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Authigenic, detrital and diagenetic minerals in the Laguna Potrok Aike sediment sequence

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ABSTRACT

The ~100 m-long Laguna Potrok Aike sediment sequence yielded a record spanning the Last Glacial period to the Holocene. This paper presents and discusses two aspects of the mineralogy of the lake. The first aspect is based on a semi-quantitative X-ray diffraction analysis of bulk and clay mineralogical assemblages. Minor mineralogical changes are observed throughout the glacial section suggesting relatively uniform sediment sources. The transition into the Holocene is characterized by increasing fluxes of endogenic calcite thought to relate to lower lake levels. The second aspect is based on analysis of uranium-series disequilibria in diagenetic vivianite from the glacial section. U-series ages were expected to yield minimum ages for the host-sediment. Unfortunately, very little authigenic U is present in vivianite grains. The low primary productivity of the lake and thus low organic carbon fluxes might have prevented the development of strong redox gradients at the water-sediment interface and thus reduced diagenetic U-uptake into the sediment. One vivianite sample, at a 56.9 m composite depth, yielded enough authigenic uranium to calculate a ^{230}Th-age of 29.4 ± 5.9 ka (±2σ). This age is younger than the one indicated by the radiocarbon chronology. It is thus concluded that a relatively late diagenetic evolution of the U–Th system characterizes the recovered vivianite minerals. The authigenic U displays a very high excess in ^{234}U (over ^{238}U) with an activity ratio of 4.58 ± 0.58 (±2σ). It suggests that it originates from the transfer of highly fractionated U from surrounding detrital minerals through very low U-content pore waters.

1. Introduction

Laguna Potrok Aike (51°58′ S, 70°23′ W in south-eastern Patagonia, Argentina) is one of the older maars of the Pali Aike Volcanic Field (PAVF), which is the most extensive maar field in South America. A ~200 km^2 watershed contains a quasi-circular bowl-shaped crater ~5 km in diameter filled by a lake of ~100 m depth and ~3.5 km width (Zolitschka et al., 2009). The crater was formed by an explosive eruption of rising magma contacting ground water, meltwater from ground ice or permafrost (Corbella, 2002; Fig. 1). ^{40}Ar/^{39}Ar data of a basaltic clast from the phreatomagmatic tephra outcropping on the eastern side of the maar provided an age of 0.77 ± 0.24 Ma for the event (Zolitschka et al., 2006; Fig. 1). Seismic surveys indicate an exceptionally thick lacustrine sediment infill (up to 370 m in thickness) likely underlain by volcanoclastic deposits (Anselmetti et al., 2009; Gebhardt et al., 2011) which seemed to be protected from glacial erosion, deflation or desiccation (Zolitschka et al., 2006). Therefore, Laguna Potrok Aike has the potential to preserve a continuous and high-resolution Late Quaternary sediment record suitable to extract a long paleoenvironmental reconstruction for the Southern Hemisphere (Zolitschka et al., 2006; Haberzettl et al., 2007; Anselmetti et al., 2009).

The Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO) was thus undertaken within the framework of the International Continental Scientific Drilling Program (ICDP). From the available material, a ~100 m-long composite record from the southern part of the lake was investigated using multiple tracers (Ohlendorf et al., 2011). Our contribution to this project is twofold. First, using semi-quantitative X-ray diffraction analyses, we investigated mineralogical changes in order to document potential changes in soil hydrolysis conditions and in sediment sources through time, since minerals might reflect weathering conditions in the watershed (e.g., Velde, 1992; Moore and Reynolds, 1997;

