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Potrok Aike Maar Lake Sediment Archive Drilling Project

PASADO

2nd International ICDP Workshop PASADO

Vienna (Austria)

May 1 and 2, 2010

Program and Abstracts

icdp

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Arno-Holz-Str. 14, 12165 Berlin, Germany
Tel.: +49 (0)30 7900660, Fax: +49 (0)30 79006612
E-Mail: infos@geo-union.de

Editorial office
Schriftleitung

Dr. Christof Ellger
GeoUnion Alfred-Wegener-Stiftung
Arno-Holz-Str. 14, 12165 Berlin, Germany
Tel.: +49 (0)30 79006622, Fax: +49 (0)30 79006612
E-Mail: Christof.Ellger@gfe-berlin.de

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Prof. Dr. Bernd Zolitschka
Geomorphologie und Polarforschung (GEOPOLAR)
Institut für Geographie im Fachbereich 8, Universität Bremen
Celsiusstr. FVG-M, 28359 Bremen, Germany
Telefon: +49 (0)421-218-67150, Fax: +49 (0)421-218-67151
E-Mail: zoli@uni-bremen.de

Editorial staff
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Program and Abstracts

Bernd Zolitschka
(Editor)

Vienna (Austria)

May 1 and 2, 2010

Table of content

Introduction

This 2nd International PASADO Workshop is based on the research initiative “Potrok Aike Lake Sediment Archive Drilling Project” (PASADO) within the framework of the “International Continental Scientific Drilling Programme” (ICDP). PASADO addresses several challenging issues of geoscientific and socioeconomic relevance related to Earth history and climate like qualitative and quantitative climatic and environmental reconstruction as well as reconstruction of the palaeosecular variation of the Earth's magnetic field and natural hazards like fire history, frequency of volcanic activity including tephra fallout or dust deposition. The history of volcanic activities for the last ca. 50,000 years is another interesting topic. Moreover, dust and tephra records will provide means to link this unique southern hemispheric terrestrial record to marine sediment archives and to ice cores from Antarctica. Finally, obtained reconstructions of climate variability will be compared statistically with the output of Global Circulation Model (GCM) simulations to improve our understanding of forcing mechanisms of the global climate.

After the 1st International PASADO Workshop in Rio Gallegos, Argentina (March 15-19, 2006) the international and highly interdisciplinary PASADO research team has successfully obtained funding to carry out the ICDP deep lake drilling in 2008. Since coring, core splitting, documentation and subsampling has been completed earlier this year, it is now the time to discuss first scientific results and to fine-tune further investigations as well as interpretations of obtained data in an interdisciplinary manner. Therefore, we will focus during this 2nd International PASADO Workshop on discussing the first preliminary results and on establishing closer links of collaboration between involved science teams. Currently, there are around 60 scientists involved in the study of PASADO sediment cores of which ca. 40 will be present at the 2nd International PASADO Workshop in Vienna. Moreover, data sharing, publication strategies and funding of ongoing and future projects will be additional foci of this workshop.

Project outline of the Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO)

Principal Investigators: B. Zolitschka, University of Bremen, Germany; F.S. Anselmetti, EAWAG Dübendorf, Switzerland; D. Ariztegui, University of Geneva, Switzerland; R.S. Bradley, University of Massachusetts, USA; L. Brown, University of Massachusetts, USA; H. Corbella, Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina; P. Francus, INRS Quebec, Canada; A. Lücke, Research Centre Jülich, Germany; N.I. Maidana, University of Buenos Aires, Argentina; C. Ohlendorf, University of Bremen, Germany; F. Schäbitz, University of Cologne, Germany; S. Wastegard, University of Stockholm, Sweden

Short history: PASADO developed from the German project "South Argentinean Lake Sediment Archives and modelling" (SALSA) and started after 6 years of several pre-site surveys. These included detailed limnogeological studies (gravity and piston coring), on-site monitoring of modern processes, climatic and hydrologic modelling as well as four seismic surveys at the maar lake of Laguna Potrok Aike. These studies demonstrated that ~400 m of pelagic sediments were deposited and underlain by an unknown thickness of volcaniclastic breccias. This provides an excellent background for deep drilling in the framework of the ICDP.

Questions to answer: What kind of variability can be detected for climate-related catchment parameters like vegetation change, fire history or dust storms as well as volcanic activity? How did the lacustrine ecosystem respond to this forcing since oxygen isotope stage 4? What is the temporal and regional variability of the Southern Hemispheric Westerlies? Water availability is the main factor influencing this dry steppe region in South America: can quantitative reconstructions of temperature, precipitation, wind intensity and direction provide keys to the timing and intensity of regional aridity? How is this terrestrial record linked to other natural archives from the southern hemisphere like marine sediments of the southern oceans and Antarctic ice cores? What can we learn by comparing our results with the output of climate modelling?

Samples collected: We recovered 533 m of lacustrine sediments from 2 sites and 7 holes to a maximum sediment depth of 102 m.

Analyses to be applied: We carry out high-resolution non-destructive scanning techniques (XRF, physical properties, digital photography, X-ray images, spectrometry), deep biosphere analyses, rock- and paleomagnetic studies, paleobiological investigations (pollen, diatoms, chironomids) for quantitative reconstructions applying training sets and transfer functions, mineralogical, physical, geochemical, stable isotope (^{2}H, ^{10}Be, ^{13}C, ^{15}N, ^{18}O) and biomarker analyses, all backed-up by various dating (AMS ^{14}C, U/Th, Ar/Ar, OSL) and stratigraphic correlation methods.

Preliminary results: We recovered a high-resolution archive spanning the last 50,000 years with a sedimentation rate of 1 m per 1000 years (corrected for mass movement deposits). This is a so far unprecedented environmental and climatic record for South America south of the tropics. Cores were opened, a 106 m long composite record was established and analyses are currently carried out.

Why should society care?
Regionally: Water availability is the backbone of southern Argentinean agriculture (sheep farming). Understanding its variability in the past is important to improve predictions based on climate modelling and thus mitigation of the impact of ongoing global climate changes.
Globally: Climate reconstructions from the South American continent in combination with climate modelling contribute to a better understanding of the global climate system.

Location and map

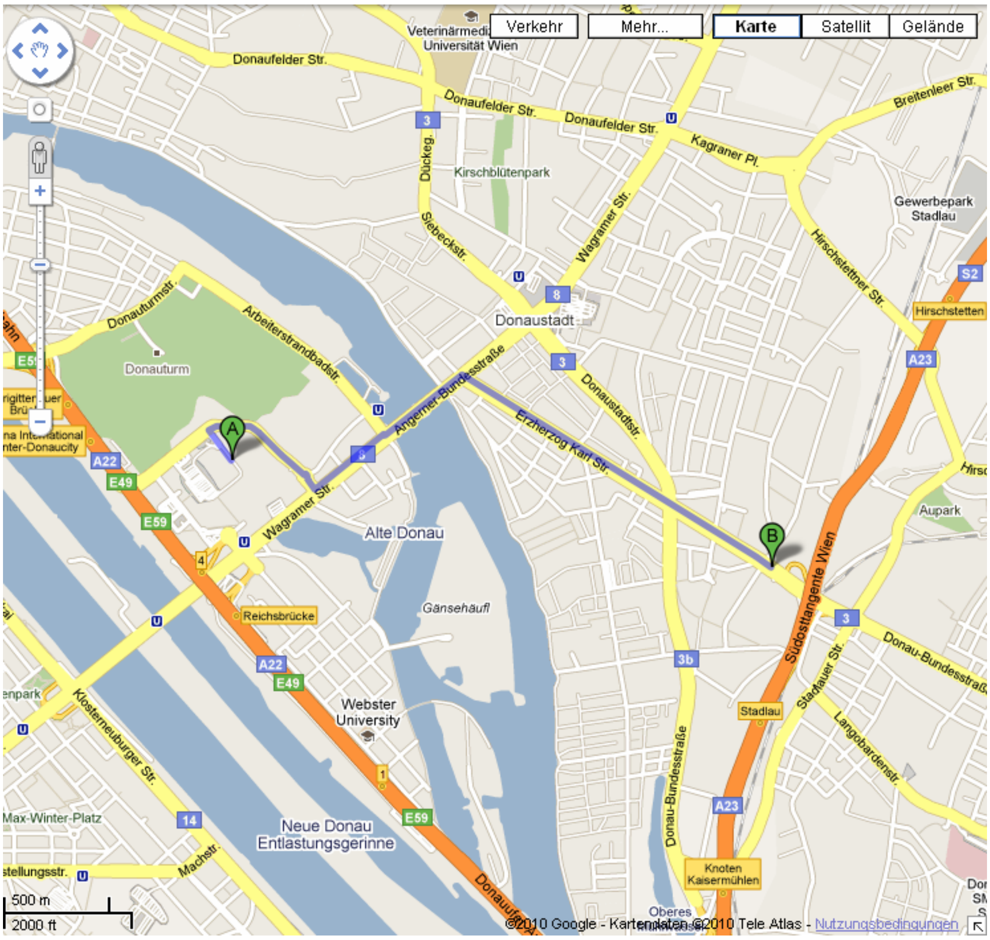
Getting from Vienna Airport to Hotel Hillinger

Address: Erzherzog-Karl Straße 105, A-1220 Wien
Phone: +43 1 204 46 46-0; Fax: +43 1 204 46 46-50
E-Mail: hotel@hillinger.at

Taxi: A taxi takes about 20 minutes and costs ca. 35 €.

Public transportation: Use the City Airport Train (CAT) to downtown Vienna. From the Airport Vienna (Wien) to the City Air Terminal ("Wien Mitte/Landstrasse") the CAT runs daily every 30 minutes. The one-way fare is 8 € and the two-way fare is 15 € if ordered online at www.cityairporttrain.com.

The CAT ends at the U-Bahn-Station (subway station) „Landstrasse/Wien Mitte", where you have to change to the subway U4 (green line) with the direction to „Heiligenstadt". After 2 stops get off at „Schwedenplatz", change to U1 (red line) with the direction to "Leopoldau". After 7 stops get off at the stop called "Kagran". From there take the tram (streetcar) No. 26 or bus No. 26A in the direction of „Aspern". After 4 stops you will reach the stop „Polgarstrasse" which is right in front of the Hotel Hillinger.



Location of Hotel Hillinger (B) and the Austria Center Vienna (ACV), the venue of EGU in 2010 (A). Walking distance between A and B is 3.5 km or 45 minutes (map source: http://maps.google.de). There is also public transportation available.

Scientific Program

Friday, April 30:

	Arrival in Vienna and transfer to Hotel Hillinger
21:00h	Get together at the hotel

Saturday, May 1:

08:40h	Bernd Zolitschka: Opening of the 2nd ICDP-Workshop PASADO and organizational details
09:00h	Daniel Ariztegui & Flavio Anselmetti: Swiss Participation in the Potrok Aike Maar Lake Sediment Archive Drilling Project – An overview
09:15h	Pierre Francus: Canadian Participation in the Potrok Aike Maar Lake Sediment Archive Drilling Project – An overview
09:30h	Bernd Zolitschka: German Participation in the Potrok Aike Maar Lake Sediment Archive Drilling Project – An overview
09:45h	Frank Schäbitz: Introduction of the “PASADO Microfossil Working Group”
10:00h	*Discussion about the current project structure*
10:30h	**Coffee break**
11:00h	Catalina Gebhardt et al.: Origin and development of the maar Laguna Potrok Aike, Southern Patagonia (Argentina): Seismic data
11:20h	Bernd Zolitschka & the PASADO Science Team: PASADO Lake Drilling – Management and pitfalls
12:10h	Christian Ohlendorf et al.: On-site and off-site core processing procedures applied during the ICDP-project PASADO
12:30h	**Lunch break**
13:30h	Bernd Zolitschka et al.: The long sediment record from Laguna Potrok Aike, Argentina (ICDP-project PASADO)
13:50h	Pierre Kliem et al.: Characterization of mass movement deposits in the south Patagonian maar lake Laguna Potrok Aike, Argentina
14:10h	David Fortin et al.: High resolution densitometry of the Laguna Potrok Aike composite record: Methods, comparison and calibration
14:30h	**Break**
14:45h	Guillaume Jouve et al.: Microsedimentology and geochemistry of lacustrine sediments from Laguna Potrok Aike – Hydrological and

sedimentological reconstructions of sudden climate changes during the last glacial period

15:05h Peter Rosén et al.: Fourier transform infrared spectroscopy – A technique for rapid, quantitative analysis of biogeochemical properties of sediment

15:25h Annette Hahn et al.: Developing an efficient method for high resolution biogeochemical analysis - a comparative study of infrared spectroscopy techniques

15:45h *Discussion about sedimentological and geochemical investigations*

16:15h **Coffee break**

16:45h Andreas Lücke et al.: Carbon and nitrogen isotope composition of core catcher samples from the ICDP deep drilling at Laguna Potrok Aike (Patagonia, Argentina)

17:05h Christoph Mayr et al.: Carbonates from the ICDP-site Laguna Potrok Aike: Mineralogy, isotopic composition and sample pre-treatment effects

17:25h Kyeong Kim et al.: Significance of Beryllium records from Laguna Potrok Aike, Argentina

17:45h **Break**

18:00h Agathe Lisé-Pronovost et al.: Paleomagnetism, magnetostratigraphy and environmental magnetism of Late Pleistocene and Holocene sediments from Laguna Potrok Aike (Argentina): Preliminary results from the ICDP-PASADO drilling

18:20h Claudia Gogorza et al.: Paleo- and rock magnetic study in support of the Laguna Potrok Aike maar lake sediment archive drilling project

18:40h *Discussion about isotopic and paleomagnetic investigations*

Sunday, May 2:

08:40h Aurèle Vuillemin et al.: Exploring the subsurface biosphere in Laguna Potrok Aike sediments: constraining the microbial role into diagenesis, a new prospect for ICDP

09:00h Michael Wille et al.: Vegetation history in southern Patagonia: First palynological results of the ICDP lake drilling project at Laguna Potrok Aike, Argentina

09:20h Cristina Recasens et al.: Diatoms as indicators of hydrologic and climatic change in Lake Potrok Aike, Argentina - A step toward deciphering changing patterns of paleoecological conditions in Southern Patagonia

09:40h Isabelle Larocque-Tobler et al.: Chironomids (non-biting midges) as indicators of environmental and climate changes

10:00h *Discussion about deep biosphere and paleobiology*

10:30h **Coffee break**

11:00h Stephanie Kastner et al.: Spatial sediment distribution at Laguna Potrok Aike, southern Patagonia, Argentina – An areal sediment survey to analyse the influence of late Holocene climate variability on sediment characteristics

11:20h: Torsten Haberzettl et al.: Laguna Potrok Aike as recorder of eolian (dust) input

11:40h Sebastian Wagner: Regional climate model simulations for the mid-Holocene over central and southern South America

12:00h *Discussion about the potential of the sediment record from Laguna Potrok Aike for regional to global environmental and climatic reconstructions*

12:30h **Lunch break**

13:30h To allow everybody to participate in discussions, we will not break-up into different groups. Instead, the discussion will be carried out as a plenary discussion with all participants. The following topics will be discussed:

- Dating
- Sedimentology
- Geochemistry
- Magnetic studies
- Isotopic investigations
- Microfossils
  - Pollen
  - Phytoliths
  - Chironomids
  - Diatoms
  - other algae
- Modeling

16:00h **Coffee break**

16:30h Continuation of the plenary discussion

- Data sharing
- Publication strategies
- Future funding options

19:00h *Final discussion and closing remarks*

Monday, May 3:

Departure from Vienna or participation in the EGU conference

Abstracts

(Abstracts are sorted alphabetically according to the first author)

Measuring biogenic and endogenic elemental ratios in lacustrine carbonates using flow-through analysis

Bart De Baere & Roger Francois

Department of Earth and Ocean Sciences, The University of British Columbia, 6339 Stores Road, Vancouver, British Columbia, V6T 1Z4, Canada

Trace element chemistry of biogenic carbonates in lacustrine microfossils such as ostracods is used as a proxy for past environmental conditions. In particular, Mg/Ca and Sr/Ca ratios have been used, combined with $\delta^{18}O$ analysis of the host carbonate, to reconstruct paleotemperature and/or paleosalinity in many lacustrine settings over the past few decades (e.g. Anadon and Julia, 1990). Similarly, element to calcium ratios (El/Ca) of endogenic (inorganically formed in water column) carbonates in lacustrine sediments can be used as a proxy for past hydrological and/or climatic conditions, independent of complicating biological factors.

However, contaminating authigenic carbonates (i.e. carbonate formed diagenetically in sediments) obscure the biogenic and endogenic carbonate phases that record the targeted information. Ostracods are known to only secrete low-Mg calcite shells (Xia et al., 1997a, b), but compelling evidence suggests that El/Ca of ostracod shells can be affected by diagenetic carbonate overgrowths (e.g. Holmes, 1996). Similarly, it has been challenging to separate endogenic carbonates from the authigenic and detrital carbonate phases of lacustrine sediments.

In order to address this problem, we have developed the flow-through analysis technique at the University of British Columbia (UBC). This technique consists of a flow-through dissolution module linked to an ICP-MS and provides an advanced alternative to conventional batch dissolution (for details see e.g. Haley and Klinkhammer, 2002). A key benefit of this technique is the ability to chemically separate different mineral phases over the course of a dissolution experiment, based on their dissolution susceptibility to the eluent flowing over the sample under controlled conditions. The resulting chromatograph consists of over a thousand data-points, allowing for continuous monitoring of the exact elemental composition as the sample is gradually dissolved. In addition, only a small amount of sample is needed for analysis (~0.2 mg).

Applying the flow-through dissolution technique to ostracod microfossils for El/Ca is needed, as order of magnitude variations in Mg/Ca ratios within an individual ostracod shell has been identified in a pilot study (De Baere, unpublished data). Likewise, we will explore the potential of the technique to distinguish the elemental ratios of the different non-biogenic carbonate phases (endogenic, authigenic and detrital) that accumulate in lacustrine sediments.

References:

Anadon, P., Julia, R., Hydrobiologia 197, 291-303 (1990)

Holmes, J. A., Journal of Paleolimnology 15: 223-235 (1996)

Haley, B.A., Klinkhammer, G.P., Chemical Geology 185: 51-69 (2002)

Xia et al., Journal of Paleolimnology 17, 85-100 (1997a)

Xia et al, GCA 61, 383-391 (1997b)

High resolution densitometry of the Laguna Potrok Aike composite record: Methods, comparison and calibration

David Fortin[1], Pierre Francus[1], Guillaume St-Onge[2] and J. Labrie[2]

[1] *Institut National de la Recherche Scientifique, Centre Eau, Terre et Environnement, 490 rue de la couronne, Québec, QC G1K 9A9, Canada*

[2] *Institut des sciences de la mer de Rimouski (ISMER) & GEOTOP, Université du Québec à Rimouski, 310 allée des Ursulines, Rimouski, Québec, G5L 3A1, Canada*

Density variability of sediment profiles can inform on a variety of processes, limnological 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 preliminary measurements on U-channels obtained from the main composite sedimentary profile (Site 2) of Laguna Potrok Aike. The first set of measurements 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 measurements was obtained using a medical tomography (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 preliminary results, density changes in Laguna Potrok Aike sediments reflect mainly changes in grain-size and mineralogy. We will discuss the advantages of the different methods and show tentative calibration of density grey scale into actual density. The final density logs will be soon made available to the entire PASADO community.

Reference

St-Onge G. and Long B.F., 2009. CAT-scan analysis of sedimentary sequences: An ultrahigh-resolution paleoclimatic tool. Engineering Geology, 103: 127-133.

Canadian participation in Potrok Aike Lake Sediment Archive Drilling Project – An overview

Pierre Francus[1,2]

[1] *Institut National de la Recherche Scientifique, Centre Eau, Terre et Environnement, 490 rue de la couronne, Québec, QC G1K 9A9, Canada*

[2] *GEOTOP, Montréal, Canada*

This presentation introduces the Canadian participation to PASADO. Canadian scientists are supported by a three-year grant from the Natural Sciences and Engineering Research Council of Canada (NSERC). Ten PIs from 7 universities across Canada, 3 post docs, 6 PhD, 1 MSc and one undergraduate student as well as 4 collaborators are involved in this project. The topics covered by the Canadian team are: sedimentology, modeling, organic petrology, isotopic geochemistry, paleomagnetism, volcanology, paleontology, and biogeochemistry. Seven Canadians took part to the field party in Patagonia, and seven contributed to the sampling party in Bremen. A web site (http://can-pasado.ete.inrs.ca/) describes our team and our contribution to the project.

This presentation will summarize the ongoing work, the methodology and the plans of the Canadian participants.

Origin and development of the maar Laguna Potrok Aike, Southern Patagonia (Argentina): Seismic data

A. Catalina Gebhardt[1], Marc De Batist[2], Frank Niessen[1], Flavio S. Anselmetti[3], Daniel Ariztegui[4], Torsten Haberzettl[5], Christian Ohlendorf[6] and Bernd Zolitschka[6]

[1] *Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany*

[2] *Renard Centre of Marine Geology, University of Gent, 9000 Gent, Belgium*

[3] *Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department of Surface Waters, 8600 Dübendorf, Switzerland*

[4] *Section of Earth and Environmental Sciences, University of Geneva, 1205 Geneva, Switzerland*

[5] *Institute of Geography, Friedrich-Schiller-University Jena, 07743 Jena, Germany*

[6] *Geopolar, Institute of Geography, University of Bremen, 28334 Bremen, Germany*

Seismic reflection and refraction data provide insights into the sedimentary infill and the underlying volcanic structure of Laguna Potrok Aike, a maar lake situated in the Pali Aike Volcanic Field, Southern Patagonia. The lake has a diameter of ~3.5 km, a maximum water depth of ~100 m and a presumed age of ~770 ka. Its sedimentary regime is influenced by climatic and hydrologic conditions related to the Antarctic Circumpolar Current, the Southern Hemispheric Westerlies and sporadic outbreaks of Antarctic polar air masses. Multiproxy environmental reconstructions of the last 16 ka document, that this terminal lake reacts highly sensitive to climate change. Laguna Potrok Aike has recently become a major focus of the International Continental Scientific Drilling Program (ICDP) and was drilled down to 100 m below lake floor in late 2008 within the PASADO project.

Seismic reflection data show relatively undisturbed, stratified lacustrine sediments at least in the upper ~100 m of the sedimentary infill but are obscured possibly by gas and/or coarser material in larger areas. A model calculated from seismic refraction data reveals a funnel-shaped structure embedded in the sandstone rocks of the surrounding Santa Cruz Formation. This funnel structure is filled by lacustrine sediments of up to 370 m in thickness. These can be separated into two distinct subunits with low acoustic velocities of 1500-1800 m s^{-1} in the upper subunit pointing at unconsolidated lacustrine mud, and enhanced velocities of 2000-2350 m s^{-1} in the lower subunit. Below these lacustrine sediments, a unit of probably volcanoclastic origin is observed (>2400 m s^{-1}). This sedimentary succession is well comparable to other well-studied sequences (e.g. Messel and Baruth maars, Germany), confirming phreatomagmatic maar explosions as the origin of Laguna Potrok Aike.

Seismic reflection data of the uppermost 100 m of the sediments reveal a rather dynamic development of the lake: on top of pelagic sediments a desiccation horizon is found, probably with sand dunes in the eastern part of the lake basin. These are overlain by a series of paleo shorelines documenting the history of lake level rise in this early stage of the newly formed lake. While this new lake formed in the central and eastern part of the maar depression, the western part probably was filled by stacked coarse-grained, delta-type sediments. The latter quite likely derive from the hinterland of the only inlet that is sporadically active at present. After this early lake stage, a stage of probably rapid lake level rise can be observed in the seismic reflection data.

Paleo- and rock magnetic study in support of the Laguna Potrok Aike maar lake sediment archive drilling project

Claudia S.G. Gogorza[1,2], Christian Ohlendorf[2] and Bernd Zolitschka[2]

[1] IFAS, Universidad Nacional del Centro, Pinto 399, 7000 Tandil, Argentina and CONICET, Rivadavia 1917, 1033 Buenos Aires, Argentina

[2] Institute of Geography (Geopolar), University of Bremen, 28334 Bremen, Germany

Objectives: Three composite sediment cores collected from the centre of Laguna Potrok Aike, which represent a total of approximately 150 m of sediment, will be used to obtain a continuous and well-dated record of paleomagnetic and paleoenvironmental changes for the last 40,000 to 50,000 years. The coring activities were carried out from August 31 to December 1, 2008 in the framework of the ICDP-project PASADO.

In detail, the objectives for this study are:

a) To extend the paleosecular variation record into the period of the last glaciation. Creer et al. (1983) carried out first paleomagnetic studies of sediments from Argentina. Gogorza et al. (1999; 2000a,b; 2002) presented paleomagnetic results of sediments from Lakes Escondido, Moreno and El Trébol of south-western Argentina (41°S; 72°W; Irurzun et al., 2006) and established a regional paleosecular variation (PSV) type curve (Gogorza et al., 2000a).

b) To reconstruct hydrological variations. Understanding the rock magnetic properties in a sedimentary sequence and the processes involved in formation, transport, and preservation of these magnetic minerals will lead to the identification of magnetic parameters with the best performance as environmental proxies.

c) To investigate sources (e.g. fluvial vs. eolian) of magnetic minerals.

d) To determine post-depositional changes in magnetic minerals caused by diagenesis or authigenesis and by biological processes. Magnetic mineral assemblages (combined with geochemical data) in a relatively small lake are helpful to analyze diagenetic dissolution as a result of changing redox conditions associated with e.g. eutrophication (Anderson and Rippey, 1988).

Methods: The following measurements will be carried out:

(1) Intensity and directions (declination, inclination) of natural remanent magnetization using a 2G high-resolution cryogenic magnetometer with RF SQUID sensors. Stability of the magnetization will be analyzed by alternating-field (AF)

demagnetization. The directions of the stable remanent magnetization will be determined by vector analysis of the demagnetization results;

(2) Low-field susceptibility (specific, X and volumetric, k), using a Kappabridge KLY-2 (Agico) with operating frequency of 920 Hz, and a magnetic induction of 0.4 mT;

(3) Isothermal remanent magnetisation (IRM) acquisition in fields up to 0.7T using a 2G high-resolution cryogenic magnetometer with RF SQUID sensors;

(4) Anhysteric remanent magnetisation (ARM) using a 2G high-resolution cryogenic magnetometer with RF SQUID sensors, in a peak 100 mT AF and 0.1 mT bias field and stepwise AF demagnetisation in nine steps up to 100 mT and k_{ARM}.

For a set of pilot samples the temperature dependence of susceptibility, up to a maximum temperature of 700°C, with a furnace-equipped Kappabridge KLY-2 and the hysteresis properties (such as saturation magnetisation M_S, saturation remanence M_{RS}, coercitivity H_C, coercitivity of remanence H_{CR} and high-field susceptibility (k_h)) using a PMC Alternating Gradient Field Magnetometer will be measured. The ratios ARM/k, SIRM/ARM and B_{CR} (remanent coercitive field) and the S_{ratio} will be calculated. Assuming a uniform ferromagnetic mineralogy dominated by magnetite, grain size variations can be deduced from the inter-parametric ratios k_{ARM}/k, k_{ARM}/ M_{RS} and M_{RS}/k (Maher and Thompson, 1999; Peck et al., 1994). However, these ratios should be used as grain size indicators with caution due to influence of dia- or paramagnetic minerals and non-linear behaviour with concentration (Stockhausen and Zolitschka, 1999).

