The International Continental Scientific Drilling Program (ICDP)

Funding and support through the International Continental Scientific Drilling Program (ICDP)

Ulrich Harms

ICDP, Program Management, GeoForschungsZentrum Potsdam, Germany

The ICDP aims with its international efforts in scientific continental drilling on topics of high scientific priority and its drilling projects are conducted at locations of global geological significance. The program focuses on challenging themes of both geoscientific and socio-economic relevance such as Earth history and climate, natural hazards, volcanic systems and thermal regimes, impact structures and mass extinctions, or deep biosphere (Fig. 1).

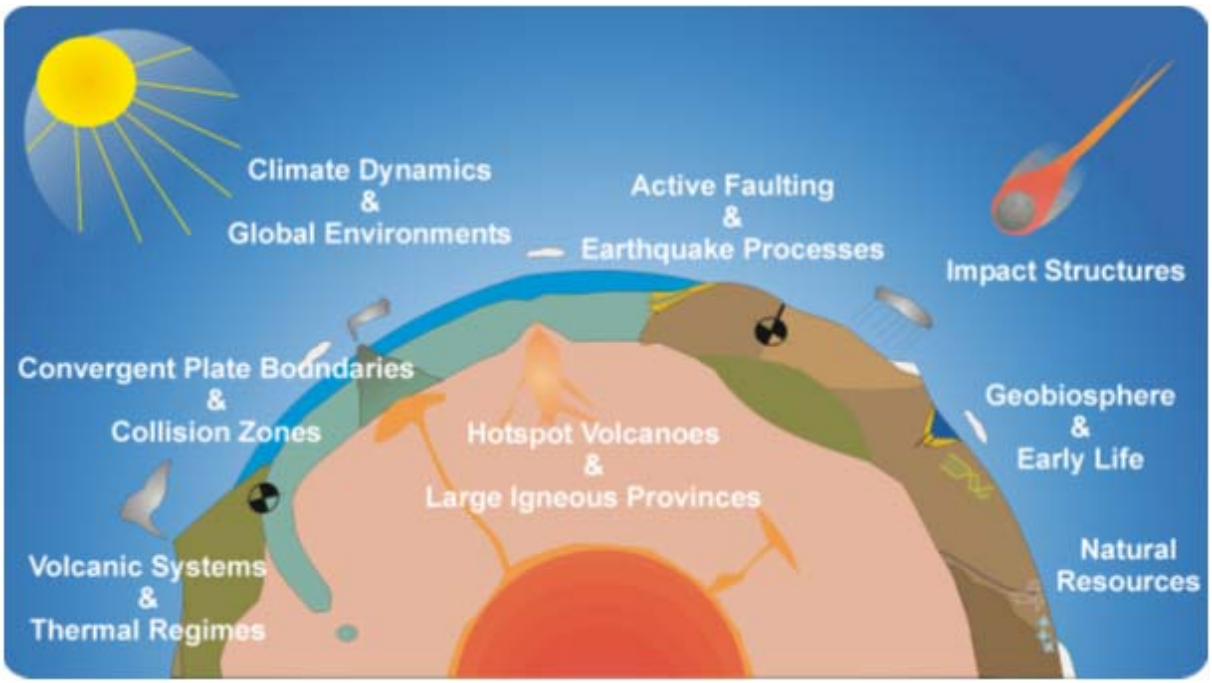

Fig. 1: Major Scientific Themes addressed by the ICDP

Previously supported drilling projects with a major paleo-environmental component comprise the recovery and investigation of lacustrine sediments from Lakes Baikal, Titicaca, Bosumtwi and Malawi. Also in future, the theme “Climate Dynamics and Global Environments” will be one of the major issues addressed by the ICDP.

On the one hand, ICDP funds drilling operations and drilling-related activities with international financial contributions paid from the annual membership fees of the currently 13 ICDP member countries. On the other hand, ICDP provides scientific-technical assistance through its Operational Support Group (OSG) and offers access to the ICDP equipment pool and operational expertise. This pool comprises drilling

tools including the Global Lake Drilling Facility GLAD800 as well as scientific instruments and measurement assistance such as downhole logging sondes with a full suite of slimhole logging tools (Gamma, DLL, Sonic, Mag-Sus, Dipmeter, Televiewer, Fluidsampler). These in-hole facilities are complemented e.g. by downhole monitoring capabilities and core measurement devices including optical and petrophysical scanning. A web-based data and information management system allows direct data entry, exchange, and retrieval for participating scientists. ICDP is striving to provide these capabilities for the PASADO project.

GLAD800 drilling in Laguna Potrok Aike, Argentina

Dennis L. Nielson

Drilling, Observation and Sampling of the Earth's Continental Crust (DOSECC), Salt Lake City, USA

Drilling in modern lakes presents technical and logistical challenges. Each project is unique and requires planning and close coordination between scientists and drilling personnel. The GLAD800 (Global Lake Drilling to 800 m) was developed as a joint research venture between DOSECC and the International Continental Scientific Drilling Program (ICDP). The components of this system are a modular barge, drill rig and sampling tools. The barge is made up of 8 shipping containers arranged in a 3 x 3 array with the vacant center position serving as the moon pool; the containers are partially flooded to resist heave. Recently, we have added additional containers to form a barge that is 24 m long by 7 m wide that provides additional working space. The barge is not powered and must be towed from site to site by a service boat; position is maintained during drilling operations by four anchors. The drill is a modified CS-1500 diamond coring rig. The sampling tools include the following: push core, hydraulic piston corer, extended nose, extended core bit and non-sampling assembly. These tools are changed by wireline without pulling the bottom hole assembly. They collect cores of 62 mm in diameter standard ODP plastic liners and are available in 3-meter lengths.

There are two aspects that commonly affect the efficiency of the drilling operations. The first is weather. Although the barge is very stable, wind and waves do affect its performance, and storms or sustained winds may result in drilling operations being suspended to protect equipment and personnel. Another common issue is the presence of sands in the stratigraphic section. These are often not identified before drilling commences and commonly lead to operational difficulties. Personnel and environmental safety is an important consideration on all drilling projects, and DOSECC has established a Drilling Environmental Protection and Safety (DEPS) Panel that will review the project before the final proposals are submitted.

Two publications that may be useful in the planning process are "Best Practices in the Development of Scientific Drilling Projects" and "Lake and Marine Drilling Planning and Operations Manual". Both of these are available on DOSECC's web site (www.dosecc.org).

Reconstructing Late Quaternary Environmental Change in the Lowland Neotropics – The Lake Petén-Itza Drilling Project (January-March 2006)

Ariztegui D.[1], Anselmetti, F. S.[2], Hodell, D.[3], Brenner, M.[3] & the Scientific Drilling Party

[1]*Institute Forel and Dept. of Geology & Paleontology, University of Geneva, Switzerland*
[2]*Geological Institute, ETH Zurich, Switzerland*
[3]*Department of Geologic*al Sciences, University of Florida, Gainesville, USA

All shallow lake basins in the northern lowland Neotropics were dry during the last glaciation due to increased aridity and/or lowered sea level. Detailed high-resolution and airgun seismic surveys of Lake Petén-Itza, Guatemala, have revealed that it is deep (160 m) and possesses a thick (>100 m) stratigraphic record that extends back to at least Marine Isotope Stage 5. It is the only lake known to us from the region that is deep enough (160 m) to have held water continuously through the latest Pleistocene. The lake is presently a drilling target for the International Continental Drilling Project (ICDP). The objective of the Petén-Itza Drilling Project is to recover continuous, high-quality sediment cores and pore fluids that will be used to test hypotheses related to three broad scientific themes:

- Paleoclimatic history of the northern lowland Neotropics on orbital to suborbital time scales emphasizing marine-terrestrial linkages (e.g., Cariaco Basin, Greenland ice cores, etc.),
- Paleoecology and biogeography of the Maya tropical lowland forest including the history of vegetation change and disturbance by humans, climate change, and fire and
- Biogeochemical cycling in deep lake sediments emphasizing integrated studies of microbiology, geochemistry (interstitial waters), and mineral authigenesis/diagenesis.

Six primary and four alternate drill sites have been identified that fall along a depth transect extending from ~30 m to near the deepest point (~150 m) in the lake. A sequence stratigraphic approach will be employed to constrain the vertical range of past lake level variations for glacial, interstadial, and interglacial stages during the late Pleistocene. The integration of seismic profiles and a depth transect of piston cores have shown to be an effective strategy for defining lake level during the last glacial period and reconstructing paleoclimate and paleoenvironmental change for the most recent glacial-to-interglacial transition. Although the basal age of the sections to be drilled is not certain it can be estimated that sequences should extend through the last interglacial (MIS 5). An international team of research scientists has been assembled to produce a comprehensive suite of paleoenvironmental and biogeochemical measurements on the cores and pore fluids recovered from Lake Petén-Itza.

Understanding the evolution of maar volcanoes

Magnetometric survey of Laguna Potrok Aike

Marcelo Paterlini[1] & Hugo Corbella[2]

[1]Servicio de Hidrografía Naval, Buenos Aires, Argentina
[2]Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina

Laguna Potrok Aike (51°58' S, 70°23'W), the largest phreatomagmatic lake in the Pali Aike Volcanic Field in Southern Patagonia, has a diameter of ~3 km and is 100 m deep. The depression is carved into Miocene sandstones and micro-conglomerates of the Santa Cruz Formation, till deposits and ~1 Ma old basaltic lavas. Phreatomagmatic deposits dated to 0.7 Ma and loessic soils follow on top of the sequence.

