Are stromatolites in the northern Perth Basin following the End Permian mass extinction?

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SUMMARY

Following the End Permian Mass Extinction (EPME) event, global stromatolite distributions rapidly increased. There are three documented examples of stromatolites occurring in intracontinental settings following the EPME; Greenland, Madagascar and west Australia's Northern Perth Basin. We are reporting the west Australian stromatolite occurrence to be much further than previously thought, through detailed mapping and analysis of stromatolites in the Northampton region. A review of the stromatolites show alternating stromatolite morphologies, with a minimum of four phases. These alternating morphologies are attributed to environmental changes in energy and detrital input, as well as microbe community induced structural changes. Two primary morphologies are documented, large smooth domal and micro-digitate structures. Using sedimentological characteristics of the conglomerates below and the stromatolite unit itself, a revised palaeo-environmental model is proposed for the growth of the stromatolitic unit. The model places the system in an intracontinental marine setting with shallow basinal margins defined by the mid-Palaeozoic Tumblagooda Sandstone. Mass flow deposits come in from the margins, defined by cobble conglomerates, on which the stromatolites grow. The stromatolites have previously been considered to be Early Triassic in age. However, revised stratigraphic relationships suggest they may be older than previously thought. Raising the question, do the northern Perth Basin stromatolites truly correlate with a mass extinction event?

Key words: microbialites, source rocks, Siberian Traps, Triassic, Perth Basin

INTRODUCTION

Stromatolites are laminated structures, formed by microbial activity (Logan et al., 1964), and they dominated the first 85% of life on Earth (Awramik, 1992; Awramik and Sprinkle, 1999; Djokic et al., 2017; Suosaari et al., 2016). After the evolution and diversification of complex lifeforms in the Cambrian, the stromatolite record significantly declines (Awramik et al., 1976; Bosak et al., 2013; Garrett, 1970; Schubert and Bottjer, 1992).

Since the Cambrian, stromatolites have proliferated for short intervals directly following mass extinction events (Chen and Benton, 2012; Kershaw et al., 2012; Schubert and Bottjer, 1992). As the ecosystems recover, the stromatolites only occur in restricted environments (Chen and Benton, 2012; Schubert and Bottjer, 1992). Hence, understanding the environmental and temporal context of stromatolites following a mass extinction event is important to understand biotic recoveries.

The End Permian mass extinction (EPME) event resulted in the loss of 80-96% of marine species and 70% of terrestrial vertebrates (Chen and Benton, 2012; Erwin, 1994; Keller, 2005). Following this extinction event, global stromatolite abundance rapidly increased. Stromatolite occurrences were common along marginal Tethyan environments. However, there are only three recorded occurrences in intracontinental settings at high palaeo latitudes at this time: Eastern Greenland, Madagascar and west Australia. Of these three intracontinental occurrences the west Australian was most distal (ca. 60°S) from the driver of the EPME, the Siberian Traps (Wignall and Twitchett, 2002).

The Perth Basin records sequences from the mid-Palaeozoic (Tumblagooda Sandstone) to Cretaceous (Toolonga Calcilutite) (Mory et al., 2005). The Kockatea Shale, a prominent source rock in the Perth Basin, ranges from the Late Permian (Changhsingian) to the Early Triassic (Olenekian) crossing the EPME boundary (Grice et al., 2005; Haig et al., 2015). It is defined by alternating beds of organic rich shales, siltstones and fine sandstones. The basal Kockatea Shale is assigned to the Hovea Member, which is topped by a limestone marker. The Hovea Member crosses the Permian – Triassic boundary (Haig et al., 2015).

The west Australian stromatolite occurrence has been tentatively assigned to the limestone marker of the Hovea Member (Chen et al., 2014; Mory et al., 2005). Previous work focused on trace fossils in the shales overlying the stromatolites and developing a palaeo-depositional model for the Early Triassic (Chen et al., 2012; Chen et al., 2014; Mory et al., 2005).

