

# IPA-IAL 2018 | Joint Meeting

## Unravelling the Past and Future of Lakes



## ABSTRACT BOOK



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# IPA-IAL Joint Meeting: Unravelling the Past and the Future of Lakes

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# Award winners

## **The Hominin Sites and Paleolakes Drilling Project (HSPDP): How lakebeds are reshaping our understanding of the environmental context of human origins**

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The role that environmental, and particularly climatic change and variability may have played in regulating human evolution has been a subject of significant debate among paleoanthropologists for many years. Whereas a significant part of the uncertainty surrounding this debate is related to the general paucity of hominin fossils, the lack of continuous and high resolution paleoenvironmental records through critical intervals of hominin evolutionary history has also been problematic. HSPDP was conceived as a means to address the hominin evolution/paleoclimate debate in East Africa, through the collection of drill cores from lake deposits in close proximity to key fossil hominin and archaeological sites. Six locations were drilled between 2012–2014, resulting in ~2 km of core, spanning important evolutionary events in human prehistory over the last ~3.5 Ma. A large, international team (~150 scientists from 11 countries) has been investigating these drill cores to extract physical property, sedimentological, geochemical, and paleoecological records constrained by state-of-the-art geochronology, to understand what was happening to both the landscapes and lakescapes of Kenya and Ethiopia during that time. Significant findings are emerging from the project, particularly related to the Plio-Pleistocene transition (associated with the origin of both *Homo* and the robust australopithecine lineages, the earliest stone tools, and the extinction of *Australopithecus afarensis*), the middle Early Pleistocene (origin of *H. erectus* and the Acheulean hand axe technology) and the last ~600ka (transition from the Acheulean to Middle Stone Age and then Late Stone Age, origin of modern *H. sapiens*). Those core studies are bolstered by teams of Earth System, geomorphic and demographic modelers to better interpret the environmental and evolutionary dynamics underpinning the combined lake drill core/fossil outcrop records from this key region for human origins research.



# Climate and human influences on global sediment transfers during the past 10,000 years

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Accelerated soil erosion has substantial implications for land productivity, downstream lake ecosystems and biogeochemical cycles<sup>1,2</sup>. However, the lack of long-term instrumental data and the scarcity of large-scale paleolimnological synthesis are limiting our understanding on the timing, the amplitude and the extent of soil erosion for the last millennia<sup>3</sup>. As such, the responses of soil erosion to long-term climate and land cover changes, the effects on lakes C accumulation and the feedbacks on the climate system are still unclear today<sup>4</sup>. Here, we reconstruct sedimentation rates based on <sup>14</sup>C chronologies for 651 lakes to assess the relative changes in lake-watersheds erosion over the period 12,000 B.C. to A.D. 2000. Estimated soil erosion dynamics are then complemented with land cover reconstructions inferred from pollen records and with JSBACH-model climate reconstructions. We find a constant trend in our global signal of inferred-erosion during the Holocene until trends started to increase at the continental scale beginning around 3,000 years ago, with large spatial heterogeneity between local trends. In particular, increased inferred soil erosion is recorded in 35.1% watersheds, and most of these sites show a decrease in arboreal pollen that is congruent with the erosion rate changes. Further analysis reveals that land cover change is the main driver of soil erosion in 70% of all studied watersheds. Most of erosion variations in the last 50 years are related to agricultural intensification rather than land clearance or predominance of agricultural lands<sup>5</sup>. In contrast our synthesis strongly suggests that - at least in the Northern Hemisphere - human land cover change has been the primary driver of accelerated erosion during the Holocene.

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# Building a Long-Term Perspective into Ecotoxicological Research

Jennifer B. Korosi (1), Cynthia Cheney (2), John P. Smol (3), Joshua R. Thienpont (2), and Jules M. Blais (2)

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The development of water and sediment quality guidelines for aquatic pollutants requires an understanding of the toxic impacts on biota, communities, and ecosystem function. Classical toxicological studies conducted in a lab or mesocosm setting are effective for characterizing pollutant impacts on biota in a controlled, simplified environment. Nonetheless, it is well-acknowledged that predictions based on the results of these studies must be tested in a natural ecosystem setting, and over long timescales, to account for increased complexity and multiple stressors. Lake sediments cores are routinely used to document deposition histories for many pollutants of concern (“dose”), and also preserve the subfossil remains of several important ecological groups (“response”), including many commonly used ecotoxicological indicator organisms. Consequently, paleolimnological approaches are highly complementary to more traditional methods of inquiry in ecotoxicology, and can be used to address key knowledge gaps regarding the long-term consequences of pollutant exposure in an environmentally realistic, multi-stressor context. Using historic gold mining activities in Yellowknife (Northwest Territories, Canada) as a case study, we have been exploring techniques to merge standard paleolimnological approaches with new “paleoecotoxicological” tools in order to generate novel insights into the legacy impacts of exposure to arsenic. Giant Mine, operational between 1948 and 1999, released an estimated 20 million kilograms of toxic arsenic trioxide dust during its lifetime. Most emissions occurred during the first 10 years of operations, and yet arsenic concentrations in Yellowknife lakes remain well above water quality guidelines. Limited water quality monitoring occurred in the region while the mine was operational, and lake sediment cores provide a historic archive that is invaluable for understanding the magnitude of ecological impact resulting from chronic arsenic exposure, and the potential for ecosystem recovery.

# Plenary Talks

## Monotheism and the future of palaeolimnology

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In the ~40 years since the second international meeting in Koli (Finland), palaeolimnology has advanced considerably. This progress has been driven in part by the demands of contributing to environmental debates (e.g. notably acidification) which drove the incorporation of new statistical techniques, i.e. weighted averaging based transfer functions, and the rapid increase in the use of  $^{210}\text{Pb}$ -dating. More recently, there have been rapid methodological advances in stable isotopes, biomarkers and most recently aDNA techniques.

The contingencies of funding framework goals which, in part, reflect shifts in environmental foci (e.g. nutrients [eutrophication] in the 1970s to acid deposition [acidification] in the 1980s) as much as drive them, have meant that palaeolimnologists have tended to focus on single drivers when interpreting sediment records. Most recently, the emphasis has shifted to climate change as the key driver of the changes observed in lakes. Clearly, this is an over-simplification, both in terms of the possible forcing mechanisms and the ecological response: there is considerable co-variation in space and time of anthropogenic disruption of global biogeochemical cycles. This focus on a single driver, notably climate, is ecologically naïve and ultimately constrains the relevance of palaeolimnology to wider debate and its role in environmental management.

In this presentation, I will attempt to explain recent trends in palaeolimnology in the context of its historical development and highlight some of the limitations of focussing on single drivers, using examples from the literature as well as my own work.

*\*monotheism, \*/n. /the doctrine that there is only one God.*

# The Critical Role of Chronology in Understanding Past Climate Change

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For comparison to climate patterns in modern observations and climate model simulations, which operate on timescales of hours, months, and years, paleoclimate reconstructions have driven to higher and higher resolution, in some cases approaching the decadal and annual scale. However, in order to accurately and precisely correlate these records between sites, the accompanying chronology must be of similar resolution, with explicitly quantified uncertainties. Although an increasing number of proxy records have decadal-scale resolution, many have chronologies with multi-centennial precision at best, casting uncertainty on any interpretations at the finer scale. This is a particular challenge for lake records, which are generally radiocarbon dated. Although the imprecision introduced by the radiocarbon calibration curve is an underlying difficulty, the limiting factor for chronologies is often the availability of dateable material; that is, well-preserved terrestrial organic matter. One possible solution to this problem is pollen, which is quite robust and present in most lake sediments, and whose carbon isotope composition is tied directly to the atmosphere. We present early results of radiocarbon dating of pollen which has been concentrated chemically and purified by flow cytometry. These results suggest that pollen can be reliably separated and dated, but like everything in lakes must be interpreted within the specific geologic system where it was produced, deposited, and preserved. If pollen dating proves robust in many lake systems, it may provide the high-precision chronologies required for spatial mapping of past terrestrial climate changes.

# **Application of DNA-based methods in paleolimnology: new opportunities for investigating long-term changes in lacustrine biodiversity**

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The emergence of molecular analyses based on the sequencing of sedimentary DNA has opened up many new areas of inquiry in paleolimnology.

Sedimentary ancient DNA offers the possibility to consider taxa that were traditionally not accessible because they do not leave distinct morphological fossils. Recent applications that considered a diversity of biological groups (including bacteria, protists, zooplankton, fish) illustrate how efficiently DNA-based methods complement classical paleolimnology proxies. The knowledge gained from this approach is very diverse in scope, ranging from quantifying natural variability in population and community dynamics to understanding how biological variables respond to anthropogenic disturbances locally (at the watershed scale) or more globally (e.g. climatic change).

Here, we discuss (i) the potential and challenges associated with the study of DNA in paleolimnology to address critical research questions in lacustrine ecology (ii) the main methodological precautions to be taken into account for implementing these types of DNA analyses, and (iii) the emerging topics that could be addressed using sedimentary DNA, in particular to reconstruct the temporal dynamics of lacustrine biodiversity.

## **Building a Long-Term Perspective into Ecotoxicological Research**

**Jennifer B. Korosi (1), Cynthia Cheney (2), John P. Smol (3), Joshua R. Thienpont (2), and Jules M. Blais (2)**

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The development of water and sediment quality guidelines for aquatic pollutants requires an understanding of the toxic impacts on biota, communities, and ecosystem function. Classical toxicological studies conducted in a lab or mesocosm setting are effective for characterizing pollutant impacts on biota in a controlled, simplified environment. Nonetheless, it is well-acknowledged that predictions based on the results of these studies must be tested in a natural ecosystem setting, and over long timescales, to account for increased complexity and multiple stressors. Lake sediment cores are routinely used to document deposition histories for many pollutants of concern (“dose”), and also preserve the microfossil remains of several important ecological groups (“response”), including many commonly used ecotoxicological indicator organisms. Consequently, paleolimnological approaches are highly complementary to more traditional methods of inquiry in ecotoxicology, and can be used to address key knowledge gaps regarding the long-term consequences of pollutant exposure in an environmentally realistic, multi-stressor context. Using historic gold mining activities in Yellowknife (Northwest Territories, Canada) as a case study, we have been exploring techniques to merge standard paleolimnological approaches with new “paleoecotoxicological” tools in order to generate novel insights into the legacy impacts of exposure to arsenic. Giant Mine, operational between 1948 and 1999, released an estimated 20 million kilograms of toxic arsenic trioxide dust during its lifetime. Most emissions occurred during the first 10 years of operations, and yet arsenic concentrations in Yellowknife lakes remain well above water quality guidelines. Limited water quality monitoring occurred in the region while the mine was operational, and lake sediment cores provide a historic archive that is invaluable for understanding the magnitude of ecological impact resulting from chronic arsenic exposure, and the potential for ecosystem recovery.

# **An integrated approach to recognizing lake cycles and their controls: using trace fossils and stratigraphy in lake basins from Kenya and North America**

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The use of trace fossils with sedimentology to interpret the stratigraphic packaging of lake-basin successions helps to provide the physical framework needed to integrate multi-proxy datasets from lacustrine systems. The packages can represent relatively short-term cyclical orbitally-forced successions of lake level rise-and-fall, and sets of stacked packages can represent longer-term changes in basin configuration, drainage capture, or lower-frequency orbital cycles. Examples from the Eocene Green River Formation, Pliocene to Recent Kenya Rift Valley lakes, and the Cretaceous early foreland basin of Canada each demonstrate how trace fossils in shallow-lake to terrestrial settings can be used to help package lacustrine successions in order to answer questions about tectonics and climate in lake basins. In examples with high-resolution geochronology, we can recognize climate-control on transgressive-regressive packages, and begin to differentiate climate from basin-scale tectonic influences on lake-type. The distribution and composition of trace fossil assemblages can also help to determine the lake-type basin and its deposits by providing clues to hydrochemical conditions (e.g., oxygenation, salinity). Terrestrial trace fossils, of termites and beetles for example, can also rework sediments metres below exposure surfaces and disrupt paleoecological and geochemical information, even from profundal sediments. The delineation of lake-cycle packaging using a sequence stratigraphic approach that includes trace fossils can thus provide the framework from which we can recognize cyclicity as well as departures from predictable cycles at different scales.



# Advances and applications of novel analytical techniques

*Stephen J. Roberts, Sarah J. Davies*

## Session 01



## **S01-001 - Characterizing the Anthropocene with High-Resolution Analysis of Chemical Contamination in Lake Sediment**

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The overwhelming increase in human interference with the environment has left traces that provide evidence for the beginning of a new geological era, informally named the Anthropocene. The rate and variability of these human modifications at the local and global scale remain largely unknown, but new analytical methods such as high-resolution mass spectrometry (HRMS) can help to characterize chemical contamination over time. Although many studies have analyzed natural records of anthropogenic pollution, no attempts have been made to gain a comprehensive picture of the occurrences of thousands of pollutants simultaneously in different paleorecords. This work uses state-of-the-art, novel analytical techniques such as HRMS and multivariate statistics to explore thousands of time series of unknown anthropogenic organic substances deposited in natural archives to investigate the contamination history of two lakes in Central Europe over the past 100 years.

Our results revealed 13,000 anthropogenic features in Greifensee and 29,000 in Lake Lugano sediments and gives a holistic picture of contamination. In addition, this non-target screening method allows for the identification of groups of compounds that may otherwise be overlooked. For example, increases in the prevalence of 5,000 (out of the 13,000) anthropogenic features until today were observed in Greifensee, and of 20,000 (out of 29,000) of these features in Lake Lugano. Moreover, environmental changes recorded in both lakes give evidence of past and present water quality, management and mitigation measures and clearly define the beginning of a large-scale human impact around the 1950s. The obtained results are also in agreement with other geological deposits (e.g. nutrient pollution and radioisotope fallout signals) and clearly ratify a long-lived phenomenon as was shown for thousands of time series with steady increasing trends until today and not yet successfully targeted by environmental regulation and pollution reduction initiative.

