3rd International PASADO Workshop

Hosted by GEOTOP
In collaboration with INRS-ETE and NSERC

At Pavillon des Sciences de l'UQAM, Montréal, Canada

March 21-23rd, 2011

PROGRAM AND ABSTRACTS

3rd International

PASADO

Workshop

March 21-23, 2011

Montréal, Québec, Canada

Organizing committee :

Pierre Francus
David Fortin
Guillaume Jouve
Vicky Tremblay

TABLE OF CONTENTS

DIRECTIONS FROM THE AIRPORT

By bus :

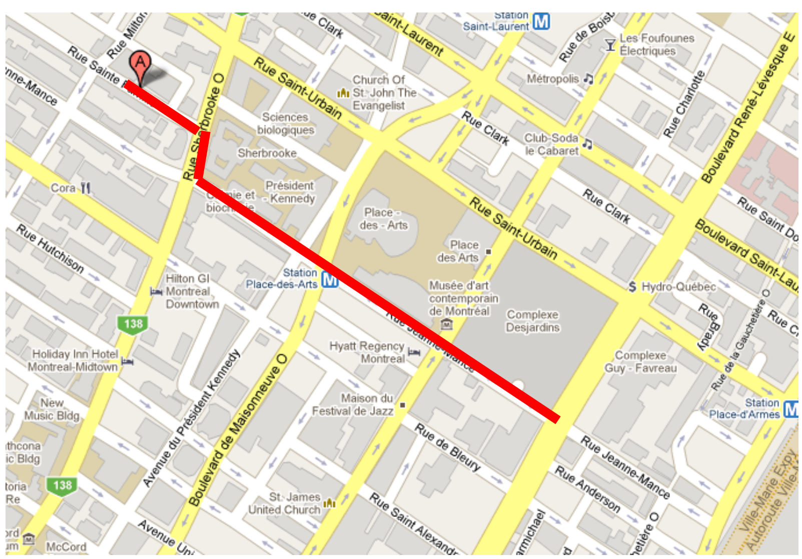
The Société de transport de Montréal (STM) runs an express bus line ("747") between the airport and downtown. The 747 line uses only low-floor buses and is in service 24 hours a day, 7 days a week.

The trip between Montréal-Trudeau Airport and the Montréal bus terminal at Berri-UQAM metro station takes approximately 35 minutes outside of rush hour. The service stops at Lionel-Groulx metro station, and along Boulevard René-Lévesque at Guy, Drummond, Peel, Mansfield, **Anderson** and Saint-Laurent.

The 747 is free for holders of 1 or 3-day tourist passes. Individual tickets valid for 24 hours across the entire STM network are also available, priced at $8 for a one-way trip. At the airport, tickets are sold at the International Currency Exchange (ICE) counter on the international arrivals level.

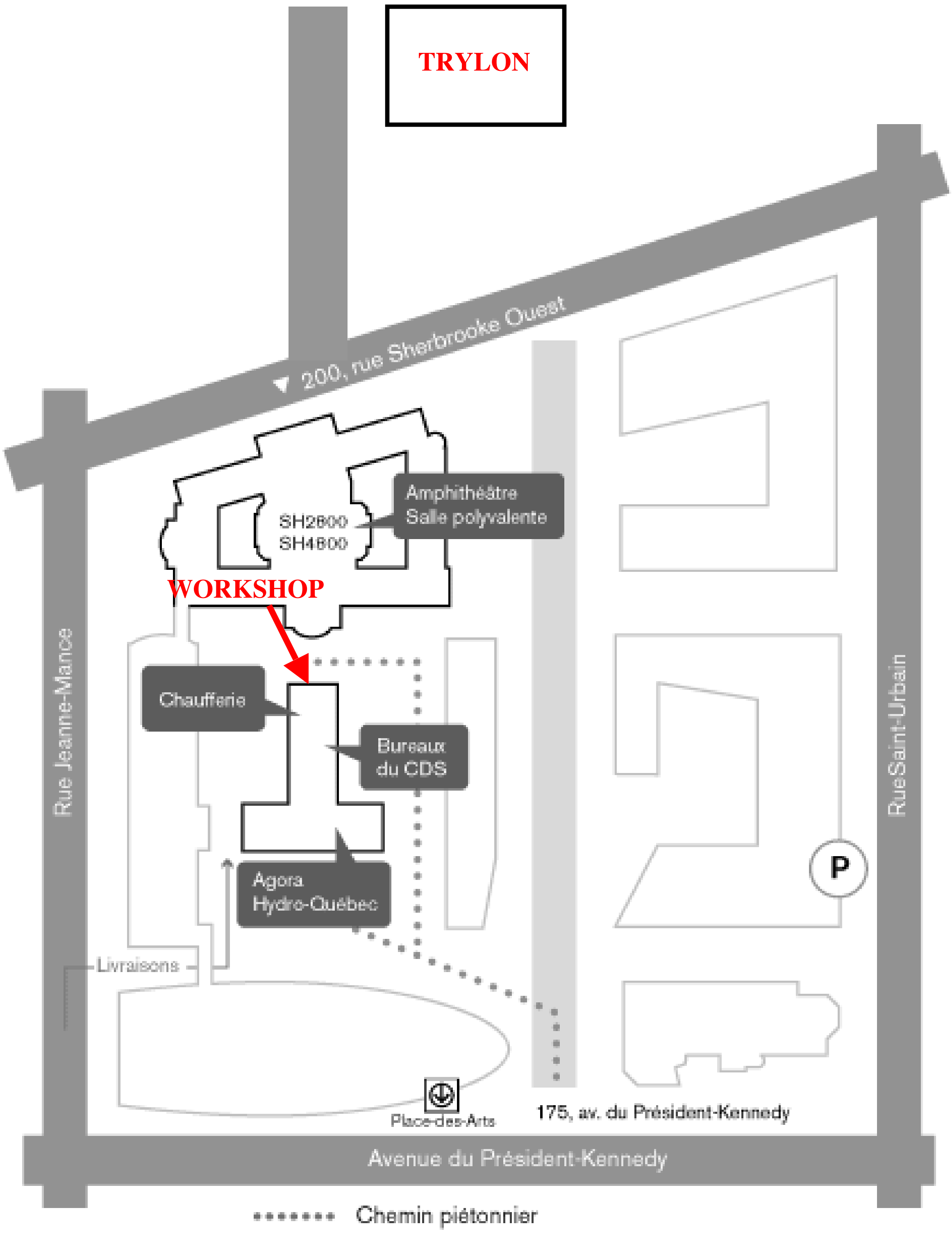
Rapid directions :

- Take the express bus line 747;
- Exit at Anderson or Jeanne-Mance street;
- Walk on Jeanne-Mance (north direction);
- Turn right on Sherbrooke ouest;
- Turn left on Ste-Famille



MAP OF METRO STATIONS

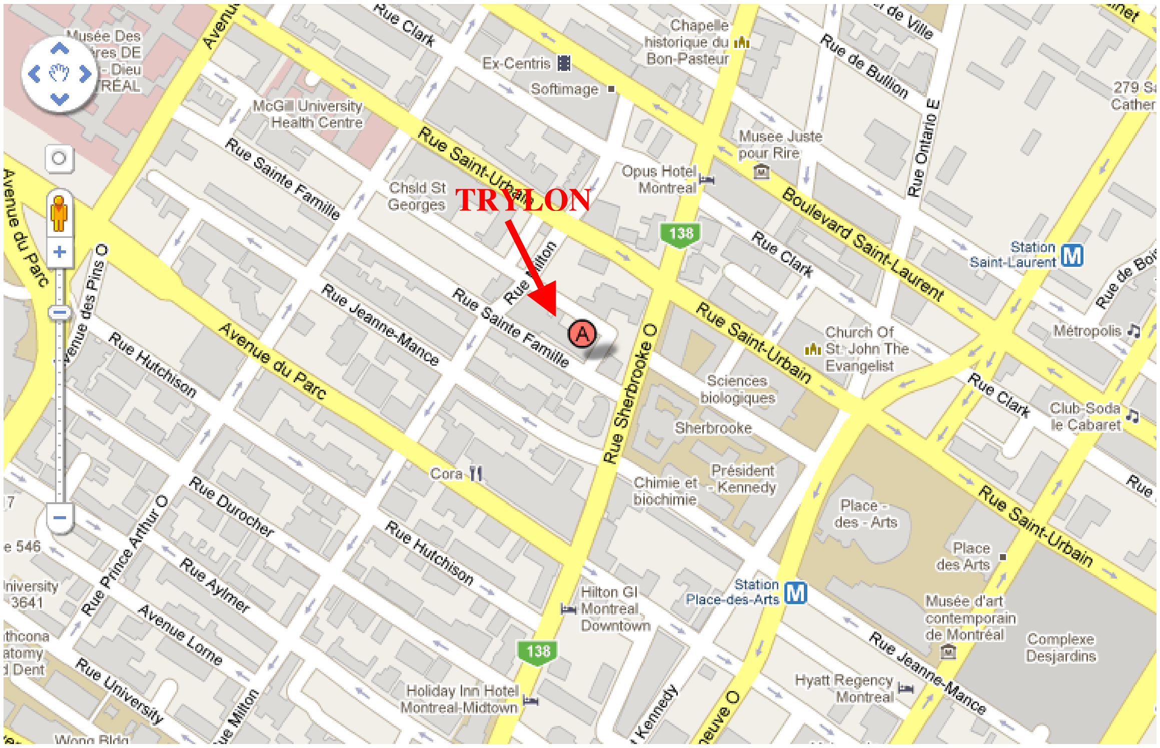
MAP OF UQAM



TRYLON
200, rue Sherbrooke Ouest
SH2800
SH4800
Amphithéâtre
Salle polyvalente
WORKSHOP
Chaufferie
Bureaux du CDS
Agora Hydro-Québec
Livraisons
Rue Jeanne-Mance
Rue Saint-Urbain
P
Place-des-Arts
175, av. du Président-Kennedy
Avenue du Président-Kennedy
Chemin piétonnier

MAP OF SURROUNDING AREA

Trylon apartments : 3363 Ste-Famille, Montréal



LIST OF RESTAURANTS

Name	Address	Type
Benelux	245 Rue Sherbrooke Ouest	bar
Cora	3465 Avenue du Parc	breakfast
Koko	8 Sherbrooke Ouest	japonese
Subway	205 Sherbrooke Ouest	sandwiches
Bâton Rouge	180 Rue Sainte-Catherine Ouest	lunch / dinner
St-Hubert	100 Rue Sainte-Catherine Ouest	chicken (lunch / dinner)
Mikes	150 Rue Sainte-Catherine Ouest	pasta
Eggspectation	190 Rue Sainte-Catherine Ouest	breakfast, lunch, dinner
Sushi Shop	439 Avenue du Président Kennedy	sushi
Cafeteria	175 Avenue du Président Kennedy	variate meals at low cost
Complexe Desjardins	150 rue Ste-Catherine Ouest	many variate restaurants services (pharmacy, grocery)

SCHEDULE

Monday MARCH 21st 2011

9 :30 **Pierre Francus**
Welcome all

9 :45 **Bernd Zolitschka**
Quo vadis PASADO?

10h15 Break

10 :45 **Ted Pollock**
Atmospheric Simulations of Present and Past Climate over Southern South America

11 :15 **Séverine Delpit**
How much of a tephra ring is preserved around Laguna Potrok Aike?

11 :45 **Hugo Corbella** (by Julieta Massaferro)
Eruptive landforms in the Potrok Aike lake area, southern patagonia, Argentina.

12 :00 Lunch

13 :45 **Stephan Wastegård**
Tephrostratigraphy of the Potrok Aike Maar Lake Sediment Sequence

14 :15 **Agathe Lisé-Pronovost**
High-resolution paleomagnetic record from the Late Pleistocene sediments of the maar lake Laguna Potrok Aike, southern South America

14 :45 Synthesis discussion today's topic

15 :00 Break

15 :15 **Bernd Zolitschka – GEOTOP TALK**
A long lacustrine sediment record from southern Patagonia, Argentina: the ICDP deep drilling project PASADO at Laguna Potrok Aike

17 :15 Departure for the Cabane à sucre (Sugar shack)

Tuesday MARCH 22nd 2011

9 :00 **Pierre Kliem**
Dating, age-depth modeling and hydrological interpretation of the 51 cal. ka BP composite profile from Laguna Potrok Aike in southern Patagonia, Argentina

09 :30 **Guillaume Jouve**
Microsedimentology and geochemistry of lacustrine sediments of Laguna Potrok Aike (LPA): Discussion on hydrological reconstructions during late glacial.

10 :00 **David Fortin**
A composite record of sediment density for Laguna Potrok Aike

10 :30 Break

11 :00 **Annette Hahn**
Geochemical characterisation of the PASADO sediment record from Laguna Potrok Aike, southern Patagonia (Argentina)

11 :30 **Laurence Nuttin**
Clay mineral changes and U and Th series isotopes in early diagenetic and authigenic minerals of the Potrok Aike Lake sequence

12 :00 Synthesis discussion on Sedimentology

12 :15 Lunch

14 :00 **Aurèle Vuillemin**
Tracking microbial influence on nutrient cycling and early diagenesis in Laguna Potrok Aike sediments since the Late Pleistocene

14 :30 **Peter Leavitt**
Historical changes in production, gross algal community composition, and ultraviolet radiation regime in Laguna Potrok Aike, Patagonia, Argentina, during the past 35,000 years.

15 :00 **Jiayun Zhu**
Carbon and nitrogen isotope composition of bulk sedimentary organic matter from Laguna Potrok Aike during the last Glacial and the Holocene

15 :30 Break

16 :00 **Christoph Mayr**
Late Glacial isotope records of endogenic carbonates from Laguna Potrok Aike

16 :30 **Markus Oelerich**
Origin of sedimentary carbonates from Laguna Potrok Aike - a multiple stable isotope approach

17 :00 **Bart de Baere**
Measuring endogenic elemental ratios in lacustrine endogenic carbonates using a purpose-built flow-through sample introduction module

17 :30 Synthesis discussion on Geo(bio)chemistry

Wednesday MARCH 23rd 2011

08 :45 **Julieta Massaferro and Flavia Quintana**
Modern freshwater organism analysis for quantitative paleoenvironmental reconstructions in southern Patagonia (Santa Cruz, Argentina)
Long-term trends of fire activity based on records of macroscopic charcoal remains from Laguna Potrok Aike (51°58' S, 70°23' W), Santa Cruz, Argentina

09 :15 **Frank Schäbitz**
Paleoclimate reconstructions based on the pollen record from Laguna Potrok Aike

09 :45 **Cristina Recasens**
The diatom record of Laguna Potrok Aike, Argentina

10 :15 Synthesis discussion on Paleontology

10 :30 Break

11 :00 **Group Discussion 1**
Topic to be discussed – decided during the workshop

Group Discussion 2
Topic to be discussed – decided during the workshop

Group Discussion 3
Topic to be discussed – decided during the workshop

12 :15 Lunch

14 :00 **Bernd Zolitschka and Pierre Francus**
Plenary discussion

15 :00 **Bernd Zolitschka**
Wrap up

15 :30 Possibility for working group discussion

17 :30 End of workshop

Suggestions for discussions : Age Model
Quantitative reconstructions
Publication strategy
Continuing discussions on Sedimentology, Geobiochemistry and Paleontology

ABSTRACTS

ERUPTIVE LANDFORMS IN THE POTROK AIKE LAKE AREA, SOUTHERN PATAGONIA, ARGENTINA.

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[3] CADIC-CONICET-UNP San Juan Bosco Sede Ushuaia, B. Houssay 200, (9410), Ushuaia, Argentina.

The Laguna Potrok Aike (LPA) area is located in the western flank of the Pali Aike volcanic field in the Magellan Basin, 300 kilometres East of the Andean volcanic front and at the edge of huge morainic arches proceeding from the Andes, W and the Magellan Strait, S.

The predominant fault systems controlling most of the eruptive activity in the area have a NW direction, later followed by faults of E-W and ENE strike. The NW fault system coincides with the direction of the underlying Jurassic palaeo-rift zone. The ENE and E-W structures were caused by a NW stretching due to a new stress field in the Southern flank of the Magellan Basin.

In LPA the stratigraphic column is composed by: Santa Cruz Formation deposits; deeply eroded Mio-Pliocene table basalts; till deposits; scoria cones, lava flows and maar phreatomagmatic sediments; glacifluvial, fluvial, lacustrine and aeolian deposits and distal Andean Holocene tephras.

The Miocene molassic Santa Cruz Formation (SCF) crops out in a wide area around the LPA. It consists of a package of grey, yellowish or greenish weakly lithified continental tuffaceous sandstones, micro-conglomerates and siltstones, 660m thick at the vertical of LPA. Fossil fragments of mammal's bones and osteoderms found at the lake beach indicate that there, the outcropping sediments belong to the middle or upper levels of SCF.

Most of the basaltic outcrops in the area are part of a Mio-Pleistocene back-arc volcanic field. Table mountains, scoria cones, lava flow fields and maars are the main volcanic features.

Basaltic table mountains are the oldest volcanic outcrops in Pali Aike. They form most of the tableland landscapes that span to the North and West of the LPA. Transitional to alkali basaltic lavas, 10 and more metres thick, lie on the SCF through a package of few metres of reddish pyroclastic deposits (tuff, micro-breccias and agglomerates). Remnants of old lava flow fields, eroded by glaciers, cut by rivers, buried by glacial deposits, covered by aeolian sediments, submitted to several periods of periglacial conditions and swept by strong winds, at present remain as table mountains up to 100m above the surrounding terrains.The relatively steep scarps around theses plateaux, are frequently affected by mass wasting phenomena.

In Bella Vista table mountain, the widest of the area (33 km^2), four lava field units with different surficial geomorphic expression are piled up. The oldest (Nubes) was dated in 9.16 ± 0.08 My (Mejia et al., 2003). It is covered to the NE and SW by younger lava units. The emission centres of these basaltic lavas are greatly eroded and in some cases entirely leveled down. The SW edge of the youngest unit is partially covered by morainic deposits. Over these table mountain basalts the Carlota and Obus maars crop out on NW alignments.

The INTA basaltic tableland, partially covered by glacial deposits, is situated SE of Bella Vista table mountain with a much eroded emission centre in the SW corner (Cerro Descabezado) and the NW alignment of Cuatro Marías degraded scoria cones and its small lava flow field emerging in the Northern flank area.

Further eastwards, North of LPA the Petrus basaltic table mountain crops out. A sample from the basaltic scarps of the Petrus W tableland -just NE of the INTA station- dated by Ar/Ar on total rock, yields 3.78 ± 0.12 My (Corbella, 2002). While their flat western edge is covered by morainic deposits, in the central area, raised 50 m above the surrounding terrains, the basalts show deep linear marks and grooves resulting from glacial erosion.
The elevation of this central section of the Petrus basaltic tableland, and the up-folded outcrops of tills and SCF deposits located immediately to the North, are ~coincident with the subsurficial area of a sill detected by seismic at 900m depth. The surveyed raised oval area looks like a gentle cryptodom, and can correspond to the injection of a relatively young hypabyssal body.

