lowering of its eastern section, at variable mean rates of between 1 and 2 mm/yr in both senses, which has generated a total differential movement of at least, and perhaps more than 12 m since the maximum of the Middle Holocene transgression.

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SEDIMENTARY PROCESSES IN LAKE PUYEHUE OVER THE LAST 500 YEARS: IMPLICATIONS FOR PALEOENVIRONMENTAL RECONSTRUCTIONS IN THE CHILEAN LAKE DISTRICT (41°S) 10-03

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Summary

The synthesis of the first results of a multidisciplinary study of lake Puyehue sedimentary infill involving high-resolution seismic profiling and multi-proxy analyses of sediment cores is presented. Sub-bottom profiling was essential to optimise the selection of two coring sites, receiving the clastic supply of the main tributary of the lake (the Golgol River). Age-depth models for coring sites PU II and PU I are based on radionuclide measurements and a detailed analysis of the core lithologies (including varve counting on thin sections). These age-depth models are strongly supported by the reconnaissance of historic events such as the sedimentary record of 1960 Valdivia major earthquake

and the eruptions of Puyehue volcano in 1960 and 1929. These two coring sites are characterised by contrasted sedimentary processes and sensitivities to the active geodynamic setting of the SW Andes. This study revealed that detailed, continuous paleo-environmental reconstructions in the study area should be based on coring site PU II.

Abstract text

The middle latitude Chilean coastal range is a key area of our global climate system because the interactions of major oceanic (the Peru-Chile Current, PCC), atmospheric (the Westerlies) and geomorphologic features (the Andes) are responsible for strong precipitation on the continent and for the formation of the third-largest continental ice volume on Earth (the Patagonian Ice Cap). During the last glaciation, the Chilean Lake District was at the North-Western frontier of the Patagonian Ice Cap (Fig. 1), and large piedmont lakes formed as glaciers retreated higher up in the Andes since the early phases of the deglaciation. Furthermore, the glacier retreat in the area coincided -and might have contributed- to the development of some of the most active volcanoes on the American continent (i.e. Llaima and Villarica volcanoes). The growth of these volcanoes, together with major subduction earthquakes (i.e. the 1960 Valdivia event, M 9.5) produced very important geomorphologic changes in the catchments and related drainage basins.

Strong precipitations in the area are related to the strength and latitude of the Westerlies, and favour today an exceptional rainforest (Moreno et al, 2003), strong erosion rates in the Andes and a very large sediment yield. These sediments are partly trapped in the lake systems that characterise the area, but large volumes of nutrients still reach the Pacific coast where, interacting with the PPC, they have triggered exceptional blooms in the recent past resulting in very high sedimentation rates (Lamy et al. 2001). The current knowledge of environmental changes in this key area of the Southern Hemisphere is essentially based on studies on soils, moraines, peat bogs, ponds, small peri-glacial lakes and oceanic sediments, but the sedimentary records of the large glacial lakes characterising the region are yet to be explored.

In this paper, we present the first results of an integrated multidisciplinary study of the historic sedimentary processes in Lake Puyehue, where the regional impact of the volcanism, the seismicity and climate changes is well documented.

