Continental Shelf Research 86 (2014) 85–102

Contents lists available at ScienceDirect

Continental Shelf Research

journal homepage: www.elsevier.com/locate/csr

Research papers

Spatial and temporal variability in sediment deposition and seabed character on the Waipaoa River margin, New Zealand

J.P. Walsh [a,b,*], D.R. Corbett [a,b], J.M. Kiker [a], A.R. Orpin [c], R.P. Hale [d], A.S. Ogston [d]

[a] East Carolina University, Greenville, NC, USA
[b] UNC Coastal Studies Institute, Wanchese, NC, USA
[c] National Institute for Water and Atmospheric Research, Wellington, New Zealand
[d] University of Washington, Seattle, WA, USA

ARTICLE INFO

Article history:
Received 12 March 2014
Received in revised form
27 June 2014
Accepted 3 July 2014
Available online 19 July 2014

Keywords:
Waipaoa
Shelf
Sedimentation
Deposition
Accumulation
Strata

ABSTRACT

The stratigraphic record is the manifestation of a wide range of processes, interactions and responses to environmental drivers. Understanding the functioning of river sediment dispersal systems is necessary to determine the fate of sediment and associated material in the marine environment and differentiate key influences in the development of the stratigraphic record. To that end, this study uses sediment cores collected on four successive cruises (January, May and September 2010 and February 2011) on the Waipaoa River margin, New Zealand, to provide insight into spatial and temporal variability in sediment deposition and seabed character.

The Waipaoa River discharges a large sediment load into an energetic coast that has a complex margin morphology. Several flood and wave events occurred during the study, and sedimentation varied spatially and temporally. X-radiographs and short-lived radioisotopes indicate emplacement of new event layers prior to all cruises. Notable variation in surficial seabed character (grain-size composition, loss-on-ignition percentage) was apparent on the inner shelf (water depths <40 m), but mid-shelf areas and seaward had more homogeneous sediment properties. ^{7}Be inventories indicate variable patterns of deposition related to fluvial and oceanographic conditions prior to cruises. Ephemeral sediment storage occurs on the inner-shelf of Poverty Bay, into which the Waipaoa River discharges directly, and subsequent export and dispersal patterns are linked to the relative timing and size of flood and wave events. Surficial deposits with characteristics of fluid muds and wave-enhanced sediment gravity flows were noted at some (<25 sites total) mid-shelf and shallower sites from all cruises. During the last cruise considerable inter- and intra-site seabed variability occurred in the interbedded river-proximal inner-shelf deposits over spatial scales of less than a few kilometers. Evidence from earlier sidescan data infer that this could be related to variation in bedform development or influence. Contrasts in the observed event layering recorded over the experiment with the longer pattern of accumulation suggests stochastic dispersal behavior and reworking over time must shape the seabed to produce the time-averaged pattern of shelf sediment accumulation. This research highlights our improved ability to comprehend strata development and sheds light on the challenge of interpreting historical and ancient strata across spatial and temporal scales.

1. Introduction

Steady rates of sediment accumulation in river-influenced continental margins are often reported in the literature, implying slow, steady deposition. Such a presumption is at odds with the geologic record, which has been produced by a compilation of punctuated events over a range of temporal and spatial scales, including episodes of rapid construction, erosion or hiatal periods (Barrell, 1917). Because of the relative strength of event forcings in continental shelf areas of high sediment input (e.g., near river mouths), stratigraphic development is hypothesized to potentially provide detailed records of floods, storms and other events. However, the fidelity of the stratigraphic record is a function of many factors, including sediment dynamics, sediment supply, shelf morphology, fluvial and oceanic interactions, and biota (Nittrouer et al., 2007 and references therein).

Sediment transport models are increasingly being used as a means to determine how fluvial and oceanographic conditions yield sediment deposition, erosion and eventual accumulation

* Corresponding author at: East Carolina University, Greenville, NC, USA. Tel.: +1 252 475 5429.
E-mail address: walshj@ecu.edu (J.P. Walsh).

http://dx.doi.org/10.1016/j.csr.2014.07.001
0278-4343/

(e.g., Friedrichs and Scully, 2007; Bever et al., 2009; Bever and Harris, 2014). These models may take into account a variety of factors, including wave characteristics, tidal and low-frequency currents, sediment properties, flocculation dynamics, and sediment supply (Hill et al., 2007; Warner et al., 2008 and references therein), but knowledge of the temporal variation of the surficial shelf seabed remains limited.

The formation, character and preservation of sediment layers is dependent on the sequential timing and magnitude of sediment deposition events, which dictate the residence time of event layers (e.g., those emplaced following floods) in the seabed surface mixed layer (Wheatcroft and Drake, 2003; Bentley and Nittrouer, 2003). The internal layering and associated grain-size signatures of stratigraphy on shelves may be transient features with bioturbation and physical reworking occurring in days to months after their emplacement (Wheatcroft et al., 2007; Gõni et al., 2007; Tesi et al., 2012).