In the LPA area several scoria cones of Plio-Pleistocene age, devoid of rills, gullies or drainage pattern, crop out: Policía, Cuatro Marías, Bettrus, Vigilante, Tetas de la China and Alan. Of basanitic, alkali basaltic or thepritic composition, all of them show mid to highly degraded morphologies. Low mean maximum cone slope, low cone height/cone width (Hco/Wco) ratios (Wood, 1980 a,b) and low crater depth/crater width or diameter (Dcr/Wcr) ratios (Hooper & Sheridan, 1998) testify that all these scoria cones and their associated lava fields have undergone a moderate to severe morphological degradation, product of weathering, gravity and erosion along a relatively extended period of time. On the SW shore of the LPA, near the Cerro Policía dismantled scoria cone, a basaltic lava flow spilled prior to the incision of the diatreme yields an Ar/Ar age of 1.19 ± 0.02 My (Corbella, 2002).

The abundance of maars is a characteristic of the Pali Aike volcanic field. In the LPA area these maars show contrasting surficial characteristics of size and proportions. While some are relatively large and shallow, others are smaller and deeper.

The diameter/depth ratio (D/d) has been considered as an indication of maar's age. The youngest maars have D/d ratios of 5:1. This ratio increases with age as the crater becomes filled with epiclastic sediments and erosion enlarges their diameter (Cas & Wright, 1987; Carn, 2000). In the LPA area, the "fresher" maars are Carlota and Obus with D/d ratios of 15:1 and 13:1 respectively. Most of the larger maars seated in SCF sediments (a soft substratum) have high ratios: Flamencos W and E 39:1 and 42:1; and the Potrok Aike maar >30:1.
In contrast, Carlota and Obus maars, seated on competent basaltic rocks that cover the SCF sediments (hard-soft substratum), show the smallest diameters and D/d ratios.
When these ratios are plotted on a crater diameter vs. crater depth diagram (Simon et al., 2010) Carlota and Obus fall together with the "older" maars, but Flamencos and Potrok Aike given their respective big diameters are out of the diagram.

Based on their diameter measurements, maars were classified as small (Ø<500m), medium (Ø=500-1000m), and large (Ø>1000m) (Gevrek & Kazanci, 2000).
At least two factors have been invoked as determinant of the diameter of a maar: the hardness or softness of the rock environment (Lorenz, 2003) and the state of the water during the interaction with the lavas (Béget & al., 1996).
Maar-craters developed in a soft-substratum are larger than craters carved in a hard-substratum (Martin-Serrano, 2009), but exceptional big craters seem only to occur when country rocks are affected by permafrost.
The only well-known maars with diameters ranging from 4 to 8 km described are the 4 Espenberg maars in the Seward Peninsula, Alaska. The exceptional diameters of these maars were attributed to the extremely explosive hydromagmatic eruptions that occur when ascending lavas contact water from grown ice (permafrost). "The high heat capacity of ice in permafrost modulate the supply of water interacting with magma during the eruption, producing consistently low coolant-to-fuel ratios in an environment with a sustained, abundant water supply" (Béget & al.,1996).

In the LPA area, mean diameters of the large maar-craters are: Potrok Aike 4500m, Flamencos (W and E) 1960m and 1470m, Cerro Negro 1300m, the largest ones of the Rosario alignment (a W-E 8 km long chain of coalescent maars) 1100m and 1200m and Sombrero Mejicano 900m.

The Potrok Aike Maar has a broad and flat morphology. The present lake inside the maar's diatreme (113 masl and 100m deep) has an almost circular shape 3 km Ø. The entire depression is ~4.5 km wide and the altitude difference between the lake level and the surrounding morainic plain is ~50 m. XX Topographic profiles, bathymetric contour maps (Zolitschka & al., 2009) and seismic surveys (Anselmetti & al., 2009; Gebhardt & al., 2011) show that the maar depression+diatreme ensemble has a champagne glass shape, which is characteristic of maars erupting in soft-rock environments (Lorenz, 2003, 2007).

The Potrok Aike diatreme was carved in brittle sandstones and micro-conglomerates of the molassic SCF deposits, crowned by unconsolidated till deposits, gravels and buried argillaceous soils. Cryogenic features such as relict sand wedges and cryoturbations affecting tills and overlying materials, attest permafrost conditions in an extremely arid periglacial tundra environment (Coronato & al., 2010). How many times and when these conditions prevailed is still uncertain, but if the ascent of lavas occurred when the surface was frozen (permafrost), it could explain the extraordinary size of the Potrok Aike maar.

On the other hand, the soft and unconsolidated country rock allowed the development of inner crater walls of low slope angles which caused a very wide crater. Once the eruptive period ended, the walls of the crater -specially if they were in contact or soaked with water- could have collapsed inside the diatreme. The erosive action of the lake swash and swell could contribute in the same way.

Most of the preserved phreatomagmatic deposits of the surrounding rim, crop out in the SE flank. Other smaller outcrops were found scattered around to the South, Southwest, West and North of the lake. They lie above glacial sediments and are covered by aeolian soils. The phreatomagmatic deposits accumulated by the SW blanket over the W slope of Cerro Policía blocked the surficial flow of the Bandurrias Creek.

The South-eastern biggest phreatomamatic outcrop, with a surface of ~3 km^2, presents a fine layering containing chilled juvenile sideromelane clasts and minor tachilitic fragments, basanitic lapilli and abundant lithics such as glacial or glacifluvial pebbles, silty-sand clasts and peridotitic xenolihs and xenocrysts. Age determinations of a juvenile lapilli clast of this deposit by Ar/Ar method on total rock yield 0.77 ± 0.24 My -great uncertainty- (Zolitschka & al., 2006).

Another peculiarity of maar Potrok Aike is the present crater-lake deepness. As remarked by Lorenz (2003), only the youngest maars still contain a lake. Older maar crater lakes are filled by post eruptive sediments of various kinds and eventually changes into a ¨dry¨maar crater. In the Pali Aike Volcanic Field the ~one hundred outcropping maars depressions are already filled by sediments; one of the rare exception is Potrok Aike which still maintains a 100 m deep water body. Given the mature morphology of this maar, the load transported by the fluvial affluents ending in the lake and the aeolian contribution (specially throughout periglacial tundra periods with their associated strong winds and available particulate glacial materials) the Potrok's lake deepness is a notable feature.

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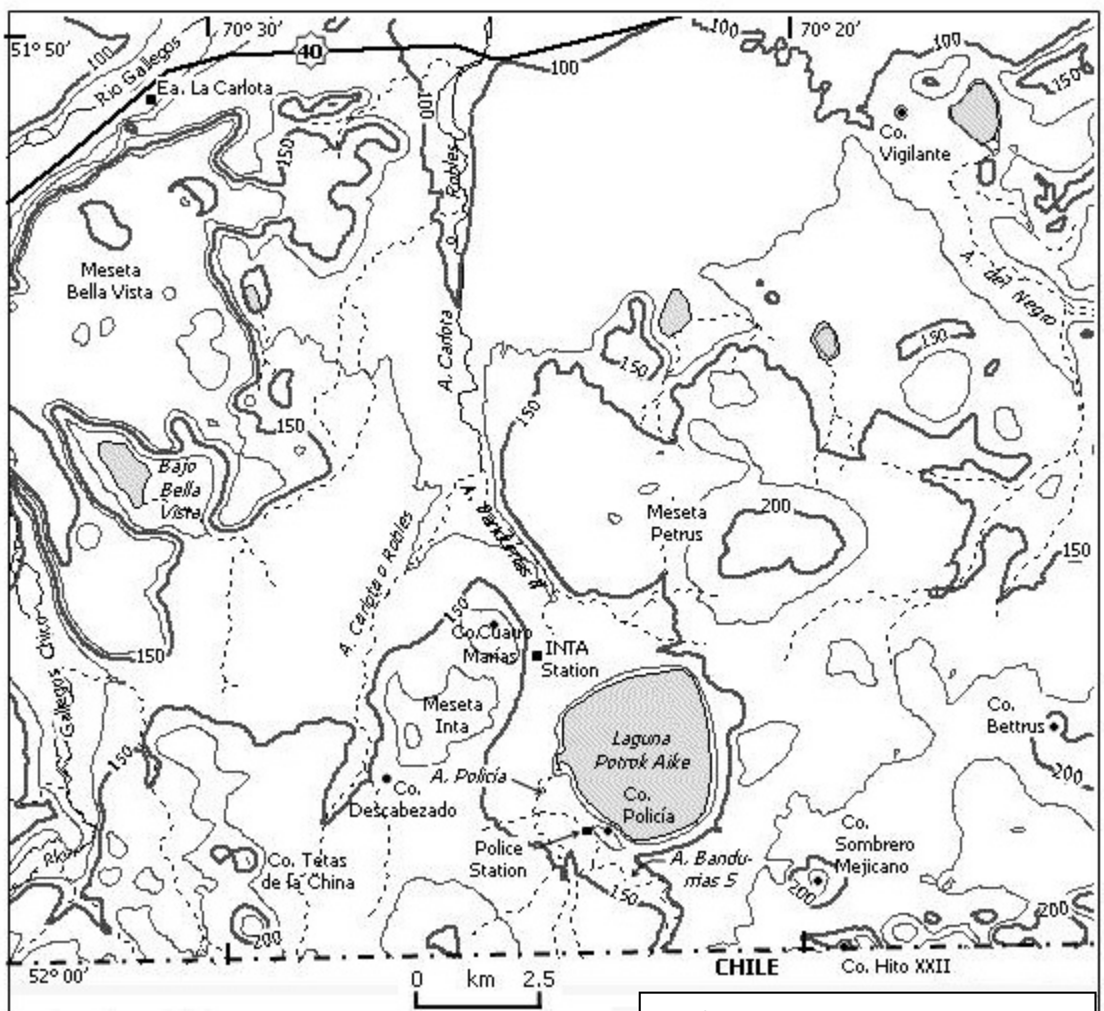
Acknowledgments to UNPA-UARG (PI 29/A195) and ANPCT-SECyT for the financial support (PICT 02338 PIPA).



LOCATION MAP

References:
Ea.: Estancia or Ranch
Co.: Cerro or Mount
A. : Arroyo or Creek

Contour interval: 25m.

MEASURING ENDOGENIC ELEMENTAL RATIOS IN LACUSTRINE ENDOGENIC CARBONATES USING A PURPOSE-BUILT FLOW-THROUGH SAMPLE INTRODUCTION MODULE.

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Trace element to calcium ratios (El/Ca) of endogenic carbonates in lacustrine sediments can be used as a proxy for past hydrological and/or climatic conditions, independent of complicating biological factors. However, contaminating clays and diagenetic carbonates often obscure the biogenic and endogenic carbonate phases that record the targeted information.

In order to address this problem, we are developing the flow-through analysis technique at UBC. This technique consists of a flow-through dissolution module linked to an ICP-MS and provides an alternative to conventional batch dissolution (for details see e.g. Haley and Klinkhammer, 2002). The key benefit of this technique is the ability to gradually dissolve a sample over time, whilst eliminating the possibility of re-deposition after dissolution since clean eluent is continuously introduced to the sample holder. The analysis results in thousands of data-points in a typical 30 min run, allowing for continuous monitoring of the exact elemental composition of the eluant as the sample is gradually dissolved. In addition, only a small amount of sample is needed for analysis (~0.2 mg).

We are currently further developing the data analysis. Using laboratory-made mineral mixes (of which we know the end-member composition) we are measuring a number of elemental ratios (such as Sr/Ca and Mg/Ca) at various time-step to create a series of non-linear equations. Given the vast amount of non-linear equations that can be produced using the flow-through technique (since the number of time-steps are virtually unlimited), the system essentially becomes over-determined. Subsequently, the end-member minerals composition can be quantified using a least square method. Using this novel data-analysis approach, the flow-through technique will be able to distinguish the elemental ratios of the endogenic carbonate that accumulate in lacustrine sediments.

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HOW MUCH OF A TEPHRA RING IS PRESERVED AROUND LAGUNA POTROK AIKE?

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As part of the PASADO project, we investigated several monogenetic volcanoes belonging to the Pali Aike Volcanic Field (PAVF), the southernmost expression of the Cenozoic Patagonian Plateau Lavas. Volcanism in the PAVF (Corbella, 2002) occurred on top of 2-3 km of sediments from the Magallanes Basin (or Austral basin). The volcanic field covers about 4500 km^2, and is located 80 km west of the city of Río Gallegos (north of the strait of Magellan), 220 km north of the conservative boundary between the Scotia and South American plates, approximately 400 km north-east of the modern Chile Trench and about 300 km east of the active Andean volcanic arc.

The PAVF volcanic rocks are mostly alkaline basalts and basanites. Despite the back-arc position of volcanism, geochemical data (D'Orazio et al., 2000; Ross et al., 2010) shows a trace element signature characteristic of intra-plate ocean island basalt (OIB)-like magmas. These data have lead several authors to establish different geodynamic models but the most popular hypothesis calls for a slab window under the South American plate in this area.

Two main types of volcanoes are exposed in the PAVF, as in most monogenetic fields worldwide: scoria cones and maars. These are respectively the first and the second most common volcano types, on continents and islands. Scoria cones form as a result of magmatic ("strombolian") explosive eruptions and are characterized by steep slopes and associated lava flows. Their pyroclastic deposits are very poor in lithic fragments and rich in juvenile ones. The juvenile fragments (named "scoria") contain abundant vesicles, except in spatter deposits where welding and compaction can make the vesicles collapse. In general, the pyroclastic material of scoria cones is coarse, and since it consists largely of fallback from an eruption plume, it is relatively well sorted. Scoria is made mostly of tachylite, a fine-grained product of basaltic magma that cools in contact with air. Maar volcanoes are the phreatomagmatic equivalent to scoria cones and form when the same magmas interact with groundwater to produce explosive eruptions that excavate craters below the pre-eruptive surface. Maar craters are surrounded by tephra rings, which are relatively thin pyroclastic deposits with gentle outward slopes. These tephra rings are characterized by numerous thin beds rich in lithic fragments, and in which the juvenile pyroclasts can be glassy (sideromelane) and less vesicular than those of scoria cones. The beds are mostly deposited by pyroclastic surges and tend to be poorly sorted, with an abundant ashy matrix. Palagonite is the typical alteration product of sideromelane and is common from some maar tephra rings. This alteration gives a yellow or brown color to these phreatomagmatic deposits.

One of the best preserved maars in the PAVF belongs to a volcanic complex, composed of two juxtaposed maars, at around 70.155°W, 51.995°S. The tephra ring from the eastern maar is well preserved and studying it gives us an idea about what to expect from phreatomagmatic deposits in the PAVF, given the type of magma involved in the volcanic activity, the type of shallow substrate through which this magma was erupted, the climate of the region, and the age of the pyroclastic deposits. The eastern maar from the complex has a near elliptical shape, 1.40 km E-W by 1.28 km N-S, and a depth of 89 m (to the lake level). The tephra ring reaches a maximum thickness on the eastern side, and surrounds the crater which contains a shallow saline lake (Fig. 1). In the SW inner slope of the crater, we studied a 4.9 m-thick outcrop of overwhelmingly phreatomagmatic layers (Fig. 2).

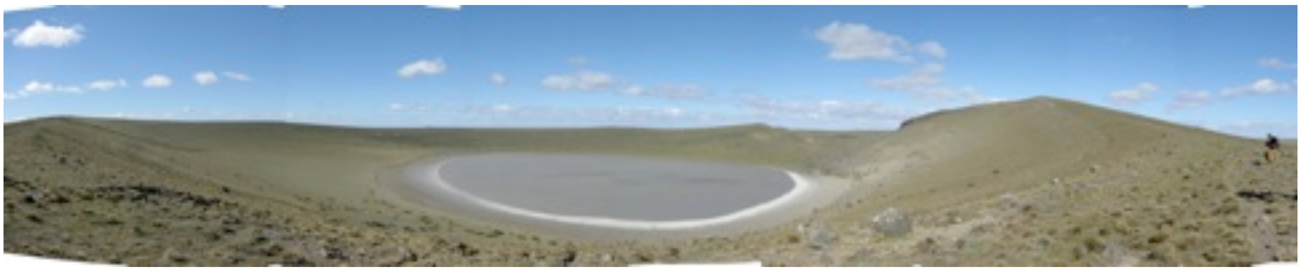

Fig. 1. Overview of the East Maar from the two-maar complex.

Fig. 2. The best outcrop of phreatomagmatic deposits from the East Maar tephra ring.

The following observations are suggestive of a phreatomagmatic surge origin for these deposits: erosive channels and low angle cross-bedding; a high proportion of lithic clasts (sedimentary rocks, lava fragments, quartz grains) versus juvenile clasts; the presence of some accretionary lapilli; the poorly sorted nature of the deposits; and the fact that the majority of glassy juvenile clasts are former sideromelane altered to palagonite (Fig. 3). Moreover, the high proportion of free magmatic crystals and sedimentary grains (mainly olivine and quartz) and a significant proportion of fine-grained particles reflect very effective fragmentation.

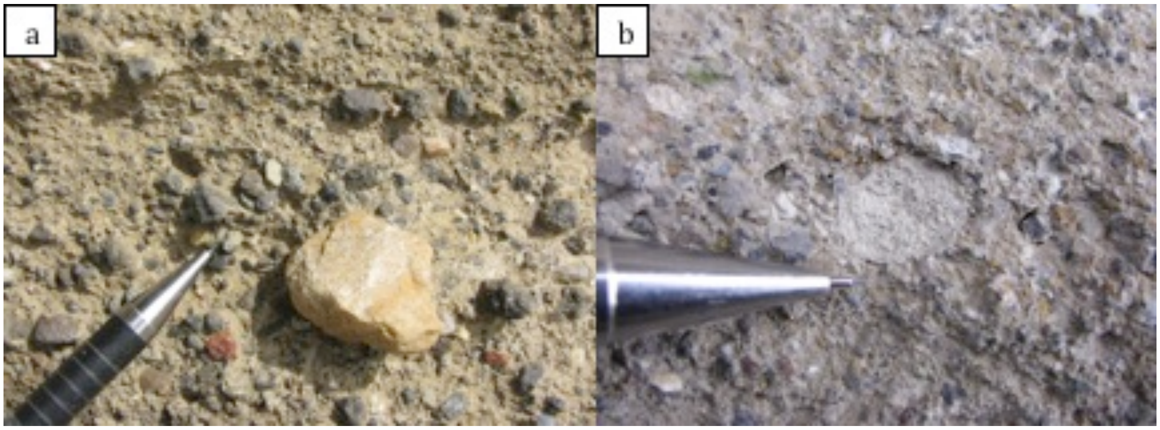

Fig. 3. Close-up views of phreatomagmatic deposits from the East Maar tephra ring. Note in photo (a) the large proportion and the diversity of lithic clasts in term of nature and angularity compared to the juvenile clasts. These are set in a palagonitized matrix and the deposit is poorly sorted. The photo (b) shows an accretionary lapillus.

In addition to these typical phreatomagmatic deposits, two layers display different characteristics: they are better sorted, coarser-grained, and contain fewer lithic clasts, suggesting strombolian fall deposits. Note that only two such layers are present in the nearly 5 m-thick exposure, suggesting they occur only rarely in the tephra ring of the East Maar. Ross et al. (2010) provide more information on this locality, and laboratory work is currently being performed (by the senior author of this abstract) on samples from this locality, amongst several others.

