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Sedimentology, chemostratigraphy, and stromatolites of lower Paleoproterozoic carbonates, Turee Creek Group, Western Australia

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ABSTRACT

The ca. 2.45–2.22 Ga Turee Creek Group, Western Australia, contains carbonate-rich horizons that post-date earliest Proterozoic iron formations, bracket both Paleoproterozoic glaciogenic beds and the onset of the Great Oxidation Event (GOE), and predate ca. 2.2–2.05 Ga Lomagundi-Jatuli C-isotopic excursion(s). As such, Turee Creek carbonate strata provide an opportunity to characterize early Paleoproterozoic carbonate sedimentation and carbon cycle dynamics in the context of significant global change. Here, we report on the stratigraphy, sedimentology, petrology, carbon isotope chemostratigraphy, and stromatolite development for carbonate-rich successions within the pre-glacial part of the Kungarra Formation and the postglacial Kazput Formation.

Kungarra carbonate units largely occur as laterally discontinuous beds within a thick, predominantly siliciclastic shelf deposit. While this succession contains thin microbialite horizons, most carbonates consist of patchy calcite overgrowths within a siliciclastic matrix. C-isotopic values show marked variation along a single horizon and even within hand samples, reflecting spatially and temporally variable mixing between dissolved inorganic carbon in seawater and isotopically light inorganic carbon generated via syn- and post-depositional remineralization of organic matter.

In contrast, the Kazput carbonates consist of subtidal stromatolites, grainstones, and micrites deposited on a mixed carbonate–siliciclastic shelf. These carbonates exhibit moderate $\delta^{13}C$ values of −2‰ to +1.5‰ and likely preserve a C-isotopic signature of seawater. Kazput carbonates, thus, provide some of the best available evidence that an interval of unexceptional C-isotopic values separates the Lomagundi-Jatuli C-isotopic excursion(s) from the initiation of the GOE as inferred from multiple sulfur isotopes (loss of mass independent fractionation). The Kazput Formation also contains unusual, m-scale stromatolitic buildups, which are composed of sub-mm laminae and discontinuous, convex upward lenticular precipitates up to a few mm in maximum thickness. Laminae, interpreted as microbial mat layers, contain quartz and clay minerals as well as calcite, whereas precipitate lenses consist of interlocking calcite anhedra, sometimes showing faint mm-scale banding. These cements formed either as infillings of primary voids formed by

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gas emission within penecontemporaneously lithified mats, or as local seafloor precipitates that formed on, or within, surface mats. It is possible that both mechanisms interacted to form the unique Kazput stromatolites. These microbialites speak to a distinctive interaction between life and environment early in the Paleoproterozoic Era.

1. Introduction

Lower Paleoproterozoic sedimentary rocks record a number of first-order changes in the Earth system, including globally extensive ice sheets, one or more extreme states of the carbon cycle characterized by uniquely high $\delta^{13}C$ in carbonates, and the initial accumulation of oxygen in the atmosphere and surface oceans (Akin et al., 2013; Asael et al., 2013; Bekker and Holland, 2012; Bekker et al., 2004, 2013; Farquhar et al., 2000; Fralick et al., 2011; Hoffman, 2013; Konhauser et al., 2011; Lyons et al., 2012, 2014; Melezhik and Fallick, 2010; Partin et al., 2013; Planavsky et al., 2012, 2014; Pufahl and Hiatt, 2012; Pufahl et al., 2010, 2011; Reinhard et al., 2013; Scott et al., 2014; Swanner et al., 2014; and references therein). Co-occurring global glaciation, carbon isotopic variation, and redox change also characterize Neoproterozoic rocks, and for this younger interval, carbonate strata have played an important role in both recording key events and providing context for the interpretation of these events (e.g., Halverson and Shields-Zhou, 2011; Johnston et al., 2012). Detailed analyses of platform and shelf carbonates are available for Neoarchean successions [e.g., the Campbellrand/Malmani subgroups of the Transvaal Supergroup, South Africa; (Knoll and Beukes, 2009; and references therein)] and younger Paleoproterozoic rocks (e.g., 2 Ga platform carbonates of the Slave Province, Canada; (Hotinski et al., 2004)). To date, however, relatively few studies have focused on lower Paleoproterozoic carbonates, despite their potential importance in understanding early Paleoproterozoic evolution and environmental change.

