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7. Future horizons in marine and continental research drilling

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7. Future horizons in marine and continental research drilling

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Commission of Oceanography and Limnology (COL)

7.1

Exploring 200'000 years of climate and environmental history with ICDP drill cores from Lago Petén Itzá, Northern Guatemala

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As part of a recent ICDP initiative, more than 1.3 km of lake sediment were recovered at seven sites of varying water depths in Lago Petén Itzá, northern Guatemala. Multiple holes with a maximum depth of 133 m were drilled at each core site using the GLAD800 drill-rig mounted on the RV/Kerry Kelts superbarge. This ensured complete recovery of lacustrine sediment sequences that contain a long, continuous record of continental climate change from the lowland Neotropics. Radiocarbon and tephrochronologic dating indicates that the record spans the last ~200 kyr, permitting to study the long-term tropical hydrologic and temperature changes as well as the correlation to other regional and global paleoclimate records.

Lake Petén Itzá is the deepest lake in the lowlands of Central America, with a maximum depth >160 m. It is hydrologically “closed,” making it highly sensitive to past changes in the ratio of evaporation to precipitation. Pre-drilling seismic surveys and the new drill cores confirm that the lake sediments are sensitive recorders of past hydrologic changes as reflected by variations in lithology and physical properties.

Site PI-6 (water depth = 71 m) was drilled to a maximum sediment depth of 75.9 m. Radiocarbon dates on terrestrial organic matter are well ordered and indicate a mean sedimentation rate of ~1 mm/yr to ~44 kyr BP at a depth of ~49 m. The age of the basal section is constrained by an identified ash layer at 70.4 m, 1.5 meters above limestone bedrock. The elemental geochemical fingerprint of this rhyolitic tephra layer is consistent with the Los Chocoyos eruption of the Atitlán Caldera around 84 kyr BP. This age of the tephra layer results in a sedimentation rate of 0.6 mm/yr for the lower section and chronologically confines a transgressional sequence, which represents the onset of lacustrine sedimentation in the basin at this site. At Site PI-6, the top 10.8 m were deposited during the Holocene and consist primarily of gray carbonate clay with abundant charcoal. The Pleistocene/Holocene boundary is marked by a transition to Holocene clay from underlying, interbedded, dense gypsum sand and clay deposited during the Late Glacial (~17 to 9.3 kyr). This transition represents a switch from relatively arid conditions during the Late Glacial to moister climate during the early Holocene. In contrast to the Late Glacial period, the Last Glacial Maximum (LGM), from 23 to 17 kyr, consists of gray carbonate clay that is similar to Holocene deposits, suggesting high detrital input and high lake level, i.e. moist conditions. This finding contradicts previous results that suggested the LGM was dry in the Guatemalan lowlands. In Lake Petén Itzá, clay deposition during the LGM was preceded by interbedded gypsum and gray carbonate clay deposited before ~23 kyr during Marine Isotope Stage 3. This pattern of clay–gypsum (wet–dry) oscillations closely resembles the temperature records from Greenland ice cores and North Atlantic marine sediment cores and precipitation proxies from the Cariaco Basin. The most arid periods coincided with Heinrich Events when cold sea surface temperatures prevailed in the North Atlantic, meridional overturning circulation was reduced, and the Intertropical Convergence Zone (ITCZ) was displaced southward. Sediments deposited during MIS 4 and 5a consist of fine-grained clay-rich lithologies with variable content of carbonate and organic matter reflecting rather moist conditions.

The basal ~85 kyr horizon was penetrated in two drillsites, where a deeper and older stratigraphic succession was recovered. Tephrastratigraphic analysis document that this older lacustrine succession dates back to ~200 kyrs, providing thus an unprecedented long paleoclimatic/paleoenvironmental record of the Central American tropics

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7.2

Potential and limits of drill cuttings for lithostratigraphical interpretations in siliciclastic environments: preliminary results from the IODP NanTroSEIZE Stage 2 Expedition 319 Site C0009 (Nankai Trough, Kumano Forearc Basin, Japan).

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During the IODP NanTroSeize Expedition 319 riser-drilling system was employed for the first time to collect cuttings and core for scientific purposes at Site C0009A (Nankai Trough, Kumano forearc basin). Cuttings are the mixture of rock fragments and sediments produced as the drill bit cuts through the formation. During riser drilling, the cuttings are transported via the circulation of drill mud with suspended cuttings material within riser pipe between the drill ship and the bottom of the hole.

We present first geologic results from riser drilling, coring, and cuttings collection at the Site C0009A in the Kumano forearc basin. One of the scientific objectives for this site was to characterise the lithology and deformation of the Kumano forearc basin sediments and underlying units through analysis and integration of (i) cuttings, (ii) core, (iii) measurements while drilling, and (iv) wireline logging data. Cuttings were retrieved from each 5 m intervals from 703.9 to 1604 m below sea floor and cores were recovered from 1509.7 to 1593.9 m below sea floor. As core availability was strongly limited by operational costs and time restrictions, the study of cuttings was important for the understanding of their potential and limits for lithostratigraphical interpretations compared to the core.