Laguna Potrok Aike (LPA) has been described as a lake occupying a maar crater (Zolitschka et al., 2006). The LPA depression has a diameter of approximately 5 km. The lake (113 m a.s.l) is 100 m-deep with a maximum diameter of 3.5 km and it has a surface area of 7.58 km^2 (Zolitschka et al., 2006). The bathymetry data shows a bowl-shaped structure with a flat bottom in its central part, as is typical of maar lakes. The usual tephra ring surrounding a maar crater is however not obviously preserved at LPA, suggesting the volcano is comparatively old. Erosion of the tephra ring could be explained by the strong wind typical of the region, or perhaps by glaciations, although the latter would probably have filled up the depression entirely. A low hill on the E side of the lake is the best candidate for tephra rim remnants. In a couple of gullies on this hill, yellowish indurated deposits, appearing more or less in place, are plausible phreatomagmatic deposits, but their exposed thickness is only a few decimeters at most. In an effort to obtain a better stratigraphic section we manually dug several pits, up to 1.7 m-deep, around the lake. Our two pits from the E hill together exposed several meters of stratigraphy (Fig. 4).

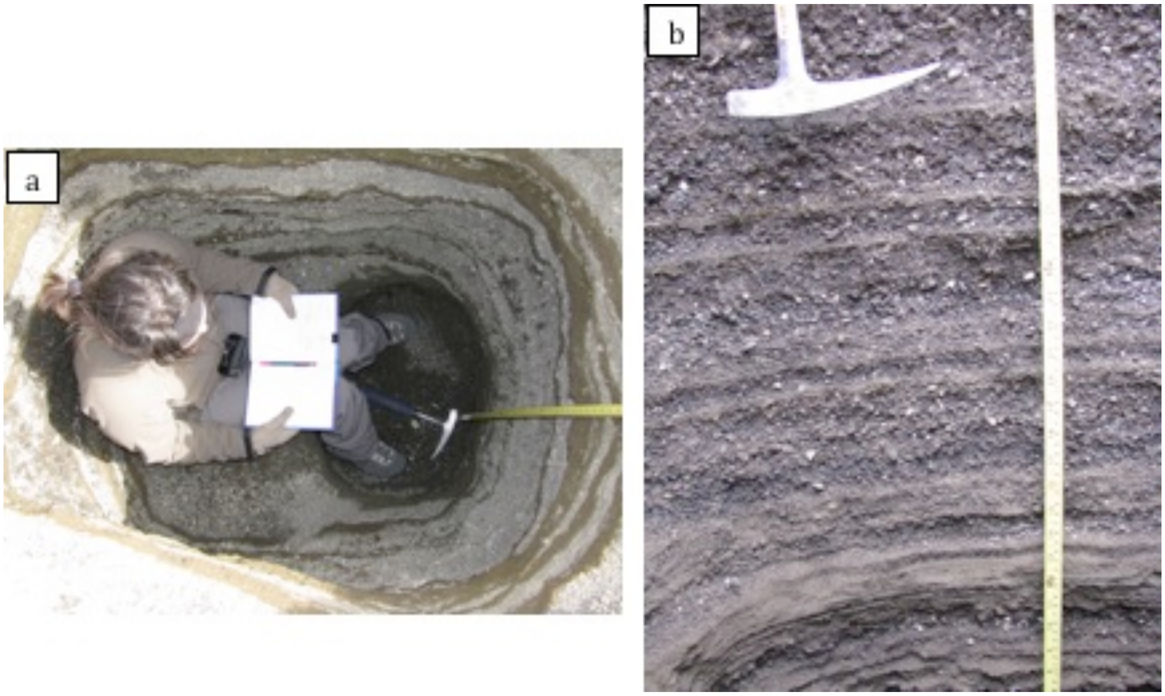

Fig. 4. Overview (a) and close-up (b) of one of the pits dug in the inner slope of the low hill on the E side of LPA.

The strata in the pits appear to be undisturbed pyroclastic deposits and consist mostly of relatively well sorted scoriaceous lapilli & coarse ash layers with few lithics (Fig. 5), very typical of pyroclastic fall from scoria cone-forming eruptions. The apparently younger volcano informally known as the "Mexican Hat", 2.4 km toward the SSE relative to the pit, is partly a scoria cone and represents a good candidate for the origin of these scoria fall layers. More work on the volcaniclastic stratigraphy is needed at LPA before a definitive assessment of the origin of this hill can be made, but the layers exposed in our pits were very unlike the typical phreatomagmatic deposits of the East Maar.

Fig. 5. Details of strombolian fall deposits in a pit dug on the low hill on the E side of Laguna Potrok Aike.

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GEOMORPHOLOGICAL REMARKS ABOUT
THE POTROK AIKE AREA, SANTA CRUZ, ARGENTINA.

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The landscape evolution of the Laguna Potrok Aike (LPA, 51º 58' S/ 70º 23' W) and surroundings has a complex history, mainly linked with glacial fluctuations and an extensive volcanic activity. This geomorphological study has been focused on provide a basic knowledge of the spatial distribution and chronostratigraphic relationships among landforms, according to morphogenetic criteria. The geomorphic units were recognized by remote sensing and field works. Air photograms, satellite images and SRTM digital elevations models under SIG environment provided the basis for mapping. The landscape morphogenesis is the result of combined actions of the Mio-Pleistocene Pali Aike volcanic field (PAVF) activity, and several geomorphic processes occurred under semiarid climatic conditions, which in turn modified a substratum of sub-horizontal friable sedimentary rocks (Santa Cruz Fm.) of Miocene age. Among the exogenic processes the glacial activity has played a streaking role. It is considered that the study area received the direct influence of two of the six glacial advances that took place in the region (Meglioli, 1992). Coming from the Andean Cordillera, the Rio Gallegos glacial lobe deposited its oldest and easternmost moraine sequence at 70º 40' W close to the Estancia Bella Vista (BVG), *ca*.1 My ago. A lobe advancing from the Magellan Strait (S) reached the area at an equivalent age. The following glaciation, named Cabo Virgenes (CVG), took place *ca*. 780 ka B.P., but at this time only reached the area the meltwater streams flowing from the S. During this glaciation and the subsequent glacial advances a tundra environment prevailed in the study area as it is indicated by different cryogenic features (Bockheim et al., 2009).
Two regional fault systems, occur in the area. An NW system, and a younger transversal to the Andean cordillera axis, witch controlled the channeling of ancient rivers -as Rio Gallegos- and Pleistocene glaciers as those that flowed by the, Skyring and Otway sounds and the Magellan Strait. The origin of this faulting was attributed to a NW stretch field still active during the Upper Tertiary.
The following landscape components were distinguished in LPA area:

Structural aggradation reliefs

The former landscape is represented by vast sub-horizontal surfaces formed by Santa Cruz Fm. sedimentary rocks. In a regional scale, they are overlain by conglomerates of varied lithology coming from the Andean front ("Rodados Patagonicos") and/or by lava flows of different age forming volcanic tablelands. Where lava flows are absent, erosion remains of the former plain surface are present at lower topographic levels, such as in the western side of Carlota (or Robles) creek. Rotational slumps frequently occur at the slopes of volcanic tablelands (eg.: Bella Vista).

Volcanic genesis reliefs

The volcanic plateaux are the highest topographic surfaces of this area (160 to 200 m). They were formed by the eruption of Mio-Pliocene volcanoes giving way to lava flow fills. Over the INTA volcanic plateau, the Cuatro Marias small and deeply eroded scoria cones crop out.
Scoria cones stand out from the high and low terrains. On the highlands, represent here by the volcanic plateaux, very old and eroded edifices crop out over the basaltic flat surface. Cerro Arrasado located on the Bella Vista table mountain and the Cerro Descabezado on the southwester flank of the INTA tableland, hardly uprise on the surrounding terrains. The Cuatro Marias, an scoria cones alignment, erupted over the INTA tableland showing mid degraded morphologies. The crater rim of Tetas de la

China, a couple of old and degraded cones standing on plateau lavas, rise 230 and 245 masl. Scoria cones stand out from the low terrains in the southern part of the studied area. They rise: Cerros Policia (187 masl), Bettrus (221 masl), Vigilante (128 masl), and Sombrero Mexicano (247 masl).
The abundance of maars is one of the main characteristics of PAVF. During the eruptions generated by the interaction between lava and underground water or fozen soils, the phreatomagmatic rings ¨Potrok Aike¨, ¨Flamencos¨, ¨Sombrero Mejicano¨ and "Carlota", among others, were formed. Their diameters vary between 0.6 to 3.5 km. The phreatomagmatic ring deposits originated by the Potrok Aike, the larger maar of the area, crop out discontinuously at the S, N and E flanks of the lake. This intermittency can be due to later mass-wasting, aeolian and/or alluvial erosive processes.

Glacial genesis reliefs

Glacial and meltwater features related to old piedmont glaciations are widespread in the area. The glacial erosion is especially notable in the Petrus basaltic plateaux (N of LPA) where rocks has polished surfaces, glacial striaes and grooves. Some volcanic cones show strong erosive impact, such as those emerging from plateaux Petrus and INTA (W of LPA) where eroded outcrops resemble roches moutonnées, proving the flow of ice over them. Others cones were highly degraded as those of Nubes alignment located over Bella Vista plateau, in the NW corner of the area.
The most frequent landforms are sub-glacial moraines covering both tablelands and low terrains. On the INTA and Petrus plateuax they appear as relative low level hills along a W-E direction. Similar characteristics have those located in the lowlands eastwards LPA. Glacial boulders are scattered on the surface, their size varies from 6 to 1 m in their longest axis. Some of them have a metaquartzitic or quartz lithology, confirming their allochthonous character and glacial origin. Large areas of elongated, subglacial hills are found at the lee-side of the basaltic plateaux, so the sedimentary glacial load deposition must have been controlled by the pre existent volcanic relief.
Till can be observed in few outcrops mostly at the eastern slope of the LPA. It lies in unconformity on the Tertiary sedimentary substratum. Of sub-glacial type, with a grey to light brown clayey sandy lime matrix, it has scarce boulders but high contents of medium to fine gravel. This is the fraction usually outcropping at the moraines surface. They probably correspond to “Rodados Patagónicos” gravels incorporated into the glacial load together with fine sediments, basalts and allochthonous rocks, taken in the western glacial accumulation areas, near the Andes. Once being part of the ice they were transported and redeposited as part of the glacial sediments.
Cryogenic features such as relict sand wedges and cryoturbation affecting till and overlaying materials (gravels and/or buried argillic soils) are exposed in a few outcrops. Medium sand deposits penetrate the till´s clayey lime matrix forming wedges many decimeters long. All along an outcrop in the NE part of the area, a number of wedges, separated 0.5 - 1 m, can be seen. Relict sand wedges indicates that permafrost was nearly continuous in an extremely arid periglacial tundra environment (precipitations $\leq$ 100 mm/yr). How many times and when prevailed these cold desert conditions are still uncertain, but they should be developed during one or more glaciations occurred sometime after the major piedmont glaciation (*ca.* BVG, 1 My ago).
Mealtwaters flows gave origin to three levels of fan-shaped landforms along the Carlota creek and Gallegos river. The outwash fans have very flat surfaces and low general slopes (0.2 – 0.3º). They appear as the highest terraces levels related to the present valley bottoms. The formation of Level I fan was controlled by the foot of the Bella Vista and INTA plateaux and its apex lie at a valley narrowing between the Tetas de la China cones and the Descabezado edifice; the distal sector shows evidences of later glaciofluvial erosion. Level II fan developed from the narrowness between the Tetas de la China cones and its distal part reaches the apex of Level I fan. It also developed a prolongation to the NE towards the paleovalley where LPA stands at present. Both fans levels are oriented in S-N direction and

were deposited over a pre-existent subglacial morainic low relief with a gradual general slope towards the E. The fans´ genesis is interpreted as the result of outwash deposition during deglaciation stages, probably associated with BVG. Level III fan developed its apex in the valley between INTA and Petrus basaltic plateaux. At first, it extents towards the NW eroding the distal section of the Level I fan and then continue northwards laying on the first level of the Gallegos river terraces. From this level emerges a basaltic outcrop dated by Meglioli (1992) in *ca.* 2 My. The ancient stream that formed this big outwash came from the morainic front (CVG) located further south, in Chilean territory, flowing along the paleovalley where the LPA stands at present.

Fluvial genesis reliefs

The fluvial streaking feature is the Carlota (Robles) creek, a tributary of the main Gallegos river, where four high and wide terraces levels were recognized along the middle and lower reaches, just downstream of the confluence with the N Bandurrias creek. The building up of the Carlota creek's terraces is assigned to periods of major water availability, due to increased precipitations or to glacial melting in the southern morainic fronts, where the river sources were placed. Nowadays the river has an intermittent regime, flowing only downstream of the confluence, probably, sub-surficially fed from the LPA. The Bandurrias creek seems to have higher discharges in the past, as at least three terrace levels can be traced up-valley to the morainic front. This paleovalley pre-date the pheatomagmatic eruption of the maar Potrok Aike, which in turn intercepted the water flow dividing the paleovalley. At present, two ephemeral creeks, N and S Bandurrias (related to LPA position), flow along this paleovalley. In addition, at the Diego Ritchie Police Station, the S Bandurrias creek was blocked by phreatomagmatic deposits forming a divide in the main channel. Arid climatic conditions can be assumed for the region since maar eruption because both, the divide -4 m high- is still present and new terraces levels weren´t developed. Headwards erosion and stream piracy occurred downstream the Police Station, thus the main channel eroded its outlet at the LPA.

Lacustrine-aeolian genesis reliefs

The LPA (~112 masl) is the most important permanent water body in the region formed by a volcanic maar eruption. Though, smaller temporary lakes of different genesis also exist, located in minor maars, basaltic tablelands or carved by deflation in sedimentary bedrock. Associated to the LPA littoral dynamics, different levels of beach ridges were developed reaching altitudes of +21 m above the present level lake, or lying below it.

The regional aeolian activity is represented by a widespread and almost continuous mantle of sand and silt, covering all surfaces with a subtle morphology of ridges oriented W-E. Locally, large aeolian plumes originated by deflation in big depressions occur. The largest is located at the base of Bella Vista volcanic plateau, riding up 70 m height and extending along 2.6 km over the plateau. Other aeolian features are deflation basins formed on volcanic plateaux and over wide basal till plains. During periods of more humid climatic conditions, beach crests were developed in these basins due to lacustrine activity.

Final remarks

The geomorphological study allows us to establish some hypotheses about the evolution of the environment, albeit a precise chronostratigraphy is still unavailable. It can be inferred that between the Late Miocene, after the volcanic plateaux formation, and the Middle Pleistocene (*ca*. 1 My B.P.) glacial lobes reached the study area advancing from both, the W and the S. As the area is placed just at the confluence of both lobes, it’s a difficult task to interpretate the interactions between them, as well as, their accurate boundaries. Nothward of the area, a glacial advance mounting the Bella Vista, INTA and Petrus plateaux, eroding basalts, depositing till and erratic boulders and forming depressed paleosurfaces between the plateaux, can be suggested. Thus, as these glacial features are located eastwards to the external moraines of the BVG (*ca*. 1 My B.P.), one ore more previous glacial advances, not yet described, can't be rouled out. Confirmation depends on-going radiometric ages of basalts stratigraphically related to the till. The existence of a younger morainic front (CVG, ~780 ka B.P.) south of the studied area favoured the arrival of glaciofluvial streams that increased the water supply of the rivers flowing northwards, generating terrace systems and large glaciofluvial fans. The necessary water to explain the phreatomagmatic activity of the LPA area could be supplied by meltwater from BVG and/or CVG or by the ice contained in permafrost (Corbella et al., 1990). Relict sand wedges, widespread aeolian activity and diminished fluvial activity support the idea of large periods of arid climatic conditions since the maaric eruption. On going geomorphological and geological research will help to the comprehension of the relations between glacial events, terraces formation and volcanic relief modelling under different climatic conditions along the Quaternary.

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Acknowledgments

To UNPA-UARG (29/A195 PI) and ANPCT-SECyT (PICT 02338 PIPA) for the financial support.

HIGH RESOLUTION DENSITOMETRY OF POTROK AIKE MAIN COMPOSITE CORE : METHODS COMPARISON AND CALIBRATION

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Density variability of sediment profiles can inform on a variety of processes, limnologic and sedimentary conditions and should be considered along other sedimentary proxies when investigating long term environmental changes form lake sediments. From decrease in water content, changes in porosity, to mineralogical and grain-size related changes in density, high resolution continuous densitometry offers a quick overview of the physical characteristics and structural properties of a sediment profile.

Given their highly variable sedimentary content, the sediment cores of Laguna Potrok Aike, offers a unique opportunity to test the feasibility of a sedimentary characterisation based on 2D (standard X-radiographs) and 3D (tomography) density measurements.

We present here density measurements obtained from the main composite sedimentary profile (u-channels) from Laguna Potrok Aike. The first set of measures was obtained using the X-radiograph sensor from the ITRAX core analyser. It provides positive X-radiograph images at a resolution of 100 microns. The second set of measures was obtained using a medical tomograph (CAT-scan) which uses a pixel intensity scale to quantify and map X-ray attenuation coefficients of the analyzed object on longitudinal (tomograms) or transversal (tomograms) images (St-Onge and Long 2009).

According to our results, density changes in Potrok Aike sediments reflect mainly changes in grain-size, organic matter content and mineralogy.

GEOCHEMICAL CHARACTERISATION OF THE PASADO SEDIMENT RECORD FROM LAGUNA POTROK AIKE, SOUTHERN PATAGONIA (ARGENTINA)

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During the lake deep drilling campaign PASADO in 2008 (ICDP expedition 5022) more than 500 m of lacustrine sediments were recovered from the maar lake Laguna Potrok Aike. From Site 2 a composite profile (5022-2CP) with the total length of 106 m was assembled. Discrete 2 cm thick samples from 5022-2CP were analyzed for total inorganic carbon (TIC), total organic carbon (TOC) and total nitrogen (TN) content at 8-16 cm spatial resolution using an elemental analyzer (EuroEA). Furthermore, the major element composition was assessed with a spatial resolution of 5 mm using an ITRAX XRF core scanner (COX analytical systems, Croudace et al., 2006). Prior to the interpretation of XRF-scanning data, some methodological aspects have to be taken into consideration.

The grain size of Laguna Potrok Aike sediments is often relatively coarse. This is known to affect count rates of XRF-scanning (Croudace et al. 2006). Moreover, fluctuations in sediment mineralogy, particle size and water content affect the mean atomic number of the sediment volume excited by the X-ray beam of the XRF core scanner. These effects are recorded as differences in the intensity of the scatter peaks (Rayleigh and Compton scattering) which therefore can be used to correct for mineralogy, particle size and water content (Potts et al. 1997). Despite the application of a Rayleigh scatter correction there are still indications for the necessity of a calibration using element concentrations determined on discrete samples and possibly water content corrections using the element Cl (Tjallingi et al. 2007).