## **S01-O02 - Lake sediments show the magnitude and frequency of recent extreme catchment-scale flooding in the northwest UK**

**R.C. Chiverrell (1), D.A. Sear (2), J. Warburton (3), N. Macdonald (1), D.N. Schillereff (4), J.A. Dearing (2), I. W. Croudace (5), J. Brown (1), J. Bradley (1)**

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We present the first quantified lake sediment reconstruction of flood frequency and magnitude, which allows a more accurate estimation of the recurrence probability of rare floods and the magnitude of extreme flooding. We show that the 2000 to present cluster of devastating floods in the 350 km<sup>2</sup> river Derwent catchment (NW England) is without precedent in the 520-year sediment record. Novel application of the flood magnitude frequency analyses routinely used by hydrologists have been applied to the palaeoflood record., and show that the 2009 event was the largest flood in >520 years and it had a recurrence interval far larger (1:16000 year) than revealed using short term gauged records (1:1500 year). Similar records have been developed from 4 additional large catchment lakes in the northwest of the British Isles, Buttermere, Ullswater, Brotherswater, Bala and Loch of the Lowes showing a regional palaeoflood signature. The extended record from Bassenthwaite Lake shows that the association of floods with climate indices has varied over time, with the recent cluster associated with warmer Northern Hemisphere Temperatures and positive Atlantic Multidecadal Oscillation. Extreme flooding is the world's most damaging natural hazard, with river flooding affecting >100 million people each year and this is projected in many regions to increase in frequency with climate warming. Flood hazard managers and insurers require precise estimates of the magnitude and frequency of extreme floods to inform estimates of future risk, but are challenged by the lack of data often resulting from short instrumental records that fail to capture the rare high magnitude events.

## **S01-O03 - Pushing research boundaries: New technologies to determine respectively $\delta^{13}\text{C}$ , $\delta^{34}\text{S}$ and to reveal the isotopic anatomy of molecules.**

**Søren Dalby (1), Danijela Smajgl (1), Oliver Kracht (1) and Ulrike Wacker (1)**

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This presentation will focus on three newly developed instruments that have been developed by Thermo Fisher Scientific as tools to precisely and accurately determine the isotope ratio and composition of molecules of different origin.

First presented is data and the technology behind the instrumentations that enables scientists to determine accurate  $\delta^{13}\text{C}$  in the field using the Thermo Scientific Delta Ray Isotope Ratio Infrared Spectrometer (IRIS). Data will be presented from measurements of carbonate  $\delta^{13}\text{C}$  values in samples containing 200–300  $\mu\text{g}$  NBS 18. Calcite was measured with accuracy better than 0.03‰ VPDB on three instruments. The precision over 20 vials was better than 0.08‰ for all instruments.

Second will be discussed the advantages of using temperature ramped gas chromatography to separate gases in EA-IRMS. The Thermo Scientific EAIsolink elemental analyzer isotope ratio mass spectrometer (EA-IRMS) employs a temperature ramped GC column that improves peak separation, peak fidelity, analysis of very small sample amounts and precision of replicate measurements. Data and the technology behind the Thermo Fisher Scientific EAIsolink will be discussed.

Finally the new Thermo Scientific 253 Ultra high resolution isotope ratio mass spectrometer will be presented. The 253 Ultra HR-IRMS runs at 10 kV. The 253 Ultra combines an electron impact ionization source, a high-mass-resolution double-focusing magnetic-sector mass analyzer and a variable collector array. The 253 Ultra HR-IRMS delivers a guaranteed mass resolving power of  $>30,000$ . Data measurement of isotopologues (clumped isotopes) in trace compounds will be presented.

## **S01-O04 - A multi-lake approach towards the first calibrated lacustrine paleo-earthquake record in the Eastern Alps, Austria**

**Christoph Daxer (1), Jyh-Jaan Huang (1), Nicole Dörr (1), Ariana Molenaar (1), Maddalena Sammartini (1), Marcel Ortler (1), Christa Hammerl (2), Michael Strasser (1) and Jasper Moernaut (1)**

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Several studies have proven the applicability of lacustrine sedimentary archives to overcome the shortness of instrumental and historical earthquake records in formerly-glaciated intraplate regions. These investigations, however, focused either on single lakes, lakes with similar types of earthquake-induced deposits, or lacked high-quality historical and instrumental calibration of the paleoseismic record.

Here, we explored six well-distributed Carinthian lakes differing in size (1.1 km<sup>2</sup> to 19.4 km<sup>2</sup>), morphology, sediment composition/dynamics, hydrology and catchment area/lithology, using a combined approach of reflection seismics and short sediment cores. This region, located in the southern part of Austria, has experienced several well-documented historical earthquakes in a wide intensity range (V-IX; EMS-98) in 1201, 1348, 1690, 1857 and 1976, with the 1348 event considered to be the strongest historical earthquake (moment magnitude of ~7) in the Alps. Understanding the relationships between seismic intensity and the type of mass transport deposits, turbidites and sediment deformation associated with these earthquakes enables us to use lake sediments as calibrated paleoseismographs.

We investigated the well-dated cores via visual description, high-resolution XRF scanning, medical X-ray CT scanning and multi-sensor core logging. In this way, we were able to distinguish flood vs. earthquake-related turbidites and assess sediment dynamics and multi-source signatures of turbidite deposition. Seismic-to-core-correlation shows that the 1348 and 1690 events led to slope failures in some of the lakes. In others, however, these events are not represented as turbidites. We interpret this to be caused by insufficient seismic intensity and/or lower sensitivity to seismic shaking. In these shallow organic-rich lakes, seiche deposits can serve as a proxy for seismic activity.

The calibrated paleoseismic record for Carinthia will soon be extended into the Late Glacial using long (~15 m) sediment cores. Moreover, identifying the geotechnical properties of the sediments will improve our general understanding of lacustrine sediment response to different seismic intensities.

## **S01-O05 - Reconstructing past bottom-water redox conditions in lacustrine and marine basins using sedimentary trace metals measured with an X-ray Fluorescence core scanner**

**Rick Hennekam (1), Tim Sweere (2,3), Rik Tjallingii (4), Gert J. de Lange (3), and Gert-Jan Reichart (1,3)**

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Trace metals form powerful tools for paleoenvironmental reconstructions, including sediment provenance, phytoplankton production, and organic-matter preservation in lacustrine and marine basins. However, the analyses of sedimentary trace metal concentrations using conventional methods, such as Inductively Coupled Plasma-Mass Spectrometry, are rather costly and time consuming. X-Ray Fluorescence (XRF) core-scanning is currently established as a routine tool for fast and cheap analyses of major and minor elements, but generally not trace elements, as the spectral resolution of XRF detectors is often too low. Here, results are shown for an Avaatech XRF core scanner, equipped with a novel state-of-the-art detector, which now allows fast determination of a suite of trace metals (e.g., redox-sensitive elements V, Mo, and U). We present the most advantageous approach, i.e., optimum analytical accuracy with highest time efficiency, by extensive testing on sediments containing the imprint of past events of bottom-water anoxia in the Mediterranean Basin. Synthetic mixtures using common sedimentary matrices are used to show that matrix effects, inherent to XRF analyses, are primarily of importance for V. However, we developed an efficient way to correct for such effects using Compton scattering. Measurements through XRF core scanning on synthetic, laminated sediments show that trace elements can now be determined at high sub-mm resolution, being suitable for varved sediments. Lastly, we show that XRF-core-scan intensities can be quantitatively transformed into concentrations using a multivariate log-ratio calibration approach. As such, new valuable paleoenvironmental information from lacustrine and marine sediments can be unlocked using the Avaatech XRF core scanner.

## **S01-O06 - Use of a binary mixture model to reconstruct 300 years of Athabasca River sediment metal concentration from floodplain lake cores**

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The Peace-Athabasca Delta (PAD) in northern Alberta is the world's largest boreal freshwater delta. For the past 50 years, there have been many unresolved concerns over the potential effects of the Alberta oil sands development on the downstream flood-prone perched-basin lakes of the PAD. Sediment archived in these lakes provide access to baseline metal concentrations otherwise unavailable due to inadequate monitoring prior to industrial development. Stratigraphic interpretation of raw metal concentrations in floodplain lakes is complex because sediment is derived from two distinct sources. Allochthonous (river-sourced) and autochthonous (lake produced) pathways both contribute to delta lake sediment accumulation and the proportions of each varies based on hydrological conditions. Understanding past hydrological conditions is critical for interpreting past metal deposition because organic matter can serve as a weak to strong dilutant of metal concentrations. Here, we developed a binary mixing model using a conservative element (Al) and organic content to calculate the proportion of sediment that originated from allochthonous and autochthonous sources to reconstruct the historical bulk concentrations of metals of concern (Be, Cr, Cu, Ni, Pb, V, Zn) in Athabasca River sediment deposited in lakes of the Athabasca Delta. Results from eight lakes along a ~45 km transect in the Athabasca Delta floodplain show that Athabasca River sediment metal concentrations in recent decades are not yet elevated above pre-industrial concentrations. This novel approach can be applied readily in other river-floodplain settings to quantify past changes in river-sediment metal concentrations from stratigraphic analysis of flood-prone lake cores.

# **S01-O07 - Measuring sediment composition by multiple regression of end member IR spectra, applied to the Loch Grannoch Holocene record**

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Here we develop a novel method for quantifying sediment components from NIR spectra based on fitting by multiple regression of measured spectra for end-member materials. We show that with suitable end-members, multiple regression gives excellent simultaneous quantification of the major components of sediment, as judged against independent methods. We find comparable results to widely-used partial least squares (PLS) regression, but with the advantages of greater simplicity, theoretical robustness, and negating the need for the large training data sets used by PLS. Furthermore, the method is truly simultaneous and offers the potential for quantification of specific components.

We demonstrate that component NIR spectra are additive, a prerequisite for use of multiple regression to un-mix the compound spectra, and show that a number of environmental materials make suitable end-members for this analysis. We show that spectral mixing is not conservative with respect to mass proportion, but rather to the relative chromatic intensity of contributing components. Mass proportions can be calculated, however, from measured spectra by correction using a measurable chromatic intensity factor (CIF). We have applied our approach to the postglacial sediment sequence from Loch Grannoch (SW Scotland) revealing varying dominance of biogenic silica, organic and mineral content from the late glacial to present. With isolation and measurement of appropriate end-members the multivariate regression approach to interrogating NIR spectra has utility across a wide range of sedimentary environments.

## **S01-O08 - Compound-specific oxygen isotope ( $\delta^{18}\text{O}$ ) analyses of sugar biomarkers in lacustrine sediments – rationale, first applications and perspectives for future research**

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The oxygen isotopic composition ( $\delta^{18}\text{O}$ ) of lacustrine sediments is a highly demanded paleoclimate/-hydrologic proxy. In most cases it reflects lake water and can thus be interpreted either in terms of reflecting  $\delta^{18}\text{O}$  of paleoprecipitation or in terms of reflecting precipitation/evaporation (P/E) due to lake water evaporative  $^{18}\text{O}$  enrichment. From an analytical point of view,  $\delta^{18}\text{O}$  is usually obtained by analysing biogenic carbonates, silica of diatoms or aquatic cellulose. All those techniques have their advantages but at the same time also their analytical challenges and shortcomings.

Here we propose a recently developed novel analytical technique (Zech and Glaser, 2009, RCM 23, 3522-3532) that allows the hydrolytic extraction of (hemi-) cellulose/polysaccharide-derived sugar biomarkers such as arabinose, fucose and xylose from lacustrine sediments. The extracted and purified sugars are subsequently derivatized in order to make them gas chromatography-(GC-)amenable. Finally, compound-specific  $\delta^{18}\text{O}$  values are obtained for each individual sugar biomarker by using the instrumental coupling of a GC via an online  $^{18}\text{O}$  pyrolysis reactor to an isotope ratio mass spectrometer (GC- $^{18}\text{O}$  pyr-IRMS).

In one of the first applications, this technique was applied to the well-dated high-resolution Late Glacial-Holocene lacustrine archive of Lake Panch Pokhari that is situated at 4050 m a.s.l. in a small carbonate-free catchment in Helambu Himal, Nepal (Zech et al., 2014, Journal of Paleolimnology 51, 241–251). The relatively high abundance of fucose provides evidence for a primarily aquatic origin of the sugar biomarkers (Hepp et al., 2016, Organic Geochemistry 98, 98–104). We will demonstrate how the coupling of the Panch Pokhari  $\delta^{18}\text{O}$  sugar record with the  $\delta^2\text{H}$  record obtained for n-alkane lipid biomarkers from the same archive can be used to disentangle the isotopic precipitation signal from the evaporative enrichment signal (Hepp et al., 2015, Journal of Hydrology 529(2), 622–631).



# Poster Presentations

## **S01-P01 - What trace elements in ostracod shells can tell us about environmental change on the Tibetan Plateau**

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In paleolimnological studies ostracod shells are often used as source material for the analysis of stable isotopes as well as Mg/Ca and Sr/Ca ratios, which provide insight into past hydrological changes. In order to reconstruct the monsoon dynamics on the Tibetan Plateau we (I) tested the suitability of trace elements in ostracod shells as tracers of environmental change in Lake NamCo, where a detailed climate history since the LGM is already established, and (II) compared the records from NamCo and Tangra Yumco in order to assess the interaction of Indian summer monsoon and Westerlies. Both lakes feature an alkaline environment but differ in conductivity (1.8 mS/cm, NamCo; 12 mS/cm, Tangra Yumco). In two sediment cores, covering the past 18 ka cal. BP, trace elements in shells of *Leucocytherella sinensis* were analyzed using laser ablation ICP-MS.

Mg/Ca, Sr/Ca and Ba/Ca ratios reflect salinity and hence changes in moisture. In addition, the interrelations of these element/Ca ratios inform about the type of carbonate precipitation and allow identification of phases of calcite, aragonite or monohydrocalcite precipitation. Fe/Ca, Mn/Ca and U/Ca ratios reflect oxygen saturation and microbial activity, indicating changes in primary productivity. Rare earth elements (REEs) provide information on weathering intensity, transport medium and also source area, if the distribution of REEs in the catchment is known. The lake records from NamCo and Tangra Yumco show similarity in climate evolution during the late Quaternary. We identified two dry periods (18–16 ka and 13–11.5 ka BP), each followed by an increase in summer monsoon precipitation. Moist conditions were prevalent during the Holocene. A shift to drier conditions, due to weakened monsoon intensity, occurred at 2600 BP at Tangra Yumco and 2000 BP at NamCo, resulting in rapidly decreasing lake levels. In conclusion, trace elements in ostracod shells provide a detailed hydrological history.

## **S01-P02 - A test of Itrax molybdenum incoherent:coherent scattering ratio as a proxy for organic content of unconsolidated sediments**

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Organic Matter (OM) measurements have been used since the 1970s to determine carbonate and organic matter in sedimentary rocks. This information can shed a light on the accretion processes as well as the environmental changes that may have occurred in the past. Organic matter measurements have been widely used since its emergence and are still used as a routine technique for the determination of organic matter in sediment cores and soil samples. Most common method of obtaining approximate organic matter percentages is by igniting the samples at 550°C, commonly known as loss-on-ignition (LOI). This method requires samples to be sub-sampled at 0.5 cm to 1.0 cm intervals and ignited in a furnace at 550°C for 4 hours. Although relatively cheap, this method is destructive, labour intensive and time consuming. For over a decade since the emergence of Itrax core scanner, the use of the ratio of Molybdenum incoherent and Molybdenum coherent (Mo Ratio), which are the Compton and Rayleigh scattering respectively from the tube have been used to infer organic matter in the sediments. Itrax core scanners can achieve a resolution of 100 µm for the newer systems and 200 µm for some of the older systems in use. In this study, we investigated sediment cores from New Zealand where conventional LOI measurements were carried out at 0.5 cm to 1.0 cm intervals and compared them with Mo Ratio at 1 mm interval from the core scanner results. The aim was to see if the Mo Ratio values obtained from the scanner can be used to predict the OM content of the sediment. Furthermore, can high resolution OM be calculated by using only a few samples to calibrate sediments? Here we will extend the research further to see if OM can be quantified using Mo Ratio.