First, cuttings were described based on visual macroscopic description of the bulk material. We estimated (i) the relative amount of coarser (sand/silt) and finer (clay) material, (ii) the appearance, relative amount and size of hard rock chips, and (iii) the abundance of wood fragments. Then, we separated the grains of the size more than 45 μm by sieving in order to describe them under the binocular microscope and prepare smear slides. We distinguished specific minerals, volcanic glass and lithic fragments, made qualitative estimations of their relative abundance, roundness, sorting, and relative variation in grain size. The chips of hard rock of 1-4 mm size were separated and used for the preparation of thin-sections, X-ray diffraction and X-ray fluorescence analyses. We also compared cuttings and cores in the cored interval to determine possible artifacts and uncertainties related to the use of cuttings for lithostratigraphical interpretations.

Cuttings allowed us to recognise major lithological variations and trends in mineralogical and chemical data. We distinguished four lithological units composed of mud and mudstone with coarser silty and sandy interbeds, and volcanic ash/tuff. Based on the integration of cuttings description, measurements while drilling, wireline logging data, seismic data and biostratigraphy, first three lithological units are interpreted as fine-grained turbidite-rich deposits of the Kumano Basin accumulated during Pleistocene to Present. The lower part of Unit III (Subunit IIIB) had an increased amount of wood fragments and of rounded glauconite. This fact points to the increased terrigeneous input in transgressional settings. The Subunit IIIB is represented by the first sediments deposited above the angular uniconformity with slightly older deposits of Unit IV of Late Miocene age. The depth of the unconformity is 1285 mbsf. The Unit IV is composed of thin-bedded turbidites which are more fine-grained than overlying deposits. Compositional maturity of sediments is increased compared to the first three units. This Unit could be interpreted either as accreted trench sediments, or as trench slope deposits or as sediments deposited in

the distal reaches of the early Kumano Basin.
Consistency between unit boundaries determined from cuttings and those determined from log data is good in terms of depth, with typical mismatches of less than 10m. The lithological futures and variations at the scale smaller than 5m could not be recognised. Problems affecting the preservation of cuttings are (i) degree of lithification, (ii) mixing of cuttings/cavings, and (iii) possible contamination with drill-mud. Small size of cuttings (< 2 cm) and desegregation of poorly lithified sediments during the transport in the drilling mud makes difficult to obtain the information about lithofacies and sedimentary structures. Mineralogical and chemical analyses in cuttings are biased by the preferential consolidation of fine-grained sediments with respect to coarse-grained sediments. XRD and XRF analyses from cuttings are more homogeneous than those from core samples, and the composition of cuttings is similar to the samples of silty claystones from the cores.
In the future, more accurate quantitative characterisation of cuttings through the use of digital imaging can improve the description of lithofacies. Although the quality of cuttings is affected by caving and drilling mud contamination, our results clearly indicate that cuttings analysis in combination with seismic and logging data to coring in deep ocean drilling is a viable analogue to core for general lithostratigraphical interpretations when no scientific requirements for precise sedimentological analysis are required. To make precise lithostratigraphical description and interpretation in critical intervals, the study of core is needed.

7.3

Lithospheric heterogeneities, hydrothermal activity and serpentinization at slow spreading ridges: Insights through ocean drilling

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The formation and alteration of the oceanic lithosphere are fundamental processes that determine the chemical and physical evolution of our planet. In the nearly 40-year history of the scientific ocean drilling programs, a limited number of sites have been drilled into oceanic basement; however, only two holes, ODP Hole 735B and IODP Hole 1309D, have been drilled to depths >1000m in lower crustal sequences. These have led to a better understanding of mid-ocean ridge processes and, in turn, have led to the recognition of fundamental differences in crustal accretion and alteration processes related to spreading rates. In contrast to the apparently more layered and spatially homogeneous oceanic lithosphere at fast-spreading ridges (e.g., ODP Hole 504B and Hole 1256D), slow- and ultra-slow spreading centres are markedly heterogeneous with respect to lithology, deformation and degree of alteration. These heterogeneities reflect profound variations in magmatic, tectonic and hydrothermal activity along- and across-isochrons.

At many sites on the Mid-Atlantic Ridge (MAR), the magmatic layer is discontinuous and mantle lithologies are exposed at or near the seafloor within oceanic core complexes (OCCs): the footwalls of long-lived low-angle detachment faults. IODP Expeditions 304 and 305 targeted the 1.5 to 2 Myr old dome-like Atlantis Massif, located just west of the MAR at 30° N. The Atlantis Massif forms the inside corner of the intersection between the MAR and the Atlantis Transform Fault and is now one of the best studied OCC comprised of lower crustal and upper mantle rocks. Three domains are distinguished on the basis of lithology and morphology: a central dome, a peridotite-dominated southern wall and a basaltic eastern bloc, interpreted as a hanging wall separated from the OCC by a detachment fault. Here we review recent results of drilling at Site 1309 on the central dome of the Atlantis Massif, and compare these with results from detailed submersible studies of the southern wall, 5 km to the south.