Bathymetric and on-board seismic surveys carried out with different methods during the summers of the years 2003, 2004 and 2005 allow to infer the presence of 300 m or more of undisturbed pelagic lake sediments. The continuous seismic reflections of the lacustrine sediments showed that they are cut by steep crater slopes with shoulders in the upper part and also some slumping structures. To better know the structure of the Potrok Aike diatreme, the existence of slumping involving the country rock and to check the possible presence of an ultimate eruptive event as a volcanic body hidden inside the lacustrine sedimentary pile, a subaquatic magnetometric survey is proposed.

As field procedures for this research a protonic geometric G877 marine magnetometer will be used. The sensor fish will be towed by a small boat as near as possible to the lake bottom, taking care not to disturb the sediments. For the survey, two multi-line grids are planned. One exploration grid 500 m large will initially be done, followed by a 100 m detail grid to cover the most interesting areas. Along the lines the magnetic field and the GPS position will be simultaneously registered. Additionally, a land proton magnetometer will be located to monitor the diurnal magnetic variation, before, during and after the survey.

After the survey normal data reductions will be applied. IGRF or the local regional magnetic field will be removed to define the anomalies. Modeling methods will be used to define the anomaly origin. Contour maps and profiles will be made to show the results.

Reconstruction of the volcanic history of the Potrok Aike Maar: Part 1: Volcanological and sedimentological characterization of volcaniclastic units

Ulrike Martin & Helga de Wall

Institut für Geologie, Julius-Maximilians-Universität Würzburg, Germany

Aim of the study is to prove the phreatomagmatic origin of the Potrok Aike Maar by applying quantitative and qualitative volcanological methods to reconstruct the genesis of the Potrok Aike Maar. This allows a detailed physical volcanological reconstruction of the processes that took place during eruption. The development of the maar from the beginning of the eruptive phase until the sedimentation into the maar basin will be clarified in context to the tectonic volcanological development of the Pali Aike Volcanic Field. Results also should contribute to understand the tephra deposition mechanisms and feeding systems of such systems. The knowledge of volcanological, volcano-tectonic and sedimentological processes is important for the geneses of repositories but also of generally significance for studies dealing with phreatomagmatism which includes

- The reconstruction of the primary and syn-eruptive relocation processes during the formation of maar-diatreme volcanoes and
- A detailed description of the transition zone at the end of volcanic activity into the post-eruptive lake-forming phase.

Depending on the depth of the drilling it would be possible to get a detailed description of the transition from primary erupted tephra to post-eruptive sequences. In addition to these volcanological investigations the post-eruptive tectonic deformations of the sedimentary body can also be studied to get the rate of subsidence.

The base of these studies are macroscopic and microscopic descriptions of the drilled core and the compilation of a profile seen under volcanological aspects. The description of the core should also be done under geophysical aspects (e.g. susceptibility) to get the base of a solid interpretation. The correlation of the beds with geophysical characteristics will be undertaken in cooperation with the second part of the proposal (de Wall & Martin, this volume) and colleagues form the GGA, Hannover (Wonik, this volume).

Reconstruction of the volcanic history of the Potrok Aike Maar: Part 2: Rockphysical and geochemical characterization of volcaniclastic units

Helga de Wall &Ulrike Martin

Institut für Geologie, Julius-Maximilians-Universität Würzburg, Germany

The Potrok Aike Maar structure is envisaged as target area for a drilling project within the frame of the ICDP. The here proposed research project will contribute to the reconstruction of the volcanic history of maar formation and will prove the phreatomagnetic origin of the structure by field studies and interpretation of borehole data. It is designed as a complementary project to the volcanological study described in Part 1 of this proposal (Martin & de Wall, this vol.).

A current research project, carried out in cooperation with colleagues from the GGA institute, Hannover, is situated in a comparable geological setting: a scientific drilling in the Messel pit in Germany (Forschungsbohrung Messel in 2001) has explored the structure of a maar diatreme that forms the host structure for the world-famous fossil-bearing Messel pelites, the so-called oil shales (UNESCO World Heritage Site). Our project focused on the origin of magnetic anomalies in the Messel Maar structure and has shown that rockmagnetic studies can be used for the subdivision of lithological units and can significantly contribute to the reconstruction of the depositional history of volcaniclastics. Furthermore, we found studies of the anisotropy of magnetic susceptibility (AMS) particular useful to evaluate cryptic magnetic fabrics in macroscopically unstructured volcaniclastic units. AMS can be used to detect transport directions of volcanic material as well as to trace post-eruptive deformations of the sedimentary body by tectonic or gravitational stresses.

For a comprehensive model of the maar structure, borehole measurements are particular useful as they provide quasi-continuous information on the drilled section. By compiling log responses from tools sensitive for both, lithological and structural variations a reconstruction of the geological profile can be achieved. In the frame of the ICDP, downhole logging can be carried out by the ICDP operational support group (GFZ Potsdam) if the logging campaign is scheduled and requested by the PI`s and thus forms a part of the financial calculation of the ICDP project. However, borehole measurements can also be integrated into a DFG project proposal.

Understanding the evolution of maar craters

Miguel J. Haller[1], Helga de Wall[2], Ulrike Martin[2] & Károly Németh[3]

[1]Universidad Nacional de la Patagonia San Juan Bosco; Bvard. Brown 3700, 9120 Puerto Madryn, Argentina
[2]Institut für Geologie, University of Würzburg; Germany
[3]Institute of Natural Resources, Dept. Soil and Earth Sciences, Massey University, Palmerston North, New Zealand

Two innominate lakes located 12 km SEE of Laguna Potrok Aike at ~51º 59' 51”S; 70º 09' 18”W fill maar related tuff-ring interiors. The more western maar has an ellipsoidal shape, a size of 1.300 m × 700 m and the water level is 70 m below the surrounding topography. The eastern lake, of sub-circular shape is 650 m in diameter and its water level is 40 m below the average surface.

The interior tuff-ring cliffs show ca. 60 m thick succession of tephra bedded in 0,3 m thick beds inferred to have been deposited from high energy pyroclastic density currents. The beds contain predominately olivine crystals, ultramafic xenoliths, basanoid rock fragments, blocky non- to moderately vesicular volcanic glass shards and accretionary lapilli. Plastering of fine grained tephra over larger clasts is prominent. Accidental lithic clasts from deeper seated volcanic sequences as well as lacustrine sediments possible from maar lake(s) have also been recognized. The textural characteristics of the tephra beds and its fragments such as the shape, size, and distribution pattern of different fragments suggest inhomogeneous magma/water interaction events during the eruption.

We propose the detailed volcanological, sedimentary and paleomagnetic study of the pyroclastic succession of the tephra rings. Results should contribute to understand the evolution of maar craters, tephra deposition mechanisms, feeding systems and the palaeosecular variation of the Earth's magnetic field for the last several glacial to interglacial cycles. A potential drilling through the maar lacustrine beds of the maar lake would give a good base for correlation of events occurred after formation of these craters. Moreover, the detailed study at Potrok Aike and the two mentioned maars are closely spaced and presumably of similar age. These volcanic craters would give a good chance to identify distal pyroclastic fall events. Such tephra beds are likely to have been accumulated in these craters. Moreover, succeeding to drill a core reaching the diatreme below the lacustrine maar succession would give raw data to understand the eruptive history of maar volcanoes developed in a “soft sediment” filled basin. The evolution and the development of a maar in such a setting is not understood yet. Studies over this subject only have been done on old, commonly eroded maar volcanic structures. The proposed research site would be among the very few sites in the world, where during an interdisciplinary approach the evolution of such volcanoes could be well understood. Eventual correlations with the Laguna Potrok Aike sediment record will reinforce regional interpretations.

Deciphering high-frequency environmental variations

Physical properties, structural features, and climate signals in lake sediments and phreatomagmatic breccias of the Potrok Aike Maar derived from downhole logging

Thomas Wonik

Leibniz Institute for Applied Geosciences (GGA), Hannover, Germany

Deep drilling in Laguna Potrok Aike will be performed to obtain a complete paleoenvironmental record (lake sediments) over glacial cycles for southern hemispheric mid-latitudes and to study the subsurface structure of the maar (phreatomagmatic breccia).

Downhole logging in lacustrine sediments and diatreme breccia enables to obtain continuous, fine scale, in-situ physical and chemical parameters around the borehole walls. The most important physical parameters/tools are natural gamma ray, density, resistivity, seismic velocities, susceptibility, dipmeter, and borehole televiewer. Geophysical logging in the Laguna Potrok Aike will provide unique continuous data of the evolution and of events recorded in the lake sediments as well as of lithological and structural data of the underlying rocks.

Downhole logging data in the scientific drilling of the Tertiary maar Messel (Germany) allows to correlate the lithological description of the cores with variations in physical and chemical properties. Especially the three major lithological units, laminated lake sediments, lapilli tuff and diatreme breccia, show distinct combinations of physical parameters. The diatreme breccia shows larger changes in the physical properties caused by its composition of clasts (granodiorite, amphibolite or Lower Permian sediment). A separation of these three clast types can be achieved with the help of the down-hole logging data.