The magnetometer that will be used in the measurements is equipped with a pneumatic auto-sampler which had been developed by the Marine Geophysics Section (Dr. Tilo von Dobeneck and Dr. Thomas Frederichs, University of Bremen). The 'robot' takes sets of up to eight samples at a time from the tray and inserts them into the magnetometer. After completing the measurement, the 'robot' takes the sample set out again, stores it back on the tray and continues with the next set. The exact sample sets and the type(s) of measurement are defined by a script file that can manage up to 96 samples. This equipment is essential for carrying out the proposed tasks due to the number of samples and measurements involved.

This work plan forms part of the postdoctoral studies of Dr. Claudia Gogorza (Scholarship of CONICET, Argentina) at the University of Bremen. Claudia Gogorza belongs to the Group of Geomagnetism at the Instituto de Física Arroyo Seco-Universidad Nacional del Cenro in Argentina. Other members of this team are Dr. Ana Sinito, Dr. María A. Irurzun and Dr. Marcos Chaparro.

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Laguna Potrok Aike as recorder of eolian (dust) input

Torsten Haberzettl[1], Annemarie Stopp[2], Christian Ohlendorf[3], Bernd Zolitschka[3], Hilmar von Eynatten[2] and Ilka Kleinhanns[4]

[1] Physical Geography, Institute of Geography, Friedrich-Schiller-University Jena, Löbdergraben 32, 07743 Jena, Germany

[2] Sedimentology and Environmental Geology, Geoscience Center, University of Göttingen, Goldschmidtstr. 3, 37077 Göttingen, Germany

[3] Geomorphology and Polar Research, Institute of Geography, University of Bremen, Celsiusstr. FVG-M, 28359 Bremen, Germany

[4] Department of Earth Science, University of Bergen, Allegt. 41, 5007 Bergen, Norway

The source of dust deposited during the last glacial on the East Antarctic Plateau has been attributed to Patagonia for a long time (Delmonte et al., 2008). Recently, a study from Berkner Island demonstrated that recent deposition at least during spring/summer is also influenced by dust contributions from Patagonia (Bory et al., 2010). Atmospheric transport models coupled to global circulation models (GCM), however, have so far failed to reproduce quantitatively the most prominent features of these records, specifically the large increases in mineral dust content observed in polar ice during cold periods such as the Last Glacial Maximum (Bory et al., 2010;

Lunt and Valdes, 2001; Mahowald et al., 1999). Additionally, up to now studies comparing depositional systems which mean also samples of the same age in the source area (Patagonia) with results from Antarctica have rarely been carried out.

Here, we present a magnetic susceptibility record for the past 48 ka from Laguna Potrok Aike. Magnetic susceptibility is assumed to be a proxy for dust deposition in this lake (Haberzettl et al., 2009). Distinct similarities were found between an independently dated magnetic susceptibility record from a “short” core, i.e. 12 m, from Laguna Potrok Aike and the non-sea-salt calcium (nss-Ca) flux from the EPICA Dome C ice core record (75°06’S, 123°24’E). The latter is commonly used as a proxy for mineral dust deposition in Antarctica (Röthlisberger et al., 2002).

Comparison of the two records and grain size analyses of the Laguna Potrok Aike sediment indicate a relatively high eolian activity in southern South America during the glacial period. During the Holocene climatic conditions driving sediment deposition seem to have been more variable and less dominated by wind compared to glacial times. Although the source of the dust found in Antarctic ice cores often has been attributed to Patagonia (Delmonte et al., 2008), we present the first evidence for contemporaneity of eolian deposition in both the target area (Antarctica) and the major source area (Patagonia). Considering the similarities of the two records, magnetic susceptibility might yield the potential for chronological information, i.e., the transfer of the ice core age-depth model to a lacustrine sediment record. This would be important as additional time control for the recently recovered sediment record within the ICDP deep drilling project PASADO.

To support this idea of similar provenance, we performed Sr and Nd isotopic analyses on the assumed eolian fraction (63-200 µm) which is very well sorted and was deposited in Laguna Potrok Aike during the last glaciation. Additionally, we analysed the <5 µm fraction which is commonly found as dust on the East Antarctic Plateau during glacial periods. Both grain size fractions were extracted from the same subsamples. Results are compared to the Sr and Nd isotopic signatures measured directly on dust from Antarctic ice cores (Delmonte et al. 2004). The isotopic data field of sediments from Laguna Potrok Aike superposes a large part of isotopic data from Antarctic dust. However, the 87Sr/86Sr-data seems to show a slight offset to lower values.

In conclusion our analyses support and confirm previous studies that suggested southern South America to be the main source area for east Antarctic dust during glacial periods. However, this is the first evidence for a contemporaneous dust deposition pattern in the source and target area - Patagonia and Antarctica.

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Developing an efficient method for high resolution biogeochemical analysis - a comparative study of infrared spectroscopy techniques

Annette Hahn[1], Pierre Kliem[1], Christian Ohlendorf[1], Per Persson[2], Bernd Zolitschka[1], Peter Rosen[3] and the PASADO Science Team

[1]*Geomorphology and Polar Research (GEOPOLAR), Institute of Geography, University of Bremen, Celsiusstr. FVG-M, D-28359 Bremen, Germany*

[2]*Department of Chemistry, Umeå University, SE-901 87 Umeå, Sweden*

[3]*Climate Impacts Research Centre, Umeå University, SE-981 07 Abisko, Sweden*

In order to answer the questions we have about past and future climate we need to track long- term climatic changes. The physical, chemical and biological responses of lake systems to changes in climate are registered in various ways by lake sediment records (Battarbee, 2000). Climate influences many lacustrine processes and subsystems in an interlinked manner. Therefore, it is necessary to include as many proxies as possible for climate reconstructions using a lake core (Mann, 2002). However, multiproxy studies can be time consuming and expensive, especially if done on long sediment cores at high resolution. The analysis of sediment samples in the visible to mid-infrared region is ideal for such records. It requires only small amounts (0.01-0.1g dry weight) of sample material and facilitates rapid and cost efficient analysis of a wide variety of biogeochemical properties on minerogenic and organic substances (Kellner et al., 1998). Four essential proxies that will be considered in this study are total organic carbon (TOC), total inorganic carbon (TIC), biogenic silica (BSi) and total nitrogen (TN). The Diffuse Reflectance Fourier Transform Infrared Spectrometry (DRIFTS) technique has already been successfully applied to lake sediments from very different settings and has shown to be a promising technique for high resolution analyses of long sedimentary records on glacial-interglacial timescales (Vogel et al. 2008; Rosén et al. 2009). However, the DRIFTS technique includes a time-consuming step where sediment samples are mixed with KBr. To assess if alternative and more rapid infrared (IR) techniques can be used, four different IR spectroscopy techniques are compared for core catcher sediment samples from Laguna Potrok Aike – an ICDP deep drilling site located in southernmost South America (Fig. 1).

Calibration models were developed using the DRIFTS technique, Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIRS) and Visible Near Infrared Spectroscopy (VNIRS). All FTIRS spectra were baseline corrected and wavenumbers which contain no spectral information (3750-3800 and 2210-2200 cm^{-1}) were set to zero. The baseline correction reduces noise due to differing measurement conditions. Multiplicative Scatter Correction (MSC) was applied to all FTIRS and VNIRS spectra to remove variations in the spectra that are related to noise and distortions and to maximize the chemical information from the sediment (Geladi et al., 1985). Partial least square (PLS) regression is used to assess calibration models between the spectra and the traditionally measured sediment properties. For TOC and TN square root transformations had to be applied in order to achieve normal distributions. Model performance was evaluated by analyzing the cross validated coefficient of determination (R_{cv}), the cross-validated root mean squared error of prediction (RMSECV). The DRIFTS technique, measuring in the 400-3750 cm^{-1} range, was the most robust method (Table 1). Good statistical performance was also obtained by using the ATR-FTIRS technique (Table 1). Sample preparation for ATR-FTIRS analysis only includes freeze drying and grinding of sediment and is thus faster than DRIFTS. However, the ATR technique does not use carousels and it is necessary to clean the equipment after every measurement. Two ATR-FTIRS devices were used: the full-sized Bruker Equinox and the smaller and less expensive Bruker Alpha. As the penetration depth of the IR beam is frequency dependent, a firm surface contact of the sample is necessary. This could not be accomplished; therefore absorbance in higher wavenumbers was not recorded correctly. As a result of the poor spectral quality, a calibration model was not established for BSi using the Equinox device.

Calibration models were also developed using spectra from the VNIRS region at 400-2500 nm (25000-4000 cm^{-1}). VNIRS spectra have previously been used for the analysis of the biogeochemistry of lacustrine sediments (Malley, 1999; Vogel, 2006). Sample preparation for VNIRS analysis is faster than for DRIFTS analysis and includes only freeze drying and grinding of sediment. However, FTIRS calibration models seem to perform better than those for VNIRS (Table 1). NIRS primarily measures overtones of molecular vibrations and is typically used for quantitative measurements of organic functional groups, especially O-H, N-H, and C=O. FTIRS is similar to NIRS, but FTIRS uses longer wavelengths and directly monitors molecular vibrations. As a consequence, FTIRS allows more detailed structural and compositional analysis of both organic and inorganic compounds. While raw FTIRS spectra show peaks that can be attributed to specific molecular bounds, the VNIRS technique gives rise to a spectrum with broad peaks and many overlapping signals which makes the spectrum difficult to interpret without statistical analyses (Fig. 2). A loading plot shows that the PLS calibration model depends on specific wave numbers, which compares well with spectra of pure compounds. For the DRIFTS technique, positive loading values for the TIC model show that absorbance bands at 710, 880, 1470, 1800 and 2520 cm^{-1} are important for model performance. These regions are linked to absorbance from C-O vibrations in calcite minerals (White, 1974). Positive loading values for the DRIFTS-TOC and -TN models correspond well with known absorbance bands for humic and organic substances; 1100-1400, 1450-1600, 1550-1650 cm^{-1} and 1700 cm^{-1} (Fig. 3; Calace, 1999). In the region 2850-2950 cm $^{-1}$ CH vibrations in -CH3, -CH2 and -CH groups of organic compounds have absorbance peaks (Kellner et al., 1998). This demonstrates that a part of DRIFTS-TOC and -TN models are based on the direct relationship between organic substances in the sediment and spectral properties. However, the models for TOC and TN have loading plots that are almost identical and can therefore not be assessed independently. As the FTIRS spectra contain more information about C, it is most likely that the TOC mode is more robust. Positive loading values for the DRIFTS-BSi model corresponds well with known absorbance values for triply-degenerated stretching vibration modes of the [SiO4]-tetrahedron, a constituent of BSi, at around 1100 cm $^{-1}$ (Fig. 3, Gendron-Badou et al., 2003). Furthermore, the spectrum of an individual diatom valve shows high absorbance in the 1050-1250 cm $^{-1}$ region (Rosén et al., 2009).

In conclusion, this study shows that it is possible to use IR spectroscopy to assess several biogeochemical parameters for the long (>100 m) lake sediment sequence of Laguna Potrok Aike. Large environmental changes over time cause major variations in the sediment properties, however these do not inhibit the construction of stable models. The only calibration model that could not be established was for BSi using the Equinox device. Since BSi is by far the most time-consuming and elaborate conventional measurement, this is a considerable drawback. Otherwise, the statistical performance was good for most of the models, but the DRIFTS technique shows the best statistical performance for the analysis of biogeochemical properties. The VNIRS techniques and especially the ATR-FTIRS measured with the Alpha device show comparable results and may also be used as more rapid screening tools when time and costs are limiting factors.

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Table 1: Statistical Performance of the calibration models for the estimation of biogeochemical properties of Laguna Potrok Aike using spectra from DRIFTS, ATR-FTIRS and NIRS measurements.

Statistics	DRIFTS				ATR-FTIRS Equinox			ATR-FTIRS Alpha				NIRS			
	TOC (%)	TN (%)	TIC (%)	BSi (%)	TOC (%)	TN (%)	TIC (%)	TOC (%)	TN (%)	TIC (%)	BSi (%)	TOC (%)	TN (%)	TIC (%)	Bsi (%)
R_{CV}	0,90	0,91	0,91	0,81	0,73	0,79	0,73	0,90	0,91	0,85	0,69	0,87	0,91	0,76	0,33
RMSECV	0,34	0,02	0,29	0,77	0,50	0,05	0,48	0,52	0,02	0,31	0,75	0,49	0,03	0,33	0,94
RMSECV (% gradient)	4.54	4.33	8.09	8.72	6,60	8,16	13,22	6,87	3,64	8,56	8,52	6,47	5,45	9,12	10,68

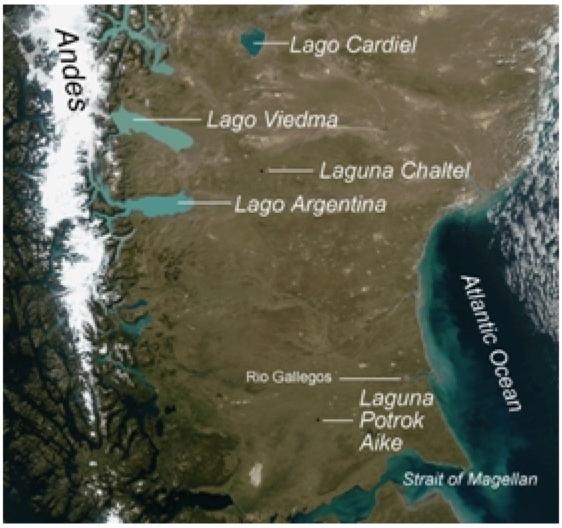

Fig. 1: Location of Laguna Potrok Aike in Southern Patagonia, Argentina.

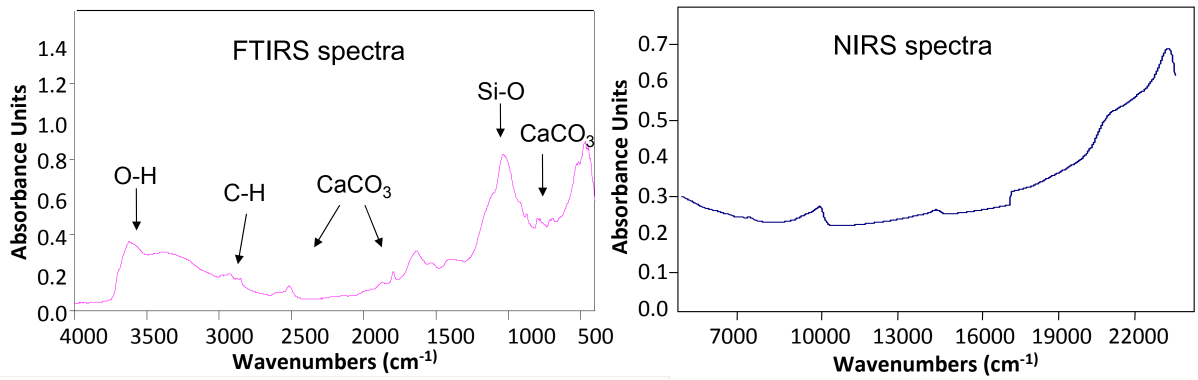

Fig. 2: Comparison of DRIFTS and VNIRS raw spectra of a core catcher sample from Laguna Potrok Aike.

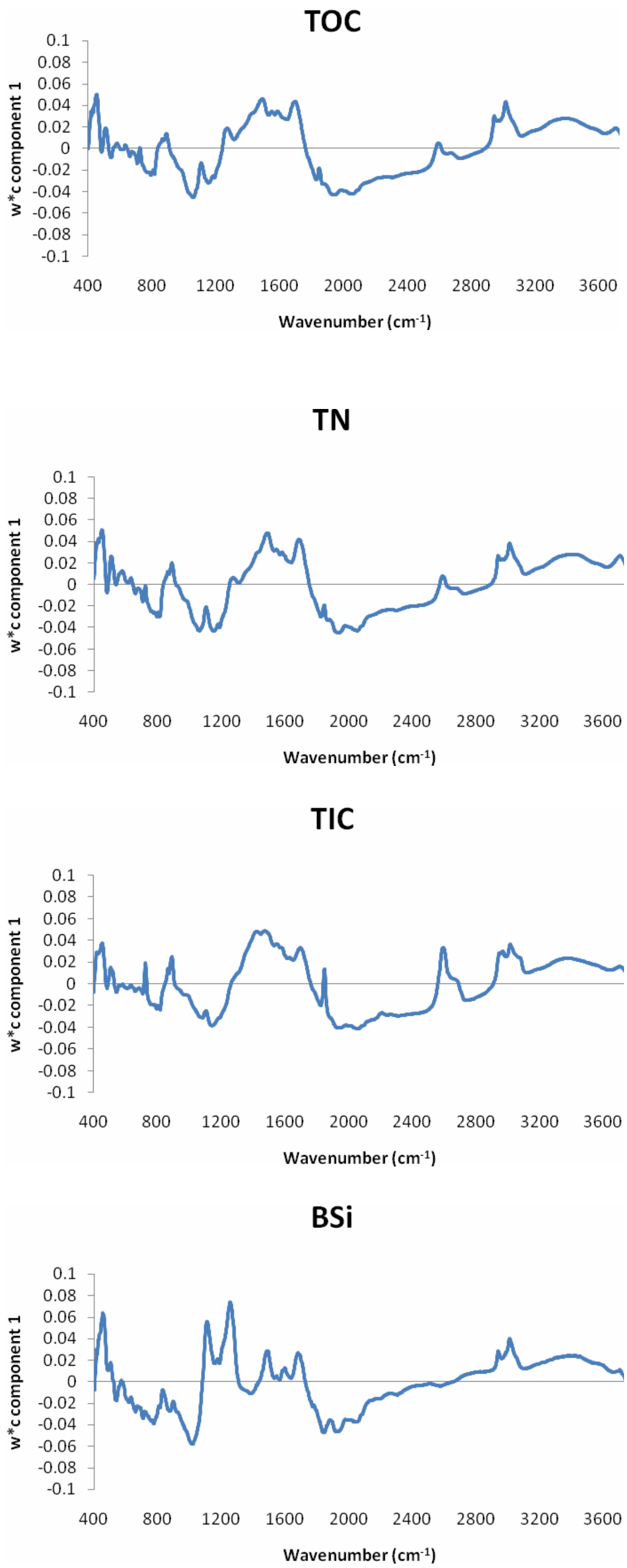

Fig. 3: Loadings expressed by weight vectors (w*c) of the PLSC1 (y-axis) for the DRIFTS- inferred properties of sediment from Laguna Potrok Aike. Positive loadings indicate wavenumbers positively correlated to the sediment property and negative loadings indicate wavenumbers negatively correlated to the sediment property.

Microsedimentology and geochemistry of lacustrine sediments from Laguna Potrok Aike: Hydrological and sedimentological reconstructions of sudden climate changes during the last glacial period

Guillaume Jouve[1], Pierre Francus[1] and Scott Lamoureux[2]

[1] *Institut National de la Recherche Scientifique, Centre Eau, Terre et Environnement, 490 rue de la couronne, Québec, QC G1K 9A9, Canada*

[2] *Department of Geography, Queen's University, Kingston, Ontario, K7L 3N6, Canada*

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 to contribute to the sedimentological characterization and hydrological reconstruction of LPA.

Three methods will be used to fulfil these objectives. First, image analysis of thin-sections involves the extraction of quantitative information from digital images retrieved at the Scanning Electron Microscope: image acquisition, image processing and measurement of images. Measurements are made on each particle in the digital image. They reveal their center of gravity, area, major axis, minor axis and angle to the horizontal. These measurements are then recorded in a spreadsheet for further processing. Second, we will use an ITRAX™ Core scanner from Cox Analytical Systems. The principle of operation is based on the simultaneous acquisition of microdensity (radiography) and microcompositional variations (XRF) using two separate X-ray detection systems. A line-scanning camera is also incorporated into the system to provide an optical image. The analysis is performed without touching the sample surface and is completely non-destructive with a resolution up to 0.1 mm. Third, grain-size analyses will be performed on a Beckman Coulter LS 200 laser scattering particle size analyser at Queen’s University (Kingston, Ontario). This study will allow comparison with results obtained with particle image analysis for a better interpretation and validation of work.

The first objective of this work is to characterize the sedimentary facies at the microscale. For that purpose, we collected thin-sections to sample all facies recognized macroscopically in the 106 m of the composite record. A total of 206 thin-sections are studied for the description of the microfacies. 565 samples for grain-size analysis of sediments collected at the same depths as thin-sections will be done at Queen's University.

This work will also characterize the sedimentological and hydrological changes in LPA during the events of abrupt climatic warming and cooling measured in ice cores from Antarctica. These are: Antarctic Warm Event 1 and the Antarctic Cold Reversal. For that purpose, about 15 m of U-channel will be analysed with ITRAX microfluorescence at high resolution. These are several sections that correspond to continuous intervals of significant facies variations. The good correlation of magnetic susceptibility of sediment cores from core 5022-2A and -2C with those used by

Haberzettl et al. (2007), also taken in the deep basin of the lake, has enabled us to approximate the age of our sediment for the first 20 m of composite sections through the age model provided by Haberzettl et al. (2007). Then, the extrapolation of that model to the rest of the composite sequence, taking into account the events of rapid deposition (sediment remobilized and turbidites), is consistent with preliminary ^{14}C results (about 50 ka cal. BP).

Preliminary results in grain-size analysis will be present during the PASADO workshop in Vienna in March 2010.

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Spatial sediment distribution at Laguna Potrok Aike, southern Patagonia, Argentina – An areal sediment survey to analyse the influence of late Holocene climate variability on sediment characteristics

Stephanie Kastner[1], Christian Ohlendorf[1], Torsten Haberzettl[2], Andreas Lücke[3], Nora I. Maidana[4], Christoph Mayr[5,6], Frank Schäbitz[7] and Bernd Zolitschka[1]

[1] *Institute of Geography (Geopolar), University of Bremen, Germany*

[2] *Institute of Geography, Friedrich-Schiller-University Jena, Germany*

[3] *Institute of Chemistry and Dynamics of the Geosphere 4: Agrosphere (ICG 4), Energy & Environment, Research Center Jülich, Germany*

[4] *Department of Biodiversity and Experimental Biology, University of Buenos Aires, Argentina*

[5] *GeoBio-Center LMU and Dept. of Earth & Environmental Sciences, University of Munich, Germany*

[6] *present address: Institute of Geography, Friedrich-Alexander-University Erlangen-Nuremberg, Erlangen, Germany*

[7] *Seminar for Geography and Education, University of Cologne, Germany*

Situated in the dry steppe environment of southern Patagonia the Quaternary maar lake and ICDP drilling site (Zolitschka et al., 2009) Laguna Potrok Aike (51°58'S, 70°23'W) is exposed to the influence of the prevailing Southern Hemispheric Westerly winds. Geomorphological features of the lake and multi-proxy reconstructions of the lacustrine sediment sequence document the sensitivity of the lake's hydrological budget to the varying intensity of the Southern Hemispheric Westerly winds, related pressure systems and thus precipitation changes (cf. Mayr et al., 2007). Hydrological fluctuations correspond to lake level changes documented by aerial and sub-aquatic lake level terraces (Anselmetti et al., 2009) and depositional changes (Haberzettl et al., 2009). Thus, the lake provides a unique paleoclimatic and paleoenvironmental record of the late Holocene (Haberzettl et al., 2005) and early to mid to Holocene (Haberzettl et al., 2007) with its warm and dry or cold and wet periods .

In most paleolimnological studies, long-term trends of paleoenvironmental variations are interpreted from a single point in a sediment basin. However, only little is known about the spatial variability of sedimentary proxies within lacustrine systems and thus the influence of climate variables on a spatial scale.

Laguna Potrok Aike represents a bowl shaped and nearly circular lake, about 3.4 km in diameter. The gently dipping and flat littoral zone is separated from the 100 m deep and flat profundal by steep slopes. In preparation for the ICDP deep drilling project PASADO (Potrok Aike maar lake sediment archive drilling project) a survey of the spatial sediment distribution was proposed to (A) develop an understanding of the dynamics of modern and sub-recent processes that control the areal sediment characteristic in the lake and (B) to improve the potential for interpretation of the long sediment record recovered by the PASADO project.

Analysing the influence of modern climate conditions on the areal sediment distribution a dense grid of 63 gravity cores was recovered in 2005 and 2008 from the lake floor. The cores were up to 49 cm in length and were recovered from water depths between 9 and 100 m. Additionally 40 near-shore samples were collected to represent modern sediment characteristics. Surface sediments of all cores were subsampled. Subrecent influences were analysed for selected time windows covering different hydrological settings (Haberzettl et al., 2005). The selected time windows – AD 1960, 1800, 1610, 1500 and 1380 – are supposed to represent the periods of the 20th century warming, the Little Ice Age (LIA) and the Medieval Climate Anomaly (MCA). All cores were scanned with X-ray fluorescence technique and magnetic susceptibility with 1 and 4 mm spatial resolution, respectively. Using the scanning data, all cores were correlated and thereafter linked to an established age-depth model (Haberzettl et al., 2005). The scanning profiles do not allow unequivocal correlation of profundal and littoral cores across the steep slopes. Thus, a correlation prior to the present sediment surface is solely based on cores from water depths exceeding 45 m. Samples of surface sediments were taken from all 63 cores while subsampling of the selected time intervals was only possible for up to 43 well correlated cores from the deep central basin. Thereafter, the sediment was analysed geochemically (for element concentrations of C, N, S, and P), sedimentologically (grain size), palynologically, diatomologically, and for stable isotopes of organic matter (C, N) and carbonates (C, O). Subsequently, distribution maps for all parameters and for each time window were compiled by an exact point kriging method.

The modern sediment distribution confirms pronounced differences between littoral and profundal cores (Kastner et al., submitted-a). Interpolated patterns of grain size, benthic diatoms, total inorganic carbon, Ti and Ca point to distinct internal depositional dynamics induced by the dominant westerly winds (Fig. 1). Frequent erosion, resuspension and redistribution of littoral sediment are followed by transport to a profundal accumulation area. Hence, sedimentation within this lake is not only influenced by lake level changes, episodic inflows and the surrounding geology but also by wind driven wave action, resulting in internal currents and shoreline erosion.

The subrecent spatial sediment distribution is evaluated and interpreted in the context of modern processes (Kastner et al., submitted-b). The aim of the analyses of time windows was to evaluate if the modern conditions could be identified for distinct past lake level stages. Due to difficulties with core correlation, the spatial resolution of the distribution maps is diminishing back in time. Thus, the interpretation is restricted to information of the deep central basin area. As a result information of the interpolated patterns becomes less clear with less data points available. Finally, distribution maps of the time window AD 1380, covering the MCA, could not be compared to modern low lake level conditions. Mineralogical parameters and stable isotope values of organic matter seem to be important proxies to evaluate the mechanisms of sediment distribution during selected hydrological settings. The data of the AD 1960 low lake level conditions explicitly indicate sediment reworking from the lake margins. In contrast, time windows of high lake level stages during the LIA (AD 1800 and 1610) indicate the influence of tributaries, especially at the western part of the lake (Fig. 1).

In conclusion, the interpretation of the distribution pattern strongly depends on the amount of cores used for the interpolation and thus on the quality of the recovered cores, the accuracy of the used age-depth model and the reliability and possibility of core correlation. Nonetheless, distribution patterns and sediment characteristics of modern and subrecent sediments reveal intensified sediment redistribution during low lake levels and strengthened winds, i.e. during post LIA times (around AD 1960) and around AD 1500. In contrast, LIA conditions (around AD 1800) with a lake level high stand and less intense westerly winds result in a more homogeneous sediment distribution within the deep central basin. Furthermore, spatial sediment distribution reveals distinct influences of the main western and smaller tributaries at the eastern shore.

