Earth and Planetary Science Letters 393 (2014) 146–158

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Complex sediment deposition history on a wide continental shelf: Implications for the calculation of accumulation rates on the Great Barrier Reef

Stephen E. Lewis [a,*], Jon Olley [b], Takahisa Furuichi [c], Ashneel Sharma [c], Joanne Burton [c]

[a] Catchment to Reef Research Group, TropWATER, James Cook University, Townsville QLD 4811, Australia
[b] Australian Rivers Institute, Griffith University, Nathan, QLD 4111, Australia
[c] Chemistry Centre, Department of Science, Information Technology, Innovation and the Arts, Dutton Park, QLD 4102, Australia

ARTICLE INFO

Article history:
Received 23 December 2013
Received in revised form 12 February 2014
Accepted 15 February 2014
Available online 15 March 2014
Editor: T.M. Harrison

Keywords:
Burdekin River
optically stimulated luminescence
sediment resuspension
Great Barrier Reef
turbidity

ABSTRACT

Understanding the key processes controlling the delivery, deposition and fate of sediments on continental shelves is critical to appreciate the evolution of coasts and estuaries and to interpret geological sequences. This study presents radiocarbon and Optically Stimulated Luminescence (OSL) ages of sediment cores collected from key locations offshore from the Burdekin River, Australia, the largest single source of sediment delivered to the Great Barrier Reef (GBR) lagoon. The ages show variable sediment accumulation rates at the different locations that coincide with the Holocene avulsion history of the Burdekin River. Our data show that most fine sediment (<63 μm) delivered from the Burdekin River is retained within 50 km of the mouth, a finding that contrasts previous studies which postulated that fine sediments are advected northwards via longshore drift processes. The pairing of radiocarbon and OSL ages provides insights on resuspension regimes operating on the inner shelf of the GBR. It was thought that turbidity on inshore GBR coral reefs and seagrass meadows has increased as a result of increased erosion in the adjacent catchment from agricultural development. Our data show that the age of the sediments in Cleveland Bay (derived from the radiocarbon ages from shell and organic material) can be several thousand years older than when the sediment was last deposited (OSL ages). However, the increased turbidity could conceivably be caused from 'new biologically-produced sediment' (i.e. particulate organic matter) as a result of increased nutrient export to the GBR. We suggest that the composition of sediment in resuspension events before and after the wet season be analysed to examine whether newly delivered organic-rich sediment can affect coral reefs and seagrass meadows.

1. Introduction

Researchers have long examined the transport and fate of fluvial sediments delivered to continental shelves (Alexander and Simoneau, 1999; Puig et al., 2003; Harris et al., 2004; Fielding et al., 2006). Understanding these processes allows geological sequences to be interpreted in the context of past sea-level change and provides insights on the development and evolution of riverine deltas and estuaries. Furthermore, such knowledge is fundamental to predict the geomorphological and ecological effects of changed sediment delivery on coastal and inshore environments due to natural or anthropogenic changes in the river catchments.

Sediment delivery to the Great Barrier Reef (GBR) of northeastern Australia has been estimated, using catchment scale models, to have increased five-fold since European settlement around 150 years ago (Kroon et al., 2012). This increase has been implicated in the degradation of inshore reefs as a result of increased turbidity from the elevated sediment loadings (Fabricius and De'ath, 2001; Fabricius et al. 2003, 2005). However, this finding has been disputed by sedimentologists who argue that the volume of the 'old' sediment available for resuspension on the sea floor far outweighs the volume of 'new' sediment delivered from the rivers (Woolfe and Larcombe, 1998; Larcombe and Woolfe, 1999; Orpin and Ridd, 2012). Indeed turbidity generated by wind-driven resuspension events at inshore coral reefs greatly exceeds levels measured in river flood plumes at the same location (Woolfe and Larcombe, 1998; Larcombe and Woolfe, 1999; Devlin and Brodie, 2005; Orpin and Ridd, 2012). Research on some estuaries also suggests that much of the sediment is retained close to the river mouths (Bostock et al., 2007; Bryce et al., 1998; Webster and Ford, 2010). The scientific debate has more recently

* Corresponding author. Tel.: +61 7 4781 6629; fax: +61 7 4781 5589.
E-mail address: stephen.lewis@jcu.edu.au (S.E. Lewis).

