Quaternary Science Reviews 71 (2013) 154–166

Contents lists available at SciVerse ScienceDirect

Quaternary Science Reviews

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

Climate induced changes as registered in inorganic and organic sediment components from Laguna Potrok Aike (Argentina) during the past 51 ka

A. Hahn [a,*], P. Kliem [a], C. Ohlendorf [a], B. Zolitschka [a], P. Rosén [b], The PASADO Science Team [1]

[a] Geomorphology and Polar Research (GEOPOLAR), Institute of Geography, University of Bremen, Celsiusstr. FVG-M, D-28359 Bremen, Germany
[b] Climate Impacts Research Centre, Umeå University, SE-981 07 Abisko, Sweden

ARTICLE INFO

Article history:
Received 30 November 2011
Received in revised form
18 June 2012
Accepted 7 September 2012
Available online 6 October 2012

Keywords:
Carbonates
Organic matter
Biogenic silica
Diffuse Reflectance Fourier Transform Infrared Spectrometry (DRIFTS)
Lake level
Primary productivity
Patagonia
Argentina
ICDP project PASADO

ABSTRACT

Total organic carbon, total inorganic carbon, biogenic silica content and total organic carbon/total nitrogen ratios of the Laguna Potrok Aike lacustrine sediment record are used to reconstruct the environmental history of south-east Patagonia during the past 51 ka in high resolution. High lake level conditions are assumed to have prevailed during the Last Glacial, as sediments are carbonate-free. Increased runoff linked to permafrost and reduced evaporation due to colder temperatures and reduced influence of Southern Hemispheric Westerlies (SHW) may have caused these high lake levels with lake productivity being low and organic matter mainly of algal or cyanobacterial origin. Aquatic moss growth and diatom blooms occurred synchronously with southern hemispheric glacial warming events such as the Antarctic A-events, the postglacial warming following the LGM and the Younger Dryas chronozone. During these times, a combination of warmer climatic conditions with related thawing permafrost could have increased the allochthonous input of nutrients and in combination with warmer surface waters increased aquatic moss growth and diatom production. The SHW were not observed to affect southern Patagonia during the Last Glacial. The Holocene presents a completely different lacustrine system because (a) permafrost no longer inhibits infiltration nor emits meltwater pulses and (b) the positioning of the SHW over the investigated area gives rise to strong and dry winds. Under these conditions total organic carbon, total organic carbon/total nitrogen ratios and biogenic silica cease to be first order productivity indicators. On the one hand, the biogenic silica is influenced by dissolution of diatoms due to higher salinity and pH of the lake water under evaporative stress characterizing low lake levels. On the other hand, total organic carbon and total organic carbon/total nitrogen profiles are influenced by reworked macrophytes from freshly exposed lake level terraces during lowstands. Total inorganic carbon remains the most reliable proxy for climatic variations during the Holocene as high precipitation of carbonates can be linked to low lake levels and high autochthonous production. The onset of inorganic carbon precipitation has been associated with the southward shift of the SHW over the latitudes of Laguna Potrok Aike. The refined age-depth model of this record suggests that this shift occurred around 9.4 cal. ka BP.

1. Introduction

In order to answer questions about possible future climate changes and contribute to prediction efforts, we need to consider the long-term climate variability of the past. The southern mid-latitudes of South America are a key area that has been scarcely studied in the past, even though it is of importance due to its proximity to the climatically sensitive areas of Antarctica and the Southern Oceans (Knorr and Lohmann, 2003). Recent studies have underlined the relevance of the southern hemisphere oceanic and atmospheric circulation to global climate changes. The ventilation of the deep southern ocean and thus the flux of CO_2 from the ocean into the atmosphere are controlled by strength and position of the SHW (Toggweiler and Lea, 2010). Anderson and Burckle (2009) suggest that the shift of the SHW caused CO_2 to increase at the onset of the

* Corresponding author.
E-mail address: anhahn@uni-bremen.de (A. Hahn).
[1] PASADO Science Team as cited at: http://www.icdp-online.org/front_content.php?idcat=1494.

0277-3791/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.quascirev.2012.09.015

Antarctic warming period at ca 17 ka cal. BP. Laguna Potrok Aike is located on the only large continental land mass in the southern hemispheric mid-latitudes and contains one of the longest high resolution continental archives that continuously records climate and environmental changes in this area. Its key location has attracted scientific attention to this climate archive; in the framework of the "South American Lake Sediment Archives and Modeling" (SALSA) project a 19 m core that documents climatic and environmental variability during the last 16 ka, was recovered (Haberzettl et al., 2007). In order to extend this continuous high resolution climate record further back into time the ICDP deep drilling campaign "Potrok Aike Maar Lake Sediment Archive Drilling Project" (PASADO) was initiated. In this paper, Diffuse Reflectance Fourier Transform Infrared Spectrometry (DRIFTS) technology (Rosén et al., 2010, 2011; Hahn et al., 2011) was used in order to efficiently achieve high resolution analyses of the 106 m long PASADO record and to reconstruct lake level (TIC) and paleoproductivity (BSi, TOC) and the origin of organic matter (C/N ratio). By means of comparison with other southern hemispheric archives, we aim to gain insights into inter-hemispheric climate coupling and regional differences in past climate changes e.g. moisture, temperature and wind speed during the past 51 ka.