Some examples for important information which can be deduced from downhole data: In collaboration with other working groups (e.g. de Wall and Martin, see also this vol.) the characterization of volcaniclastic units will be possible. Variations in the content of total inorganic carbon mirror the lake's water volume. GGA uses a unique borehole tool that allows to measure the contents of several chemical elements including carbon under in-situ conditions. Furthermore, using geostatistical methods on the downhole logging data allows to determine among other parameters the mean sedimentation rate. Travel-time data from a vertical seismic profile (VSP) experiment can be used to determine velocities to serve as a basis for comparison with downhole sonic and core measurements and can also be used to tie directly into marine seismic reflection data, resulting in a reliable depth-time conversion for seismic reflection data.

Microfacies characterization using image analysis, physical and chemical properties for understanding sedimentary processes and reconstructing climate at high-resolution at Laguna Potrok Aike

Pierre Francus[1] & Scott Lamoureux[2]

[1]Institut national de la recherche scientifique, Centre Eau, Terre et Environnement, Québec, Canada
[2]Department of Geography, Queen's University, Kingston, Ontario, Canada

In order to understand and identify the sedimentary processes occurring in Laguna Potrok Aike and to decipher their relationship with climate, we suggest using detailed sedimentology coordinated with a set of advanced imaging and non-destructive techniques.

In collaboration with Saint-Onge & Francus (this vol.), we will coordinate obtaining non-destructive CT scans prior to subsampling U-channels from the core for analyses with an ITRAX core scanner. This instrument permits (1) a good quality visual image of the sediment, (2) a corresponding radiograph with a spatial resolution down to 20 µm and (3) an XRF elemental analysis with a spatial resolution down to 100 µm. Digital sediment color analysis can be used to obtain a high-resolution climate proxy record (Nederbragt et al., 2004). The constant thickness of the U-channel samples results in uniform digital radiographs that can be used to obtain a continuous record of sediment density at high resolution (Ojala et al., 2004). If varves are present, these images can be used to quickly count varves and measure their thickness and density parameters. Preliminary XRF-analyses conducted on a 1 m long section of Laguna Potrok Aike with a lower resolution (1 cm), showed the value of such information (Haberzettl et al., 2005). For instance, these non-destructive chemical analyses can be used to infer and distinguish between detrital and aeolian inputs (and potentially other sources) and to detect tephra. The XRF-analyses and corresponding digital radiograph are particularly valuable for the interpretation of environmental paleomagnetic measurements obtained from the same U-channel (St-Onge & Francus, this vol.).

Then, we suggest subsampling for thin-sections in order to obtain a detailed qualitative and quantitative characterization of the sedimentary facies. Detailed sedimentary characterization and event or lamination thickness measurements can be obtained using conventional light microscopy. Complementary quantitative measurements will be performed using a recently developed technique for image analysis of thin-sections. The technique relies on backscattered electron microscope photographs digitized from undisturbed thin-sections, cut by freeze-drying (Francus & Asikainen, 2001; Lotter & Lemcke, 1999). Processing of the greyscale pictures (256 grey tones) produces binary (black & white) images, where white pixels represent the clay-rich sedimentary matrix and black pixels represent siliciclastic grains. Measurements include grain surface, perimeter, shape, orientation and center of gravity. Processing of the data allows the retrieval of grain-size, bioturbation (Francus, 2001), and quantified sedimentary fabric information. The image analysis-derived grain size information can be compared to measurements made on a laser scattering particle size analyzer at Queen's University at high depth resolution (1 mm) to resolve changes to fine grained components (<3.9 µm) and verify the image results. We have developed a new software system that integrates and automates

the entire image processing procedure and allows the analysis of a very large number of thin-sections in a reasonable amount of time.

The comparison of instrumental and sediment trap data with the microfabric of the uppermost sediments is a powerful tool to decipher how the climate signal is recorded in the sediment (Francus et al., 2002). Through advanced time series analysis, we also can identify the recurrence properties of major hydroclimatic events (e.g. floods) and investigate sediment erosion dynamics (Lamoureux, 2000, 2002). Time series analyses will also be performed on the other data we suggest to acquire.

In brief, information retrieved using a combination of thin section microscopy, image analysis, and sediment physical and chemical properties provides a quality control and sedimentary context for the other climate proxies, and can also be used as important environmental indicators.

References

Francus P. 2001. Quantification of bioturbation in hemipelagic sediments via thin-sections image analysis. *J. Sediment. Res.*, 71, 3, 501-507.

Francus P. & Asikainen C., 2001. Sub-sampling unconsolidated sediments: a solution for the preparation of undisturbed thin-sections from clay-rich sediments. *J. Paleolimnol*., 26: 323-326.

Francus P., Bradley R., Braun C., Abbott M. & Keimig F. 2002. Paleoclimate studies of minerogenic sediments using annually resolved textural parameters. *Geophysical Research Letters*, 29, 20, 1998.

Haberzettl T., Fey M., Lücke A., Maidana N., Mayr C., Ohlendorf C., Schabitz F., Schleser G., Wille M., Zolitschka B. 2005. Climatically induced lake level changes during the last two millennia as reflected in sediments of Laguna Potrok Aike, southern Patagonia (Santa Cruz, Argentina). *J. Paleolimnol*., 33: 283-302.

Lamoureux S.F. 2002. Temporal patterns of suspended sediment yield following moderate to extreme hydrological events recorded in varved lacustrine sediments. *Earth Surface Processes and Landforms*, 27: 1107-1124.

Lamoureux S.F. 2000. Five centuries of interannual sediment yield and rainfall-induced erosion in the Canadian High Arctic recorded in lacustrine varves, *Water Resources Res.*, 36: 309-318.

Lotter A. & Lemcke G. 1999. Methods for preparing and counting biochemical varves. *Boreas*, 28: 243-252.

Nederbragt A., Francus P., Bollmann J. & Soreghan M. 2004. Image calibration, filtering and processing. In: Francus P. (Ed.), 'Image analysis, sediments and paleoenvironments', Springer, Dordrecht, The Netherlands: 35-58.

Ojala A.E.K. 2004. Application of X-Ray radiography and densitometry in varve analysis. In: Francus P. (Ed.), 'Image analysis, sediments and paleoenvironments', Springer, Dordrecht, The Netherlands: 187-202.

High-frequency climate variability in Laguna Potrok Aike

Juergen Thurow and group

Palaeoceanography and Sedimentology, Department of Earth Sciences, University College London, U.K.

We propose to analyse characteristic interannual to centennial climate variability in the proposed ICDP drill hole in the maar lake Laguna Potrok Aike in southern Patagonia in the context of other high-resolution records in and around South America. The proposed research will be part of a wider project in our group to determine the geographic extent of short climate cycles, like ENSO, NAO, and Southern Ocean climate oscillations, and their interaction with longer centennial cycles, like the Gleisberg cycle. Our aim is to document the temporal and spatial evolution of the Pacific and Atlantic influences across South America, i.e. which climate system is dominating/controlling lacustrine and near-shore marine depositional systems, and how these patterns change at glacial/interglacial time scales. We are currently working on a non-volcanic lake record (last Glacial and Holocene) from near Cusco/Peru, and are trying to develop a programme to take long marine cores near-shore Peru. We also have and are working on very long Marion Dufresne cores (varved) from the Gulf of California and the Cariaco Basin (Venezuela).

The focus of our research will be on fast and non destructive but high resolution methods like digital imaging and XRF-scanning to generate long continuous records of sediment colour and elemental composition. X-radiography and backscatter electron imagery of slab samples will be used in critical intervals in any laminated sediments in combination with mm-scale chemical analysis. The generated time series will be analysed statistically to determine if there are characteristic climate frequencies, how persistent they are, and if they change over time. In addition we would like to test if the sediments are suitable for biomarker palaeothermometry, which works in some, but not in all lakes. All proposed analyses can be carried out in-house at UCL with equipment already in place or arriving soon.

In the wider context of the PASADO initiative I would like to add that I have been mandated (as an SSEP member) by IODP to explore the demand in the scientific community for ultra high-resolution drilling. If there is enough interest, IODP will establish a programme planning group (PPG) as early as next March (2006), which should identify target areas and ideally also develop drilling proposals. I would like to see a PPG which is not only focussed on palaeoclimate records in the marine realm but also addresses together with the ICDP "terrestrial - marine" links, timing and extent of volcanism, geohazards, to name a few. It also seems appropriate to use for such subject areas the full range of drilling platforms available.

History of volcanic eruptions and dating of the sediment record

Tephrochronology - A high potential correlation tool in palaeoenvironmental investigations

Christel van den Bogaard

IFM-GEOMAR Leibniz Institut für Meereswissenschaften, Kiel, Germany

The climatic development of the past is a complex and sometimes rapid process. However, detailed investigations of the Greenland ice cores and annually laminated lake sediments in Europe have shown that conventional dating methods do not yield a satisfying time resolution to correlate single events. To improve the age models an alternative method has been established over the last decade: the correlation of volcanic ash layers. Ash layers from explosive volcanic eruptions are distributed and deposited within hours and days over a wide region, up to several thousand kilometers away from their source. These isochronous marker horizons were used to correlate sediments on a high precision time scale. Tephra layers in these investigations range from several cm thickness close the volcano to a few very small (µm scale) single glass shards thousands of kilometers away from their source. The tephra layers found e.g. in Europe are characterized and correlated by major- and minor element geochemistry and are now valuable fix points in ice cores, lacustrine, terrestrial and marine sediment stratigraphies. They enable a high resolution correlation of these deposits independent of radiometric or stratigraphic dating.