The stromatolites have been reported from one locality (Chen et al., 2014) only, however, in this research the stromatolites distribution is reported and mapped more extensively than previously thought. Morphological changes in the stromatolites are linked with environmental and biological drivers. With a revised palaeo-environmental model proposed based on observations of the sedimentological characteristics of the stromatolite unit and units above and below it.

RESULTS AND DISCUSSION

Detailed mapping of the stromatolite unit reveals a lateral distribution extending over 8 km north to south (Figure 1). The stromatolites are growing on three different substrates; the Mid-Palaeozoic Tumblagooda Sandstone, a bi-modal conglomerate and a cobble conglomerate.

The bi-modal conglomerate has sub-angular, moderate-sphericity quartz clasts of 10 – 100 mm suspended in a matrix of medium-grained quartz. The cobble conglomerate in contrast has lithic clasts of the underlying Tumblagooda Sandstone as well as quartz pebbles. The cobble conglomerate is composed of 40% clasts within a matrix of medium-grained sandstone, which dominantly comprises quartz. The clasts exhibit two orders of magnitude variation in size from ~10 mm to 200 mm and comprises moderate sphericity, well-rounded quartz (ca. 70 %) and moderate sphericity, sub-angular fragments of Tumblagooda Sandstone. The nature of these conglomerates suggest a mass depositional system, such as a fan deposit, in contrast to a wave cut platform lag proposed by Chen et al. (2014).

Growing directly atop the conglomerates are stromatolites, which display three primary morphologies, smooth domal, columnar and micro-digitate. Smooth domal stromatolites are predominantly spherical, with diameters of 20–60 cm and maximum heights of 15 cm. Elongate 'tear' shaped domal structures also exist with their long axes trending 023–061º. In some instances, smooth laminae blanket individual domes forming a larger dome.

Columnar stromatolites have diameters of 6–8 cm and amplitudes of ~2 – 3 cm. The base of the columnar structures have clast nuclei. There appears to be a positive correlation between the size of the clasts and the diameter of columnar and smooth domal stromatolites. Columnar structures are tightly packed with interstitial gaps between domes up to 5 cm. Trace amounts of detrital material (chiefly quartz) is preserved within the columnar structures. Structural lows between columns are infilled with sub-angular, medium-grained quartz grains.

Micro-digitates have individual diameters of ~6–10 mm with branching columns. Sub-angular, medium- to coarse-grained quartz infills spaces between the structures. Detrital material appears to perpetuate micro-digitate growth. In some cases it provide a substrate for micro-digitate growth, with thrombolytic textures at the base of the structure transitioning into stromatolitic textures. In some instances branches of micro-digitate structures merge together to form broad smooth domes, whereas others are capped by quartz grains preventing further growth.

Regionally the stromatolites morphologies alternate vertically, between columnar, smooth domal and micro-digitates (Figure 2). The transitions between the different morphologies is primarily gradual, however, is quite abrupt in some areas. A minimum of four morphological transitions has been identified across the region.

Where the stromatolites are growing directly on the conglomerates, they exhibit columnar and smooth domal morphologies. The stromatolites nucleate directly on top of the clasts, with the clast size and shape directly influencing the nature of the dome or column developed. Where there are no conglomerates present, the stromatolites form either smooth laminae or micro-digitate structures.

The stromatolites are directly overlain with Olenekian shales of the Kockatea Shale (Chen et al., 2014). The shales onlap onto the stromatolite layer, indicating a temporal gap between stromatolite growth and deposition of the shales.

A revised palaeo-environmental model is proposed for when the stromatolites grew. A marine system, likely in an intracontinental ocean setting, with shallow basinal margins defined by the mid-Palaeozoic Tumblagooda Sandstone. Mass flow deposits, defined by the conglomerates, come off the margins. Stromatolites grow atop the conglomerates and sandstone basement in shallow marine conditions. Embayments protect stromatolites from storm events.