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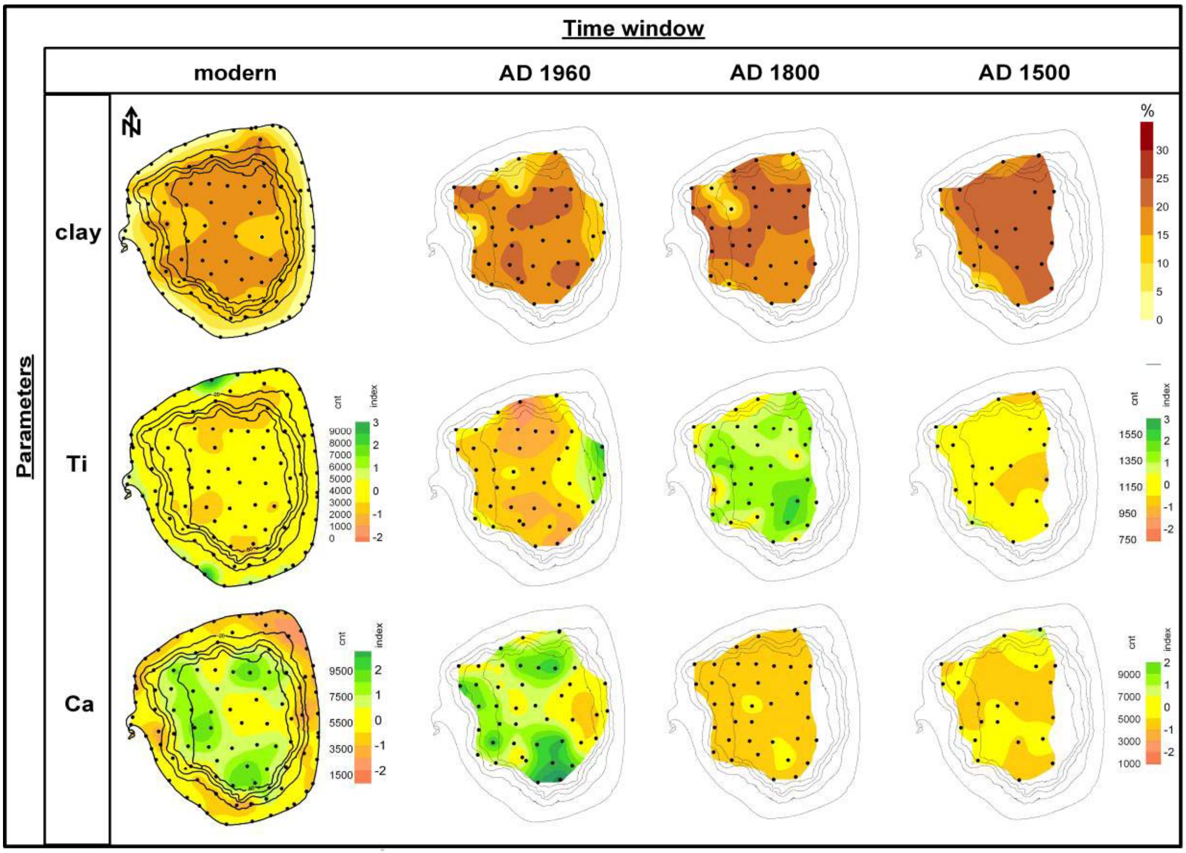

Fig. 1: Distribution maps of clay (percentage), titanium (Ti: counts) and calcium (Ca: counts) for time windows of low lake levels (modern and AD 1960), high lake level (AD 1800: LIA) and an intermediate lake level stage (AD 1500). Contour map shows bathymetric information of Laguna Potrok Aike, black dots indicate coring locations. Note: values for Ca and Ti are standardised by a z-transformation. Values are reported as index-values (-5 to 5; mean = 0) and equivalent absolute counts (cnt). Due to data processing value ranges are slightly different for modern and subrecent time windows.

Significance of Beryllium Records from Laguna Potrok Aike, Argentina

Kyeong Ja Kim[1], A. J. Timothy Jull[2], Jun-Ho Kim[1], Hiroyuki Matsuzaki[3], Christian Ohlendorf[4] and Bernd Zolitschka[4]

[1]*Korea Institute of Geoscience and Mineral Resources, 92 Gwahang-no, Yuseong-gu, Daejeon, 305-350, Korea*

[2]*NSF Arizona AMS Laboratory, University of Arizona, Tucson, AZ 85721*

[3]*MALT, University of Tokyo, Tokyo, Japan*

[4]*Geomorphology and Polar Research, Institute of Geography, University of Bremen, Celsiusstr. FVG-M, 28359 Bremen, Germany*

We have examined the relationship between Beryllium isotopes and the hydrological record of the Laguna Potrok Aike sediment record for the last 16 kyr. Our study shows that Beryllium isotope concentrations are inversely correlated to the water balance of the lake. When the lake level was high, concentrations of Beryllium-10 (Be-10) and Beryllium-9 (Be-9) were relatively low, e.g. at around 13,000 cal. BP. At the same time, however, the Be-10/Be-9 ratio was the highest of the entire period studied, which indicates that the Be-10 concentration was relatively higher than at any other time of this record. This result could be caused by the increase of the Be-10 production rate as well as by climatic change of this area. Our study confirms that Beryllium isotopes may be useful for climate change studies in a lacustrine environment. It is unclear if the Be-10 fluctuations represent a concentration mechanism in the lake or less precipitation. However, the investigation of the Laguna Potrok Aike sediment record suggests that Be isotope studies will be useful in providing environmental and climatic change records from this and other lakes, similar to studies carried out for Lake Malawi by McHargue et al.

Characterisation of mass movement deposits in the south Patagonian maar lake Laguna Potrok Aike, Argentina

Pierre Kliem[1], Annette Hahn[1], Christian Ohlendorf[1], Bernd Zolitschka[1] and the PASADO Science Team[2]

[1] *GEOPOLAR, Institute of Geography, University of Bremen, 28334 Bremen, Germany*

[2] *http://www.icdp-online.org/contenido/icdp/front_content.php?idcat=960*

Laguna Potrok Aike is a 100m deep maar lake located in the dry steppe of southern Patagonia (52°58'S, 70°23'W). The catchment area of >200km² mainly consists of till from Bella Vista and Río Ciaike Glaciations as well as of alkali-olivine basalts of the Pali Aike Volcanic Field. Today's regional climate is affected by the Southern Hemispheric Westerlies and the rain shadow effect of the north-south striking Andean mountain chain. Since lakes are valuable terrestrial paleoclimate archives, sediments of Laguna Potrok Aike should reflect shifts of mid latitude wind and pressure fields as well as precipitation changes in south-eastern South America. Aiming at the reconstruction of past climate, the deep drilling at Laguna Potrok Aike was accomplished in the framework of the ICDP project PASADO during September to November 2008.

By correlation of three holes drilled at Site 2 located ca. 700 m south of the lake's center, a composite profile of 106.09 mcd (meters composite depth) was established. According to the lowermost ^{14}C-age of aquatic macro remains from 80.6 mcd, the entire record comprises at least 50,000 years (Fig. 1). Although we tried to avoid remobilized units for ^{14}C-sampling of aquatic plant remains, age reversals occur. Most occurrences of aquatic plant remains (mostly aquatic mosses) are associated to layers of supposedly reworked sediments and thus contain older lacustrine carbon. Additional dating of aquatic mosses is in progress. Results of the sampled layers will be evaluated according to the principle of superposition.

The initial lithological description indicates that 50.74 m (i.e. 47.8%) of the sediment record consists of remobilized sediment (homogenites; ball and pillow structures, gravel units, slumps; turbidites) (Fig. 1, 3). Such deposits are almost absent in the top 12 mcd, where laminated clays and silts dominate. Correlation with an existing piston core (Haberzettl et al. 2007) allows a temporal relation to the Holocene. Apart from obviously remobilized deposits Holocene sediments are distinguished from Late Glacial deposits by a lower frequency of coarse silt and fine sand layers within a silt/clay matrix as well as by a higher concentration of autochthonous calcite.

Frequency and thickness of remobilized deposits increase with sediment depth. Most reworked sections are composed of three units: (1) a dark, coarse and fining upward base overlain by (2) a homogeneous layer of silt and (3) capped by a relatively thin light coloured clay layer (Fig. 2). Such sequences were often described as homogenites from marine sediments but are only rarely known from lakes.

In the record from Laguna Potrok Aike the thickest homogenites reach up to 3 m in thickness. In contrast, turbidites are characterized by a fining-upward pattern of the entire sequence. Apart from lithological descriptions such sequences are characterized by their magnetic susceptibility (Fig. 2). The peak of magnetic susceptibility occurs directly at the base and decreases upwards to the overlying homogeneous unit. The latter is bordered by decreasing values in the overlying light coloured clay cap. A comparable pattern is also reflected in the radiography (Fig. 2) where the absorbance of x-rays decreases upwards in unit 1, is almost constant in unit two and shows a minimum in unit 3.

Homogenites in lake and marine sediments are generally regarded as representing a record for regional seismicity or tsunami activity. Since homogenites are not only triggered by seismotectonic activity [Bertrand et al. 2008; Schmidt 1998] and no such deposits are represented in the Holocene sediments of Laguna Potrok Aike, we hypothesize that the generation of homogenites could be linked to different climate conditions during glacial times. Reasons for this climate link may be (1) higher clastic input through the main tributary or (2) an extremely low lake level.

The first option could be the result of more intense morphodynamic processes in the catchment area than today due to periglacial conditions with permafrost, forcing precipitation and melt water to run off superficially. Evidence for permafrost conditions in this region until the end of the last glacial is given by an OSL-dated sand wedge in the catchment area (19.1 ± 1.4ka). The latter explanation is supported by the occurrence of coarse gravel at the bases of some homogenites as well as by one chaotic gravel-dominated unit between 87 and 89 mcd, considering that the distal core today is located 1.8 km away from the main tributary. Furthermore, some Holocene seismically detected mass-wasting events of Laguna Potrok Aike were already explained by a lake level lowering [Anselmetti et al. 2009].

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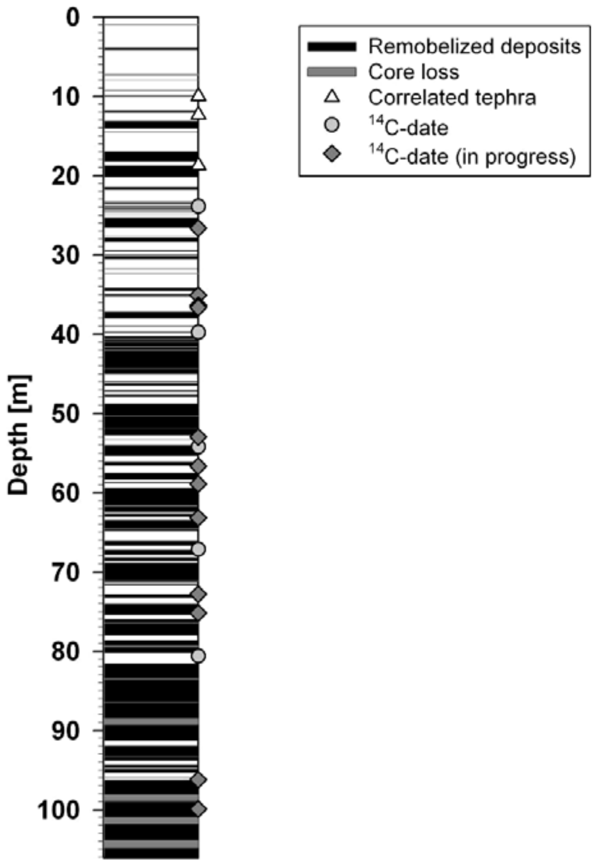


Fig. 1: Occurrence of remobilized deposits (black) as well as preliminary 14C-dates (ages in cal. BP), 14C-dates in progress and correlated tephra layers in the composite profile PTA-2.

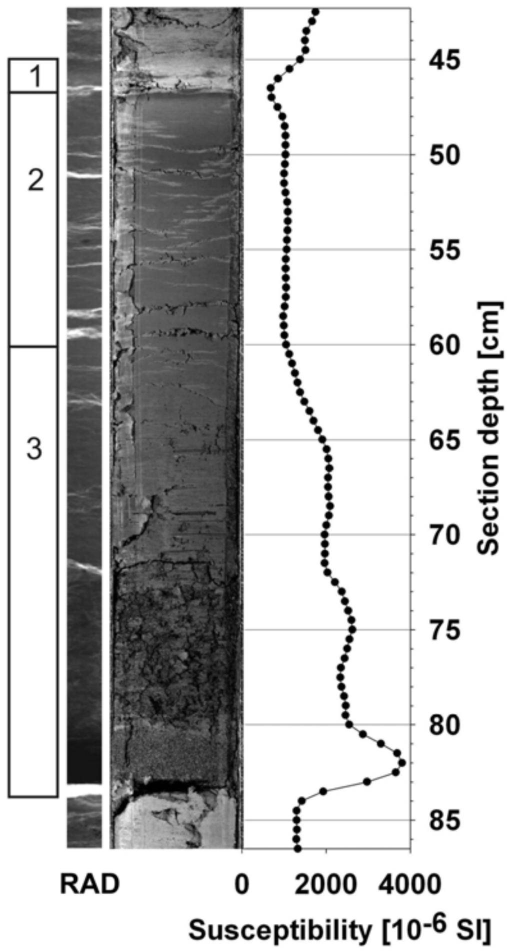
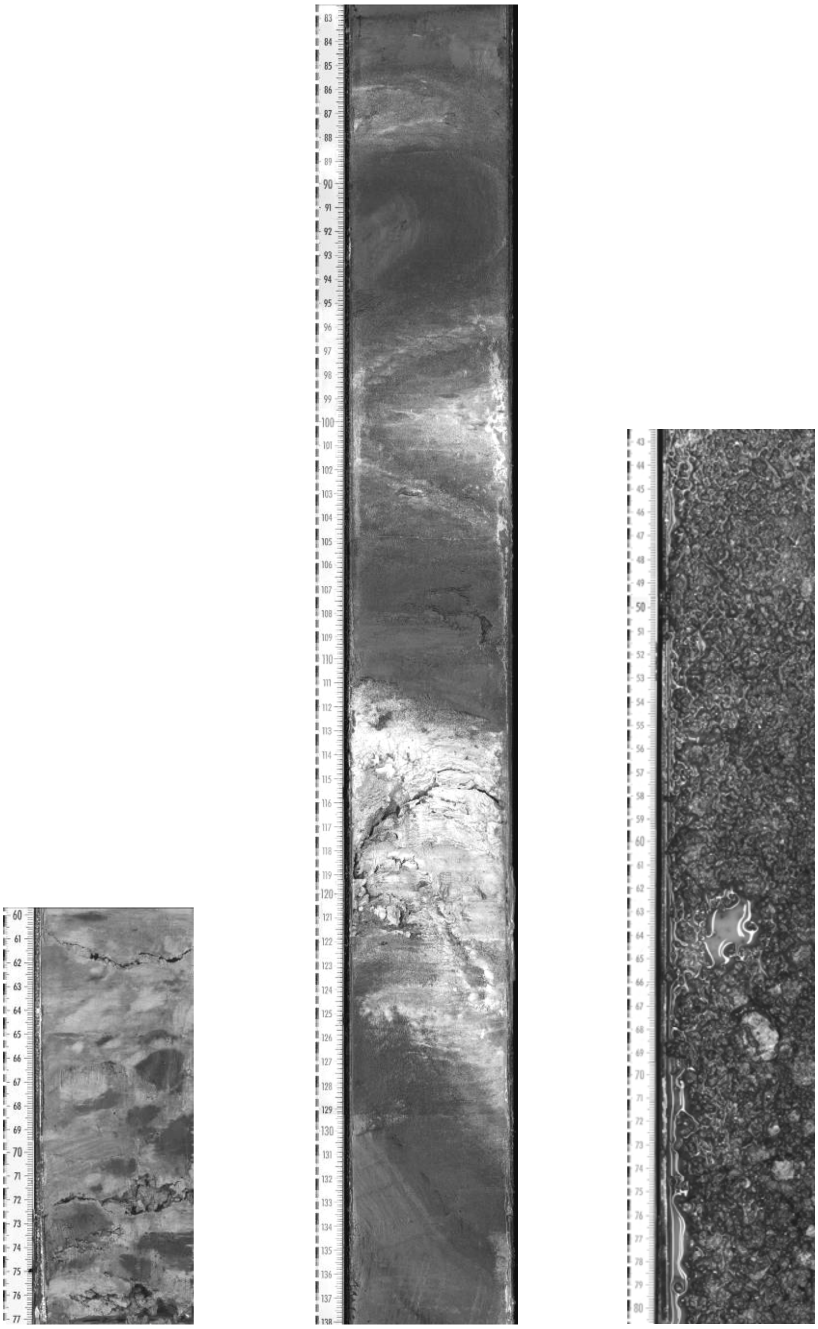


Fig. 2: Homogenite between ca. 21.4-21.8 mcd in core section 2A-8H-2 consists of three units (1: clay cap; 2: homogeneous layer of silt and clay; 3: fining upward sand and silt) outlined by visual lithological description, magnetic susceptibility (measured with a point sensor in 5 mm increments) and radiography (RAD). Note the horizontal expansion cracks in the radiographic image.



A: ~ 19.7-20.0 mcd B: ~ 77.4-77.9 mcd C: ~ 97.8-98.1 mcd

Fig. 3: Features of mass movement deposits in PTA-2 (A: ball and pillow structures; B: slump of a white tephra layer in between over- and underlying lacustrine sediment; C: unit of coarse sand and gravel).

Chironomids (non-biting midges) as indicators of environmental and climate changes

Isabelle Larocque-Tobler[1,2], Julieta Massaferro[3], Juan Jose Scagliotti[4], Vicky Tremblay[1] and Pierre Francus[1]

[1] Institut National de la Recherche Scientifique, Centre Eau, Terre et Environnement, 490 rue de la couronne, Québec, QC G1K 9A9, Canada

[2] Institute of Geography, University of Bern, Erlachstrasse 9A, 3012 Bern, Switzerland

[3] CENAC APN, CONICET, Bariloche, Argentina

[4] ILPLA CONICET, La Plata, Buenos Aires, Argentina

One of the most promising biological proxies preserved in lake sediments to reconstruct summer temperatures are chironomids (non-biting midges, e.g. Battarbee, 2000). Chironomids are abundant aquatic insects. They can be found on all continents, in an extremely diverse array of environments (reviewed in Armitage et al., 1997).

While the adult stage is a terrestrial winged insect (Figure 1), the larvae develop in or on the surface of different substrates (sediments, plants, dead wood, other invertebrates), in aquatic, humid or semi-terrestrial environments (lakes, ponds, rivers, estuaries, bogs, marshes, etc). Most species go through four distinct larval stages, each leaving behind a molted head capsule with the potentiality of being preserved. Different species have specific ecological preferences and tolerances which make them useful indicators of various environmental variables.

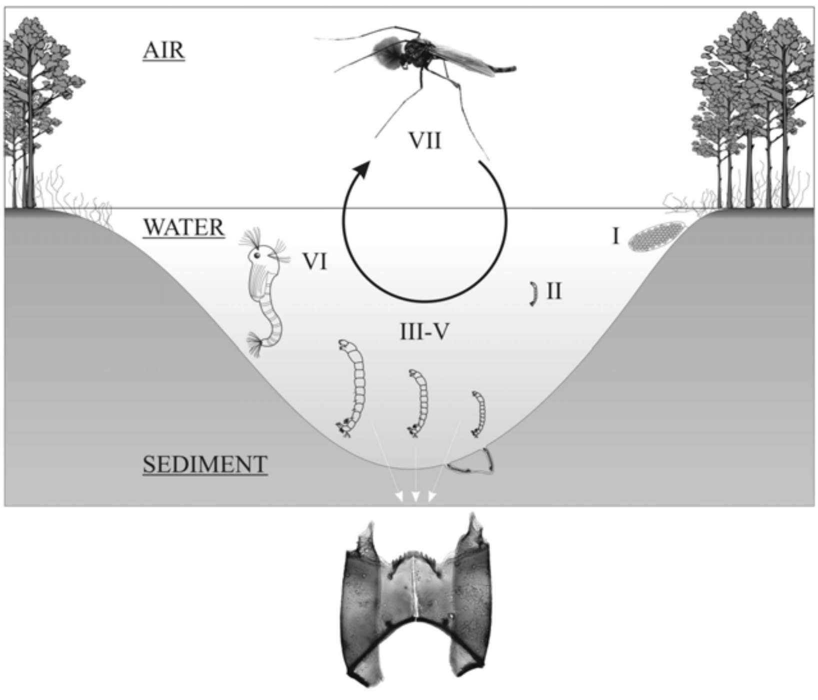


Fig. 1: Life cycle of a chironomid (from Larocque and Rolland, 2006).

In lake sediments, the chitinous ($C_6H_{12}O_5N$) head capsules of chironomid larvae preserve well and can be identified to genus, even to species level in certain cases, making it possible to characterize past assemblages with a high degree of accuracy. This has made the use of subfossil chironomid assemblages a powerful paleoenvironmental tool used both qualitatively and quantitatively to infer various limnological variables such as trophic status (Lotter et al., 1998), oxygen level (Quinlan and Smol, 2002), salinity (Heinrichs et al., 2001), depth (Korhola et al., 2000), lake size and acidification (Mousavi, 2002) and chlorophyll a (Brodersen and Lindegaard, 1999).

In the late 1980’s, Walker and Mathewes (1989a) showed that temperature is an important factor explaining the distribution of chironomids in lakes in northern Canada. This pioneer study brought a heated discussion on the relationship between chironomids and climate (Warwick, 1989; Walker and Mathewes, 1989b). Since then, studies on the distribution of chironomid communities in many lakes in various countries have demonstrated the relationship between temperature and chironomid assemblages (e.g. Walker et al., 1997; Brooks and Birks, 2000; Porinchu et al., 2009). In the 1990’s, the development of statistics (Birks, 1998) brought the necessary tools (called transfer functions) to quantitatively reconstruct climate using biological proxies.

The principles for developing a reconstruction model are quite simple (Fig. 2). First, a number of lakes are sampled along a large temperature gradient. The complete set of lakes is called a “training set”. In these training set lakes, the surface sediment is sampled and chironomid head capsules are extracted and identified. In each lake, chemical, physical and environmental parameters are measured. Using canonical correspondence analysis (CCA), the parameters which explain the distribution of the subfossil chironomids in the training set lakes are determined. The taxa found in each lake are linked to the physical parameter which has a greater influence on their distribution (in our case, temperature). Based on their distribution in the training set lakes, a temperature optimum is calculated for each chironomid taxon. A mathematical model (called transfer function) is then developed, and this transfer function is used to infer the temperature from chironomid assemblages preserved in the sediment of various lakes.

Climate reconstruction

Such a transfer function is being developed in Argentina (J. Massaferro) to quantitatively reconstruct climate from chironomids preserved in Laguna Potrok Aike. Preliminary results in 16 lakes located between 50 and 53 degrees south (Fig. 3) suggests that climate (wind and/or temperature) and lake levels might be one of the parameters influencing the distribution of chironomids in these lakes. Other lakes will be sampled in 2010 to increase the number of lakes in the training set.

The main objectives of this research will be to reconstruct climate and answer these key questions:

How did climate change through time over the last two interglacials?

What was the rate of climate change following deglaciation?

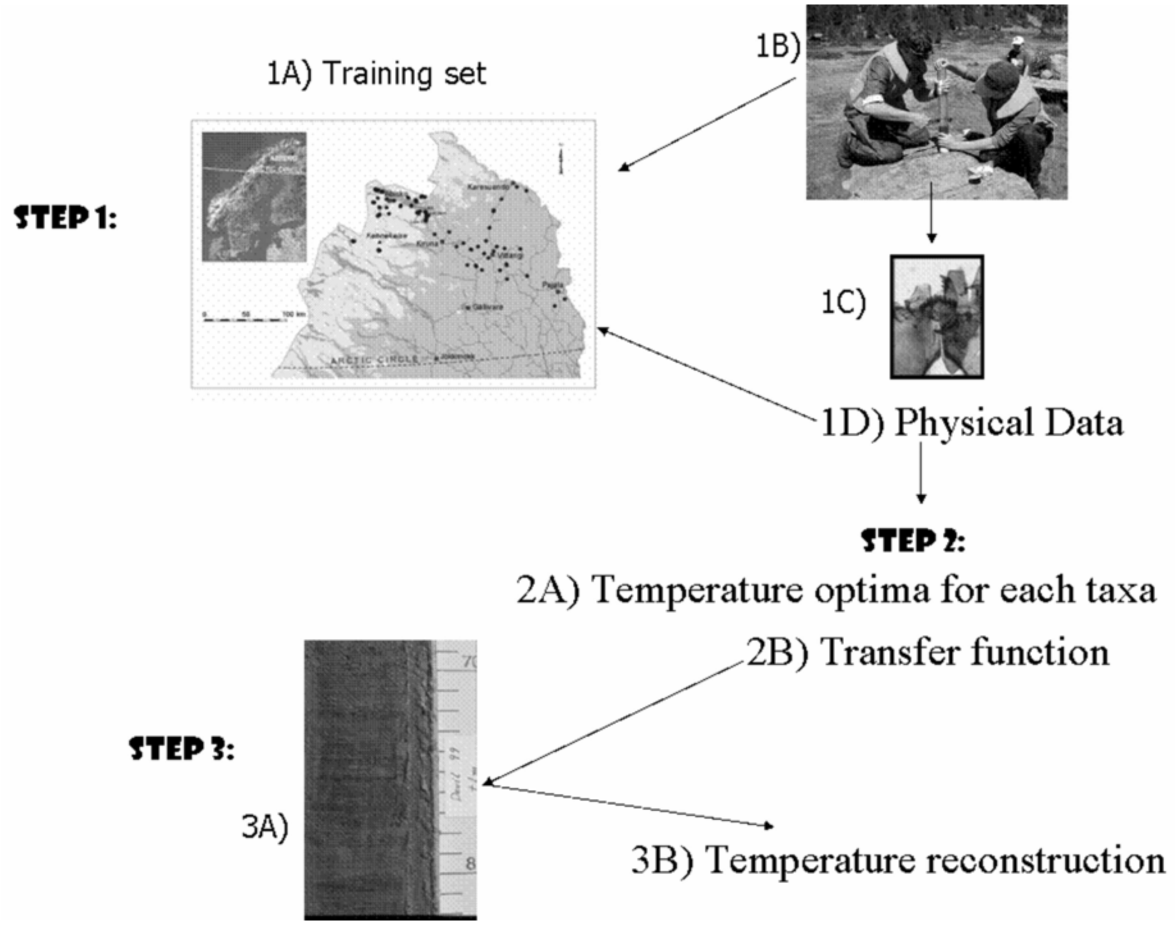


Fig. 2: Steps in the development of a transfer functions (from Larocque and Rolland, 2006).

Fig. 3: Distribution of transfer-function lakes in southern Patagonia, Argentina.

To answer these two questions, chironomid head capsules will be extracted from two sets of samples: a) at 4-cm intervals along the cores to obtain a climate reconstruction over the last two interglacials and b) at 2-cm intervals in two subsections (1332 – 1577.4 cm and 3803.4 – 4157.2 cm) to have a higher-resolution climate reconstruction following deglaciation.