In this study on the Waipaoa shelf, repeated and detailed time-series coring coupled with down-core radionuclide activities provides a means of identifying areas of sediment deposition and accumulation, and to inform and/or ground-truth sediment-transport modeling efforts. Here, shelf time-series seabed observations of ^{7}Be and ^{234}Th in surface sediments are combined with grain-size and organic content, to provide insight into spatio-temporal variability in sediment deposition. The Waipaoa River margin is an ideal study area because of the large riverine sediment input and regular occurrence of flood and wave events, but it is also a challenging system to investigate because of its complex morphology created by regional deformation in response to subduction. More specifically, this research is guided by the following objectives: (1) evaluate the character (e.g., extent) of discrete event layers created on the Waipaoa shelf; (2) determine the variability in surficial seabed properties (e.g., grain size); (3) relate spatial and temporal variability in sediment deposition to the oceanographic conditions and processes; and (4) compare short-term deposition with longer-timescale sediment accumulation patterns.

2. Background

2.1. Sediment dynamics

Sediment dynamics include the deposition, resuspension, post-depositional mixing, and dispersal of sediment particles, and these processes dictate the cycling of carbon, nutrients and contaminants (McKee et al., 2004). The dominant mechanisms driving sediment transport on continental margins are waves and currents, with dispersal on the shelf, either diffusively in the boundary layer or as sediment gravity flows, typically enhanced during storms (Hill et al., 2007 and references therein). Currents governing transport are directed predominantly in an along-isobath direction, but sediment gravity flows can traverse down bathymetric gradients to produce more shore-perpendicular movement. Indeed, sediment transport conditions are often characterized by variable fluvial and oceanographic conditions and dispersal behaviors. For example, some events involve new supply while others are comprised of wave- and current-driven redistribution. A “wet storm” is characterized by significant river discharge (i.e., a flood) synchronous with energetic ocean conditions, while rough seas during low riverine discharge may be referred to as a “dry storm” (Sommerfield et al., 2007 and references therein). Both conditions can lead to significant sediment transport and the formation of fluid muds (e.g., Ogston and Sternberg, 1999; Puig et al., 2003). Sediment gravity flows have become more appreciated for their potential role in cross-isobath sediment movement in recent decades (Hill et al., 2007). They are generally defined in the literature as having sediment concentrations $>10\ \mathrm{g\ l^{-1}}$ (Kineke et al., 1996; Ross and Mehta, 1989) and therefore are transported down slope under the influence of gravity on continental margins with gradients $>0.7°$ (Wright et al., 2001). High energy waves (e.g., on the Eel River shelf off California; Traykovski et al., 2000), strong currents (e.g., on the Waiapu shelf off East Cape of New Zealand Ma et al., 2008, 2010) or convergent flows (e.g., the Amazon River mouth; Kineke et al., 1996) may be responsible for their formation.

The loci of sediment deposition and accumulation on continental margins are influenced by fluvial and oceanic interactions and margin morphology (Nittrouer and Wright, 1994; Friedrichs and Wright, 2004; Walsh and Nittrouer, 2009). For example, the amount of sediment discharged by rivers dictates how much material is available for transport upon reaching the marine environment, and in turn, this along with marine transport affects the depositional area and rates of sediment accumulation. However, the margin character, such as the shelf width and existence of a shelf-incising a canyon, also regulates sedimentation. Anthropogenic alterations have affected many catchments by increasing yields through augmented soil erosion or reducing them be damming (Syvitski and Milliman, 2007), and these changes have affected dispersal system behavior (e.g., Syvitski and Saito, 2007 and references therein), including the Waipaoa (Orpin et al., 2006; Miller and Kuehl, 2010; Gerber et al., 2010).

2.2. Particle-reactive tracers

The distribution and activity of radioisotopes in marine sediments can aid in resolving the impact of complex coastal processes on the seabed, with the half-life of the radioisotope dictating its application. Due to their short half-lives, ^{7}Be ($t_{1/2}$=53.3 d) and ^{234}Th ($t_{1/2}$=24.1 d) are powerful tools to evaluate processes such as sediment deposition, resuspension, erosion, and mixing occurring on timescales of days to months (Olsen et al., 1986; Feng et al., 1999). Time-series sampling allows for the evaluation of seabed changes based on the net increases or decreases in downcore inventory through time (e.g., Canuel et al., 1990; Giffin and Corbett, 2003; Corbett et al., 2007). ^{7}Be is atmospherically produced via cosmic ray spallation reactions with nitrogen and oxygen, while ^{234}Th occurs naturally in the water-column and seabed sediments, produced from the decay of ^{238}U (Aller and Cochran, 1976; Aller et al., 1980; Waples et al., 2006). Excess ^{234}Th in the surface seabed results from sediment mass accumulation or focusing (e.g., Corbett et al., 2007). However, high surface excess ^{234}Th may be diffused downward in the seabed through subductive mixing of sediment associated with bioturbation (e.g., Wheatcroft, 2006). These radioisotopes are most useful in assessing sediment deposition when combined with X-radiographs that provide insight into differences in sediment density; these data provide independent chemical and visual evidence of layering.

2.3. Waipaoa River margin

The Waipaoa is located on the tectonically active Hikurangi subduction margin of northeastern New Zealand (Fig. 1), where oceanic crust of the Pacific Plate is being subducted obliquely beneath the Raukumara Peninsula. The Waipaoa River drains a small and rugged catchment (2205 km^2), but delivers a large amount (15 Mt y^{-1}) of sediment to a narrow shelf (~20 km). Much of this sediment is generated through gully erosion (e.g., DeRose et al., 1998) and mass-wasting events (e.g., Jones and Preston, 2012), which are a function of the duration and intensity of precipitation. The Waipaoa catchment is dominantly comprised of strongly jointed and highly erodible lithologies of sandstone,