Marine Geology 270 (2010) 11–29

Contents lists available at ScienceDirect

Marine Geology

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

Holocene sedimentary record from Lake Tutira: A template for upland watershed erosion proximal to the Waipaoa Sedimentary System, northeastern New Zealand

A.R. Orpin [a,*], L. Carter [a,b], M.J. Page [c,d], U.A. Cochran [c], N.A. Trustrum [c,d], B. Gomez [e], A.S. Palmer [f], D.C. Mildenhall [c], K.M. Rogers [d], H.L. Brackley [c,d], L. Northcote [a]

[a] National Institute of Water and Atmospheric Research (NIWA), Private Bag 14-901, Kilbirnie, Wellington, New Zealand
[b] Antarctic Research Centre, Victoria University of Wellington, PO Box 600, Wellington, New Zealand
[c] GNS Science, PO Box 30 368, Lower Hutt 5040, New Zealand
[d] Manaaki Whenua-Landcare Research, Private Bag 11-502, Palmerston North, New Zealand
[e] Geomorphology Laboratory, Indiana State University, Terre Haute, Indiana 47809, USA
[f] Soil and Earth Sciences, Institute of Natural Resources, Massey University, Palmerston North, New Zealand

ARTICLE INFO

Available online 3 November 2009

Keywords:
lake sedimentation
storms
earthquakes
mass-transport deposit
diatoms
climate
ENSO
colonisation
erosion
Holocene
New Zealand

ABSTRACT

A Holocene lake record from northeastern New Zealand provides a detailed record of environmental controls on upper watershed sedimentation, and is proximal to the Waipaoa MARGINS Source-to-Sink focus site. In that context, Lake Tutira in Hawke's Bay was cored in 2003 to recover a complete sedimentary record since the lake's formation ca 7.2 ka. The 27.14 m-long core contains alternating lithotypes that are sedimentary responses to lacustrine organic accumulation, normal to severe rainfalls, earthquakes and volcanism. A diatom allochthonous ranking scheme, pollen counts, and C and N percentages were used to identify intra-lake and watershed-derived storm deposits and modes of lithotype deposition. The lithotypes and depositional modes are: tephras (volcanic airfall); organic-rich mud (algal-rich lake sedimentation); massive to weakly graded, brown silty clay beds (homogenites and redeposited lake sediments); grey, graded sandy mud beds (intense storm-delivered sediment); and, thin yellow clay layers (run-off from small storms). Using 12 tephras and 3 radiocarbon ages to provide a chronology, the long-term sedimentation rate is ca 3.3 mm/year, which increases to >10 mm/year following European colonisation.

Storm beds occur in response to rainfall events, with no obvious correlation to El Niño-Southern Oscillation polarity or strength. Moreover, no single climate index appears to correlate strongly with the historic rainfall event record. Having characterised and identified storm-beds over the lake's history, a hindcast relationship implies that around 53 pre-historic storms occurred with a magnitude similar to the severe Cyclone Bola event of 1988, plus 7 potentially larger storm events.

Despite the prominence of storm beds, a summation of the total percent thickness as an indication of the relative modes of emplacement for each lithotype shows that proportionally, the balance of intra-lake versus storm sources preserved in the lake bed is 69% and 26%, respectively. As well as storms, lake sedimentation is strongly influenced by earthquakes that destabilize the terrigenous, sediment-laden lake margins to generate homogenites, represented by the brown silty clay beds. These deposits tend to be thicker after a hiatus in seismic activity and after sustained periods of lake-margin loading, as inferred from the occurrence of thick graded storm beds.

Comparison with marine records on the adjacent continental margin suggests that more terrestrial events are captured in the lake record, due to: (i) close hillslope–lake connectivity, with little intervening storage of sediment compared with the Waipaoa sedimentary system; and, (ii) the preservation of event stratigraphy at Tutira compared to its reduced preservation in the dynamic marine environment. Only major storms such as Cyclone Bola leave an imprint traceable to the ocean, whereas identifiable sedimentary responses to individual earthquakes are localized, although through landscape preconditioning and sediment production they contribute to the overall high terrigenous input to the ocean. In contrast, low-frequency, high magnitude perturbations (volcanic eruptions, European deforestation) are preserved through the Source-to-Sink sedimentary system, consistent with earlier hypotheses.

1. Introduction

Given the concern surrounding projected global climate change and the potential for more extreme and unpredictable weather,

* Corresponding author. Tel.: +64 4 386 0356; fax: +64 4 386 2153.
E-mail address: a.orpin@niwa.co.nz (A.R. Orpin).

0025-3227/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.margeo.2009.10.022

detailed and well dated environmental records form valuable tools to help gauge future responses. The small, landslide-dammed Lake Tutira, located in northern Hawke's Bay (Fig. 1), was cored to obtain a high-resolution record of environmental change extending back to around ~7.2 ka (all ages in calendar years) when the lake was formed (Page and Trustrum, 1997). Because of the lake's proximity to the Waipaoa watershed (Source-to-Sink study site), the lacustrine record provides insight into watershed responses to climatic and tectonic processes that have likely affected the Waipaoa source through time. It also acts as a point of reference to compare with the adjacent marine record at the Poverty Bay continental margin.