Principal component analysis (PCA) is a useful tool for analyzing large datasets like element counts from XRF-scanning and this approach helps to reduce noise and/or element-specific biases (Shanahan et al. 2008). A PCA was applied to normalized counts of all elements if their profiles contain an interpretable geochemical signal defined by low noise, high variability and a sufficiently high number of counts.

The sharp boundary between the carbonate-bearing and the carbonate-free depositional systems at 15,6000 cal. BP (18.82 m composite depth) dominates the PCA of 5022-2CP marking the transition from the Glacial to the Late Glacial (Fig. 1). Holocene and Late Glacial sediments can easily be distinguished by elements that are indicative of organic-rich sediments (Br, Cl) or of calcite (Ca). Ca in the Holocene sediments of Laguna Potrok Aike can be attributed to calcite precipitation (Haberzettl et al. 2005). Br and Cl have been related to organic sediment components (Br) containing Cl-bearing pore water (Thomson et al. 2006). For Laguna Potrok Aike a correlation is only detected between TOC and Br (R^2 = 0.64). Glacial sediments are characterized by elements that represent terrigenous sediment fluxes (Fe, Zn, Al, Si, K, Ti, Zr, Mn, Cu) (Cohen 2003).

Variations in the geochemistry of the clastic glacial sediments have been explored by excluding all data points from the PCA that are linked to the sediments above 18.82 mcd (Fig. 2). As expected, elements indicative of clastic input (Fe, Zn, Al, Si, K, Ti, Cu) are responsible for positive scores in the first component and indicators of organic matter (Br) and calcite (Ca) have little importance. The accumulation of Mn along with the bulk of elements related to clastic input was probably inhibited by reducing conditions during glacial high lake levels conditions (Haberzettl et al. 2005). With regard to the PCA of the entire composite profile the loadings of Cl, Zr and to a lesser extent of Sr become inversed. During the Glacial Cl probably reflects the effect of highly porous sand layers and is therefore correlated with lithogenic elements. Sr is most common in biogenic carbonates; its strong negative loadings could therefore be attributed to occasional remains of calcareous organisms in the sediments. Negative loadings of the immobile element Zr may indicate that clastic input during the Glacial is characterized by fresh physical weathering products rather than by increased transport.

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Fig. 1. Scores in the first (PC1) and the second (PC2) principle component express the geochemical composition of the pelagic site 2 composite sediment profile (5022-2CP) Holocene (green), Late Glacia (blue) and Glacial (red) sediments. Element signs indicate the contribution of each element to the explanation of the varying geochemical composition.

Fig. 2. Scores in the first (PC1) and the second (PC2) principle component express the geochemical composition of the pelagic site 2 composite sediment profile (5022-2CP) below 18.82 mcd (red). Element signs indicate the contribution of each element to the explanation of the varying geochemical composition.

MICROSEDIMENTOLOGY AND GEOCHEMISTRY OF LACUSTRINE SEDIMENTS OF LAGUNA POTROK AIKE (LPA): DISCUSSION ON HYDROLOGICAL RECONSTRUCTIONS DURING LATE GLACIAL.

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Lacustrine sediments of Laguna Potrok Aike (LPA) in Patagonia can provide high-resolution paleoenvironmental and paleoclimatic reconstructions from tens of thousands of years (for example, Haberzettl et al., 2005, 2007, 2009). The objective of this work is twofold. First we contribute to the sedimentological characterization of all observed facies along the 107 meters of sediments of the composite profile. These analyses include image analysis of thin-sections to obtain grain-size and quantify sedimentary fabric at microscopic scale, grain size analysis using laser diffraction (1-5 mm sample intervals), and micro-XRF at 100μm resolution for elemental chemistry.

Second, our work aims to contribute to the hydrological reconstruction at LPA using our sedimentological and geochemical indicators during the events of abrupt warming and cooling climate measured in ice cores in Antarctica. These are: Antarctic Warm Event 1 and 2 (isotope stage 3) and the Antarctic Cold Reversal (Late Glacial period). For that purpose, about 15 meters of U-channels were analyzed.

During this workshop, we will present our results for Late Glacial period. XRF results could provide hydrological reconstructions in LPA using ratio of elements like Ca/Ti or Fe/Mn already used during SALSA project (Haberzettl et al., 2007). Our new XRF and image analysis results seem to indicate that several lake level variations appeared from the middle of the Antarctic Cold Reversal (ACR) (~ 14 ka cal. BP) to the end of the Younger Dryas chronozone (11,7 ka cal. BP).

DATING, AGE-DEPTH MODELING AND HYDROLOGICAL INTERPRETATION OF THE 51 CAL. KA BP COMPOSITE PROFILE FROM LAGUNA POTROK AIKE IN SOUTHERN PATAGONIA, ARGENTINA

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Different dating methods (AMS radiocarbon, OSL, Ar/Ar-dating of tephra layers) are applied in order to obtain absolute dates and a reliable chronology for the sedimentary sequence recovered during the lake deep-drilling project PASADO (ICDP expedition 5022) at Laguna Potrok Aike, southernmost Argentina. In this contribution we first report on the results of radiocarbon dating on organic plant remains along the entire 106 m long composite record from Site 2 (5022-2CP). These ages were used to establish a chronology for this unique late Pleistocene record from the Southern Hemisphere. With regard to age-depth modeling we present methodological aspects and discuss the criteria that were applied for the selection of ages that had to be excluded from the final age-depth model. Secondly, a first interpretation of 31 currently available OSL dates in support of the radiocarbon chronology is discussed as well as the potential for additional Ar/Ar-dating of the frequent volcanic ash layers. Finally, we interpret the resulting sedimentation rates in terms of climatic fluctuations which are mainly driven by changes in precipitation and evaporation in this part of the world, e.g. by hydrological variations as reflected by lake level changes of the lacustrine system.

The selection of 37 radiocarbon dates is restricted to samples from below 18 mcd (meter composite depth) of 5022-2CP. For the topmost 18 m an additional set of 16 radiocarbon ages was correlated to 5022-2CP from the published chronology elaborated for the composite sediment record of PTA-03/12+13 (Haberzettl et al., 2007) by means of lithology and supported by magnetic susceptibility. For the Holocene and the Late Glacial part of the lacustrine record from Laguna Potrok Aike radiocarbon dating was carried out on calcites that were precipitated from the water column (no hard-water effect was recognized), bulk sediment and on different organic macro remains (Haberzettl et al., 2007). But almost no calcite occurs in the sediments of 5022-2CP older than the Late Glacial. Hence, AMS ^{14}C dating could not be applied to calcites below 18 mcd. Macro remains of aquatic mosses were the only component available in a sufficient quantity on which to perform radiocarbon dating. These aquatic mosses are concentrated in layers intercalated within pelagic sediment sections as well as dispersed in mass movement deposits. The former were preferred because for mass movement deposits the likelihood of obtaining too old ages that do not represent the time of deposition for the surrounding pelagic sediment is high.

However, the occurrence of aquatic mosses in the pelagic facies is limited. Moreover, it has to be kept in mind that the origin of this organic material is the littoral zone of the lake. Hence, it is not surprising that some dates from pelagic sediments distinctly tend towards higher ages indicating some degree of reworking. For this reason, an inspection of dated samples including an interpretation of the outliers was indispensable prior to, as well as during age-depth modeling. This was carried out on the event-corrected record from 5022-2CP by running two iterations with a mixed-effect regression procedure as described by Heegaard et al. (2005), a method which is relatively robust with regard to outliers. The first iteration reveals that (1) some radiocarbon dates considerably exceed the confidence interval of the age-depth model and (2) the age-depth modeling below 81 mcd produces an age reversal caused by a lack of reliable material for dating and because the radiocarbon method as such is very close to its lower limit (>45 cal ka BP). Therefore, the second iteration using the mixed-effect regression was restricted to dates of the upper 81 m of the record and excluding dates considerably exceeding the confidence interval of the first iteration. The resulting age-depth model V.2 was extrapolated below 81 mcd back to the final depth of 106 mcd.

To obtain a chronology independent from radiocarbon dating OSL dating was performed on sand-sized K-feldspar grains. The analyses were carried out at the Nordic Laboratory for Luminescence Dating (Aarhus University, Risø DTU, Denmark). A post-IR IRSL dating protocol (modified from Buylaert et al., 2009) was employed which isolates a more stable K-feldspar signal and thus avoids undesirable fading corrections. Dating was successful for 31 OSL samples, while 7 samples did not contain the necessary amount of sand-sized K-feldspar grains and thus were not datable with this method. In general, post-IR IRSL dates confirm the radiocarbon-based age-depth model. Between 65 and 80 mcd the match between both independent dating methods is almost perfect. Below 80 mcd and for the topmost 15 m the post-IR IRSL dates seem to overestimate the radiocarbon based age-depth model. Insufficient bleaching can explain overestimations in both parts. In the bottom part differences might also result from dating at the limit of the radiocarbon method. Surprisingly, between 20 and 65 mcd post-IR IRSL ages seem to underestimate the radiocarbon-based chronology. An additional source of error is related to the fact that OSL samples – for the sake of obtaining enough material for dating – integrate along several centimeters or even decimeters of the record and thus could integrate small-scaled redeposited sediment layers.

The third method applied is Ar/Ar-dating. Altogether, for this approach five samples were taken from tephra layers. Because of the age ranges and errors involved with this method only volcanic ashes below 55 mcd were sampled. Even though these tephra layers reach several decimeters in thickness they contain very few minerals suitable for Ar/Ar-dating; volcanic glass, pumice and amorphous clasts dominate. However, four of the five samples contain amphibole and plagioclase but no K-rich mineral phase (e.g. sanidine). Consequently, amphiboles are the target for the ongoing Ar-Ar measurements.

Results of the radiocarbon-based age-depth modelling were used to calculate sedimentation rates for the entire record. Previously, a time window with high sedimentation rates during the early Holocene was interpreted as a period with a low lake level; as a result we hypothesize that low lake levels can also be assumed for older sections with increased sedimentation rates. We recognized two such additional periods that could match these conditions: 24-31 cal. ka BP and 45-51 cal. ka BP. There is evidence that at least the older phase with high sedimentation rates was caused by low lake levels: according to seismic reflection data this sediment depth corresponds to a phase dominated by aeolian dune morphologies in the eastern part of the lake basin (Gebhardt et al., in prep.). This fact supports a very low lake level or even desiccation.

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HISTORICAL CHANGES IN PRODUCTION, GROSS ALGAL COMMUNITY COMPOSITION, AND ULTRAVIOLET RADIATION REGIME IN LAGUNA POTROK AIKE, PATAGONIA, ARGENTINA, DURING THE PAST 35,000 YEARS.

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Climatic variability is projected to alter lake ecosystems by changing the influx of energy (heat, irradiance, kinetic energy) and mass (water, solutes, suspended material) both directly to the lake surface and indirectly via the local drainage basin. Lake response to changes in forcing functions has been described variously using changes in basin morphometry, biogeochemistry, and composition of biological fossils. To date, biological responses to millennial-scale variation in climate have been recorded most often using morphological remains from siliceous or carbonaceous algae, especially diatoms. However, in many modern lakes, these taxa comprise only a seasonal subset of algal species, such that analysis of morphological fossils may not record historical changes in primary production by prokaryotic and eukaryotic algae, or variation in gross algal community composition (e.g., cyanobacteria, diatoms, cryptophytes, chlorophytes, etc.). To address this issue, we quantified changes in concentrations of chlorophyll (Chl), carotenoid, and derivative pigments from algae and bacteria in sediments recovered from Laguna Potrok Aike, Patagonia, Argentina, as part of the Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO). In addition to allowing quantification of historical changes in algal abundance and community composition, fossil pigment analysis also allows estimation of past ultraviolet radiation (UVR) regimes using extracellular compounds produced by some algae in response to high intensity irradiance (see Leavitt et al. 1997. Nature 388: 457-459).

Analyses were conducted on composite core 5022-2CP collected during expedition 5022 to Laguna Potrok Aike. Details on core collection and establishment of preliminary chronology are presented elsewhere. Samples for pigment analyses consisting of ~1 g dry sediment mass were collected every 4 cm throughout the most recently deposited 44 m of the composite core, an interval of ca. 35,600 ^{14}C years, according to preliminary chronological analyses. Each sample was freeze-dried to constant mass to remove water, weighed to 0.01 mg, and pigments extracted by repeated addition of a standard mixture of acetone, methanol and water (80:15:5, by volume). Extracts were filtered (0.45-µm pore), dried under an N_2 atmosphere, and re-dissolved in a standard injection mixture before introduction into a Agilent model 1100 high performance liquid chromatography (HPLC) system which has been calibrated previously with authentic standards. All compounds were tentatively identified using a combination of chromatographic position and visible light absorbance spectrum, following standard methods (loc. cit.). All pigment concentrations were calculated as nmoles pigment g^{-1} dry sediment mass for the purposes of preliminary analysis. Analyses will be conducted also using organic-matter specific concentrations.

Fossil pigment concentrations exhibited two distinct phases during the past ca. 35,000 ^{14}C years BP (referred to as yr BP hereafter). In general, pigment concentrations were very low (< 0.1 nmol g^{-1} dry mass) during ~35,000 to ~16,000 yr BP, although ratios of labile precursor compounds (chlorophyll *a* = Chl *a*) to stable products (pheophytin *a*) were elevated (>1) throughout this period, consistent with excellent preservation of organic compounds. Subsequently, total algal abundance (as ubiquitous *β*-carotene and Chl *a*) increased over 10-fold after ca. 16,000 yr BP, with particularly elevated concentrations of many fossil compounds during the next 7,000 years, and again after 4,900 yr BP. Overall, these patterns are consistent with those seen in cores obtained from alpine and temperate lakes in the Northern Hemisphere, where end of the glacial interval and establishment of terrestrial soils and vegetation is associated with 10- to 100-fold increases in lake production (e.g., Leavitt et al. 2003. Limnol. Oceanogr. 48: 2062-2069; Bunting et al. 2010. Limnol. Oceanogr. 55: 333-345).

Analysis of sediments deposited during the Holocene suggest that lake production and algal community composition changed substantially both at ca. 8,500 and ca. 4,900 yr BP. Elevated concentrations of most pigments during ca.16,000-8,500 yr BP correspond with elevated Chl *a*:pheophytin *a* ratios (increased preservation), and nearly 100-fold increases in okenone and isorenieratene, carotenoids from photosynthetic sulfur (S) bacteria. Because these bacteria are require anoxic conditions (obligate anaerobes), we infer that Laguna Potrok Aike was strongly stratified, possibly meromictic, during the early Holocene, but that the intensity of anoxia may have declined since ~8,500 yr BP. Because pigment preservation is normally enhanced by anoxia, it is difficult to evaluate whether inferred declined in algal abundance near 8,500 yr BP reflect variation in algal production, or changes in fossil preservation. Regardless, analysis of fossil pigments of similar chemical stability suggests that the Holocene was marked generally declining concentrations of fossils from S bacteria, an increase in those from flagellate algae (cryptophytes, chlorophytes), and, after 4,900 yr BP, a marked increase in the carotenoid fucoxanthin, a biomarker of siliceous algae (diatoms, chrysophytes) and some dinoflagellates.

Analysis of UVR- photoprotective pigments (Leavitt et al. 1997. Nature 388: 457-459) suggested a sharp decline in exposure of algae to high intensity irradiance after ca. 16,000 yr BP. Specifically, concentrations of UVR-absorbing pigment increased up to 100-fold after 16,000 yr BP, concomitant with general increases in total algal abundance. However, when standardized to algal abundance, the relative (%) abundance of these photoprotective compounds declined over 10-fold, suggesting that, on average, algae experienced less exposure to UVR during the Holocene than during the glacial era. This pattern has also been recorded in Antarctica and has been proposed to arise from longterm changes in atmospheric ozone concentration (Hodgson et al. 2005. Earth Planet. Sci.Lett. 236: 765-772). Further research is required to compare pigment stratigraphies with those of other fossil indicators (organic C content, diatoms, etc.) to evaluate whether reductions in UVR exposure at Laguna Potrok Aike are consistent with atmospheric or catchment-scale controls of UVR.

HIGH-RESOLUTION PALEOMAGNETIC RECORD FROM THE LATE PLEISTOCENE SEDIMENTS OF THE MAAR LAKE *LAGUNA POTROK AIKE*, SOUTHERN SOUTH AMERICA

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High-resolution paleomagnetic records are scarce in the Southern Hemisphere relative to the Northern Hemisphere. The uneven distribution of the records around the globe limits our understanding of what governs the rapid changes in the Earth's magnetic field. In particular, more high-resolution records from the Southern Hemisphere is crucial to assess the possible global nature of the centennial- to millennial-scale variability. Because of its position at the southern tip of South America (52°N, 70°W) and its high sedimentation rates (>1 m/kyr), *Laguna Potrok Aike* is a key site for a high-resolution paleomagnetic study. In the austral spring 2008, the Potrok Aike maar lake Sediment Archive Drilling prOject (PASADO) science team drilled the maar lake *Laguna Potrok Aike* in the framework of the International Continental scientific Drilling Program (ICDP). Here we present the full paleomagnetic reconstruction (inclination, declination and relative paleointensity) from the sediments of the maar lake *Laguna Potrok Aike* and we compare the results of the last 25 000 cal BP with the closest available records from marine and lake sediments, as well as with geomagnetic model outputs.

The natural remanent magnetization (NRM) was first measured at 1 cm intervals with step-wise alternating field demagnetization using a 2G u-channel cryogenic magnetometer at the sedimentary paleomagnetism laboratory of the *Institut des sciences de la mer de Rimouski* (ISMER). Stability of the magnetization was analyzed by alternating-field (AF) demagnetization and the paleomagnetic directions were calculated using principal component analysis (PCA).The anhysteretic and isothermal remanent magnetizations (ARM and IRM) were then induced and measured using the same instrument in order to derive paleointensity proxies and to inform on the magnetic grain assemblage. A detailed rock magnetic study was also conducted in order to precisely identify the magnetic mineralogy and grain size. The hysteresis properties were measured on all core catcher samples from site 2 hole A (5022-2A-CC) and at ca. 50 cm intervals on the composite profile site 2 (5022-2CP) using an alternating gradient force magnetometer. In addition, the temperature-dependant magnetic susceptibility was measured from 50 to 700 ˚C on all 5022-2A-CC using a Bartington system, the frequency-dependent magnetic susceptibility was measured on cube samples at ca. 200 cm intervals on the 5022-2CP and the volumetric magnetic susceptibility was measured on the u-channels using a point sensor mounted on a multi-sensor core logger (MSCL). The magnetic assemblage of the normally deposited sediment is dominated by low coercivity mineral such as magnetite in the pseudo-single domain state, which is optimal for paleomagnetic studies. Furthermore, reworked material such as tephra, sand and intervals with abundant vegetal remains display distinct rock-magnetic properties and are thus readily identifiable throughout the record.