In the Laguna Potrok Aike lake sediment core we expect numerous tephra layers to be present. The tephra layers will be from the vicinity of the volcano, as the core is situated in an active volcanic area, but will also contain wide spread airfall tephra layers derived from Antarctic volcanoes and from the Chilean volcanic chain.

The tephra horizons in Lake Potrok Aike core will allow to develop a detailed record of explosive volcanic eruptions in the area. They will enable a correlation among local stratigraphies and thus provide information on the eruption frequency. The detailed investigation of the core will also enable us to define a stratigraphy of wide spread ash layers and will eventually allow us to independently correlate these with tephra layers found in Antarctic ice cores and sediment cores from the South Atlantic and the South Pacific. The wide spread tephra layers in the Laguna Potrok Aike core will provide fix points in the stratigraphy and support the detailed age stratigraphy gained from radiometric dating.

Tephrochronology in the North Atlantic region – a potential to link marine, terrestrial and ice-core records from the last glacial cycle

Stefan Wastegård

Department of Physical Geography and Quaternary Geology, Stockholm University, Sweden

Tephrochronology is a fast developing field in Quaternary sciences and particularly in the North Atlantic region. The need to improve and refine the coverage and recognition of new, older and significant tephra strata is greatly improving detailed event correlation and refinement of chronologies around the Atlantic region, ranging from ice-cores from Greenland, marine cores to terrestrial peat and lacustrine deposits in north-western Europe. I will here report on the work being undertaken to identify and geochemically characterize tephra horizons within the Greenland ice-core records, marine cores from the Faroe Islands region and lake sediments from Scandinavia. Several visible and cryptotephra horizons (a cryptotephra is a tephra horizon invisible to the naked eye) are detected and analyzed by electron microprobe analysis within the NGRIP and GRIP ice-cores spanning the Late Glacial and the Early Holocene (ca 30-10 cal. ka BP; e.g. Davies *et al.,* 2004; *in prep.*; Mortensen *et al.,* 2005). These include a number of previously unreported tephra deposits of Icelandic origin as well as some well-known marker horizons. One such example is the Fugloyarbanki tephra (ca 23-24 ^{14}C ka BP) – a widespread marker horizon in North Atlantic marine records. It occurs as a 2-10 cm thick tephra in the Faroe Islands region and is one of two basaltic components in an ash zone dated to ca 23 ^{14}C ka BP in the Labrador Sea. The Fugloyarbanki tephra occurs in GIS 3 in all analyzed marine cores and in NGRIP, right after the warmest peak of the interstadial. This tephra horizon provides a key tie-point for the correlation of marine and ice-core sequences during oxygen isotope stage (OIS) 2, but also allows an estimation of the magnitude of the marine radiocarbon reservoir error at this time.

A technique for extracting cryptotephra has revolutionized the application of tephrochronology in minerogenic deposits from the Last Glacial/Interglacial transition (LGIT, ca 15-8 cal. ka BP; Turney, 1998), especially in NW Europe. This technique relies upon the difference between the specific gravity of the tephra shards and the host sediment matrix and has led to the first discovery of the Vedde Ash on the British mainland as well as the previously unrecorded Borrobol Tephra. In Sweden and in NW Russia, the technique led to the first discovery of the Vedde Ash, greatly extending the distribution of this important marker horizon (Wastegård et al., 2000). Today, more than 15 tephra horizons from the LGIT have been identified in terrestrial deposits in NW Europe (Turney et al., in press).

References

Davies, S.M., Mortensen, A.K., Baillie, M.G.L., Clausen, H.B., Grönvold, K., Hall, V.A., Johnsen, S.J., Pilcher, J.R., Steffensen, J.P., and Wastegård, S. (2004). Tracing Volcanic Events in the Greenland Ice Cores. *PAGES news* **12,** 10-11.

Mortensen, A.K., Bigler, M., Grönvold, K., Steffensen, J.P., and Johnsen, S.J. (2005). Volcanic ash layers from the Last Glacial Termination in the NGRIP ice core. *Journal of Quaternary Science* **20,** 209-219.

Turney, C.S.M. (1998). Extraction of rhyolitic component of Vedde microtephra from minerogenic lake sediments. *Journal of Paleolimnology* **19,** 199-206.

Turney, C.S.M., van den Burg, K., Wastegård, S., Davies, S.M., Whitehouse, N.J., Pilcher, J.R., and Callaghan, C. (in press). North European Last Glacial-Interglacial transition (LGIT; 15-9 ka) tephrochronology: extended limits and new events. *Journal of Quaternary Science*.

Wastegård, S., Wohlfarth, B., Subetto, D.A., and Sapelko, T.V. (2000). Extending the known distribution of the Younger Dryas Vedde Ash into northwestern Russia. *Journal of Quaternary Science* **15,** 581-586.

Reconstruction of the Earth's magnetic field and characterization of minerogenic sediment fractions

Magnetic Studies at Laguna Potrok Aike

Laurie Brown

Department of Geosciences, University of Massachusetts, Amherst, U.S.A.

Magnetic parameters from Laguna Potrok Aike sediments will prove useful in establishing a paleosecular variation of the Earth's magnetic field, providing correlation within the local environment, and augmenting the paleoclimate signal and age model derived for the region. Studies on lakes in other parts of the world indicate that magnetic measurements on the core material can provide detailed paleoclimate information as well as more specific stratigraphic and chronologic data. The volcanic setting of Laguna Potrok Aike ensures a strong magnetic component in the material, and the ability to make detailed magnetic measurements of several kinds.

Magnetic measurements proposed fall into four categories: magnetic susceptibility, paleomagnetic intensity and directions, rock magnetic parameters, and magnetic petrology. Standard magnetic susceptibility measurements will be made continuously on all core sections preferably with spot-reading sensor at 1 mm intervals for the most detailed results. In lieu of spot-readings, discrete samples will be collected and susceptibility measured on them. These measurements will be used to develop a susceptibility stratigraphy, provide correlations to other climate-induced proxies, and help to establish an age model for the entire core. Paleomagnetic directions (inclination and declination) and intensity will be measured on a cryogenic magnetometer, and used for correlation to the geomagnetic time scale for age determinations and for paleosecular variation (PSV) studies. Comparison of the PSV record to ones from Australia and the Northern Hemisphere will provide insight on field variations over millennium and longer time periods. The paleomagnetic data will also be key in establishing the oldest sediments encountered especially if older than 0.79 Ma when reversed directions dominate. Rock magnetic studies on selected core samples will include the measurement of hysteresis properties (saturation remanence, saturation magnetization, coercive force and remanence coercivity), isothermal remanent magnetization behavior, and susceptibility at high and low temperatures. Rock magnetic data will be used to characterize the magnetic carriers (composition, grain size, provenance), investigate variations in magnetic susceptibility (dissolution of magnetite grains, variations in composition), and validate the stability of paleomagnetic directions. Magnetic petrology will provide data on the composition, shape, and state (weathered, exsolved, chemically altered) of oxide particles in the sediment. This will be done using magnetic separates, mounted for optical viewing on a reflected light microscope. When necessary, additional data on the magnetic separates will be collected from microprobe analyses and TEM observations. The resulting magnetic data set from Laguna Potrok Aike will be the most extensive from anywhere in the Southern Hemisphere, and will rival the very best of the records from the Northern Hemisphere.

CT-scan image analysis and magnetic properties at Laguna Potrok Aike

Guillaume St-Onge[1] & Pierre Francus[2]

[1]Institut des sciences de le mer de Rimouski (ISMER), Rimouski, Québec, Canada
[2]Institut national de la recherche scientifique, Centre Eau, Terre et Environnement, Québec, Canada

2-D and/or 3-D radiographic digital images of the entire core can be obtained using our CT-Scanner. This non-destructive analysis allows for a rapid overview of the entire core prior to its opening. Digital radiographic images can be used to direct further sampling towards optimal intervals and to build a composite section among the best sections. In addition, using image analysis software, we propose to extract and construct a continuous log of the pixel intensity (CT number) from these high-resolution CT-scan images (St-Onge and Long, in review). Because CT numbers primarily reflect changes in bulk density, it will allow the rapid setting of a continuous log of bulk density with a 1 mm down-core resolution. These results will be compared with the radiographs obtained using the ITRAX core scanner (Francus and Lamoureux, this vol). The CT-scan images can also be used to identify and quantify bioturbation, erosional features and other sedimentary facies and structures (Dufour et al. 2005).