The main hole 1309D was drilled on the crest of the central dome of the massive at a water depth of 1656 mbsf and penetrated 1415.5 mbsf with an average core recovery 75%. Quite unexpectedly, the predominant lithology recovered was gabbroic rocks (91.4%) with minor intercalated ultramafic rocks (5.7%) and diabase (~3%). The gabbroic rocks are compositionally diverse and are the most primitive ever cored in slow-spreading ocean lithosphere (with high Mg# (74–90), low TiO_2 (<0.49 wt%) and Na_2O (0.1–3.7 wt%). Mantle peridotites are very rare (<0.3%) and are concentrated in the upper part of the hole. The gabbroic rocks are relatively undeformed and show limited seawater-rock interaction downhole, as indicated by relatively homogeneous and mantle-like Sr-, Nd-, and S-isotope compositions.

The dominance of primitive gabbroic rocks, the absence of significant amounts of serpentinized mantle peridotites, and the low degree of fluid-rock interaction at Site 1309 contrasts greatly with results of submersible studies of the southern wall of the massif. The southern wall of the AM is dominated by serpentinized harzburgites, intruded by minor gabbroic bodies, and hosts the recently discovered Lost City Hydrothermal Field (LCHF), a peridotite-hosted hydrothermal system composed of spectacular, up to 60 m high, carbonate and brucite chimneys that vent low-temperature and high-pH fluids resulting from serpentinization reactions at depth. The Lost City fluids are enriched in hydrogen, methane and other hydrocarbons, produced abiotically through Fischer-Tropsch type reactions. Production of reduced volatiles and variable mixing with seawater in the subsurface and in near-vent environments are important processes in creating strong chemical gradients that provide micro-niches for distinct communities of hydrogen-, sulphur- and methane-utilizing archaea, bacteria as well as eubacteria. Geochemical investigations of the serpentinites hosting Lost City indicate long-lived seawater-peridotite interaction at 150-250°C and high fluid-rock ratios (>100 and up to 10^6), which produced enrichments in B, U and light REE, and systematic changes in Sr- and Nd-isotope ratios towards seawater values. Our multidisciplinary investigations of Lost City highlight the complex interplay between deformation, fluid flow, mass transfer and microbial activity within this long-lived system and are changing our views not only about the conditions under which life can thrive on our planet but, perhaps, on others as well.

The fact that IODP Hole U1309D on the Atlantis Massif (AM) on the MAR unexpectedly yielded 1400m of gabbro adjacent to where peridotite had previously been recovered, and close to the peridotite-hosted Lost City vent field, is testament to how laterally variable magmatic accretion processes and hydrothermal activity are at slow spreading ridge environments. Through studies of the Atlantis Massif and drilling at ODP Site 209 (along the MAR from 14° to 16°N on both sides of the Fifteen-Twenty Fracture Zone), a new model for the structure and formation of slow-spread ridges has emerged. Slow spreading ridges are probably less magma starved than previously believed, but melt is retained in the upwelling mantle as it ascends, and becomes incorporated into a relative thick lithosphere. The latter deforms and extends along localized zones of deformation, some of which become major detachment faults operating via a rolling hinge model. Such detachment faults may therefore at least locally constitute the de facto plate boundary. Drilling has also contributed to modifying our notions of ophiolites as analogues for ocean crust formation and has shown that slow-spread crust cannot be considered comparable to dismembered ophiolitic crust.

7.4

Scientific drilling in the ocean lithosphere : what's next?

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The mid-ocean ridges and the new oceanic lithosphere that they create are the principal pathway for thermal exchange and physical/chemical interactions between the earth's interior, the hydrosphere, and the biosphere. Hence the ocean lithosphere records the inventory of global thermal, chemical and associated biological fluxes.

A key outcome of the InterRidge-IODP "Melting, Magma, Fluids and Life" workshop (Southampton, 27-29 July, 2009; www.interridge.org/WG/DeepEarthSampling/workshop2009) was the formulation of integrative scientific questions and implementation approaches that will elucidate the role of ocean lithosphere processes within the broader Earth System. There are three, equally important main themes, each comprising geological, hydrological, chemical, and biological processes that are closely interdependent.

- Understanding the accretion of ocean crust. This goal requires full section characterization of minimally-disrupted ocean crust and a sufficient portion of underlying uppermost mantle, and detailed understanding of active processes within the axial zone;
- Understanding lithospheric heterogeneity in slow- and ultraslow spread crust, in particular the impact of serpentinization on global biogeochemical cycles and plate rheology.
- Following the maturation process of lithosphere from the axis to the ridge flanks and investigating the hydrological-geochemical-microbiological feedbacks during the aging of the oceanic basement.