The relationship between chironomid changes through time and various parameters will need to be studied before applying a transfer function. Laguna Potrok Aike is a very deep lake (maximum water depth: 100 m) and the relationship between chironomids and temperature was established mostly for lakes shallower than about 20 m (e.g. Larocque et al., 2001; 2006). It is highly possible that other factors such as changes in oxygen levels might influence the chironomid assemblages in Laguna Potrok Aike. However, Larocque et al. (2009) have shown a good relationship ($r=0.65$, $p<0.01$) between mean July air temperatures inferred by chironomids and instrumental data in Lake Silvaplana, a lake with a maximum depth of 77 m (Fig. 4). It is thus possible that even in Laguna Potrok Aike chironomids could be used to quantitatively reconstruct climate.

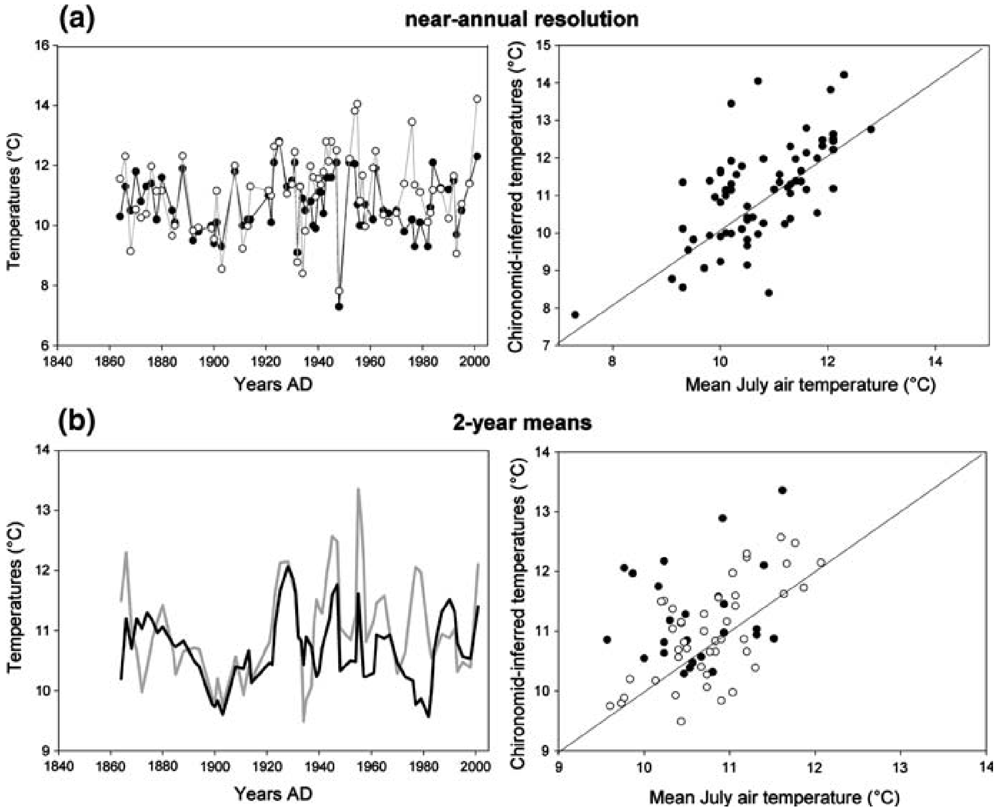


Fig. 4: Temperature inferences (mean July air temperature) obtained with chironomids compared with the instrumental data at (a) near-annual resolution. The left panel shows the general pattern of temperature changes as inferred from chironomids (empty circles) and the instrumental data (black circles). The right panel is the relationship between inferences and instrumental data. The line is the 1:1 relationship (b) with running means. On the left panel, the grey line is a 2-point running mean in the temperature inferences while the black line is a 2-year running mean in the instrumental data. The horizontal line is the climate normal (average mean July air temperature between 1960 and 1990). The right panel is the relationship between inferences and instrumental data. The empty circles represent

the samples before 1950 and the black circles represent the samples after 1950. The line is the 1:1 relationship.

Environmental changes and evolution

The chironomid study at Laguna Potrok Aike also offers the possibility of studying evolution of chironomid taxa through time. No other study using chironomids has been achieved on such a long temporal scale. While transfer functions are based on the assumption that the taxa were never modified through time, a longer temporal scale study could bring insight on questions such as:

Have some taxa disappeared through time?

Did taxa change their relationship with climate through time?

Preliminary results on a Holocene core from Laguna Potrok Aike has shown that the chironomid diversity was low (Massaferro et al., in prep) and the main taxa were littoral such as *Phaenopsectra*, *Cricotopus spp*, *Smittia* and *Limnophyes* (Fig. 5).

Another question that this project will try to answer is:

Did the diversity increase or decrease with climate change?

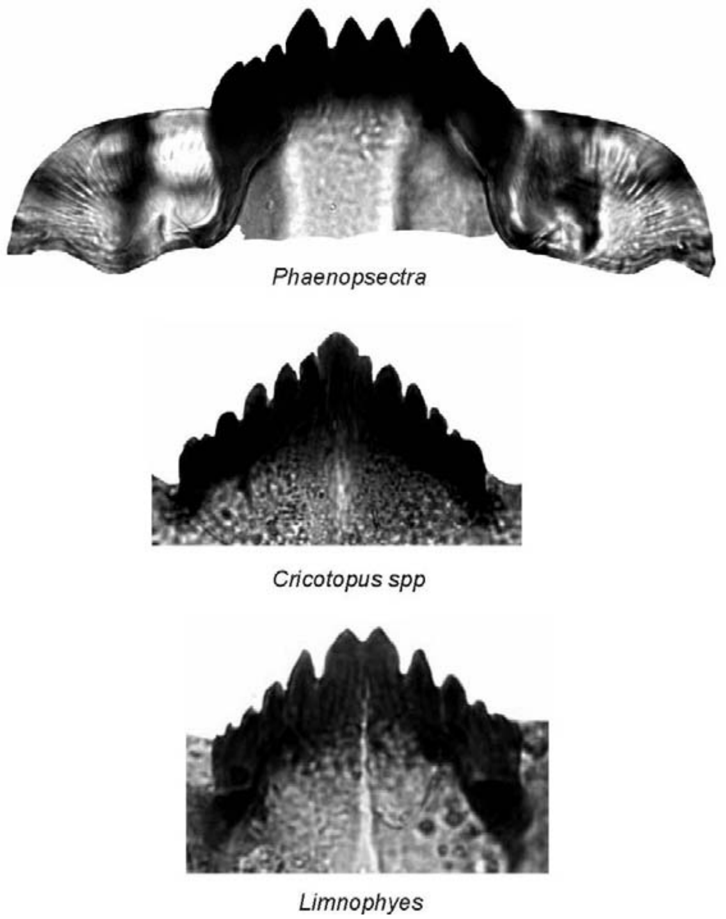


Fig. 5: Examples of chironomid taxa found in Laguna Potrok Aike (Photos: N. Rolland).

Larocque et al. (2009) and Larocque-Tobler et al. (2009) have shown that the chironomid diversity increased during warm periods of the past in Lake Silvaplana, Switzerland. Similarly, diversity was at its maximum in association with warmer climate in lakes of Norway (Velle et al., 2005) and Canada (Palmer et al., 2002). It will be interesting to determine if this is true in Laguna Potrok Aike as well. The main interest will be to evaluate the possible changes in chironomid community with climate warming.

Preliminary results on a 16m core from Laguna Potrok Aike already suggest that the concentration in chironomids is highly variable (Fig. 6). According to Scagliotti and Massaferro (in prep.), the variation in concentration might be due to higher erosion of chironomid head capsules due to changes in lake levels, associated with colder and windier climate. However, this hypothesis will be tested on longer temporal scales in this project.

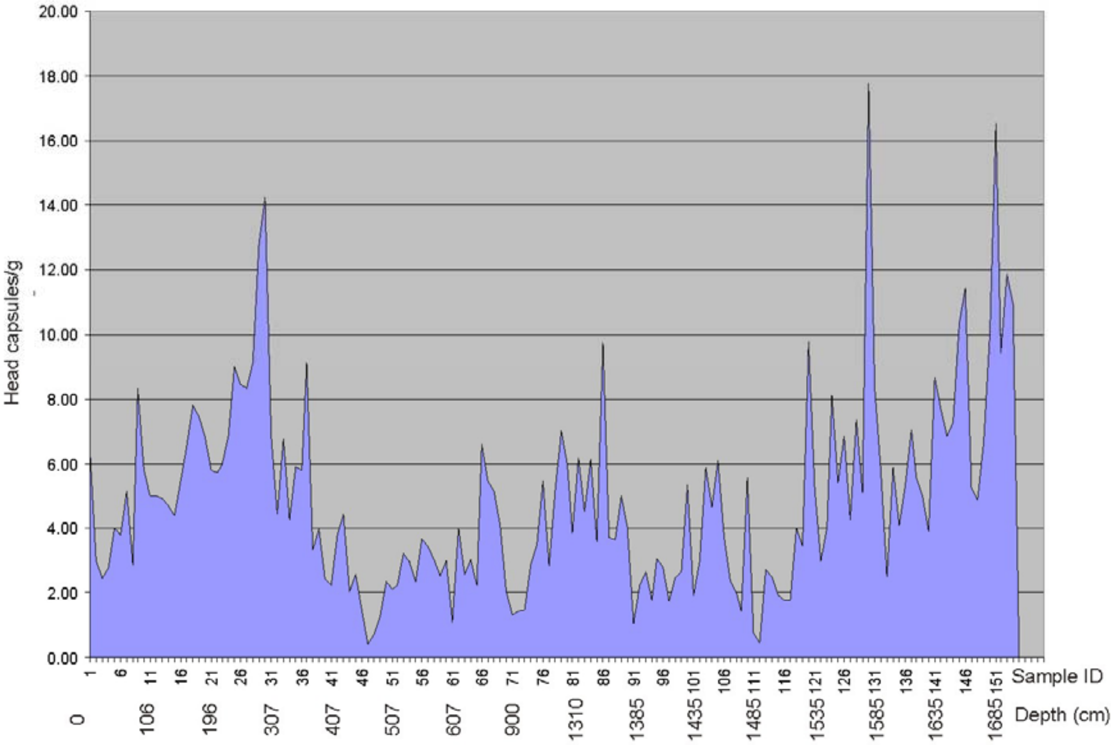


Fig. 6: Variations of chironomid head capsules with core depth. These variations are possibly associated with changes in lake levels and windier and colder climate

Comparison with other proxies

The strength of this project is in using the multi-proxy approach to reconstruct climate and/or other environmental parameters to better understand the link between climate and hydrological processes. Chironomids will be used to make a multi-proxy quantitative climate reconstruction. But other proxies will also be used for independent climate reconstruction to answer the environmental and evolution questions raised here.

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Paleomagnetism, magnetostratigraphy and environmental magnetism of Late Pleistocene and Holocene sediments from Laguna Potrok Aike (Argentina): Preliminary results from the ICDP-PASADO drilling

Agathe Lisé-Pronovost[1,2], Torsten Haberzettl[3], Guillaume St-Onge[1,2] and the PASADO science team[4]

[1] *Institut des sciences de la mer de Rimouski (ISMER), Université du Québec à Rimouski (UQAR), 310 allée des Ursulines, Rimouski G5L 3A1, Québec, Canada*

[2] *GEOTOP research center*

[3] *Physical Geography, Institute of Geography, Friedrich-Schiller-University Jena, Löbdergraben 32, D-07743 Jena, Germany*

[4] *http://www.pasado.uni-bremen.de/index.html*

High-resolution paleomagnetic reconstructions from sedimentary sequences are scarce in the Southern Hemisphere. Therefore, the millennial- to centennial-scale variability of the geomagnetic field is under-represented relative to the Northern Hemisphere and the possible global nature of that variability cannot be assessed. This project is the first high-resolution Late Pleistocene and Holocene paleomagnetic reconstruction from a continental archive south of 42°S in South America. Laguna Potrok Aike (51°58', 70°23'W) is a maar lake located in the Pali Aike Volcanic Field in southern Patagonia (Argentina), where sediments accumulated at very high rates during the Holocene (> 100 cm/ka). In austral spring 2008, the multi-national Potrok Aike maar lake Sediment Archive Drilling prOject (PASADO) science team drilled two ~100 m holes under the framework of the International Continental scientific Drilling Program (ICDP). The scientific objectives of this sub-project are to 1) reconstruct the full geomagnetic vector (inclination, declination and relative paleointensity); 2) use magnetostratigraphy as a regional chronostratigraphic tool for Laguna Potrok Aike, in addition to radiocarbon, luminescence, uranium isotopes series and tephrochronology dating approaches; 3) develop paleoenvironmental proxies for rapid climate changes using magnetic properties of the sediment.

A preliminary Holocene age model of the PASADO-ICDP core based on comparison of magnetic susceptibility data from that core with a well-dated (radiocarbon- and tephra-based chronology) core located nearby in the center of the lake (PTA03-12) indicates a deposition of ~19 m of lacustrine sediments since 16 ka cal BP. Hysteresis measurements in this interval using an alternating gradient force magnetometer indicate a magnetic assemblage dominated by magnetite grains in the pseudo-single domain range. Principal component analysis (PCA) inclination and declination profiles were constructed from the stepwise alternating field demagnetization of the natural remanent magnetization (NRM) measured on u-channels at 1 cm intervals using a 2G Enterprises cryogenic magnetometer. The PCA inclinations vary around the expected geocentric axial dipole (GAD) inclination for the latitude of the coring site and the maximum angular deviation (MAD) values are generally lower than 5°, indicating high quality paleomagnetic data. Furthermore, the PASADO-ICDP paleosecular variation (PSV) record for the last 16 kyr BP displays similar variations with the available records from marine sediments in the South Atlantic, South Pacific and Southern oceans, as well as from lacustrine sediments further north in Argentina. Altogether, the preliminary results indicate a genuine geomagnetic origin of the recently gained data and indicate the great potential of the drilled core for further paleomagnetic investigations which will be accomplished within the next year.

Carbon and nitrogen isotope composition of core catcher samples from the ICDP deep drilling at Laguna Potrok Aike (Patagonia, Argentina)

Andreas Lücke[1], Holger Wissel[1], Christoph Mayr[2,3], Markus Oehlerich[2], Christian Ohlendorf[4], Bernd Zolitschka[4] and the PASADO Science Team

[1] *Institute of Chemistry and Dynamics of the Geosphere 4: Agrosphere (ICG 4), Energy & Environment, Research Center Jülich, Germany*

[2] *GeoBio-CenterLMU and Dept. of Earth & Environmental Sciences, University of Munich, Germany*

[3] *present address: Institute of Geography, University of Erlangen, Germany*

[4] *Institute of Geography (Geopolar), University of Bremen, Germany*

The ICDP project PASADO aims to develop a detailed paleoclimatic record for the southern part of the South American continent from sediments of Laguna Potrok Aike (51°58'S, 70°23'W), situated in the Patagonian steppe east of the Andean cordillera and north of the Street of Magellan. The precursor project SALSA recovered the Holocene and Late Glacial sediment infill of Laguna Potrok Aike and developed the environmental history of the semi-arid Patagonian steppe by a consequent interdisciplinary multi-proxy approach (e.g. Haberzettl et al., 2007).

From September to November 2008 the ICDP deep drilling took place and successfully recovered in total 503 m of sediments from two sites resulting in a composite depth of 106 m for the selected main study Site 2. A preliminary age model places the record within the last 50,000 years. During the drilling campaign, the core catcher content of each drilled core run (3 m) was taken as separate sample to be shared and distributed between involved laboratories long before the main sampling party. A total of 70 core catcher samples describe the sediments of Site 2 and will form the base for more detailed investigations on the paleoclimatic history of Patagonia.

Here we report on the organic carbon and nitrogen isotope composition of bulk sediment and plant debris of the core catcher samples. Similar investigations were performed for Holocene and Late Glacial sediments of Laguna Potrok Aike revealing insights into the organic matter dynamics of the lake and its catchment as well as into climatically induced hydrological variations with related lake level fluctuations (Mayr et al., 2009). The carbon and nitrogen content of the core catcher fine sediment fraction (<200 µm) is low to very low (around 1 % and 0.1 %, respectively) and requires particular attention in isotope analysis (Fig. 1, 2). The carbon isotope composition shows comparably little variation around a value of -26.0 per mil. The positive values of the Holocene and the Late Glacial (up to -22.0 ‰) are only sporadically reached down core (Fig. 3). Compared to this, separated moss debris is remarkably ^{13}C depleted with a minimum at -31.5 ‰. The nitrogen isotope ratios of glacial Laguna Potrok Aike sediments are lower (2.5 ‰) than those of the younger part of the record (Fig. 4). The core catcher samples indicate several oscillations between 0.5 and 3.5 ‰. Data suggest a correlation between nitrogen isotopes and C/N ratios (Fig. 5), but no linear relation between carbon isotopes and carbon content and an only weak relationship between carbon and nitrogen isotopes. Increasing nitrogen isotope values from 80 m downwards could probably be related to changed environmental conditions during Marine Isotope Stage 3 (MIS 3) compared to MIS 2. Further analyses will increase the resolution in the composite profile and include the oxygen isotope composition of discrete plant debris layers as well as of phases bearing biogenic silica.

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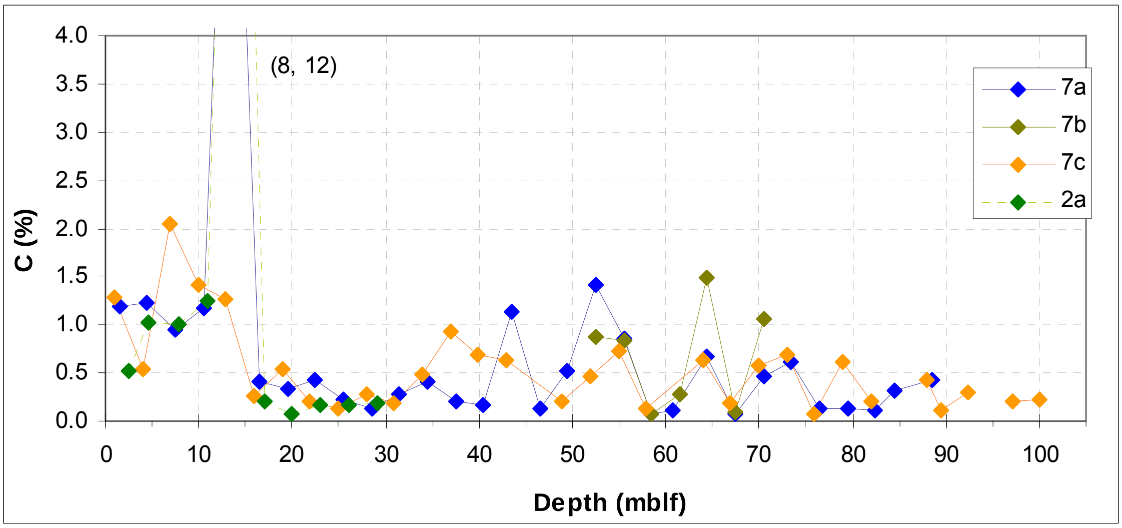

Fig. 1: Carbon content of core catcher samples as determined with IRMS.

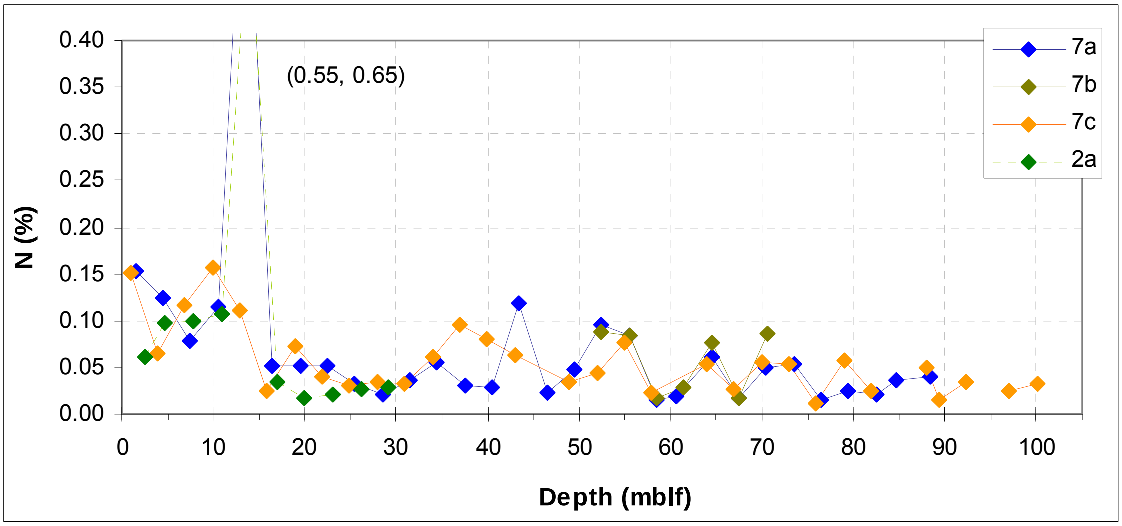

Fig. 2: Nitrogen content of core catcher samples as determined with IRMS.

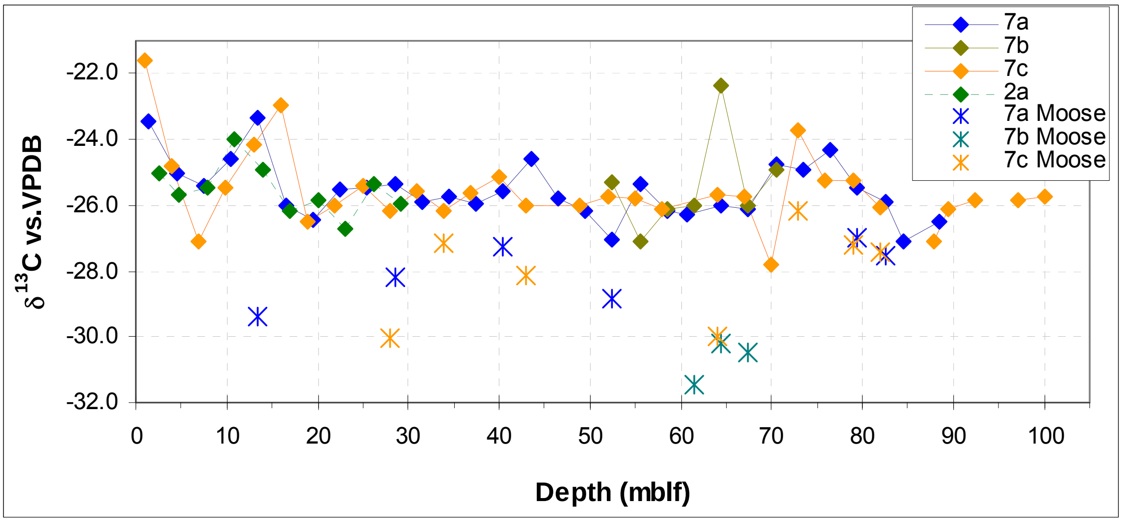

Fig. 3: Organic matter carbon isotope composition of sieved decarbonized sample and selected mosses.

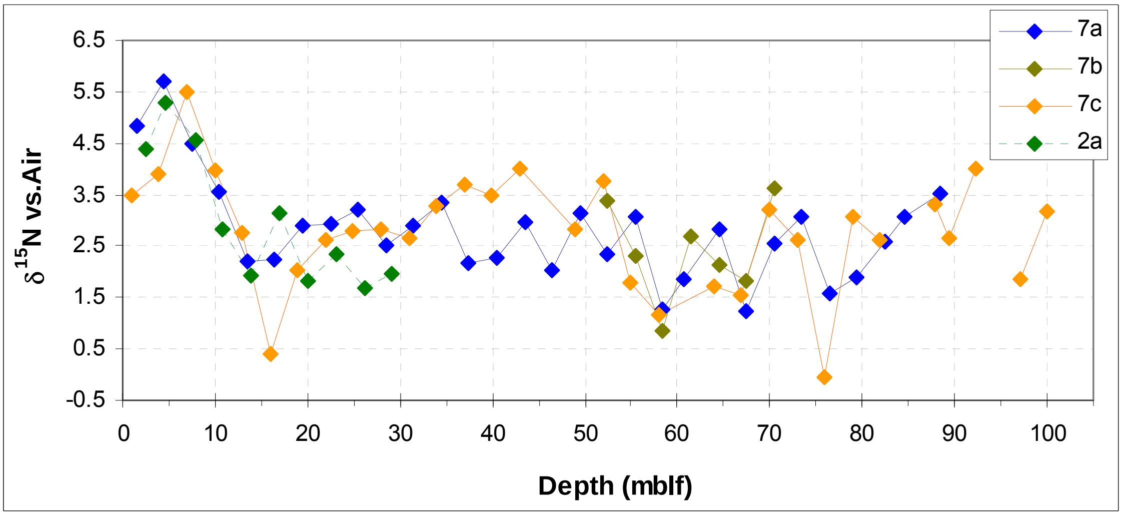

Fig. 4: Organic matter nitrogen isotope composition measured on untreated sieved sample.

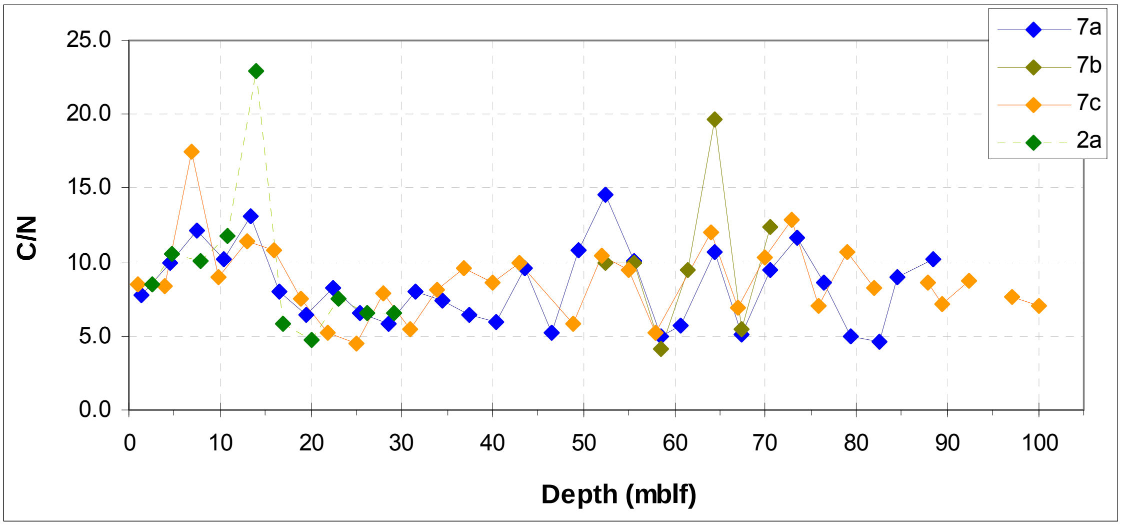

Fig. 5: Total organic carbon to total nitrogen ratio (TOC/TN) as determined on the sieved core catcher samples.