The new high-resolution paleomagetic inclination, declination and relative paleointensity record from *Laguna Potrok Aike* since 25 000 cal BP is compared with the closest available records, including lacustrine records from further north in Argentina (lakes El Trébol and Escondido) and marine records from offshore Chile (ODP-1233), the Antarctic Peninsula (Palmer Deep and West Bansfeld Basin) and the South Atlantic (SAPIS stack). The millennial- to centennial-scale variability is generally comparable between all records. Even though age offsets of several hundreds of years are observed, sharp and large amplitude paleomagnetic features can easily be correlated between the high-resolution records. Noteworthy is a 1000 yr-long period of low inclination recorded at ca.18 000 cal BP and observed in all the other southern Hemisphere records. Interestingly, a similar geomagnetic feature is observed in Hawaiian lavas and Arctic marine sediments between 18 and 22 cal BP, hinting at the possible global nature of the event. Altogether, the paleomagnetic results of *Laguna Potrok Aike* reveal a genuine Late Pleistocene geomagnetic record and indicate that high-resolution magnetostratigraphy could be useful to constrain the chronology of 5022-2CP.

MODERN FRESHWATER ORGANISM ANALYSIS
FOR QUANTITATIVE PALEOENVIRONMENTAL RECONSTRUCTIONS
IN SOUTHERN PATAGONIA (SANTA CRUZ, ARGENTINA)

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INTRODUCTION

In the last 20 years, Patagonia has become increasingly important for paleolimnological research due to its exceptional geographic location and the abundance of lakes, ponds and bogs. Santa Cruz province is the southernmost continental landmass extending far as 52ºS. Its relative proximity to Antarctica makes it a crucial area for paleoenvironmental research and to establish intra- and interhemispheric climate links to understand global climate variability.
Subfossil and fossil remains of aquatic organisms usually are excellent paleoindicators. The different species have specific ecological preferences and tolerances which make them useful indicators of past environmental changes.
Paleoenvironmental reconstructions using bioproxy assemblages have played an important role in NW Europe specially in reconstructing climate changes during the Late Glacial-Interglacial Transition and Holocene. Indeed, there is a close relationship between temperature and the distribution and abundance of chironomid larval head capsules (HC) which has been used to develop temperature inference models to produce quantitative climate reconstructions. Other proxies, such as ostracods provide information about the physical and chemical properties of their host water, including salinity, solute composition, temperature, and flow conditions as well as lake levels changes. Diatoms are extremely useful as paleoenvironmental indicators indeed. Many species have predictable distribution patterns related to water chemistry characteristics, mainly nutrient concentrations and pH. Charcoal records recovered from lake sediments are crucial to understand the mode and variability of past fire regimes. Fire activity varies in response to climate, vegetation changes and human land uses and is considered an important disturbance agent affecting directly the vegetation structure and its dynamics. The combined analysis of pollen and macroscopic charcoal records is relevant to better understand about vegetation, climate and natural/anthropogenic disturbances relationships.
All these bioproxy records show great promise for determining climate change in South American, however the lack of information about organism taxonomy and ecology inhibit the construction of robust inference models for quantitative reconstructions.
The Proyecto Interdisciplinario Patagonia Austral (PIPA) proposes a multidisciplinary approach with the main goal of decoding environmental information archived in lakes located in southern Patagonia, more specifically in Santa Cruz province. To do that, we are currently undertaking a compilation of freshwater organisms, pollen and charcoal from more than 30 lakes to develop biodiversity and ecological databases. This information blended with geochemical, geophysical and sedimentological data will allow building transfer functions which, in turn, will be applied to interpret several Quaternary lacustrine sedimentary records in southern Patagonia.

Study area

The study is currently being conducted in two main areas: the subantarctic forest, which lies principally within the boundaries of the Los Glaciares National Park, and the Patagonian steppe. The climate is dry, cold and windy. The strong precipitation gradient determines the distribution of vegetation in southern Patagonia. Four vegetation units, subantarctic forest, grass steppe, shrub steppe, and semidesert are recognized along the west–east precipitation gradient on the east side of the Andes between 46 and 52°S (Mancini, 1998, 2002; Oliva et al., 2001). Mean annual precipitation is higher than 400 mm and mean temperature is about 4.46°C in the forest. The tree deciduous species of the subantarctic forest Nothofagus pumilio (G. Forster) (lenga), N. antarctica Oerst. (ñire), and Lomatia hirsuta (radal) are present in the area. While N. antarctica is found at all altitudes of the subantarctic forest, L. hirsuta occurs only in the lower forest, developed below 400 - 500 masl. The grass steppe is found in areas that receive between 400 and 250 mm annual precipitation. South of 50°S, grass steppe is divided into xeric grassland in the east and humid grassland in the west at the 250mm isohyet. The shrub steppe and the semidesert are present in the region that receives less than 200 mm precipitation (Tonello et al., 2009; Oliva et al., 2001).

Methodology

Samples from the upper layer of bottom sediments were analysed for chironomids, ostracods, diatoms, pollen and charcoal. Surface sediment samples were preserved in 70% alcohol. In the lab, the sediment was prepared for the different analysis. Chironomid larval HC were picked under stereomicroscope from fresh sieved sediment (mesh size 100 and 200 μm). Head capsule slides were prepared using euparal and identification was made under optical microscope following Cranston (1995) and Massaferro and Brooks (2002). Samples for ostracods were examined under stereomicroscope, previously washed sieved (75 μm) and dried at 40 ºC. Any ostracod found was picked and placed in a micropaleontological slide, and finally counted and identified under a binocular microscope. For diatom analysis, a subsample of each sample was processed following Battarbee (1986) and permanent slides were mounted with Naphrax© and deposited in Dr. Maidana´s personal collection. For charcoal analysis, 5cc of sediment by sample was treated with potassium hydroxide (10%) overnight. Samples were filtered using mesh sieves of 250-125- and 63μ for obtaining different charcoal particles sizes and counting was performed under stereomicroscope. Water samples were analysed for the main chemical variables in order to get a first assessment of the trophic status of the lakes, according to nitrogen and phosphorus content. The ionic composition of lake water was also determined, and analysed in relation to the main geographical attributes and characteristics of the catchments.

Statistics/ Quantitative reconstructions

Quantitative paleoenvironmental reconstructions involve the modeling of modern analogs and the development of transfer functions. In order to develop these functions it is necessary a compilation of extensive datasets involving species abundance, distribution and ecological data, physical- chemical parameters, and obtaining a large number of modern environmental samples containing a large number of taxa to build what is called a "training set" from which those functions are developed

PROJECT PROGRESS

Field work

To have a good estimation of modern bioproxies distribution it is important to sample different lakes located within an environmental gradient. In our set of lakes, we choose an E-W gradient which covers mainly a mean precipitation range from ca. 1400 mm at the Argentina-Chile border to less than 200 mm on the Patagonian plateau.

Sediment surface samples from thirty two lakes were sampled in two field seasons carried out in January 2009 and April 2010 (N=15 in 2009 and N=17 in 2010). Location of the lakes is shown in Figure 1. Some of them are of volcanic origin while others are of glacial origin. All the lakes are located in pristine and remote areas. Chironomids, pollen, charcoal, ostracods and diatoms were analysed from those samples. Water chemistry analysis was also performed at the same sites. According to our knowledge, no hydrochemical data have been previously collected on these sites.

A third fieldwork to accomplish the goals proposed for this research is expected for next April 2011. This last fieldwork is particularly important to improve the model, because it is necessary to strengthen the size of the training set from which transfer functions will be developed by adding new samples, provide a better taxonomic resolution of modern and fossil bioproxies, and increase the number of new morphotypes and species from modern environments. Extending the number of sites will add strength and robustness to the model.

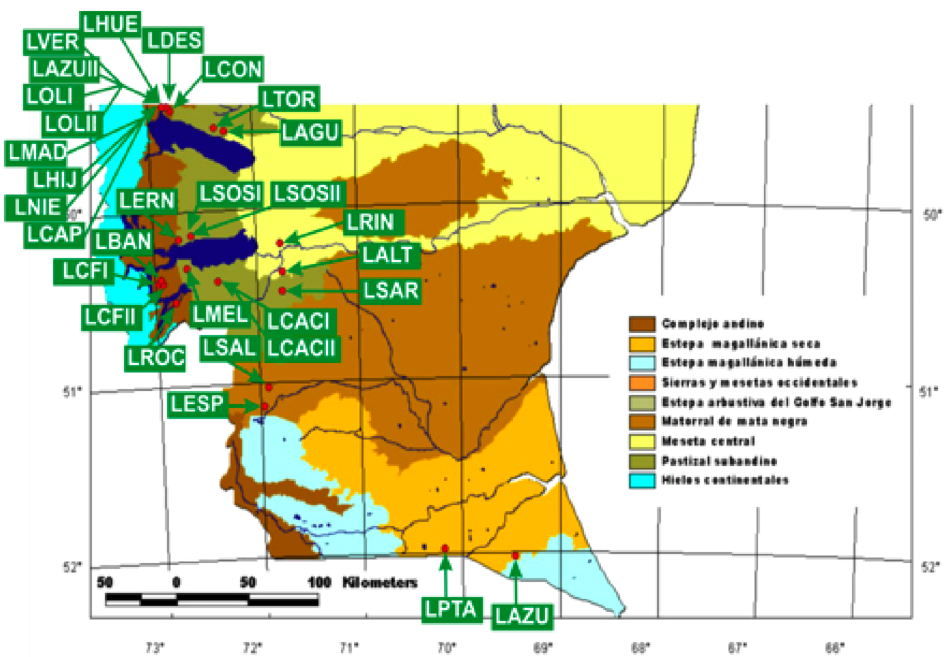

Figure 1 Sampling locations. The abbreviations stand for: LAGU = L. Agustín; LALT = L. Alta; LAZU = L. Azul; LAZUII = L. Azul II; LBAN = L. Bandera; LCACI = L. Cachorro I; LCACII = L. Cachorro II; LCAP = L. Capri; LCFI = L. Cerro Frías I; LCFII = L. Cerro Frías II; LCON = l. Cóndor; LDES = L. Desierto; LTOR = L. Toro; LERN = L. Ernesto; LESP = L. Esperanza; LHIJ = L. Hija; LHUE = L. Huemul; LOLI = L. Las Lolas I; LOLII = L. Las Lolas II; LMAD = L. Madre; LMEL = L. Mellizas; LNIE = L. Nieta; LPAJ = L. Pajonales; LPTA = L. Potrok Aike; LRIN = L. Rincón; LROC = L. Roca; LSAL = L. Salada; LSAR = L. Sarmiento; LRES = L. Torres; LVER = L. Verde; LSOSI = Mallín Sosiego I; LSOSII = Mallín Sosiego II

Activities developed

Although some improvements are needed, most of the main objectives of the PIPA Project have been already achieved:

- Development of a modern chironomids, ostracods, diatoms (Fig. 2) and pollen biodiversity database along a geographical gradient of lentic ecosystems from the Andes mountains to the Atlantic from southern Santa Cruz (between 50º and 52ºS)
- Physical and chemical analyses of lake waters, mainly trophic status and main elements
- Statistical relationship between the modern bioproxy distribution and physical and chemical properties of water from the habitats they occupy and/or they were found to better understand the ecological ranges of species and the processes of fossil assemblage formation.
- Subfossil bioproxy analysis from short sediment cores (Chaltel and Vizcachas Lakes).
- Analyses of fire events records and macroscopic charcoal content of surface lakes sediments (Fig. 2) along an east-west gradient (50°-52°S).

PRELIMINARY RESULTS (Fig 2)

Water chemistry

The lakes analysed span a wide geographical area as well as a wide range of morphological attributes and catchment characteristics in terms of lithology and vegetation cover. Data analysis revealed a first, evident distinction between the two volcanic lakes (Laguna Potrok Aike and Laguna Azul), located in the southernmost part of the study area, and the rest of the lakes, all of glacial origin. Among glacial lakes, a correlation was found between latitude and solute content because the northern lakes are characterised by the lowest conductivities and concentrations of major ions. Several lakes, mainly the deepest ones (depth > 10 m) usually showed a low nutrient content, especially regarding TP, and can be classified as oligotrophic or ultraoligotrophic. Shallow lakes, mainly located in the central and southern part of the area, were characterised by decisively higher concentration of TP (from 50 to 400 μg P L^{-1}) and dissolved organic carbon (DOC) (up to 10 mg C L^{-1}). Organic nitrogen is the main form of N in these lakes, representing between 50 and 90% of the TN content. Nitrate is usually low, as can be expected due to the remoteness of the study area; exceptions are the shallow, eutrophic lakes which were affected by the presence of birds.

Chironomids

This research shows the first steps in the development of a transfer function to quantitatively reconstruct climate from chironomids preserved in lacustrine surface sediments of 31 lakes for southern Santa Cruz province (50-52°S). Preliminary results from 15 permanent lakes in the study area (Echazú et al., 2009; Ramón Mercau et al., 2010) suggested that biodiversity and distribution of the taxa, are associated with some physical-chemical parameters measured in the respective environments. The chironomid assemblage consisted of a total of 31 different sub-fossil taxa belonging to sub-families Chironominae, Tanypodinae, Orthocladiinae, and Diamesinae. Orthocladiinae was the most diverse and abundant (72.8%). The second sub-family in importance was Chironominae (25.3 %), followed by

Tanypodinae (1.5 %). The sub-family Diamesinae had a very low relative abundance (0.4 %). Some of the most representative quironomids found in the study area were Cricotopus sp., Limnophyes sp., Smittia sp., Labrundinia sp., Polypedilum sp. and Parachironomus sp.

Ostracods

Ostracods were found in five samples. Additionally, another six samples held some isolated ostracod valves which were deemed too scarse to be included in the database. Abundance and diversity of assemblages are unexpectedly low. Among the 11 recovered ostracod taxa, 9 taxa were identified down to the species level and one to the genus level, whereas one taxon comprises indeterminate juveniles of Candoninae. The ostracod assemblage consists partly of cosmopolitan or widely distributed species like Potamocypris smaradigma, Isocypris beauchampi and Penthesilenula incae. The second group of ostracods are typical species described previously from northern Patagonia (cf. Schwalb et al., 2002; Cusminsky et al., 2005) like Limnocythere patagonica, Limnocythere rionegroensis, Eucypris virgata, Eucypris cecryphalium, Eucypris fontana and Ilyocypris ramirezi. The ecological range for each species was defined according to the environmental parameters at the sampling site, when the species occurred. Anyway, these data do not reflect the species tolerance as the only a limited gradient is covered by the studied waters. L. patagonica was found in permanent lakes with Na-Ca-Mg, bicarbonate-dominated waters. In contrast, L. rionegroensis inhabits mainly ephemeral waterbodies with Cl/SO4-HCO3, sodium-dominated waters. In turn, E. virgata, E. cecryphalium and E. fontana characterize Na-Ca-Mg, bicarbonate-dominated waters; the latter species can also be found in Na-HCO3 waters. While E. virgata and E. fontana have been found both in permanent and ephemeral habitats, E. cecryphalium has been found so far only in permanent lakes and - with very low abundance - in a little stream (Schwalb et al., 2002; Cusminsky et al., 2005). I. ramirezi have been found in Na-Ca-Mg/HCO3 waters. This species had been proposed as an indicator of running waters. However, in this study it was found alive in permanent lakes with no creeks or seeps near the sampling site. Therefore, some considerations on the ecological preferences of I. ramirezi might need to be revisited. Finally, K. megapodus was found in Northern Patagonia in chlorurated and/or sulphated, sodium dominated waters. In this study K. megapodus was found in Na-Ca-Mg, bicarbonate dominated waters. This species might therefore be considered as (slightly) tolerant of saline waters, but characteristic of alkaline waters. A further dependence of species distribution on the water body type was not observed.

Diatoms

Diatom analysis of surface sediment samples collected in 2009 was completed and samples collected in 2010 are still under study. 200 species of diatoms have been identified so far, of which 17 taxa are new records for Argentina and 29 are new to the province of Santa Cruz. The genera best represented in terms of number of species were Navicula (60), Nitzschia (33) Gomphonema (25), and Pinnularia (17). Species of the genera Staurosira, Staurosirella, Pseudostaurosira and Stauroforma, grouped as "small fragilariod", were represented by small individuals <15 μm long, very difficult to differentiate using only light microscopy. Some species are still being studied; mainly species of the genera Navicula sensu lato, Nitzschia and Fallacia, probably are new to science. Some species apparently endemic to Patagonia such as Stauroneis nebulosa and Veigaludwigia willeri have also been identified, while Cyclotella ocellata could be considered as an invader species coming from the Northern Hemisphere.
Preliminary statistical analysis suggests that the dissolved oxygen and the electric conductivity would be the variables that best explain the distribution of most abundant diatoms (> 3%) in the studied

environments. Some taxa, mainly Navicula, Gomphonema and Nitzschia spp., could not be identified at specific level and will be the subject of further study. Diatom species identification can be often difficult due to the scarcity of literature on South America phycofloras, and researchers have to compare their materials with those of the Northern Hemisphere. This can lead to misinterpretations because species may have morphological similarities but different ecological requirements. Our results confirm the importance of continuing stepping up surveys of the diversity of phycoflora of Patagonia.

Charcoal

A high content of charred particles, indicative of regional fire activity, were found in steppe environments. Charcoal concentrations tend to decrease to the west, towards ecotone and the subantarctic forest. According to fire activity recorded between 2000 and 2007, the number of fire events in the steppe was higher and associated with human intervention. This trend in the concentration of charcoal macro remains might relate to the intensity of the westerly winds. Pollen analysis is still in progress

3. Future work

- Quantitative reconstruction of the environmental/climate history of the area using the transfer functions to the fossil record. The different training set in progress will allow the development of transfer functions for Southern Patagonia to be applied to the paleoclimate and paleoenvironment reconstruction of the last 100,000 years, which is the main objective of ICDP-PAST (Potrok Aike Maar Lake Sediments Archive Drilling Project) which is part of this research group.
- Comparison of the results between the different biological indicators (ostracods, diatoms, pollen, etc.). The multiproxy comparison will add strength and robustness to the obtained results.
- Calibrating the relationship between the characteristics of modern fire events (location, seasonality, size, frequency, intensity and severity) and macroscopic charcoal particles deposition.

