Quaternary International 374 (2015) 3–14

Contents lists available at ScienceDirect

Quaternary International

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

Middle and Late Holocene paleotemperatures reconstructed from oxygen isotopes and GDGTs of sediments from Lake Pupuke, New Zealand

Alexander M. Heyng [a], Christoph Mayr [a, b, c, *], Andreas Lücke [d], Robert Moschen [d], Holger Wissel [d], Bernd Striewski [e], Thorsten Bauersachs [f]

[a] Dept. of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, Richard-Wagner-Str. 10, D-80333 Munich, Germany
[b] GeoBio-Center, Ludwig-Maximilians-Universität München, Richard-Wagner-Str. 10, D-80333 Munich, Germany
[c] Institute of Geography, Friedrich-Alexander-Universität Erlangen-Nürnberg, Wetterkreuz 15, D-91058 Erlangen-Tennenlohe, Germany
[d] Institute of Bio-and Geosciences, IBG-3: Agrosphere, Forschungszentrum Jülich, D-52425 Jülich, Germany
[e] Geological Survey of Western Australia, Department of Mines and Petroleum, 100 Plain Street, East Perth, WA 6004, Australia
[f] Institute of Geosciences, Christian-Albrechts-Universität, Ludewig-Meyn-Str. 10, D-24118 Kiel, Germany

ARTICLE INFO

Article history:
Available online 13 January 2015

Keywords:
Paleotemperatures
New Zealand
Holocene
Oxygen isotopes
Biogenic silica
Branched GDGTs

ABSTRACT

Quantitative Holocene temperature reconstructions for Southern Hemisphere terrestrial environments are still restricted to few records, and multi-proxy methods are rarely applied to the same system. Here, we test the applicability and comparability of temperature reconstructions inferred from different methodological approaches. We combined sedimentary cellulose and diatom oxygen isotope data from Lake Pupuke (North Island New Zealand) to derive a record of lake water temperatures. This record is complemented with mean annual air temperatures derived from the branched GDGT index MBT measured on the same sedimentary record. The datasets of both reconstructions show little temperature variation for the period 1320–7110 cal. BP. The exceptions are a warmer period culminating between 1700 and 1600 cal. BP reflected in both proxies and centennial-scale intervals with cooler water temperatures at 3380 and 2750 cal. BP recorded in the oxygen-isotope-based temperature reconstruction but not in the MBT-inferred air temperature estimates. We suggest that variations in lake circulation are the likely reason for deviations between temperature reconstructed from different proxies.

1. Introduction

Beside ice-core, tree-ring and marine sediment records, lacustrine sediments are the most important paleoclimatic archives used for Holocene paleotemperature studies. For the marine realm, a carbonate-isotope paleothermometer was originally developed for calculations of paleotemperatures (Emiliani, 1955), but variable oxygen isotopic compositions of host waters hampers temperature reconstructions, especially when using this proxy for lacustrine archives (Leng and Marshall, 2004). If no calcareous micro- or macrofossils are preserved in lacustrine sediments, the temperature signal recorded in oxygen isotopes of biogenic opal in combination with proxies suitable for reconstructing the oxygen isotope signature of ancient lake waters ($\delta^{18}O_{lake\ water}$), e.g. sedimentary cellulose, may be used for temperature calculations (Rozanski et al., 2010). If separated sedimentary cellulose is of endogenic (lake internal) origin, it can serve as a $\delta^{18}O_{lake\ water}$ proxy due to a rather constant cellulose-water oxygen isotope fractionation factor (Edwards and McAndrews, 1989). However, up to now the oxygen isotope paleothermometer utilizing combined cellulose-opal investigations was rarely applied to lake sediments (Rozanski et al., 2010), possibly because only a few lacustrine records meet the requirements for this approach. Firstly, the lake sediments need to contain sufficient quantities of lacustrine cellulose and biogenic silica for analyses. Secondly, it must be possible to isolate and purify these components in quantities required for isotope analyses. In recent years improved methods were developed to separate pure lacustrine cellulose (Wolfe et al., 2001, 2007; Wissel et al., 2008) and biogenic silica (SPLITT fractionation, Leng et al., 2001, 2006, 2008; Rings et al., 2004) from the bulk sediment samples, and to

* Corresponding author.
E-mail address: christoph.mayr@fau.de (C. Mayr).

http://dx.doi.org/10.1016/j.quaint.2014.12.040

minimize the biasing effects of opal-bound water in the isotopic analysis of biogenic opal (Lücke et al., 2005; Chapligin et al., 2012). Hence, the δ^{18}O-analysis of lacustrine cellulose and opal has become more robust and reliable.