Carbonates from the ICDP-site Laguna Potrok Aike: Mineralogy, isotopic composition and sample pre-treatment effects

Christoph Mayr[1,2,3], Markus Oehlerich[1], Andreas Lücke[4], Erika Griesshaber[1], Stephanie Kastner[5], Oliver Oeckler[6], Christian Ohlendorf[5], Wolfgang Schmahl[1], Bernd Zolitschka[5] and the PASADO Science Team

[1] *Earth and Environmental Sciences, LMU Munich, Germany*

[2] *Geo-Bio-Center, LMU Munich, Germany*

[3] *present address: Institute of Geography, University of Erlangen-Nuremberg, Germany*

[4] *Institute of Chemistry and Dynamics of the Geosphere 4: Agrosphere (ICG 4), Energy & Environment, Research Center Jülich, Germany*

[5] *GEOPOLAR, Institute of Geography, University of Bremen, 28334 Bremen, Germany*

[6] *Department of Chemistry, LMU Munich, Germany*

Endogenic carbonates occur in two different phases, calcite and ikaite at the International Continental Drilling Project (ICDP) site Laguna Potrok Aike (51°57´S, 70°23´W). Calcite ($CaCO_3$ of the trigonal crystal system) is abundantly present in Holocene sediment sections as finely dispersed crystals of less than 10 µm in size. These crystals resemble the features of endogenically precipitated calcites as known from many other lakes (e.g., Raidt & Koschel, 1988). Ikaite was detected during the ICDP drilling campaign in September 2008. Up to ca. 3 mm large, transparent, sigmoidally shaped and idiomorphic crystals were found abundantly in the 4°C cool lake water, especially on submerged items like aquatic plants or ropes. Single crystal X-ray diffraction analyses on samples that were permanently kept cool document that these crystals were ikaite ($CaCO_3 \cdot 6H_2O$ of the monoclinic crystal system), a hydrated calcium carbonate mineral occasionally found in marine sediments but rarely reported from non-marine environments. Ikaite precipitation has been observed only at temperatures below 5-8°C (DeLurio & Frakes, 1999). Because of the stability field of ikaite (Marland, 1975), after air exposure, the crystals from Laguna Potrok Aike soon transformed to porous, polycrystalline, fragile pseudomorphs that rapidly disintegrated into µm-sized calcite crystals.

Calcite pseudomorphs after ikaite can be preserved by calcite cementation (e.g., Larsen, 1994) and then their presence in the sedimentary record indicates cool water temperatures. So far no preserved pseudomorphs have been identified in the sediment record of Laguna Potrok Aike. However, the similar morphologies of originally precipitated calcite and calcite from disintegrated modern ikaite raise the question, if µm-sized ikaite-derived calcite crystals are also present in the lake sediment and how to distinguish between both carbonate sources. Stable isotope analyses were applied to resolve that question. Preliminary $\delta^{13}C$ and $\delta^{18}O$ results separate isotope values of calcites derived from ikaite from those of the surface sediments of the same lake. These first isotopic results suggest that the calcites from profundal sediments have a different origin than the ikaite-derived calcites from the littoral zone.

The sediment profile recovered during the ICDP drilling at Laguna Potrok Aike archives more than 50,000 years of environmental change in the steppe of southern Patagonia. The isotopic composition of carbonates can give information about past water temperatures and hydrological variability. First results show that the carbonate content is high (up to ~20 wt. %) in the Holocene, but low or even absent in the glacial interval of the sediment record. The presence of organic matter, especially in conjunction with low carbonate content, can bias carbonate isotope values due to the release of carbon dioxide from organic matter decomposition during the acidification necessary to produce measuring gas. Thus, a sample pre-treatment is often advised to remove organic compounds (e.g., Ito, 2001). Therefore, we tested several methods to pre-treat bulk samples for removal of organic compounds. First results show that the commonly used pre-treatment with sodium hypochlorite (NaOCl) to remove organic compounds from sediment samples leads to erroneous results. This is in accordance with recent investigations by Wierzbowski (2007). Our present efforts are to overcome these difficulties by (1) investigating which organic materials potentially affect carbonate stable isotope analyses and (2) testing alternative methods (e.g. H_2O_2 bleaching, no pre-treatment). The method with the least impact on isotope composition will then be applied for investigating the carbonate isotope record from Laguna Potrok Aike.

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On-site and off-site core processing procedures applied during the ICDP-project PASADO

Christian Ohlendorf[1], Catalina Gebhardt[2], Annette Hahn[1], Pierre Kliem[1], Bernd Zolitschka[1] and the PASADO Science Team[3]

[1] *Geopolar, Institute of Geography, University of Bremen, 28334 Bremen, Germany*

[2] *Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany*

[3] *PASADO Science Team as cited at: http://dc-app1-02.gfz-potsdam.de/site/contacts/contacts-search-all?select=3&term=pasado*

Lake drilling in the framework of the ICDP project PASADO (Potrok Aike Maar Lake Sediment Archive Drilling Project) was carried out between September and late November 2008. From the maar lake Laguna Potrok Aike (52°S, 70°W; 116 m a.s.l.; diameter: 3.5 km; water depth: 100 m) in southern Patagonia, Argentina, in total 510 m of lacustrine sediments have been recovered using the GLAD800 platform equipped with a CS-1500 drill rig. At two drill sites quadruplicate (site 1) and triplicate (site 2) cores down to a maximum depth of 101.5 m below lake floor have been recovered using mainly the hydraulic piston coring tool. Recovered core sections and core catcher samples were transferred to the shore-based field laboratory where first on-site measurements were done.

Owing to the great diversity of continental drilling projects, workflow in an ICDP deep drilling project seems to be much less standardised then it is the case for IODP projects. For instance, according to our knowledge, PASADO was the first ICDP project where continuous subsamples were taken for the entire sediment sequence (106 m). Such an approach requires logistical preparations different from sub-sampling campaigns of cores drilled in the framework of most other projects. We therefore take this as an opportunity to present field and lab protocols that were applied during the PASADO drilling and subsampling campaigns. Sample handling begins already on-site as soon as the core is handed over from the drilling crew to the onboard scientists with cutting the core runs into sections and packaging the core catcher samples. For the latter, analysis in the on-site field lab included sample description, photography, smear slide preparation and the determination of water content, as well as producing a suspension and a HCl-extract in which conductivity, Ca^{2+}- and Cl^- concentration were measured. Core sections were weighted and magnetic susceptibility was logged.

For the off-site lab procedures it was important to design a workflow that accounts for the needs of all involved research groups. In 2009 all cores from Site 2 (southern part of the deep, central basin) and all except one core from Site 1 (central deep basin) were opened, described, documented by digital high resolution photography and scanned with different non-destructive techniques. Core scanning was performed at 5 mm resolution for all parameters and involved the following techniques: 1) color scanning with a handheld X-rite spectrometer, 2) magnetic susceptibility scanning with a Bartington MS2F-sensor, 3) XRF scanning and X-radiography with an ITRAX core scanner (COX analytical systems) and 4) p-wave velocity/transmission seismograms and gamma ray absorption with a modified Geotek MSCL tool.

Immediately after non-destructive scanning analyses were finished, core halves were covered with cling-film, vacuum sealed in tubular film and stored at 4°C to prevent drying and surface oxidation of sediments until sampling begun.

An essential task was to amalgamate all cores from one site to establish a composite profile that then could be sampled in consecutive steps. For Site 2, a 106.08 m long composite profile was composed based on visual core correlation and core scanning data. The working half of this composite profile was then sampled completely in consecutive 2 cm thick intervals. Using an especially designed sampling device each sample was divided into 6 volumetric and one non-volumetric sub-samples during the sampling process, whereas smeared sediment close to the liner wall was discarded. Subsamples were stored and processed according to the needs of the respective research groups. From the archive half a U-channel was taken, which is regarded as the archive sediment for the PASADO project, since only non-destructive rock- and paleomagnetic analyses will be performed on it. In the trench that was left behind from U-channel trepanning, samples for thin section preparation, grain size analysis and micro magnetic properties were taken. Based on the core description and a detailed inspection during sampling 1) 18 samples of aquatic moss remains were sieved out for AMS ^{14}C dating, 2) 16 samples of tephra layers were taken for geochemical fingerprinting and 3) a first identification of redeposited sediment sections was accomplished. According to first results from these samples, the sedimentary record from Laguna Potrok Aike reaches back to approx. 50 ky BP and exhibits contrasting lithologies down core especially in the Pleistocene part of the record. First estimates indicate that up to 50% of the record consists of redeposited sediments.

Core series 1A, 1B and 1C from Site 1 were opened and sampled for rock- and paleomagnetic studies whereas core series 1D was reserved for OSL-dating. From the latter core series selected sections were split and sampled under red light. The sampled halves as well as the non-sampled archive halves were photographed digitally to assure 1) the exact positions of OSL samples and 2) the exact correlation with parallel cores from Site 1 and with the composite profile of Site 2. All not sampled core sections from 1D were then opened under red light. The archive half was immediately sealed in black tubular film to conserve the possibility of later OSL sampling, whereas the working half was photographed digitally, vacuum sealed in tubular film and stored at 4°C. Through a thorough correlation of Site 1 cores with the Site 2 composite profile the OSL chronology will then be available for both sites.

Macroscopic charcoal analysis from lacustrine sediments as a methodology to reconstruct fire history: First results from Santa Cruz (50°-52°S), Argentina

Flavia A. Quintana & Maria M. Bianchi

Instituto de Investigaciones en Biodiversidad y Medio Ambiente, INIBIOMA, CONICET-CRUB, Quintral 1250, 8400 San Carlos de Bariloche, Río Negro, Argentina

This research is aimed to determine the relationship between the characteristics of modern fire events (magnitude, severity, location) and macroscopic charcoal particle deposition in lakes of Southern Santa Cruz (Patagonia, Argentina). This calibration constitutes the first step for reconstructing the fire history of this region based on macro charcoal data obtained from cores within the PASADO project. Relationships between fire episodes, climatic variability and human activity at millennial to centennial scales have been studied in sedimentary records from Patagonia showing the importance of fire as an agent operating since the postglacial period. However, no records far beyond the Last Glacial Maximum have been recovered yet and most of the obtained records have been acquired from sites located in the Subantartic Forest and forest-steppe ecotone. Therefore, charcoal records of PASADO would give the unique opportunity to contrast trends of fire regimes in other ecosystems than the forests in the region. Due to the current low frequency of lightening in this area, the origin of past fires is still under discussion (climate variability vs. human activity). Past fire occurrences have been attributed to activities of prehistoric inhabitants. However, other authors suggest that the Holocene climatic variability would have influenced the natural agents of fire production, e.g. the lightening frequency. The charcoal analysis of the PASADO records would give the opportunity to asses this controversial issue. The current methodology includes the size and quantitative analysis of macro-particles of charcoal along with pollen content in modern and fossil lacustrine sediment samples. A method to examine the macroscopic charcoal content (charcoal size >0.125 mm) instead of microscopic charcoal on pollen slides is proposed. Microscopic charcoal counting has been pointed out as non-adequate for calculating fire frequency because it is dependent on the resolution of pollen analysis and the source area (local, regional) is ambiguous. As a first approach, the macroscopic charcoal content of surface sediments from fifteen lakes along an east-west gradient has been analyzed and a number of known fire events in this area have been mapped. This constitutes the first step of calibration in order to correlate size and quantity of charcoal particles in lakes with the proximity and spatial characteristics of known fire events. Current fire records from 2000 to 2007 (Consejo Agrario Provincial, Santa Cruz) point out that most of fires occur in the steppe due to human causes. In the forest, records of Parque Nacionales indicate that one fire event per year also occurs due to human causes. Preliminary results indicate that concentration of particles bigger larger than 63 μm in the steppe (2.8 to 187.2 particles/cm^3) is higher than in the forest-steppe ecotone (11.4 to 49 particles/cm^3) and the forest (8.6 to 74.8 particles/cm^3). Concentration of particles bigger than 125 μm and 250 μm display high values in the forest (1.4 to 32.8 particles/cm^3 and 1.4 particles/cm^3, respectively) and the forest-steppe ecotone (1.8

to 26 particles/cm^3; 0.6 to 1.4 particles/cm^3), and low values in the steppe (1.6 to 18.4 particles/cm^3 and 0.2 to 0.4 particles/cm^3). This proposal is in the framework of the Proyecto Interdisciplinario Patagonia Austral (PIPA, PICT 2006-02338). One of the major aims of PIPA is to construct a modern biodiversity data base of organisms and organic remains sensitive to or indicative of environmental variability and its relationship with physical and chemical characteristics of lakes and climatic factors between 50º and 52ºS in the Santa Cruz Province.

Diatoms as indicators of hydrologic and climatic change in Lake Potrok Aike, Argentina - A step toward deciphering changing patterns of paleoecological conditions in Southern Patagonia

Cristina Recasens[1], Nora I. Maidana[2], Daniel Ariztegui[1], Flavio S. Anselmetti[3] and the PASADO Science Team

[1] Department of Geology & Paleontology, University of Geneva, Rue des Maraichers 13, CH-1205 Geneva, Switzerland

[2] Departamento de Biodiversidad y Biología Experimental. Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina

[3] Swiss Federal Institute of Aquatic Science and Technology (EAWAG), Dübendorf, Switzerland

Diatom stratigraphy in well-dated sedimentary records is widely used as a tool to characterize and often quantify the impact of past environmental changes in aquatic systems. This study investigates the diatoms of Laguna Potrok Aike, a maar lake located in Southern Patagonia as part of the Potrok Aike Maar Lake Sediment Archive Drilling Program (PASADO).

A low resolution diatomological analysis on PTA-1D, a 97.3 m long sedimentary core from the central part of the lake, has been achieved in order to track changes in lake conditions and tackle the most interesting sections to carry out higher resolution analyses. The first radiocarbon datings from another core taken in the lake suggest an approximate age of at least 50 kyrs for the record and more samples are being analyzed at the moment in order to better constrain this preliminary age model.

Diatom concentrations fluctuate between 0 and $7x10^8$ valves/g along the core and so far, more than 200 different taxa have been identified in the sediment. While *Cyclotella agassizensis* dominates in the top part of the core together with *Thalassiosira patagonica*, as previously seen in earlier studies on this lake (Wille et al., 2007), these indicators of more brackish conditions are rare or not found at all in deeper sediments. Variations in the planktonic/non-planktonic species ratio, with a particularly high amount of non-planktonic taxa between 12 and 17 m depth, could most likely point toward lower lake-level stands. Nevertheless, a correlation with other proxies is necessary to further develop this hypothesis.

We are persuaded that the multi-proxy approach that is the hallmark of the PASADO project, and its combination with the modern training set for Patagonia that will be produced within the framework of the ongoing Argentinean PIPA project will provide unique paleoecological information for the Southern Hemisphere.

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Fourier transform infrared spectroscopy: a technique for rapid, quantitative analysis of biogeochemical properties of sediment

Peter Rosén[1], Hendrik Vogel[2], L. Cunningham[3], Annette Hahn[4], Per Persson[5]

[1] Climate Impacts Research Centre (CIRC), Umeå University, Abisko, Sweden, Peter.Rosen@emg.umu.se
[2] Institute of Geology and Mineralogy, University of Cologne, Cologne, Germany.
[3] Department of Geography and Geosciences, University of St Andrews, Scotland
[4] Geomorphology and Polar Research (GEOPOLAR), University of Bremen, Celsiusstr. FVG-M, 28359 Bremen, Germany

[5] Department of Chemistry, Umeå University, Umeå, Sweden

Over the past decade, the recovery of long sedimentary records from terrestrial sites and in particular large and ancient lakes has been made possible by the International Continental Scientific Drilling Program (ICDP) and associated partners. To receive important information about past climate from these records we need highly resolved multi proxy studies which can be time consuming and expensive. The potential of the Fourier transform infrared spectroscopy (FTIRS) technique arises from the fact that infrared (IR) spectra in the mid-infrared (MIR) region contain a wide variety of information on minerogenic and organic substances and, importantly, it is a rapid, cost-saving technique, which only requires small amounts (0.01g dry weight) of sample material.

In this study we use a large data set from Antarctica, Argentina, Canada, Macedonia, Siberia and Sweden for quantitative estimations of biogenic silica (BSi), total nitrogen (TN), total organic carbon (TOC), and total inorganic carbon (TIC) using FTIRS. The PLS model is applied to sediment successions from ICDP deep drilling sites. FTIRS calibrations for BSi, TN, TOC, and TIC yielded good statistical performances and confirm the potential of the technique for high-resolution investigations of long sediment successions (Vogel et al. 2008; Rosén et al. 2009).

The basic principle of the FTIRS technique is that infrared radiation stimulates molecular vibrations and, as a consequence of the quantum mechanical behaviour, this radiation is absorbed at specific wavenumbers. Major changes of organic and inorganic properties present in the sediment can therefore be qualitatively identified from the FTIR spectra. For example, the band between 2850 and 2950 cm^{-1} is due to C-H vibrations in $-CH_3$, $-CH_2$ and –CH groups of organic compounds. Bands centred on 1715 cm^{-1} are assigned to the stretching vibration of the –C=O group of fatty acids. Carbonate in calcite minerals has important C-O molecular vibrations around 710, 875, 1425, 1460, 1800 and 2500 cm^{-1} and SiO in biogenic silica has an important absorbance maximum at 1100 cm^{-1}. FTIRS can thus provide information on a large number of organic and minerogenic components, e.g. carbohydrates, humic substances, silicates and carbonates. This information is of particular interest for paleolimnological studies since sediment is commonly composed of a mixture of various organic and minerogenic compounds originating from the fossilization of tissues and skeletons of aquatic organisms and from the erosion of catchment soils. Absorbance in FTIR spectra from the mid-infrared region directly relates to the concentration of specific compounds, and thus many organic and minerogenic sedimentary components can also be quantified by their own “fingerprint-like” infrared spectra. For references please see Vogel et al. (2008) and Rosén et al. (2009).

An important advancement of this technique is the creation of a globally applicable calibration model, which shows even better statistical performance than previous studies (Vogel et al. 2008, Rosén et al. 2009). A model that is applicable to most limnological settings world-wide would greatly reduce the amount of work when the technique will be applied to new lakes. Our results demonstrate that FTIRS is a useful analytical alternative for quantitative inference of BSi, TN, TOC, and TIC in lake sediments and might therefore also be interesting for other ICDP lake drilling projects where long sediment successions are recovered and need to be analyzed. In combination with X-ray fluorescence scanners and multi-sensor core loggers, FTIRS can provide highly resolved, qualitative and quantitative information on the inorganic geochemistry, mineralogy, magnetic and biogeochemical properties and thus provide robust proxy data for climate and environmental reconstructions.

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Introduction of the “Microfossil Working Group”

Frank Schäbitz

Seminar für Geographie und ihre Didaktik, Universität zu Köln, Gronewaldstr. 2, D-50931 Köln, Germany

The microfossil working group of the PASADO Science team consists of scientists mainly from Argentina, Canada, Germany and Switzerland, specialized in the following proxies: pollen, diatoms, chironomids and phytoliths. Results from the first workshop held in Cologne in July last year are presented as well as the analytical strategy and first available results.

Exploring the subsurface biosphere in Laguna Potrok Aike sediments: constraining the microbial role into diagenesis, a new prospect for ICDP

Aurèle Vuillemin[1], Daniel Ariztegui[1], J. Pawlowski[2], J. Poté[3], S. Templer[4,5], C. Vasconcelos[4], Flavio S. Anselmetti[6] and the PASADO Science Team

[1] *Department of Geology & Paleontology, University of Geneva, Switzerland*

[2] *Department of Zoology, University of Geneva, Switzerland*

[3] *Institute Forel, University of Geneva, Switzerland*

[4] *Geological Institute, ETH-Zürich, Switzerland*

[5] *Massachusetts Institute of Technology, Cambridge, USA*

[6] *Eawag, Swiss Federal Institute of Aquatic Science & Technology, Dübendorf, Switzerland*

Microbial activity is fully recognized as a major player in lithification processes. Results from sediment cores retrieved during ODP- and IODP-sponsored drilling campaigns have shown that these organisms are active even in extreme environments and, moreover, capable of catalyzing and enhancing diagenetic reactions. The distribution and diversity of microbes in marine sediments have been already studied for several years but these investigations are still missing for their lacustrine counterparts. In lake basins these studies have been mainly focused on either the water column and/or the very recent sediments. Modern lakes, however, are ideal systems to study early diagenetic processes using a combination of the physical, chemical and biological features of their sediments. Geomicrobiological studies aim to determine the role played by microbes in this late process, as microbial biomass, although ruling a substantial part of the organic matter record, is often difficult to distinguish from terrestrial and/or algal inputs. Other factors such as sediment grain size and/or nutrient content both highly dependent on the hydrological regime (i.e., lake level), are decisive for the microbial colonization of lacustrine substrates. Lake sediments retrieved for multiproxy studies such as those from ICDP-sponsored research programs provide a unique opportunity to explore and apply recent developments on the marine geomicrobiological field to the lacustrine realm.

More than 500 m of sediment cores were retrieved from Laguna Potrok Aike for multi proxy investigations. A 100 m long core was fully dedicated to a geomicrobiological study. A sampling strategy was specially tailored to avoid contamination enabling the inspection of undisturbed lacustrine sediments and tracking ongoing microbial activity through depth. Special windows were cut in the liners immediately after core recovery for direct sampling under the most sterile conditions possible. Samples were chemically fixed and/or frozen right away, optimizing the preservation of their initial signatures for further analyses such as methane determination, cell counting, DGGE (molecular fingerprinting technique) and cell cultivation. In situ ATP (adenosine 5'-triphosphate) measurements were taken as indication of living organisms within the sediments.

The C/N ratio and grain size data show variations in both the sources of the bulk organic matter and the sediments, respectively, that are consistent with proposed lake level changes. In situ ATP measurements reveal a constant low microbial activity below 40 m sediment depth and three main peaks appear at 34, 10 and 4 m below lake floor. The statistical analyses of DGGE gels (approach based on 16S rDNA) allowed us to identify a broad and constant diversity pattern in the older sediments. Conversely, a decreasing trend and a more variable microbial diversity characterize the upper section of the core. This negative correlation between microbial activity and diversity may indicate a systematic depletion of nutrients through bacterial activity that forces microbial communities to adapt to a decreasing trophic state. H, C and N elemental results support this preliminary interpretation: carbon, being the energy source, decreases with the metabolic needs of the community indicated by the ATP curve, whereas N and H acting as nutrient sources follow an opposite behaviour as their content increases while microbial activity diminishes after 40 m depth. Sediment compaction may be another important factor. Methane content was measured using the headspace gas chromatography technique showing a constant increase in organic matter decomposition process from the surface to 2 m sediment depth. The entire gas record shows a quite constant trend peaking at 65, 38, and 10 m suggesting that methane is best preserved in fine sediments. These preliminary results suggest that microbial communities are tightly related to distinctive sediment types representative of changing lake levels.

Ongoing analyses include DAPI (nucleic acid stain for cell counting) to further quantify the bacterial biomass and certify the validity of in situ ATP data; $\delta^{13}C$ on bulk sediment to track the prokaryotic signal and measure its contribution to the organic matter record; pore-water chemistry to determine the dominant types of metabolism of the microbial mass within the sediment; DGGE targeting the Archaea domain to assess the diversity of methanogens; and sequencing of selected species based on DGGE patterns to finally identify the dominant bacterial species throughout depth. The integration of these datasets with those produced within PASADO will bring new light into living microbial activity in lacustrine systems and its role in diagenetic processes. It will further allow to better understand potential links to climatically-induced environmental changes.

Regional climate model simulations for the mid-Holocene over central and southern South America

Sebastian Wagner

GKSS Research Center, Institute for Coastal Research, Paleoclimate Group, Max-Planck-Strasse 1, 21502 Geesthacht, Germany

The present study focuses on regional climate model simulations carried out with the community model CCLM for the mid-Holocene (MH) period 6,000 years before present. The regional model was driven with lateral boundary conditions from the global general circulation model (GCM) ECHO-G. As reference simulations a pre-industrial (PI) simulation has been carried out representing conditions of 1750 AD. The regional simulations have been carried out as time slice experiments each covering 40 years.

The main purpose of the simulations is to test the hypothesis based on proxy data from south-eastern Patagonia, i.e. Laguna Potrok Aike (LPA). Here lower lake levels have been reconstructed for the MH compared to pre-industrial times.

Analysis based on statistical downscaling using the same global climate model indicated higher precipitation on an annual basis between MH and PI times. Most pronounced differences are however evident on a seasonally resolved basis. To overcome the drawback of lacking evaporation rates in the statistical downscaling approach, the regional climate model simulations will also be used to investigate in greater detail precipitation-evaporation changes. These are important for lake level changes at LPA.

Results of regional climate model simulations indicate that most pronounced thermal and hydrological changes occur over the Andes Mountains between the MH and PI times. For south-eastern Patagonia, and here more specifically the LPA region, precipitation and evaporation changes between the MH and PI times are rather small concerning the order of magnitude and do therefore show no statistical significance. Despite the uncertainties involved in simulations (e.g. related to shortcomings of the climate models used and the short integration periods) the simulations indicate a very heterogeneous spatial pattern of hydrological variables with changes between pronounced positive and negative anomalies within only tenth of kilometres. This may put new insights for the discussion of potentially contradicting hypotheses derived from spatially closely related proxy locations.

First analyses of tephra from the 2008 PASADO cores from Laguna Potrok Aike

Stefan Wastegård[1], Daniel Veres[2] and the PASADO Science Team

[1] *Department of Physical Geography and Quaternary Geology, Stockholm University, S-106 91 Stockholm, Sweden*

[2] *Institutul de Speologie "Emil Racovita", Clinicilor 5, PO Box 58, Ro-400006 Cluj-Napoca, Romania*

A total of 15 samples were analysed at the Tephrochronology Analytical Unit at the University of Edinburgh in November 2009, of which 14 are from the reference core 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 (Si, Al, Fe, Ti, Mn, Mg, Ca, Na, K, P). Most samples consist of a mixture of pure glass (sometimes contaminated by phenocrysts) and minerals. Analyses of the glass show that all layers except T-35 are rhyolithic with SiO_2 contents between ca 74.5 and 78% (Fig. 1). Two main groups occur, one group with K_2O contents between ca 1.5 and 2.0%, indicating an origin in the Mt. Burney volcano and one group with K_2O% contents between ca 2.5 and 3.2%, which suggests that these layers are products of eruptions of the Reclús volcano. The dacitic T-35 layer (SiO_2 ca 70.5%) is geochemically similar to the t5-8 layer, described by Haberzettl et al. (2009) in a previous core from Laguna Potrok Aike, with an estimated age of ca 34 ka. Efforts will be undertaken in order to compare the geochemical data with previous tephrochronological studies on Laguna Potrok Aike and other sites in southernmost Patagonia. Three tephra samples have been submitted for Ar-Ar dating which will improve the chronological control of the lower part of the sediment record.

Reference:

Haberzettl, T., Anselmetti, F. S., Bowen, S. W., Fey, M., Mayr, C., Zolitschka, B., Ariztegui, D., Mauz, B., Ohlendorf, C., Kastner, S., Lücke, A., Schäbitz, F., and Wille, M. (2009). Late Pleistocene dust deposition in the Patagonian steppe - extending and refining the paleoenvironmental and tephrochronological record from Laguna Potrok Aike back to 55 ka. *Quaternary Science Reviews* 28, 2927-2939.

