Earth and Planetary Science Letters 430 (2015) 296–307

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

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A new high-resolution record of Holocene geomagnetic secular variation from New Zealand

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ARTICLE INFO

Article history:
Received 12 May 2015
Received in revised form 14 August 2015
Accepted 18 August 2015
Available online 2 September 2015
Editor: B. Buffett

Keywords:
geomagnetic secular variation
palaeomagnetism
Holocene
age model
relative palaeointensity
virtual axial dipole moment

ABSTRACT

We present the first full Holocene palaeomagnetic secular variation record from New Zealand. The 11 500 year-long record, from the sediments of Mavora Lakes, comprises composite declination, inclination and relative palaeointensity logs, compiled from two six-metre long cores and the uppermost 1.5 m of another. An age model has been developed from 28 AMS radiocarbon age determinations on fragments of southern beech (*Lophozonia menziesii* and *Fuscospora cliffortioides*) leaves. The excellent between-core correlation in all three components of the field results in a high-resolution palaeosecular variation record, with precise and accurate age control. The variations change in character from high amplitude in-phase declination and inclination swings in the earliest part of the record to low amplitude variations in the middle part and declination and inclination swings that are 90° out of phase, leading to broad looping of the vector in the upper part of the record, that is consistent with westward drifting sources in the outer core. The present-day field at the site (Dec = 24.2°E, Inc = −70.7°, $F = 59$ μT) represents a rare steep and easterly extreme direction, but close to average intensity. The palaeointensity is inferred to have varied between about 40 and 90 μT, with variations that, to some extent, mirror variations in the virtual axial geomagnetic dipole moment seen from global data, but also show some notable differences, particularly in the past few thousand years.

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1. Introduction

Global databases of palaeomagnetic secular variation data spanning the past few thousand years are heavily weighted towards records from the northern hemisphere. As a result, mathematical models of the global field (e.g. Korte et al., 2011; Nilsson et al., 2014) are less well constrained in the southern hemisphere than in the northern hemisphere, making it difficult to evaluate features of interest such as the time variability of southern high latitude flux lobes on the core–mantle boundary (Constable et al., 2000; Korte and Holme, 2010), the longevity of low latitude reverse flux patches (Jackson, 2003; Nilsson et al., 2014), the enigmatic South Atlantic magnetic anomaly (Heirtzler, 2002; Hartmann and Pacca, 2009), and the long-debated "Pacific dipole window" (e.g. Merrill et al., 1998).

Records of the detrital remanent magnetization (DRM, the net remanent magnetization acquired as a result of both depositional and post-depositional processes) of lake sediment cores play a central role in secular variation studies due to their widespread occurrence and the often continuous and uniform nature of their accumulation. The sole published lake sediment record from New Zealand dates to 1994 (Turner and Lillis, 1994), and is a 2500 year long record compiled from five parallel cores from Lake Pounui in the south of the North Island. Despite excellent correlation between multiple cores, the record is from a single sedimentary basin, it is relatively short compared with typical features of the secular variation, and age control of the prehistoric part of the record is based on radiocarbon dating of bulk sediment – a practice that is fraught with problems and has now become rare (e.g. Nilsson et al., 2014; Snowball et al., 2007).

We present 11 500 year-long records of declination, inclination and relative palaeointensity from three cores of sediment from Mavora Lakes in the Fiordland region of the South Island of New Zealand. High precision age control of the sediments is based on accelerator mass spectrometry (AMS) radiocarbon dating of fragments of southern beech leaves (*Lophozonia menziesii* and *Fus-*

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http://dx.doi.org/10.1016/j.epsl.2015.08.021
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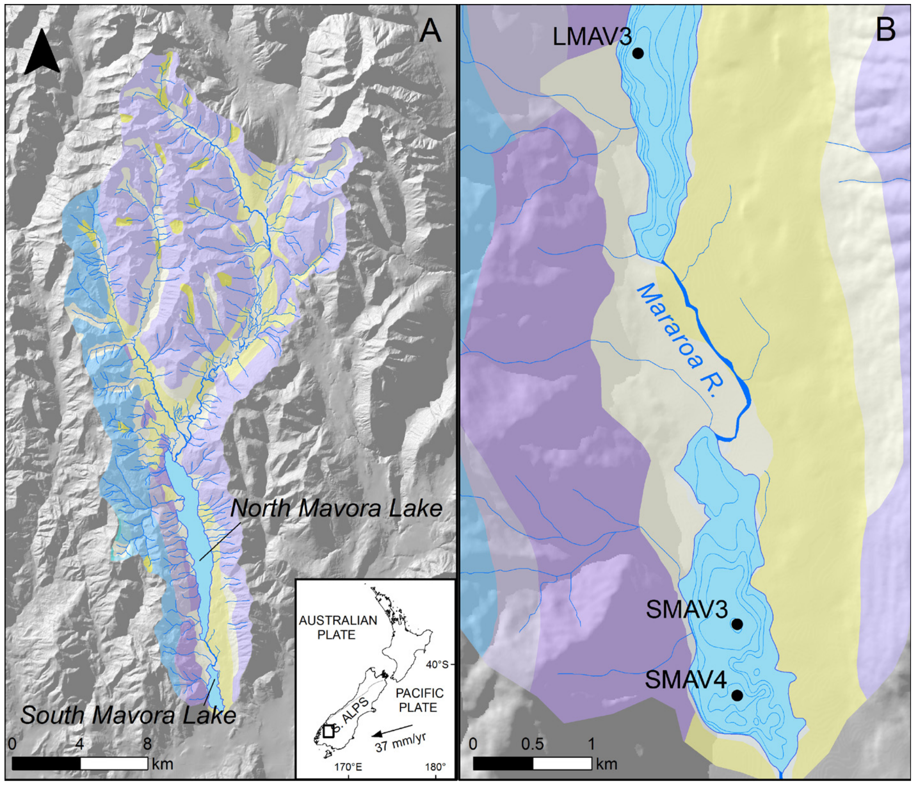

