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Stratigraphic architecture and evolution of a barrier seagrass bank in the mid-late Holocene, Shark Bay, Australia

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ABSTRACT

Within the Faure Sill complex (Shark Bay, Western Australia), a combination of remote sensing analysis, seismic stratigraphy and cores to ground truth, together with radiocarbon dating, demonstrate the interconnection between sediment body morphologies, seagrass related substrates and pre-existing topography and reveal the system as a channel–bank complex. Sea level fluctuations appear to have largely controlled the hydrodynamic conditions of the bank, contributing to each stage of its evolution. 1) Not earlier than 8.5–8.0 ka BP, in a lowstand period, after an erosive event of underlying palaeosurfaces, seagrass establishment progressively contributed to initiating bank growth. 2) Around 6800 years BP, bank accumulation reached its apex, in conjunction with a rapid sea transgression. 3) During the Late Holocene, succeeding a slow decline to present sea level, bank growth continued to fill available accommodation space and a number of hiatuses, indicating temporal and spatial discontinuities within the process of bank building, are recognised. Average depositional rates of bank building (1.3 m/ka) conform to previous estimates derived for seagrass banks but rates are strongly facies dependent, attesting to the dynamic nature of this channel–bank complex. The extensive seagrass meadows are essential for a wide range of aspects of the environment of the Shark Bay area. Not only are they particularly important for the entire shallow benthic ecosystem, but they also had a major role in the partial closure of the southern basins and hence determining the development of hypersaline conditions and associated oolitic microbial and evaporitic facies in Hamelin Pool and L'Haridon Bight. Moreover, this system has a critical role in producing, sequestering and storing organic carbon.

1. Introduction

Registered as a World Heritage Property in 1991 on the basis of its “natural heritage” values (Hancock et al., 2000), Shark Bay is located approximately 800 km north of Perth on the west coast of Australia (Fig. 1A). It has a “W” shape, open to the Indian Ocean to the north and divided by the Peron Peninsula into two narrow gulfs: Freycinet Basin on the western side and L'Haridon Bight and Hamelin Pool, to the east (Fig. 1B). Faure Sill, a seagrass bank, is one of Shark Bay's most notable structures, lying approximately between 25° 45′ S and 26°30′ S and 113° 40′ E and 114° 15′ E (Fig. 2), orientated east–west across the axis of the Hamelin and L'Haridon hypersaline basins and covering an area of around 1000 km^2 (Davies, 1970a). The bank extends from Kopke Point (Gladstone Embayment/Wooramel Complex) to Faure Island, Petit Point (Nanga Peninsula) and to Dubaut Point (southern part of Peron Peninsula); it is nearly emergent at Faure and Pelican Islands and it is characterised by shallow water and relatively deep and broad channels, mainly north–south oriented (Fig. 2).

The two most prominent natural assets of Shark Bay are stromatolites and seagrass. Stromatolites are common in fossil sequences, widely recorded back to the Precambrian (Schopf, 1993; Allwood et al., 2006), but rare in modern waters, where their occurrence is limited to some locations in Western Australia, in the Bahamas and in a few other places elsewhere (e.g. Dravis, 1983; Cohen et al, 1993; Moore and Burne, 1994; Jahnert and Collins, 2013). It is well known that seagrass communities provide a wide range of services (Duarte, 2002; Gibbes et al., 2014). They are fundamental in controlling fluid dynamics across the bank where they reside (Fonseca et al., 1982; Belperio et al., 1984; Verduin and Backhaus, 2000; Koch et al., 2006). The extensive seagrass meadows at Shark Bay, the largest reported assemblage in the world (Walker, 1990), has had a significant control during Holocene time on the sedimentary regime and the growth of the bank, leading to major environment changes, which have caused a partial closure of the southern basins of Hamelin Pool and L'Haridon Bight (Davies, 1970b; Logan et al., 1970a,b; Hagan and Logan, 1974; Read, 1974; Walker, 1985; Walker and Woelkerling, 1988; Walker et al., 1988; Jahnert and Collins, 2013; Collins and Jahnert, 2014). Its role in reducing the rate of water flowing through the sill has resulted in a decrease or loss of