## **S01-P03 - X-ray fluorescence (XRF) core-scanning of organic-rich sediments: suggestions based on the analysis of incremental spiking reference materials**

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X-ray fluorescence (XRF) core-scanning is a fast and nondestructive technique to assess elemental variations of unprocessed sediments and have revolutionized paleoenvironmental research over the last decade. However, down core variabilities in organic contents can effectively dilute the elemental intensities obtained by XRF- scanners (the closed-sum effect) and therefore limit the usage of scanning results for robust paleoenvironmental reconstructions. Although there are several calibration methods, such as elemental ratios, standardized method and centered log-ratio (CLR) transformation, have been proposed by previous studies. A systematic investigation is still needed for exploring the practicalities and limitations of such calibration procedures. To address this issue, incremental spiking of reference basaltic standard (working standard of Austrian Core Facility at the University of Innsbruck) with glucose (as the organic surrogate, ranging from 0 to 100%) was scanned by the Itrax-XRF core scanner to allow a comparison of different calibration methods in the ideal condition. The result shows that the centered log-ratio transformation can provide the best calibration for most scanned elements with organic contents below 40 wt. %. Furthermore, as the real-case comparison, lacustrine core FIS-16 (high alpine lake Fischer see, Saldur area, South Tyrol, northern Italy) with ~1-cm resolution data available from conventional-XRF (by energy dispersive XRF analyser) and organic carbon analyses, has also been scanned by the Itrax-XRF core scanner and further calibrated. The result shows that the organic dilution effects can be filtered by the centered log-ratio transformation and thus provided the robust XRF-scanning results for further paleoenvironmental interpretations.

## **S01-P04 - Hyperspectral imaging for lake sediment cores analysis**

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The aim of this presentation is to overview some applications of hyperspectral imaging for core sediment analysis in paleoenvironmental studies. Sampling methods (millimetre or centimetre) and routine analyses are destructive and non-spatially resolved methods that consume time and material. Hyperspectral Imaging is a way to have the advantages of spectroscopy (non-destructive, fast analysis) and of imaging (high resolution, information is spatially referenced). coupling hyperspectral imaging with data mining methods makes possible to study several proxies at micrometric scale in each area of the core.

Two hyperspectral cameras are used, a Visible-Near InfraRed VNIR (spectral range: 400-1000nm, spatial resolution: 60µm) and a Short Wave InfraRed SWIR (spectral range: 1000-2500nm, spatial resolution: 189µm). The two datasets produced can be fused in a unique one used to model environmental proxies. This methodology was achieved on a core from the lake Le Bourget (Western Alps, 53cm long and 9cm width).

Quantitative prediction models can be made with partial least squares regression PLSR. This method links spectra with a reference analysis by the creation of a regression model. Assuming a scale homogeneity, it can be spread to all the spectra of the hyperspectral image to predict high spatially resolved proxies. Total Organic Carbon and Grain Size class models have been developed with a validation determination coefficient of 0.86 for TOC and 0.85 for clay. Concentration maps are used to study variation inside each stratigraphic unit event at the scale of laminae.

These datasets can be used for classification. Based on pattern recognition and artificial neural network, it is possible to classify the type of lithology defined by the user, for example: summer or winter lamina, floods with labelled areas of less than 1% of the image. For varved sediments, this method can be used to count the varve and apply statistics on them.

# **S01-P05\* - Long-term productivity and meromixis dynamics on the Swiss Plateau (Lake Moossee, Switzerland) inferred from Hyperspectral Imaging**

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Anthropogenically altered biogeochemical cycles, combined with climate change have resulted in adverse ecosystem impacts, increased productivity and anoxia in freshwater systems (Hecky, 2010). However, little is known about lake eutrophication and episodes of hypoxia and meromixis in the past, because this is difficult to measure analytically. Our aim is to investigate the following research questions: How did meromixis/hypoxia develop in small eutrophic lakes over Holocene/Late Glacial time scales? Which were the forcing factors (climate, land use, vegetation cover) and what was the influence of human impact? A sound scientific assessment of such changes must rely on a long-term perspective and high-resolution data. Hyperspectral Imaging (HSI) is a novel method to detect diagnostic sedimentary pigments at ultra-high spectral (3 nm) and spatial (40 µm pixel size) resolution. These provide quantitative information about paleoproductivity, past mixing regimes and anoxia in lakes over long time scales (Butz et al, 2015, 2017). We are currently focusing on a small eutrophic lake on the Swiss Plateau, Lake Moossee with biogenic varves. We use hyperspectral imaging proxies, quantitative Chl a and chlorins for aquatic productivity and quantitative Bphe a for meromixis (Butz et al, 2016). Bphe a is a diagenetic product of Bacteriochlorophyll a, produced by anoxygenic phototrophic bacteria. Pigment compositions are inferred from sets of spectral indices, such as the Relative Absorption Band Depths (RABD). Indices are calibrated with absolute pigment concentrations of selected samples, measured by HPLC. Lake Moossee contains a complete paleoproductivity and meromixis record at annual resolution (varve years) for the Holocene and Late-Glacial times (past 15,500 years). Hyperspectral data provide evidence for repeated meromixis events in the mid-Holocene. Pollen data suggest that changes in meromixis were related to Neolithic and Early Bronze Age land use (deforestation and reforestation after land abandonment) thus presenting evidence for early anthropogenic disturbance and land-lake coupling.

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## **S01-P06\* - A novel 4D-view on sediments: insights to sedimentation processes and post-sedimentary mineral formation**

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Until recently, analyses of lake sediments were either limited to a 2D study of the sediment core surface, or volumetric analysis, for which the sedimentological structure needed to be destroyed. To overcome these limitations, we combined high-resolution 3D-microCT-scanning ( $\mu\text{m}$ -scale) of fresh lake sediment with XRF-scanning, micro-XRF mapping, and traditional thin section analysis. MicroCT-scanning facilitates the observation of sedimentary structures at the mm-scale in 3D prior to analysis, while high-resolution mapping in 2D aids characterisation of the observed structures once the fragile sample is conserved in resin.

We present a study of sediments from Lake Towuti ( $2.75^{\circ}\text{S}$ ,  $121.5^{\circ}\text{E}$ ), one of the oldest and deepest lakes in Indonesia. Cores of the entire sediment infill have been recovered in the ICDP Towuti Drilling Project in 2015, including lacustrine sediments covering several glacial-interglacial cycles. In the cores, high density contrasts between the clay-rich sediment matrix and postdepositional alteration products such as siderite ( $\text{FeCO}_3$ ) and Millerite ( $\text{NiS}$ ) provide an ideal setting for microCT analysis on characteristic sediment core sections. Geochemical information from the embedded sections is provided by high-resolution XRF-scanning and micro-XRF mapping of the samples.

MicroCT scans reveal  $\mu\text{m}$ -thick vertical voids filled with high density mineral precipitates related to post-depositional fluid circulation, as well as coatings of high-density material (mainly siderite), around low-density centres. We observe beds of siderite, which appear continuous in 2D, but prove to be separated structures in 3D space. A crack showing vertical displacement in the sediment is, in 3D space, visualised as a plane, which points towards a rupture, perhaps seismically induced, that promoted precipitation of siderite on the newly-formed surface. The combination of high-resolution imaging with XRF element scans allows a novel, very detailed 4D-view of sedimentary structures that identifies processes involved in authigenic mineral formation and their relation to palaeoenvironmental changes in the lake and its catchment.

## **S01-P07\* - Using glycerol dialkyl glycerol tetraethers (GDGTs) to reconstruct Holocene climate and deglaciation from Antarctic lake sediments**

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Temperature calibration models based on the relative abundances of sedimentary temperature sensitive glycerol dialkyl glycerol tetraether (GDGT) membrane lipids of Archaea/Bacteria have enabled past temperature reconstructions in both marine and terrestrial environments. Nevertheless, to date these methods have not been widely applied in high latitude terrestrial environments due to poor performance of global GDGT-temperature calibrations at lower temperatures.

To address this we examined environmental controls on GDGT composition in 38 lakes from Antarctica, the sub-Antarctic Islands and Southern Chile. The composition of brGDGTs is strongly correlated with mean summer air temperature (MSAT). This enabled the development of a regional brGDGT-temperature calibration for use in Antarctic and sub-Antarctic lakes.

Here we present the first quantitative reconstructions of past temperature change from Antarctic and sub-Antarctic lake sediments using GDGTs, and examine Holocene palaeoclimate change and the deglaciation of ice-free areas on the Antarctic Peninsula and South Georgia. Reconstructed summer temperatures from strategically-located palaeolimnological records reveal that deglaciation near to present limits was likely completed by or during a late Holocene temperature maxima, centred on c. 4–3 ka, with a significant cooling trend into, and minor glacial readvances during, the C16–19<sup>th</sup> Southern Hemisphere Little Ice Age. Holocene temperature shifts and regional lags suggest variations in the strength of Westerly winds and Southern Hemisphere insolation.

# **S01-P08\* - Fingerprinting rhyolitic tephra layers in New Zealand with micro-XRF core scanning: Towards a faster and non-destructive method for tephrochronology**

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Late Quaternary paleoenvironmental and volcanic hazard studies, especially in volcanically-active Northern New Zealand, rely on tephrochronology for reliable age control. The robust application of tephrochronology requires the tephra layers to be reliably identified. However, so-called ‘fingerprinting’ of tephra layers involves time-consuming and destructive analytical steps that make the application of modern micro-XRF core scanners advantageous for this task.

Here we outline and discuss the potential of the Itrax micro-XRF core scanner to differentiate between rhyolitic tephra layers sourced from different northern New Zealand volcanic centres and eruptions. These tephra were deposited and preserved in maar lakes of the Auckland Volcanic Field (Auckland City, New Zealand). In particular, high Si, K, Ca and very low Br and Ti elemental counts characterise all rhyolitic tephra layers. However, different rhyolite tephra layers vary in their relative abundance of other major, minor and trace elements as is apparent from prior electron microprobe and LA-ICP-MS analyses of their glass shards. Even though micro-XRF core scanning cannot detect Na, Mg and detection of light elements (Ca, Al) is of lower quality, we demonstrate that the micro-XRF derived elemental count signal and multivariate statistics can be used to distinguish and differentiate between tephra layers previously identified using traditional destructive approaches. These tephra layers were sourced from different volcanic centres and eruptions. Refinement of our approach requires expansion of the  $\mu$ -XRF dataset to a wider range of rhyolitic tephra layers so as to produce a reference database with standard elemental micro-XRF data for each tephra layer that will serve as a point of comparison for unidentified tephra layers.



# **S01-P09 - Tracking historical changes in cyanobacterial productivity in eutrophic Florida lakes (USA) using Near Infrared Reflectance Spectroscopy (NIRS): A pilot study**

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The large number of nutrient-impaired lakes within the state of Florida USA pose considerable challenges to lake management. Many lakes lack historical information about anthropogenic impacts. Routine monitoring of water quality began in earnest only in the 1980s, decades after many sites first experienced eutrophication. Cyanobacterial blooms are a key management concern, and our paleolimnological research has focused on describing linkages between changes in water quality, cyanobacterial proliferation, and diatom community composition. We are exploring the feasibility of using NIRS to provide data about historical cyanobacterial productivity that can supplement traditional chemical analyses used in paleolimnology. NIRS is rapid, non-destructive, and has the potential to address a wide diversity of paleolimnological and paleoecological questions during single scanning procedures.

Surface sediment samples from ~74 Florida lakes representing a wide-range of chlorophyll a, Total Phosphorus, and Total Nitrogen ranges were used in developing calibration models for cyanobacterial pigments. Freeze-dried sediment samples were sieved and homogenized and NIRS spectral data (400-2500 nm) were obtained using a Metrohm NIRS XDS Rapid Content Analyzer. Sediment pigment concentrations were measured using UV-Vis spectroscopy or High Performance Liquid Chromatography and algal pigment standards were used in pigment identification and quantification. NIRS pigment models developed from the calibration lakes were applied to sediment cores from several eutrophic Florida lakes that had been the subject of previous paleolimnological research. Pigment inferences based on NIRS models were compared with values obtained from other lines of evidence. We present preliminary results of our pilot calibration study, and discuss the potential for using NIRS to track historical cyanobacterial productivity.

## **S01-P10\* - Penguin colony responses to climate change and volcanism**

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Changes in penguin populations on the Antarctic Peninsula (AP) have been linked to several environmental factors, but the potentially devastating impact of volcanic activity has not been considered. Genetic, biogeochemical and modern count studies all suggest gentoo populations increase during ‘warmer’ periods. Using detailed biogeochemical analysis, we tracked penguin colony change over c. 8,500 years on Ardley Island, currently home to one of the AP’s largest populations of gentoo penguins. By comparing our data with sub-fossil evidence of penguin occupation and records of past climate, sea-ice extent and volcanic activity from across the AP, we found that the first sustained penguin colony was established on Ardley Island c. 6,700 years ago. The colony experienced five population peaks during the Holocene, reaching its maximum, c. 4,000–3,000 years ago during a phase of regional warming, but there are no consistent relationships with local-regional atmospheric and ocean temperatures or sea-ice conditions. Instead, three of the five phases of colony expansion were ended abruptly by the deposition of volcanic ash from large eruptions of the nearby Deception Island. Sustained post-eruption colony recovery took, on average, 400–800 years, and was slowest following the most disruptive event, c. 5,500–5,000 years ago. We are undertaking biomarker and DNA analysis of lake sediments and sub-fossils from the AP to better understand drivers of long-term penguin population change.