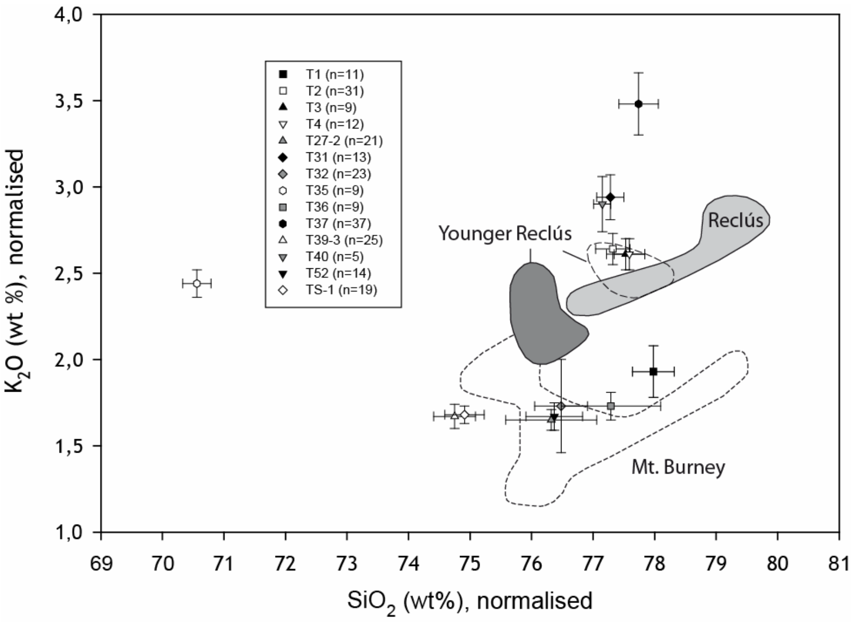

Fig. 1: Mean SiO_2 and K_2O concentrations with 1 standard deviation for the analysed tephra samples, normalised to 100%. Fields for Mt. Burney and Reclús tephras are from Haberzettl et al. (2009) and references therein.

Vegetation history in southern Patagonia: First palynological results of the ICDP lake drilling project at Laguna Potrok Aike, Argentina

Michael Wille, Frank Schäbitz and the PASADO Science Team

Seminar für Geographie und ihre Didaktik, Universität zu Köln, Gronewaldstr. 2, D-50931 Köln, Germany

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 first results of pollen analyses from sediment material of the core catcher. Absolute time control is not yet available. 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 show a 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 forest 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 record were more humid and/or warmer causing higher fuel availability for charcoal production compared to full glacial times.

The long sediment record from Laguna Potrok Aike, Argentina (ICDP-project PASADO)

Bernd Zolitschka[1], Christian Ohlendorf[1], Catalina Gebhardt[2], Annette Hahn[1], Pierre Kliem[1], and the PASADO Science Team[3]

[1] *Geopolar, Institute of Geography, University of Bremen, Celsiusstr. FVG-M, 28359 Bremen, Germany*

[2] *Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany*

[3] *http://www.icdp-online.org/contenido/icdp/front_content.php?idcat=960*

Laguna Potrok Aike is located in the South-Patagonian province of Santa Cruz (52°58'S, 70°23'W; 116 m a.s.l.; diameter: 3500 m, water depth: 100 m) and was formed by a volcanic (maar) eruption in the late Quaternary Pali Aike Volcanic Field several hundred thousand years ago (Zolitschka et al., 2006). This archive holds a unique record of climatic and environmental variability (Mayr et al., 2009) from a region sensitive to fluctuations in southern hemispheric wind and pressure systems, which provide a cornerstone for the understanding of the entire global climate system (Mayr et al., 2007; Wagner et al., 2007). Moreover, Laguna Potrok Aike is close to many active volcanoes allowing a better understanding of the history of volcanism in the Pali Aike Volcanic Field as well as in the Andean mountain chain. The latter is located in a distance of less than 150 km to the west with volcanic ash layers being deposited as far away as the Antarctic continent (Narcisi et al., 2010). Additionally, Patagonia is the source region of eolian dust blown from the South American continent into the South Atlantic and onto the Antarctic ice sheet (Delmonte et al., 2010; Gabrielli et al., 2010; Haberzettl et al., 2009). The currently ongoing global climate change, the threads of volcanic hazards and the regional dust storms are of increasing socio-economic relevance and thus challenging scientific themes that are tackled for southernmost South America with an interdisciplinary research approach in the framework of the ICDP-funded "Potrok Aike Maar Lake Sediment Archive Drilling Project" (PASADO).

Drilling operations for this southernmost ICDP project PASADO are dedicated to terrestrial climatic and environmental reconstruction. Field work was completed in late November 2008 (Zolitschka et al., 2009). From the maar lake Laguna Potrok Aike in total 510 m of lacustrine sediments have been recovered using the GLAD800 platform equipped with a CS-1500 drill rig. Quadruplicate and triplicate cores down to a maximum hole depth of 101.5 m blf (below lake floor) have been taken mainly using the hydraulic piston coring tool. Total core recovery was 94,4 % from two drill sites located 700 m apart from each other in the central deep and profundal plane of the lake. In 2009 cores were opened, described and documented by digital high-resolution photography and scanned with different non-destructive techniques. A 106 mcd (meters composite depth) long profile was constructed for Site 2 based on visual core correlation (Fig. 1) and thereafter subsampled in consecutive 2 cm thick intervals. Core scanning was performed with 5 mm spatial resolution for all parameters and involved the following techniques: (1) color scanning with a handheld X-rite spectrometer, (2) magnetic susceptibility scanning with a Bartington MS2F-sensor, (3) XRF scanning and X-radiography with an ITRAX core scanner (COX analytical systems) and (4) p-wave velocity/transmission seismograms and gamma ray absorption with a modified Geotek multi sensor core logger tool (MSCL).

The composite profile consists of undisturbed laminated and sand-layered lacustrine silts with an increasing number of coarse gravel layers, turbidites and homogenites at depth (Fig. 2). Below 80 mcd two mass-movement deposits of 10 m and 5 m in thickness are recorded. These deposits show tilted and distorted layers as well as nodules of fine-grained sediments and randomly distributed gravel. Such features either indicate an increased seismicity that cannot be completely excluded for this late Quaternary back arc volcanic field or they are the result of hydrologically induced lake level variations and hence relate to changes in hydrological conditions within the catchment area. Intercalated throughout the record are 24 macroscopically visible volcanic ash layers (Fig. 2) that document the regional volcanic history and open the possibility to establish an independent time control through tephrochronology supported by Ar/Ar dating. Moreover, these isochrones potentially act as links to marine sediment records from the South Atlantic and to Antarctic ice cores. Preliminary extrapolation of the mean sedimentation rate of 1.1 mm/a determined for the upper 16 ka (Haberzettl et al., 2007) indicates that a continuous and high quality record may go back in time to approximately 50,000 years (Fig. 2). Such a time frame is supported by first radiocarbon dates obtained from aquatic mosses.

According to this preliminary age model, the sedimentary record from Laguna Potrok Aike reaches back to Oxygen Isotope Stage 3 and exhibits contrasting lithologies downcore especially in the Pleistocene part of the record. Moreover, first estimates indicate that up to 50% of the record consists of redeposited sediments. Element profiles acquired by XRF core logging document these pronounced down core lithological changes.

As a terminal lake, the sedimentary record of Laguna Potrok Aike is well suited to trace temporal changes in the hydrological cycle. Subaerial and subaquatic terraces evidence large lake level variations of more than 50 m (from +21 m to -35 m) during Holocene and Late Glacial periods (Anselmetti et al., 2009). These have been recorded as variations of inorganic carbon percentages and of XRF counts for calcium (Ca) in the sedimentary record. However, while the element profile of Ca is controlled by the proportion of authigenically precipitated calcite in the lake since the Lateglacial this seems to be different during earlier periods of the Pleistocene. Hence, XRF Ca counts in this older interval, which represents more than 80% of the sediment thickness recovered during the PASADO drilling campaign, seem to be controlled by different mechanisms.

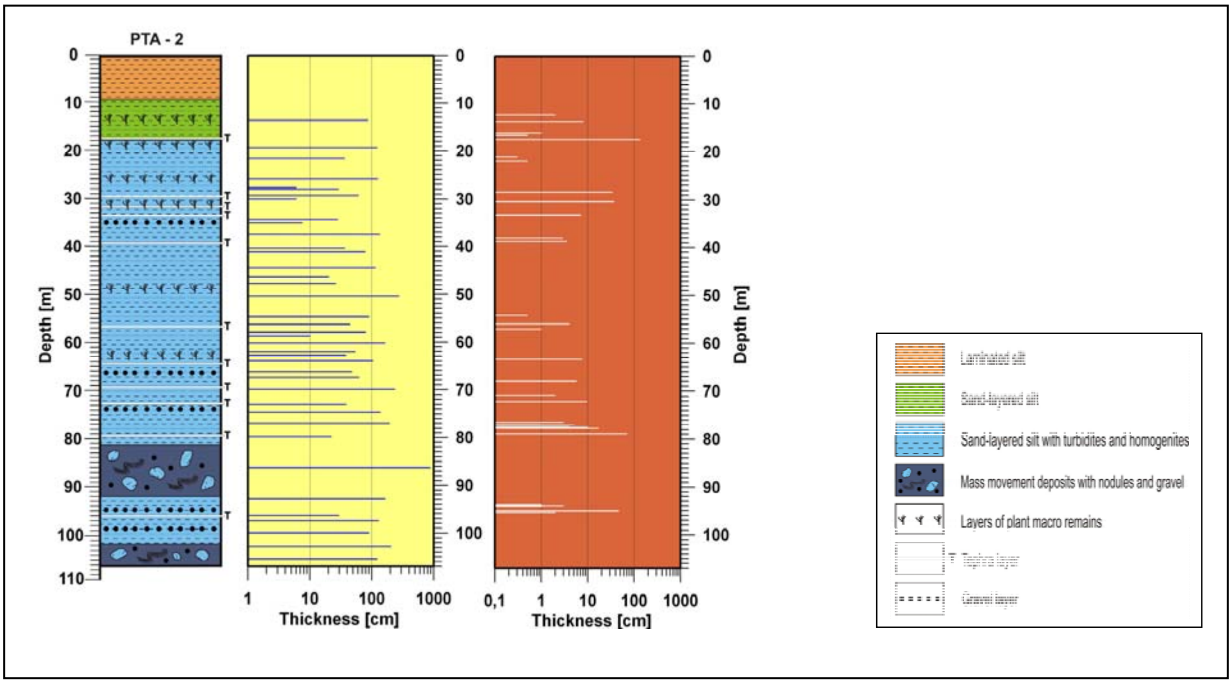

Fig. 1: Lithology of the composite profile (left) from Site 2 of Laguna Potrok Aike (PTA-2) with the thickness of redeposited sediment layers (center) and volcanic ash layers (right).

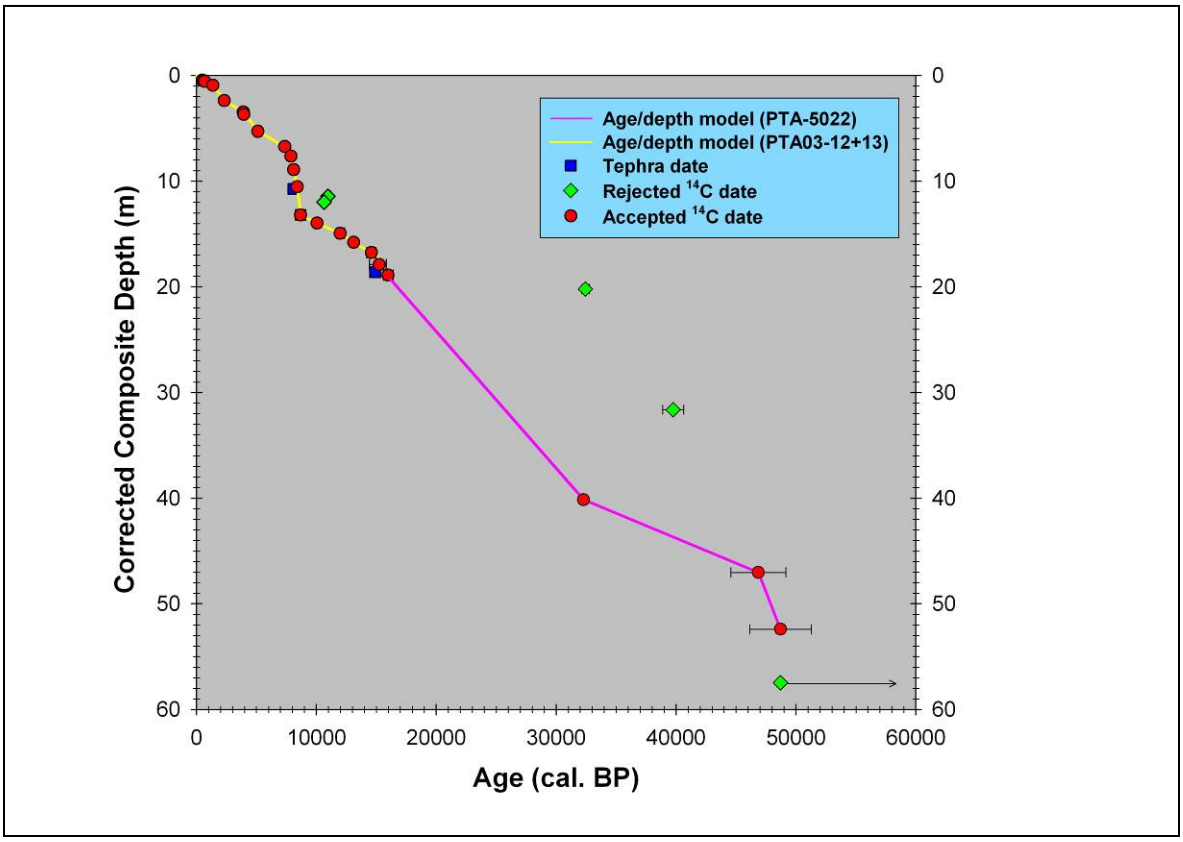

Fig. 2: Age-depth plot for the composite profile of Site 2 from Laguna Potrok Aike. Note that the “corrected composite depth” refers to the fact that all redeposited sediment sections have been subtracted from the entire length of the record. The age-depth model for core PTA 03-12 and -13 is from Haberzettl et al. (2007, modified).

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Technical Report about the Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO)

Bernd Zolitschka

Geopolar, Institute of Geography, University of Bremen, Celsiusstr. FVG-M, 28359 Bremen, Germany

1. Introduction and aims

The Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO) is one of currently three deep lake drilling projects coordinated by German principal investigators, all of them supported by the „International Continental Scientific Drilling Program“ (ICDP). Based on international cooperation under the umbrella of the ICDP and after seven years with detailed limnogeological studies, pre-site surveys, on-site monitoring, climatic and hydrologic modelling an international team of scientists from Argentina, Canada, Germany, Sweden, Switzerland and the United States (Tab. 1) representing a wide array of research fields was excited to obtain long sediment cores from Laguna Potrok Aike (Fig. 1). This crater (maar) lake is located in the late Quaternary Pali Aike Volcanic Field of southern Patagonia (Province of Santa Cruz, Argentina). Seismic surveys demonstrated that ~400 m of pelagic sediments were deposited in the lake centre underlain by an unknown thickness of volcaniclastic breccias. Based on this seismic data, three primary and three alternative drilling sites were selected:

(1) From the deepest part to obtain a continuous and high-resolution record of climatic and environmental changes (0-400 m – in triplicate) and to unveil the phreatomagmatic history including more precise age constrains for the maar-diatreme formation from the volcaniclastic sediments below (400-600 m),

(2) From a subaquatic lake level terrace at 35 m water depth to constrain the range of lake level variations (0-50 m – in triplicate) and

(3) From an angle hole passing through lacustrine sediments and the crater wall into the molasse-type basement rocks (0-400 m) to study the impact of explosive volcanism in this relatively young maar-diatreme structure.

The proposed drilling operation plan had the objective to achieve all necessary technical needs in close cooperation with DOSECC, which provides the technical infrastructure and the know-how to carry out the drilling at water depths of almost 100 m.

2. Mobilisation

Field work started as scheduled with the arrival of DOSECC drillers and first scientists on August 31, 2008. The day before all containers arrived in Río Gallegos but could not be transported to the lake due to impassable roads. This year’s August was exceptional with respect to weather conditions: it was the coldest and also the wettest August with highest amounts of snow on record (Fig. 2). Then, during the last week of August, a rain storm caused the 20 cm thick snow cover to melt such that all soils and the unpaved dirt roads were extremely soft, too soft for heavy trucks carrying containers and for crane trucks to pass. It took almost two weeks of waiting time and several days for transporting all containers with trucks getting stuck many times, until the last container finally arrived at the highest lake level terrace on September 12. For the same reason the set up of the field camp was delayed until September 10. But then it was operational with sleeping trailers (6), bathroom trailers (2), one laboratory trailer, one cooking and dining trailer as well as one storage container (Fig. 3). Electricity was provided by a 110 kVA diesel generator, water was supplied from a well on the premises of the nearby INTA field station "Potrok Aike" and waste water was dumped into a special pit. Communication with the rest of the world was only possible via a satellite-linked internet connection rent for the duration of field work.

More than a week later, on September 21, the purpose-built catamaran which served as a shuttle and rescue boat, was launched with a fork-lift (sky track). For the first time the launching of the platform "R/V Kerry Kelts" needed to be accomplished without any harbour facilities and without a crane near shore. This task was tackled by Capitan Moreteau in close cooperation with DOSECC by constructing a launching device on 8 huge all terrain tires called "the launcher" (Fig. 4) capable to carry the platform with the drill rig on top down to the lake and into the water. After endless struggles, countless delays and with the help of two tractor trucks, two oilfield trucks with a 50 t winch each and an additional 40 t crane the platform was finally watered on October 10. Rigging up was completed in a few days. After the platform was towed to the first drill site, drilling started on October 15.

3. Drilling operation

During the entire drilling operation, including mobilisation and demobilisation, a total of 42 people (26 scientists, 10 DOSECC staff, 4 Argentinean support personnel, 2 technicians) were present, but only 11 people for the entire three months period (Tab. 1). In total, 1986 man days were used for this operation. In the following list of drilling statistics, applied (in italics) and realised times and hole depths for drilling are summarised:

Drilling statistics:

Mobilisation applied for:	*14 days*
Time used for mobilisation:	45 days
Drilling applied for:	*60 days*
Platform being operational on the lake:	34 days
Drilling being operational:	12 days (35%)
Downtime related to weather conditions:	16 days (47%)
Downtime related to technical conditions:	6 days (18%)
Total hole depth applied for:	*1850 m*
Total hole depth reached with the GLAD800:	533 m
Average recovery per drilling day:	44 m
Demobilisation applied for:	*14 days*
Time used for demobilisation:	10 days

For a detailed calendar of events that occurred during this field expedition see Appendix 2.

3.1 Technical issues

Drilling was carried out from the platform R/V "Kerry Kelts" with the GLAD800 drill rig. The drill pipe was stabilised with a casing that was run down from the deck of the platform to a few meters above sediment surface. The drilling tool almost exclusively used was the Hydraulic Piston Corer (HPC). Core liners had a total length of 3.3 m and were, under ideal circumstances, cut into two sections each 1.5 m long.

Drilling operations in the framework of PASADO have been successful in obtaining more than 500 m of sediments but dramatically failed to attain the drilling objectives as described in the ICDP Full Proposal. From three targets only the central deep was partly realised. Out of the 1850 m of cores initially planned for recovery, only 533 m have been obtained from 7 holes, just two of them reaching a depth of more than 100 m. One reason was that fieldwork has been marked by extended periods of strong winds (Fig. 5). Other than for precipitation and temperature during August 2008 (Fig. 2), monthly wind velocities were not high if compared to the last year's means (Fig. 6). However, available data are from Río Gallegos Airport as the local weather station at Potrok Aike was not recording continuously. These wind data are usually less intense compared to Potrok Aike, ca. 120 km further to the west. For example: for the day we experienced strongest wind gusts (November 12) Río Gallegos Airport measured 121 km/h while at Potrok Aike 177 km/h were recorded.

In addition to wind-related down-time of drilling, we noted numerous defaults from DOSECC and believe these are similarly responsible for not attaining the objectives of the PASADO drilling campaign. Three kinds of problems occurred: organisational, technical and security issues. Under „normal" weather conditions most of the organisational and technical deficiencies would not have been as significant, but with the prevailing Patagonian winds such delays turned out to be crucial. Moreover, the DOSECC on-site team had not the necessary equipment, tools and training to successfully conduct the intended drilling with environmental conditions to be expected for southern Patagonia. We are furthermore convinced that the challenges of this project have been largely underestimated by the management of DOSECC. Many of the mentioned issues seem to us to be the result of insufficient planning and coordination. Finally, the almost 30 year old drill rig itself was not only working at its limits but exceeded its technical capacity many times during this expedition.

Loss of equipment occurred four times for various reasons (Fig. 5):

19.10. : Due to sand in the Bottom Hole Assembly (BHA) it was decided to lift the BHA and to ream down with the Alien tool. This was used instead of a missing centre bit. However, the Alien was lost in hole 1C for unclear reasons and drilling at hole 1C needed to be stopped.

22.10.: Due to a sudden and strong increase in wind speed with gusts up to 109 km/h, not announced by the local weather forecast, anchors did not hold the platform which drifted ashore. Almost 200 m of pipe, 95 m of casing and one anchor were lost.

3.11.: At hole 2B we run out of sheer pins for the HPC, continued with the Extended Nose tool which was sanded in with the second shot. A moderate wind came up with gusts up to 72 km/h and the pipe broke at the sediment/water interface. Ca. 50 m of pipe was lost.

17.11.: At slightly more than 100 m of sediment depth the overshot failed to pick up the tool, probably because the drill pipe was broken in the sediment as we learned later. The downhole logging tool determined a window to the sediment at 35 m sediment depth and had contact with sediment at 45 m where it got stuck. While pulling out the logging tool it was canted also at the sediment/water transition. Pulling out the drill pipe we realised that it was broken at this position. About 100 m of drill pipe were lost. The reason for this failure remained unclear. The wind was down to a daily maximum of 27 km/h and a mean of 13 km/h.

3.2 Scientific issues

Having lost 30 days due to the extended mobilisation, we had to change the proposed sequence of drill sites. The near shore site at 35 m water depth was cancelled and we started with the central deep site 1 at 98 m water depth (Figs. 7-10). After the first site had to be abandoned (lost pipe and casing did not allow to continue drilling at this site) without reaching volcaniclastic deposits underneath of the lacustrine sediments, we moved 700 m to the south remaining in the central deep basin (ca. 95 m water depth) but shifting towards an area, where the Sparker seismic survey revealed a region with deeper penetration (Figs. 7, 9). The second and last site 2 confirmed our assumptions and we recovered finer grained lacustrine deposits. Downhole logging was intended to be carried out at least for one (the deepest) hole of every site. All equipment was ready to be deployed, except for the radioactive source needed for one of the logging tools which was not allowed to be imported into Argentina. However, due to strong winds and problems with safely anchoring the platform, there was not one option for logging down a complete hole during the entire period of operation.

3.2.1 Core recovery

For site 1 a total of 295 m of cores were obtained with a core recovery rate of 92% (Tab. 2). For site 2 there are 208 m with a recovery rate of 99% (Tab. 2). The better recovery rate for site 2 seems to be linked to the generally finer grained lacustrine deposits. More sandy sections mainly caused problems for site 1 with imploded or deformed liners stuck in the core barrel. A total number of 178 core catcher samples were taken. Before being stored away, parts of the core catcher samples were processed and subsampled in the field laboratory.

3.2.2 Field laboratory

Several parameters were measured immediately after core recovery onshore at the camp-site laboratory. This field laboratory was especially designed prior to the field period to fulfil our requirements. It was purpose-built based on a standard 40-foot working container split into two sections. One section was used for first physical and chemical analyses of the core catcher samples such as pH, Cl^-, Ca^{2+}, electrical conductivity, water content and dry density measurements as well as for an initial lithologic description (digital photographies, macroscopic description, smear slide preparation with microscopic description; see Fig. 11). Selected measured sediment parameters are displayed in Fig. 12.

The second section of the field laboratory was designed to hold the 5.5 m long Geotek Multi Sensor Core Logger (MSCL) and a small office to process the MSCL data (Fig. 13). The MSCL used for PASADO was provided by the ICDP-OSG and equipped to measure temperature, core diameter, p-wave velocity, magnetic susceptibility and GRAPE density. Unfortunately, it was not possible to import the ^{137}Cs radioactive source to Argentina, thus GRAPE density was not measured on-site. In addition, the gas content in the liner did not allow to reliably measure p-wave velocities. Therefore, magnetic susceptibility was the only parameter measured on-site with the MSCL (Figs. 14-16). For this reason all other petrophysical parameters will be measured in the home laboratory at the Alfred Wegener Institute Bremerhaven prior to core opening.

Magnetic susceptibility was measured on all core sections with a loop sensor (80 mm diameter) in 2 cm measuring intervals (Fig. 13). Data were processed after acquisition and turned out to be a highly reliable data set for core correlation from the different holes of one site (Figs. 14-15) as well as between the two drilled sites (Fig. 16). Using magnetic susceptibility data as a reference, cores were correlated to composite profiles for site 1 and site 2.

The 178 core catcher samples (site 1: 107 and site 2: 71 core catcher samples) have been archived and described following a certain protocol. In addition to the mentioned on-site analyses, core catcher samples were subsampled for further and more detailed investigations to be carried out in the respective home laboratories. Scheduled investigations for which samples have been taken include: pollen, diatoms, stable isotopes and bulk geochemistry. Moreover, analyses to determine the microbial activity in sediments (deep biosphere) have been carried out for the first time within an ICDP-sponsored deep lake drilling project. For lakes a new sampling strategy was designed and adapted from those existing for marine sediments. On-site samples for microbial activity were measured by fluorescence using an ATP device. Adenosine-tri-phosphate or ATP is only produced when living bacteria exist and thus gives immediate information about microbial activity. Samples were also taken for sequencing DNA and for cell counting in the home laboratory.

4. Demobilisation

After drilling had to stop on November 17, the platform was pushed ashore, dismantled (18.-22.11.) and retrieved from the lake (26.-27.11.). As soils were much drier and stable compared to mobilisation, the crane truck drove to the lake shore and lifted out all parts of equipment (Fig. 17). Everything was loaded onto semi-trailers and winched up to the uppermost lake level terrace by oilfield trucks. After everything was shuttled uphill, containers were packed on November 28. The field camp was broken down when the last scientists had left (30.11.). However, the DOSECC containers remained at the lake until January 6, 2009, when their return trip started. The two containers from Bremen, one of them was a reefer that needed to be hooked to electricity (380 V), were transported to Río Gallegos on November 26 and stored there until January 6.

5. Conclusions

Although the total catch of cores was less than one third of the proposed amount, PASADO recovered the so far longest environmental and climatic record of South America south of the tropics, which will be analysed soon with the highest possible temporal resolution. Moreover, lacustrine deposits have not been penetrated completely. Thus there is a potential for future coring activities if a drilling platform can be anchored securely and all the other problems that occurred with this remote Patagonian maar lake can be overcome.

More information about PASADO is available from the ICDP homepage (http://www.icdp-online.org) that includes a general description (http://www.icdp-online.org/contenido/icdp/front_content.php?idcat=722) and pictures from the drilling operations (http://www.icdp-online.org/contenido/icdp/front_content.php?idart=2185). Another source of information is the PASADO homepage located at the University of Bremen (http://www.pasado.uni-bremen.de).

Tab. 1: Scientists, drillers as well as support personnel and their presence in man days during the PASADO drilling operations (PI: principal investigator).