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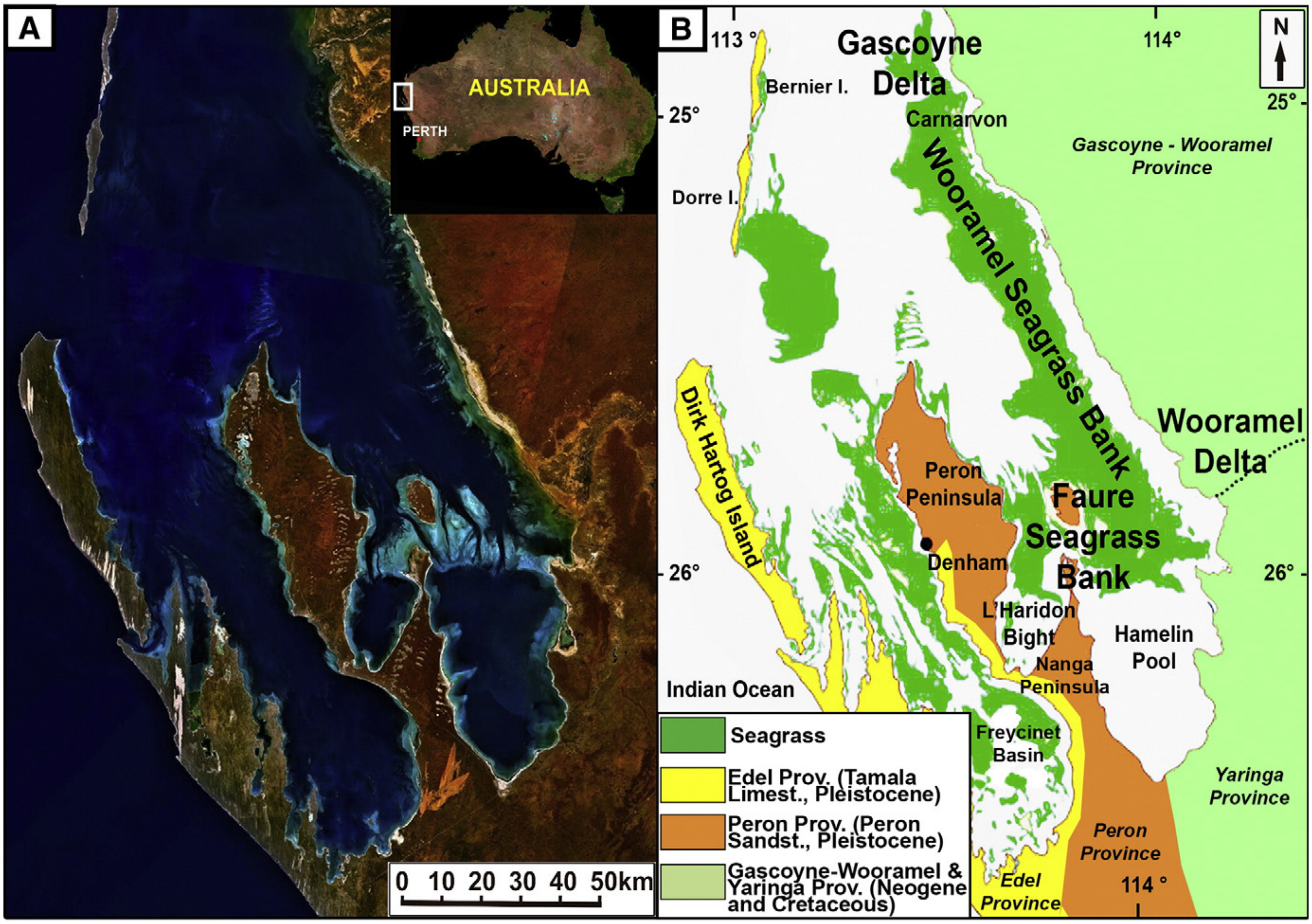

Fig. 1. A) Aerial view of the area from Geoscience Australia. B) Simplified map of Shark Bay, with seagrass distribution. The two most notable banks are the Faure and Wooramel seagrass banks, adjacent to the Wooramel and Gascoyne Deltas.
Modified from Walker et al. (1988), Jahnert and Collins (2013), Playford et al. (2013) and www.sharkbay.org.

sediment movement, which is trapped and bound by the roots and rhizomes, stabilising and enhancing the accretion of the seabed (Walker et al., 1999). The thick meadow acts as protection from cyclones and other severe conditions and, as well, prevents erosion of the seafloor (Walker, 1990; Duarte, 2002). Moreover, epiphytes and other organisms (such as molluscs and foraminifera), which live in their rhizomes, produce a significant amount of calcium carbonate and play an important role in the deposition and accumulation of sediment (Hagan and Logan, 1974; Walker and Woelkerling, 1988). Barrier banks, climatic conditions and restricted tidal exchange control the salinity of the enclosed waters (Logan and Cebulski, 1970), creating unique environments with metahaline to hypersaline conditions, which provide a basis for the development of a variety of biogenic and physical structures such as microbial communities (stromatolites) and oolitic shoals (Jahnert and Collins, 2013). Thus, explaining the evolution of the seagrass banks is crucial to understanding the development of the hypersaline facies association in basins to the south.

During the 1970s, pioneering research was described in two American Association of Petroleum Geologists Memoirs (Logan et al., 1970b, 1974) and subsequent work undertaken by Playford and Cockbain (1976) Playford (1990), Chivas et al. (1990). Recent research has provided the first detailed regional evaluation of the subtidal microbial system and tidal flat evolution (Jahnert and Collins, 2011, 2012, 2013; Collins and Jahnert, 2014).

Besides these local values, seagrass banks provide global ecosystem services. For instance, seagrass meadows are involved in producing, sequestering and storing organic carbon (Duarte, 2002; Grimsditch et al., 2012; Duarte et al, 2013; Lavery et al., 2013) and significantly contributing to carbon, nitrogen and phosphorus cycles in the ocean (Fourqurean et al., 2012). Moreover, the wider Gascoyne Delta–Wooramel Bank–Wooramel Delta–Faure Sill system (Fig. 1B) has potential as an analogue for some Browse Basin hydrocarbon reservoirs in the North West Shelf, Western Australia (Barber et al., 2004; Tovaglieri and George, 2014).

To investigate the Holocene development of the Faure channel–bank complex, remote sensing imagery analysis, acoustic profiles and sedimentological information were combined, in order to correlate internal architecture, sediment bodies and lithofacies. Integrating these data with radiocarbon dating, information about the accumulation rates was obtained, together with an estimated age of bank onset. This paper reports the analyses conducted on the Faure Sill and new insights and understanding of its evolution, growth and chronology, by considering morphostratigraphic elements, channel architecture and geometry, and linking traditional research with newly developed facies associations and stratigraphic relationships.

2. Geology and environmental setting

The landscape of Shark Bay has been significantly controlled by tectonism (Butcher et al, 1984). Fold and fault systems have been shaping the geography of the area since the Palaeozoic (van de Graaff et al., 1983; Hocking et al., 1987). Anticlinal folds, oriented NNW–SSE, are responsible for the formation of peninsulas and islands and synclines are associated with the gulfs and bays (Butcher et al., 1984; Playford et al., 2013). A regional normal fault system oriented N–S has operated in