We also suggest measuring the magnetic properties of the sediments from the U-channels subsampled for micro-fluorescence X-ray analysis (ITRAX core scanner). Using the recently funded Paleo- and Environmental Magnetism Laboratory of ISMER, we propose to continuously measure the magnetic susceptibility, NRM, ARM, and IRM for paleomagnetic, magnetostratigraphic and environmental magnetism purposes. Indeed, we hope to use changes in inclination, declination and relative paleointensity for the identification of well-dated geomagnetic field polarity reversals and/or excursions and for correlation to well-dated Southern Hemisphere marine paleomagnetic profiles (e.g., SAPIS, Stoner et al., 2002; ODP Site 1233, Southern Chile), also allowing the direct comparison of marine and lacustrine records. In addition, we will use the continuous magnetic measurements to determine mineralogical, concentration and magnetic grain size variations, possibly allowing the development of magnetic proxies of environmental or climatic changes. Finally, hysteresis properties will be measured using a few mg of sediment from the U-channel in specific intervals with an alternating gradient magnetometer in order to estimate the impact of para- and superparamagnetic minerals, as well as to provide additional information on the magnetic mineralogy and grain size.

References

Dufour S. et al. 2005. A new method for three-dimensional visualization and quantification of biogenic structures in aquatic sediments using axial tomodensitometry. Limnology and Oceanography: Methods 3, 372-380.

Stoner, J. et al. South Atlantic and North Atlantic geomagnetic paleointensity stacks (0–80 ka): implications for inter-hemispheric correlation. Quaternary Science Reviews 21, 1141-1151.

St-Onge G. & Long B., in review in a special number on CAT-Scan in geosciences. CAT-scan analysis of sedimentary sequences: an ultrahigh-resolution paleoclimatic tool. Engineering Geology.

Reconstruction of lacustrine and catchment-related environmental conditions

Understanding the links between fire, vegetation, and climate change in Patagonia: records and opportunities

Cathy Whitlock[1], Maria Martha Bianchi[2] & Vera Markgraf[3]

[1]Department of Earth Sciences, Montana State University, Bozeman, U.S.A.
[2]CONICET – Universidad Nacional del Comahue, San Carlos de Bariloche, Argentina
[3]INSTAAR, University of Colorado, Boulder, USA

High-resolution macroscopic charcoal records provide information on past variations in local fire occurrence, which can be compared with other proxy data of environmental change to better understand past climate variations. When pollen, charcoal and other proxy are analyzed in a network of sites, the data permit examination of regional and hemispheric linkages between climate, fire, and ecosystem response. The current network of South American fire records show: (1) an abrupt increase in fire activity at the Pleistocene/Holocene transition at high-latitudes; (2) widespread fire activity and drought in the early Holocene despite the summer-insolation minimum; (3) north-south differences in fire activity in the mid-Holocene suggesting the onset of the current dipole climate, and (4) locally variable fire signals and a shift to smaller surface fires in the late Holocene consistent with cooler conditions and greater interannual variability. Widespread fire activity in southern South America in the early Holocene is consistent with recent model simulations that suggest warmer SSTs, a weakened pole-to-equator temperature gradient, and a southward shift of westerly storm tracks as a result of the strong obliquity forcing.

Pollen and charcoal records from low-elevation forest and forest-steppe ecotone between lat 41 and 42.5°S offer a closer examination of these relationships. The period prior to 15,000 cal yr B.P. was characterized by steppe vegetation with sparse *Nothofagus* forest, which implies drier but not necessarily colder conditions than today. After 15,000 cal yr B.P., the forest remained open with substantial amounts of steppe and steppe shrub taxa. Increased fire activity between 13,250 and 11,400 cal yr B.P., corresponds with the Huelmo/Mascardi Cold Reversal defined in the region. After 11,400 cal yr B.P., decreased *Nothofagus* and increased shrub cover at the expense of grass suggest warming. Fires were infrequent in moist sites but frequent in dry locations. *Austrocedrus* expanded between 6000 and 5500 cal yr B.P. in moist sites and between 3500 and 1700 cal yr B.P. in dry sites. The period between 6000 and 3500 cal yr B.P. was an interval of maximum aridity and increasing climate variability in the region. After 3500 cal yr B.P., increased *Nothofagus* in moist sites, the eastward expansion of *Austrocedrus* to dry sites, higher-than-previous fire activity everywhere, and a shift to ground fires indicate the onset of effectively wetter conditions than before and high interannual variability in precipitation.

A high-resolution charcoal record from Laguna Potrok Aike will allow us to extend our understanding of fire-climate-vegetation linkages into steppe regions. The

area experiences year-round precipitation and contrasts with the more seasonal precipitation regime of regions already studied, these differences should be registered in the fire response. Moreover, the possibility of a long record spanning multiple climate cycles will allow us to examine the response of regional climate to a broader array of large-scale changes in the climate system than is current possible.

Non-siliceous microfossils in paleolimnological reconstruction

Hedi J. Kling

Algal Taxonomy and Ecology Inc., Canada

In the absence of long term data it is possible to determine lake history archived in sediment records. Siliceous microfossils such as diatoms and chrysophytes leave good historic records of changes in most lakes but in some lakes and under certain conditions siliceous microfossils can leave no record. The remains of non-siliceous algae such as green and blue-green algae can also be used as indicators since they also leave remnants (akinetes or spore cases, mucilage cases, cell walls, zygotes) preserved in sedimentary assemblages. Species of cyanophytes (blue-green algae) and chlorophytes (green algae) become dominant at certain conditions such as natural events like droughts that increase the trophic status along with increased conductivity and pH, flooding, fires or any other event which results in an increased nutrient transfer to a lake as well as anthropogenic eutrophication. In oligo-mesotrophic lakes diversity and numbers of some siliceous algae (such as diatoms and chrysophytes) are usually dominant and they increase during the initial stages of eutrophication but under continued eutrophication and/or hypertrophic conditions these siliceous microfossils decrease in importance and in some case where silica becomes limited they tend to dissolve, sometimes before being incorporated into the sediments. Often, in cases where they disappear, other microfossils such as the gelatinous remains of chroococcoid bluegreen algae, cell walls of green algae, cysts of dinoflagellates or cryptomonads, akinetes of N-fixing bluegreen algae as well as the non siliceous remains of some protozoans and zooplankton can be used to obtain paleolimnological data. This paper documents the joint use of non siliceous and siliceous microfossil together with other multiple indicator groups of organisms, chemistry and isotopes for reconstructing the paleolimnological records in some arctic, temperate and tropical lakes.

Phytoplankton and algal microfossils in the crater lake Laguna Azul

Beata Messyasz

Department of Hydrobiology, Adam Mickiewicz University, Poznań, Poland

Traditionally, the study of lacustrine productivity is based on the analysis of diatom composition and pigment contents (mainly chlorophyll and carotenoids) in the sediments. Less intensively other algal microfossils are analysed. The majority of well preserved sedimentary microfossil algae are green algae, chrysophyceans, cyanobacterial acinets, fossil cyanobacterial tubular sheats and cellular trichomes. Analyses of these microfossils enable to observe the natural environmental variability and to estimate the direction of future changes. In Patagonia anthropogenic influence is small and changes occurring in Laguna Azul are mainly controlled by the influence of edaphic and climatic factors. Analysis of algal microfossils preserved in the sediment will enable us to understand the complex environmental conditions and changes in this area much more thoroughly. Fossil algal material becomes very important in cases of diatom absence in sediment core samples. Such a situation can occur in the case of chemical changes, e.g. increased calcification.

The purpose of this work is the reconstruction of environmental conditions based on ecological differences among the algal flora preserved in the sediments. Analysis includes the use of sediment cores from the lake as well as modern algal samples to reconstruct past conditions of the lake and to show the temporary changes. The results of this analysis will be compared with data obtained on fossil diatoms by other investigators.

Spores from chrysophyceans are very well preserved in lacustrine deposits. This allows to use them as an indicator group for the reconstruction of ecological conditions. Observations of the behaviour of algae from the *Chrysophyceae* group show that in short periods of time only particular taxons appear. A qualitative and quantitative determination of the composition of cysts is particularly important. Therefore, their identification will be based on their morphology and sizes. SEM photographs will enable the assessment of the ornamentation of the surface of cysts and the shape of the hole.

In relatively large numbers filamentous green algae are represented by cysts of *Mougeotia* sp. and *Spirogyra* sp. Moreover, in the fossil material the diagnosis of green algae from the following genera is possible: *Pediastrum*, *Tetraedron*, *Scenedesmus*, *Coelastrum*, *Botryococcus*. The analysis of green algae is very important because the phytoplankton of Laguna Azul is dominated by this group (*Coenococcus planctonicus* Korsh., *Oocystis* spp., *Elkatothrix* spp.; Messyasz, unpublished data).

The comparison between modern phytoplankton samples and the algal assemblages in the sediment, especially near the sediment surface, should give an answer whether the present trophic conditions represent a continuation of the natural evolution of the lake or are artificially imposed by external factors such as pollution.

Fossil chironomids (Insecta –Diptera) as indicators of environmental change in Laguna Portrok Aike, Argentina

Julieta Massaferro

Natural History Museum London, U.K.

In recent years, subfossil chironomids (non-bitting midges) have proven to be a powerful independent paleo-proxy indicator of environmental change. They are increasingly used as indicators of eutrophication [1], water-level changes [2] and, especially, as indicators of climatic change [3, 4, 5]. Because midge abundance and distribution are strongly influenced by mean July air temperature, this can be used to infer past climate by analyzing changes in midge assemblages recovered from lake sediments [6, 7].

Chironomid assemblages from lake sediments are extremely sensitive to temperature changes being able to pin-point climatic oscillations of short duration and low amplitude. Nevertheless, the best results have been achieved in studies by using a multi-proxy approach that enables the comparison of chironomids to other lines of evidence such as pollen sequences, diatom profiles, oxygen isotopes [8] or chemical analysis in a sedimentary column.