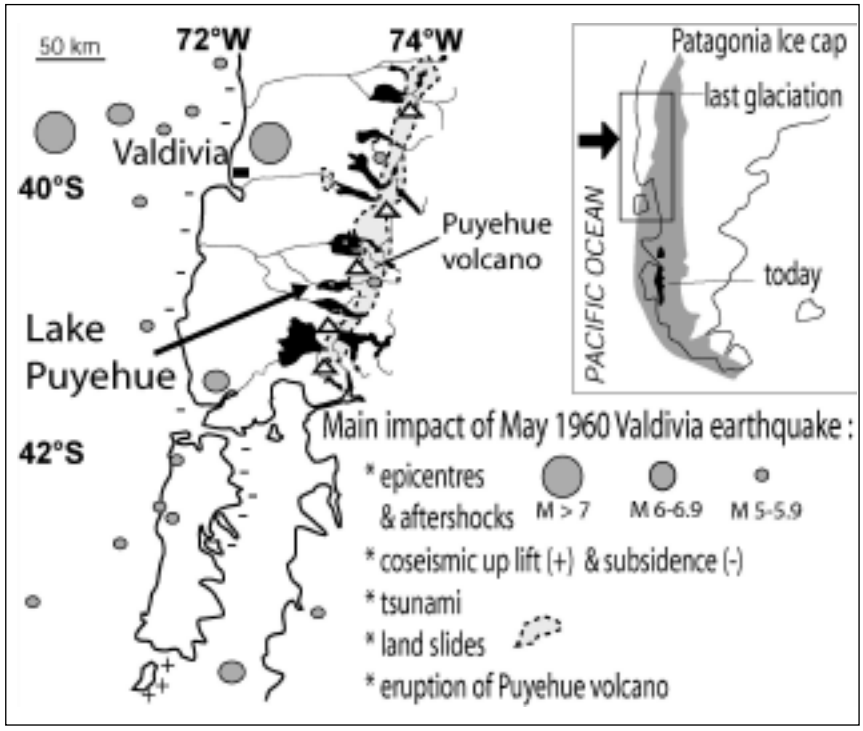

Fig. 1 - General location of Lake Puyehue in the Chilean Lake District in front of the Andes. The extension of the Patagonia Ice cap during the last glaciation is also indicated (after Denton et al., 1999). During the 1960 Valdivia earthquake, the eruption of Puyehue volcano together with large land slides all along the front of the Andes and aftershocks largely affected the catchment areas of the lakes (after Oñat, 1960; Rothé, 1961; Gerlach et al., 1988).

High-resolution seismic profiling using sparker (1 KHz) and pinger (3.5 KHz) sources (Charlet et al., 2003) was essential to select the most suitable sites for obtaining long sediment cores in the different depocenters that are presently accumulating the clastic supply of the main tributary of this lake (the Golgol River, Fig. 2). Two sites where sampled using UWITEC piston and short gravity coring devices (Bertrand et al., 2003): PU-I in the deepest basin (-122 m) facing the large Golgol delta and PU-II on top (- 48 m) of stratified sediments covering a well-developed sub-aqueous moraine ridge.

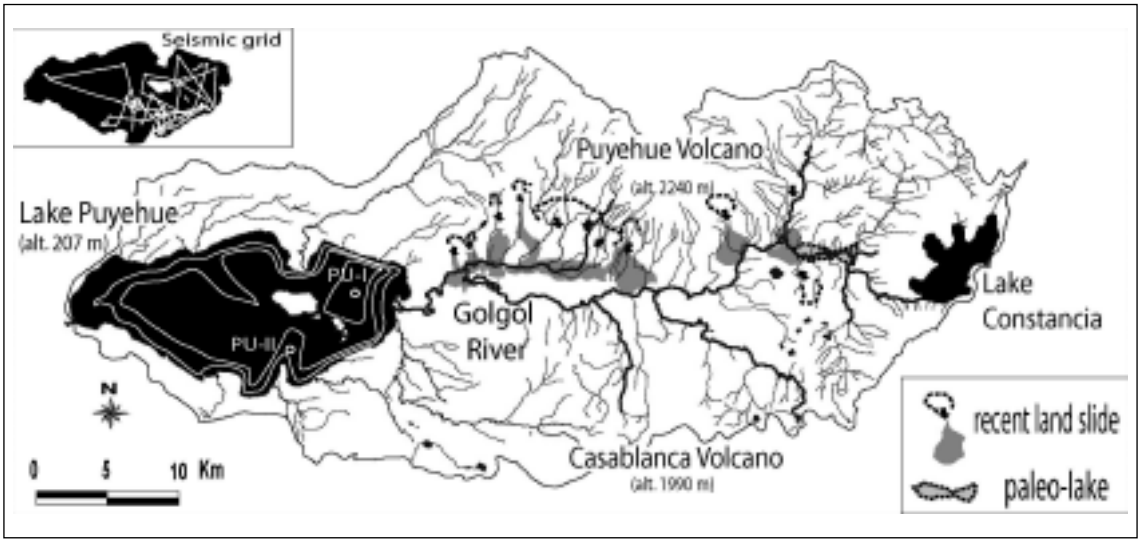

Fig. 2 - The drainage basin of lake Puyehue and location of high-resolution seismic profiles and coring sites. The Golgol river is the main tributary and formed a large delta clearly visible in the bathymetry of the lake (isobaths: 40 m, after Campos et al., 1989). Several large recent land slides affected the southern flank of Puyehue Volcano and the Golgol River. A land slide-damned paleolake is also indicated in the upper catchment.

On each coring site, multiples short gravity cores where retrieved and then they where logged with a GEOTEK multisensor track (gamma density, P wave velocity, magnetic susceptibility (MS)) before being opened. Once split, the lithologies of these cores were carefully described and digitalized. The best cores where then sampled for ^{210}Pb, ^{137}Cs and ^{241}Am dating as well as high-resolution multi-proxy measurements (MS, laser grain size, clay mineralogy, tephrostratigraphy, palynology, diatom assemblages and large thin sections; Chapron et al., 2003; De Batist et al., 2003).