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Site	Diatoms											Chironomids					Ostracods					Charcoal particles		
	Small frag.	Ach. min.	Ach. mod.	Psa. sub.	Enc. mic.	Cyc. oce.	Fra. cap.	Nit. Pa.l	Nit. sp 38	Nav. sp 59	Dip. chi.	Pol.	Cri.	Tan.	Lim.	Smi.	Pen. inc.	Lim. pat.	Ily. ram.	Euc. fon.	Euc. vir.	>250 μ	>125μ	>63μ
LAGU	0	0	0	0	0	0	0	8	0	13	0	0	66	0	11	9	0	0	0	0	0	0	17	96
LALT	0	8	19	0	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	1	0	53	68	1	8	283
LAZU	25	0	0	0	0	33	0	0	0	0	0	0	0	83	0	17	0	0	0	0	0	0	0	3
LAZUII	0	21	19	0	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	0	0	3
LBAN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	14
LCACI	aip.	aip	aip	aip	aip	aip	aip	aip	Aip	aip	aip	aip	aip	aip	aip	aip	0	0	0	0	0	0	8	41
LCACII	40	10	6	0	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	2	14	79
LCAP	aip	aip	aip	aip	aip	aip	aip	aip	Aip	aip	aip	aip	aip	aip	aip	aip	0	0	0	0	0	0	0	1
LCFI	15	0	0	0	0	0	0	0	0	0	0	9	32	23	14	11	8	9	51	13	3	1	11	31
LCFII	9	0	0	0	0	12	7	0	0	0	0	3	26	10	21	5	0	0	0	0	0	0	26	75
LCON	33	0	0	0	0	0	0	0	0	0	0	0	14	0	14	50	0	0	0	0	0	0	2	10
LDES	7	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	20
LTOR	6	0	0	0	9	0	0	0	0	0	10	0	0	0	0	0	14	53	3	6	0	0	4	15
LERN	8	0	0	0	9	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	0	1	3
LESP	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	59
LHIJ	aip	aip	aip	aip	aip	aip	aip	aip	Aip	aip	aip	aip	aip	aip	aip	aip	0	0	0	0	0	1	4	26
LHUE	0	0	0	0	0	0	0	0	0	0	0	0	30	0	35	4	0	0	0	0	0	1	34	109
LOLI	0	16	9	0	14	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	0	1	28
LOLII	8	24	10	0	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	0	0	20
LMAD	0	0	0	11	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	0	0	0
LMEL	0	0	0	0	0	0	9	0	0	0	0	17	83	0	0	0	0	0	0	0	0	0	2	60
LNIE	12	12	0	11	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	2	9	52
LPAJ	nd	nd	nd	nd	nd	nd	nd	nd	Nd	nd	nd	aip	aip	aip	aip	aip	100	0	0	0	0	0	1	15
LPTA	14	0	0	0	0	0	0	0	0	0	0	7	29	0	2	4	0	0	0	0	0	0	6	50
LRIN	20	0	0	0	13	0	0	31	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	0	9	28
LROC	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	22
LSAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	57
LSAR	0	0	0	0	0	0	0	0	30	0	0	0	0	0	67	33	0	0	0	0	0	0	22	211
LRES	0	0	0	0	0	0	0	0	0	0	0	20	35	12	10	6	0	0	0	0	0	0	0	0
LVER	0	10	23	14	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	0	11	70
LSOSI	20	6	0	0	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	88	0	0	0	0	5	35	175
LSOSII	64	0	0	0	0	0	0	0	0	0	0	aip	aip	aip	aip	aip	0	0	0	0	0	13	41	149

Figure 2 Relative abundance of most important bioproxies present in each sample. Abbreviations stand for: aip = analysis in progress; nd = no data; Small frag. = Small fragilarioids; Ach. min. = Achnanthidium minutissimum; Ach. mod. = Achnanthidium modestiforme; Psa. sub. = Psammothidium subatomoides; Enc. mic. = Encyonopsis microcephala; Cyc. oce. = Cyclotella ocellata; Fra. cap. = Fragilaria capuchina; Nit. pal. = Nitzschia palea; Nit. = Nitzschia; Nav. = Navicula; Dip. chi. = Diploneis chilensis; Pol. = Polypedilum; Cri. = Cricotopus; Tan. = Tantytarsini; Lim. = Limnophyes; Smi. = Smittia; Pen, inc. = Penthesilenula incae; Lim. pat. = Limnocythere patagonica; Ily. ram. = Ilyocypris ramirezi; Euc. fon. = Eucypris fontana; Euc. vir. = Eucypris virgata

LATE GLACIAL ISOTOPE RECORDS OF ENDOGENIC CARBONATES FROM LAGUNA POTROK AIKE

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The 106 m long composite profile 5022-2CP from the ICDP site Laguna Potrok Aike offers a unique possibility to reconstruct past hydrological and west wind variability during the last 54,000 years (according to age model V.1) in the Patagonian steppe. Oxygen isotopes of endogenically precipitated carbonates commonly serve as a proxy for water temperatures and lake water isotopic composition. The carbon ($\delta^{13}C_{carb}$) and oxygen ($\delta^{18}O_{carb}$) isotope records of 5022-2CP show concurrent variations in the Holocene and the Late Glacial, a typical pattern for closed basins. From the present to the early Mid-Holocene, $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ values both increase, suggesting lower lake levels than today in the early Mid-Holocene in accordance with other proxies. Prior to that period, $\delta^{18}O_{carb}$ values decrease towards the Late Glacial. Presently, more detailed isotope studies of Late Glacial samples are carried out on samples from the sediment core PTA03/12 recovered during the SALSA project which has a higher sampling resolution compared to 5022-2CP. These high-resolution studies clearly show a $\delta^{18}O_{carb}$ increase within the Late Glacial which occurs exactly during the Younger Dryas chronozone (YD). The combination of these results with $\delta^{18}O$ values of lake water derived from $\delta^{18}O$ values of aquatic moss cellulose from the same time interval (Fig. 1) allows estimations of Late Glacial water temperature changes. Accordingly, water temperatures were several degrees colder during the YD than before and thereafter. Whether enhanced mixing of the lake or climatic cooling caused these lower water temperatures is the object of further multi-proxy studies.

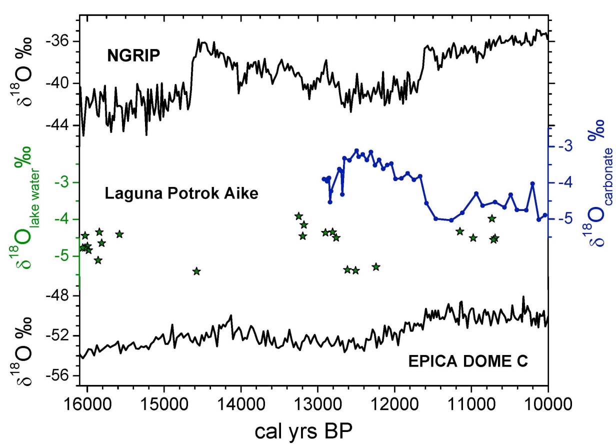

Fig. 1 Late Glacial $\delta^{18}O$ records from Laguna Potrok Aike compared to ice-core $\delta^{18}O$ records from Greenland (NGRIP, Rasmussen et al., 2006) and Antarctica (EPICA DOME C, Stenni et al., 2003)

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CLAY MINERAL CHANGES AND U AND TH SERIES ISOTOPES IN EARLY DIAGENETIC AND AUTHIGENIC MINERALS OF THE POTROK AIKE LAKE SEQUENCE

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By studying the ~ 100 m-long sequence spans part of the last glacial period and the Holocene, our specific objectives in the framework of the PASADO project were: i) the documenting of the chronology of the sequence based on U-series measurements in early diagenetic minerals, such as vivianite, and ii) the recovery of information about hydroclimatic conditions in surrounding soils from semi-quantitative XRay analysis of clay mineral assemblages. The selection of vivianite for the setting of U-series ages was based on studies of Baikal Lake reporting significant amounts of uranium in these minerals. Unfortunately, the vivianite grains from the Potrok Aike core did not experienced any significant U-fixation during their growth. Controls on similar material from other lacustrine sequences under sub-arctic conditions confirm that the authigenic uranium found in vivianite is not significant and definitely not enough for the dating of an early diagenetic U-uptake phase. We hypothesize that the low productivity of periglacial environments results in low organic carbon fluxes, thus weak redox gradients at the water sediment interface and reduced U-fluxes into the sediment. XRay mineralogical investigations have been performed, at high resolution in the upper core section (5m) and with a lower resolution below. Aside the major transition between the Holocene, characterized by high authigenic calcite fluxes, and the underlying glacial section, the core mineralogy shows an overall low variability, suggesting minor changes in detrital sediment sources. In addition, clay minerals are not much abundant and semi-quantitative estimates of changes in their relative abundance, if any, could not be deciphered based on the present data set. Larger samples will be required to document further potential variability in clay supplies relating to soil conditions in the catchment basins and/or long distance wind supplies.

ORIGIN OF SEDIMENTARY CARBONATES FROM LAGUNA POTROK AIKE – A MULTIPLE STABLE ISOTOPE APPROACH

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Oxygen isotope ratios of carbonates are frequently used for paleo-temperature and hydrological reconstructions. The endorheic lake Laguna Potrok Aike in the Patagonian steppe is an ideal site for this kind of investigation. However, in Laguna Potrok Aike, carbonates occur as different $CaCO_3$ polymorphs. Aragonitic shells of *Limnea* sp. are only sporadically present in sediment cores and therefore not suitable for continuous paleoclimate reconstruction. In contrast, calcite is frequently present as µm-sized crystals in the Holocene sediment record. As a third carbonate mineral ikaite, the calcium-carbonate hexahydrate ($CaCO_3$ □ 6 H_2O) was found in the austral winter 2008 in the trophogenic zone of the lake. This metastable mineral phase is known to precipitate only at temperatures close to the freezing point. At temperatures above *ca.* 4°C and/or after air exposure the modern ikaite disintegrated within minutes to hours into highly porous, polycrystalline calcite pseudomorphs. Their < 10 μm-sized calcite crystals were weakly bound and disintegrated in a whitish powder at the lightest touch. Then they were microscopically indistinguishable from the calcite of the sediment cores.

For paleoclimatic reconstructions, it is important to know the origin of the sedimentary carbonates, as the oxygen isotopic fractionation factors between the different carbonate phases and precipitation temperature can be different. For the first time, the oxygen and calcium isotope-fractionation factors for the freshwater-ikaite system were determined directly in natural samples. Preliminary results show that $\delta^{44/40}Ca$, $\delta^{13}C$, and $\delta^{18}O$ values allow separating ikaite-derived calcite from sedimentary calcite. These first results will be confirmed by additional analyses of surface sediments and modern ikaites as well as comparisons with the isotope records of the Site 2 composite profile 5022-2CP obtained during the ICDP expedition 5022 (project PASADO) from Laguna Potrok Aike, Argentina. The Holocene sediment sequence of Laguna Potrok Aike contains sufficient carbonate for stable isotope analyses. However, only few data are available throughout the Glacial due to generally low carbonate contents during this period.

The study of the isotopic composition of bulk carbonates is hampered by the release of CO_2 from organic matter during sample preparation for isotope analysis. During isotope analyses of bulk samples it turned out that the commonly used treatments to remove organic matter prior to isotope analysis are not feasible for the sediments from Laguna Potrok Aike. Therefore, artificial mixtures of various organic compounds with a calcite standard were used to determine thresholds for reliable isotope values from non-treated samples. These experiments showed that carbonate-standard isotope values were reproducible to a minimum inorganic-carbon-to-organic-carbon ratio (TIC/TOC) of *ca*. 0.05. Thus, carbonate isotope analyses of bulk sediment from 5022-2CP were and will be restricted to samples with a TIC/TOC ratio above this threshold.

INTRA- AND INTER-SITE CORE CORRELATION FOR PASADO DEEP DRILLING SITES 5022-1 AND 5022-2 FROM LAGUNA POTROK AIKE, ARGENTINA

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For the comparability of results obtained in the multidisciplinary studies conducted on the sediment cores taken from Laguna Potrok Aike during the PASADO deep drilling campaign (ICDP expedition 5022) in autumn 2008, a precise correlation of cores is of vital importance. This involves the correlation of all cores drilled at every site, but also the correlation between the two sites that were drilled 750 m apart from each other. Such a correlation is especially critical for the transfer of the chronology that was determined (i) for the composite profile of Site 2 (5022-2CP) in the case of AMS ^{14}C and (ii) on one hole of Site 1 (5022-1D) in the case of OSL dates. In this contribution, we therefore try to visualise both the intra-site and the inter-site correlations.

For the correlation of cores from Site 2, all sections from holes 5022-2A, -2B and -2C were put side by side in the GEOPOLAR hallway. The position of the cores was then shifted until a visual correlation became obvious. In cases where a macroscopic correlation based on sedimentary structures was impossible, additional information from magnetic susceptibility and XRF core scanning was used to help finding similarities between cores from different holes. To establish a composite profile, levels where sampling should switch from one core section to the same level in a parallel core section were marked with a white plastic label and noted down in an Excel spreadsheet. This resulted in an initial reference profile that consisted of 99 core sections. During sampling of the cores, this spreadsheet was continuously updated according to actually sampled levels. Using the detailed documentation produced for each of the 5089 sample depths (35,623 subsamples), a composite profile for Site 2 was constructed. This file was distributed among all PASADO science team members. The current version (dating from November 21, 2010) of this file is called "PASADO_Site2_CompositeProfile_UV(4).xls" and contains a column with first age estimates.

For Site 1, the correlation of the four different holes drilled at this site was done in a similar manner, with the difference that cores were not inspected visually (macroscopically). Instead, correlation levels were identified by analysis of core photographs that have been taken with the smart CIS system shortly after cores have been split in two halves. Core section photographs were arranged run by run, i.e. all sections that constitute one core run were stitched together without gaps or considering the gaps as they were documented in the platform journals. Between core runs of 2.92 m length, gaps of 8 cm were allowed which represent the length of the core catcher if no different lengths were stated in the platform journals. Thus, runs of the four different holes from Site 1 were put side by side using the software Adobe Illustrator. Correlation levels were identified, marked and noted down in an Excel spreadsheet. The final correlation was controlled by magnetic susceptibility data from all cores of Site 1. This file (dating from January 05, 2011) is currently available as "PASADO Reference profile 5022-1.xls".

During this process, several features that are not immediately obvious from the inspection of only a single site or a single hole became apparent. Examples of these are:

1) Although the cores of Site 1 were drilled with a maximum lateral distance of 32 m, differences concerning the sediment depth of matchable sediment layers are quite large.
2) In the uppermost part of the cores from Site 1, between the Mt. Burney tephra (ca. 8600 cal. BP) and the Reclus tephra (ca. 15,600 cal. BP), an unequivocal correlation across all 4 cores was not possible, which indicates the occurrence of re-deposition in this sediment section
3) The thicknesses of some layers identified as re-deposited sediments vary considerably between holes whereas other layers do not show any noteworthy lateral variation in thickness.
4) For some laminated sections that feature an undisturbed appearance it is not immediately obvious that they are part of a thick package of re-deposited sediment. This is detectable only by inter-site comparison of cores.
5) Core 5022-1D is heavily disturbed by the on-site sampling procedure for deep-biosphere samples. This procedure included cutting of windows of approx. 4 cm^2 in the middle of each core section. Oxidation phenomena originating from these windows in most cases affect the entire core section.
6) A comparison of the composite profile of Site 2 with that of Site 1 located 750 further to the north in the central deep basin reveals significant differences concerning the occurrence of mass movement deposits. However, the maximum basal depth below lake floor that was reached during drilling is almost the same for both sites.

Because of the length of more than 100 m for the entire sediment core sequence at every site studied and the need to show several cores parallel to each other in the same picture, we will visualize the described correlation stepwise by scrolling through Adobe Illustrator pictures. Each of these pictures will show an approximately 20 m long detail of all core sections belonging to Site 1. On these, correlation levels and parts that belong to the composite profile of Site 1 (5022-1CP) will be indicated.

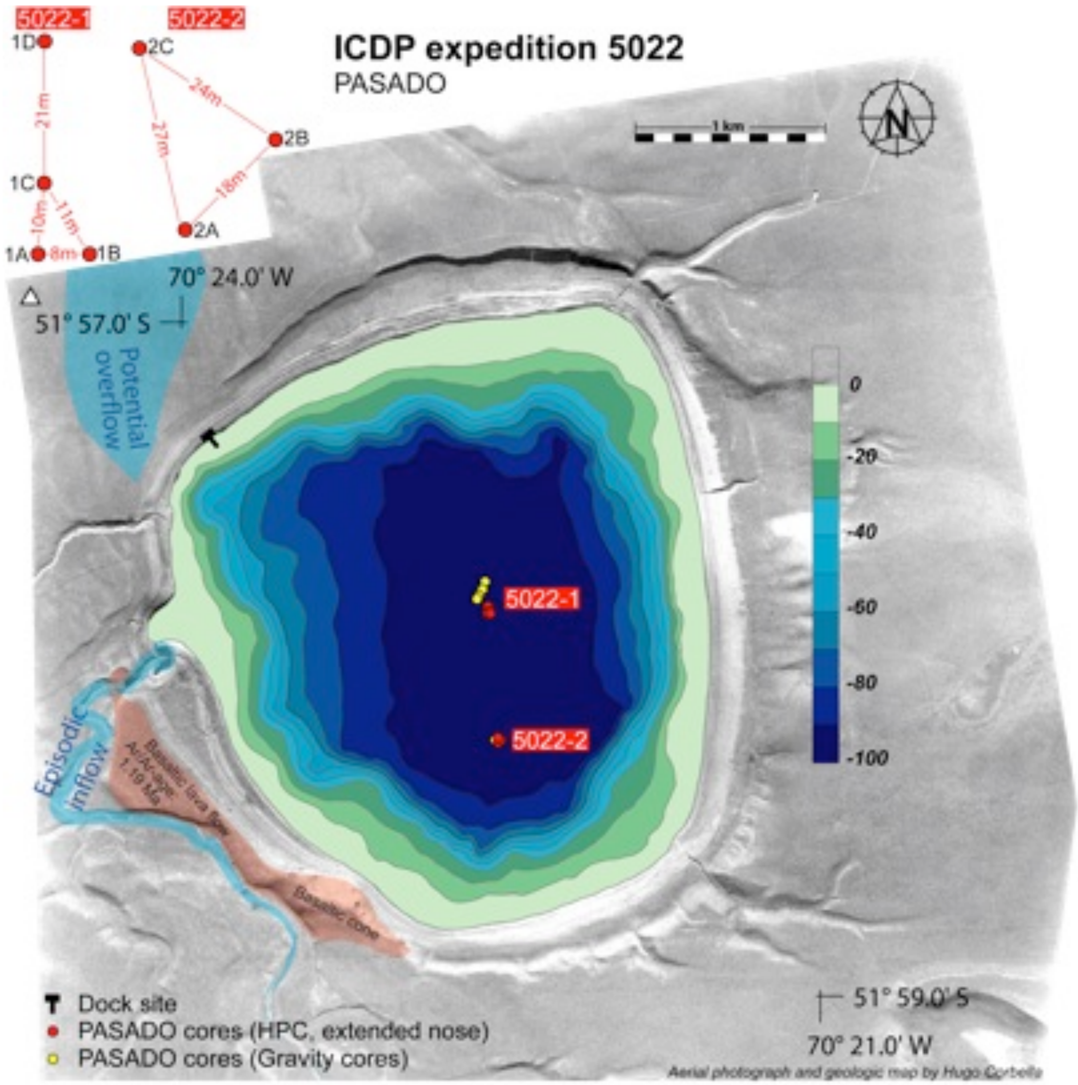

Figure 1: Bathymetric map of Laguna Potrok Aike superimposed on an aerial photograph. PASADO drill sites are indicated by red and yellow dots.