The use of fossil insects in Quaternary studies at mid-latitudes of South America is relatively limited, and the major reason is the lack of taxonomical information available from these remote areas of the world. Many of these studies have been conducted in the southern part of South America, in Argentina (41° S) [9, 10, 11] and in southern Chile (46°S) [12].

I propose to study the fossil chironomids (insects) of Laguna Potrok Aike sediments in order to reconstruct the environmental changes that occurred in the area during several glacial/interglacial cycles. Results from this study will be compared to other proxies to give an accurate environmental reconstruction for this area in South America. This study will be a contribution to the project “Potrok Aike Lake Sediment Archive Drilling Project” (PASADO), a research initiative within the International Continental Scientific Drilling Program (ICDP) with the ultimate goal to reconstruct climate change in southern South America spanning multiple glacial to interglacial cycles.

References

1. Brodersen, K. & Lindegaard, C., *Freshwater Biology*, 1999. 42: p 142-157
2. Hofmann, W.. Journal of Paleolimnology,1998. 19: p. 55-62
3. Korhola, A, H .Olander and T. Blom,. Journal of Paleolimnology, 2000. 24:p. 43-54.
4. Lotter, A., I. Walker, S. Brooks and W. Hofmann, Quaternary Sciences Review, 1999. 18: p. 717-735.
5. Brooks, S and J. Birks,. Journal of Paleolimnology, 2000. 23: p. 77-89.
6. Brooks, S. Palaeogeography, Palaeoclimatology, Palaeoecology, 2000. 159. p: 261-279.
7. Heiri, O. and A. Lotter, Ecological Bulletin, 2001. 37.p: 58-63.
8. Schwander, J., U. Eicher, and B. Ammann, Palaeogeography, Palaeoclimatology, Palaeoecology, 2000. 159: p. 203-214..
9. Ariztegui D, Bianchi MM, Masaferro J, Lafargue E, Niessen F. 1997.. *Journal of Quaternary Science* 12: 333-338

10. Corley JC, Massaferro JI. 1998. *Journal of the Kansas Entomological Society* 71: 407-413.
11. Massaferro, J. & J. Corley. 1998. *Aquatic Conservation: Marine and Freshwater Ecosystem,* 8:315-323 .
12. Massaferro, J and Brooks, S. 2002. *Journal of Quaternary Sciences* 17(2):101-111

Potrok Aike Lake Sediment Archive Drilling Project, southernmost Argentina (PASADO): chironomid analysis

Isabelle Larocque

Institut National de Recherche Scientifique, Eau, Terre et Environnement, Québec, Canada

Chironomids (Diptera: Chironomidae) have been used successfully to reconstruct various environmental (TP, chlorophyll-a, oxygen availability, nutrients, water depth) and climatic (water and air temperature) parameters. Chironomids have the potential of being the best quantitative biological indicators preserved in lake sediments (Battarbee, 2000). They have been useful in reconstructing colder period such as the Younger Dryas and the Little Ice Age. In Switzerland and Canada, there were used to reconstruct the 8.2 cal. years BP event. When compared with meteorological data, the inferences obtained by chironomid analysis were statistically valid (Larocque & Hall 2003). Recently, chironomids were also used to reconstruct hydrological variations (Gandouin et al. 2005; Larocque, work in progress). Their relationship to fire events is also being studied in Canada (Tremblay & Larocque, work in progress). Unfortunately, most chironomid studies are located in the northern hemisphere. But chironomids have been shown to react to climatic patterns, metal pollution, human impact, and water level changes in Africa (Eggermont & Verschuren 2005), in Chile (Massaferro & Brooks 2002) and northern Patagonia (Guevara et al. 2002; Massaferro & Corley 1998; Massaferro et al. 2004). In the PASADO project, it would be possible to reconstruct climate, hydrological variations and/or effect of fire events on this lake ecosystem using chironomids in a multi-proxy framework. We should also discuss the possibility of developing a quantitative inference model using chironomids in Patagonia. This could possibly be made by joining the effort of “chironomid teams”.

Diatoms and ostracods as palaeoclimate proxies in the Laguna Potrok Aike sediment record

Reinhard Pienitz & Finn Viehberg

Paleolimnology-Paleoecology Laboratory, Centre d'Études Nordiques, Université Laval, Québec, Canada

Inland saline aquatic ecosystems and their sedimentary sequences are of special interest to palaeoclimatologists (Williams, 1996), as many of the aquatic organisms that respond to fluctuations in salinity leave identifiable fossils in the sedimentary record that can be interpreted in terms of past climatic conditions. For example, the abundance and species composition of microscopic siliceous algae (diatoms) is strongly related to the ionic concentration and composition of saline lakes and lagoons, and changes in diatom communities can be used to infer past salinities by the use of quantitative models (Fritz et al., 1999; Pienitz et al., 2000). Similarly, valves and appendages of calcareous microcrustaceans (ostracods) are often preserved in sediments of saline lakes and offer evidence of past hydrological changes (Holmes & Chivas 2002, Ito et al., 2003). Because species shifts in these saline systems are generated in direct response to the salinity and ionic composition of the brine, the composition of the fossil assemblages in these stratigraphic records has the potential to provide information on changes in water chemistry (temperature, pH, salinity, TP), water-column stratification, water level, as well as changes in atmospheric relative humidity.

Based on the information available through detailed seismic and preliminary biostratigraphic surveys of the Laguna Potrok Aike sediment record, the relative abundance of fossil diatoms and ostracods will ideally be determined in counts of 500 valves and ca. 300 soft part remains, respectively, in subsamples with up to decadal resolution. In addition, valves of time-consistent ostracod species will be collected for isotope ($\delta^{18}O$ and $\delta^{13}O$) and trace element analyses (Sr/Ca and Mg/Ca). Preferably, and if possible within the PASADO project, we would like to develop a training set based on lacustrine sediments from southern Patagonia for the quantitative reconstruction of environmental changes from diatoms and ostracods. Preparation techniques for both indicator groups will follow standard procedures (Pienitz et al. 1992; Schwalb 2003).

References

Fritz, S.C. et al. 1999. Diatoms as Indicators of Hydrologic and Climatic Change in Saline Lakes. In: Stoermer, E.F. &Smol, J.P. (eds), The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press 41-72.

Holmes, J.A. & Chivas, A.R. 2002: Ostracod shell chemistry - overview. In: Holmes, J.A. & Chivas, A.R. (eds.), The Ostracoda: applications in Quaternary research. Geophysical Monograph, Vol. 131, American Geophysical Union, Washington, DC: 185-204.

Ito, E., De Deckker, P., & Eggins, S.M. 2003: Ostracodes and their shell chemistry: implications for paleohydrologic and paleoclimatologic applications. The Paleontological Society Papers 9**:** 119-151.

Pienitz, R. et al. 1992. Biomonitoring past salinity changes in an athalassic subarctic lake. Internat. J. Salt Lake Res. 1: 91-123.

Pienitz, R. et al. 2000. Multi-proxy Holocene palaeoclimatic record from a saline lake in the Canadian Subarctic. The Holocene 10(6): 673-686.
Schwalb, A. 2003: Lacustrine ostracodes as stable isotope recorders of late-glacial and Holocene environmental dynamics and climate. Journal of paleolimnology,29 (3): 267-351.
Williams, W.D. 1996: The largest, highest and lowest lakes of the world: Saline lakes. Verhandl. Internat. Verein. Theor. Angew. Limnol. 26: 61-79.

Vegetation and climatic conditions in the southeast of Patagonia, Argentina

María Virginia Mancini

Lab. Paleoecología y Palinología, Universidad Nacional de Mar de Plata, Argentina

Pollen analysis from archaeological, mire and soil sequences provide a regional analysis of the vegetational changes and contribute to the understanding of the climatic history during the Late Holocene in southeast Patagonia, Argentina. In the Cabo Vírgenes area shrubland at the mire sites and a grass-shrub steppe allow to infer climatic condition drier than present-day before ca. 1000 yr BP. The increase in Poaceae and Juncaginaceae and later Cyperaceae preponderance in the mire sequence as well as a grass steppe similar to the present-day at regional scales according to soil pollen records suggest a moisture increase after ca. 700 yr BP. Pollen record data from upper sections of the soil profile, buried by recent eolian deposit, present the highest Rumex values probably in relation to impact produced by sheep introduction at the end of 19th century (Mancini, ms). Comparison of these pollen sequences with others sampled in the northern sector of the Pali Aike Volcanic Field allows to evaluate the regional expression of the environmental changes during the late Holocene. These analyses included in archaeological studies provide paleoenvironmental information to evaluate circulation patterns between maritime coastlines and interior Patagonia (Borrero and Franco, in press; Franco et al., 2004).

References

Borrero, L.A. and N.V. Franco (in press). Arqueología de Cabo Vírgenes, provincia de Santa Cruz. Actas del XIV Congreso Nacional de Arqueología Argentina, Córdoba.
Mancini, M. V. (manuscript). Variabilidad climática durante los últimos 1000 años en el área de Cabo Vírgenes, Argentina. Ameghiniana.
Franco, N.V.; Borrero, L.A. and Mancini, M.V. 2004. Environmental changes and hunter-gatherers at the south of Patagonia: the cases of Lake Argentino and Cape Vírgenes. Before farming: the archaeology and anthropology of hunter-gatherers 3: 1-17.