Focussing in on the first theme, sampling a complete section of the ocean crust, from the ocean floor to the uppermost mantle through the seismic Mohorovi i discontinuity (the 'Moho'), was the original inspiration for scientific ocean drilling, and remains the main goal of the 21st Century Mohole Initiative in the IODP Science Plan. Fundamental questions about the composition, structure, and geophysical characteristics of the ocean lithosphere, and about the magnitude of chemical exchanges between the mantle, crust and oceans remain unanswered due to the absence of in-situ samples and measurements. The geological nature of the Moho itself remains poorly constrained.
The "Mission Moho" proposal submitted to IODP in April 2007, sets the ambitious goal to drill completely through intact oceanic crust, across the Moho and into the uppermost mantle, in lithosphere formed at a fast spreading rate. Although, no

long-term mission has been adopted by IODP, the scientific objectives related to deep drilling in the ocean crust remain essential to our understanding of the Earth. Our current knowledge if in-situ ocean crust remains limited; much will be learned on the way to the mantle. The journey and the destination are equally important.

Fundamental scientific goals include:

- Determine the bulk composition of the oceanic crust to establish the chemical links between erupted lavas and primary mantle melts, understand the extent and intensity of seawater hydrothermal exchange with the lithosphere, and estimate the chemical fluxes returned to the mantle by subduction,
- Test competing hypotheses of the ocean crust accretion at fast spreading mid-ocean ridges, and quantify the linkages and feedbacks between magma intrusion, hydrothermal circulation and tectonic activity,
- Determine the geological meaning of the Moho in different oceanic settings,
- Determine the in situ composition, structure and physical properties of the uppermost mantle (and its variability), and understand mantle melt migration,
- Calibrate regional seismic measurements against recovered cores and borehole measurements, and understand the origin of marine magnetic anomalies,
- Establish the depth limit of deep biosphere and hydrological/geobiological processes in the lithosphere.

The “MoHole” was planned as the final stage of Mission Moho. At the recent InterRIDGE-IODP Workshop "Melting, Magma, Fluids, Life", scientists re-iterated their enthusiasm and support for an ultra-deep hole in intact oceanic crust and into the uppermost mantle. This project would provide major inspiration for the next generation of scientists and engineers. The challenge is formidable, and requires as soon as feasible careful site selection, geophysical site survey, and the development of cutting edge technology including drilling capability to achieve +6000m of penetration in +4000m water depth. The next drilling program needs a mechanism to enable the community to move forward with planning, design and implementation in order to complete one of the major goals of scientific ocean drilling.

7.5
The age of sedimentary fillings of overdeepend valleys in the Alps

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Overdeepened basins and valleys are known from several areas within the Alps, in particular from Switzerland and northern Italy (e.g. Schlüchter, 1979). It is furthermore remarkable that glacial erosion partly left remains of older deposits in lateral valley positions such as Gnadenwaldterrasse of the Inn Valley (Fliri et al., 1973), Austria, or Thalgut in the Aare Valley (Schlüchter, 1989), Switzerland, that represent former valley bottoms. Several of the deep basins and relics contain complex sedimentary sequences that indicate deposition before the last glaciation of the Alps (Würmian). Recent results from palynology and luminescence dating indicate a complex deposition history for such sediments, for example for the complex sequence of Meikirch, Aare Valley (Preusser et al., 2005). The available data implies that deep erosion and shaping of the present subsurface occurred throughout several phases during the Quaternary. However, the exact timing of these processes is still poorly constrained as the number of sites available is rather limited. Since most of the valley fillings are deeply covered by sediments of later glaciations, further detailed information about this issue can only be achieved by recovering cores from such structures by deep drillings (down to some hundred metres). First results from a case study in the Wehntal (Züricher Unterland) will be presented.

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7.6

New sights on Late Pleistocene climate variability in Southernmost Patagonia: An ICDP approach

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Laguna Potrok Aike, at 52°S, 70°W in Southern Patagonia, contains a unique paleoclimatic record of southern South America. This ~770 ka old maar located in the province of Santa Cruz, Argentina, is one of the few permanent lakes in this steppe region, providing a continuous sedimentary record over an extended time span in this area of the world. Within the framework of the ICDP-sponsored Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO), three sites were cored during October and November 2008 by an international group of scientists using the GLAD800 drilling rig operated by DOSSEC (Figure 1).