Fig. 1. Location map showing North and South Mavora Lakes and their catchments. (a) The lithology of the catchment, dominated by sandstones, mudstones and schistose sand- and mudstones of the Caples Terrane (purple), melange of the Livingstone Volcanic Group (blue), and Quaternary sediments (yellow). (b) Bathymetry and coring locations in South Mavora and Eldon Basin of North Mavora; isobaths are at 10 m intervals.

cospora cliffortioides). The Mavora record agrees very well with that from Lake Pounui in the overlapping time interval, but shows that the Pounui timescale is seriously affected by erroneously old ages.

2. Mavora Lakes

2.1. Geological setting

Mavora Lakes are situated in south western South Island, New Zealand (45°18′S, 168°10′E), at an elevation of 619 m a.s.l. (Fig. 1A). The Mavora Lakes system contains two lakes, North Mavora (10.83 km^2) and South Mavora (1.23 km^2) that were formed as glaciers receded at the end of the last glacial period. They are joined by a 2 km reach of the Mararoa River. North Mavora is a multi-basin lake. We focus on the southern, Eldon Basin that has a maximum water depth of 30 m. South Mavora has a single basin with a maximum water depth of 48 m that is differentiated into multiple sub-basins at the southern end of the lake. Both lakes receive between 1200 and 2400 mm/a of precipitation.

The fluvial catchments of North (322.55 km^2) and South Mavora (20.21 km^2) are underlain by sandstones, mudstones, and schistose sand- and mudstones of the Caples Terrane (Turnbull, 2000). Livingstone Volcanic Group lithologies, primarily volcanics, dikes, microgabbros and sediments of the Windon Melange, are also prominent. The topography is dominated by steep (26–35°) hillslopes. Hillslopes in the South Mavora catchment are vegetated by largely unmodified indigenous *Lophozonia menziesii* and *Fuscospora cliffortioides* forest below a treeline of 1100 m a.s.l., while the North Mavora catchment is primarily vegetated by tussock grassland.

2.2. Sediment sampling and stratigraphy

The sediments of South and North Mavora Lakes were sampled using a modified Mackereth corer capable of retrieving continuous cores, 50 mm in diameter and up to 6 m long (Mackereth, 1958). Cores were collected from the centres of basins to maximize the potential for obtaining continuous sequences of fine-grained sediments. Our palaeomagnetic measurements were made on two cores from South Mavora and one core from North Mavora (Fig. 1B). The 5.49 m SMAV3 core was taken from the depocentre of the main basin of South Mavora and provides the master core on which the radiocarbon chronology is based. SMAV4 was retrieved from a small sub-basin at the southern end of South Mavora and is 5.41 m long. LMAV3 from North Mavora was located in the depocentre of the southern-most basin, Eldon Basin, and the upper 1.5 m of the 5.7 m core is included in this study.

The sedimentology of the cores is characterized by four bed types described using the classification of Howarth et al. (2014). Deposits of layered silt dominate the sedimentary record of all three cores. They are characterized by inter-bedded fine to medium silt and are between 1 mm and 500 mm thick. Layered silts are formed by deposition from suspension settling during ambient conditions. Deposits of layered silts are episodically interrupted by three types of rapidly deposited layers (RDL). Type 1 RDLs are 50 to 400 mm thick beds of deformed lacustrine silts interpreted as deposits formed by subaqueous slumping of lacustrine sediment. These deposits are confined to SMAV4, which is located close to basin marginal slopes, the likely source of the slumped sediments. Type 2 RDLs invariably overlie type 1 RDLs. These beds are 20–200 mm thick, and are composed of a massive coarse to medium silt unit, capped with a thin, fine silt unit. Type 2 RDLs represent turbidites formed by turbidity currents that evolve from subaqueous slumps, an interpretation supported by the close stratigraphic association with the underlying slump-derived type 1 RDL. Type 3 RDLs are composed of very fine sandy silt, normally grading into fine silt and are between 1 mm and 30 mm thick. These beds are turbidites that were most probably formed by high magnitude discharge from the fluvial system.

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