# **S01-P11\* - Tracking the source of heavy metal pollution in Lake X (Switzerland): A combination of mercury isotopes, XRF core scanning and ICP-OES**

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The release of heavy metals into the aquatic environment has drastically increased over the last century, posing health risks for all biota. Heavy metals of anthropogenic origin can be found in waters, soils and even the atmosphere, where they often precipitate with rain and are deposited in sedimentary basins, such as lakes. Industrial activities on the shore of Lake X (Switzerland) caused widespread heavy metal pollution at a site adjacent to the shore, which was previously investigated by a governmental agency. Due to the lack of high-resolution sediment profiles and sediment dating, the source of the contaminations was unclear. This study seeks to find the age and source of the contaminations by using high resolution XRF core scans, ICP-OES and Hg-AFS for quantitative measurements of heavy metals and MC-ICP-MS for the isotope analysis of mercury. Radiometric dating ( $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$  and Pu dating) for two cores and varve chronology for one core suggest that the contaminations stem from around 1960 (Zn, Cd) and 1880 (Cr, Cu, Hg, Pb, Sn). The XRF data suggest two different sources of contamination: One by landfill of contaminated soil and another one by industrial wastewater effluents. Maximum concentrations found within all samples are in the range of percent (m/m dry weight) for Cr, Cu, Hg, Pb, Sn and Zn and lie within the topmost 10 cm of the sediment cores. The analysis of mercury isotopic ratios ( $\delta^{202}\text{Hg}$  and  $\delta^{199}\text{Hg}$ ) shows a significantly different ratio for one of the cores, which indicates a second source of mercury. Due to the wide range of mercury isotopic ratios encountered in earlier studies, no conclusions can be drawn regarding the exact source or process leading to the isotopic fractionation found in the mercury of the landfill.



# Ancient DNA in lake sediments

*Mikkel Winther Pedersen, Barbara Wohlfarth, Laura Parducci, and Inger Alsos*

## Session 03

## Oral Presentations

### **S03-001 - How does climate-driven weather variability impact a lake ecosystem? Tracking changes in microbial communities in a 40-year varved record from an ice-covered boreal lake using sedimentary DNA**

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Climate change is a key driver of changes in lakes, especially in northern ecosystems. The structure, composition and metabolism of aquatic communities may be highly sensitive to climate-driven weather variability with possible negative effects on lake functioning and ecosystem services. Ice-covered lakes are particularly interesting because of the substantial modifications in snow/ice phenology related to climate-driven processes exposing lake biological communities to several forcing factors including modifications in terrestrial inputs of organic/mineral matter into lakes.

In this study we coupled long-term monitoring data (e.g. temperature, spring snow loss, and lake ice-off timing) with paleo-proxies from an annually laminated sediment record assessed by cutting-edge methods in paleolimnology (pyrolysis GC-MS, high-throughput sequencing of sedimentary DNA). Together with data on sediment composition (geochemistry, varve properties), we investigated the consequences of annual weather variability on terrestrial inputs to the lake and the subsequent responses of aquatic biological communities (here phytoplankton and heterotrophic protists).

Our data indicate temporal relationships between temperature and snow/ice phenology, with lower temperatures leading to higher spring snow loss. Then, temporal changes in spring snow loss were related to modifications in terrestrial inputs to the lake, with higher spring snow loss inducing higher terrestrial inputs. Biological communities appeared to be highly correlated to modifications in spring snow loss and terrestrial inputs more particularly during two periods (late-80s/early-90s and mid-2000s) marked by changes in richness and structure of the protistan community and cyanobacteria's relative abundance. Phototroph groups (i.e. Chlorophytes, Dinophyceae, Cyanobacteria) appeared to be particularly impacted by climate-driven environmental changes.

The outcome of this study are in line with the hypothesis that climate-driven modifications of terrestrial inputs into lakes may be a major forcing factor for biological communities from ice-covered lakes.



## **S03-O02 - Arctic shrub colonization lagged postglacial climatic optimum: Molecular evidence in lake sediment from Baffin Island, Arctic Canada**

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The shrubification of a warming Arctic is altering ecosystems and impacting global climate through multiple feedback mechanisms. The rates and mechanisms involved in northward shrub encroachment, however, remain poorly understood. Paleo records from past warm periods can provide useful insight into the ecological response to climate change. Here, we present a Holocene paleoenvironmental reconstruction from southern Baffin Island based on a multi-proxy lake sediment record that sheds light on the postglacial colonization of dwarf birch (*Betula*). We combine a sedimentary ancient DNA (sedaDNA) record of vegetation with paleotemperature estimates based on the distribution of bacterial cell membrane lipids, branched glycerol dialkyl glycerol tetraethers (brGDGTs), to place ecological change within a climatic context over the last 7.4 ka. The sedaDNA results unambiguously indicate that *Betula* colonized the lake catchment at ~6 ka, in contrast to nearby pollen records in which *Betula* pollen appears significantly earlier. Paleotemperatures are highest in the earliest part of the record, with significant cooling prior to 6 ka. Together, these molecular proxies highlight that a thermophilous woody shrub colonized this Arctic island after peak warmth of the early Holocene, suggesting that dispersal vectors may have been more of a limitation than climate in this case.

## **S03-O03 - Ancient DNA of aquatic plants from lake sediment cores as a paleolimnological proxy**

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High latitudes are currently experiencing profound changes in both terrestrial and aquatic environments and have done so in the past, and ancient DNA from lake sediment cores presents a highly efficient tool to reconstruct such changes. Analyses of plant sedimentary DNA, in particular, has become an established tool, revealing a highly local signal of terrestrial vegetation changes. At the same time, the vascular plant DNA from lake sediments also record aquatic taxa, which potentially offer valuable information, but the use of this DNA as paleolimnological proxy has, until now, not received much attention. In contrast to terrestrial vegetation, which is traditionally studied using pollen, the record of aquatic macrophytes, as well as of shoreline vegetation, is often poor in microscopic investigations. We have explored the signals of aquatic plants in a number of vascular plant DNA datasets from lake sediment cores as well as from a transect of modern surface sediments. Our focus is on areas of Northern Siberia that have undergone severe changes in terrestrial vegetation, in particular related to past fluctuations of the arctic-boreal treeline. In the surface sediment transect, the DNA of aquatic plants faithfully records modern conditions within the lakes, such as water depth and temperature. In the cores it reveals distinct historical successions that capture both the development of the lakes and ecological conditions. Plant DNA in lake sediments thus not only presents a powerful proxy for terrestrial vegetation history, but can provide inferences on environmental conditions that are independent of the terrestrial vegetation development.

## **S03-004 - Vegetation and land use trajectories around the perialpine Lake Aiguebelette (Northern French Alps)**

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During the last decade, an increasing number of studies have used lake sediment DNA targeting plants to trace past landscape changes and agricultural activities. This technique is often used in combination with pollen and/or plant macroremains analyses, especially to assess the differences and complementarity of the different approaches. Here, we propose to cross this emerging and promising tool with pollen and coprophilous fungi analyses in order to obtain a more detailed reconstruction of past vegetation dynamic and land use history in the large watershed of Lake Aiguebelette (373 m a.s.l., 5.45 km<sup>2</sup> area, 70 km<sup>2</sup> catchment area, 70 m max depth). This watershed has a long history of human occupation with the presence, in particular, of lakeside settlements since the Neolithic (UNESCO World Heritage Sites).

The sediment core analysed and presented in this paper covers the last 2000 years. The high-resolution reconstruction suggests a decline of agricultural activities at the end of the Roman Empire. From 500 AD, the different analyses evidence the development of the cultivation of diverse fruit trees (such as the vines, chestnuts, walnuts, plums or cherries) and of pastoral activities. Then between 800 and 1000 AD, a transition phase with the reorganisation of activities is recorded. From 1000 to 1850 AD agricultural activities intensify. Peasants developed the crops of fruit trees, hemp, hop, buckwheat, beans and peas as well as pastoral activities. The last century is characterised by the decline of most of agricultural activities but the development of vegetable gardens, similar to the ones that we can see today, with for instance celery, green beans, beetroots or cardoons. The main added value of DNA analyses concerns the reconstruction of agricultural activities. Indeed, this technique provides more cultivated taxa and thus a more detailed picture of activities.



## **S03-O05 - Investigating the response of sedimentary diatom community composition to agricultural land-use change using morphology, metabarcoding and pigments**

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Long-term agricultural inputs of nutrients and sediment can drive significant change in lake ecosystem state, most often manifest as eutrophication. In New Zealand 37% of monitored lakes have eutrophic to supereutrophic productivity status largely due to intensive agricultural land-use. While environmental information is available for some lakes, long-term monitoring data are generally lacking, limiting knowledge on lake natural state and evidence for the causes of decline. Sedimentary diatom community composition is a commonly used proxy for reconstructing paleolimnological environments. Whilst this technique is well-established and effective, it is time consuming restricting the temporal and spatial resolution and scope of paleo-reconstructions. New DNA barcoding methods show potential for more efficient reconstruction of paleo-communities. However, development of these methods for diatoms remains limited, and there are few examples where they have been aligned with traditional identification techniques. We compared the use of DNA metabarcoding with microscopic identification and analysis of diatom-specific pigment diatoxanthin, for reconstructing sediment diatom community profiles. DNA was extracted from two New Zealand lake sediment cores dating back 1,000 years. Both lakes have histories of agricultural impact, and are currently classified as eutrophic and supereutrophic. The DNA was analysed using metabarcoding of the V4 (diatom) and V9 (general eukaryote) regions of the 18S rRNA gene. By overcoming some of the intrinsic limitations of traditional paleolimnological techniques, molecular methods have potential to complement traditional paleo-reconstructions, and may provide novel insights into how lake ecosystems respond to long-term agricultural impacts.

## **S03-O06 - Beneath the lake sediment: why is there plant DNA in the underlying glacial debris?**

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Beneath Holocene lake sediments in northern Fennoscandia you often find plant DNA fragments in the underlying glacial material. Can this aDNA be used to reconstruct pre-deglaciation environments or are these fragments the result of post-depositional processes? In this presentation, I will argue for the most likely origin of plant aDNA in glacial deposits underlying Holocene sediments in northern Sweden. Our findings suggesting that aDNA records of glacial debris can identify vegetation communities growing under the MIS-3 interstadial (approximately 45 cal. kyr BP) as well as younger plant community that seems to have established prior to deglaciation of the region. We base our interpretations upon findings from terrigenous sediments largely resemble 'plant-trash' deposits in North America, known to form as vegetation established on stagnant ice became buried along with glacial debris during the deglaciation. Here, macrofossil findings in combination with aDNA analyses seems to suggest that exposure of englacial material during the Bølling-Allerød interstadial created patches of supraglacial debris capable of supporting vascular plants about three millennia before deglaciation. The composition and life-length of this early plant community remain uncertain. Yet the younger group of macrofossils, in combination with pollen analyses of inclusions, suggest that shrubs (*Salix* sp., *Betula* sp. and *Ericaceae* sp.) and even tree species (*Larix*) was present in the debris during the final deglaciation stage.

## **S03-007 - Exploring the DNA in a Sedimentary Sequences from Chalco Lake, México**

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The basin of Mexico (BM) is located in the central part of the Trans-Mexican Volcanic Belt. The Chalco sub-basin is located in the southern portion of the basin at 2,200 m a.s.l. Through the extensive study of several proxies in the sedimentary records from Lake Chalco, the historical reconstruction of its last 150,000 yr BP is known. To introduce a novel approach to complement and support this findings, the study of DNA was considered. In the present study, we aim to describe the biodiversity in large-scale data during the Holocene by exploring the use of the DNA metagenomics method in a sedimentary sequence from this lake. Results obtained show DNA from 12 samples dating up to 12,000 years B.P. Sequencing of these samples generated 1,421,823,631 total reads. The taxonomic annotation was compared to the LSU database and the abundance results suggested 81% of Bacteria, 15% of Archaea, 3% of Eukaryota and 1% of unclassified sequences. We observed differences in diversity between the superficial (up to 5,000 yrs B.P) and the rest of the samples. In the case of the functional metagenomics annotation, we used the subsystem database. In addition, we observed that the superficial samples were separated from the rest of the samples. With this information, we can conclude that the superficial samples have different composition of taxa and genes biodiversity when compared with the deeper samples. We could identify a transition sample corresponding to 5,700 yrs B.P., that was isolated from the rest of the sample groups. We can conclude, DNA sediments evaluated through metagenomic approaches can help to better understand highly biodiverse environments, such as those of the Neotropics. To the best of our knowledge, our study is the first to evaluate biodiversity from the sediments of Lake Chalco, thus resulting in a considerable contribution to the area.

## **S03-O08 - Past methane dynamics in Arctic lakes under climate change retrieved through genetic profiles of ancient microbes**

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Arctic landmasses and lakes release significant amounts of methane (CH<sub>4</sub>), a greenhouse gas with an atmospheric warming potential 25 times higher than CO<sub>2</sub> that contributes heavily to global climate change. Yet the effect of rapid warming in the Arctic on the fate of natural CH<sub>4</sub> emissions from lakes is poorly understood. We use a metagenomic approach on ancient environmental DNA to determine the impact of long-term climate change on microbial CH<sub>4</sub> cycling in Arctic lakes.

We present preliminary results from the Godthaabsfjord region, Southwest Greenland. We used a shotgun sequencing approach to acquire the microbial community profiles. This method yielded information on the diversity and function of both CH<sub>4</sub> producers (Archaea) and consumers (Bacteria), as well as other groups of microbes and higher organisms that may also be involved in lake CH<sub>4</sub> dynamics.

This baseline study will be expanded to a Holocene sediment collection from Greenland and Svalbard (14 lakes) encompassing major environmental gradients and lake ontogenies. To test the influence of long-term climate change on CH<sub>4</sub>-related microbial dynamics, our paleogenomic approach will be supported by targeted analysis of other long-term biological and biogeochemical changes affecting the elemental carbon reservoirs in the watershed and its aquatic network. For the first time, ancient microbial metagenomics will be applied on multiple sites across the Arctic and over extended timescales to determine the effects of long-term climate change on this important yet understudied greenhouse-related biogeochemical process.

## **S03-O09 - Using sedaDNA alongside palaeoenvironmental proxies for understanding wetland and lakeside archaeological sites**

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Wetland sites, including settlements on lake shores and artificial islands, often provide a wealth of well-preserved archaeological material, but are generally difficult and expensive to excavate conventionally. An alternative, or complimentary approach, can be the retrieval archaeological data from lake sediments, which can under certain conditions contain a continuous record of the archaeological site, the lake and its surrounding catchment.

Here we present early data from a study of three crannogs (artificial island settlement) and an Iron Age lakeshore village in Scotland where sedaDNA data was analysed from proximal sediment cores. The sedaDNA provides detailed information about the plants and mammals that lived, died, or were kept on the sites in different periods of site use. This information is compared with a range of traditional palaeolimnological proxies that allow us to differentiate between (i) changes that happened regionally in the lake catchment (based on pollen, x-ray fluorescence scanning, stable carbon and nitrogen isotopes, n-alkanes), (ii) changes that happened in the lake ecosystem (based on loss-on-ignition, diatoms, biogenic silica, invertebrates, C:N ratios), and (iii) changes that occurred very locally at the sites (based on pollen and spores, invertebrates, sterols, PAHs, and sedaDNA).

Our sedaDNA results complement data from both archaeological excavation and traditional palaeoenvironmental proxies to provide a more detailed and robust image of the environment in which our ancestors were operating. We also show that different proxies in the same sediment core provide insights in past environments at different spatial scales.

