cross-bedded sandstone. A glacigene origin is indicated by rare faceted and striated clasts.

Empress 1 and 1A was drilled about 170 km southwest of the nearest outcrop of the Lupton Formation (Fig. 1) and, based on lithostratigraphic similarity, the interval from 317.1 – 486.0 m (Fig. 3) is here assigned to the Lupton Formation. Clasts in the diamictite are compact to platy or elongate, subangular to subrounded, and sometimes faceted, and there are rare striations, indicating a glacial origin. The Lupton Formation grades upwards into an unnamed sandstone-dominated unit (286 – 317.1 m) that is fine to medium grained with minor coarse to very coarse grained bands.

Six facies types were identified in the Lupton Formation in Empress 1 and 1A (Fig. 3). Massive and stratified diamictite dominates the succession (Dmm and Dms, Fig. 3), with an approximate cumulative thickness of 90 m, and is associated with mudstone and sandstone facies (Fl, Fm, Sm, Sh, Fig 3). Massive diamictite (Dmm) is structureless and consists of clasts scattered in a muddy, medium-grained sandstone matrix. Stratified diamictite (Dms) shows crudely developed bedding defined by poorly organized concentrations of clasts or changes in matrix texture (or both). Associated fine-grained laminated and graded sandstones and mudstones are interpreted as the deposits of dilute, low concentration turbidity currents; isolated clasts found within these facies were probably ice-rafted. Sandstone facies are massive (Sm) or horizontally laminated (Sh) and often contain deformation structures that typically result from downslope subaqueous slumping. Sandstone characteristics are also consistent with a depositional origin by sediment gravity flows such as turbidites. The close association of diamictites with muddy and sandy turbidites suggests a subaqueous origin for diamictite facies, either by slumping and sediment gravity flows (debris flows) or by ice-rafting and 'rain-out' of suspended fines. A glacio-marine setting is provisionally suggested.

The uppermost Lupton Formation (317.1 – 318.7 m) consists of interlaminated and interbedded, fine- to coarse-grained sandstone, mudstone, and thin dolomite bands (Fig. 4). It contains patches of rounded jaspilitic grains, and resembles the bed of 'dark red-brown cherty dolomite about 1 m thick' that forms the Marinoan cap dolomite at the top of the Pioneer Sandstone in the Amadeus Basin (Walter et. al., 1979; Fig. 2). Additionally, thin bands of laminated, micritic, light-grey dolomite contain incipient stromatolite columns (Fig. 4), here assigned to ?*Elleria minuta* Walter and Krylov *in* Walter et al. 1979, a form previously recorded from the Pioneer Sandstone cap dolomite (Walter et al., 1979).

Correlation of the dolomite in Empress 1A with the Marinoan cap dolomite is supported by isotope chemostratigraphy (Walter and Hill, 1999). Analyses of $\delta^{13}C_{carbonate}$ samples from the dolomitic bands show similar values to those recorded from (1) the cap dolomite immediately above the Boondawari Formation diamictite; (2) carbonate in the glacigenic Boord Formation, a lateral equivalent of the Pioneer Sandstone in the western Amadeus