ATMOSPHERIC SIMULATIONS OF PRESENT AND PAST CLIMATE OVER SOUTHERN SOUTH AMERICA

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This study investigates the effects of mountain ranges on the simulated climate of the last glacial maximum over Southern South America through the use of the PSU/NCAR MM5 mesoscale model (MM) nested within the Princeton GFDL global atmosphere-ocean model (GCM). This approach is taken to obtain climate data with much higher spatial resolution, which is important in regions like Patagonia, having steep mountain ranges which generate large amounts of orographic precipitation. A comparison between the last glacial maximum and modern simulations provides an estimate of the magnitude of climate change in particular geographical regions between glacial and interglacial states, while the mid-Holocene simulations provide information on the transition between these two states. The outer domain of the regional model covers Southern South America and much of the Southern Ocean upstream of Lago Petrok Aike and the Andes mountains and the two-way nesting capability of the model currently acquires a 6 kilometre spatial resolution with its inner domain. A simple energy balance model comparing simulations of present and past climate indicates that the elevation of equilibrium net snow accumulation in the Southern Andes is lower during the last glacial maximum, caused by decreases in continental temperature and increased westerly orographic forcing. Theses changes are shown to be linked with consistent increases in cyclonic rotation of the lower level winds over Southern South America. This results in a substantial expansion of the area receiving net snow accumulation, which encompasses a much larger area in Eastern mountain ranges during the last glacial maximum. Although an expansion is evident, last glacial maximum equilibrium net snow accumulation elevations do not approach lake elevations and mean surface temperatures at the lake remain above freezing.

LONG-TERM TRENDS OF FIRE ACTIVITY BASED ON RECORDS OF MACROSCOPIC CHARCOAL REMAINS FROM LAGUNA POTROK AIKE (51°58□ S, 70°23□ W), SANTA CRUZ, ARGENTINA.

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Paleoecological studies about the relationship among fire events, vegetation changes and human activity at multi-millennial scales showed the relevance of fire as a process operating in a wide latitudinal range of Patagonia (Bianchi, 2007; Heusser, 2003; Huber et al., 2004; Markgraf and Huber, 2010; Markgraf et al., 2009; Moreno et al., 2009; Whitlock et al, 2007; Wille et al., 2007; Wille and Schäbitz, 2008).

Most of these records are representatives of temperate forest and forest-steppe transition environments. Hence, the charcoal analysis from records of Laguna Potrok Aike would give the opportunity to contrast regional trends of fire previously proposed in forest ecosystem (Whitlock et al., 2007) with the steppe. In the Laguna Potrok Aike area a grass steppe of *Festuca gracillima* predominates (Fig. 1; Oliva et al., 2001).

The aim of the current research is to reconstruct the fire history around Laguna Potrok Aike based on macroscopic charcoal analysis. Samples were obtained from cores within PASADO project (Potrok Aike Maar Lake Sediment Archive Drilling Project). To determine sections (periods) of major interest for future high resolution analyses, a preliminary survey of the core 5022-2CP with a sample resolution of 16cm is in progress. A continuous charcoal analysis will allow identify several characteristics of fires regimes such as frequency, intensity and severity.

In the present abstract we display preliminary trends of fire activity of the last ~15,500 cal yr BP, enlarging the upper 1802cm of this core. This survey involved the analysis of 115 samples and still continues to complete the entire profile analysis.

The specific aims are:

- To analyze the content of charcoal particles >125µ with a 16cm resolution of the core 5022-2CP.
- To determine periods of major interest in the core 5022-2CP for future high resolution analyses (every centimetre) in order to reconstruct the local fire regime's history (fire frequency, intensity and severity).

Method

A method to reconstruct local fire events analyzing macroscopic charcoal content (>125*µ*) is performed (Whitlock and Larsen, 2001). An amount of 1cc of sediment *per* sample is soaked in sodium hexametaphosphate (5%) overnight. Samples are washed through a 125*µ* mesh sieve. A 125*µ* mesh size is selected because it is assumed that particles greater than this size are not dispersed distant from the source area, providing information about local fire history. Counting is performed under stereoscopic microscope. Grass particles are differentiated from the other types of charred particles. The fuel composition analysis offer information about the type of vegetation that has been burnt in relation to the intensity (surface and crown fires) and severity of the fire events.

Chronology is based on the correlation of the pre-existing composite profile (SALSA, Haberzettl et al. 2007) with the upper 1802cm of the core 5022-2CP (Kliem et al., in prep).

Preliminary results

The 5022-2CP charcoal record indicates changes in the amount and type of burnt particles since the Late-Glacial to the present (Fig. 2):

- Before 12,000 cal yr BP (Late Glacial – early Holocene) the content of macroscopic charcoal is low, increasing up from this age to about 8000 cal yr BP.
- Around 12,000 cal yr BP (early Holocene) charred grass content is mostly higher than present, whereas around 8500 cal yr BP wood charcoal content are mostly higher than present. This last tendency occurs together with high values of charred grass.
- After 8000 cal yr BP and until 3000 yr cal BP (mid Holocene) the major trend indicates low charcoal levels.
- From 3000 cal yr BP (late Holocene) the number of grass charred particles raises and remains with these values to the top of the sequence.

These trends suggest changes in fire regime around the Laguna Potrok Aike area, during the Late Glacial, early, mid and late Holocene. On the base of these results, two periods of major interest were selected to increase the resolution of the analysis. One of them covers the period 9000 – 7500 cal yr BP and the second encompasses the last 3000 cal yr BP.

Future steps

-To continue the fire history reconstruction of the Southern tip of South America, based on high resolution macroscopic charcoal analyses of the 5022-2CP core.

-To compare macroscopic charcoal data with pollen trends of the same periods in order to achieve a complete reconstruction of past fire regimes.

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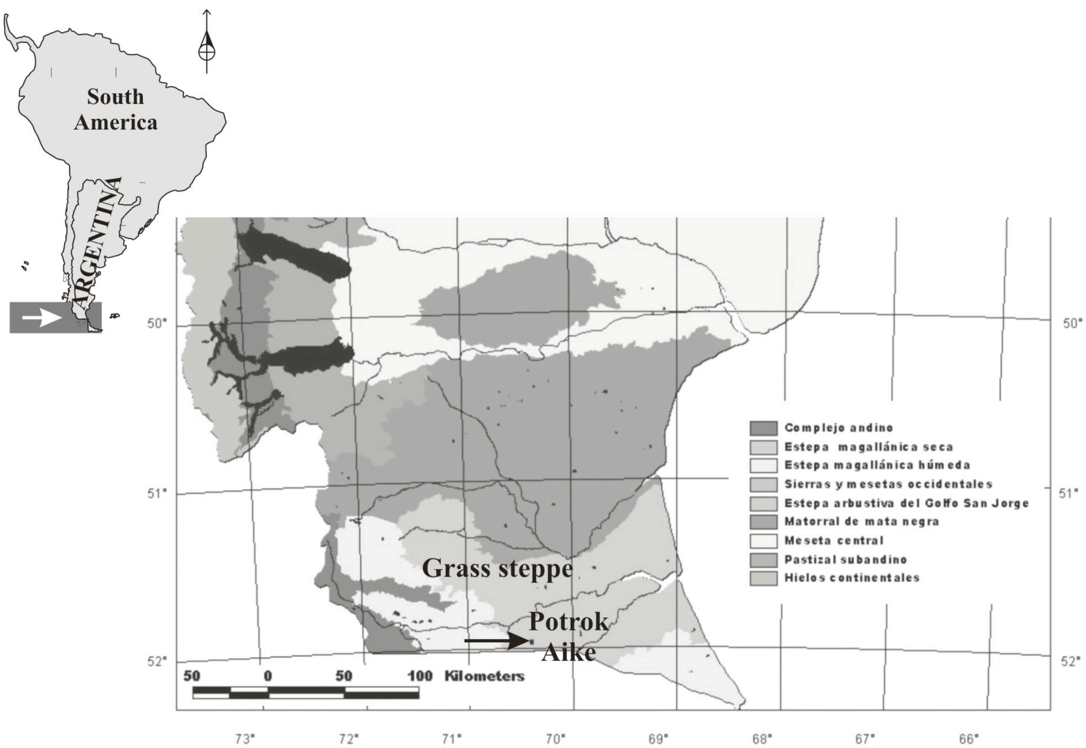

Fig. 1: Location map of the research area. Main vegetation units after Gonzalez and Rial (2004).

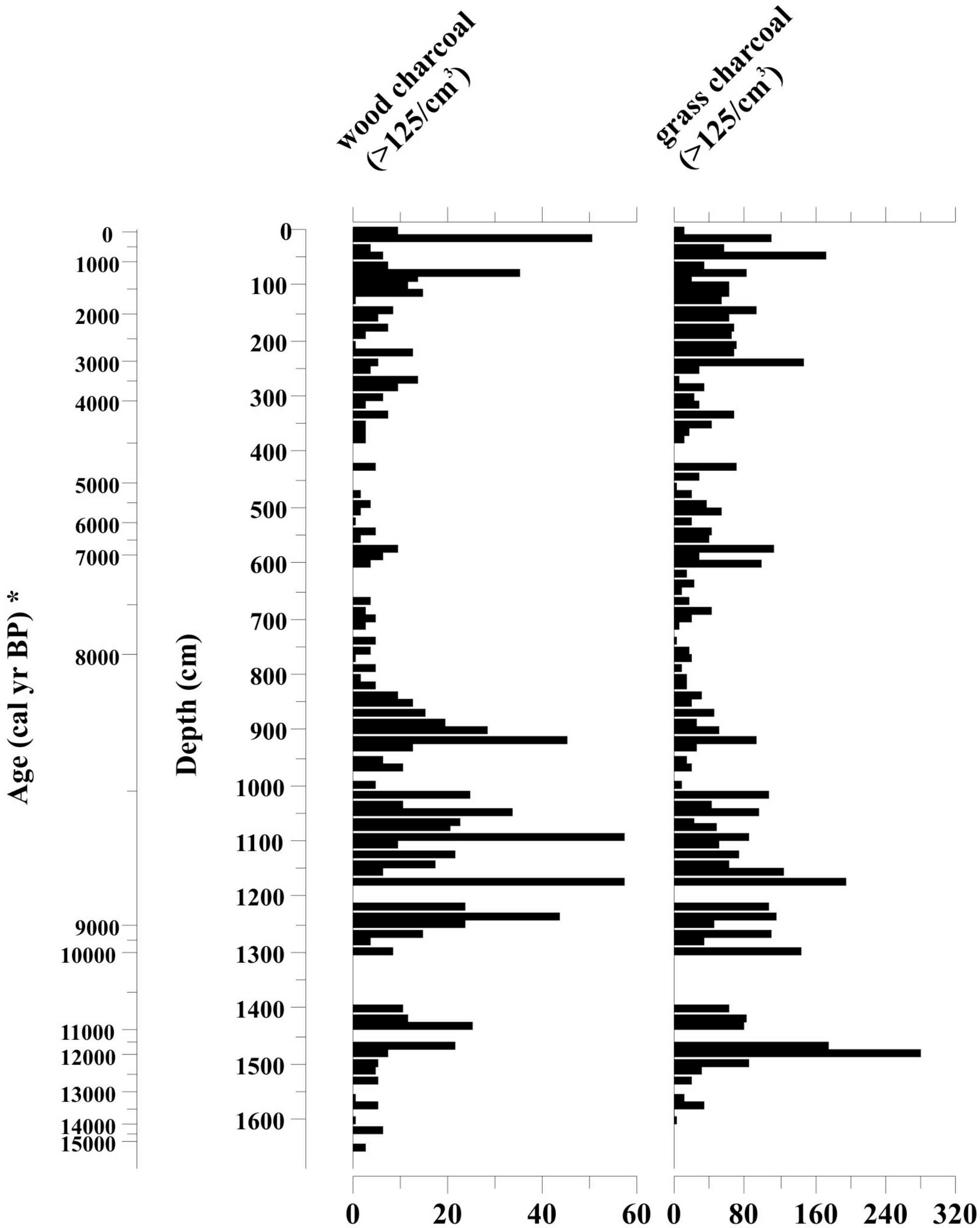

Fig. 2: Diagram of wood and grass charcoal concentration of 5022-2CP core.
*** Preliminary age model (Kliem et al., in prep.).**

THE DIATOM RECORD OF LAGUNA POTROK AIKE, ARGENTINA

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The sediment record from Laguna Potrok Aike, obtained in the framework of the ICDP-sponsored project PASADO (Potrok Aike Maar Lake Sediment Archive Drilling Program), was sampled for diatom analysis in order to provide a continuous record of hydrological and climatic changes since the Late Pleistocene. Diatoms are widely used to characterize and often quantify the impact of past environmental changes in aquatic systems. We use variations in diatom concentration and in their taxonomical assemblages, blended with other proxies, to track these changes.

Diatomological analysis was performed on a set of 94 samples from 5022-1D (Fig.1), a 97.3 m long sedimentary core from the central part of the lake covering approximately the last 50 kyrs. This relatively low-resolution study was carried out in order to obtain a first complete diatom record, determine the dominant taxonomical assemblages and tackle the most interesting sections to attain higher temporal resolution. Sediments from the top part of composite core 5022-2CP were analyzed at higher resolution (sampling resolution ranging from16 to 32 cm). More than 216 species, varieties and forms have been found so far in the sediment record (including several endemic species and most probably some new ones). The quantitative analysis reveals diatom abundances ranging from nearly none to 460 million valves per gram of dry sediment, with substantial fluctuations along the record. The results of approximately the top 12 m of the analysis on both cores are consistent with previous results on a shorter core from the former SALSA project covering the last 16’000 cal yrs BP (Wille et al. 2007). The top part of the record is dominated by *Cyclotella agassizensis*, along with *Thalassiosira patagonica*, althought these indicators of more brackish conditions are rare or not found at all in deeper sediments. The appearance of *Cyclostephanos patagonicus* in this previous record at approximately 15’550 cal yrs BP allows us a preliminary pinpoint of this age in the new cores. Another age we could infer from that shorter core is the 8’600 cal yr BP corresponding to the peak in *Thalassiosira patagonica*, which in 5022-1D occurs at approximately 10 m. The new results in the middle and lower part of the record will shed light onto the glacial conditions in this lake, yet undefined. Remarkable concentration peaks corresponding to diatom blooms, at 75 m, 45 m, 25 m, 15 m and 10 m most probably reflect variations in the nutrient availability in the system. The causes for these changes in nutrients supply will be inferred from more detailed analyses and validated with other proxies. Moreover, the occurrence of *C. patagonicus* at 65 m witnesses of a freshwater input, in a period which, according to the sedimentology, the lake was dried out. Indeed, variations in diatom abundance and the species distribution could point toward lake level variations and periods of ice-cover in the lake. Nevertheless, a correlation with other proxies is necessary to further develop these hypotheses.

The multi-proxy approach of the PASADO project, and its combination with the modern training set for Patagonia (Proyecto Interdisciplinario Patagonia Austral, PIPA), is already providing unique paleoecological information for the Southern Hemisphere.

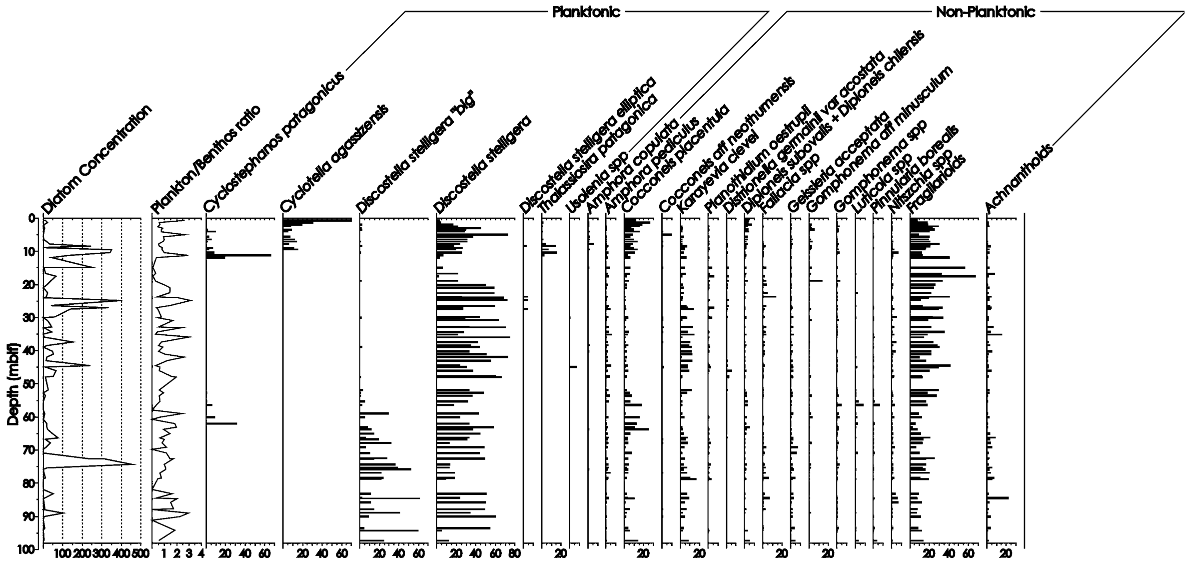

Fig.1: Diatom diagram of core PTA-1D (only dominant taxa are shown)

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PALEOCLIMATE RECONSTRUCTIONS BASED ON THE POLLEN RECORD FROM LAGUNA POTROK AIKE

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Laguna Potrok Aike located in southern Argentina is one of the very few locations that are suited to reconstruct the paleoenvironmental and climatic history of southern Patagonia. In the framework of the multinational ICDP deep drilling project PASADO several long sediment cores to a composite depth of more than 100 m were obtained. Here we present results of pollen analyses from sediment material of the core catcher and lower parts of the composite profile on the base of the first age model covering roughly the last 50 ka BP. Pollen spectra with a spatial resolution of three meters show that Laguna Potrok Aike was always surrounded by Patagonian Steppe vegetation. However, the species composition underwent some marked proportional changes through time. The uppermost pollen spectra from the core catcher samples show changing but high contribution of Andean forest and charcoal particles as it can be expected for Holocene times and the ending last glacial. The middle part shows no or very low forest signals and relatively high amounts of pollen from steppe plants indicating cold and dry full glacial conditions. The lowermost samples are characterized by a significantly different species composition as steppe plants like Asteraceae, Caryophyllaceae, Ericaceae and *Ephedra* became more frequent. In combination with higher charcoal amounts and an algal species composition comparable to Holocene times we suggest that conditions during the formation of sediments at the base of the PASADO record were more humid and/or warmer causing a higher fuel availability for charcoal production compared to full glacial times. Furthermore, estimated precipitation amounts based on a transfer function between pollen and climate values are presented for these analyzed PASADO-pollen samples.

TRACKING MICROBIAL INFLUENCE ON NUTRIENT CYCLING AND EARLY DIAGENESIS IN LAGUNA POTROK AIKE SEDIMENTS SINCE THE LATE PLEISTOCENE

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Diagenetic processes attributable to microbial activity, such as organic matter mineralization (Fenchell, 1999) and carbonate lithification (Castanier et al., 1999) are today relatively well understood. Conversely, there are still many uncertainties concerning their impact on older sediments and extreme environments. Results from recent ODP and IODP drilling campaigns have shown a somehow unexpected large distribution and diversity of microbes in marine sediments while discovering their enhanced abilities to survive in the subsurface often under extreme conditions (Teske, 2005).