## **S03-O10 - Reconstructing the first plant and animal colonizers within North America's ice-free corridor using ancient environmental DNA**

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During the Last Glacial Maximum, continental ice sheets isolated Beringia (northeast Siberia and northwest North America) from unglaciated North America. By around 15 to 14 thousand calibrated radiocarbon years before present (cal. kyr bp), glacial retreat opened up an approximately 1,500-km long corridor between the ice sheets. However, it remained unclear when plants and animals colonized this corridor and when it became biologically viable for human migration. We used a combination of radiocarbon dates, pollen, macro fossils and shotgun sequencing of ancient environmental DNA from lake sediment cores to reconstruct the timing and succession of plants and animals within the interior of the corridor. We found evidence of steppe vegetation, bison and mammoth by approximately 12.6 cal. kyr bp, followed by open forest, with evidence of moose and elk at about 11.5 cal. kyr bp, and boreal forest approximately 10 cal. kyr bp. Our findings reveal that the first humans in America, whether Clovis or earlier groups in unglaciated North America prior to 12.6 cal. kyr bp, are unlikely to have been able to travel this route into America. However, later groups may have used this north-south passageway.

## Poster Presentations

### **S03-P01 - Crossing pollen and ancient DNA to reconstruct socio-ecological trajectories at lake Gers (Northern French Alps) over the last 4600 years**

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Alpine Ecosystems are the result of a long history of human-environment interactions. Natural archives, such as lake sediments, provide a unique opportunity to reconstruct long-term socio-ecosystem trajectories. Indeed, lake sediments integrate the history of human activities such as agro-pastoral activities.

In the Northern French Alps, several studies have already been carried out on different lakes mostly located in the subalpine belt (e.g. Lake Anterne, 2063 m a.s.l.). In this paper, we will present an environmental reconstruction spanning the last 4600 years, based on the analysis of environmental DNA and pollen from the lake Gers (1540 m a.s.l.) sediment core (5.8 m long). Whereas, this site is located only at 6 km far from Lake Anterne, it provides a different agro-ecosystem trajectory partly due to its location in the Mountainous belt.

The first results reveal a long phase dominated by *Picea*, *Ulmus* and *Alnus* ending with the first significant herbaceous expansion at the Roman Period. This event is concomitant with the first identification of cow herds by DNA. Then, about 1000 AD, the tree covers drastically declined probably due to an intensification and a diversification of pastoralism (*Ovis* sp., *Bos* sp. and *Capra* sp.). The chronology of the pastoral history is almost similar to the one recorded around Lake Anterne, while the livestock composition was roughly different. On both sites, the mammal DNA record shows a specialisation in cow herding in the Northern French Alps from the 13<sup>th</sup> to 15<sup>th</sup> centuries.

Here, we demonstrate the interest of combining these biomarkers in order to reconstruct more precisely plant community changes over the time, both in terms of spatial distribution and taxonomic resolution.

## **S03-P02\* - A Metagenomic exploration of Lake Constance using historical DNA records of Environmental Change**

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Following world war two, lake Konstanz once an oligotrophic lake, was soon exposed to industrial input. This resulted in the eutrophication of the lake between the 1960s–1990s, during which, measures have been taken by the community, resulting in the water quality returning to its past levels. In order to track the effect of this anthropogenic change on the lake's local flora, researchers have since been compiling an encompassing database of the local ecosystem using traditional classification techniques. Hence, the idea of using sedaDNA to track environmental change in terms of micro/macro -invertebrates.

The current project studies the effect of environmental factors on the local lacustrine community's biodiversity using metabarcoding techniques. It is hypothesized that a species succession pattern in relation to time will be visible throughout the different depths of the sediment stratas covering the past century, as have previously been outlined by past studies e.g. Eric Capo's study of lake Bourget in 2016. This can then be correlated to existing database as a method comparison and for future environmental monitoring programmes in the area.

For hypothesis confirmation and method establishment, replicates of DNA extracts from sixty centimetre cores representing 100 years were taken and processed using deep amplicon sequencing of mitochondrial DNA and cytochrome c oxidase 1 (COI) for higher taxonomic resolution. Throughout all downstream processing of the samples, all eDNA conformed measures were followed to ensure the reproducibility of the results and problems overcome.

Preliminary results obtained using generic 18S rRNA gene sequences show that there is a pattern in the community composition along the temporal gradient. This pattern is most noticeable within the planktonic community i.e. ciliophora, rotifera, dinoflagellates and copepod in relation to the reads per sample count. This will additionally be confirmed with COI from the same data set in the hopes for obtaining similar significant pattern.



## **S03-P03\* - Intra-lake diatom variability in the sub arctic Lake Bolshoe Toko, Yakutia, Russia.**

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Complex lake systems are suitable archives to investigate intra-lake variability in terms of physical, chemical and biotic differences. The large sub-arctic Lake Bolshoe Toko (South Eastern Yakutia, Russia) is characterised by a complex catchment system leading to strong intra-lake differences in ice cover thickness, water depth (>70 m) and nutrient input providing diverse habitats for diatoms. Diatom diversity and turnover was investigated by a metabarcoding approach combined with next generation sequencing on sedimentary DNA and microscopic analysis of seventeen surface sediment samples within the Bolshoe Toko. The metabarcoding approach identified 212 diatom sequences types (identified to family level or lower) and microscopy revealed 109 diatom species. We tested the similarity of NMDS analyses of both data sets using procrustes rotation analyses and PROTEST and identified a significant correlation between the two data sets. Further both data sets indicated similar localities within the lake, which show the highest rates of turnover in diatom composition (LCBD value) and a significant correlation of diatom diversity with measured lake water depth. In addition, we conducted a phylogenetic network of lineages of a dominant genus *Staurosira*, which supports that more distantly related lineages occur mostly in the marginal area and partly separated localities within the lake. In conclusion, we exemplified significant similarities of DNA and microscopic data, although total richness, Shannon diversity and taxonomic resolution differ between the two data sets and identifies evolutionary patterns that might relate to habitat allocation in the *Staurosira* genus. Thus, our investigations support that compositional and evolutionary patterns of diatoms help to understand intra-lake variations in a complex lake setting.

The background of the slide is a grayscale scanning electron micrograph (SEM) of various microfossils, likely foraminifera. The fossils exhibit diverse shapes, including circular, cylindrical, and elongated forms, many with intricate perforated or reticulated surface patterns. The lighting creates highlights and shadows that emphasize their three-dimensional structure.

# Whither quantitative palaeolimnology?

*Gavin L. Simpson*

## Session 04

# Oral Presentations

## **S04-S01 - Can human and climatic influences be distinguished in diatom associations in north German lowland lakes since AD 1200?**

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Paleolimnologic multi proxy studies at different lakes in the lowland regions of northern Germany were carried out. In the past, most of the temporal changes in diatom communities were related to changes in settlement activities in lake catchment areas. The projects were focussed on the reconstruction of the total phosphorous, the main driver of lake productivity, based on sedimentary diatoms (DI-TP). Based on a recent temperature reconstruction from the temperate lowland region of Poland (Balanzategui et al. 2017) and motivated by studies from Juggins (2013) and Juggins et al. (2013) we tried to characterize the influence of temperature as an additional variable on diatom associations found in the sediment cores. Using Generalized Additive Mixed Models we identified a significant influence of temperature on the reconstructed DI-TP. But when analyzing the data for each individual lake separately, the influence of temperature on the species composition varied strongly. For a few lakes no temperature effects were detectable and reconstruction of DI-TP was reasonable. But for several lakes a significant relation of the species scores within a multivariate analysis to temperature were found. If the correlations between species scores and temperature on one hand and DI-TP on the other hand were related to different axis in the multivariate space, the DI-TP reconstruction might still be acceptable. But for at least one lake we found a high correlation between species scores and temperature as DI-TP related to the same axis which indicates that the species dependent DI-TP reconstruction is strongly affected by temperature. One important difference between the sediment samples derived from different lakes was how they reflected temperature changes through time. In conclusion it can be stated that the availability of independent proxies, e.g. temperature, can help to scrutinize our traditional way to analyze sediment cores and how we should subsample the cores in the future.

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## **S04-S02 - Quantitative lithostratigraphy of long sediment sequences through end-member modelling of high-resolution XRF core scanning datasets**

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X-ray fluorescence (XRF) core scanning is a fast and non-destructive method to determine the geochemical composition of sediments. These advantages have facilitated the generation of high-resolution (sub-cm) geochemical records of long sediment sequences (>100 m), creating large data sets, which require new statistical tools to identify and visualise different processes interacting through time. We combine high-resolution XRF core scanning, a thorough empirical calibration of the XRF measurements, and statistical end-member analysis to get an objective and quantitative description of the lithologies in our long sediment sequences.

We present a study of sediments from Lake Towuti (2.75°S, 121.5°E), one of the oldest and deepest lakes in Indonesia. Cores of the entire sediment infill have been recovered in the ICDP Towuti Drilling Project in 2015, including lacustrine sediments covering several glacial-interglacial cycles. We obtained XRF core scans of the Lake Towuti lacustrine sediments (~100 m) at 0.5 cm resolution. After correcting for systematic biases and matrix effects in the record, we find high correlations between corrected XRF measurements of the wet core surface and discrete volumetric ICP-MS measurements. Based on these correlations, we converted XRF counts to quantitative element abundances (wt-%).

On this quantitative geochemical dataset we performed an end-member analysis, which allows unmixing the data into characteristic clusters of - in this case - similar elemental composition. The analysis reveals seven distinct end-members, which are interpreted to represent climatic, diagenetic, and tectonic influences. For each XRF measurement point, the calculated end-members provide information about the relative importance of the different processes for the formation of the respective sediment. Amongst others, this enables to generate a high-resolution stratigraphic column of the sediment sequence based on the end-member scores. End-member analysis thus allows a detailed and objective description of sediment sequences and their respective sedimentological units beyond more subjective visual description.

## **S04-S03 - A training set for diatom – phosphorous quantitative reconstructions for montane to alpine lakes of the northern Alps**

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The background for the presented study is a major project running at the Limnological Research Station of the Technical University Munich, which investigates the impacts of climate change on mountain lakes in the northern Alps. Prognosis models predict rising temperatures and stronger rainfall due to global warming. We hypothesize that this fact leads to further rise of the tree line and to an intensifying of weathering and will result in an increase of the load of organic matter into the lakes. To test this we developed a training set for establishing a diatom – phosphorous transfer function, which will be presented here.

There has been increasing debate concerning the reliability and applicability of quantitative methods in paleolimnology. It has been shown that the fundamental assumptions for the application of transfer functions are rarely met. Yet there exists a row of successful examples of quantitative reconstructions, especially concerning lake pH value and phosphorous content. These issues will be discussed by means of the presented training set.

Our lake data set comprises 45 lakes situated between 700 and 2500 m a.s.l.. These lakes can be grouped (1) into shallow and deep lakes and (2) into waters with and without macrophyte cover. The lakes represent a phosphorous gradient from oligotrophic to mesotrophic conditions. All studied lakes are situated -at least partly- on calcareous bedrock. Therefore, they are well buffered and show stable pH values between 8 and 9.5. Additionally to diatom and hydrochemical analysis, summer water temperatures were measured and lake morphometry was surveyed.

The study was funded by the German Federal Environmental Foundation.

## **S04-S04 - Estimating rates and magnitudes of temporal change in stratigraphic records using generalized additive models**

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Despite palaeolimnology having developed into a quantitative subject in some respects, the basic description of temporal trends in community composition or geochemical proxies often remains descriptive, limited to zonation or summary via ordination axes. Formal estimation and testing of trends via statistical methods is rarely practised, and on those occasions that it is, inference generally follows inappropriate methods that fail to account for the temporal dependence between samples.

In large part, this lack of formal statistical trend analysis has developed because classical time series models assume that samples are evenly spaced in time; most stratigraphic data sets within palaeolimnology do not meet this most basic of assumptions. Consequently, many researchers do not attempt to formally estimate trends, or naively use linear correlation or regression analysis, despite the often gross violations of assumptions of those techniques. Whilst modern statistical developments have led to formal time series models that handle irregular data, these are often inappropriate for many stratigraphic records owing to their short length or the complex statistical or computational background required to make good use of them.

Generalized additive models (GAMs) on the other hand are relatively easy to apply to stratigraphic data. GAMs are formal regression models, that estimate trends in data as smooth functions, which are learned from the data. Modern developments in GAM theory allow for automatic selection of the smooth functions, yet, in practical terms, fitting a GAM requires little additional knowledge beyond that of linear regression. GAMs provide a formal statistical framework for trend estimation and hypothesis testing for stratigraphic data.

Here I present a summary of GAMs, illustrating their use for trend estimation whilst accounting for temporal autocorrelation, and discussing recent developments that extend their applicability to pressing ecological questions pertaining to resilience and how it has changed over palaeo timescales.



## **S04-S05 - Challenges for sub-decadal resolution palaeoenvironmental reconstructions from microfossil assemblages**

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Palaeoecologists are understandably attracted to high-resolution archives, and despite the amount of labour involved, several sub-decadal – or even annual – resolution microfossil stratigraphies have been generated. Reconstructions of palaeoenvironmental conditions derived from these stratigraphies using transfer functions apparently compare well to instrumental data.

High-resolution reconstructions face challenges from several ecological, taphonomic, and chronological factors that are small or negligible for lower-resolution reconstructions. The extent of these problems varies with microfossil group and the properties of the environmental variable being reconstructed.

For example, long-lived organisms are likely to be less sensitive to the climate of a particular month than short lived organisms; taphonomic problems will be smallest for planktic organisms and greatest for benthic organisms that live in shallow water; and reconstructions of environmental variables with pronounced high-frequency variability will suffer more from chronological errors.

The excellent performance of some sub-decadal resolution reconstructions despite the severe challenges they face is surprising. The reproducibility of these papers needs to be verified.

Several research fields have recently been shown to have lower reproducibility than desirable, but little work has been done to ascertain the reproducibility of palaeoecological papers. I will conclude by suggesting how palaeoecology can be made a more reproducible science.



## Poster Presentations

### **S04-P01\* - Ordination analysis on geochemical data from Lake Stymphalia reveals Late Antique Little Ice Age in Southern Greece**

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Although not widely applied, multivariate data analysis can be a useful statistical tool in paleoclimatology. Here, we present a Principal Component Analysis (PCA) on a geochemical dataset from Lake Stymphalia, the last remaining natural lake of the Peloponnese, Southern Greece.

To obtain a semi-quantitative geochemical dataset, lacustrine sediment cores were scanned with an Avaatech X-ray fluorescence (XRF) core scanner and combined with Bayesian age-depth-modeling of  $^{14}\text{C}$  dates to obtain subdecadal paleoclimate information. Relative changes in chemical composition can be traced back to changes in paleoenvironmental conditions. As paleoenvironmental reconstructions with high temporal resolution are still relatively sparse for Southern Greece, our dataset represents a valuable record for the region.