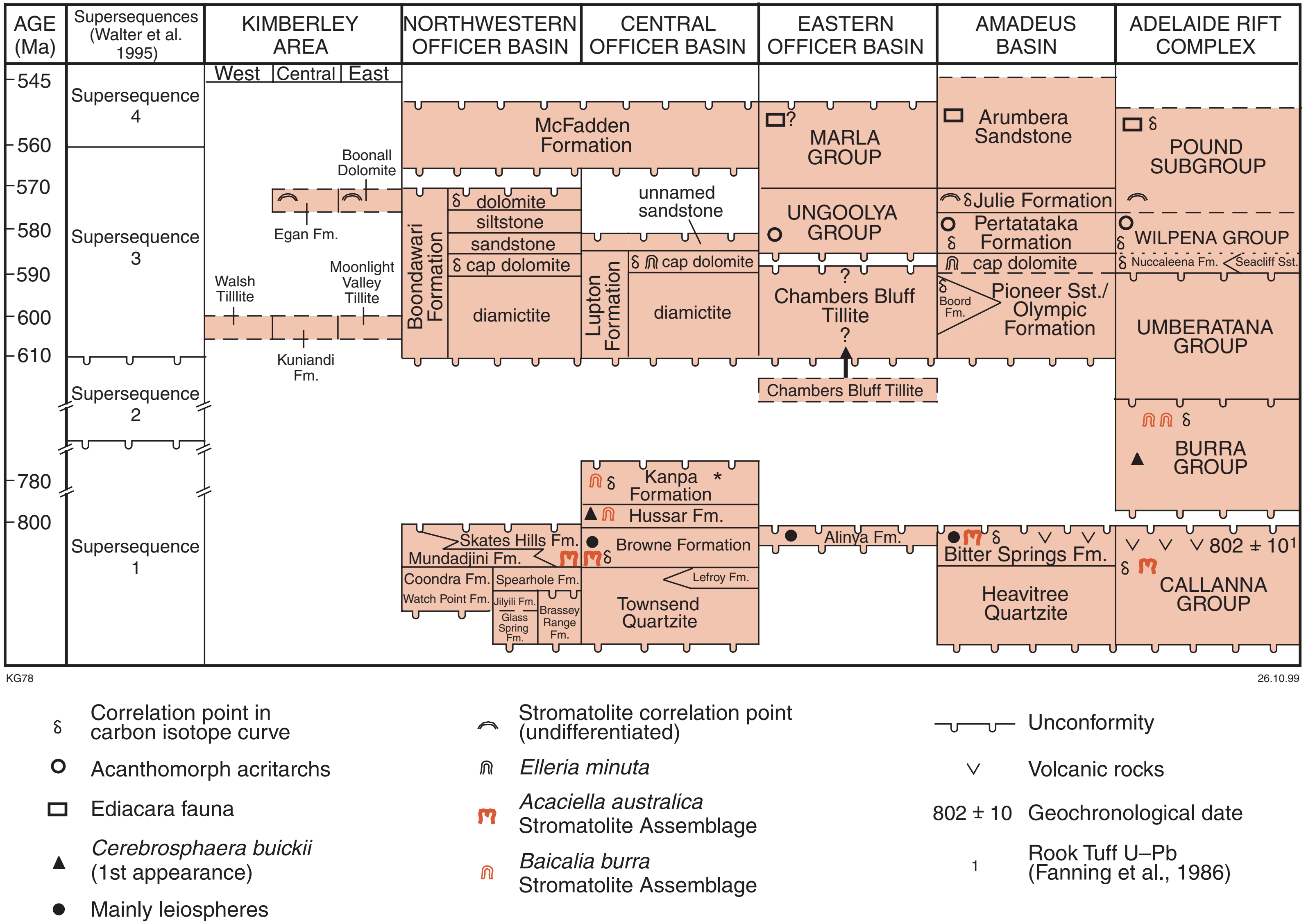

*Figure 2. Neoproterozoic glacigene stratigraphy (Supersequence 3) of the western Officer Basin, and stratigraphic correlation with selected units from other areas of the Centralian Superbasin and Adelaide Rift Complex. Type of data used for correlation of units is indicated. * See revision to stratigraphy in Apak and Moors (in prep.)*

