Marine Geology 346 (2013) 355–365

Contents lists available at ScienceDirect

Marine Geology

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

Signals of watershed change preserved in organic carbon buried on the continental margin seaward of the Waipaoa River, New Zealand

Elana L. Leithold [a,*], Neal E. Blair [b,c], Laurel B. Childress [c], Benjamin R. Brulet [a], Michael Marden [d], Alan R. Orpin [e], Steven A. Kuehl [f], Clark R. Alexander [g]

[a] Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695, USA
[b] Department of Civil and Environmental Engineering, Northwestern University, Evanston, IL 60208, USA
[c] Department of Earth and Planetary Sciences, Northwestern University, Evanston, IL 60208, USA
[d] Landcare Research, P.O. Box 445, Gisborne, New Zealand
[e] National Institute of Water and Atmospheric Research (NIWA), Private Bag 14-901, Kilbirnie, Wellington, New Zealand
[f] Virginia Institute of Marine Sciences, College of William and Mary, Gloucester Point, VA 23062, USA
[g] Skidaway Institute of Oceanography, Savannah, GA 31411, USA

ARTICLE INFO

Article history:
Received 5 October 2011
Received in revised form 24 September 2013
Accepted 12 October 2013
Available online 19 October 2013

Communicated by G.J. de Lange

Keywords:
continental margin
sediments
watershed change
radiocarbon
carbon isotopes
New Zealand
anthropogenic change

ABSTRACT

Holocene sediments buried on the continental shelf seaward of the Waipaoa River, northeastern New Zealand, preserve a stratigraphic record of terrestrial environmental change. The well characterized, long-term record of storms, volcanism, and human disturbance in this region provides an opportunity to examine how such changes are reflected in the character of organic carbon (OC) buried on the continental margin. Complimentary evidence obtained from analyses of the ^{14}C content and the elemental and stable carbon isotopic composition of different sedimentary fractions, including charcoal, wood, and clay-sized isolates, indicates that these perturbations led to mobilization of OC components with variable storage histories in the watershed.

Charcoal transported in the modern Waipaoa River and buried in offshore depocenters includes a highly aged component that has apparently been slowly released from storage in soil or alluvial terraces. The charcoal fraction ages become dramatically younger in sediments deposited after the Taupo volcanic eruption (1717 cal yr BP) and then Polynesian settlement (ca. 700 cal yr BP), both signaling biomass burning. The mean age of woody plant fragments and clay-bound OC deposited on the shelf also varies over time, with older material having accumulated in the middle Holocene and since human occupation. Deposition of older-than-average wood fragments and clay-bound OC between about 5 and 3.6 kyr BP correlates with evidence for a period of increased storm frequency in the region and may reflect the enhanced delivery of aged soil and sedimentary rock mobilized from hill slopes via earthflows and/or deep seated landslides. Similarly, the deposition of older wood and clay-bound OC commensurate with the first anthropogenic disturbance ca. 700 years ago is consistent with accelerated mass wasting due to deforestation. At the same time, a change in the elemental and stable isotopic composition of bulk and clay-bound OC buried on the shelf may reflect increased marine primary productivity and/or mobilization of OC from deep levels in soil profiles. Deforestation of the Waipaoa headwaters by European settlers beginning in the middle 19th century is evinced by a sharper rise in the age of clay associated OC buried offshore. Today, deep gully incision into fractured sedimentary bedrock is a major source of sediment and kerogen to the river, and this process has left its mark on the age of sedimentary OC delivered to the adjacent margin.

1. Introduction

As the primary sites for accumulation of particulate matter eroded from land, continental margins contain some of the most complete stratigraphic records of long-term terrestrial environmental change. Deciphering those records requires the use of multiple sedimentary proxies, and organic carbon (OC) can be particularly informative. The stable carbon isotopic composition of sedimentary organic matter buried on the margins, for example, has been widely used to disentangle long-term variations in relative sea-level, river discharge, and terrestrial vegetation (e.g., Meyers, 1997; Lamb et al., 2006; Weijers et al., 2009). Recent work, however, suggests that sedimentary organic carbon has yet to be fully exploited as a paleoenvironmental tool. It has become apparent that riverine organic carbon is a more complex mixture than has commonly been appreciated, and that the composition and age of that material is a function of the geomorphic processes that deliver it to the fluvial network (e.g., Leithold et al., 2006; Hilton et al., 2008; Gomez et al., 2010). Sediment delivery mechanisms such as sheetwash, shallow landslides, and debris flows carry organic fractions that are primarily derived from surficial horizons and are relatively young and

* Corresponding author.

0025-3227/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.margeo.2013.10.007

fresh. In contrast, deep seated landslides and earthflows tend to entrain older, more refractory material derived from deeper soil horizons and sedimentary rocks. Bank erosion of lowland soils can mobilize material with a complex mixture of ages from multiple upland sources. By determining the balance of OC in stratigraphic sequences sourced from surficial versus deeper horizons in the regolith, the relative roles of landscape erosion processes may be assessed. Integrating over geological timescales, such reconstructions can be used to more completely resolve large-scale forcing in watersheds including signals derived from climate change, tectonics, and human disturbance.