Lago Puyehue is an oligotrophic and temperated monomictic lake (Campos et al., 1989) where sedimentation appears to be rather different in our two coring sites:

In site PU II, sediments are finely laminated silts (mean grain size: 20 microns) with few intercalated sandy events (tephra, turbidite). The lamination results from a succession of thin biogenic light lamina (rich in diatoms) and clastic dark lamina (rich in organic matter). PU II site is characterized by a mean sedimentation rate (SR) of 1 mm/yr, deduced from the decay of ^{210}Pb and from the reconnaissance of the ^{137}Cs and ^{241}Am picks produced by atmospheric nuclear tests culminating in 1965. Counting on thin sections revealed an annual lamination (i.e. “biogenic” varves) and confirms the radiogenic measurements till 1960, but then suggest higher SR till the 30’. The age-depth model based on varve counting and on the extrapolation of these SRs down core, is confirmed by the reconnaissance of several sedimentary events and their correlation with historical data: (1) a 2-3 cm thick slope failure deposit can be correlated with the Valdivia 1960 major earthquake; (2) a 0.5 cm thick sandy layer bearing high MS values with Puyehue volcano historic eruption in 1929 and (3) possibly a 0.5 cm thick sandy layer bearing normal MS values with the major subduction earthquake of 1575, which is considered as an equivalent of the Valdivia 1960 event.

Background sedimentation in coring site PU I is coarser (sandy silts with a mean grain size of 30 microns) and contrast with several large flood deposits (1 to 3 cm thick, mean size 15 microns), a coarser mega flood deposit (35 cm thick) and a thin sandy tephra at the base of the short core (Fig. 3). These sedimentary events have different grain size signatures suggesting high flow energies. In

particular, grain size, MS and density profiles of the mega flood deposit are bearing the typical signature of a catastrophic hyperpycnal flow deposit (Syvitski & Schafer, 1994; St Onge et al., in press; Schneider et al., accepted). The mega flood deposit is also clearly visible on 3.5 kHz seismic profiles where it appears associated with sub aqueous slope failure deposits in the deep basin facing the Golgol delta (Fig. 3).

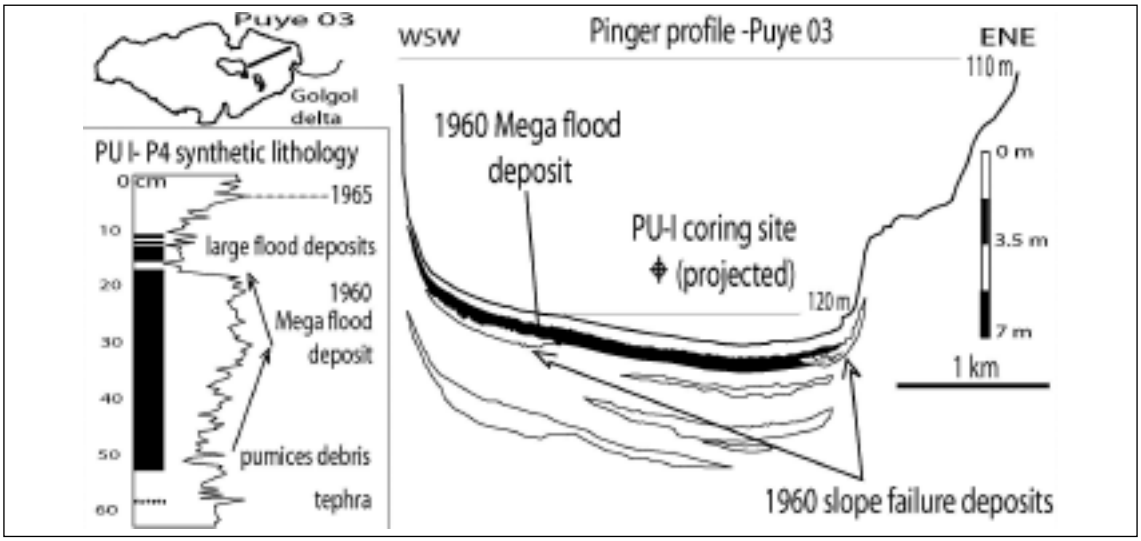

Fig. 3 - Location and interpretation of seismic profile Puye-03 across PU I coring site in the deep basin facing the Golgol delta. The 1960 mega flood deposit is clearly visible and associated with slope failure deposits. The synthetic lithology of short core PU I P4 is also presented and discussed in the text.