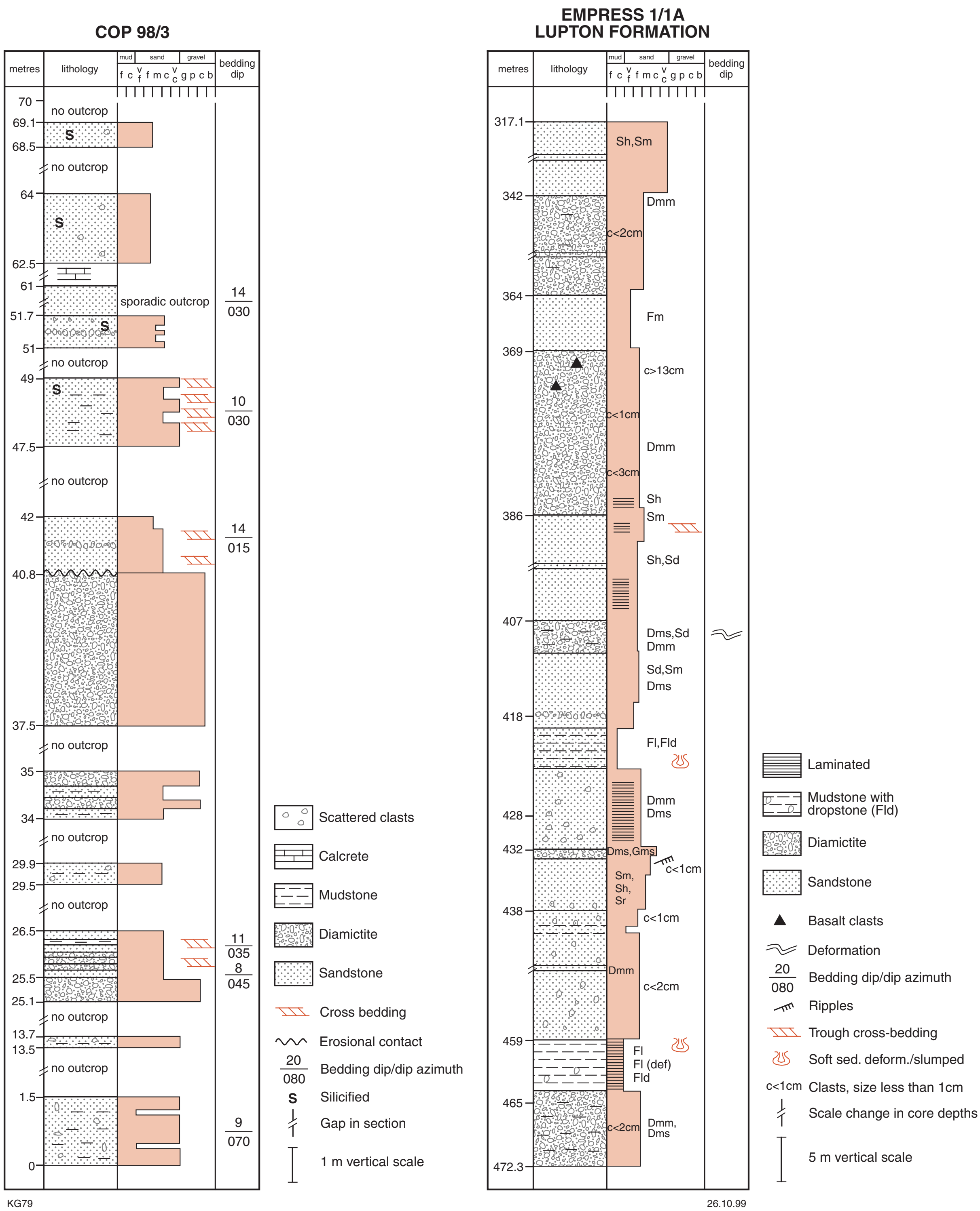

Figure 3. Lithostratigraphic columns for the type section of the Lupton Formation at Lupton Hills (COP 98/3), and the Lupton Formation in Empress 1 and 1A, western Officer Basin. D = diamictite facies; Dmm = matrix supported, massive; Dms = matrix supported, stratified; G = conglomerate facies; gms = stratified; S = sandstone facies; Sm = massive; Sd = deformed; Sh = horizontally laminated; Sr = rippled; F = fine-grained (mudstone) facies; Fm = massive; Fl = laminated; Fl(def) = laminated and deformed; Fld = laminated with dropstone

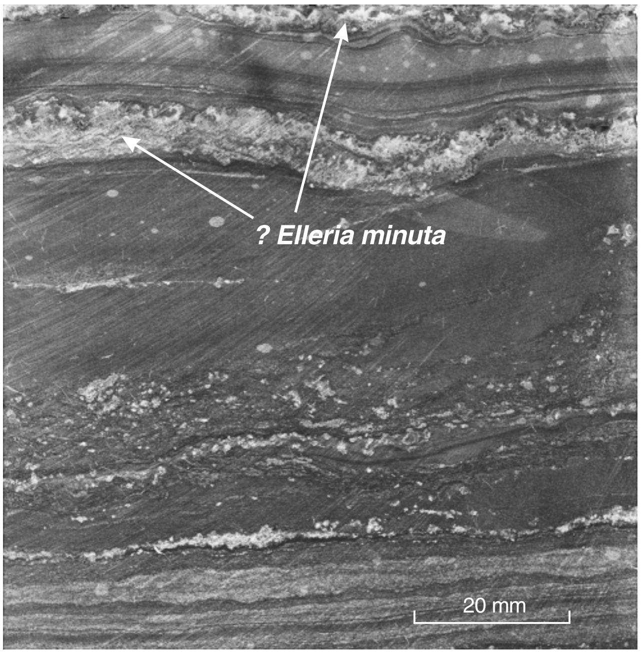

*Figure 4. Photograph of cap dolomite in Empress 1 and 1A (317.62 – 317.79 m) showing incipient stromatolite columns of ?***Elleria minuta** *(arrowed)*

Basin; (3) the cap dolomite above the glacigene Pioneer Sandstone, central Amadeus Basin; and (4) in the Nuccaleena Formation, Adelaide Rift Complex (Preiss, 1987; Walter et al., 1994, 1995; Calver, 1995; Calver and Lindsay, 1998; Fig. 2).