By virtue of its geography combined with a vigorous, temperate, maritime climate, storms have regularly produced distinctive deposits in Lake Tutira, during both the period of enhanced post-colonisation erosion, and pre-historic time under undisturbed forest cover. Previous studies of Lake Tutira cores spanning the last 2.25 ky, identified rainfall events preserved as graded sandy mud beds (e.g. Page et al., 1994; Eden and Page, 1998). Such data helped identify the frequency and intensity of rainfall and provided an insight into the waxing and waning of regional weather patterns. Similarly, sedimentary sequences preserved on the adjacent East Coast margin of New Zealand also retain signals generated by perturbations to terrestrial conditions that have occurred over a range of timescales (e.g. Stewart and Neall, 1984; Wilmshurst et al., 1999; McGlone, 2001; Carter et al., 2002). The link between the El Niño-Southern Oscillation (ENSO), rainfall, and watershed erosion has been inferred from previous core

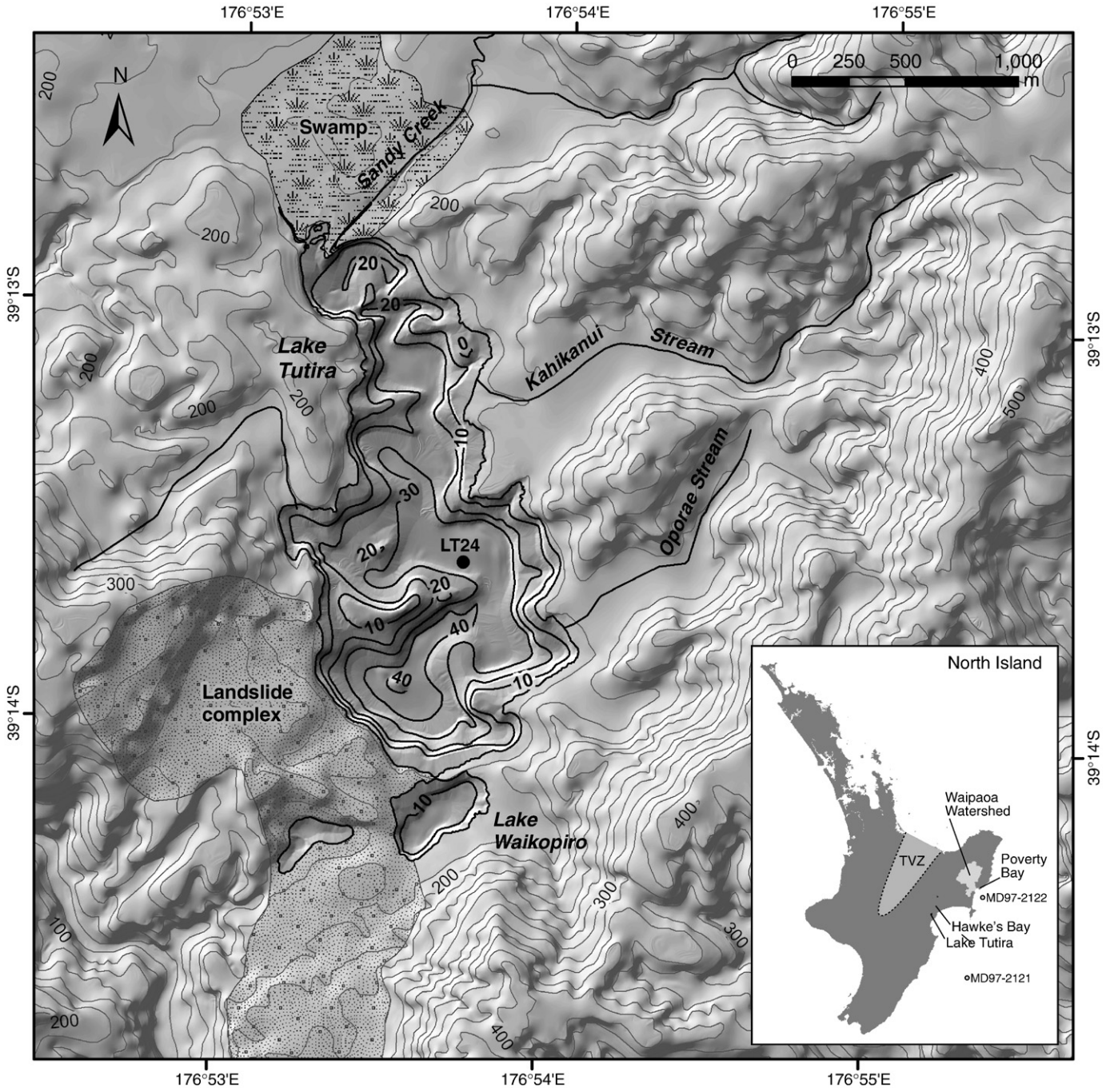

Fig. 1. Locality and bathymetry of Lake Tutira and hinterland in Hawke's Bay, eastern North Island of New Zealand. Land contours interval is 25 m, and the lake bathymetry contour interval is 10 m. The Taupo Volcanic Zone (TVZ) extends northeast through the central North Island.