By applying PCA to the geochemical dataset, we aimed for obtaining a condensed dataset containing only the most important information indicating changes in the hydrological dynamics. The first Principal Component (PC1) nicely depicts temperature fluctuations, showing the intensively studied Little Ice Age as well as the Medieval Warm Period. Furthermore, we determine a cold anomaly for the period 550–760 AD at Lake Stymphalia. Recently, Büntgen et al. (2016) used the term Late Antique Little Ice Age (LALIA) to describe this climatically cold interval in the 6<sup>th</sup>–7<sup>th</sup> century AD for the Alps and the Altai mountains. This period is previously unknown or undescribed for Southern Greece. Additionally, PC1 is in almost ideal accordance with the Rb/Sr ratio, a proxy usually describing chemical weathering intensity. We show on one hand that PCA is a useful approach to answer relevant paleoclimatological research questions and on the other hand PCA validates the results obtained via a more common approach based on elemental ratios. This study is the starting point for a more detailed environmental reconstruction including several (paleo) lakes on the Northern Peloponnese (cf. contribution by Unkel et al. (2018) in Session 08).

## **S04-P02\* - Paleolimnological records reveal biotic homogenization driven by eutrophication in tropical reservoirs**

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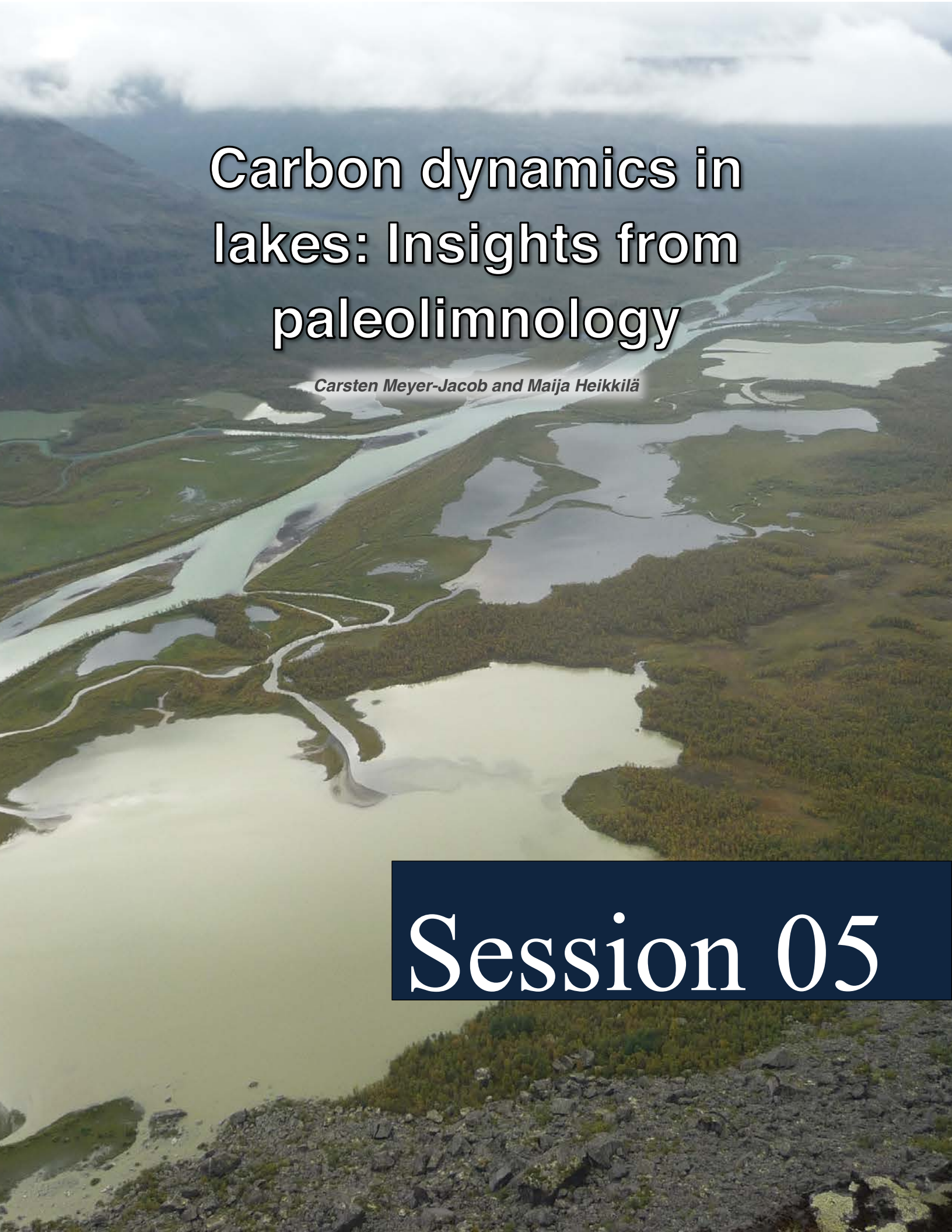
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Biodiversity changes in response to eutrophication, climate variability and species invasions. These pressures have been shown to reduce community heterogeneity at various scales; however, how productivity drives homogenization patterns in a community of primary producers, such as diatoms, has not been studied. Using a dataset with good temporal resolution, obtained from cores collected from seven tropical reservoirs, we evaluated patterns of spatial and temporal homogenization, i.e. the trends in temporal alpha-diversity and spatial beta-diversity (change in community composition), of diatom assemblages over the past 60–100 years. The paleolimnological records allowed us to study biodiversity trends since the initial community (reservoir construction) in those systems with low anthropogenic impact and also those undergoing eutrophication. No clear trend of spatial beta-diversity change over time was found when all reservoirs were analyzed together. However, when only eutrophic reservoirs were considered, a marked decrease in the spatial beta-diversity occurred, suggesting that eutrophication leads to homogenization of the diatom assemblage. These findings were reinforced by the lack of change in beta-diversity when the age of the reservoirs was standardized, indicating that the reservoirs' ontogeny did not influence the spatial beta-diversity trend and beta-diversity did not increase even in the reservoirs with low anthropogenic impact. In addition, the results showed a decrease of  $\alpha$ -diversity over time for almost all the eutrophic reservoirs, as well as a decrease in the total species pool for the reservoirs, although periphytic diatoms may be favored by the appearance and sometimes mass development of floating macrophytes in warm, shallow eutrophic reservoirs. This study supports the role of eutrophication as one of the main drivers of diatom assemblage homogenization in tropical reservoirs, with a significant loss of species over time.



# Carbon dynamics in lakes: Insights from paleolimnology

*Carsten Meyer-Jacob and Maija Heikkilä*

Session 05

## **S05-001 - The impact of Roman land-use on Lake Murten (Switzerland) and its catchment – New insights from leaf wax radiocarbon dating**

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Deforestation and field cultivation have followed the rise and fall of civilizations for thousands of years, impacting the environment to a great extent. Although agriculturally induced soil erosion has a great influence on the global carbon cycle, large uncertainties remain concerning its historical evolution and its extent and rate. This study seeks to address this issue by investigating the sedimentary record of Lake Murten (Switzerland), which witnessed several phases of intensive human land-use over the past 3000 years.

Sediment mass accumulation rates, magnetic susceptibility and detrital element distribution (XRF Ti) reveal that soil erosion increased drastically towards the end of the Iron Age and the rise of the Roman City of Aventicum (0 CE). Substantial deforestation and intensified agriculture is marked with decreasing tree pollen percentages and an increase in charcoal flux, *Cerealia*, *Plantago lanceolata* and Poaceae pollen. Leaf wax n-alkane distribution also reveals a rough vegetation change from a tree to a more grass dominated landscape. At the same time radiocarbon ages of bulk sediment and plant derived C<sub>27</sub>, C<sub>29</sub>, C<sub>31</sub>, C<sub>33</sub>, C<sub>35</sub> alkanes increasingly deviate from the modeled deposition age, indicating rapid flushing of old soil OC from the surrounding catchment driven by intensive land-use. Enhanced nutrient delivery resulted in cultural eutrophication, as shown by the deposition of varved sediments. Human activity decreased after the end of the Roman period, resulting in land abandonment and renaturation. Soil erosion indicators suggest that steady state conditions in the surrounding landscape were not attained for 200 years after anthropogenic perturbation. These findings suggest that ecosystem recovery might take several centuries following release from human perturbation.

## S05-002 - $\delta^{13}\text{C}$ values of planktivorous invertebrate remains in small European lakes: Exploring the potential for quantitative methane reconstructions

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We present a dataset that assesses the relationship between  $\delta^{13}\text{C}$  values of fossilizing resting stages of planktivorous filter feeders (planktonic cladocerans, bryozoans) in surface sediments and late summer methane concentrations in small European lakes. The aim is to explore whether  $\delta^{13}\text{C}$  measurements on these resting stages (ephippia, statoblasts) can be used to constrain past methane concentrations in lakes. It has been shown that at least some of these organisms, particularly planktonic cladocerans, can feed on carbon originating from methane oxidizing bacteria. Since biogenic methane is characterized by exceptionally negative  $\delta^{13}\text{C}$  values,  $\delta^{13}\text{C}$  values of these invertebrates may also become distinctly negative in lakes where methane forms a relevant carbon source for planktonic foodwebs. We show that  $\delta^{13}\text{C}$  values of the resting stages of some cladoceran groups (e.g. *Daphnia*, *Ceriodaphnia*) are strongly and negatively related with in-lake methane concentrations.  $\delta^{13}\text{C}$  values as low as -44 to -52‰ are observed for some sites, well below the values typically reported for plant biomass in lake ecosystems (ca. -25 to -36‰), indicating substantial contributions of methane-derived carbon. In contrast  $\delta^{13}\text{C}$  values of other groups, such as the bryozoan *Plumatella*, appear much less influenced by the uptake of methane-derived carbon. Our results suggest that strongly negative  $\delta^{13}\text{C}$  values of *Daphnia* or *Ceriodaphnia* below ca. -38‰ can be considered indicative for lakes with high methane concentrations in the open water column. Furthermore, they indicate that such systems are characterized by large offsets between  $\delta^{13}\text{C}$  values of remains of methane-sensitive (e.g. *Daphnia*, *Ceriodaphnia*) and methane-insensitive invertebrate groups (e.g. *Plumatella*). We show for some of these groups that regression models (e.g. log-linear regression, logit regression) can successfully capture the relationship between  $\delta^{13}\text{C}$  values of their remains and in-lake methane availability.

## **S05-O03 - Carbon accumulation and fluxes in a north boreal lake chain: Catchment influence on carbon source and processing**

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Northern lakes play an important role in the global carbon (C) cycle by sequestering C in sediments and emitting carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) to the atmosphere. To advance understanding on the sources and quality of aquatic C and its processing, we are studying past and present C dynamics in a catchment located in the boreal-subarctic ecotone in Finland where climatic and vegetation transitions have occurred over the Holocene. The four study lakes have had similar climatic forcing, but different positions along the catchment, and thus different surface and groundwater inputs, and catchment land cover. The sediment cores spanning the past ~9 000 years were analyzed for C and nitrogen (N) elemental and isotopic ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) compositions. High-resolution sediment chronologies were based on radiocarbon (<sup>14</sup>C) and lead (<sup>210</sup>Pb) dating. Past variations in lake water total organic carbon and chlorophyll a concentrations were reconstructed using visible-near-infrared spectroscopy. Lake-atmosphere fluxes of CO<sub>2</sub> and CH<sub>4</sub> were measured using floating chambers, and lateral C fluxes were determined on the basis of concentration and discharge measurements for the period May to August, 2017. We will address 1) How the lake's position in the catchment and corresponding variation in water inputs and catchment land cover impact the rate and source of sediment C accumulation and the C fluxes between the lakes and the atmosphere? 2) How the sediment geochemical records correspond with the existing climatic reconstructions for the area and how coherent the lake climatic responses are along the catchment? 3) How the ratio of C efflux to sequestration varies along the lake chain? We expect that the Holocene climatic shifts shape the sedimentary records through shifts in vegetation cover and hydrology, and that the strength of the signal varies between the lakes depending on the magnitude of peatland development in each sub-catchment.



## **S05-O04 - Patterns in Chironomidae functional assemblages and carbon utilization in space and time**

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Sensitive northern lake ecosystems are challenged by the on-going climate change, especially in the forms of altered temperature and precipitation regimes and associated shifts in allochthonous carbon input. These environmental changes may alter biotic carbon processing, cause modifications in functional structures and test ecosystem resilience. To identify responses to such environmental gradients, we investigated chironomid fossil assemblages for their functional composition and carbon utilization in a spatio-temporal setting. Our data set from subarctic Finnish Lapland (ca. 70°N) covered surface sediments from 25 lakes located on a 120 km long transect across the tree line, and a down core series from a small tundra lake covering ca. past 2000 years. We utilized functional feeding group (FFG) classification (indicating means of food acquiring) and stable isotope (SI) signatures of carbon and nitrogen (indicative of nutrition consumed) from fossil chironomids, reflected against sediment geochemical, climatological and limnological data. Bayesian three-source (pelagic, benthic, terrestrial) SI modelling on fossil chironomids was performed to define the relative importance of these nutritional sources. Based on the spatial surface sediment data set, we found that the FFG structure, SI fingerprints and resource utilization were linked with sediment organic matter (OM) quantity and quality, nutrient load and underwater light climate. For key environmental variables (OM quantity, dissolved organic carbon, nutrients), divergent responses were observed between the dominant collector FFGs suggesting different habitat preferences. From the down core record we found non-simultaneous shifts in the FFG assemblage and sediment geochemistry, which indicate differing responses to stressors and may give insight to long term resilience. Major changes in FFG structure were not reflected to the modelled benthic dominated resource utilization, rather the long-term trends followed sediment geochemistry. The results suggest that despite a varying level of discrimination against OM components, extrinsic factors exert a strong control over carbon utilization by Chironomidae.