In this setting, radionuclide measurements on PU I coring site are largely affected by thick sedimentary events and should be interpreted carefully (c.f. Arnaud et al., 2002). Therefore, based (1) on ^{137}Cs activity and on the upper measurements of ^{210}Pb, (2) on historic descriptions of earthquake-triggered land slides in the catchment area of lake Puyehue (Oñat, 1960; Rothé, 1961) and of the formation of pumices during the 1960 Puyehue eruption (Oñat, 1960; Gerlach et al, 1988), (3) on the reconnaissance of pumice debris at the base of the mega flood deposit, and (4) on lamination counting in background sedimentation, we suggest that the mega flood deposit occurred shortly after the 1960 Valdivia event and resulted from the impact of several large land slides on the course of the Golgol River (Fig. 2). We further suggest that the complex succession of large flood deposits together with the detailed evolution of the mean grain size below the 1965 pick in ^{137}Cs (Fig. 3), can be seen as the progressive recovery of the Golgol fluvial dynamic (i.e. the diffusivity coefficient of sediment load, c.f. Castelltort & Van Den Driessche, 2003) from the impact of these land slides. This age-depth model implies a mean continuous SR of ~3 mm/yr during the last 70 years, when subtracting the thicknesses of the main sedimentary events (c.f. Chapron et al., 1999; Arnaud et al., 2002), and its extrapolation down core is supported by the correlation of a tephra layer with the eruption of Puyehue volcano in 1929.

These new findings in lake Puyehue have significant implications for paleo-environmental reconstructions in the Chilean Lake District. Concerning the impact of the 1960 Valdivia earthquake (M 9.5), lake Puyehue record highlights a limited slope failure deposit on site PU II, but larger sub-aqueous slope failure deposits along the slope of the deep basin. These sedimentary features were probably directly triggered by the seismic waves of this major earthquake, together with large land slides documented in the front of the Andes in the study area (Fig. 1). This earthquake also triggered the eruption of the Cordon Caulle-Puyehue volcano (lava flow and pyroclastic flows producing pumices and a large volume of ashes towards the North and the West, according to Oñat (1960) and Gerlach et al, (1988)). Lake Puyehue sedimentary record in coring site PU I provide a key example of the huge impact of this earthquake on the drainage basin of the river Golgol, and can be summarized as follow: land slides along the flanks of Puyehue volcano probably partially damned the river and

triggered, during the winter, a major hyperpycnal flow in the lake. The volume of this major flood deposit can be estimated to be ~ 3×10^6 m^3 based on coring and seismic data. Following this crisis, River Golgol was affected by sediment load and fluvial dynamic during several years.
The sedimentary record of Puyehue volcanic eruptions such as those occurred in 1960 and 1929 in lake Puyehue infill are ranging from direct volcanic fall-out producing thin sandy tephra layers intercalated with background sediments in sites PU II and PU I, to large flood deposits in site PU I, resulting from the erosion and the transport of large volumes of volcanic particles in the drainage basin. These different sedimentary records seem to be essentially depending on the type of volcanic eruptions (Gerlach et al., 1988) and on the influence of the dominating winds during an eruption. For example, during the 1960 eruption of Puyehue volcano, SW winds limited direct and massive ashes fall-out over the lake area (Oñat, 1960), but favoured their accumulation in the upper part of its catchment area. Dominant winds originating from the West in the Chilean Lake District may thus favour the development of thick andosoils in this region of the Andes (Bertand & Fagel, in review) that is characterized by large sediment yields.
Consequently, fluctuation in climate conditions (essentially precipitation regimes associated with the Westerlies) will be recorded in lake Puyehue by a fluctuating clastic supply. Based on its sensitivity to major earthquakes and volcanic eruptions, the most suitable environment to reconstruct climate variability in lake Puyehue is the coring site PU II. Promising proxies in this site involve high-resolution MS and density profiles, together with the reconstruction of varve thicknesses and the evolution of diatoms assemblages. The reconnaissance of ^{137}Cs and ^{241}Am picks associated with atmospheric nuclear tests in 1965 might provide new insights for atmospheric circulation models.

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EOCENE COOLING RECORDED IN THE CHEMISTRY OF LA MESETA FORMATION MOLLUSKS, SEYMOUR ISLAND, ANTARCTIC PENINSULA 10-04

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Summary

Seymour Island on the Antarctic Peninsula provides an excellent setting in which to document the timing and magnitude of Eocene-Oligocene cooling and to infer the effects of climate change on the evolution of high latitude shelf biotas. The La Meseta Formation is one of only two places in