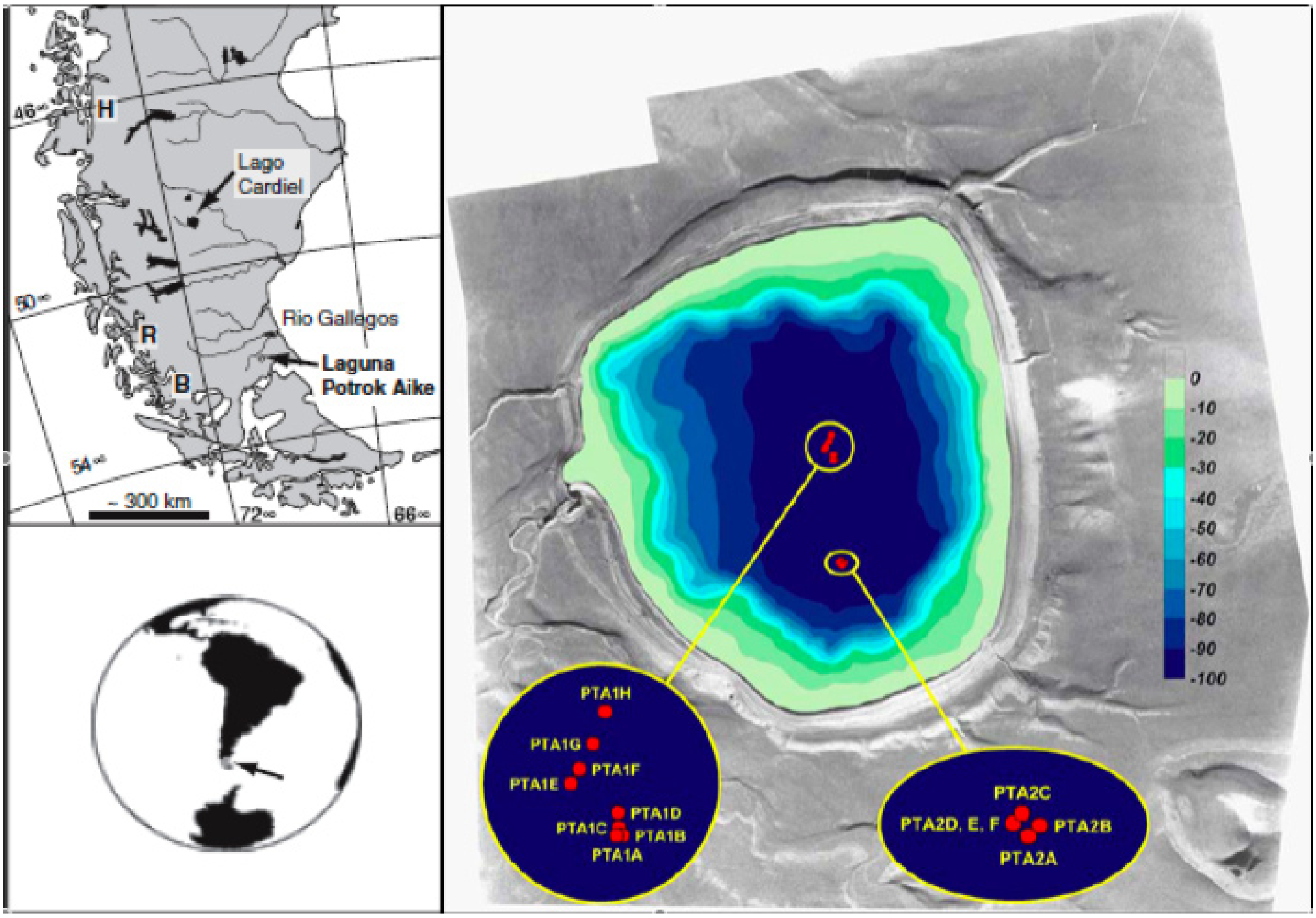

Figure 1. Bathymetric map of Laguna Potrok Aike with drill sites PTA1 and PTA2 and holes labeled alphabetically. PTA-1E to -1H and PTA-2D to -2F are gravity cores covering the sediment water interface. Inserts show location of the lake in southern South America. The volcanoes Reclús (R), Hudson (H) and Mt. Burney (B) are marked with capital letters.

The lake is located in the Pliocene to late Quaternary Pali Aike Volcanic Field, a northwest-southeast oriented tectono-volcanic belt that is ~50 km wide and more than 150 km long. The available geomorphological data indicate that Laguna Potrok Aike has neither been reached by the last glaciation nor by any other Pleistocene ice advance during the last 1 Ma. Thus, it is potentially the only site that has archived a continuous and high-resolution sediment record covering several glacial/interglacial cycles for the southern hemispheric mid-latitudes. Several drilling sites were chosen after the interpretation of the seismic profiles obtained in prior field campaigns, within the framework of the project "SALSA", South Argentinean Lake Sediment Archives and Modeling (Anselmetti et al. 2008, Wille et al., 2007). More than 500 m of sedimentary cores were recovered and the longest core reached over 100 m.

On-site laboratory analyses were carried out simultaneously to the drilling operations. All core sections were scanned for petrophysical properties prior to opening with a GeoTek® Multisensor Track Core Logger (MSCL). An in situ geochemical laboratory was also habilitated in order to achieve the first analysis on the recovered material. Core catchers (approximately one every three meters) were photographed and described, and then subsampled for water content, Ca and Cl contents as well as pH which were measured immediately in the camp. Samples were furthermore taken for stable isotopes, pollen and diatoms for subsequent analysis in the homebased laboratories. Smear slides were mounted for petrographic microscopic examination.

An international scientific team will work on the different sedimentary cores recovered at the three sites using a multidisciplinary approach. Several analyses are currently underway including more accurate MSCL scans of the cores and core catcher analysis for diatoms, pollen and stable isotopes. A sampling party at the core repository in Bremen, Germany, is actually on the go. Cores have been split and are being sampled at high resolution for all the planned analyses.
The Swiss scientific contribution to the project involves two main aspects: 1. the diatom record of the retrieved cores for paleoenvironmental reconstructions and collaboration in the development of a modern training set for diatoms in Patagonia; 2. the characterization of the deep biosphere investigating living microbial communities within the sediments, which is embedded in an integrated study including microbiology, geochemistry (interstitial waters), and mineral authigenesis/diagenesis.