Last name	First name	Position	Affiliation	Country	Man days
Anselmetti	Flavio	Prof. Dr., PI	EAWAG, Zurich	SWI	9
Ariztegui	Daniel	Dr., PI	U Geneva	SWI	35
Baldrati	Maria Jose	Cookie	Rio Dulce Catering	ARG	91
Biggs	Billy	Helper	DOSECC	USA	87
Bolin	Joe	Helper	DOSECC	USA	89
Cole	Steve	Helper	DOSECC	USA	53
Corbella	Hugo	Dr., PI	UNPA, MACN	ARG	8
Cranmer	Jim	Drilling supervisor	DOSECC	USA	65
Delahunty	Chris	Engineer	DOSECC	USA	11
Delpit	Séverine	Ph.D. student	INRS Quebec	CAN	29
Driggens	Elijah	Helper	DOSECC	USA	87
Farah	Redha	Ph.D. student	U Geneva	SWI	18
Förster	Verena	Student	U Cologne	DEU	32
Fortin	David	Dr., scientist	INRS Quebec	CAN	24
Francus	Pierre	Prof. Dr., PI	INRS Quebec	CAN	19
Gebhardt	Catalina	Dr., scientist	AWI Bremerhaven	DEU	84
Gomez Mura	Facundo	Cook	Rio Dulce Catering	ARG	91
Grelle	Thomas	Technician	GGA Hannover	DEU	48
Haberzettl	Torsten	Dr., scientist	UQAR, Rimouski	CAN	23
Hahn	Annette	Ph.D. student	U Bremen	DEU	63
Joice	John	Drilling supervisor	DOSECC	USA	89
Kastner	Stephanie	Ph.D. student	U Bremen	DEU	57
Kliem	Pierre	Ph.D. student	U Bremen	DEU	91
Langkamp	Oliver	Student	U Cologne	DEU	32
Lisè Pronovost	Agathe	Ph.D. student	UQAR, Rimouski	CAN	33
Marshall	Beau	Operations manager	DOSECC	USA	84
Marshall	William	Helper	DOSECC	USA	20
Mayr	Christoph	Dr., scientist	LMU Munich	DEU	18
Moreteau	Daniel	Capitan	Moreteau & Co.	ARG	28
Moreteau	Javier	Skipper	Moreteau & Co.	ARG	28
Müller	Frank	Ph.D. student	GGA Hannover	DEU	48
Ohlendorf	Christian	Dr., PI	U Bremen	DEU	91
Penshorn	Dietmar	Technician	AWI Bremerhaven	DEU	58
Recasens	Christina	Ph.D. student	U Geneva	SWI	43
Ross	Pierre-Simon	Dr., scientist	INRS Quebec	CAN	29
Schäbitz	Frank	Prof. Dr., PI	U Cologne	DEU	15
Schnurrenberger	Douglas	Staff scientist	DOSECC	USA	13
St-Onge	Guillaume	Prof. Dr., scientist	UQAR, Rimouski	CAN	14
Stopp	Annemarie	B.Sc., trainee	U Göttingen	DEU	50
Veres	Daniel	Dr., scientist	U Stockholm	SWE	40
Vuillemin	Aurèle	Ph.D. student	U Geneva	SWI	48
Zolitschka	Bernd	Prof. Dr., PI	U Bremen	DEU	91

Tab. 2: Relevant information about holes recovered at site 1 and site 2 during PASADO drilling operations.

HOLE ID	HOLE DEPTH (m)	CORING DEVICE	LATITUDE (°S)	LONGITUDE (°W)	WATER DEPTH (m)	SEDIMENT TOP (m)	SEDIMENT BOTTOM (m)	CORE RECOVERY (m)	CORE RECOVERY (%)	REMARKS
5022-1A	88,05	all HPC	-51,96412	-70,37599	-97,87	-97,87	-185,92	74,67	84,80	1
5022-1B	71,00	all HPC	-51,96412	-70,37588	-97,89	-97,89	-168,89	64,25	90,49	1
5022-1C	62,30	all HPC	-51,96403	-70,37596	N/A	-100,21	-162,51	62,09	99,66	2
5022-1D	100,35	all HPC	-51,96384	-70,37596	N/A	-99,15	-199,50	93,94	93,61	2
5022-2A	88,51	all HPC	-51,97062	-70,37554	N/A	-95,88	-184,39	87,78	99,18	3
5022-2B	21,12	HPC, last run: EXT	-51,97060	-70,37538	N/A	-145,39	-166,51	21,12	100,00	4
5022-2C	101,45	all HPC	-51,97038	-70,37562	-94,72	-94,72	-196,17	98,74	97,33	1
Sum	**532,78**							**502,59**		
Mean									**94,33**	

HPC: hydraulic piston corer tool

EXT: extended nose tool

N/A: not applicable

Remarks

1: Sediment-water interface undisturbed - true water depth

2: First run completely full - sediment-water interface above recovered sediment

3: Casing was lowered into the sediment - sediment-water interface disturbed

4: First shot started at about 50 m sediment depth - sediment-water interface well above recovered sediment

Fig. 1: Laguna Potrok Aike in the Province of Santa Cruz, southern Patagonia (Argentina).

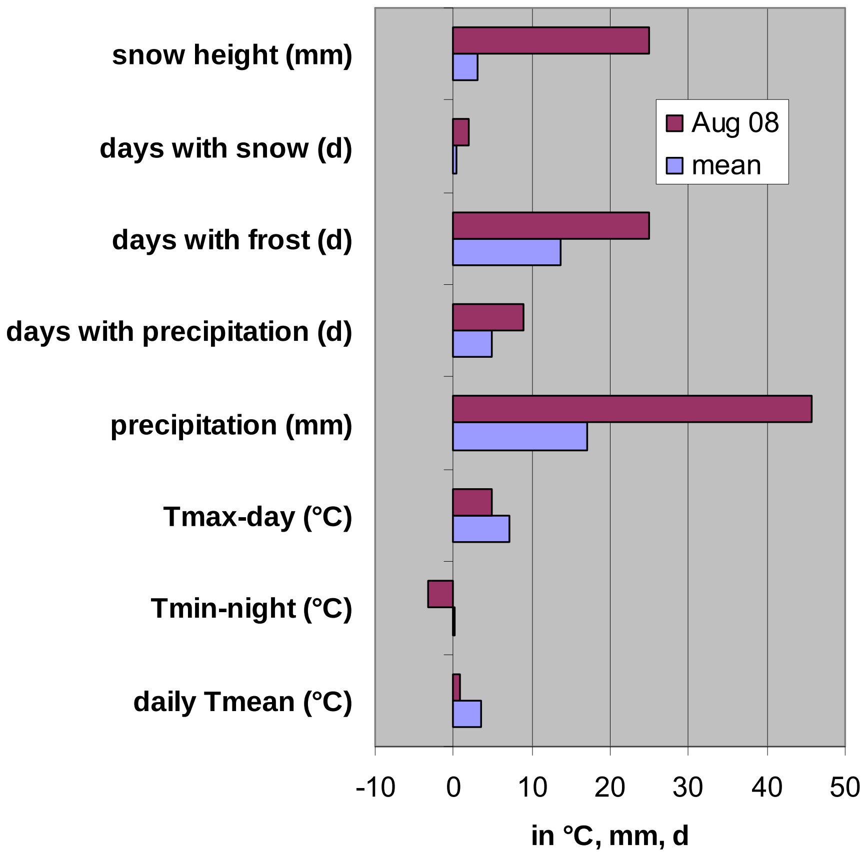

Fig. 2: Meteorological data for the month of August 2008 for the nearest weather station "Río Gallegos Airport" (www.wunderground.com). Temperature data are a mean of the last 27 years and precipitation data of the last 12 years.

Fig. 3: Field camp of “Potrok City”, areal photography of October 10, 2008.

Fig. 4: The “launcher” transporting the platform and the drill rig down the lake shore and into the lake.

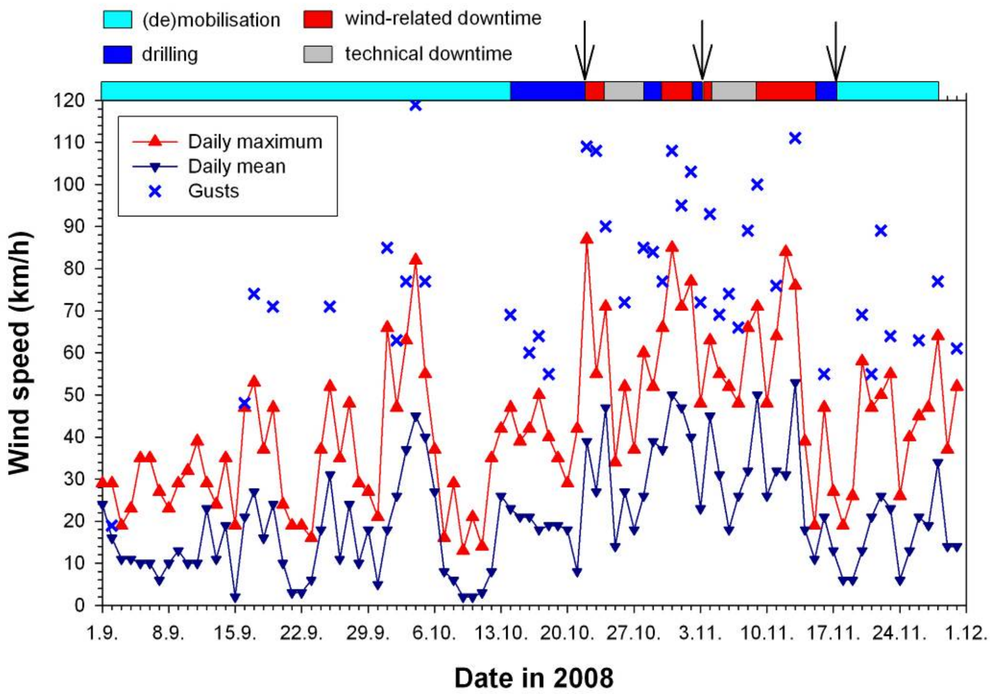

Fig. 5: Wind velocities (daily means, daily maxima, and wind gusts) for the time period of field work from the nearest weather station "Río Gallegos Airport" (www.wunderground.com). Colored bars indicate on-site activities. Arrows point to the timing when equipment was lost (cf. calendar of events in Appendix 2).

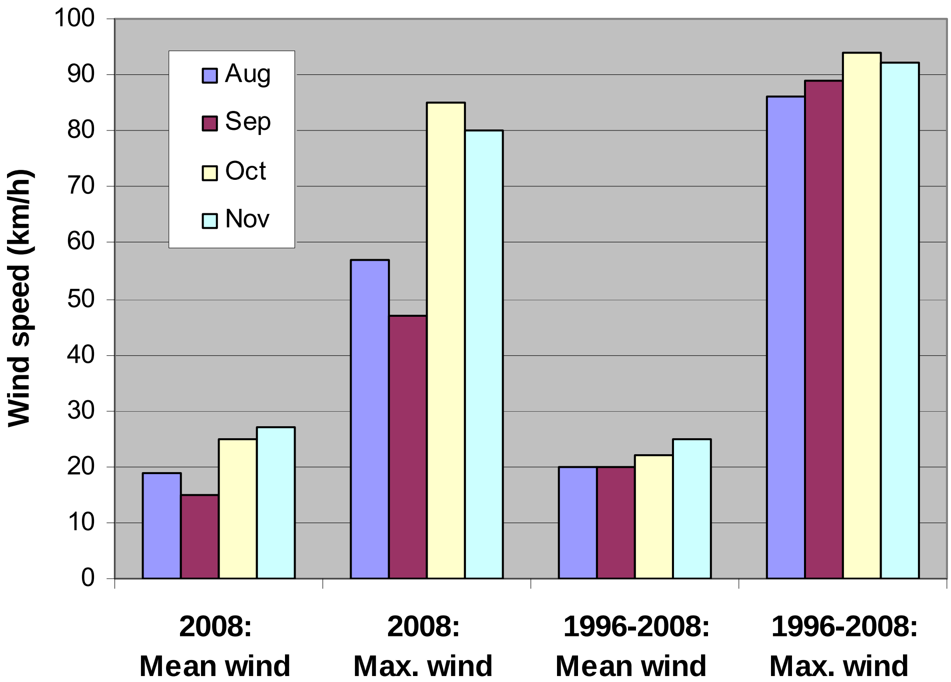

Fig. 6: Mean and maximum wind speeds for the months of August through November of the year 2008 and as a mean for the period 1996 to 2008 for the nearest weather station "Río Gallegos Airport" (www.wunderground.com).

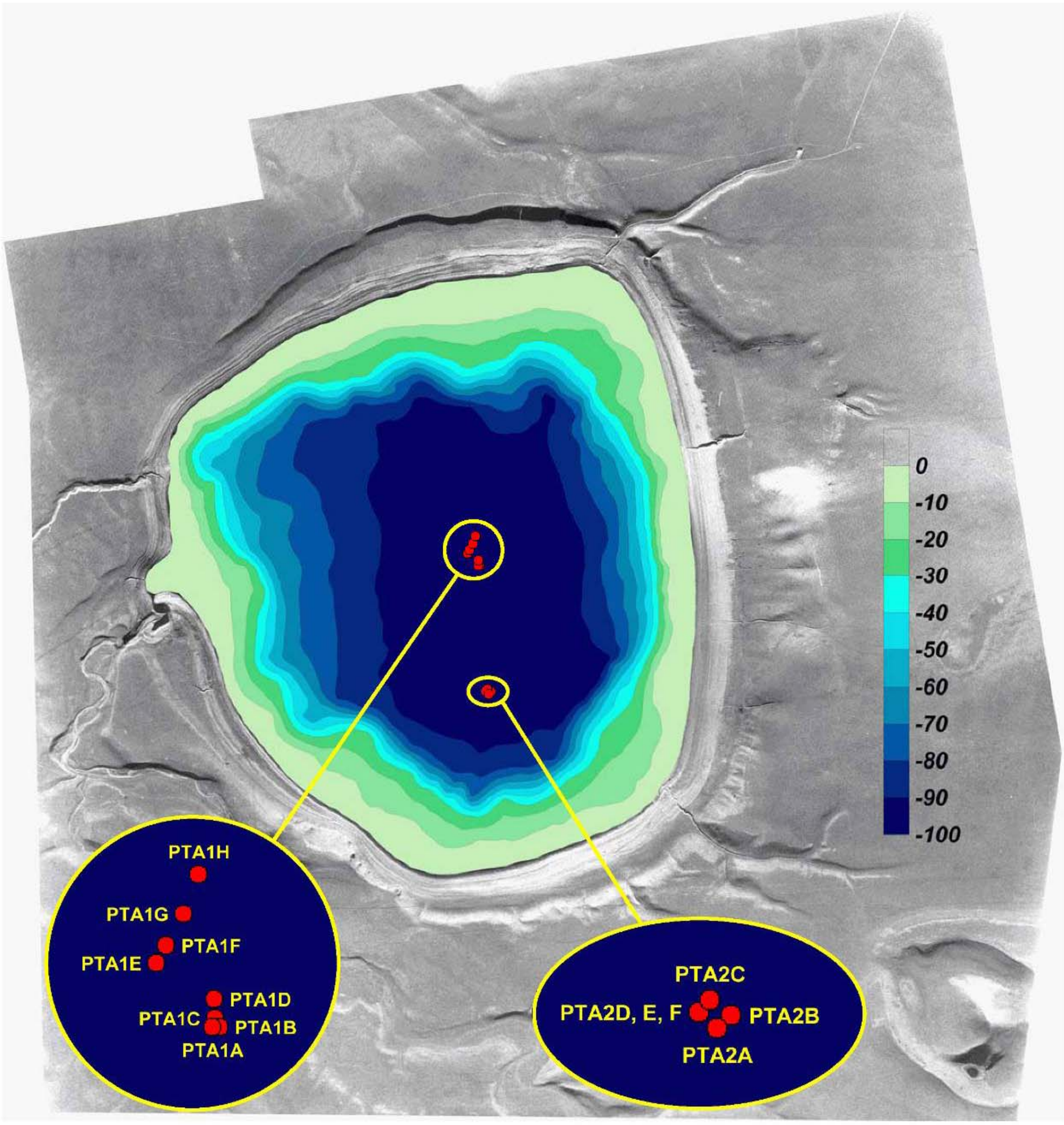

Fig. 7: Bathymetric map of Laguna Potrok Aike with drill sites PTA1 and PTA2 and holes labelled alphabetically. PTA-1E to -1H and PTA-2D to -2F are gravity cores covering the sediment water interface.

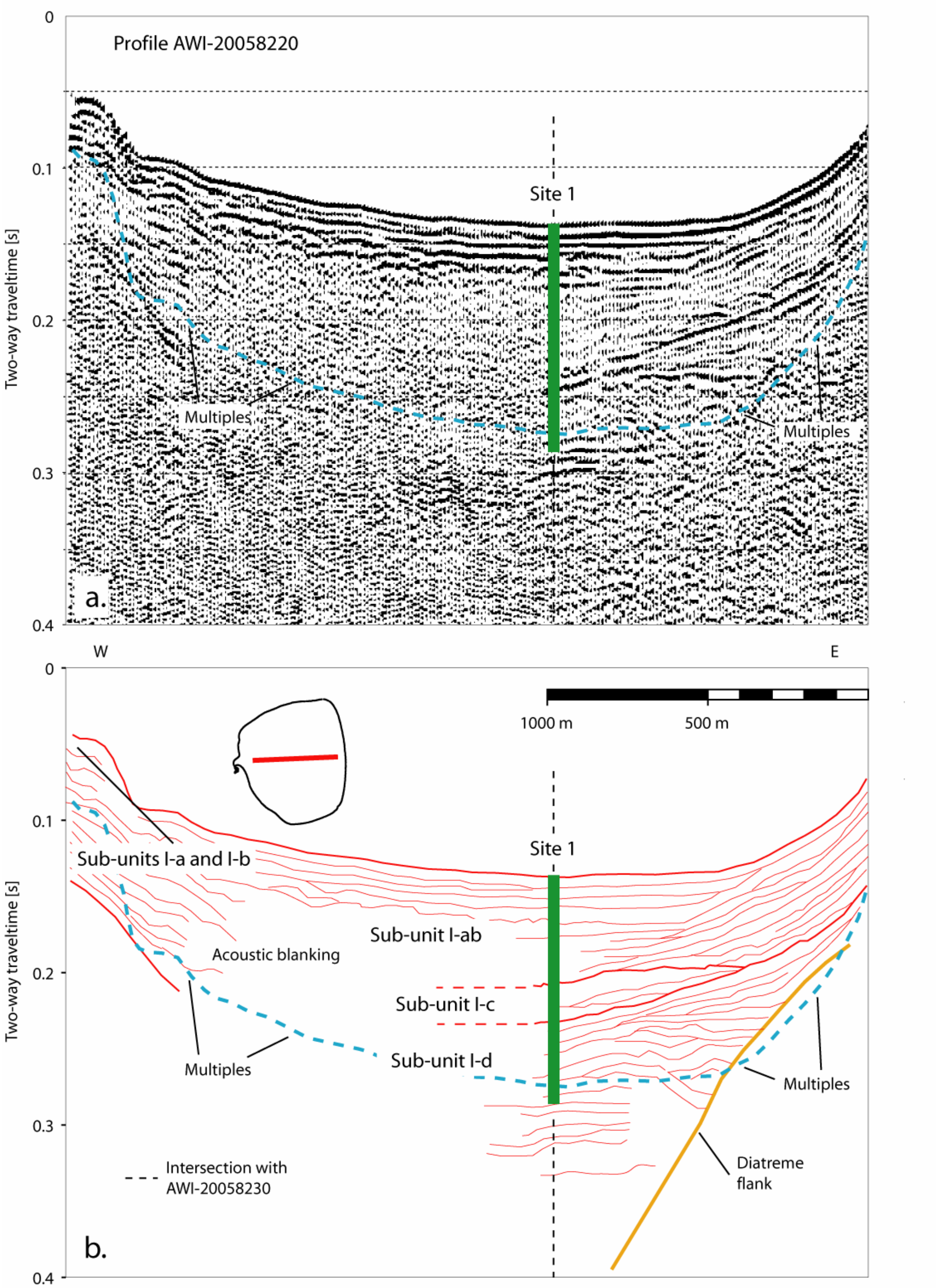

Fig. 8: W-E multi-channel seismic reflection profile AWI-20058220 from Laguna Potrok Aike: a) uninterpreted seismic section, b) interpreted line drawing. Drill site 1 is marked in the lake center. The diatreme flank is well-defined in the eastern but not visible in the western part of the lake.

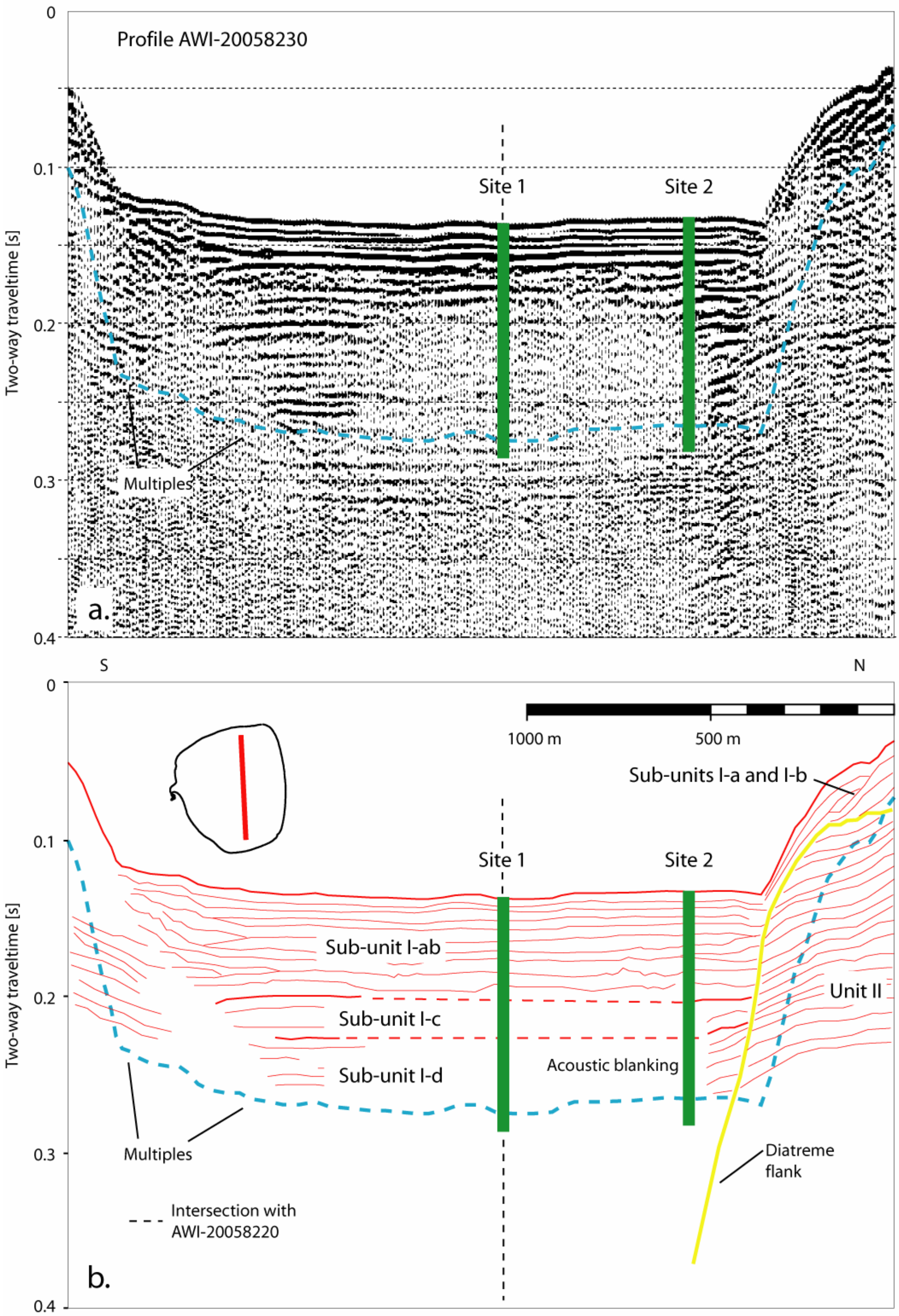

Fig. 9: S-N multi-channel seismic reflection profile AWI-20058230 from Laguna Potrok Aike: a) uninterpreted seismic section, b) interpreted line drawing. Drill sites 1 and 2 are marked in the lake center. The diatreme flank is well-defined in the northern but much less pronounced in the southern part of the lake.

Fig. 10: Platform R/V “Kerry Kelts” drilling in the center of Laguna Potrok Aike.

Fig. 11: Field Laboratory – view of the sedimentology and geochemistry part of the laboratory.

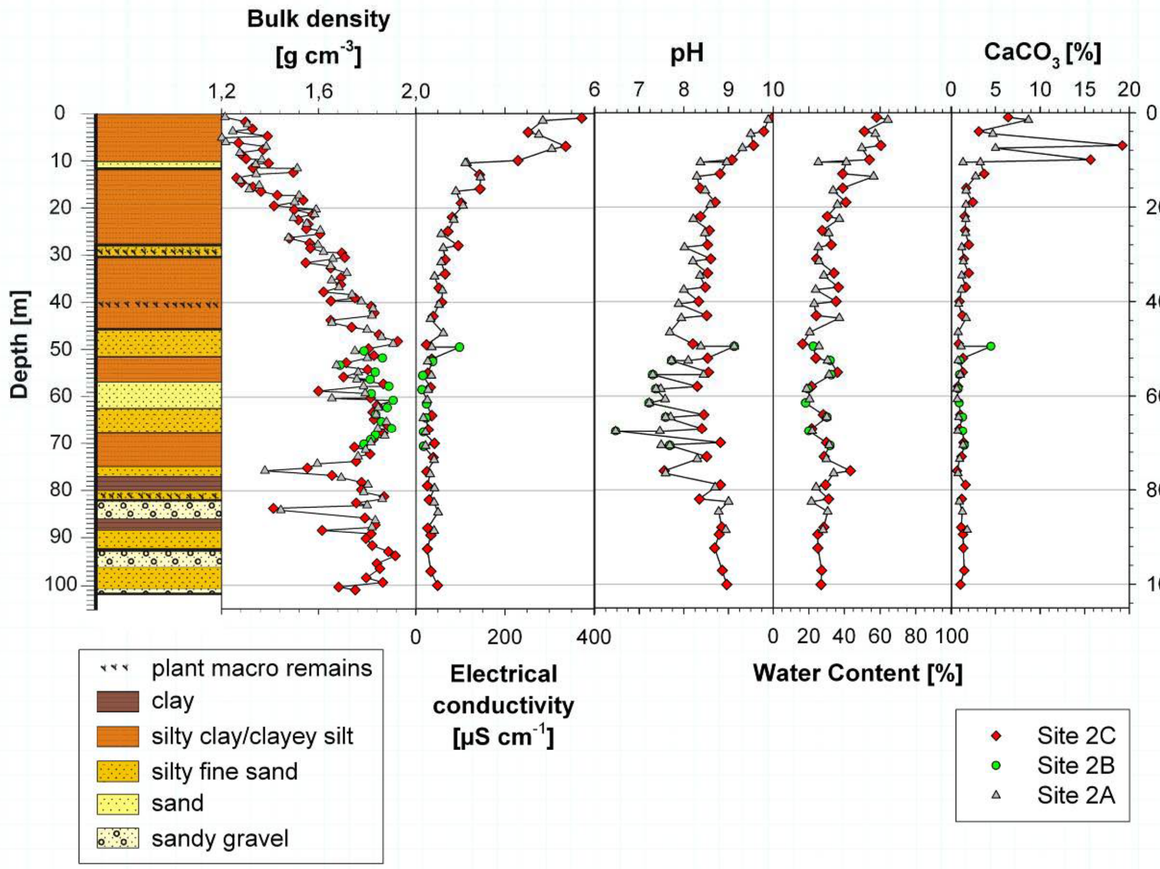

Fig. 12: Lithology and the parameters whole core bulk density, electrical conductivity, pH, water content and calcite content measured on-site in the field laboratory.