The stromatolites have previously been associated with the Early Triassic Kockatea Shale (Chen et al., 2012; Chen et al., 2014; Mory et al., 2005). However, the onlapping relationship between the stromatolites and the Kockatea Shale indicates a temporal gap between the two units. The stromatolites are conformable with the underlying conglomerates, which unconformably overlie the Mid-Palaeozoic Tumblagooda Sandstone. Therefore, the age range for the stromatolites can fall anywhere between the Olenekian, based on ammonoids found in the upper Kockatea Shale (Chen et al., 2014), and the Silurian, based on Hockings (1991) review of the Tumblagooda Sandstone.

Figure 2. Stromatolites growing atop a conglomerate (Cg), with stromatolite morphologies alternating between smooth domal (S) and microdigitate (D) structures.

CONCLUSIONS

Overall, the stromatolites demonstrate significant vertical complexity with a minimum of four alternating phases of growth. These phase changes have been associated with changes in environmental conditions and microbial drivers.

A revised palaeo-environmental model is proposed for the west Australian margin following the EPME, in an intracontinental marine setting, with the conglomerates as part of a mass depositional flow, rather than as a lag at the base of a wave cut platform proposed by Chen et al. (2014). The stromatolites grow directly atop the conglomerates, on which the Kockatea Shale onlaps. The onlapping relationship demonstrates a significant temporal gap between the two units. Hence, the stromatolites are not likely to be part of the EPME biotic recovery.

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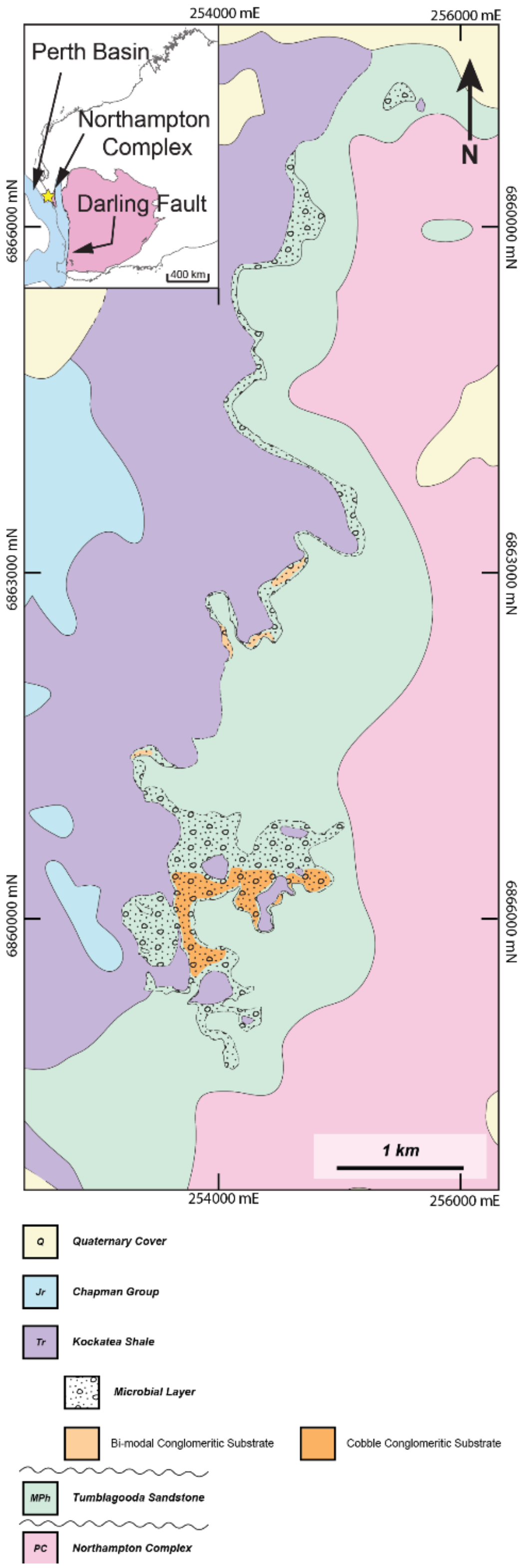

Figure 1. Geological map of study area, showing the distribution of stromatolites growing on three different substrates.

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