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Palaeoproterozoic terrestrial sedimentation in the Beasley River Quartzite, lower Wyloo Group, Western Australia

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ABSTRACT

Pre-2.2 Ga aeolianite deposits are relatively rare in the geological record, due to reworking of aeolianites either by fluvial systems, transgression or non-recognition. Here, we present high resolution sedimentary facies analysis of a section through the 2.2 Ga Beasley River Quartzite, lower Wyloo Group, Western Australia. The unambiguous presence of terrestrial (fluvial-aeolian) deposition is documented in the form of fluvial architectural elements (channel, bar, lateral accretion and overbank deposits) and aeolian features (dune, pin-stripe lamination, wind streaks, and adhesion features). These observations contrast strongly with a previous interpretation of marine deposition, which is discounted. Our data is consistent with the dominantly terrestrial depositional mode of the rest of the lower Wyloo Group, including the basal Three Corners Conglomerate Member and the subaerial Cheela Springs Basalt. We conclude that the lower Wyloo succession formed in a terrestrial regime during continental rifting.

1. Introduction

The deposition of aeolian deposits in arid subtropical regions lacking vegetation on Recent Earth has been used to imply that pre-vegetational Precambrian sedimentary successions should be replete with aeolian deposits (Eriksson and Simpson, 1998). Although aeolian deposits are well documented from the late Palaeoproterozoic to the Neoproterozoic (Table 1 in Eriksson and Simpson, 1998), early Palaeoproterozoic to Archaean aeolinites are rare (cf. Simpson et al., 2004, 2012; Chakraborty and Sensarma, 2008). This rarity is enigmatic, as the facies commonly associated with aeolian deposits—such as braided fluvial and coastal successions—are generally well preserved in modern environments. The rarity of pre-2.2 Ga aeolianites has been explained as a consequence of reworking, either by braided rivers across non-vegetated floodplains or transgression, or their non-recognition (Eriksson and Simpson, 1998; Eriksson et al., 1998).

The Beasley River Quartzite (BRQ) of the lower Wyloo Group, Western Australia (Trendall, 1979; Martin et al., 2000) is a thick succession of clastic sedimentary rocks that unconformably overlies the 2.4–2.3 Ga Turee Creek Group and is conformably overlain by the 2.2 Ga Cheela Springs Basalt (Martin et al., 1998; Müller et al., 2005). The BRQ has been interpreted as largely shallow marine (Thorne and Seymour, 1991), or fluvio-marine with offshore tidal channel and sandbar facies (Martin et al., 2000).

However, a problem with previous models of BRQ deposition is that no detailed facies analysis was undertaken and inferences regarding the depositional environment was solely based on the petrography of the clastic rocks and statistical analysis of palaeocurrent data (Martin et al., 2000; their Table 1 and references therein). Furthermore, the interpreted marine environment contrasts with a demonstrably subaerial mode of eruption of the conformably overlying Cheela Springs Basalt (a 4 km thick succession of stacked, amygdaloidal flows), and a clearly fluvial depositional environment of the lowermost member of the BRQ, the Three Corners Conglomerate Member (cf. Trendall, 1979).

The lower Wyloo Group outcrops around the Hardey Syncline (Fig. 1) and presents an ideal and unique opportunity to reconstruct the fluvial and aeolian depositional systems. Detail stratigraphic analysis of the lower Wyloo Group over a broad area is under progress. In this paper, we present sedimentary facies analysis of a section through the BRQ in the Hardey Syncline area (Fig. 1), where the sedimentary succession is well preserved. In significant contrast to the existing interpretation, our sedimentary facies analysis reveals that the Baesley River Quartzite includes at least a component of terrestrial deposition. This finding suggests that pre-2.2 Ga aeolianties may not be as rare as previously considered, but unreported due to non-recognition (see also Simpson et al., 2012).

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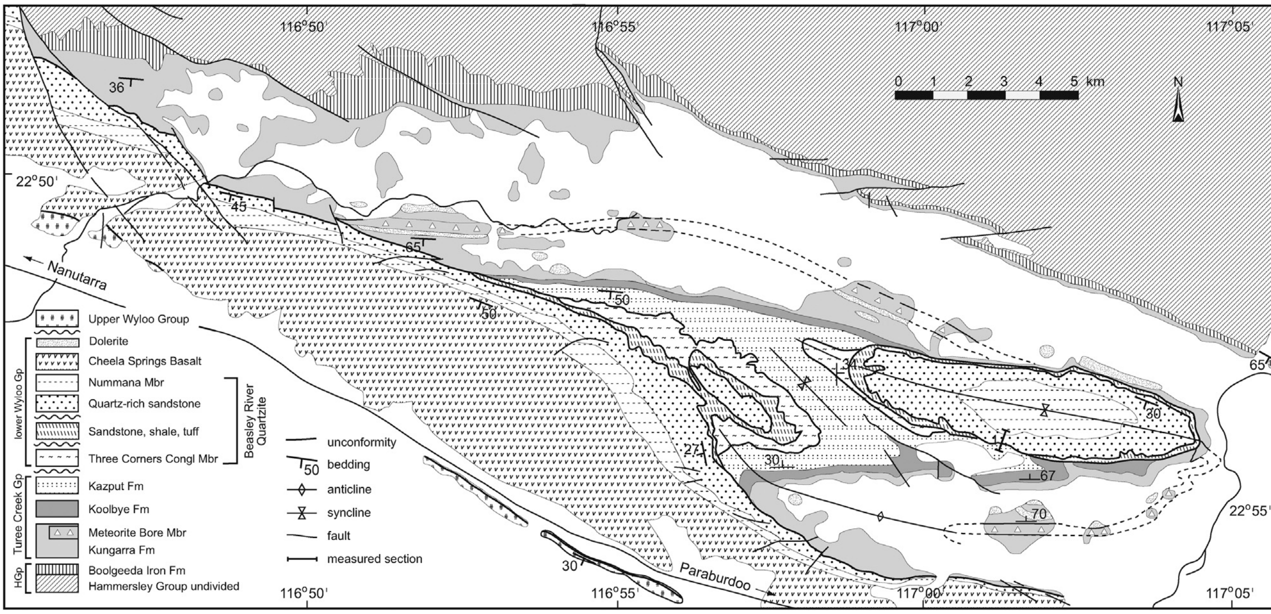

