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Lithology, radiocarbon chronology and sedimentological interpretation of the lacustrine record from Laguna Potrok Aike, southern Patagonia

Pierre Kliem [a,*], Dirk Enters [a], Annette Hahn [a], Christian Ohlendorf [a], Agathe Lisé-Pronovost [b,c], Guillaume St-Onge [b,c], Stefan Wastegård [d], Bernd Zolitschka [a] and 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] Institut des sciences de la mer de Rimouski (ISMER), Université du Québec à Rimouski (UQAR), Québec, Canada
[c] GEOTOP Research Center, Québec, Canada
[d] Dept. of Physical Geography and Quaternary Geology, Stockholm University, SE-106 91 Stockholm, Sweden

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ABSTRACT

The 106 m long composite profile from site 2 of ICDP expedition 5022 (PASADO) at Laguna Potrok Aike documents a distinct change in sedimentation patterns from pelagic sediments at the top to dominating mass movement deposits at its base. The main lithological units correspond to the Holocene, to the Lateglacial and to the last glacial period and can be interpreted as the result of distinct environmental variations. Overflow conditions might have been achieved during the last glacial period, while signs of desiccation are absent in the studied sediment record. Altogether, 58 radiocarbon dates were used to establish a consistent age-depth model by applying the mixed-effect regression procedure which results in a basal age of 51.2 cal. ka BP. Radiocarbon dates show a considerable increase in scatter with depth which is related to the high amount of reworking. Validation of the obtained chronology was achieved with geomagnetic relative paleointensity data and tephra correlation.

1. Introduction

Lacustrine sediments are often outstanding natural archives and complement marine and ice core records to reveal a consistent global picture of past environmental and climatic changes. However, terrestrial paleoclimatic data reaching far back into the Pleistocene are rare, especially from the Southern Hemisphere where southernmost South America is the only continental land mass between 40°S and 60°S. But here climate archives, mostly fen and lake sediments at the foot of the Andes, comprise only the past 18 cal. ka BP (Gilli et al., 2005; Markgraf et al., 2007; Wille and Schäbitz, 2009; Markgraf and Huber, 2010; Moy et al., 2011). Older records can only be found in extra-Andean Patagonia like at Laguna Potrok Aike, Patagonia (51°58′ S, 70°23′ W). This site emerged as a valuable terrestrial paleoclimate archive for the last 16 cal. ka BP (Zolitschka et al., 2006; Haberzettl et al., 2007; Anselmetti et al., 2009; Mayr et al., 2009), and the Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO) was established to extend the climate record back in time. Such a sediment archive would allow to investigate shifts in polar to mid-latitude pressure fields and precipitation changes related to the Southern Hemispheric Westerlies as well as the Antarctic Oscillation and allows inter-comparisons between paleodata and climate models (Wagner et al., 2007; Meyer and Wagner, 2008). Due to the location of Laguna Potrok Aike in the Patagonian steppe leeward of the Andean mountain range, it should also be suited to establish a tephra and dust record which may be linked to marine records and ice cores from Antarctica. Furthermore, the possible extension of the Patagonian tephrochronology beyond the Lateglacial will provide the needed chronological control for other investigations using terrestrial as well as marine records.

* Corresponding author.
E-mail address: kliem@uni-bremen.de (P. Kliem).
[1] PASADO Science Team as listed at http://www.icdp-online.org/front_content.php?idcatart=2794.

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Especially for multidisciplinary projects like PASADO, the initial lithological core description is essential and gives an overview about the compositional variability of the sediment record (lithological units) and the occurrence of unconformities and bedding structures (Schnurrenberger et al., 2003). This information is important to adjust the sampling scheme and to omit reworked sediment units from further time-consuming and expensive analyses. Moreover and most important, the significance of the obtained paleoenvironmental information depends on a reliable age-depth model. Only if time control is available, a comparison with other records becomes possible and lithological changes can be quantified with variations in sedimentation rates. Thus, the objectives of this study are to (1) describe the lithological changes encountered along the sediment record, (2) establish a robust radiocarbon-based age-depth model and (3) interpret the observed sedimentological variability.

2. Site description

Laguna Potrok Aike is a polymictic and subsaline maar lake located in the Pali Aike Volcanic Field (PAVF) at 113 m a.s.l. (Fig. 1). It has a maximum diameter of 3.5 km and a water depth of 100 m with a volume of 0.41 km^3 (Zolitschka et al., 2006). According to the isotopic composition of the water body Laguna Potrok Aike is a groundwater lake (Mayr et al., 2007a). Rapid hydrological variations are documented by subaerial and subaqueous lake level terraces (Haberzettl et al., 2005; Anselmetti et al., 2009). At present the lake neither has a permanent tributary nor an outflow. A paleo-outflow related to a higher lake level is discussed for the Lateglacial (Haberzettl et al., 2007). Currently, only episodic or ephemeral surface runoff incised deep gullies in the surrounding subaerial terraces (Mayr et al., 2007a).