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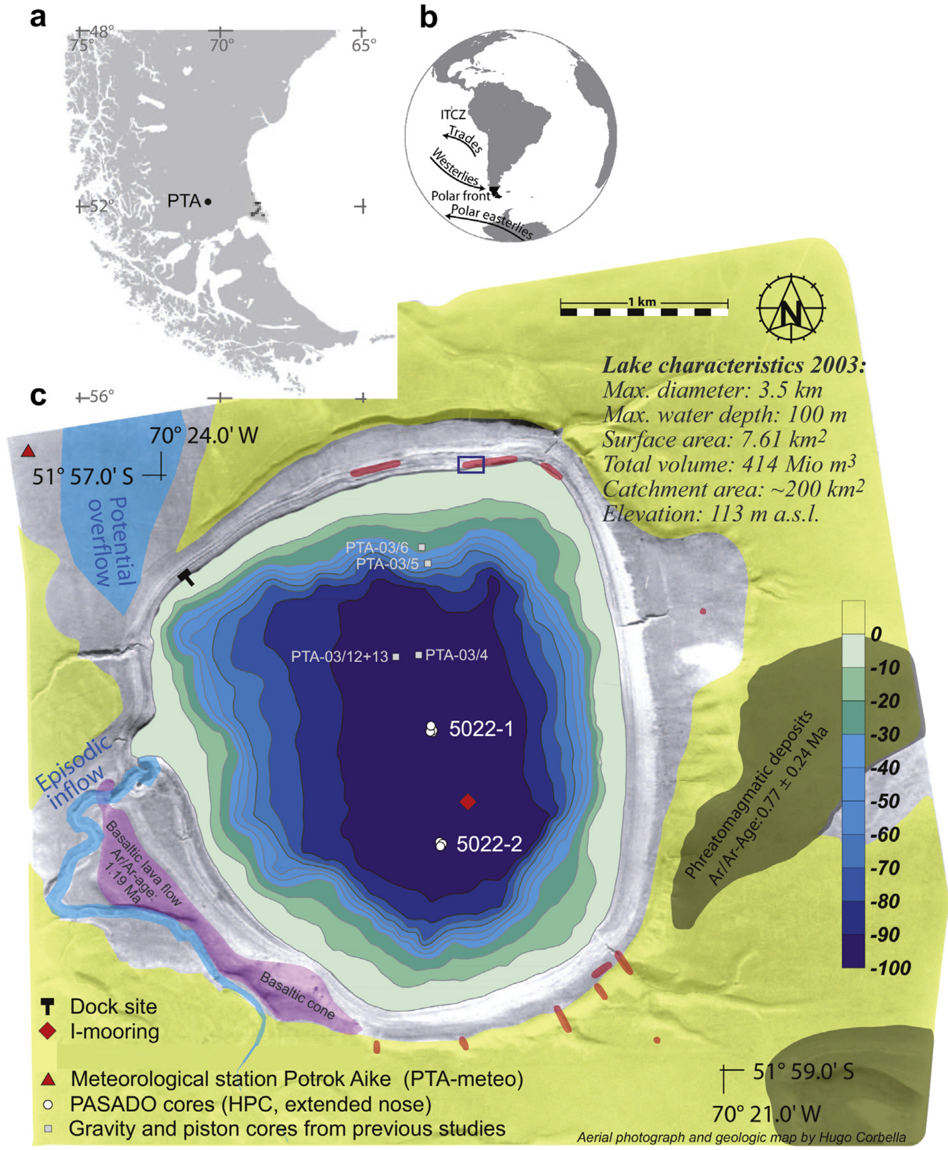

Fig. 1. Location, bathymetry and description of Laguna Potrok Aike. (a) Location of Laguna Potrok Aike (PTA) in southern Patagonia. (b) Schematic circulation of main atmospheric currents in southern America. (c) Aerial photograph of the immediate catchment area of Laguna Potrok Aike, bathymetry, core location and some site characteristics (modified after Ohlendorf et al., 2013).

Chamley, 2000; Last, 2001; Thorez, 2003). Second, we analyzed U-series isotopes in authigenic and/or early diagenetic vivianite [$Fe_3(PO_4)_2.8H_2O$], present at several depths in the composite sequence. High uranium concentrations were indeed reported in vivianite from similar settings (e.g., Lake Baikal; Fagel et al., 2005). Here, the objective was to elaborate ^{230}Th-ages for this diagenetic mineral, as successfully done in a large array of diagenetic minerals from East African Lakes by Goetz and Hillaire-Marcel (1992).

2. Regional settings

The lake is located at 113 m above sea level (lake level in 2003; Ohlendorf et al., 2011) in the older western part of the PAVF, ~300 km east of the Andes, ~85 km west of the city of Río Gallegos and ~80 km north of the Strait of Magellan. The PAVF consists of Pliocene (3.8 Ma) to Holocene (0.01 Ma) alkali-olivine basalts in a back-arc type of volcanism (Corbella, 2002). Scoria cones and plateau lavas formed during Late Miocene to Middle Pleistocene times are found in the catchment area (Coronato et al., 2013) as well as fine-grained molasse-type fluvial sandstones of the Lower Miocene Santa Cruz formation. Furthermore, Pleistocene glaciations left behind fluvioglacial deposits and tills dated between 1.2 and 0.8 Ma (Zolitschka et al., 2006). It seems that glaciers did not reach the catchment area during the last few glaciations (Mercer, 1976; Rabassa and Clapperton, 1990; Coronato et al., 2013).

Laguna Potrok Aike is currently polymictic due to the strong southern hemispheric westerly winds (mean annual wind speed of ~7.4 m/s; Zolitschka et al., 2006). This setting prevents the development of any ice cover during the austral winter and generates a non-stratified water column with oxygen-rich bottom waters. Today, subsaline conditions induce low productivity. The mean annual temperature recorded at the meteorological station of Río Gallegos is 7.4 °C (Zolitschka et al., 2006). Air masses passing over the Patagonian Andes produce a strong rainfall gradient from west to east and trigger semi-arid conditions in the Laguna Potrok Aike region with annual precipitation below 200 mm (Zolitschka et al., 2006). However, precipitation was highly variable during