Quaternary Science Reviews 170 (2017) 136–151

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

A Last Interglacial pollen-temperature reconstruction, central North Island, New Zealand

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ARTICLE INFO

Article history:
Received 20 February 2017
Received in revised form
14 June 2017
Accepted 20 June 2017

Keywords:
Last Interglacial
Pollen
Temperature reconstruction
Tephra
Volcanic impact

ABSTRACT

We present new pollen-temperature reconstructions for the Last Interglacial from central North Island, New Zealand using partial least squares regression (PLS) and modern analogue technique applied with the New Zealand pre-deforestation calibration pollen dataset. The pollen-bearing organic sequence includes numerous millimetre- to decimetre- thick tephra mostly from the adjacent Tongariro Volcanic Centre and is overlain by tephric cover-beds including the c. 25.4 ka cal BP Kawakawa/Oruanui Tephra. Fine-resolution pollen and preliminary diatom analyses above and below prominent tephra layers showed that significant vegetation impact followed only the thickest ashfall event (22 cm thickness), with vegetation recovery taking several hundred years. Apart from this, changes in the longer-term pollen record are likely to be related to climate oscillations that resemble the classic five-fold subdivision of MIS 5. The warmest interval, ascribed to MIS 5e, was characterised by tall, temperate rainforest, and occurs at the base of the sequence, with mean annual temperatures reaching around 1.1 °C higher than present. Mean annual temperatures declined to ~4 °C below present during MIS 5d and MIS 5b and were within 1–2 °C of present during MIS 5c. The PLS temperature reconstructions are corroborated by estimates derived independently from elevational changes to vegetation communities, corresponding to modern temperature controls, inferred from the Karioi pollen spectra. Temperatures reconstructed quantitatively by the modern analogue technique were up to 1.3 °C higher for MIS 5e, MIS 5d and MIS 5b, possibly reflecting weaker modern vegetation analogues for these intervals.

1. Introduction

Marine Isotope Stage (MIS) 5e (The Last Interglacial: LIG) was the most recent period when atmospheric temperature and sea level were well above current levels. The warmer LIG is not a true analogue for contemporary climate change as it resulted from unusual orbital variations (Tzedakis et al., 2012), with variations in atmospheric greenhouse gases a secondary driver (Siegenthaler et al., 2005; Loulergue et al., 2008; Spahni et al., 2005). Nevertheless the period is useful for investigating the spatial patterns of, and biophysical response to, climate change in a recent warmer world and offers insights into future climate impacts. The LIG also represents a 'test bed' for models developed for future climate prediction (Lunt et al., 2013). For example, recent modelling of the global pattern of temperature change during MIS 5e has highlighted spatial variations, notably amplification of temperature change in the polar regions and no change or even cooling in some areas of the tropics and mid-latitudes (Masson-Delmette et al., 2013). Polar amplification has also been observed in temperature patterns in recent decades (Screen, 2014), suggesting it may be common during periods of global warming. These model simulations need to be corroborated with proxy data observations of the LIG climate. However, quantitative agreement between model simulations and data has been poor, with the models in general underestimating the magnitude of response (Lunt et al., 2013; Masson-Delmotte et al., 2013). The paucity of data for the Southern Hemisphere (Turney and Jones, 2010; McKay et al., 2011) compounds the problem of greater uncertainty overall in the model

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http://dx.doi.org/10.1016/j.quascirev.2017.06.018

simulations for the Southern Ocean (Lunt et al., 2013; Masson-Delmotte et al., 2013).

In light of these difficulties, we present a new MIS 5 pollen record and temperature reconstruction from central North Island, New Zealand in the southern mid-latitudes and review the wider evidence for LIG climate from the New Zealand region. The quantified mean annual temperatures from the new record are warmer-than-present for MIS 5e and also show subsequent changes that are broadly consistent with regional and global patterns for the remainder of MIS 5. As the sedimentary sequence is located at the southwestern proximal margin of an active volcanic region and includes interbedded tephra layers of variable thickness, we also investigate the possibility of volcanic disturbance of the vegetation and depositional site that might interfere with our climatic interpretation and temperature reconstructions from the pollen record. We test for this possibility by undertaking high resolution pollen and preliminary diatom analysis of sediments deposited before and after three tephra depositional events that are broadly representative of the suite of volcanogenic deposits occurring within the sedimentary sequence.