Magallanes maar fossil pollen record re-interpreted by using a pollen-climate calibration model

A.R. Prieto[1], M.V. Mancini,[1], F.A. Quintana[1], M.M. Paez[1] & A.M Borromei[2]

[1]Laboratorio de Paleoecología y Palinología, Dpto de Biología, Universidad Nacional de Mar del Plata, Argentina
[2]Dpto de Geología, Universidad Nacional del Sur, Bahía Blanca, Argentina

The only pollen record in the latitude of the Pali Aike Volcanic Field (southeastern Patagonia) that predates the Last Glacial Maximum comes from a core drilled at the dry Magallanes Maar (52º 07´S; 69º 16'W) located in the Patagonian xeric grass steppe and is dated between 31,560 at 37 m and >51,700 yrs B.P. at 47 m (Corbella *et al*., 2000). A major problem with this record is the uncertain chronology, since it is close to the limit of the radiocarbon dating technique. Based on our experience with ongoing pollen studies, we re-interpreted the fossil sequence as either interglacial or interstadial based on the observed type of pollen assemblages. Eighty-six surface samples reflecting modern pollen dispersal from the Andes to the Atlantic coast between 50º and 52ºS represent the Subantarctic forest, the humid and xeric grass steppes and the semi-desert (Quintana, *et al*., unpubl.). These surface samples have been compared with the Magallanes Maar fossil pollen assemblages. Although only twelve samples between 29 and 56 m from this sequence have enough pollen for analysis, the comparison allows us to interpret that plant composition and climate were similar to humid and xeric grass steppe for different periods during the Marine Oxygen Isotope Stages (MIS) 3 and 4(?). This demonstrates the potential of the pollen-climate calibration model to be applicable as a modern analogue technique for paleovegetational and paleoclimatic interpretations of the anticipated long sequence from Laguna Potrok Aike.

References

Corbella, H., Borromei, A.M. and Quattrocchio, M.E., 2000. Quaternary climate changes in southernmost South America inferred from lacustrine sediments preserved in volcanic maars. In: P.P. Smolka and W. Volkheimer (eds). Southern Hemisphere Paleo-and Neoclimates, 203-273.

Quintana, F.A., Paez, M.M., Mancini, M.V. and Prieto, A.R. Modern pollen-vegetation distribution between 51º and 53ºS, southern South America (unpublished data).

Tracing atmospheric dust and volcanic aerosols

Dust sources and westerly storms in Patagonia: Comparison of in situ measurements with remote sensing estimations

Diego Gaiero[a], Barbara Villoslada[a] & Santiago Gassó[b]

[a]CIGeS, FCEFyN, Universidad Nacional de Córdoba, Argentina
[b]NASA/Goddard Space Flight Center and University of Maryland, U.S.A.

How much aerosol mass is transported from Patagonia to the South Atlantic Ocean? What are the sources, the frequency and the extent of the delivery of those particles? Is the regional forcing directly or indirectly affected by the presence of aerosols in the region? Is the amount of iron present in those particles able to control biological processes of this oceanic region? To answer the above questions we have started a two year program of *in-situ* and remote sensing dust flux measurements in 2004. Hence, four dust samplers equipped with weather stations were installed along 2200 km of the Patagonian coast (Bahía Blanca, Trelew, San Julián and Río Grande). Surface concentrations are compared with aerosol columnar concentrations derived from the MODIS detector onboard the Terra and Aqua satellites following the technique developed by Gassó and Hegg (2003).

Global dust distributions usually are estimated based on global dust cycle models which predict dust emissions, dust transport through the atmosphere and dust deposition. However, these models must be validated with available in situ observations. By means of both, remote sensing (true color pictures) and ground observation (surface visibility observations) between June 2004 and April 2005 we recorded at least 16 ocean-going dust events mainly triggered by strong westerly winds. The horizontal flux measurements were compared with the same estimates derived from MODIS. The scale of these events varied from small (single dust plumes along the coast) to large (dust front extending ~600 km). One of the most important of these dust events was perceived at the city of San Julian on October 20th, 2004, where it lasted almost four hours with an average wind speed of 56 km h^{-1} and maximal gusts of 93 km h^{-1}. Satellite images detected small individual dust plumes clearly transporting dust to the ocean in the San Julián city area.

Although, satellite retrievals help to detect the extent and distribution of dust, the retrievals are uncertain due to the optical properties of the aerosol under observation. Then, our study provides helpful information for validation of both, in situ measurements and satellite estimations. Small-scale events like the squall lines observed in Patagonia cannot be easily represented in global models and are frequently ignored thus causing underestimations of dust emission and of long-distance transport. Such small-scale events like the one of October 20th, 2004, should be taken into account in regional models to simulate specific dust storm events and to test parameterizations in global models.

Finally, satellite images supported by ground observations indicate that at the Patagonian surface the occurrence of topographic depressions (ephemeral lakes or deflation holes) in dry, unvegetated areas are important sources for fine, loose sediment which is easily deflated under strong wind conditions. One important question to elucidate is how changes in the frequency and extent of natural

inundation occurring on ephemeral lakes systems may lead to significant fluctuations in the Patagonian dust loading.

Reference

Gassó, S and Hegg DA (2003) On the Retrieval of Columnar Aerosol Mass and CCN Concentration by MODIS, *J Geophys Res,* **108**, D1, 4010, doi: 10.1029/2002JD002382.

Isotopic investigations at Laguna Potrok Aike sediments to determine recent sedimentation rates and dust fluxes and to correlate this archive with other ice core records

Martin Fleisher

Lamont-Doherty Earth Observatory, Palisades, New York, U.S.A.

My participation in the workshop could potentially focus on 3 aspects of the PASADO project. First, we have extensive experience in measuring natural and fallout isotopes that are used as indicators of recent sediment accumulation in lakes, including Be-7, Pb-210, Cs-137, and Pu isotopes. As part of our previous lake work, we have used freeze corers to collect intact surface sediments with cores up to 1 meter in length. While acknowledging the apparent difficulty of establishing a recent chronology in southern South America using these tracers, the ability to determine the age-depth relationship over the most recent century or so, is the only way to tie variations in geochemical parameters, such as stable isotopes, to the limited historical records of precipitation and temperature that exist for this area.

We are also interested in using Be-10 fluxes to constrain the timing of climate signals from various archives to the climate signals recorded by the Greenland and Antarctic ice cores. We are currently using this method in continental margin sediments off of the west coast of the North America. A complementary application of Be-10 is that it may be used as a quasi constant flux proxy, with a well-dated input history, derived from the ice core records.

Finally, I am interested in southern South America as a potential source area for dust to the southern ocean. We are actively studying changes in the dust flux to the South Atlantic and South Pacific on glacial-interglacial timescales. One of the questions remaining is to identify the source of the dust, which will help to elucidate the mechanisms by which the delivery of continental material to the ocean has varied in the past.

Study of paleoclimate change using cosmogenic nuclides produced in the atmosphere

Kyeong J. Kim[1], A. J. Tim Jull[1] & Mineo Imamura[2]

[1]NSF Arizona AMS Laboratory, University of Arizona, Tucson, U.S.A.
[2]National Museum of Japanese History, Chiba, Japan

^{14}C, ^{10}Be, and ^{26}Al are also produced in the atmosphere by nuclear interactions with nitrogen, oxygen, argon, respectively. The best known is ^{14}C, which is produced in the atmosphere by neutron capture reaction with nitrogen, and then it subsequently is mixed with atmospheric CO_2. Both ^{10}Be and ^{26}Al are produced by spallation reactions in the atmosphere, and then they are mixed with dust particles and fall out with precipitation to the land and sea. The ^{10}Be records of four sediment cores forming a transect from the Norwegian Sea via the Fram Strait to the Arctic Ocean demonstrate that ^{10}Be records with high ^{10}Be concentration are related to interglacial stages and core sections with low ^{10}Be concentration are related to glacial stages, as observed in oxygen isotopes. This study confirms that the sharp contrast of high and low ^{10}Be concentrations at climatic stage boundaries are an independent proxy for climatic and sedimentary change and can be applied for ^{10}Be stratigraphic dating of sediment core. ^{10}Be from sediments of the Arctic Ocean covering the past 350 ka shows the well defined trends of Be isotopes are coincident with interglacial/glacial climatic cycles and demonstrate that the sedimentation rates are higher during glacial periods and lower generally due to low sedimentation/accumulation rate during interglacial periods.