2. Study site

Laguna Potrok Aike (52°S, 70°W; 113 m a.s.l.) is a 770 ka old maar lake with a diameter of 3.5 km and a maximum depth of 100 m (Zolitschka et al., 2006). It is situated in the Pali Aike Volcanic Field in Southern Patagonia, 80 km NW of the Strait of Magellan and ca 110 km WSW of the city of Rio Gallegos (Fig. 1). The catchment area covers more than 200 km^2, yet runoff only occurs episodically mainly after snowmelt. The annual precipitation at Laguna Potrok Aike no more than about 200 mm and the potential evaporation rate is in the range of 1000–1600 mm per year (Borrelli and Oliva, 2001; Ohlendorf, submitted for publication). This cold and semi-arid desert (Soriano, 1983), is typified by a steppe-type vegetation. The main climatic component is the strong SHW that dominates the lake site especially during summer months.

3. Materials and methods

3.1. Previous and concurrent work

During austral spring 2008, a 106 m composite profile of lacustrine sediments was recovered from the maar lake Laguna Potrok Aike in southern Patagonia, Argentina, in the framework of the ICDP project PASADO (Potrok Aike Maar Lake Sediment Archive Drilling Project). Drilling operations were performed by DOSECC (Drilling, Observation and Sampling of the Earth's Continental Crust, Inc.) using the GLAD800 platform with a Hydraulic Piston Coring system (HPC). At two drill sites seven overlapping cores were recovered (Fig. 1). After logging, cores were split, scanned and described lithologically. Logging data and lithological descriptions

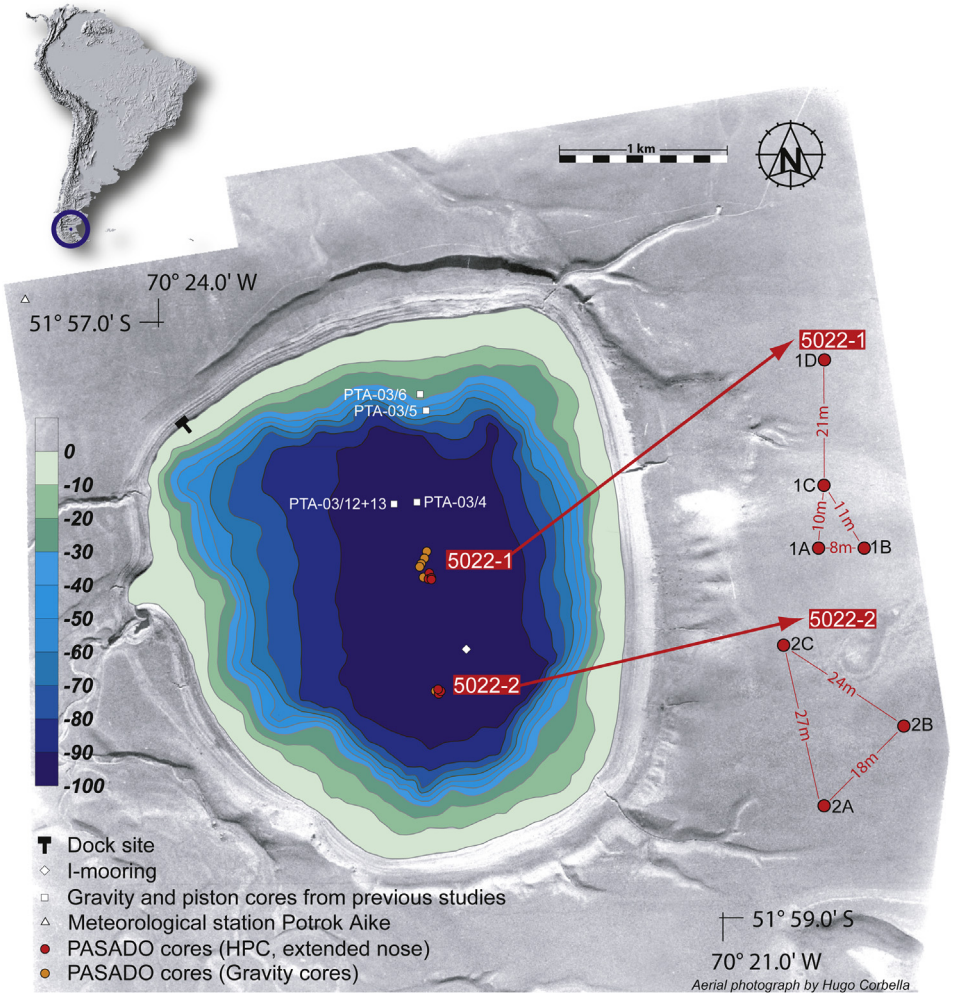

Fig. 1. Bathymetric map with coring sites of Laguna Potrok Aike and location in South America.