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Estuarine foraminiferal biofacies pattern compared to the brackish ichnofacies model: Port Stephens, southeast Australia

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ABSTRACT

Port Stephens, located in SE Australia, is a shallow estuary with an outer and inner basin separated by a narrow channel. Foraminiferal biofacies distribution reveals this complex physical environment. The flood-tide delta forms a transition between the wave-dominated open coast and the microtide-dominated estuary. Sand wave dynamics cause a shifting substrate, resulting in allochthonous assemblages of calcareous shelf species transported into the bay through a wide entrance. The muddy central basin is heavily bioturbated, and allows for an in-situ, mixed calcareous and agglutinated assemblage of a progressively more estuarine character. Burial of organic matter and increased bioturbation permits infaunal species to increase in abundance, but promotes calcium carbonate dissolution. The bayhead delta of the Karuah River is characterized by lithic-rich substrates that are associated with robust calcareous species. Tidal cycles, combined with low river-flux, provide nearly fully marine conditions far upstream into the Karuah River. Marginal regions, from sandy/muddy tidal flats to marsh, show distinct assemblages of opportunistic species that respond to tidal exposure, substrate variations, organic matter flux and salinities. Early diagenetic taphonomic loss, closely linked with bioturbation, needs to be considered in interpretations of microfossil assemblages. Foraminiferal biofacies analysis, in combination with the brackish-water ichnology model, is a powerful tool for recognizing Mesozoic marginal marine environments. Port Stephens, with its environmental complexity, offers a valuable modern analogue for estuarine deposits of the geological past.

1. Introduction

Estuaries are complex sedimentary and ecological systems, characterized by variable controlling factors that largely depend on the interplay between marine (wave and/or tidal) and fluvial processes. Foraminiferal communities in modern estuaries have been studied globally, demonstrating their integral part in identifying estuarine subenvironments (e.g. Albani and Johnson, 1975; Scott et al., 1980; Hayward et al., 1999; Cann et al., 2000; Debenay et al., 2003). In contrast, paleoenvironmental reconstruction of ancient counterparts in the form of coastal deposits or incised valley fills in the subsurface or outcrop is largely based on sedimentological character and ichnofacies (e.g. MacEachern and Pemberton, 1994; Zaitlin et al., 1995; Pemberton et al., 2001). Use of microfossils in classifying past coastal valley systems and their combined use with ichnofacies is poorly developed. Benthic foraminifera in modern estuaries resemble characteristics of brackish ichnofaunal communities featuring low species diversity but high abundances of opportunistic species, different feeding strategies and common infaunal species (e.g. Gingras et al., 1999; Buatois et al., 2005). Whereas sediment distribution is highly controlled by energy regimes, benthic foraminifera respond in varying degrees to salinity, temperature, pH, exposure to tidal cycles and supply of oxygen and organic matter (e.g. Scott et al., 1980; Pinxian, 1992; Hayward et al., 1999; Van der Zwaan et al., 1999; Debenay and Guillou, 2002). Therefore analysis of foraminiferal biofacies adds valuable proxies for the reconstruction of estuarine subenvironments in modern and ancient settings (Schröder-Adams, 2006).

The southeast coast of Australia has a number of estuaries that are extensively studied based on morphological and sedimentological characters (e.g. Roy et al., 2001 and references therein) and thus provide an excellent opportunity for integrated biofacies studies. In addition, their Quaternary-aged counterparts in the form of incised valley fills have been studied further seaward on the

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transgressed continental shelf (Roberts and Boyd, 2004). This paper addresses foraminiferal assemblages from Port Stephens, an estuary located on the central coast of New South Wales (Fig. 1A). This estuary was chosen for the following reasons. 1) The known sediment distribution patterns in Port Stephens distinctly outline the tripartite subdivision of a wave dominated estuary, including the flood tidal delta, central basin and bayhead delta (Fig. 1B) that delineate settings of distinct energy regimes and sediment sources (Dalrymple et al., 1992; Boyd, 2010). 2) The estuary's complex morphology of two basins separated by a narrow constriction, its wide entrance to oceanic water masses and its various fluvial sources (Fig. 1A) allows for rich foraminiferal assemblages that extend over numerous subenvironments. 3) In addition to tidal forces the wide entrance to the wave dominated margin of the Tasman Sea allows for effective exchange of marine waters resulting in widespread nearly fully marine conditions supporting