## **S05-O05 - A landscape perspective of Holocene organic carbon cycling in coastal SW Greenland lake-catchments**

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Arctic organic carbon (OC) stores are substantial and have accumulated over millennia as a function of changes in climate and terrestrial vegetation. Arctic lakes are also important components of the regional C-cycle as they are sites of OC production and CO<sub>2</sub> emissions but also store large amounts of OC in their sediments. This sediment OC pool is a mixture derived from terrestrial and aquatic sources, and sediment cores can therefore provide a long-term record of the changing interactions between lakes and their catchments in terms of nutrient and C transfer. Sediment carbon isotope composition ( $\delta^{13}\text{C}$ ), C/N ratio and organic C accumulation rates (C AR) of <sup>14</sup>C-dated cores covering the last ~10,000 years from six lakes close to Sisimiut (SW Greenland) are used to determine the extent to which OC dynamics reflect climate relative to lake or catchment characteristics. Sediment  $\delta^{13}\text{C}$  and C/N ratios indicate a high proportion of the organic matter is from autochthonous production but with a variable terrestrial component. Temporal trends in  $\delta^{13}\text{C}$  are variable among lakes, with neighbouring lakes showing contrasting profiles, indicative of site-specific OC processing. The response of an individual lake reflects its morphometry (which influences benthic primary production), the catchment:lake ratio, and catchment relief, lakes with steeper catchments sequester more carbon. The multi-site landscape approach used here highlights the complex response of individual lakes to climate and catchment disturbance, but broad generalisations are possible. Regional Neoglacial cooling (from ~5000 cal yr BP) influenced the lateral transfer of terrestrial OC to lakes, with three lakes showing clear increases in OC accumulation rate. The lakes likely switched from being autotrophic (i.e. net ecosystem production > ecosystem respiration) in the early Holocene to being heterotrophic after 5000 cal yr BP as terrestrial OC transfer increased.



## **S05-O06 - Holocene carbon dynamics at the forest - steppe ecotone of southern Siberia**

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The forest - steppe ecotone in southern Siberia is highly sensitive to climate change; global warming is expected to push the ecotone northwards, at the same time resulting in degradation of the underlying permafrost. To gain a deeper understanding of long-term forest - steppe carbon dynamics, we use a highly-resolved, multiproxy, palaeolimnological approach, based on sediment records from Lake Baikal. We reconstruct proxies that are relevant to understanding carbon dynamics including carbon mass accumulation rates (CMAR;  $\text{g C m}^{-2} \text{ yr}^{-1}$ ) and isotope composition of organic matter ( $\delta^{13}\text{CTOC}$ ). Forest - steppe dynamics were reconstructed using pollen, and diatom records provided measures of primary production from near- and off-shore communities. We used a Generalized Additive Model (GAM) to identify significant change points in temporal series, and by applying generalised linear least-squares regression modelling to components of the multiproxy data, we address: (1) what factors influence carbon dynamics during early Holocene warming and late Holocene cooling?; (2) how did carbon dynamics respond to abrupt sub-Milankovitch scale events?; and (3) what is the Holocene carbon storage budget for Lake Baikal.

CMAR values range between 2.8 - 12.5  $\text{g C m}^{-2} \text{ yr}^{-1}$ . Peak burial rates (and greatest variability) occurred during the early Holocene, associated with melting permafrost and retreating glaciers, while lowest burial rates occurred during the Neoglacial. Significant shifts in carbon dynamics at 10.3, 4.1 and 2.8 kyr BP, provide compelling evidence for the sensitivity of the region to sub-Milankovitch drivers of climate change. We estimate that 1.03 Pg C were buried in Lake Baikal sediments during the Holocene, almost one quarter of which was buried during the early Holocene alone. Combined, our results highlight the importance of understanding the close linkages between carbon cycling and hydrological processes, not just temperatures, in southern Siberian environments.

## **S05-O07 - Lake browning or re-browning? Impact of atmospheric deposition and climate change on lake-water organic carbon levels in central to NE North America**

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Over the past decades, organic carbon (OC) levels have increased in many lakes (i.e., “lake browning”) across Europe and NE North America. Identified drivers for this increase include reduced acid deposition, land-use/cover changes, and climate change, yet the specific contributions of these drivers are still debated. Recent paleolimnological studies have shown that it is possible to reconstruct past lake-water OC levels from sediment records using visible-near infrared (VNIR) spectroscopy models, thus providing missing key data about pre-human impact levels and natural long-term OC variability.

Here, we present centennial-scale OC reconstructions for lakes across central to SE Canada, from low to high acid deposition regions. OC reconstructions are based on a PLSR model between VNIR spectra of surface sediments and corresponding lake-water OC measurements from 345 Arctic, boreal and northern temperate lakes ( $0\text{--}41\text{ mg OC L}^{-1}$ ,  $R_{CV}^2 = 0.57$ ,  $RMSE_{CV} = 4.4\text{ mg OC L}^{-1}$ ). Inferred lake-water OC trends show a strong response to changes in atmospheric deposition across the landscape. For example, in lakes near Sudbury, northeastern Ontario – an area that has been heavily affected by acid deposition during the 20<sup>th</sup> century – OC concentrations declined by ~50% compared to pre-industrial levels. After dramatic SO<sub>2</sub> emission reductions occurred in the 1970s, OC concentrations started to slowly recover, but still remained ~30% below pre-industrial values by the 2000s. In contrast, in lakes of the low deposition Experimental Lakes Area of northwestern Ontario, OC values declined by only ~10% during the early 20<sup>th</sup> century and exceeded pre-industrial values by the 1970s (~10% relative increase by the 2000s), likely in response to climate change. Our results demonstrate the widespread “re-browning” of lakes in former low to high acid deposition regions, and suggest that OC levels will exceed pre-industrial values with complete recovery from acidification in response to ongoing climate change.

# **S05-O08 - Interpreting vegetation change in tropical arid ecosystems from sediment molecular fossils and their stable isotope compositions: A baseline study from the Pilbara region of northwest Australia**

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Detection of source diagnostic molecular fossils (biomarkers) within sediments can provide valuable insights into the vegetation and climates of past environments. However, hot and arid regions offer particularly challenging interpretive frameworks for reconstructions because baseline data are scarce, organic matter is generally very low and in the inland tropics in particular, sediments are also often subject to flooding and drought. We investigated whether biomarkers and compound-specific  $\delta^{13}\text{C}$  values could be extracted from a late Holocene sediment record from the Fortescue Marsh (Pilbara, northwest Australia) to reconstruct past catchment vegetation and hydroclimate. The low total carbon (TC) content (<1.4%) was a major challenge for the molecular analyses over the ~2000 years old sequence. Nevertheless, they revealed that the dominant hydrocarbon features (e.g., long chain n-alkanes) indicative of terrestrial plants (e.g.,  $\text{C}_4$  grasses; riparian and other  $\text{C}_3$  plants) encompassed the last ~1300 yrs and that low abundance of products from aquatic sources (e.g., n- $\text{C}_{17}$ ) were detected in the uppermost sediments only when permanently inundated conditions prevailed (recent decades). Similarly, the lower  $\delta^{13}\text{C}$  values (i.e., a difference of -2.3‰) of long chain n-alkanes in upper sediments reflected a vegetation response to the emergence of wetter conditions through the late Holocene in the region. Based on the diverging dominant source contributions obtained from the molecular distributions and arid-based Bayesian mixing model ( $\delta^{13}\text{C}$  of n- $\text{C}_{27-33}$  alkanes) results, less arid conditions may have favoured the input of  $^{13}\text{C}$  depleted n-alkanes from the Eucalyptus ( $\text{C}_3$ ) dominant riparian vegetation. The deepest sediments (<700 CE) however, had a TC content of <0.4%, and no organic compounds were detected, consistent with local and regional records of hyperarid conditions. These results demonstrate that n-alkanes can provide a molecular and stable isotopic fingerprint of important - and perhaps underappreciated - ecological processes in modern tropical arid environments for future paleoclimate investigations.

# Poster Presentations

## **S05-P01 - Developing palaeolimnological records of organic content at the UK Uplands Waters Monitoring Network using NIRS and TGA**

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Increases in concentrations of DOM have been observed in surface waters of northern and central Europe, known often as 'Brownification'. Due to the negative impacts of this there is a need to better understand the drivers and trajectory of this trend. Using both recent and longer-term (Holocene) sediment records it may be possible to further improve the understanding of carbon cycling within lakes and their catchments.

The UK Upland Waters Monitoring Network (UK UWMN) sites have been monitored quarterly for dissolved organic carbon since 1988. Here four of these sites (Llyn Cwm Mynach, Scoat Tarn, Loch Grannoch and Loch Chon) are visited, with sampling focused on the very recent sediment (approx. 200 years). At Llyn Cwm Mynach and Loch Grannoch longer records (11.5k years) have been obtained to assess equivalent patterns through the Holocene.

Analysis of the gravity cores has focused on measuring and characterising the organic content for comparison with recorded surface water DOC measurements (UK UWMN).

## **S05-P02 - A millennial-scale perspective on the relation between vegetation changes and erosion in Skogaryd Research Catchment based on lake sediments**

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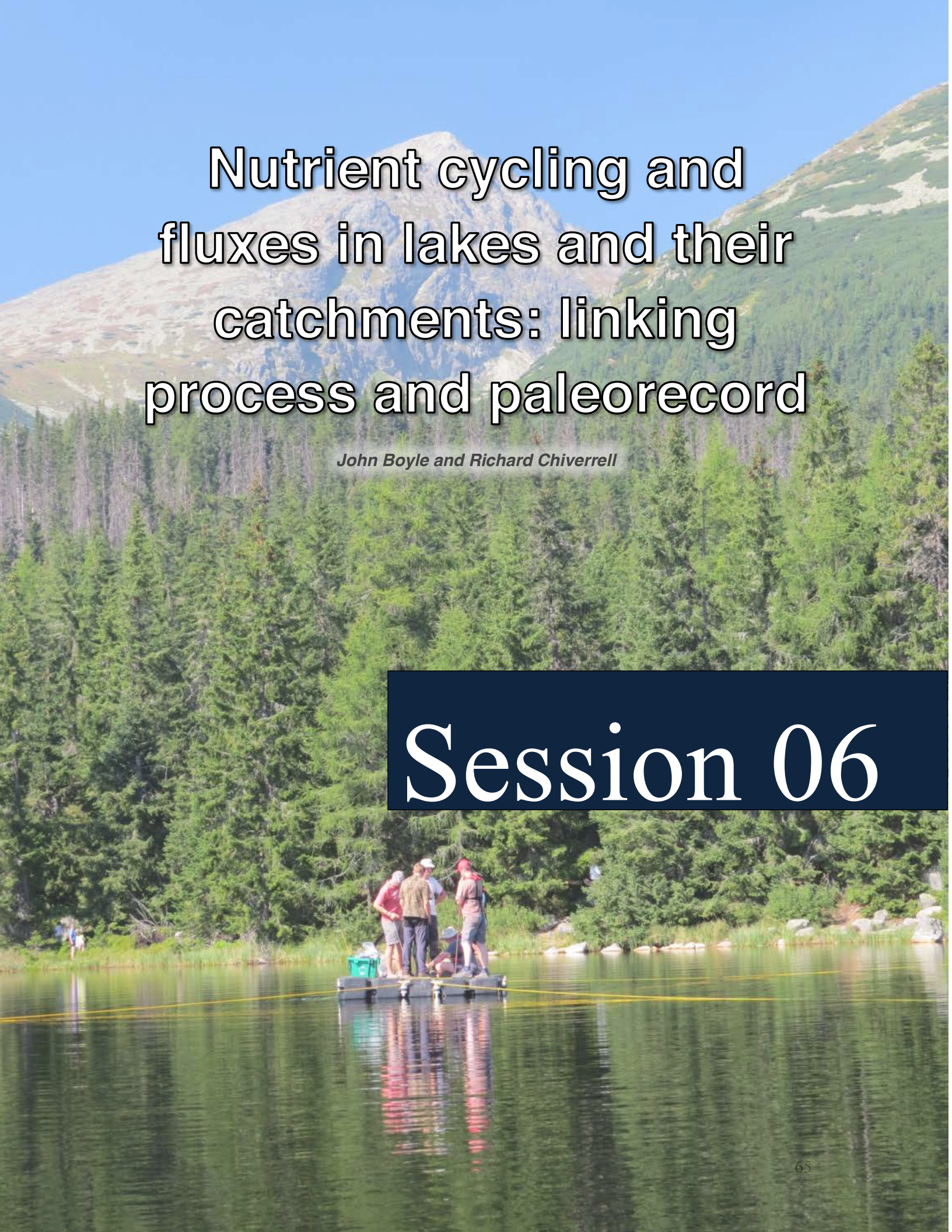
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This study focuses on the carbon cycle between the terrestrial and aquatic system in response to land-use changes in a long-term perspective based on lake sediments. Catchment-scale vegetation changes are reconstructed quantitatively using pollen analysis and the Landscape Reconstruction Algorithm (LRA). Bulk geochemical analyses in combination with organic geochemistry including lignin phenols and lipid biomarkers are used to identify the sources of organic matter derived from the catchment. By comparing the reconstructed vegetation with the geochemical results, we will analyze potential relations between land-use changes (forestry, agriculture) and changes in the delivery of organic and mineral matter from the catchment to the lake. Variations in TOC, TN, C/N ratios of organic matter, XRF data and pollen composition since AD 1000 in a sediment core from Lake Skottenesjön, downstream of the Skogaryd Research Catchment station, South Sweden, show that deforestation and agricultural activities in the lake catchment modified the organic and inorganic matter export associated with soil erosion to the lake. This is indicated by high values in lithogenic elements K, Ti, Rb, as well as a very rapid increase in C/N ratio and a drop in both TOC and TN from ca. AD 1750 to ca. AD 1900. During this time, cultivated crops (*Secale* and *Hordeum*) and grazing indicating shrubs (*Juniperus*) expanded, which corresponds well with an accelerating increase in the population in the research area between ca. AD 1700 and ca. AD 1850. A less intensive human impact can be observed between the mid-12<sup>th</sup> century and 14<sup>th</sup> century with high values of C/N ratio and the lithogenic elements K, Ti, Rb and Zr, which is attributed to soil erosion associated with expanding human activities in early medieval time interrupted by the Black Death. Further analysis, including pollen analysis and biomarkers, of the sequences are in progress.





# Nutrient cycling and fluxes in lakes and their catchments: linking process and paleorecord

*John Boyle and Richard Chiverrell*

## Session 06

# Oral Presentations

## **S06-O01 - Modelling Holocene sediment records of landscape phosphorus flux along a climate gradient in Sweden**

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A generalised model of P leakage from soils successfully captures variance between a number of temperate sites, despite using a universal parent material and climate-independent parameters. However, in the cool and dry sites of northern Sweden such a model greatly overestimates the fluxes. Here the P leakage model is modified to explicitly treat climate (temperature and precipitation), using simple and physically realistic mechanisms. It is tested at 5 lake sites spanning from Lilla Öresjön (Near Gothenburg) in the south to Sotaure (Near Jokkmokk) in the north. This presentation reports findings and wider implications.



