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Correlation of fluvial terraces within the Hikurangi Margin, New Zealand: implications for climate and baselevel controls

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Abstract

A correlation of fluvial terraces is presented for eight non-glacial catchments of the eastern North Island, New Zealand, within the actively uplifting Hikurangi Margin. Using a combination of loess and tephra coverbed stratigraphy, and radiocarbon and OSL dating of fluvial deposits and loess coverbeds, we demonstrate correlation of four fill terraces, T1–T4. The available age constraints suggest T1=15–30 ka, T2=31–50 ka, T3=50–70 ka, and T4=~115 ka, but the association and temporal link with loess deposits suggest correlation with cold periods, and thus the refinement of T2=late MIS 3 (31–40 ka), T3=MIS 4 (55–70 ka), T4=MI Substage 5b (~90 ka), 5d (~110 ka), or MIS 6 (~140–160 ka). The ability to correlate terraces between catchments, plus the lack of independent evidence for tectonic triggering events, indicates terraces have probably formed in response to either climate (terrestrial) or baselevel (sea level) control. Climate control is indicated by the temporal link of post-glacial incision with re-establishment of forest cover, and of LGM aggradation with limited grass and shrub cover and periglacial processes. Aggradation due to increased sediment supply under reduced vegetation is dramatically demonstrated by formation of the Taupo Pumice Alluvium terrace in response to inundation by volcanic deposits (unwelded ignimbrite) following the 1.8 ka Taupo eruption, and the response to post-settlement (<500 yr BP) deforestation. The upstream limit of post-glacial baselevel control is recorded by a post-glacial sediment wedge burying older terraces in six catchments. In one catchment, the inner (landward) edge of the wedge is a mid-Holocene fill terrace, interpreted to have formed in response to the post-glacial sea level highstand, and thus is a baselevel-controlled terrace. Evidence defining the downstream extent of climate control during the LGM (and thus the upstream limit of baselevel-controlled lowstand incision) is now buried beneath the continental shelf, but limited fluvial features on the inner shelf (<20 km offshore), and LGM aggradation despite a range of shelf gradients indicate climate-induced aggradation probably extended at least to the present day inner shelf.

Keywords: Fluvial terraces; Aggradation; Climate; Baselevel; Tephra; Loess

1. Introduction

A fluvial terrace records the former bed level of a river, and can be classified as either aggradational (fill) or degradational (fill-cut or strath) (e.g., Bull, 1990).

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The switch between aggradation and degradation behaviour of the rivers occurs in response to a change in one or more of external controls including climate, total catchment relief, baselevel, bedrock lithology, tectonics, and human activities (Bull, 1991). In recent years the role of climate has received considerable attention (e.g., Antoine, 1994; Fuller et al., 1998; Macklin et al., 2002; Jain and Tandon, 2003; Starkel, 2003; Pan et al., 2003). Blum and Tornqvist (2000) highlight an apparent emerging mismatch between the role of climate versus sea level. For example, in many non-glacial basins, fill terraces appear to have been constructed during glacial periods in response to increased sediment supply (e.g., Zeuner, 1945; Vella, 1963; Milne, 1973a; Yoshikawa et al., 1981; Porter et al., 1992; Sugai, 1993; Fuller et al., 1998; Bridgland, 2000 and references therein), whereas in sequence stratigraphy models glacial periods (i.e. sea level lowstands) are viewed as times of erosion (river incision) and sediment by-passing (e.g., Posamentier and Vail, 1988; Zaitlin et al., 1994; Blum and Price, 1998; Talling, 1998). In reality there is a transition point between the two, which may vary widely for different tectonic and climatic settings (e.g., Merritts et al., 1994; Blum and Tornqvist, 2000).

Fluvial terrace studies in New Zealand have also traditionally been viewed from a climate-controlled (i.e. an upland or geomorphological) perspective (e.g., Pillans, 1991 and references therein), but recently the role of other controls such as sea level (baselevel) and tectonics has started to be addressed (e.g., Leckie, 1994; Browne and Naish, 2003; Berryman et al., 2000, submitted for publication). Most of the fluvial terrace studies to date have also been on an individual river or catchment basis (e.g., Powers, 1962; Vella, 1963; Soons and Gullentops, 1973; Vella et al., 1988; Yoshikawa et al., 1988; Palmer et al., 1988; Eden, 1989; McIntosh et al., 1990; Bull, 1991, chapter 5; Almond, 1996; Berryman et al., 2000), albeit with limited correlations to well preserved terrace flights such as the Rangitikei valley terraces in the lower North Island (Milne, 1973b) and glacial outwash terraces in north Westland, South Island (e.g. Suggate, 1985; Suggate and Waight, 1999). In this study we show that fill terraces in particular can be correlated on a regional scale, throughout the eastern North Island, and thus that terrace formation has been in response to the same external control(s).

A key to correlating terraces, independent of models of the mode of their formation, is dating. An advantage to studying fluvial terraces in the eastern North Island is the ability to use tools such as loess stratigraphy and tephrochronology. Loess and tephra are particularly well preserved as coverbeds on fluvial terraces, and provide minimum ages for the underlying terrace deposits as well as aiding correlation between catchments. Numeric ages are also available by both radiocarbon and luminescence dating. Although generally sparse, organic material is present as wood within the gravel-dominated deposits, and also occurs as peat in terrace cover deposits, and charcoal within tephras. Luminescence dating is being increasingly used in New Zealand to extend age control beyond the limits of radiocarbon dating, and has particularly been used to date loess (e.g., Berger et al., 1992, 2001, 2002; Litchfield and Lian, 2004). The present study is the first to apply Optically Stimulated Luminescence (OSL) dating directly to fluvial deposits in the eastern North Island, although OSL ages of loess coverbeds have been used to estimate the minimum ages of river terrace deposits (Wang, 2001; Formento-Trigilio et al., 2003).

The aims of this paper are thus: (i) to describe and correlate fluvial terraces in the eight major catchments of the eastern North Island, (ii) to summarise and examine age constraints for the terraces, and (iii) to discuss the mechanisms of terrace formation, with particular attention to the relative effects of climate and baselevel control.

2. Regional setting

The eastern North Island comprises a zone of ranges and basins formed in response to tectonics associated with the Hikurangi Subduction Margin between the Australian and Pacific Plates (Fig. 1). The ranges can be subdivided into the axial ranges, which are the basement-cored frontal ridge, or backstop, and the lower elevation coastal ranges, comprising the partially uplifted forearc basin and outer arc high (e.g., Lewis and Pettinga, 1993). The average elevation of the axial ranges is 1300 m, and the maximum is 1752 m near the north end (Mt. Hikurangi, Fig. 2). They form a major drainage divide and topographic barrier