Fig. 1. Geological map of the study area, showing the disposition of the Beasley River Quartzite and bounding units.

2. Geological setting

Western Australia is one of the few places in the world that document a near-continuous record of early Earth history (Trendall and Blockley, 1970; Trendall, 1979; Van Kranendonk, 2010 and references therein; Hickman and Van Kranendonk, 2012). From the beginning of the Neoarchean, the terrestrial to marine Fortescue Group (2.78–2.63 Ga), marine Hamersley (2.63 to <2.45 Ga), and Turee Creek (<2.45 to >2.22 Ga) groups record almost continuous deposition for nearly 600 Ma, across the rise of atmospheric oxygen (Van Kranendonk, 2010; Williford et al., 2011). The Turee Creek Group is unconformably overlain by the Wyloo Group of the Ashburton Basin, which consists of low-grade sedimentary and volcanic rocks with a thickness of about 12 km (Thorne, 1990; Thorne and Seymour, 1991). The Wyloo Group has been informally divided into a lower Wyloo Group and an upper Wyloo Group (Fig. 1: Powell and Horwitz, 1994). The upper Wyloo Group unconformably overlies the lower Wyloo Group and these are unconformably overlain by the younger sequences of the Blair basin or the Breshnahan, Edmud, and Collier basins (Cawood and Tyler, 2004).

Age constraints for the lower Wyloo Group include a 2209 ± 15 Ma date for a tuffaceous component within the lower part of the Cheela Springs Basalt (Martin et al., 1998). This date is in excellent agreement with two identical dates of 2208 ± 10 Ma from the associated subvolcanic dolerite sills that were emplaced into the underlying rocks of the Beasley River Quartzite and the Turee Creek Group (Martin et al., 1998; Müller et al., 2005; Martin and Morris, 2010). Age data from detrital zircons from the Beasley River Quartzite indicate a maximum depositional age of 2446 ± 6 Ma, although the youngest individual zircon analysis is 2420 ± 18 Ma (Nelson, 2004). The upper Wyloo Group is constrained by an age of c. 1790 Ma from the June Hill Volcanics (Evans et al., 2003; Wilson et al., 2010).

The Beasley River Quartzite constitutes the lower unit of the lower Wyloo Group and consists of the basal Three Corners Conglomerate Member of conglomerate and sandstone, medium- to fine-grained quartz-rich sandstones, and an upper unit of siltstone, mudstone, and fine- to coarse-grained sandstone (Nummana Member). The quartz-rich sandstone member is characterized by large to small scale cross-bedding, low angle stratification, asymmetric current ripples and planar bedding. The basal Three Corners Conglomerate Member consists of sandstone and conglomerate, the latter with abundant, rounded to subrounded clasts (pebbles to cobbles) of banded-iron-formation (BIF) and chert within a sandy matrix rich in secondary magnetite. The Beasley River Quartzite is conformably overlain by the Cheela Springs Basalts, a 4 km thick succession of subaerial lavas.

3. Sedimentary facies

A detailed section through the main quartz-rich sandstone of the BRQ was measured on the southern limb of the Hardey Syncline (Fig. 1). Here, the Beasley River Quartzite is predominantly composed of medium- to fine-grained quartz-rich sandstone. In the measured section, two facies associations are stacked in a repetitive succession, tens-of-meters thick (Fig. 2). The facies associations include a braided fluvial facies association and inter bedded aeolian dune and inter dune facies association (Fig. 2).

3.1. Braided fluvial facies associations

The braided fluvial deposits are developed at the meter scale. Quartz-rich sandstones of this facies are poorly sorted with angular to sub-angular grains (Fig. 3A). This facies association is almost devoid of mud. The sandstones are characterized by planar, as well as trough cross-bedding. As paleocurrent determination from planar cross-beds is often problematic (High and Picard, 1974 and references therein), we have collected paleocurrent data (trough axis azimuth) from three-dimensional bedding plane exposures with spectacular trough cross-beds. Paleocurrent analysis has been done following the methodology prescribed by Dott (1974) and High and Picard (1974). As the dip of bedding is <25°, no tilt correction has been done (cf. Ramsay, 1961; Dott, 1974). Eight facies constitutes the braided fluvial association and differ from each other in type, scale and associated primary sedimentary structures. Individual sedimentary facies with Miall's facies and architectural element nomenclature (Miall, 1985) are described below.

3.1.1. Thick, lenticular, medium-grained trough cross-stratified sandstone (CH)

This facies is characterized by lenticular, medium-grained sandstone with trough cross-beds (Fig. 3B). The thickness of trough