The ca. 2.45–2.22 Ga Turee Creek Group, exposed in the Hamersley Range of Western Australia, conformably overlies earliest Paleoproterozoic iron formations, predates the ca. 2.2 Ga onset of the Lomagundi-Jatuli C-isotopic excursion(s), and hosts carbonate and glacially-influenced strata that record onset of the Great Oxidation Event (GOE) (Bekker et al., 2004; Martin et al., 2013; Van Kranendonk and Mazumder, 2015). Thus, these carbonates provide an opportunity to characterize the response of early Paleoproterozoic carbonate deposition and carbon cycle dynamics to significant global change, including the GOE and glaciation. Here, we report on the stratigraphy, sedimentology, carbonate petrology, carbon isotope chemostratigraphy, and stromatolite development in two closely spaced sections of the Kazput Formation of the upper Turee Creek Group. We also report lithological and isotopic data from three parallel stratigraphic sections from the older Kungarra Formation of the lower Turee Creek Group. Together, these data place carbonate strata of the Turee Creek Group in the context of profound global change following the early oxygenation of Earth's surface environments.

2. Geologic setting

The Turee Creek Group of the Mount Bruce Supergroup is the youngest sedimentary succession within the Hamersley Basin of the Pilbara Craton (Trendall, 1990). Turee Creek Group rocks conformably overlie iron formations of the Hamersley Group and sit unconformably beneath sedimentary and volcanic deposits of the Wyloo Group (Fig. 1) (Horwitz, 1982; Thorne, 1990; Thorne and Seymour, 1991; Trendall, 1969; Trendall et al., 1983). Initial research suggested conformable relationships throughout the Proterozoic stratigraphy of Western Australia (e.g., Trendall and Blockley, 1970), but continuing stratigraphic and geochronological studies have since identified significant unconformities and deformational events that point to a protracted, but episodic, depositional history spanning more than 330 Myr (Martin et al., 2000; and references therein).

Palinspastic reconstructions and basin analysis of upper Hamersley Basin and lower Wyloo Group stratigraphy led Horwitz (1982) to propose a post-Hamersley depositional feature, called the McGrath Trough, that reflects flexural subsidence driven by peripheral or retroarc foreland basin development (Horwitz, 1982; Krapež, 1996; Martin, 1999; Martin et al., 2000; Powell and Horwitz, 1994). The foreland-related tectonostratigraphic sequence most likely involves the Turee Creek and lower Wyloo groups (Martin et al., 2000); however, some authors have argued that it only involves the Turee Creek Group (e.g., Blake and Barley, 1992; Krapež, 1996) or both the Turee Creek and entire Wyloo groups (e.g., Thorne and Seymour, 1991; Tyler and Thorne, 1990). More recently, Van Kranendonk et al. (2015) suggested the Turee Creek Group was deposited in an intracratonic basin. Regardless of McGrath dynamics, the 3–4 km thick Turee Creek Group records rapid lateral facies change (e.g., Martin et al., 2000 and references therein).

The Turee Creek Group consists, in stratigraphic order, of the Kungarra (including the glaciogenic Meteorite Bore Member), Koolbye, and Kazput Formations (Fig. 1) (Thorne et al., 1995; Trendall, 1979, 1981). It is bracketed in age by the 2449 ± 3 Ma Woongarra Rhyolite (Barley et al., 1997) near the top of the underlying Hamersley Group and the 2209 ± 15 Ma Cheela Springs Basalt (Martin et al., 1998) low in the unconformably overlying Wyloo Group succession (Fig. 1). Müller et al. (2005) reinterpreted the Cheela Springs date as a reflection of provenance rather than crystallization age, but their U–Pb age on baddeleyite of 2208 ± 15 Ma for diorite sills that cut the Turee Creek Group provides an essentially indistinguishable minimum age constraint. The Kungarra Formation of the Turee Creek Group is further constrained to be younger than ca. 2420 Ma, based on U–Pb ages of detrital zircons in the Meteorite Bore Member (Takehara et al., 2010). Turee Creek Group strata record a broad shallowing-upward profile from deep-water banded iron formation (the Boolgeeda Iron Formation of the underlying Hamersley Group), through fine-grained siliciclastic deposits of the Kungarra Formation, to fluvial and shallow marine strata of the Koolbye and Kazput Formations.

Although detailed correlation with other Paleoproterozoic successions is challenging, Turee Creek Group strata record two events that guide interbasinal correlation. First, Williford et al. (2011) documented mass independent sulfur isotope fractionation, a proxy for the near-absence of environmental oxygen (Farquhar et al., 2000), in the lower part of the Meteorite Bore Member of the Kungarra Formation. On this basis, the authors suggested that the lower glaciogenic unit of the Meteorite Bore Member, locally in contact with the Boolgeeda Iron Formation, was deposited during the final stages of the GOE, when oxygen levels were still low enough for the development of MIF-S, but sufficiently high for oxidative weathering of continental sulfides and significant sulfur isotope fractionation.

The glacial character of the Meteorite Bore Member and a second recently discovered unit of glacial diamictite in the Kungarra Formation provide a means of correlation to other Paleoproterozoic