http://dx.doi.org/10.1016/j.epsl.2014.02.038

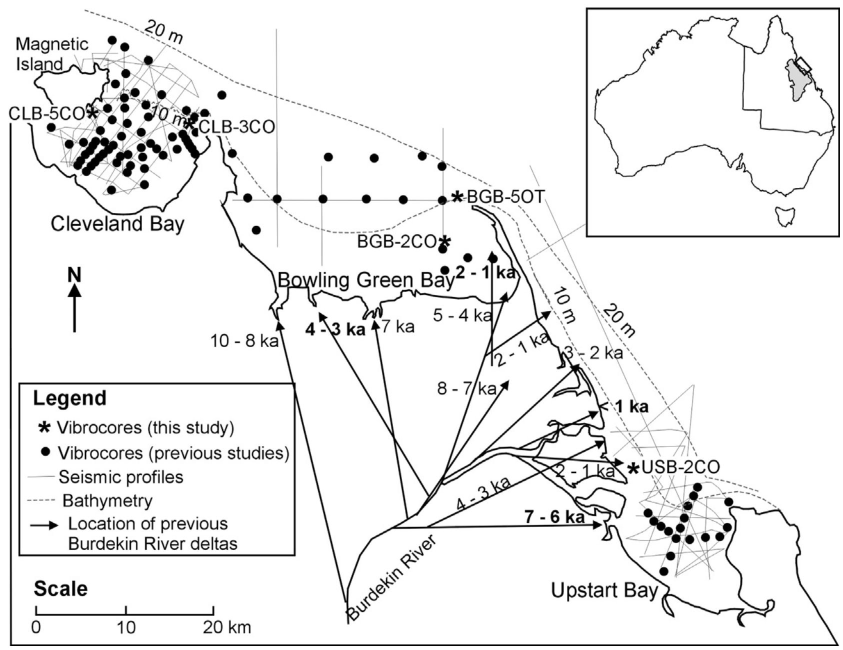

Fig. 1. Location of the Burdekin River and Upstart, Bowling Green and Cleveland Bays. Included are the previous vibrocores and seismic profiles (from Belperio, 1983; Way, 1987; Carter et al., 1993; McIntyre, 1996; Orpin et al., 2004) and the previous avulsion history of Burdekin River delta (from Fielding et al., 2006). The bolded dates coincide with key deposition periods within our sediment cores.

been refined in light of new data that suggest turbidity levels are much higher in the months following considerable river input compared to the end of the dry season (corrected for wind speed and direction) (Fabricius et al., 2013). This finding implies that the delivery of 'new' sediment plays an important role on sediment resuspension in the GBR. Modelling has also highlighted the importance of new sediment and the role of Tropical Cyclones to winnow-out the accumulated terrigenous sediment from the embayments (Lambrechts et al., 2010). Hence it is critical to better quantify the amount and fate of recently delivered sediments that reach the inshore reefs of the GBR and their influence on turbidity regimes.

Recent advances in optically stimulated luminescence (OSL) dating allows ages of recently deposited fluvial sediments to be accurately determined with high precision (Olley et al., 2004a, 2004b; Madsen et al., 2005, 2007). This advance provides an important distinction between the age of the sediment as determined through radiocarbon analysis and the timing of when the sediment was last exposed to light and hence when the sediment was last resuspended and deposited. While OSL dating has been previously used in the GBR to quantify the volume of sediment deposited in the Fitzroy River estuary during the Holocene (Bostock et al., 2007), the technique has not been used to address the question of sediment resuspension. Indeed, very few ages have been taken from inshore sediments that have been deposited since the Holocene sea-level highstand (known as the 'bay fill sediment unit'). Accumulation rates of this bay fill unit have generally been estimated using the ages of mangrove sediments that reside directly below this unit. The mangrove sediments were deposited during the marine transgression and hence the rates that have been calculated have assumed continuous deposition since this time.

Sediment cores collected from key locations offshore from the Burdekin River are examined to determine the fate of sediments delivered to the GBR. We show that the deposition of the Holocene bay fill unit has not been continuous over time and interpret our findings in light of a recent study on the avulsion history of the Burdekin River delta (Fielding et al., 2006). Based on our new data we also further refine the scientific debate on sediment resuspension in the GBR.

2. Background

The Burdekin River drains a catchment area of ~130,000 km^2 and is the largest single contributor of sediment to the GBR with an average load of 4.0 million tonnes per year (Kroon et al., 2012; Kuhnert et al., 2012; Bartley et al., 2014). Catchment scale modeling indicates that this load has increased 8 fold since European settlement (Kroon et al., 2012) largely related to the introduction of sheep and cattle in the catchment area (McCulloch et al., 2003; Lewis et al., 2007). It is thought that this additional terrestrial loading has negatively impacted on the receiving waters of the Burdekin River through a decline in seagrass habitat (Devlin et al., 2013), coral biodiversity (Fabricius and De'ath, 2001; De'ath and Fabricius, 2010; Fabricius et al., 2013) and the apparent local collapse of some species of coral (Roff et al., 2012). However, other studies suggest that terrestrial sediment delivered from the Burdekin River is largely captured in the north-facing embayments including Upstart, Bowling Green and Cleveland Bays (Woolfe and Larcombe, 1998; Orpin et al., 2004).

Several decades of field work in Upstart Bay, Bowling Green Bay and Cleveland Bay has helped define the sedimentology of this region (Fig. 1). In particular, seismic profiling, grab sampling and vibrocores have yielded valuable information on the physical composition, depositional units and the amount of Holocene sediment deposited in these embayments (Maxwell, 1968; Belperio, 1983; Johnson and Searle, 1984; Way, 1987; Carter et al., 1993; McIntyre, 1996; Larcombe and Carter, 1998; Lambeck and Woolfe, 2000; Orpin et al., 2004) since the end of the last post-glacial transgression around 8 ka (e.g. Lewis et al., 2013). The classic work of Maxwell (1968) and Belperio (1983) showed that the vast majority of terrigenous sediment is retained on the inner shelf between 0 and 20 m water depth. Vibrocores and seismic profiling in the embayments reveal 3 main Holocene sedimentary units deposited on compacted and weathered alluvial Pleistocene sediments. These units include (1) infilling deposits of palaeo-channels active during the Last Glacial Maximum; (2) a transgressive mangrove unit and; (3) the most recent Holocene bay fill unit (Carter et al., 1993).

While several radiocarbon ages have been obtained from the transgressive mangrove unit, which have provided insights on rates