LAKE MASCARDI RECORD OF HOLOCENE GLACIER VARIATIONS AT 41°S

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Summary
Lake Mascardi is feed from meltwater originating from the Tronador ice-cap in Argentina near the Chilean border. A multi-disciplinary analysis of the Holocene sedimentary record (10 ka. to present) indicate that the visible lithostratigrafic units vary in phase with magnetic susceptibility, grain-size, organic matter content and pollen percentages. These data combined with a robust accelerator mass spectrometer radiocarbon (AMS) chronology are used as indicators of glacial activity in the lake catchment. In addition, α-cellulose from Holocene subaquatic mosses was isolated and analyzed for stable isotopes. The oxygen isotopic composition of cellulose from these subaquatic mosses was in turn used to infer changes in the lake's isotopic composition and its relationship with the reconstructed changes in the Tronador ice cap during the Holocene.

Introduction
Glaciers are particularly sensitive to variability in the global climate system. Until recently, the reconstruction of Holocene glacier variations has been based largely on moraine stratigraphy. Yet, there is a very limited and fragmented data coverage of neoglaciations in the Southern Hemisphere. In Patagonia the coverage of these neoglaciations is mostly based on moraines and tree-rings data (Röthlisberger, 1986; Villalba et al., 1990). It is critical, therefore, to develop long continuous Holocene records for comparison with existing data bases, especially oceanic and ice core data.

The site
Lake Mascardi is an open basin proglacial lake, feed from meltwater originating from the Tronador ice-cap in Argentina (41°10'S, 71°53'W) near the Chilean border (Fig. 1). Recent multi-disciplinary analysis of Lake Mascardi's late-Glacial-Holocene sedimentary record (8-15 ka) indicate changes in climate associated with global perturbations such as the well-known Younger Dryas (Ariztegui et al., 1997). In particular, grain size analysis has demonstrated that the glaciers associated with the ice-cap, only 15 km to the northwest, control the median particle size delivered to the lake as they retreat and advance.

Methodology
Seismic data was collected using an ORE-geopulse 3.5 kHz single-channel pinger system with a vertical seismic resolution of ca. 10-20 cm. Sedimentary cores were retrieved using the ETH-limnogeology coring system. Magnetic susceptibility profiles where obtained in whole cores using a Bartington MS2 system and an attached MS2C core sensor.
Libby radiocarbon ages were obtained on terrestrial macrofossils, subaquatic mosses and bulk samples at the ETH-Hönggerberg AMS Facility (Switzerland). The Holocene aquatic material is particularly suitable for radiocarbon dating because of the absence of hardwater effects.
Total organic carbon (TOC) and hydrogen index (HI) were obtained using a Rock-Eval Pyrolysis. Oxygen isotopic composition was measured in the α-cellulose extracted from well-preserved mosses using CF-IRMS techniques (Anderson, 1999).

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Results and Disscussion
Seismic Survey
Approximately 60 km of 3.5 kHz profiles allow a reconstruction of the lake bathymetry and sediment structure as well as the separation of the effects of climate and neotectonics on lake sedimentation (Ariztegui et al., *in press*). This is important, because the lake is located in an area of significant Holocene volcanic activity. The profiles record up to 50 m below the lake floor, representing approximately the last 15 thousands years of infill history. Sedimentation is characterized by a paucity of chaotic debris and a relatively simple infill stratigraphy. Comparison of the seismic results with multiproxy analyses from a suite of sediment cores established a well-dated lithostratigraphy. The predominant pattern of sedimentation during the Holocene comprises simple and continuous basin infilling with variable sedimentation rates. Thus, it provides an excellent material to study Holocene glacial variations in a continuous mode.

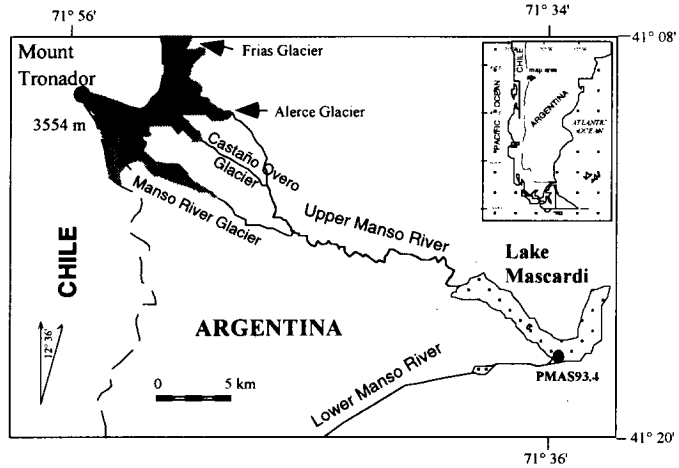

Figure 1 Lake Mascardi (800 m a.s.l., 30 km^2 in area and 200 m maximum water depth), is located about 15 km from the regenerated glacier front. The black dot indicates the location of core PMAS93.4.

Holocene Sedimentary Record
Piston core PMAS93.4 (Fig. 1) obtained from a water depth of 30 m contains a continuous Holocene sequence of fine siliciclastic sediments with a variable content of well-preserved subaquatic mosses (*Rhynchostegium*). Numerous tephra layers of variable thickness, grain size and colours are interbedded throughout the whole Holocene record.

A clear difference in the magnetic behaviour of the sediments can be observed between the Holocene and the Late-glacial sections. The magnetic susceptibility profiles for the last 10,000 radiocarbon years show major peaks associated with the presence of tephra layers of variable grain size and composition.