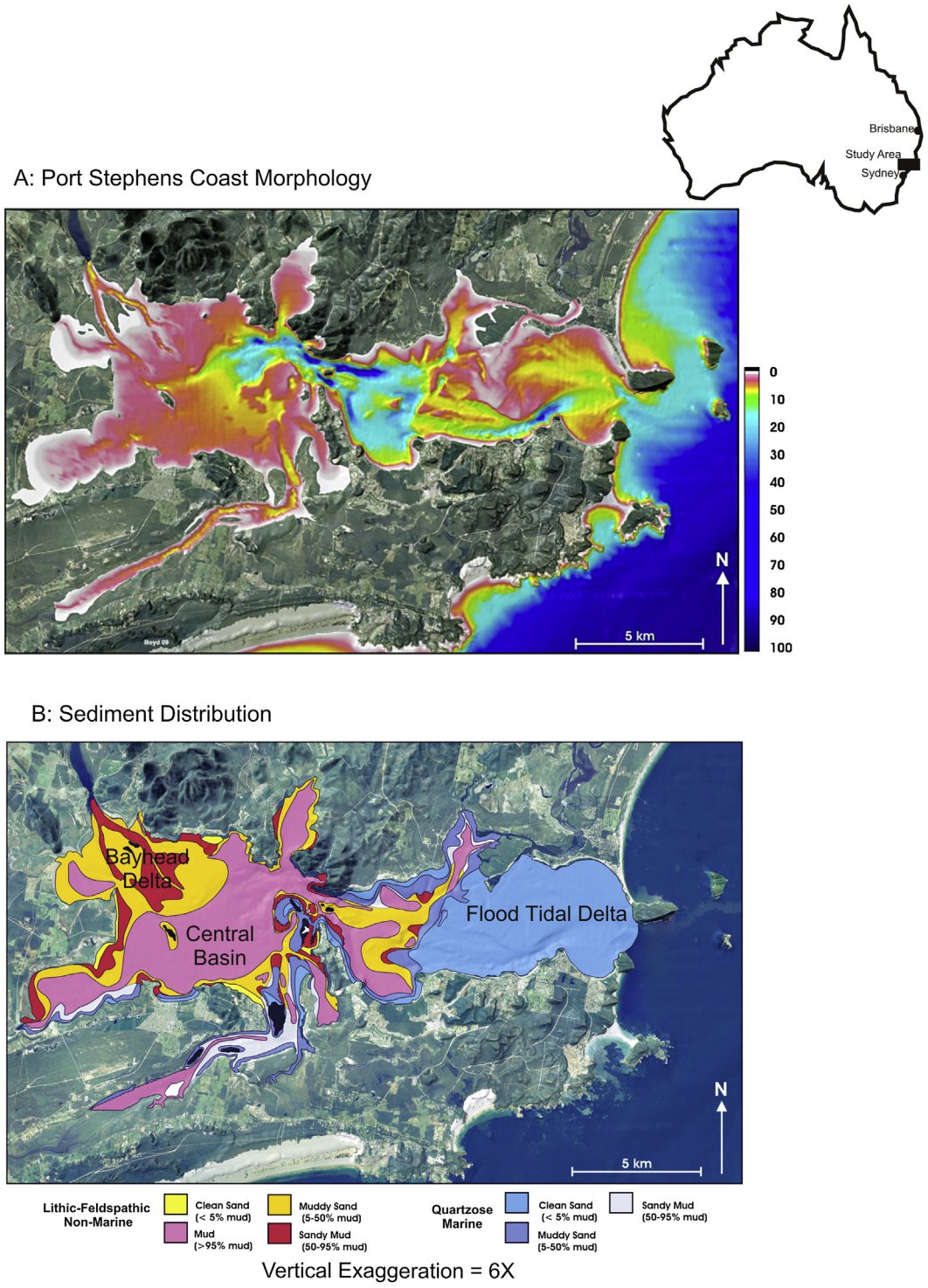

Fig. 1. A) Map illustrating the morphology of Port Stephens and surrounding areas including the transgressive coastline of NSW north of Newcastle. (Modified after Boyd, 2010). B) Sediment distribution within Port Stephens clearly outlining the flood tidal delta dominated by marine quatzose sands, the central basin characterized by finer sediments and the bayhead delta under the influence of fluvially derived litho-feldspathic sands.