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7.7

PALEOVAN - The International Continental Scientific Drilling Program (ICDP) in Lake Van, Eastern Anatolia (Turkey)

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Lake Van is the fourth largest terminal lake in the world (volume 607 km^3, area 3,570 km^2, maximum depth 460 m), extending over 130 km WSW-ENE on the Eastern Anatolian high-plateau, Turkey. The annually-laminated sedimentary record of Lake Van promises to be an excellent palaeoclimate archive because it potentially yields a long and continuous continental sequence that covers several glacial-interglacial cycles (~500 kyr). Therefore, Lake Van is a key site within the International Continental Scientific Drilling Program (ICDP) for the investigation of the Quaternary climate and paleoenvironmental evolution in the Near East .The ICDP drilling operations 'Paleovan' will be performed with active involvement of various Swiss research groups. Drilling is planned for 2010 and the technical preparations are currently underway.

As preparation for the drilling campaign, several site surveys were carried out during the past years consisting of ~850 km seismic profiles, multidisciplinary analysis of up to 9 m long cores extending back to the Last Glacial Maximum and water column analysis. Furthermore, recent investigations focused on modern particle dynamics and varve formation using sequential sediment traps, multispectral satellite images and short sediment cores (Stockhecke, 2008).

The sediment trap samples and satellite images of 2006 revealed that three annual phases of authigenic particle production occur, one in spring characterized by non-skeletal algae, one in summer with dominance of authigenic carbonate production, and one in autumn, which is characterized by diatoms and thus biogenic silica production. The sediment trap samples from 2007 to 2008 show the same organic spring-peak as the year before, but the biogenic silica concentration increased significantly. The maxima of authigenic carbonate production in late autumn of 2008 is related to significant higher air temperatures and increased water mixing processes at the corresponding depth. Further investigations are planned that document the annual cycles with seasonal resolution and their preservation potential in the lake sediments, calibrating the sensitive climate-lake-sediment system.

All these investigations show the large potential of PALEOVAN for obtaining a continuous undisturbed and long continental palaeoclimate record. This will shed new lights on paleoenvironmental conditions, the dynamics of lake level fluctuations, noble gas concentration in pore waters, history of volcanism and and earthquake activities (Litt, 2008).