The same kind of studies are still missing in lacustrine sediments where these investigations have been mainly focused on either the water column and/or very shallow sediments. Modern lakes are, however, ideal systems to study early diagenetic processes using a combined physical, chemical and biological approach. Previous work has demonstrated that the microbial colonization of lacustrine substrates can be highly dependent on the climate and/or the hydrological regime (Nelson et al., 2007). However, subsequent microbial activity within the sediments can highly modify the record and thus its paleoclimatic interpretation, even if compared to terrestrial and/or algal sources the microbial biomass only account for a minimal portion of the organic primary input in lacustrine sediments (Bastviken et al., 2003). Hence, a geomicrobiological study of these sediments can provide unique information concerning the nature and extent of the microbial inprint on these paleoenvironmental archives.

In autumn 2008, the PASADO drilling project provided the unique opportunity to explore and apply recent geomicrobiological developments to the lacustrine realm. For the first time in an ICDP–sponsored campaign, a hydraulic core was entirely dedicated to a geomicrobiological study. Following a specially designed strategy (Vuillemin et al., 2010), sixty windows were opened along the 100 meters of the core liner to allow a sterile sampling of undisturbed lacustrine sediments, thereby preserving their initial signatures to further track present and perhaps past microbial activities.

The ongoing lacustrine multiproxy study of the recovered sediments includes a broad range of geochemical and microbiological techniques. Pore waters were sampled using microrhizons and analyzed to identify shifts in types of metabolism linked to present oxidants (DeLong, 2004). Changes in $d^{13}C$ and $d^{15}N$ of bulk sediment indicate variations in organic matter sources that might have been partially overprinted by microbial activity (Lehmann et al., 2002). Methane headspace gas chromatography was used to define the volume of gas produced by methanogens within the sediments (Parkes, 1999). I*n situ* measurements of ATP (adenosine 5'-triphosphate) were taken as indication of living organisms within the sediments that were confirmed with DAPI (4',6-diamidino-2-phenylindole) cell counting to further quantify the amount of recoverable DNA (Bird et al., 2001). DGGE (16S rDNA based molecular fingerprinting technique) allowed to qualify the genetic diversity of present colonies in the Bacteria (Webster et al., 2003; Zhao et al., 2008) and Archaea domains and to assess the diversity of methanogens as well (Ye et al., 2009).

Figure 1 shows the variations of main nutrients as well as oxidants availability through depth.

The C/N ratio is indicative of variations in allochthonous and autochthonous sources of organic matter and correlates well with previously proposed lake level changes (Anselmetti et al., 2009). Pore water phosphate contents (Fig. 1) suggest that the nutrient assimilation ratio (C/N/P=106:16:1) rules the primary development of bacteria (Arrigo, 2005). Phosphorus is the first nutrient to be depleted, thus its content is limiting the assimilation of carbon and nitrogen which peak up at 10 m depth. From this depth the C/N ratio decreases to values that might indicate a relative increase of organic matter from a microbial or microalgal source. Additional release of inorganic N as a result of organic matter mineralization processes has to be considered.

A previous study in this lake has indicated that the isotopic signature of the bulk organic matter is mainly a primary signal suggesting that it is the result of changes in the relative amount of organic matter types. Varying contributions of four organic matter sources (cyanobacteria, diatoms, aquatic macrophytes and soils) can explain the observed $d^{13}C$ and $d^{15}N$ variations in the uppermost part of the Holocene sediments (Mayr et al., 2009). The opposite trends observed in $d^{13}C$ and $d^{15}N$ as shown on Figure 2 are coherent with such interpretation. This general pattern might have been partially altered by subsequent microbial activity. For instance the observed $d^{13}C$ decrease in the first 10 meters might be the result of the preferential uptake of ^{12}C by microbes and the enrichment of ^{13}C in the produced methane (Whiticar, 1999). Analogously, a favored degradation of proteins compared to fatty acids - normally enriched in ^{15}N - would also lead to an increase in $d^{15}N$ (Freudenthal et al., 2001). Denitrification processes, normally limited to the very surface of the sediments, can also be invoked, but no decrease of nitrate concentration is observable at the depth of maximum ^{15}N enrichment. The methane content also indicates a constant increase in organic matter decomposition from the surface to 2 meters depth. The sudden decrease of methane between 4 and 8 meters depth is most probably due to outgassing since it peaks up again at ca. 10 meters depth. *In situ* ATP measurements reveal two main peaks at 4 and 10 meters depth, indicating that microbial growth rate is significantly higher in Holocene sediments. The statistical analyses of DGGE gels allowed us to identify a variable microbial diversity thoughout depth. The observed diversity in the upper section of the core appears to be linked with different fermentation processes (Nealson, 1997), gradual substrate changes, and rate of methanogenesis (Whiticar et al., 1986).

The observed decrease in TOC and TN below 10 meters sediment depth provides additional supports to the interpretation that microbial communities have to adapt to a depleted substrate, and thus urgently take up carbon as an energy source and N as a nutrient. The *in situ* ATP data show a last peak at 34 meters depth followed by a constant low microbial activity below 40 meters depth. Results of the DAPI cell count further confirm that microbes are still present although dormant with increasing depth. The DGGE patterns in these older sediments show a constant increase in Bacteria diversity down to 30 meters depth that is consistent with their need to increase possibilities of degrading the remaining substrate. The latter would explain the existing negative correlation between microbial activity and diversity. These deep degradation processes might take place through syntrophic cooperations (Schink, 1997) and nutrient recycling via anaerobic oxidation of methane and/or ammonium (AOM/ANAMMOX). This is made possible by Archaea (Strous and Jetten, 2004) that are less affected by the lack of resources due to their energy conservative metabolism (Valentine, 2007). The entire gas record is also quite constant suggesting that methane is best preserved in fine sediments. Remobilization and compaction in older sediments are both important and

need to be taken into account when interpreting the different parameters. These preliminary results, however, suggest that microbial communities are tightly related to distinctive sediment types representative of changing lake levels. The integration of these dataset with those produced within PASADO will bring new light into living microbial activity in lacustrine systems and its role in diagenetic processes.
Ongoing work includes DNA sequencing and identification of biosignatures under the SEM. Based on the DGGE patterns, selected samples will be cloned to identify the species present in our bacterial assemblages. This will increase our knowledge of syntrophy relationships and/or of cold adapted methanogens (Simankova et al., 2003). Furthermore, the study of biosignatures from specific sedimentary horizons will help us understanding the conditions under which microbial mineralization processes can mediate mineral precipitations.

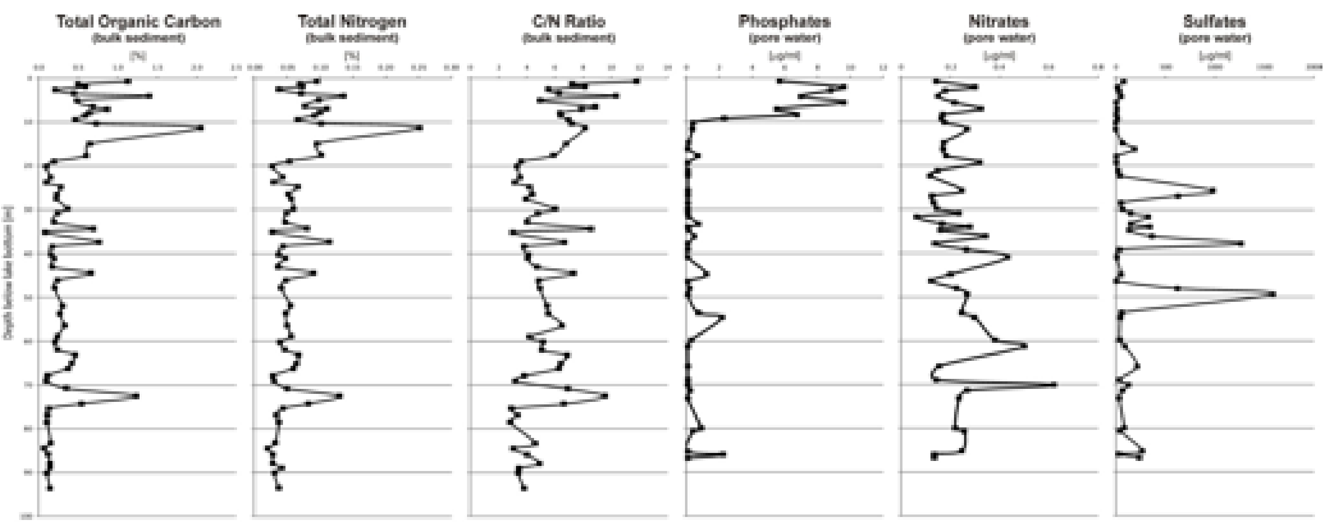

Figure 1: availability of nutrients and oxidants in sediment of core 5022-1D

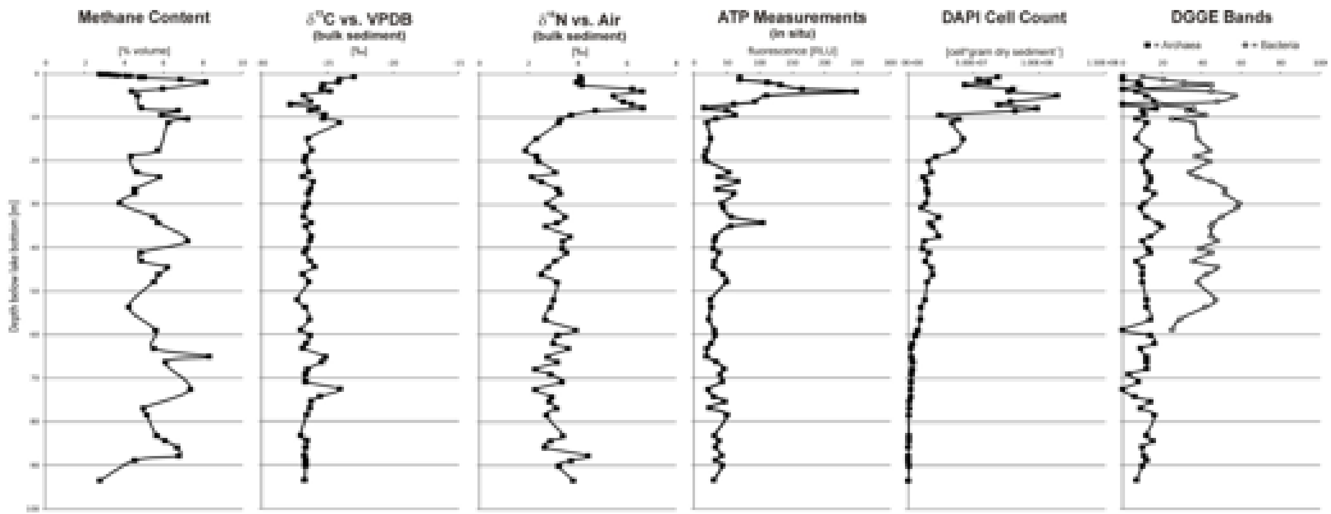

Figure 2: microbial signals measured on core 5022-1D

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TEPHROSTRATIGRAPHY OF THE POTROK AIKE MAAR LAKE SEDIMENT SEQUENCE

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There is increasing evidence that the Southern Ocean plays a key role for a better understanding of the global climate system. The southern hemisphere contains over 90% of the worlds ice and 81% of its total surface is covered by oceans. The most extreme oceanic character is between 40 and 60°S where only 2% of the earth's surface consists of land. One of very few permanent lakes between these latitudes is the 100 m deep lake Laguna Potrok Aike (52°58'S, 70°23'W) in southern Patagonia, Argentina, formed by a volcanic maar eruption several hundred thousand years ago. Seven holes were drilled in 2008 in the framework of the ICDP-funded "PASADO" project. The 106 m refe rence profile consists of laminated and sand-layered lacustrine silts with an increasing number of coarse gravel layers and turbidites with depth. In total, 24 visible tephra layers document the regional volcanic history and open the possibility to establish an independent age control supported by tephrochronology. The tephra horizons of the sequence also provide a unique potential to link the record with marine sediment cores from the Southern Oceans and ice-cores from Antarctica. Age-depth models suggest that the high quality record goes back ca. 55 ka.

A total of 19 samples were analysed at the Tephrochronology Analytical Unit at the University of Edinburgh in November 2009 and October 2010, of which 18 are from the site 2 composite profile and one is from the catchment area. Geochemical analyses were performed on a five-spectrometer Cameca SX-100 electron microprobe for concentrations of ten major oxides. Most samples consist of a mixture of pure glass and minerals. Analyses of the glass show that all layers except one are rhyolitic with SiO_2 contents between 74.5 and 78%. Two main groups occur, one group with K_2O contents between 1.5 and 2.0%, indicating an origin in the Mt. Burney volcano and one group with K_2O between 2.5 and 3.2%, which suggest that these layers are products of eruptions of the Reclús volcano. Tephras correlated with Viedma/Lautaro and the Aguilera volcanoes have also been found. Efforts are undertaken in order to compare the geochemical data with previous studies in southern Patagonia, including cores taken during the SALSA expeditions.

CARBON AND NITROGEN ISOTOPE COMPOSITION OF BULK SEDIMENTARY ORGANIC MATTER FROM LAGUNA POTROK AIKE DURING THE LAST GLACIAL AND THE HOLOCENE

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The 106 m long Site 2 composite profile 5022-2CP from the ICDP expedition PASADO to Laguna Potrok Aike offers a record of environmental variability during the last 54,000 years BP (according to age model V.1 (Kliem et al., unpublished)) in southern Patagonia, Argentina. Here we report on carbon and nitrogen isotope investigations of bulk sedimentary organic matter. For the transition period from the Last Glacial to the early Holocene (ca. 24,000 – 8,400 cal. BP) investigations were carried out with high temporal resolution (2 cm). For the other periods, the time resolution is still lower (8 cm for carbon and 16 cm for nitrogen). We have analysed the disturbed as well as the undisturbed lacustrine facies to learn more about effects of lake internal re-deposition.

Our data suggest three major units along the composite profile (Fig.1). The glacial part is characterized by very low TOC and TN contents. C/N ratio is almost completely below 10. Carbon isotope composition shows more or less constant values at around -26 ‰, although in certain periods larger variations are observed. Similar to carbon, the nitrogen isotope composition shows no clear trend during the Glacial. Around 16,223 cal. BP an abrupt shift occurs for all data interpreted as imprint of the onset of the last deglaciation. TOC and TN content increased dramatically and C/N ratio rose to above 10, occasionally above 15. The carbon isotope composition is more positive with values of around -23‰. Contrary to carbon, the nitrogen isotope composition has decreased by ca. 1‰ with deglaciation and reached the highest value of the profile during the early Holocene. According to our data and the applied age-depth model, this abrupt shift from the Glacial to the Late Glacial occurred within only ca. 70 years. Within the complete profile the carbon isotope composition correlates well with the TOC content and the C/N ratio. A clear negative correlation exists between carbon and nitrogen isotopes during the late Glacial and the early Holocene (Tab.1).

Previous studies of Holocene and Late Glacial sediments from Laguna Potrok Aike have indicated that palaeoproductivity dynamics of the lake and organic matter input from the catchment area can be tracked in carbon and nitrogen isotope signatures of bulk organic matter (Mayr et al. 2009). With an interdisciplinary multi-proxy approach and in accord with other terrestrial and marine records, the investigated carbon and nitrogen isotope data in this study will contribute to our understanding of the environmental development in southernmost Patagonia.

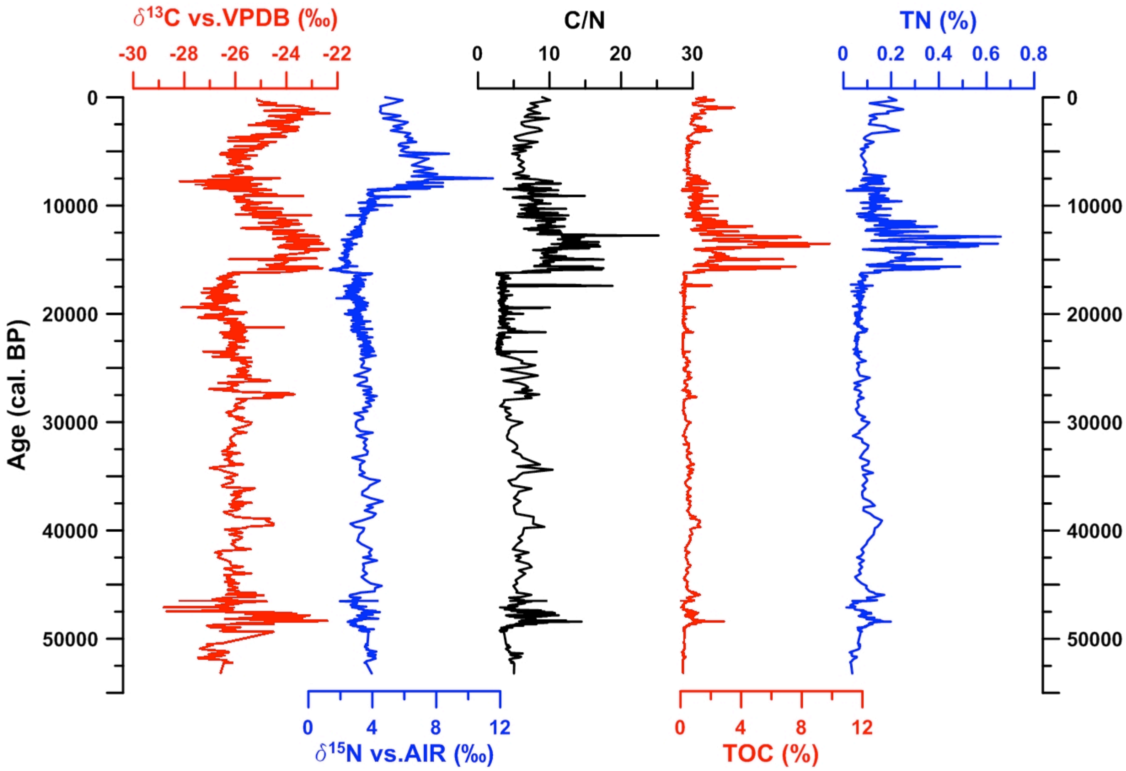

Fig. 1: Downcore changes in carbon and nitrogen isotope composition, C/N ratio, TOC and TN content for core 5022-2CP from the ICDP site Laguna Potrok Aike according to the age model V.1. Here only samples from undisturbed sediments (<200µm) were used.

Tab.1: Correlation coefficients for the entire composite profile 5022-2CP and three selected periods (7500-0 cal. BP; 16,223-7500 cal. BP; 53,210-16,223 cal. BP) between variables measured in this study.

	δ^{15}N VS TN	δ^{13}C VS TOC	δ^{15}N VS δ^{13}C	δ^{15}N VS C/N	δ^{13}C VS C/N
Entire composite profile	-0,17	0,59	-0,15	-0,09	0,66
7500-0 cal. BP	-0,53	0,57	-0,49	-0,53	0,43
16,223-7500 cal. BP	-0,51	0,58	-0.79	-0,54	0,63
53,210-16,223 cal. BP	-0,22	0,53	-0,04	-0,14	0,41

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