Records of studies using radiocarbon and ^{10}Be in sediments related to the study of paleoclimate change are well established. It was found that the production rate of cosmogenic nuclide is inversely proportional to the paleomagnetic intensity. Studies using the profile of marine oxygen isotope of the ocean sediment and ^{10}Be or ^{14}C along with paleomagnetic intensity made new guidance in understanding the paleoclimate change in the Pleistocene. A study of the correlation between ^{10}Be and oxygen isotope in Wangauni Basin, New Zealand has indicated that this ^{10}Be stratigraphy is inversely correlated to that of oxygen isotope. In order to study paleoclimate change using cosmogenic nuclides, three types of sample materials are often used: deep drill core from ocean or lake, exposed rock. Especially, ^{14}C and ^{10}Be are 'meteoric' cosmogenic nuclides. Reconstruction of temperature and precipitation of the past decade to millennial timescale is feasible with meteoritic cosmogenic nuclides and stratigraphy of oxygen isotope of the sediment core. The comparison of these meteoric cosmogenic nuclides and the stratigraphy of oxygen isotopes and paleomagnetic intensity will be an essential approach in unravelling paleoclimate change during the last glacial-interglacial cycle. Especially, the comparison of meteoritic ^{10}Be from the sediment and in situ produced ^{10}Be from glaciated materials, such as moraine boulder samples will be another approach in understanding time sequence of glacial events. Also, we propose to characterize the stratigraphy of ^{10}Be in the land and ocean along with the paleomagnetic intensity for a better understanding of ^{10}Be production and transport in land and sea for other relevant studies.

Lead (Pb) and Strontium (Sr) isotopic composition for reconstructions of dust fluxes and volcanic aerosols

Vallelonga, P., Rosman, K.J.R., Burton, G., Burn, L., Candelone, J.-P., Loss, R. & Nelson, D.R.

Thermal Ionisation Mass Spectrometry (TIMS) Laboratory, John de Laeter Centre of Mass Spectrometry, Curtin University of Technology, Perth, Australia

Lead (Pb) and Strontium (Sr) isotopic compositions measured in Antarctic ice cores have been observed to change with glacial-interglacial transitions, this being attributed to changes in the location, extent and strength of dust sources. Ice core data suggest South America, particularly Patagonia and the Pampas, to be the major source of this dust but the influence of dust from Australia and New Zealand has not yet been excluded. The measurement of Pb and Sr isotopic compositions in Southern Patagonia will provide an isotopic signature of the South American dust source, allowing the provenance of rock dust in Antarctica to be refined and quantified. Climate-related variations in the signature of South American dust should indicate variations in the contributions of various dust sources within South America. By characterising the source(s) of dust within South America and quantifying the proportions of dust transported to Antarctica from different continents of the Southern Hemisphere, climate modellers would have a substantial and valuable data for testing the accuracy of GCMs.

The TIMS laboratory has produced a detailed record of Antarctic Pb isotopic compositions from the present to 220 ky BP from ice cores from Vostok, Dome C, Law Dome and Victoria Land. This record is being complemented by Sr isotopic compositions, to further characterise the rock dust transported to Antarctica, and Nd isotopic compositions may also be measured. An understanding of the fluxes of dust transported from South America and arriving to Antarctica are also important for the evaluation of efficiencies of atmospheric dust transport and quantification of dust deposition over the Southern Ocean, which is relevant to oceanic bioproductivity in high nutrient-low chlorophyll waters.

Studies of Holocene snow and ice in Antarctica have revealed the role of volcanism as an important source of Pb during interglacials, but the source(s) of volcanic aerosols are still to be constrained. It has been assumed that volcanic aerosols found in Antarctic snow and ice originate primarily from the Trans-Antarctic Mountains, Mount Erebus (Ross Island) and sub-Antarctic volcanoes (South Sandwich and South Shetland Islands), but the influence of other volcanic systems in the Southern Hemisphere are yet to be discounted. A determination of the Pb and Sr isotopic signatures in tephra layers from the Potrok Aike Lake sediments would enable an “extra-Antarctic” volcanic aerosol signal to be established for comparison to the signature of volcanic aerosols observed in Antarctic snow and ice.

To achieve these goals, continuous sampling over the length of the core is required. Sample requirements are small, approximately 1 gram per sample, but it would be necessary to obtain samples from the interior of the core to eliminate the possibility of contamination from the coring device.

Overview of TIMS Laboratory activities: The TIMS laboratory, located at Curtin University of Technology in Perth, Western Australia, investigates various environmental systems through isotopic analyses. The laboratory features a Finnigan Triton TIMS and a Fisons Instruments VG354 90° sector TIMS. The TIMS laboratory recently commissioned the Advanced ultraClean Environment (ACE) facility, containing four Class 10 ultra-clean laboratories, a Class 10 reagent preparation laboratory and a -18ºC Class 10 cold clean laboratory.

Human impact and modelling

Bones in Pali Aike: The Late Holocene archaeological record of Cóndor and Potrok Aike localities

Ramiro Barberena[1] & Fabiana M. Martin[2]

[1]IMHICIHU-DIPA. Buenos Aires, Argentina
[2]Centro de Estudios del Cuaternario de Fuego-Patagonia y Antártica (CEQUA), Punta Arenas, Chile

The study of bones is one of the main sources of archaeological information on subsistence and geographical distribution of human populations issued through time. We plan to contribute to the ICDP workshop that will be held in Río Gallegos by presenting a review of our recent work with human and faunal bones in the Pali Aike Volcanic Field, southern Patagonia. We also integrate information produced by other teams working in the area (i.e. Gómez Otero 1993-1994).

We believe that the information already available for the site of Potrok Aike (Gómez Otero 1993-1994) provides a good starting point, on the basis of which a more intensive archaeological survey and sampling of surface and stratified deposits can be designed. Since this will contribute to expand the archaeological knowledge of the Potrok Aike locality, it will provide a stronger basis for the correlation with palaeoclimatic data. This local information, altogether with data from a wider spatial scale, can be used as a measure of the impact of particular climatic variations on human susbsistence. In particular, the intensity of the archaeological signal can be used as a proxy for human presence under different climatic situations.

Brief antecedent information: human and faunal remains inform on different levels of human subsistence. Stable isotopes values (particularly $\delta^{13}C$ and $\delta^{15}N$) from human bones are associated to the main kinds of resources consumed during the last years of an individual. In the Patagonian case, isotopic data allow us to infer the proportions in which marine and terrestrial foods were consumed on a regional scale.

On the other hand, faunal assemblages constitute a direct measure of the food that was locally consumed. Besides, intensity in their consumption can be evaluated on the basis of the degree of butchering and fragmentation displayed by the bones.

In our review, we plan to integrate isotopic data from southern Patagonia and faunal information specifically recovered at Potrok Aike and Cóndor localities. This allows us to infer the existence of periods of nutritional stress for human populations living in the PAVF during the Late Holocene, possibly associated to climatic changes that have been recently identified on a local scale (Zolitschka *et al*. 2004; Haberzettl *et al*. 2005; Mayr *et al*. 2005).

Numerical modelling of sedimentation processes in Laguna Potrok Aike, Argentina

Horacio Toniolo

Civil and Environmental Engineering Department, University of Alaska, Fairbanks, U.S.A.

On one hand, the northern continental slope of the Gulf of Mexico is riddled with numerous subsiding diapiric minibasins bounded by ridges, many but not all of which are connected by channels created by turbidity currents. Recently, Toniolo et al (in press, a) developed a theoretical analysis to describe sediment deposition processes in minibasins by ponded turbidity currents. The analytical work improved our understanding of the "fill and spill" process by which minibasins fill with mud and sand as the intervening ridges are dissected by canyons. An explicit numerical model based on the theory was successfully tested against laboratory experiments by Toniolo et al. (in press, b).

On the other hand, when a river enters to a dam or lake, the stream velocity is reduced and coarse sediment deposits to form a delta. The coarser sediments deposit fluvially to form a topset, and by avalanching to form a foreset. Finer sediments deposit beyond the toe of the foreset to form a bottomset in deep water. The reservoir or lake fills as the topset and foreset prograde downstream into the water body and the bottomset builds upward. This process has been reported in several occasions (see for instance, the bed evolution of Lake Mead on the Colorado River, and Lake Englebright on the Yuba River).

The case of a dam on a sand-bed river carrying fine suspended sediment was recently considered by Toniolo et al. (accepted). In the deltas of sand-bed streams the topset and foreset deposits are built mostly out of sand, while the bottomset consists mostly of mud. The existing numerical model captures the delta evolution in the upstream region of the reservoir and bottomset growth downstream the delta. It is clear that a lake can be considered as a dam without any water exit.

Preliminary inspection of the information available on the PASADO Project web site (Appendixes 1 and 2) indicates sediment deposition patterns associated with ponded turbidity currents in the lake, similar to the deposits found in several minibasins on the continental slope of the Gulf of Mexico and reservoirs.

In consequence, the basic analytical and numerical tools for studying sedimentation processes in the Laguna Potrok Aike are available. It is proposed here to use and expand the actual numerical models to estimate past sedimentological and hydrological conditions. This effort will aid to achieve one of the stated scientific objectives: "quantitative reconstruction of hydrological variations".

Adequate selection of drilling sites will be a key factor to gain fundamental information (grain size, layer thickness, porosity) to improve our understanding of depositional modes inside the lake.

References

TONIOLO, H., LAMB. M., AND PARKER, G. (in press, a). Depositional turbidity currents in diapiric minibasins on the continental slope: formulation and theory: *Journal of Sedimentary Research.*

TONIOLO, H., PARKER, G., VOLLER, V. AND BEAUBOUEF, R.T. (in press, b). Depositional turbidity currents in diapiric minibasins on the continental slope: experiments, numerical simulation and upscaling: *Journal of Sedimentary Research*.

TONIOLO, H., PARKER, G., AND VOLLER, V. (accepted, subject to modification). Role of ponded turbidity in sediment trap efficiency in reservoirs. *Journal of Hydraulic Engineering ASCE.*