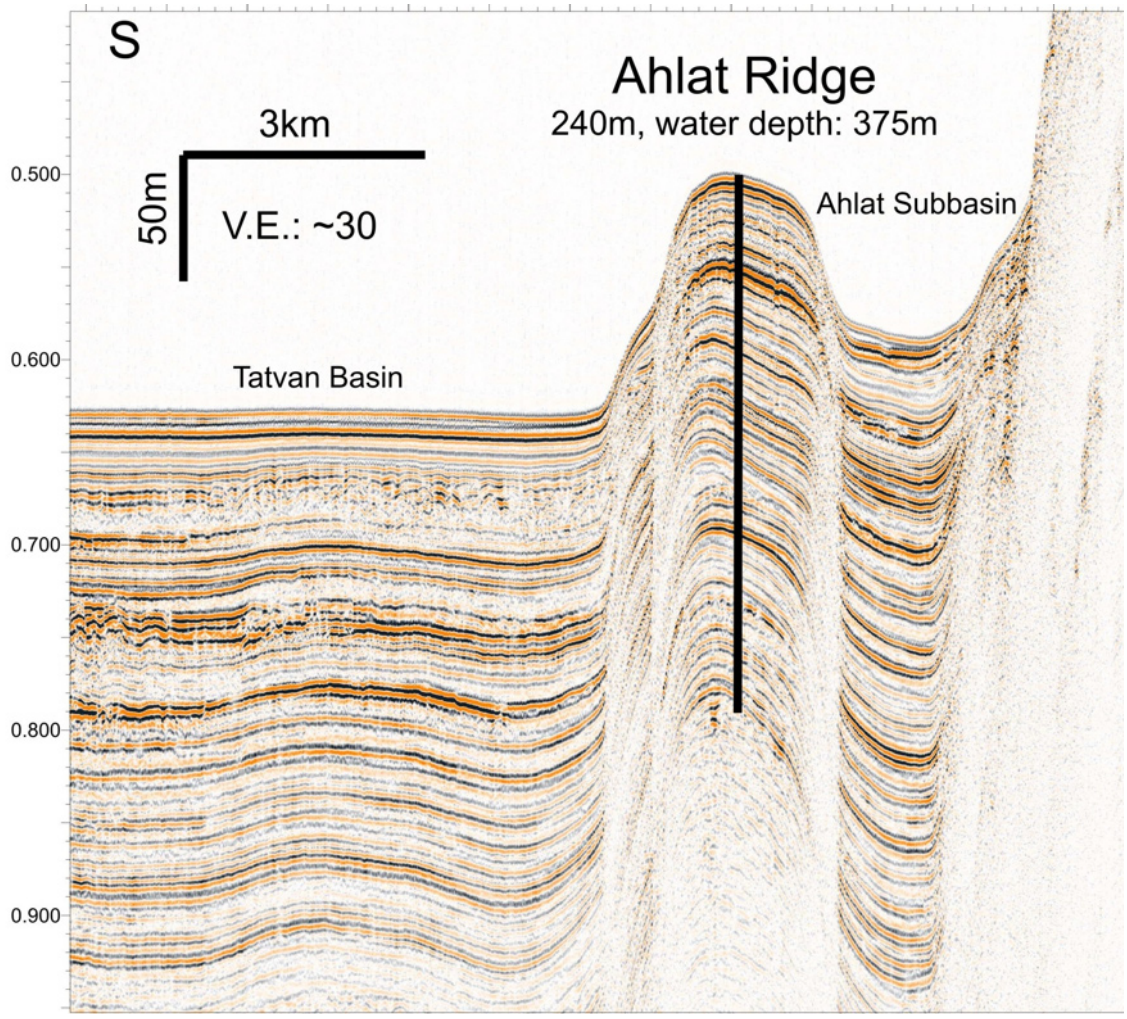

Figure 1. Part of seismic profile GEO04-007 crossing the Tatvan Basin and Ahlat Ridge in a S-N direction with the proposed ICDP drill site.

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7.8

Addressing Geohazards from Submarine Slides through Ocean Drilling: The "Nankai Trough Submarine Landslide History" drilling Proposal

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With increasing awareness of oceanic geohazards (e.g. Morgan et al., 2009), also submarine landslides are wide gaining attention not only because of their catastrophic impacts (e.g. landslide-induced tsunamis, submarine infrastructure), but also because they can be directly related to primary trigger mechanisms including earthquakes, rapid sedimentation, gas release, or clathrate dissociation, many of which represent geohazards themselves (e.g. Camerlenghi et al., 2007). Scientific ocean drilling can be a key element in understanding such geohazards, given that the submarine geological record preserves structures and past occurrences. To improve our knowledge, quantitative constraints on frequency and magnitude on relevant timescales need to be related to trigger and failure mechanisms.

Towards this goal, the IODP - Ancillary Project Letter - Proposal "**Nan**kai **Tro**ugh Submarine Land**SLIDE** History – **NanTroSLIDE**" aims to add one site to the NanTroSEIZE (Nankai Trough Seismogenic Zone Experiment; Tobin and Kinoshita, 2007) study area to constrain timing, causes and consequences of submarine landslides in this well-studied accretionary complex. On the basis of new 3D seismic data interpretation in the NanTroSEIZE study area, we have identified an ideally suited slope basin sedimentary succession that is composed of stacked Pleistocene-to-recent mass transport deposits (MTDs) that includes one exceptionally large MTD up to 150m in thickness. A 350m thick succession, comprising the distal part of the mega deposit, is proposed to be completely drilled and logged within 3 days before, during or after any of the upcoming NanTroSEIZE operations on the Japanese drilling vessel *Chickyu*.

We expect to catalog a detailed submarine landslide event history along with clues on the depositional dynamics of each MTD as they relate to tsunamigenic potential. In conjunction with 3D seismic interpretation we will be able to constrain scales and landslide magnitude. The results obtained will be interpreted in terms of short-term trigger mechanisms and long-term pre-conditioning factors by correlating the magnitudes and frequencies of MTDs to the seismicity and tectonic evolution of the margin. Additionally, data from nearby NanTroSEIZE drill sites are expected to reveal quantitative constraints on slope stability conditions and submarine landslides initiation. In combination, the available data set will allow us to establish a better physical understanding of tectonic processes and slope failures, to gain a general understanding of failure-related sedimentation patterns and the significance of large episodic mass-transport events. Ultimately, this could help us to asses the tsunamigenic potential of submarine landslides. We thus expect this proposed project to become an important case study providing the base to improve our conceptual understanding of causes and consequences of submarine landslides.

The primary goals of drilling the proposed site (NTS-1A) are:

(i) To establish a well-dated Pleistocene-to-recent mass-movement event stratigraphy
(ii) To sample the distal part of an exceptionally thick MTD for analyzing its rheological behavior to constrain sliding dynamics and tsunamigenic potential

This aims at providing answers to following questions:

1) What is the frequency of submarine landslides
2) How are MTDs and earthquakes related and can we use the MTD-inventory to interpret paleoseismology
3) What controls type, size and magnitude of turbitides and MTDs and how do they change through time?
4) What are the dynamics of large submarine landslides and can we infer ther tsunamigenic potential?

By addressing these focused key questions, we aim to isolate tectonic processes influencing magnitude and occurrence of submarine landslides along active subduction zone margins and to understand their potential for triggering catastrophic consequences both in terms of hazard (tsunamigenic landslides) and of sediment mass-transfer and margin evolution.