These peaks are superimposed to more moderate changes. These comparatively lower amplitude variations correspond to differences in the clastic/organic contents of the sediments as shown by the correlation between the magnetic susceptibility profiles and the bulk organic parameters such as TOC and HI. The sediments contain average TOC values of 1.5% and relatively constant low HI (ca. 150). Higher TOC values up to 3% are observed, however, around 7.0 and between 5.0 and 3.0 ka. B.P.

A substantial increase in *Nothofagus* percentages is observed 8.0 ka. B.P. decreasing at around 3.0 ka. B.P. Conversely, steppe and montane elements of the flora such as Poaceae as well as the total aquatic pollen seem to increase from ca. 3.0 ka. B.P. towards the present.

The sedimentary sequence of core PMAS 93.4 from Lake Mascardi provides a uniquely record of subaquatic mosses (*Rhynchostegium*) from which cellulose was isolated and analyzed for stable isotopes. The oxygen isotopic composition of cellulose from these subaquatic mosses can in turn be used to calculate the lake's isotopic composition, and thus help to develop a hydrologic balance model to assess the climatic significance of these data. The isotopic ratio of oxygen in cellulose is generally considered to be controlled by: 1) the isotopic composition of the water utilized in cellulose production and 2) the biologic fractionation between cellulose and water (DeNiro and Epstein, 1979; DeNiro and Epstein, 1981; Sternberg et al., 1986) . In terrestrial plants, these controls are further complicated by transpiration of water through the leaves' stomata. Subaquatic mosses do not have stomata, and water is only moved in and out of the cells by diffusion (Proctor, 1981). In order to avoid the problem of potentialy different biologic fractionation factors of the different plants in Lake Mascardi the same plant specimen were selected throughout the core for analysis.
The preliminary results in the isotopic ratio of oxygen in cellulose, $\delta^{18}O_{(\alpha\text{-cellulose})}$, show consistent changes when combined with the seismic, sedimentological, bulk organic matter and biological remains. Moreover, these fluctuations are coherent with other indicators of paleoenvironmental conditions in Lake Mascardi (Masaferro and Corley, 1998) as well as with previous general reconstructions of glacial fluctuations for the region (Röthlisberger, 1986). Thus, the collective evidence indicate that the changes observed in Lake Mascardi sediments can be interpreted in terms of fluctuations of the Tronador ice cap during the Holocene.

Conclussions

Presently, there is a very limited data coverage of neoglaciations in Patagonia mostly based on moraines and tree-rings data (Röthlisberger, 1986; Villalba et al., 1990). These records, however, are discontinuous and/or cover more limited time intervals. Conversely, the results of our multi-disciplinary study from Lake Mascardi's sediments combined with a robust AMS chronology provide a unique continuous reconstruction of glacier fluctuations at 41°S throughout the whole Holocene. In addition, it provide an innovative tool, $\delta^{18}O_{(\alpha\text{-cellulose})}$, to study lacustrine paleoclimate archives in lakes without bio-induced calcite precipitation. The integration of these results with other climate archives will aid in establishing more refined models of climate forcing mechanisms in this region.

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References

Anderson, W. T., 1999, Calibration of High-resolution Terrestrial Isotopic Records of Recent Climatic Change: Implications for Understanding Paleo-Atmospheric Circulation Changes. Unpublished Ph.D. Thesis. ETH-Zürich, Switzerland

Ariztegui, D., Anselmetti, F. S., Kelts, K., Seltzer, G. & D'Agostino, (*in press*), Identifying paleoenvironmental change across South and North America using high-resolution seismic stratigraphy in lakes. In: V. Markgraf (edt.), Present and Past Inter-hemispheric Climate Linkages in the Americas and their Societal Effects. Cambridge University Press.

Ariztegui, D., Bianchi, M.M., Masaferro, J., Lafargue, E., and Niessen, F., 1997, Interhemispheric synchrony of late-glacial climatic instability as recorded in proglacial Lake Mascardi, Argentina: Journal of Quaternary Science, 12: 333-338.

DeNiro, M.J., and Epstein, S., 1979, Relationship between the oxygen isotope ratios of terrestrial plant cellulose, carbon dioxide, and water: Science, 204:51-53.

DeNiro, M.J., and Epstein, S., 1981, Isotopic composition of cellulose from aquatic organisms: Geochimica et Cosmochimica Acta, 45: 1885-1894.

Massaferro, J. and Corley, J., 1998, Environmental disturbance and chironomid palaeodiversity: 15 kyr BP of history at Lake Mascardi, Patagonia, Argentina. Aquatic Conservation: Marine and Freshwater Ecosystems, 8:315-323.

Proctor, M.C.F., 1981, Physiological Ecology of Bryophytes. In: Schultze-Motel, W. (eds.) Advances in Bryology: Vaduz, Gantner Verlag K.G., 79-166.

Röthlisberger, F., 1986, 10000 Jahre Gletschergechichte der Erde, 416 pp., Verlag Sauerlander, Salzburg.

Sternberg, L., DeNiro, M.J., and Savidge, R.A., 1986, Oxygen isotope exchange between metabolites and water during biochemical reactions leading to cellulose Synthesis: Plant Physiology, 82: 423-427.

Villalba, R., Leiva, J. C., Rubulis, S., Suarez, J. and Lenzano, L., 1990, Climate, Tree-Ring, and Glacial Fluctuations in the Rio Frias Valley, Rio Negro, Argentina. Arctic and Alpine Research, 22/3: 215-232.