2. Study site and region

The Karioi section (39°26′52.4″S, 175°28′41.6″E, 672 m a.s.l) is an exposed road cutting on State Highway 49 situated 7.7 km south-east of Ohakune township, adjacent to the southwestern boundary of Tongariro National Park. The site occurs on the southern flank of the extensive central North Island Tongariro Volcanic Centre, ca. 20 km south-west of the summit of the tallest (c. 2800 m) volcano, Mt Ruapehu (Fig. 1). The section includes pollen- and diatom-bearing organic sediments as well as a variety of volcanogenic deposits. The organic sediments accumulated in a wetland that appears to have been formed following emplacement of an extensive debris flow that impeded local drainage. The probable source of most of the volcanic material is Mt Ruapehu, which forms part of the andesitic Tongariro Volcanic Centre and has been intermittently active for ~250 ka (Gamble et al., 2003). As part of this study, we have also identified tephra layers from the Taupo Volcanic Centre to the northeast and Taranaki/Egmont Volcanic Centre to the west (Fig. 1).

Fig. 1. Location of the study site, Karioi Section and nearby Raurimu Spiral Section at the margins of Tongariro National Park. Inset: North island, New Zealand showing area covered by the main map.

2.1. Regional setting

2.1.1. Climate

The Tongariro Volcanic Centre lies directly in the path of the main cyclonic depressions that pass over the North Island from west to east. At the elevation of Karioi section, annual rainfall varies from 1800 to 2500 mm (NIWA, Cliflo) with more rainfall typically in winter. Soil water deficits may occur in summer, though drought is rare. July is the coldest month with typical winter daytime maximum air temperatures ranging from 10 °C to 14 °C. January and February are the hottest months, with warm, dry and settled weather predominating and daytime maximum air temperatures ranging from 21 °C to 26 °C, rarely exceeding 30 °C. Frosts in the area are extremely common and the Karioi area is covered with snow on average 11 days of the year. A continuous temperature record (1930–1985) from the Karioi Weather Station (<1 km from the site at a similar elevation, 648 m asl), gives a mean annual temperature of 9.67 °C (NIWA, Cliflo). We estimate the mid-twentieth century MAT (mean annual temperature) for the Karioi study site to be 9.54 °C (regional lapse rate = 0.55 °C per 100 m) and use this as a modern reference point for the LIG MAT reconstructions.

2.1.2. Vegetation

Except for swamps and alpine areas, the central North Island region of New Zealand was extensively forested up until the arrival of Polynesians (McGlone, 1989). While substantial forests survive on the Tongariro volcanoes, much of the surrounding lower ground is in farmland or exotic forestry plantations. However, the south-western quadrant of Mt Ruapehu where the Kariori site is located has a continuous forest cover from *ca.* 550 m to tree line at *ca.* 1500 m. In the central North Island, lowland forests extend from sea level to approximately 600–700 m (Wardle, 1991). These forests consist of emergent tall (30 m+) podocarps (*Prumnopitys taxifolia*, *Dacrydium cupressinum*, *Podocarpus totara* most commonly), emergent hardwoods (*Metrosideros robusta*, *Laurelia novae-zelandiae* and *Knightia excelsa*) over a diverse, lower (20–25 m) canopy of hardwood trees, the major dominants including *Weinmannia racemosa, Nestegis* spp. *Eleaocarpus dentatus* and *Beilschmiedia tawa*. The subcanopy usually consists of small trees *Aristotelia serrata, Brachyglottis repanda, Carpodetus serratus, Coprosma* spp.*, Fuchsia excorticata, Griselinia lucida, Hedycarya arborea, Melicytus* spp., *Myrsine* spp., *Olearia* spp., *Pennantia corymbosa, Pittosporum* spp., *Pseudopanax* spp., *Pseudowintera* spp., and *Quintinia* spp. Lianas, epiphytes and tree ferns (*Cyathea* spp. and *Dicksonia* spp.) are common. In poorly drained areas the tall podocarp *Dacrycarpus dacrydiodes* forms dense swamp forest.

The volcanoes in Tongariro National Park provide the best examples of vegetation in the higher altitudes in the region (Atkinson, 1981). *Fuscospora* (Nothofagaceae) forest dominates the montane and subalpine areas often as pure stands or in mixed *Fuscospora fusca-Dacrydium cupressinum-Prumnopitys ferruginea* stands in the