The unnamed sandstone unit above the diamictite and caprock of the Lupton Formation in Empress 1 and 1A is a probable lateral equivalent of the Seacliff Sandstone of the Adelaide Rift Complex (Preiss, W. V., 1998, pers. comm.; Fig. 2). It was probably deposited on an open marine shelf. The lower part consists of a fining-upwards succession, including mudstone, that indicates a post-glacial transgression resulting from a rise in sea level.

In the northwestern Officer (formerly Savory) Basin (Perincek, 1998; Bagas et al., 1995, 1999), the glacigenic Boondawari Formation (Figs 1 and 2) outcrops near Boondawari Creek. It is poorly exposed, and has a total maximum thickness of about 800 m (Williams, 1992; Walter et al., 1994). Lithologies include diamictite, and a thin (~15 cm thick), red, micritic dolomite with depleted carbon isotope values similar to those recorded for cap dolomite elsewhere in the Centralian Superbasin and Adelaide Rift Complex (Walter et al., 1994). It is overlain by 30–40 m of red siltstone with sandstone interbeds, which resembles siltstone in the same relative stratigraphic position in the Pertatataka Formation of the Amadeus Basin and the Brachina Formation of the Adelaide Rift Complex. From lithostratigraphic, biostratigraphic, and isotope chemostratigraphic evidence, the Boondawari Formation appears equivalent to the entire Marinoan succession elsewhere in Australia.

Although different stromatolite taxa occur in the upper Boondawari Formation and the Julie Formation of the Amadeus Basin, they lie at the same relative stratigraphic position above the diamictite, and have similar carbon isotope values. A sample from the upper Boondawari carbonate shows marked enrichment in ^{13}C ($\delta^{13}C_{PDB}$ values ranging from +6.8 to +8.0‰) and compares with values obtained from the Julie Formation and other end-Marinoan carbonates in Australia (Walter et al., 1994; Calver 1995).

Discussion

At present there is no stratigraphic record of Sturtian age glaciation recognized in Western Australia (Fig. 2). Either deposition did not extend this far west, or, more probably, any deposits were subsequently eroded. In contrast, evidence for the presence of Marinoan glacigene rocks in the western Officer Basin is now convincing, and correlations can be made with successions in central and South Australia. The Boondawari and Lupton Formations, and the overlying unnamed unit in Empress 1 and 1A, are equivalent to the diamictite, cap dolomite, and overlying sandstone in other parts of the Centralian Superbasin and Adelaide Rift Complex (Fig. 2).

It must be emphasized that correlation between the western and eastern Officer Basin remains problematic. The Chambers Bluff Tillite (Fig. 2) of the eastern Officer Basin, presently regarded as Sturtian, could be Marinoan. A pink dolomite near the top of the formation (Morton, 1977) may be a cap-dolomite equivalent. Biostratigraphically significant acritarch assemblages in the overlying Ungoolya Group indicate correlation with the Pertatataka Formation above the cap dolomite in the Amadeus Basin (Grey, 1998). Kimberley glacigene successions (Fig. 2) are now all considered to be Marinoan in age, based on lithostratigraphy and stromatolite biostratigraphy (Grey and Corkeron, 1998), and the Egan Formation appears to be a younger glaciation that is time equivalent to the Julie Formation of central Australia (Grey and Corkeron, 1998).

Petroleum potential

The major hiatus between Supersequence 1 and the Marinoan glaciation (Fig. 2) represents a break of at least 150 million years. Karstification at the top of the Kanpa Formation unconformity includes vuggy porosity in Empress 1 and 1A (Stevens and Apak, 1999). This may indicate reservoir development, and overlying diamictite and mudstone facies of the Lupton Formation could have seal potential for poor to good source rocks identified in the underlying Kanpa Formation (Ghori, 1998; Carlsen et al., 1999).

Conclusions

The type section of the Lupton Formation has been remeasured and revised following the recognition of folding. Glacigene rocks in Empress 1 and 1A are assigned to the Lupton Formation from comparison of the lithostratigraphy. A Marinoan age for both the Boondawari and Lupton Formations in Empress 1 and 1A is indicated by the presence of a cap dolomite, $\delta^{13}C_{carbonate}$ isotope chemostratigraphy, and is supported by limited biostratigraphic data. The Neoproterozoic glacigene successions of the western Officer Basin can now be confidently correlated with the Amadeus and Georgina Basins, the Adelaide Rift Complex, and the Kimberley region.

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