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Chemostratigraphy and palaeo-environmental characterisation of the Cambrian stratigraphy in the Amadeus Basin, Australia

Susanne Schmid

CSIRO Mineral Resources, 26 Dick Perry Ave., Kensington, 6151 WA, Australia

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ABSTRACT

The sedimentary succession of the central Australian Amadeus Basin consists of Neoproterozoic to Carboniferous sedimentary rocks and contains shallow marine, subtidal carbonates of Middle to Late (Series 2 to Furongian) Cambrian age. A combination of sequence stratigraphy, geochemistry and mineralogy shows a transgressive 2nd order cyclicity deposited between ~511–490 Ma and a change from arid, low energy to humid, high energy depositional environments. This is reflected in an initially evaporitic sequence with upward decreasing halite and anhydrite abundance and transition from oxygenated to anoxic conditions, reflected by the Fe mineral species change from hematite to pyrite during transgression. Sequence boundaries of several 3rd order cycles consisting of HST carbonate rocks and LST siltstones, correlate with globally recognised sequence boundaries linked to the inferred eustatic sea level record for the upper two series of the Cambrian System. The carbon isotope record for this ~1400 m thick succession in combination with biostratigraphic age correlation allowed the identification of the globally recognised Steptoean Positive Carbon Isotope Excursion (SPICE), Drumian Carbon Isotope Excursion (DICE) and Redlichiid-Olenellid Extinction Carbon Isotope Excursion (ROECE).

1. Introduction

The Cambrian stratigraphy of the Amadeus Basin consists of post-orogenic, pre-rift Early Cambrian and post-rift Middle to Late Cambrian shallow marine sedimentary successions. The complex, halokinetic-driven tectonic framework of the 170,000 km^2 sized basin has a minimum thickness of ~1800 m, can reach up to 8 km thickness (Schmid et al., 2016), and is part of the Centralian Superbasin (Lindsay, 2002). The Centralian Superbasin covered much of northern and central Australia in the late Early Cambrian and reached its maximum Phanerozoic extend in the Middle Cambrian during continental-scale transgression (Munson et al., 2013). Babcock et al. (2015) recently presented a global 3rd order cyclicity throughout the Cambrian Series 3 and Furongian, but this record is mainly limited to studies in China. Distinct faunal assemblages and sequence stratigraphic studies helped to correlate between all the basins (e.g. Shergold et al., 1988; Kennard, 1994). However, biostratigraphic correlation in the Amadeus Basin is limited to regional correlation with the Georgina Basin, and lacks Global Boundary Stratotype Section and Point (GSSP) markers, commonly represented by first appearance of trilobite species in the Cambrian. Chemostratigraphy can significantly complement the biostratigraphic framework, but has been subject to limited studies in central Australia (Lindsay et al., 2005; Creveling et al., 2014) and South Australia (Retallack et al., 2014).

Global carbon isotopic trends in sedimentary carbonate rocks can be related, simplistically, to changes in the global carbon budget (e.g. emission of CO_2 from large igneous provinces), eustatic sea level fluctuations, and variations in rate of organic carbon burial (e.g. Lerman and Clauer, 2013; Veizer et al., 1999; Wendler, 2013). The bulk $\delta^{13}C$ signature in carbonates is not commonly effected by diagenesis unless an extra carbon source is introduced, e.g. due to hydrothermal fluids (more negative) or due to methanogenesis (more positive, Jiang et al., 2012). Carbonates that form without any other source of carbon would have the same value as the atmosphere (−6.5‰ pre-industrial) if in equilibrium. In marine to open-shallow marine systems, dissolved inorganic carbon (DIC) and deep sea sedimentary carbonates have values of ~0‰, while the oxic ocean waters are more positive with ~ + 2‰ (Sarmiento and Gruber, 2006; Wendler, 2013; Kump and Arthur, 1999). Any fractionation of C due to photosynthesis by marine phytoplankton leads to $\delta^{13}C$ values of ~−22‰. Major global isotopic excursions are commonly accompanied by mass extinctions (Kump, 2013) and euxinia, which can result in accumulation of organic-rich sediments.

A combination of mineralogical, geochemical methods and sedimentological observations were used to understand the palaeo-environmental conditions and associated isotopic variations in the Cambrian Amadeus Basin succession. This paper focusses on 1) palaeo-

E-mail address: susanne.schmid@csiro.au.

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environmental characterisation of the Cambrian succession and its relation to sea level changes, and 2) chemostratigraphic correlation to the global carbon isotope curve.

2. Geological setting

The Neoproterozoic to Palaeozoic Amadeus Basin is part of the Centralian Superbasin (Walter et al., 1995), located in central Australia (Fig. 1a). The geology of the Amadeus Basin comprises of 1) Neoproterozoic sedimentary and glacial rocks, and 2) Cambrian (Fig. 1b) to Carboniferous sedimentary rocks, including several major unconformities. The current structural framework has been modified by salt tectonics as a result of the Petermann Orogeny (~570–530 Ma, Close et al., 2003; Li and Evans, 2011) and Alice Springs Orogeny (~450–300 Ma, Haines et al., 2001). The basin mostly overlies metamorphic and igneous basement rocks of the Palaeo- to Mesoproterozoic Arunta Region and Musgrave Province. The Cambrian stratigraphy of the region was originally defined lithostratigraphically in the 1960s (see Shergold, 1986; and references within) and was later refined (e.g. McIlroy and Heys, 1997; Smith et al., 2015a; Smith et al., 2015b).