Another temperature proxy increasingly applied in paleoclimatological studies is based on the methylation and cyclization indices of branched tetraethers (MBT/CBT) (Weijers et al., 2007a). This proxy is based on the relative distribution of branched glycerol dialkyl glycerol tetraethers (GDGTs), which have been reported to be highly abundant in soils and peats (Sinninghe Damsté et al., 2000; Weijers et al., 2006), where they are thought to originate from anaerobic soil bacteria involved in the mineralization of organic matter (Weijers et al., 2006). In addition, a chemical structure thought to originate from branched GDGTs has recently been reported from laboratory cultures of *Edaphobacter aggregans* and *Acidobacteriaceae* spp., suggesting that acidobacteria may constitute an alternative source of branched GDGTs in soils (Sinninghe Damsté et al., 2011). Despite the uncertainty in the origin of branched GDGTs, it has been demonstrated that the degree of methylation and cyclization of branched GDGT in soils changes as a function of pH and temperature (Weijers et al., 2007a). As a consequence the distribution of branched GDGTs allows the reconstruction of soil temperature, which is strongly correlated with mean annual air temperature (MAAT). As branched GDGTs are

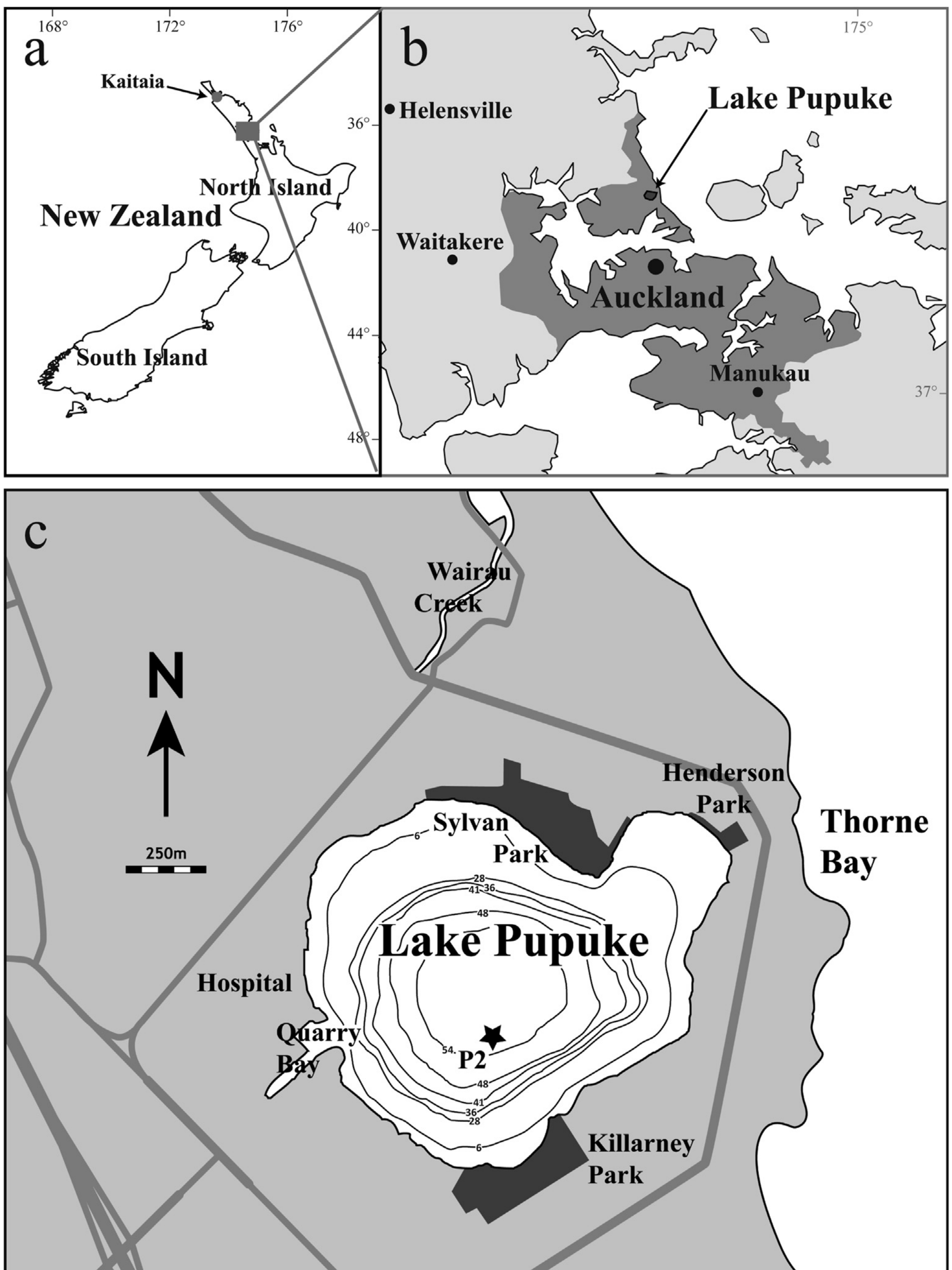

Fig. 1. a, b. Geographic position of Lake Pupuke in the Auckland area, North Island, New Zealand. c. Detailed map of Lake Pupuke; the position of the analyzed sediment core P2 is indicated by the star; areas with vegetation cover are colored in dark grey, water surfaces are given in white.