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7.9

Evidence for a middle Pliocene change in the ocean nitrate inventory based on foraminifera-bound δ15N in the Caribbean Sea

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The nitrate budget in the low-latitude surface ocean is mainly controlled by the typically opposing effects of denitrification and nitrate fixation. The state of the global ocean nitrate inventory affects primary production, which allows sequestering CO2 into the deep ocean. This may influence climate variability and control warm and cold periods in Earth history. Studies have shown that nitrogen isotopes reflect the nutrient status of the upper water column and therefore are a proxy for the state of the ocean's 'biological pump'.

So far, the N inventory has mostly been reconstructed based on bulk sedimentary N-isotope measurements, which can be affected by syn- and post-sedimentary processes. Promising approaches to circumvent these potential biases are based on measurements of foraminifera-bound $\delta^{15}N$. In the subtropical and tropical ocean, planktonic foraminifera are a main component of the sinking particle flux. The organic compounds encapsulated within the foraminiferal tests are protected from sedimentary diagenetic processes. As a result they record a pristine signal of the nitrate composition in the water column. The novel method used here employs denitrifying bacteria Pseudomonas chlororaphis and Pseudomonas aureofaciens to produce nitrous oxide (N_2O), recovered from the nitrate extracted from the organic matter sheltered within the foraminifera shell, which is analyzed for $\delta^{15}N$ with a Gas bench II – IRMS and produces results with reproducible isotopic measurements of samples down to 1 μM nitrate.

Previous data from the investigated site (ODP Leg 165, site 999A, Caribbean Sea), studying the last 30'000 yrs using the same method, indicate a systematic difference between glacial and interglacial values. The glacial state is characterized by high $\delta^{15}N$ values around ~ 5 ‰ (suggesting less N-fixation) and the interglacial state by low $\delta^{15}N$ values around ~ 3 ‰ (N-fixation increase). On contrary, our data from foraminifera-bound $\delta^{15}N$ of *G.ruber* and *G.sacculifer* reveals evidence for a change in the mean ocean nitrate compared to the last 30'000 yrs. The basic findings from the measured interval between 3.2 Ma to 2.4 Ma show glacial $\delta^{15}N$ values of ~ 4.5-7 ‰ for *G.sacculifer* and ~ 3-5.5 ‰ for *G.ruber*, interglacial values range between ~ 4-6 ‰ for *G.sacculifer* and between ~ 3-5.5 ‰ for *G.ruber*. Based on the obtained $\delta^{15}N$ values we could not differentiate between glacial and interglacial periods. This lead us to the conclusion that there probably was a general change of the ocean nitrate inventory and the dominating processes of N-fixation and denitrification performed in a different way than today. Further measurements will be necessary to understand the preliminary data and to interpret the possible changes in the ocean during late Pliocene.

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7.10

New prospects in ICDP research: investigating the subsurface biosphere in Lake Potrok-Aike sediments

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Microbial activity on recent sediments is fully recognized as a major player in lithification processes. These omnipresent organisms have the capacity of catalyzing and enhancing diagenetic reactions even in extreme environments from the very surface of the sediments to as deep as 4.5 km below the water column. Living bacterial communities have been tracked down into deep sediments and even into the deeper basaltic sub-seafloors. Although the distribution and diversity of microbes in marine sediments through depth have been studied for some years already, there is a lack of these investigations in the lacustrine realm.

Furthermore, geomicrobiology studies in modern lakes allow taking a closer look into early diagenetic processes linked to microbial activity in subrecent sediments. The foci of most of these studies, however, have been either very shallow sediments and/or the water column.

More than 500 meters of sedimentary cores were retrieved from Lake Portok Aike, a crater lake located in Southern Patagonia within the framework of the ICDP-sponsored PASADO project (Potrok Aike Maar Lake Sediment Archive Drilling Project). A 100 meters long core was dedicated to geomicrobiology sampling, allowing the inspection of undisturbed deep lacustrine sediments. Special windows were cut in the liners for direct sampling under the most sterile conditions possible immediately after core recovery. In situ ATP measurements are used as indication of living organisms within the sediments. Various samples were chemically fixed and/or frozen for methane determination, bacterial cell counting, DGGE (molecular fingerprinting technique) and cell cultivation.

In situ ATP data reveal a constant low microbial activity below 40 m sediment depth whereas three main peaks appear at 34, 10 and 5 meters respectively. Studying the microbial community based on 16S rDNA, we identified a broad, but conserved diversity pattern in the older sediments. In contrast, the diversity seems to decrease and change dramatically in the upper section. A preliminary interpretation of these results suggests that each ATP peak correlates with microbial community interphases. The latter together with the negative correlation between activity and diversity may indicate that nutrients are systematically depleted through bacterial activity cycles since each individual community may be at least partially fed by the metabolic products of the overlying community. Adaption becomes necessary for communities evolving in environments with decreasing trophic state.

The integration of these dataset with ongoing multiproxy studies in the same record will bring new light into microbial activity in lacustrine systems and their role on various diagenetic processes.