The upper **Arumbera Sandstone** is of Early Cambrian, Terreneuvian (541–521 Ma) age based on rare occurrences of small shelly fossils (Haines, 1991) and trace fossil *Plagiogmus* (McIlroy and Heys, 1997), and represents the oldest Cambrian sedimentary rocks in the Amadeus

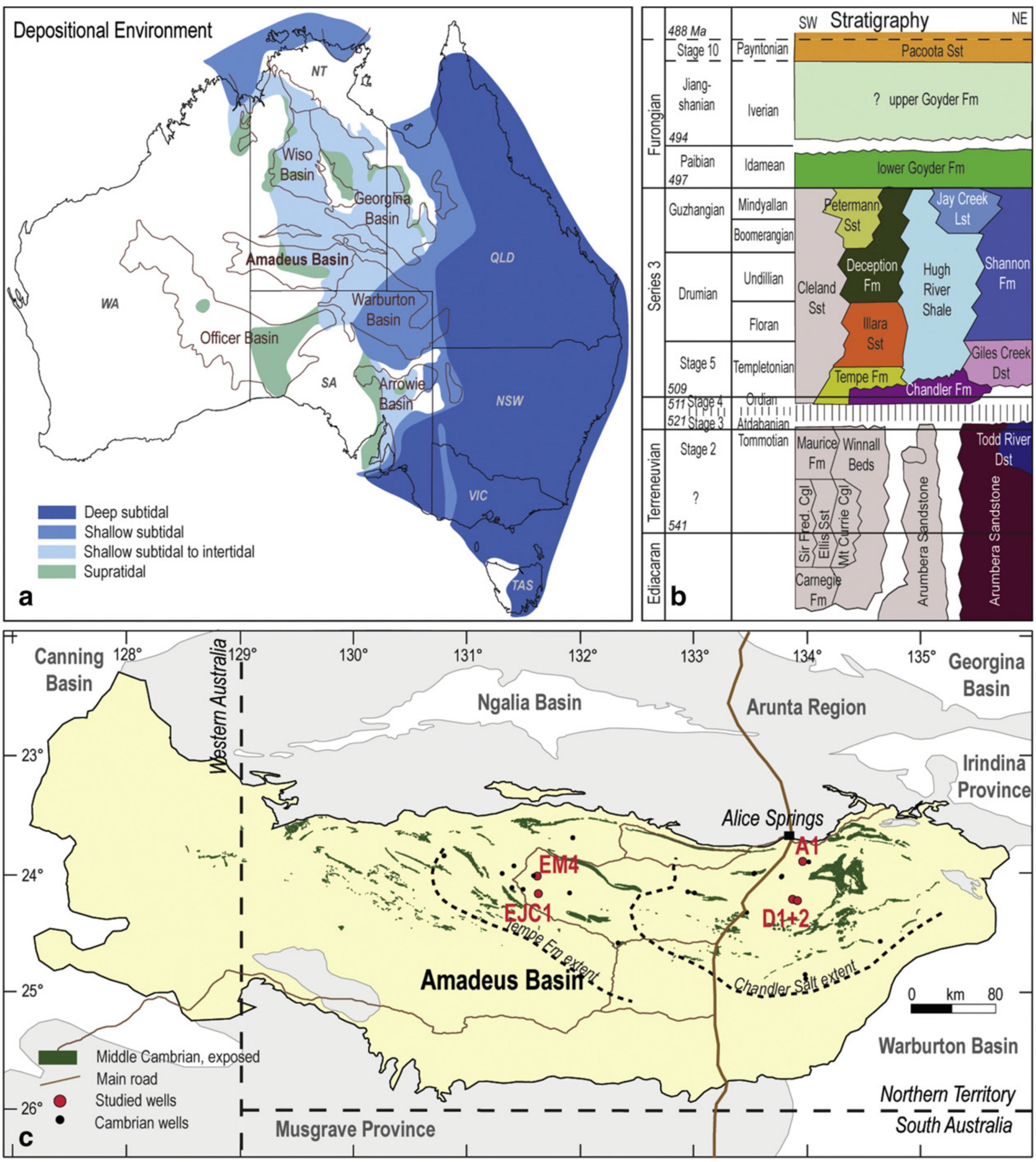

Fig. 1. a) Map of Australian Cambrian-Ordovician Basins and interpreted depositional environment during the middle Cambrian (with minor modifications from Munson et al., 2013); b) Stratigraphy of the Amadeus Basin based on Edgoose (2013) with minor modifications; c) Geological map showing exposed Cambrian sedimentary rocks, known extent of the Tempe Formation and Chandler Salt, as well as locations of studied petroleum wells (EM4 – East Mereenie 4, EJC1 – East Johnny's Creek 1, D1 – Dingo 1, D2 – Dingo 2, A1 – Alice 1). Note that age constraints in Western Australia is very poorly constrained and thus not shown here.