Fig. 13: Field Laboratory – view of the MSCL part of the laboratory.

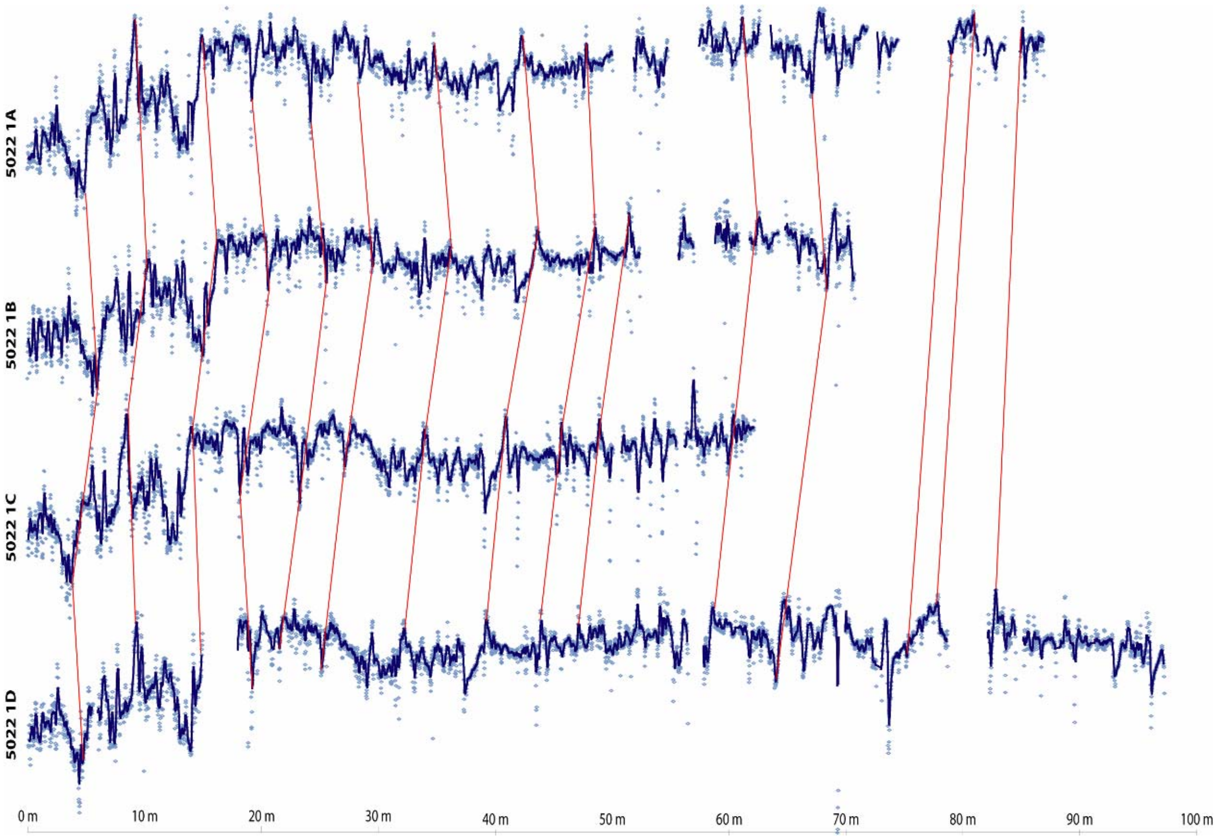

Fig. 14: Preliminary correlation of all four holes from site 1 based on magnetic susceptibility (data: C. Gebhardt).

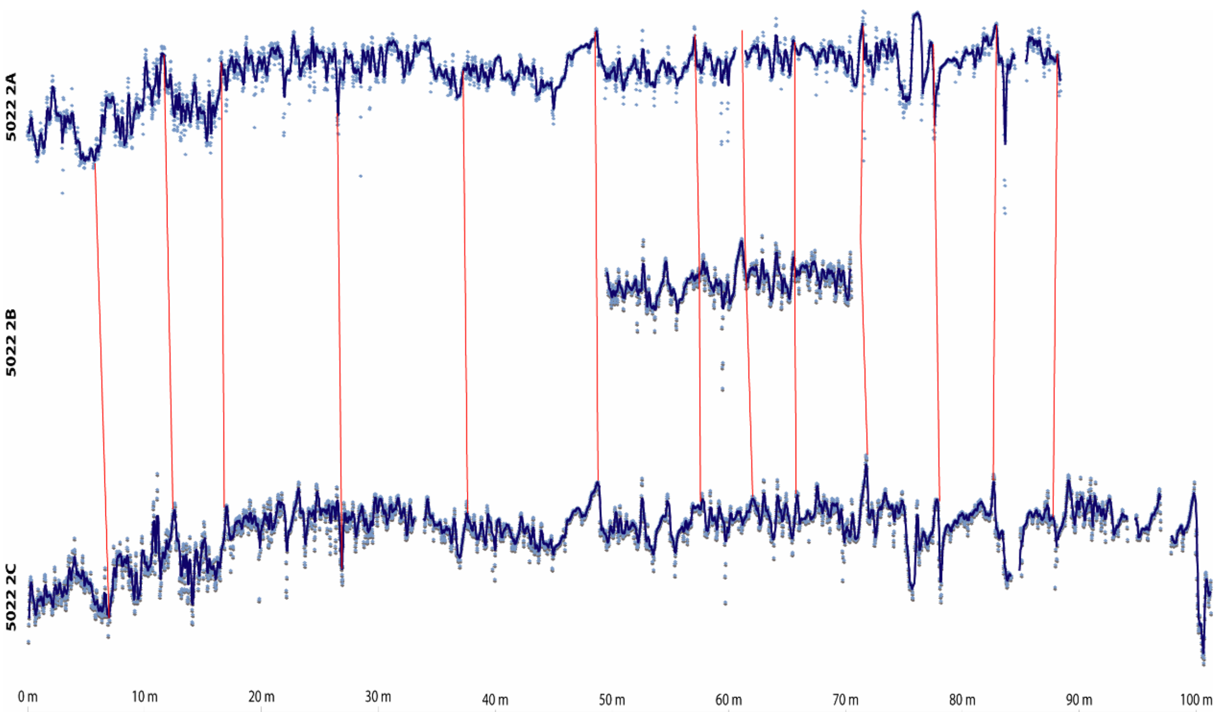

Fig. 15: Preliminary correlation of all three holes from site 2 based on magnetic susceptibility (data: C. Gebhardt).

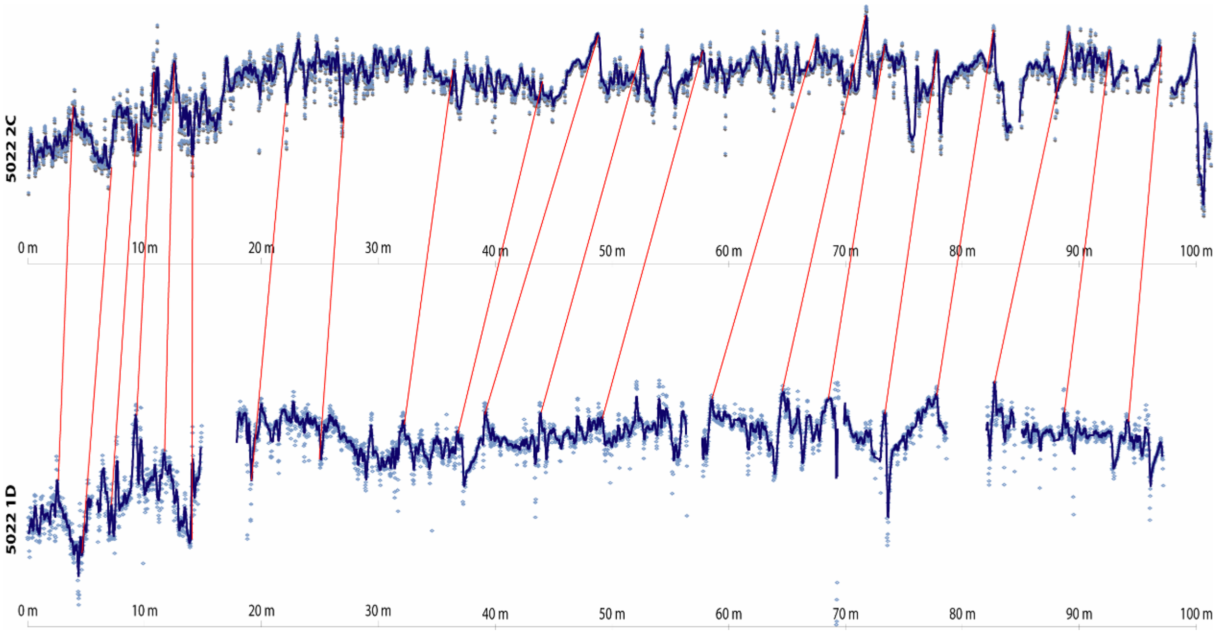

Fig. 16: Preliminary correlation of hole 1D with hole 2C based on magnetic susceptibility (data: C. Gebhardt).

Fig. 17: Crane truck at the lake shore lifting the drill rig onto the flatboard of one of the oilfield trucks during demobilisation.

Calendar of events

31.8.:	Arrival in Rio Gallegos.
8.9.:	Obtained a preliminary permit to drill Laguna Potrok Aike.
10.9.:	Field camp set up (delays due to weather conditions making roads impassable).
12.9.:	All containers arrived at the lake.
21.9.:	Launching of the new catamaran.
24.9.:	Last pieces of equipment necessary for assembling the platform arrive from Salt Lake City (delays due to custom problems).
1.10.:	Operations manager needed to go to Buenos Aires personally to free a UPS sending out of customs which did not follow Argentinean regulations and paid 800 USD customs fee and penalty. This package contained essential parts for the BHA (locking couplings). Without these drilling could not have started.
10.10.:	Platform successfully launched (delay related to contractor Moreteau in combination with communication problems with DOSECC).
13.10.:	Foam used for buoyancy in the containers of the platform blew across the lake.
15.10.	Start of drilling operation at site 1 (delays related to tandem locks breaking twice).
16.10.:	Hole 1A ended because of sand (88.05 m hole depth).
17.10.:	Hole 1B ended because of sand (71.00 m).
18.10.:	No drilling because mud and diesel were lacking. Helper injured in mud tank.
19.10.:	Because of sand the night shift tried to ream down to 66.2 m with the Alien because there was no centre bit available. The Alien was lost in the hole for unclear reasons. The hole 1C had to be abandoned (62.30 m).
20.10.:	Start of hole 1D.
22.10.:	Problems with hydraulic system (fissure) stopped drilling during nightshift (21./22.10.). The last stuck core could only be recovered at dawn: hole 1D ended at 100.35 m. Logging intended but storm came up: loss of pipe and casing.
23./24.10.:	Storm.
25.-28.10.:	Repairs, towing to new position, re-anchoring, running casing.
29.10.:	Re-start of drilling after stormy days at site 2. After 3rd shot drill head damage occurred with major oil spill, continuation after repair on the same day.
30.10.:	Stop of drilling due to upcoming storm (2A total hole depth: 88.51 m).
31.10.-2.11.:	Storm.
3.11.:	Re-start during a time window between storms. Reaming down to 80 m and continue drilling was the aim. It was only possible to ream down to 50 m (a centre bit was missing), then coring. But after 5 shots shear

pins for HPC run out. Extended nose was used. Its 2nd shot was sanded in, we got stuck, moderate wind came up, the platform was shifted and the pipe broke and was lost (2B: 21.12 m).

4.11.: Storm.

5.-9.11.: Waiting for necessary spare parts.

9.11.: Spare parts for the 3rd BHA and shear pins arrived from SLC.

11.-15.11.: Stormy weather.

16.11.: After several storms re-start of drilling.

17.11.: After the change from HPC to EXT the core could not be recovered (2C: 101.45 m). The overshot did not pick up the tool. Instead, after several attempts, the overshot broke. The tool was lost. It seems that the pipe broke again, although there was hardly any wind. Downhole logging confirmed a break of pipe near 135 m, sediment in the pipe at 145 m and difficulties to get through with the logging tools at about 100 m depth. Pulling the pipe gave the final certainty: the pipe was broken near the sediment/water interface at 100 m depth. The reason for this failure remained unclear – problems with the grade of the drill pipes were presumed by the DOSECC crew. Termination of all drilling activities was the consequence.

18.-22.11.: Dismantling of platform.

26.11.: Two containers of the University of Bremen left the camp for Río Gallegos.

26.11.: Application for the drilling permit was presented to Medio Ambiente.

26.-27.11.: Retrieving the platform from the lake.

28.11.: Containers packed and ready to leave the site.

30.11.: Field camp was broken down.

1.12.: Last scientists left Rio Gallegos.

Dec.: Foam blew away across the lake and polluted the farm “Estancia La Carlota”.

6.1.: All containers left the field and Río Gallegos to be transported to Buenos Aires.

10.2.: Containers arrived at the University of Bremen.

List of participants

Flavio ANSELMETTI
Eawag (Swiss Federal Institute of Aquatic Science & Technology)
Überlandstrasse 133
CH-8600 Dübendorf
Switzerland
E-mail: flavio.anselmetti@eawag.ch

Daniel ARIZTEGUI
Section of Earth & Environmental Sciences
University of Geneva
Rue des Maraichers 13
CH-1205 Geneva
Switzerland
E-mail: daniel.ariztegui@unige.ch

David FORTIN
Institut National de la Recherche Scientifique
Centre Eau, Terre et Environnement
490 rue de la couronne
Québec, QC G1K 9A9
Canada
E-mail: David.Fortin@ete.inrs.ca

Roger FRANCOIS
University of British Columbia
Earth and Ocean Dept
Vancouver
British Columbia
V6T 1Z4
Canada
E-mail: rfrancois@eos.ubc.ca

Pierre FRANCUS
Institut National de la Recherche Scientifique
Centre Eau, Terre et Environnement
490 rue de la couronne
Québec, QC G1K 9A9
Canada
E-mail: pfrancus@ete.inrs.ca

Catalina GEBHARDT
Alfred Wegener Institute for Polar and Marine Research
Am Alten Hafen 26
D-27568 Bremerhaven
Germany
E-mail: catalina.gebhardt@awi.de

Claudia GOGORZA
Facultad de Ciencias Exactas
Instituto de Física Arroyo Seco (IFAS)
Universidad Nacional del Centro de la Provincia de Buenos Aires (UNCPBA)
Tandil
Argentina

Present address:

Geopolar
Institute of Geography
University of Bremen
Celsiusstr. FVG-M
D-28359 Bremen
Germany
E-mail: cgogorza@exa.unicen.edu.ar

Torsten HABERZETTL
Physical Geography
Institute of Geography
Friedrich-Schiller-University Jena
Löbdergraben 32
D-07743 Jena
Germany
E-mail: torsten.haberzettl@uni-jena.de

Annette HAHN
Geopolar
Institute of Geography
University of Bremen
Celsiusstr. FVG-M
D-28359 Bremen
Germany
E-mail: anhahn@uni-bremen.de

Guillaume JOUVE
INRS-ETE Centre Eau, Terre & Environnement
490 rue de la Couronne
Québec (QC)
G1K 9A9
Canada
E-mail: guillaume.jouve@ete.inrs.ca

A. J. Timothy JULL
NSF Arizona AMS Laboratory
Physics Building
University of Arizona
1118 East Fourth St
Tucson, AZ 85721
USA
E-mail: jull@email.arizona.edu

Stephanie KASTNER
Geopolar
Institute of Geography
University of Bremen
Celsiusstr. FVG-M
D-28359 Bremen
Germany
E-mail: steka@uni-bremen.de

Kyeong Ja KIM
Korea Institute of Geoscience and Mineral Resources
92 Gwahang-no
Daejeon, 305-350
Korea
E-mail: kjkim@kigam.re.kr

Pierre KLIEM
Geopolar
Institute of Geography
University of Bremen
Celsiusstr. FVG-M
D-28359 Bremen
Germany
E-mail: kliem@uni-bremen.de

Isabelle LAROCQUE-TOBLER
INRS-ETE
490 De La Couronne
Québec, Québec
G1K 9A9
Canada
and
Institute of Geography
University of Bern
Erlachstrasse 9A
CH-3012 Bern
Switzerland
E-mail: Isabelle.Larocque@ete.inrs.ca

Agathe LISE-PRONOVOST
Institut des sciences de la mer de Rimouski (ISMER) & GEOTOP
Université du Québec à Rimouski
310 allée des Ursulines
Rimouski, Québec
G5L 3A1
Canada
E-mail:
agathe.lisepronovost@uqar.qc.ca

Andreas LÜCKE
Institute of Chemistry and Dynamics of the Geosphere 4: Agrosphere
Energy & Environment
Research Center Jülich
D-52425 Jülich
Germany
E-mail: a.luecke@fz-juelich.de

Nora MAIDANA
Lab. de Diatomeas Continentales
Departamento de Biodiversidad y Biología Experimental
Facultad Ciencias Exactas y Naturales
Universidad de Buenos Aires
Ciudad Universitaria
Pab. 2, 4° piso, Lab. 15
C1428EHA-Buenos Aires
Argentina
E-mail: nim@bg.fcen.uba.ar

Christoph MAYR
Institut für Geographie
Universität Erlangen-Nürnberg
Kochstr. 4/4
D-91054 Erlangen
Germany
E-mail: cmayr@geographie.uni-erlangen.de

Christian OHLENDORF
Geopolar
Institute of Geography
University of Bremen
Celsiusstr. FVG-M
D-28359 Bremen
Germany
E-mail: ohlen@uni-bremen.de

Reinhard PIENITZ
Centre for Northern Studies
Université Laval
Québec (Québec)
G1V 0A6
Canada
E-mail:
Reinhard.pienitz@cen.ulaval.ca

Cristina RECASENS
Department of Geology & Paleontology
University of Geneva
Rue des Maraichers 13
CH-1205 Geneva
Switzerland
E-mail: Cristina.Recasens@unige.ch

Peter ROSÉN
Climate Impacts Research Centre
(CIRC)
Umeå University
SE-981 07 Abisko
Sweden
E-mail: Peter.Rosen@emg.umu.se

Hamed SANEI
Geological Survey of Canada (GSC)
3303-33rd Street N.W.
Calgary
Alberta
T2L 2A7
Canada
E-mail: hsanei@nrcan.gc.ca

Frank SCHÄBITZ
Seminar für Geographie und ihre
Didaktik
Universität zu Köln
Gronewaldstr. 2
D-50931 Köln
Germany
E-mail: frank.schaebitz@uni-koeln.de

Enno SCHEFUß
Marine Geology
MARUM
University of Bremen
PO Box 330440
D-28334 Bremen
Germany
E-mail: schefuss@uni-bremen.de

Guillaume ST-ONGE
Institut des sciences de la mer de
Rimouski (ISMER) & GEOTOP
Université du Québec à Rimouski
310 allée des Ursulines
Rimouski, Québec
G5L 3A1
Canada
E-mail: guillaume_st-onge@uqar.qc.ca

Vicky TREMBLAY
Université du Québec
Institut National de la Recherche
Scientifique, Centre Eau, Terre et
Environnement (INRS-ETE)
490 de la Couronne
Québec (Qc), G1K 9A9
CANADA
E-mail: vicky.tremblay@ete.inrs.ca

Daniel VERES
“Emil Racovita” Institute of Speleology
Clinicilor 5
400006 Cluj-Napoca
Romania
Email: danveres@hasdeu.ubbcluj.ro

Hendrik VOGEL
University of Cologne
Institute for Geology and Mineralogy
Zülpicher Str. 49a
D-50674 Cologne
Germany
E-mail: vogelh@uni-koeln.de

Aurèle VUILLEMIN
Department of Geology & Paleontology
University of Geneva
Rue des Maraichers 13
CH-1205 Geneva
Switzerland
E-Mail: Aurele.Vuillemin@unige.ch

Sebastian WAGNER
GKSS Research Center
Institute for Coastal Research
Paleoclimate Group
Max-Planck-Straβe 1
D-21502 Geesthacht
Germany
E-mail: sebastian.wagner@gkss.de

Michael WILLE
Seminar für Geographie und ihre Didaktik
Universität zu Köln
Gronewaldstr. 2
D-50931 Köln
Germany
E-mail: mwille0@uni-koeln.de

Bernd ZOLITSCHKA
Geopolar
Institute of Geography
University of Bremen
Celsiusstr. FVG-M
D-28359 Bremen
Germany
E-mail: zoli@uni-bremen.de

Scientists not present during the workshop

but submitting an abstract

Maria Martha BIANCHI
Instituto de Investigaciones en Biodiversidad y Medio Ambiente
INIBIOMA – CONICET-CRUB
Quintral 1250
8400 - Bariloche
Rio Negro
Argentina
E-mail: mariam@bariloche.com.ar

Flavia QUINTANA
Instituto de Investigaciones en Biodiversidad y Medioambiente
INIBIOMA - CONICET
Quintral 1250
8400 - Bariloche
Rio Negro
Argentina
E-mail: flavia_quintana@hotmail.com

Stefan WASTEGARD
Department of Physical Geography and Quaternary Geology
Stockholm University
S-106 91 Stockholm
Sweden
E-mail: stefan.wastegard@geo.su.se

TERRA NOSTRA – Schriften der GeoUnion Alfred-Wegener-Stiftung

Übersicht über die erschienenen Hefte 2004-2009

2004/1 **TSK X. 10. Symposium Tektonik, Struktur- und Kristallingeologie.** Kurzfassungen der Vorträge und Poster. 31.03.-02.04.2004, Aachen. – 108 S. – *Verkaufspreis: € 11,50*

2004/2 **18th International Senckenberg Conference. VI International Palaeontological Colloquium in Weimar.** Late Neogene and Quaternary Biodiversity and Evolution: Regional Developments and Interregional Correlations. Conference Volume. April 25-30, 2004, Weimar, Germany. – 289 S. – *Verkaufspreis: € 21,-*

2004/3 **A.M.S.El. Workshop 2004. "Analytik als Werkzeug für die Klima- und Geoforschung".** Programme und Zusammenfassungen der Tagungsbeiträge. 7.-8. Juni 2004, Alfred-Wegener-Institut, Bremerhaven. – 42 S. – *Verkaufspreis: € 7,-*

2004/4 **XXVIII SCAR & COMNAP XVI.** SCAR Open Science Conference. "Antarctica and the Southern Ocean in the Global System". XI SCARLOP Symposium. "Towards the International Polar Year and Beyond". Abstract Volume. July 25-31, 2004, Bremen, Germany. – 480 S. – *Verkaufspreis: € 26,-*

2004/5 **Proceedings of the XI SCALOP Symposium. "Towards the International Polar Year and Beyond".** 28 July, 2004, Bremen, Germany. – 242 S.– *Verkaufspreis: € 21,-*

2005/1 **19th Colloquium on Latin American Geosciences.** April 18-20, 2005, Potsdam. – 147 S. – *Verkaufspreis: € 14,-*

2005/2 **2nd European Conference on Permafrost.** Programme and Abstracts. June 12-16, 2005, Potsdam, Germany. – 224 S. – *Verkaufspreis: € 20,-*

2005/3 **22. Internationale Polartagung der Deutschen Gesellschaft für Polarforschung.** Programm und Zusammenfassung der Tagungsbeiträge. 18.-24. September 2005, Jena. – 151 S. – *Verkaufspreis: € 14,50*

2005/4 **2nd International Alfred Wegener Symposium.** Programme and Abstract. October 30 - November 02, 2005, Bremerhaven, Germany. – 115 S. – *Verkaufspreis : € 13,-*

2005/5 **DFG-SPP 1135. Dynamics of the Central European Basin System.** 4th Rundgespräch. November 30 - December 02, 2005, Eringerfeld, Germany. 136 S. – *Verkaufspreis : € 14,-* **vergriffen**

2006/1 **ICDP-Workshop PASADO. Potrok Aike Lake Sediment Archive Drilling Project.** Scientific Programme – Abstract Volume – Excursion Guide – Participants. March 15-19, 2006, Rio Gallegos, Santa Cruz, Argentina. – 90 S. – *Verkaufspreis : € 11,50*

2006/2 **150 Years of Neanderthal Discoveries. Early Europeans – Continuity & Discontinuity.** Congress, July 21st-26th, 2006 in Bonn, Germany. – 170 S. – *Verkaufspreis : € 17,-*

2006/3 **Shaping the Earth's Surface: Dynamics and Changing Environments.** GV International Conference 2006 and 96th Annual Meeting of the Geologische Vereinigung e.V. September 25-29, 2006, Potsdam, Germany. – 118 S. –*Verkaufspreis : € 14,-*

2006/3a **Geomagnetic Field Variations: Space-Time Structure, Processes, and Effects on System Earth. International Final Colloquium of the German Science Foundation Priority Programme 1097.** Jointly organized by the Deutsche Forschungsgemeinschaft and the Deutsche Akademie der Naturforscher Leopoldina. October 4-5, 2006. – 120 S. – *Verkaufspreis: € 14,-*

2007/1-2 **The Oceans in the Earth System.** International Conference 2007 and 97th Annual Meeting of the Geologische Vereinigung e.V. (GV), Bremen, Germany, October 1-5, 2007. – 267 S. – *Verkaufspreis: € 21,-*

2008/1 **23. Internationale Polartagung der Deutschen Gesellschaft für Polarforschung**. Münster, 10.-14. März 2008. Programm und Zusammenfassung der Tagungsbeiträge. – 107 S. – *Verkaufspreis: € 14,-*

2008/2 **12th International Palynological Congress (IPC-XII), 8th International Organisation of Palaeobotany Conference (IOPC-VIII)**. Abstract Volume. August 30 – September 5, 2008 in Bonn, Germany. – 337 S. – *Verkaufspreis: € 25,-*

2009/1 **KALMAR – First Bilateral Workshop on Russian-German Cooperation on Kurile-Kamchatka and the Aleutean Marginal Sea-Island Arc Systems.** Program and Abstracts. *Petropavlovsk-Kamchatka, Russia, April 27 - May 1, 2009.* – 73 S. – *Verkaufspreis: € 10,-*

2009/2 **System Erde – Mensch. Handlungsoptionen und Managementstrategien**. Dokumentation der Strategiekonferenz am 12. und 13. Juni 2008 in Berlin. Herausgegeben von Rolf Emmermann, Gerold Wefer und Volker Mosbrugger. – 118 S. – *Verkaufspreis: € 5,-*

2009/3 **Paläontologie. Schlüssel zur Evolution. 79. Jahrestagung der Paläontologischen Gesellschaft, Bonn, 5.-7. Oktober 2009**. Kurzfassung der Tagungsbeiträge. – 126 S. – *Verkaufspreis: € 14,-*

2009/4 **Annual Meeting of the German Association of Stable Isotope Research (GASIR).** Abstract Volume. **– Jahrestagung der Arbeitsgemeinschaft Stabile Isotope e.V. (ASI)**. Tagungsband. – AWI Potsdam, 5.-7. Oktober 2009. – 86 S. – *Verkaufspreis: € 10,-*

2009/5 **Klima im System Erde. Klimawandel – Antworten und Fragen aus den Geowissenschaften.** Zusammenfassung der Konferenzbeiträge, dbb-forum Berlin, 2. und 3. November 2009. – 89 + 36 S. – *Verkaufspreis: € 5,-*

Gesamtübersicht über die Hefte seit 1993:
http://www.geo-union.de/TERRA_NOSTRA_1993-2009.pdf