The PAVF is a region in the Province of Santa Cruz (Argentina) characterized by backarc volcanism (Mazzarini and D'Orazio, 2003). This intra-plate volcanism consists of Pliocene (3.8 Ma) to Holocene (0.01 Ma) alkali-olivine basalts (Corbella, 2002). The investigated maar itself is located in the older western part of the PAVF with scoria cones, plateau lavas and maar volcanoes occurring in the catchment area. A basaltic clast from the phreatomagmatic tephra of the maar eruption was dated by Ar/Ar and provides an age of 0.77 ± 0.24 Ma (Zolitschka et al., 2006). Outcrops of weakly compacted sandstone exist along the perimeter of the lake on subaerial terraces. These belong to Lower Miocene fine-grained molasse-type fluvial sandstones of the Santa Cruz Formation which is the youngest formation in the Magellanes Basin (Uliana and Biddle, 1988). Plio- and Pleistocene glaciations left behind fluvioglacial deposits and till in the catchment area, but glaciers did not reach the catchment area during the last few glaciations (Caldenius, 1932; Coronato et al., 2013; Mercer, 1976; Rabassa and Clapperton, 1990; Meglioli, 1992).

Due to the proximity of the Antarctic continent, during austral summers the small land mass of southern Patagonia does not warm up as much as continents in the same latitude of the Northern Hemisphere (Weischet, 1996). The mean annual temperature at Rio Gallegos (6 m a.s.l., 85 km north-east of the study site) is only 7.4 ± 0.7 °C (Zolitschka et al., 2006). The regional climate is affected by the Southern Hemispheric Westerlies. The rain shadow effect of the north–south striking Andean mountain chain decreases precipitation to less than 300 mm (Mayr et al., 2007b). At the meteorological station next to Laguna Potrok Aike an annual precipitation sum of 150 mm has been observed (Zolitschka et al., 2006). Mean annual wind speeds of 7.4 m/s occur at Rio Gallegos; primarily from westerly directions (Weischet, 1996; Baruth et al., 1998). Recent series of precipitation measurements (1999–2005) at Laguna Potrok Aike reveal that easterly wind directions are often combined with precipitation whereas west winds do not carry considerable amounts of moisture into the area (Mayr et al., 2007b).

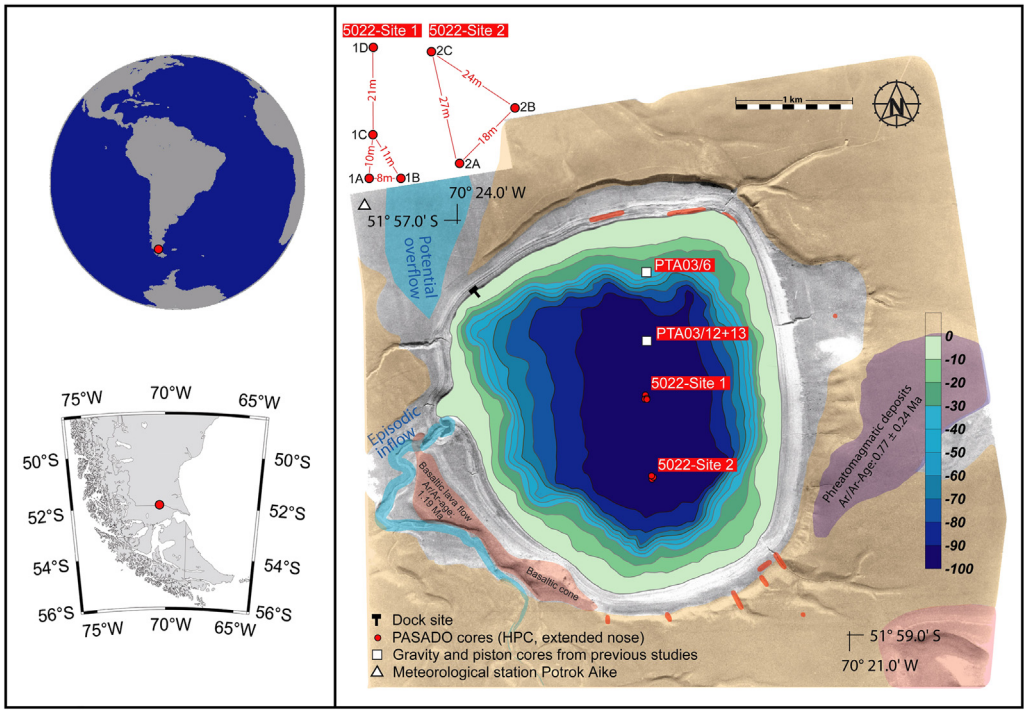

Fig. 1. Location of Laguna Potrok Aike in the southern hemisphere, in southern South America and bathymetric map with position of drill sites merged with an aerial photograph and geological data (Corbella, 2002; Zolitschka et al., 2006). Depth is given in m below lake surface. Young fluvial and lacustrine deposits (gray), a mid-Pleistocene basalt lava flow (red), phreatomagmatic tephra deposits (pink), moraine till (yellow), and the Tertiary Santa Cruz Formation (orange) are color-coded. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)