The Waipaoa Sedimentary System on the North Island of New Zealand (Fig. 1) is an ideal location to explore organic geochemical signals of watershed change in the stratigraphic record. Since the last glacial maximum, the Waipaoa River has discharged significant volumes of sediment and associated organic carbon to the ocean, forming thick depocenters on the adjacent continental shelf and slope (Orpin, 2004; Orpin et al., 2006; Gerber et al., 2010). Erosional processes in the watershed have been the subject of extensive research (e.g., De Rose et al., 1998; Hicks et al., 2000, 2004; Gomez et al., 2003a; Reid and Page, 2003; Marden et al., 2005, 2008a,b), as have the ^{14}C and stable carbon isotopic composition of recent sedimentary products (Gomez et al., 2003b, 2004a; Leithold et al., 2006; Blair et al., 2010; Brackley et al., 2010; Gomez et al., 2010). The Waipaoa system, moreover, is known to have been impacted by a range of environmental perturbations during the Holocene Epoch, including volcanic eruptions, intense storms, earthquakes, and anthropogenic deforestation (Wilmshurst et al., 1999; Gomez et al., 2004b, 2007; Kettner et al., 2007). In this paper, we examine the sedimentary record preserved on the Waipaoa continental shelf to disentangle for the first time the long-term, organic-geochemical signals of these and other environmental changes.

2. Background

2.1. Geology

The Waipaoa River drains a 2205 km^2 watershed on the eastern flanks of the rugged Raukumara Ranges of the North Island, New Zealand, flowing along a short course southeastward and discharging to Poverty Bay (Hicks et al., 2000; Fig. 1). The watershed is located in the forearc region of the Hikurangi Margin, where the Pacific Plate is

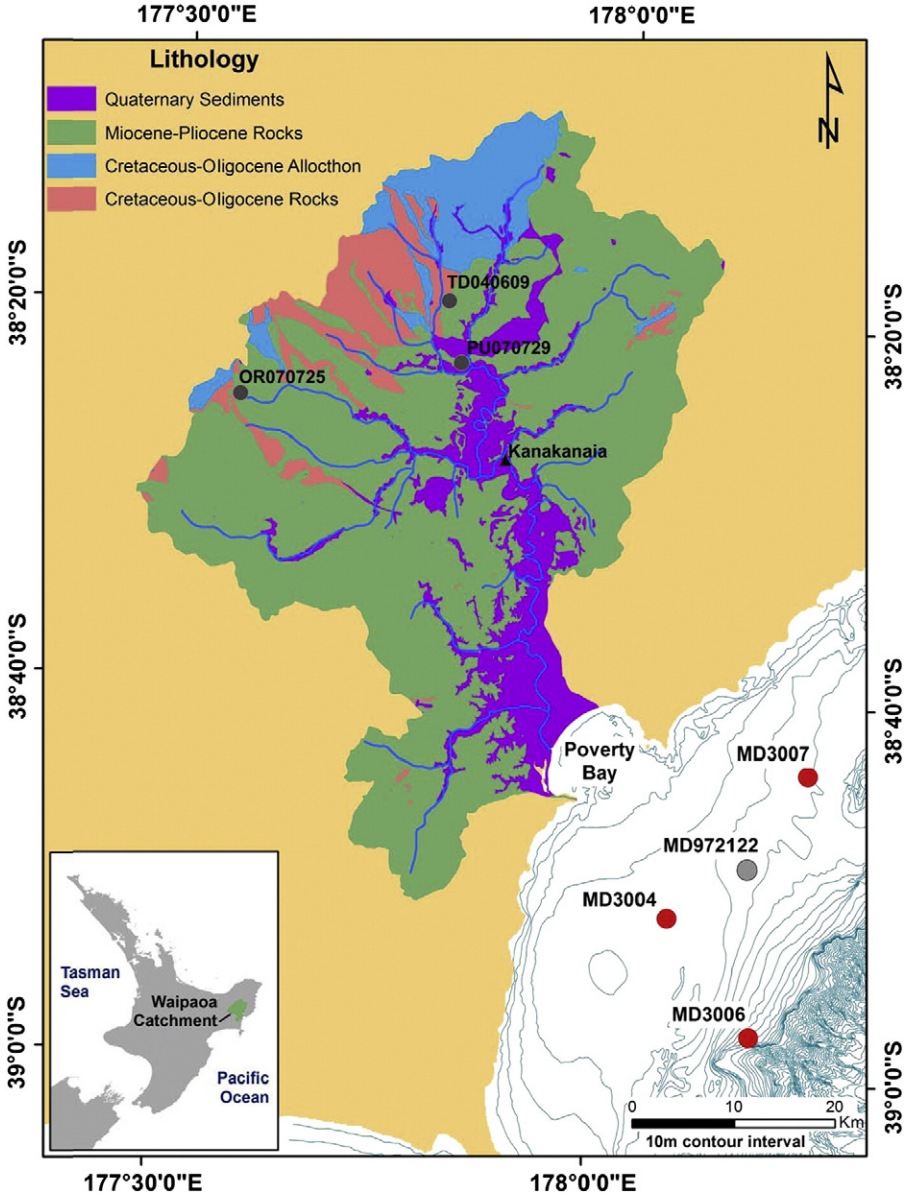

Fig. 1. Map of the Waipaoa watershed and adjacent continental shelf showing the locations where river sediment, soil, and piston core samples were collected.