## **S06-O02 - Using paleolimnology to determine colonial population trends and limnological effects of Leach's Storm-petrel (*Oceanodroma leucorhoa*)**

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The conservation of ecologically vulnerable seabird species is difficult because of a lack of long-term population surveys, therefore it is challenging to determine population dynamics prior to direct observational changes. One vulnerable seabird species is the Leach's Storm-petrel (*Oceanodroma leucorhoa*), which has been declining globally in recent years. The world's largest colony is on Baccalieu Island, Newfoundland, a seabird reserve currently supporting ~2 million nesting pairs. Because of their small stature and nocturnal behaviour, Storm-petrels are difficult to survey accurately, and thus fluctuations in colony size and the processes driving colonial trends remain unclear. Petrels build their nests underground in peat habitat throughout Baccalieu Island, particularly in the catchment of freshwater ponds. Prior to fledging, Storm-petrel chicks are fed by their parents and act as nutrient biovectors, fertilizing the nearby water bodies with their nutrient-rich guano, moulted feathers, and bird carcasses. This fertilization causes changes in the ponds' water chemistry and aquatic biota, leaving distinct geochemical and biological signatures in the sediments. Here we present preliminary analyses of changes in the water chemistry, diatom assemblage, sedimentary chlorophyll-a and stable nitrogen isotopes ( $\delta^{15}\text{N}$ ) from five sediment cores on Baccalieu ponds with varying degrees of petrel impact. Initial analyses indicate that these biological and chemical proxies track fluctuations in Leach's Storm-petrel population. To begin to understand the cause of the population changes, pollen assemblages are reconstructed to determine whether fluctuations in colony size are driven by changes in habitat. This study will directly influence the conservation and management of this ecologically vulnerable bird species by helping to reconstruct population trajectories and will help determine the mechanism of this species' decline. Additionally, the techniques employed in this study have not yet been utilized in the context of conservation biology, and therefore have broader implications in the protection of other avian and non-avian species.



## **S06-O03 - Phosphorus targets from palaeolimnology: a case study from Crose Mere, UK**

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Many UK lakes are found to be failing to meet targets for total phosphorus (P) concentration despite mitigation practices often being in place. This highlights the need to understand the context of a lake's present day nutrient status in order to assess the achievability of such targets under current management strategies. Palaeolimnological records offer the opportunity for reconstructing past lake conditions, providing a reference for water quality targets. Here a lake sediment geochemical record from Crose Mere, a UK lowland eutrophic lake, will be used to determine long-term P fluxes at the site. Viewed in the context of long-term large-scale catchment P dynamics, changes in anthropogenic influence on nutrient input will be examined. Together with a record of fossil pigments and plant macrofossils this will be used to investigate the in-lake ecological response to long-term changes in nutrient flux. Finally the present-day lake status and associated nutrient targets will be examined in light of the findings from the palaeorecord.

## **S06-O04 - The use of quantitative landscape reconstructions from pollen data for linking land use change and aquatic environments**

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Methods for quantitative reconstructions of past land cover changes from pollen data have improved significantly over the last decades, and with the increased number of studies and estimates of the relative pollen productivity of different plants, have also become much more widely applied. The different submodels within the Landscape Reconstruction Algorithm (Sugita, 2007) allows us to reconstruct vegetation changes at different spatial scales, depending on the selection of study sites. This can provide quantitative information on past human land use at different spatial and temporal scales. By analysis of the relationships between land use changes and geochemical, geophysical and biological proxies of past conditions in the aquatic environment in lakes and even coastal waters, we can improve our understanding of the interactions between humans, the terrestrial and the aquatic environment at timescales that far exceed those of observational data. This in term can perhaps give us an increased understanding of the long term processes involved, although many challenges remain, not least disentangling the role of land use and climatic changes. We will present examples of such analyses in southern Scandinavia range from small, very local to large regional catchments in terms of spatial scales, and from centuries to millennia in terms of temporal scale.

## **S06-O05 - Alterations to nutrient deposition and sediment stoichiometry in a lake ecosystem from decades of prescribed burning**

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Land-water connections are influenced by climate, environmental and human alterations to landscapes. One common terrestrial management tool that has been applied on a broad spatiotemporal scale is prescribed burning. The burning of understory can recycle nutrients, prevent intense forest fires, and promote ecosystem health. The ash that remains following a prescribed burn erodes into aquatic environments potentially altering terrestrial-aquatic connectivity and water quality, but most research has been conducted on acute burn events with little focus on landscapes that have been repeatedly burned for decades. In this study we collected a sediment core from Ocean Pond, FL, USA, a shallow, sinkhole lake that had received fire ash from decades of prescribed burning events. Paleolimnological measurements of charcoal, nutrients (C, N, P), other elements (Al, K, Fe), stable isotopes, and photosynthetic pigments were used to reconstruct natural and prescribed fire regimes, inputs of materials, and lake primary producer responses for periods of prescribed burns and natural wildfires (~4,000 YBP). Results show that the modern prescribed fires decreased C and N inputs to the lake while increasing P inputs causing alterations to total nutrient deposition and nutrient stoichiometry. However, despite the alterations in nutrient dynamics, photosynthetic pigment data showed low primary producer abundance during the prescribed burning period inferred as light limitation. The dramatic changes in nutrient dynamics during the prescribed burning period could provide new insights into biogeochemical pathways in land-water connected systems as well as support changes in other aquatic ecosystems receiving burned material where burning has not been considered as a driver of biogeochemistry.

## **S06-O06 - Interactive effects of hydrology and nutrient pollution on two shallow freshwater lakes in the middle Yangtze floodplain**

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Large river floodplains play an important role in providing societal, economic and biological benefits. However, the complex ways that rivers and their floodplains operate and interact make it difficult to understand and effectively steward these important zones. The middle and lower reaches of the Yangtze Basin which are inhabited by more than 300 million people are within an important economic and societal zone in China. Over the last several decades, with the intensification of industrial and agricultural activities and rapid population expansion, lakes in this area have suffered from problems such as eutrophication and declines in biodiversity. In addition, more than 50 thousand dams (e.g., Three Gorges Dam) have been established in this area for the benefits of hydropower, irrigation, flood control and water supply, which has modified the natural hydrological condition of floodplain lakes. In an attempt to understand how shallow freshwater ecosystems in the middle Yangtze floodplain respond to multiple drivers, paleolimnological proxies including chlorophyll and carotenoid pigments, C/N ratios and stable carbon isotopes were analysed in  $^{210}\text{Pb}$  dated sediment cores from two floodplain lakes, Wanghu Lake and Luhu Lake ( $>30\text{ km}^2$ ). C/N ratios and an index of UV penetration (water clarity), derived from pigment biomarkers, increased after dam construction in both lakes, implying that aquatic plant growth increased and light conditions improved as turbidity from suspended particles declined under more stable hydrological conditions. Since the 1990s, total algal production, indicated by chlorophyll a and  $\beta$ -carotene, and pigments from filamentous cyanobacteria (*aphanizophyll*) increased and lower UV index suggested a decline in water clarity. The proliferation of algae, including bloom-forming taxa, was correlated with increased nutrients transport into the lakes due to the intensification of agriculture and urban expansion. Our work demonstrates that in floodplain areas such as the middle Yangtze, freshwater ecosystem wellbeing is dependent on both hydrological and nutrient condition.

# Poster Presentations

## **S06-P01 - Iterative non-least squares fitting: a rapid approach to deconvolute and quantify chloropigment speciation from spectrophotometry measurements**

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Sedimentary algal and bacterial pigments have been used for decades to infer productivity changes and alga community in lakes. In particular, the ratios between the chlorophylls and chlorins may give an indication about the degree of diagenesis and food web intensity. Nowadays, conventional instruments such as HPLC and spectrophotometer (SPM) are mostly used to quantify these compounds. On one hand SPM measurements are rapid and inexpensive, on the other hand they are much less compound specific than HPLC. In order to render SPM measurements more compound specific, an iterative non-least squares method is used to deconvolute the bulk green pigment absorption peak in two components: sum of chlorophyll-a (Chl-a) and chlorins-a (Chls-a), and the sum of Chl-b and Chls-b. Afterwards on the first component, mono or dichroic equations are applied to quantify total chlorins-a (TC-a), Chls-a and Chl-a [1]. The advantage of this method is that the samples does not need chemical treatments and does not overestimates the actual concentrations. The validation of spectrophotometer measurements and subsequent peak deconvolution with pigment-specific HPLC measurements (true target values) are carried out applying linear fitting correlation. The quality of the calibration is assessed with the ratio percentage error (RPE) as a function of the pigment concentration ratio between the predicted (deconvolution) and measured value (HPLC). We tested this approach with spiked and no spiked natural sediment samples from varved lake Ponte Tresa, a eutrophic lake in southern Switzerland. Comparison between HPLC measurements and SPM measurements followed by deconvolution reveals adjusted- $R^2$  of 0.988 for TC-a, 0.979 for Chls-a and 0.974 for Chl-a with a RMSE of 0.323, 0.263 and 0.185  $\mu\text{g/g}$ , respectively. The average RPE for TC-a is 105.02%, 101.93% for Chls-a and 113.50% for Chl-a. To our knowledge, this is the first time that this approach is used to quantify TC-a, Chls-a, Chl-a in lake sediments with rapid and inexpensive SPM measurements.

### References

[1] O'Haver, T. (2018). Toolkit of functions, scripts and spreadsheet templates. <https://terpconnect.umd.edu/~toh/spectrum/functions.html>, 2018-02-27.

## **S06-P02\* - Phosphorus speciation and its relevance for historical lake eutrophication in the Ponte Tresa basin (Lake Lugano, Switzerland)**

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Phosphorus (P) is often driving the primary productivity in freshwater lakes. Previous studies showed that total P in sediments is strongly related to the lake trophic status, but little is known about the different P species in the sediments and the fractions that are permanently embedded or readily available for recycling. We aimed to determine which P species preferentially accumulate in lake sediments during periods of high eutrophication, and how lake restoration measures in the past decades are recorded in sedimentary P species.

We analyzed varved lake sediments from the Ponte Tresa basin of Lake Lugano (Switzerland). This lake has been eutrophic and mostly anoxic since the 1950s. We performed a sequential P-extraction with four fractions on the sediments (period 1940s to 2017). Each of the fractions was analyzed separately for inorganic and organic P. Subsequently, P species detected at different depths were compared with chloropigment concentrations (Chl a and chlorin) as inferred from high-resolution hyperspectral imaging.

We observed that the concentrations of different P forms in the sediments followed the order: Fe(II) bound P > Fe- and Al-oxide bound P > Ca bound P > loosely adsorbed P. Fe(II)-P and Fe, Al-oxide-P fractions decreased from 1950s onwards, while lake primary productivity continuously increased. We observed, however, a maximum of Fe(II)-P and Fe, Al-oxide-P between 1995 to 1999, which coincides with a period of very high primary productivity. The other P forms did not show a clear temporal trend.

The results indicated that Fe(II)-P, Fe, Al-oxide-P and loosely adsorbed P in the sediments can be potentially available P fractions in Lake Ponte Tresa. The Ca-P is the relatively stable form in the sediments.

Work is under way to characterize the organic P fraction by using substrate specific enzymes.

## **S06-P03\* - Stable carbon and nitrogen isotopes of invertebrate remains: a glimpse of food web structure change?**

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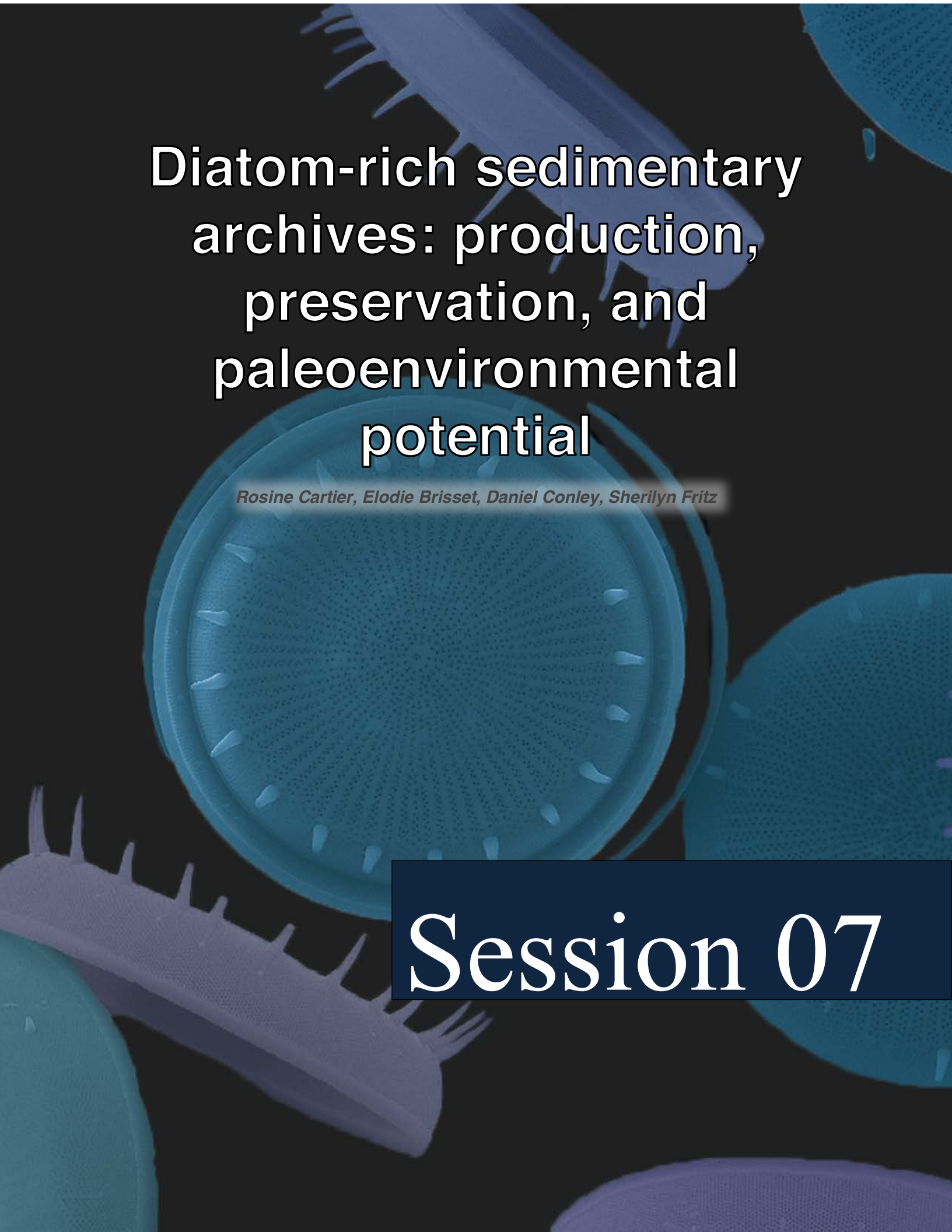
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Assemblages of microscopic remains in sediment records provide a wealth of information about past environments. A further step can be taken by analysing stable carbon and nitrogen isotopes ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) of plant and invertebrate remains. Offsets in  $\delta^{15}\text{N}$  (trophic position) and  $\delta^{13}\text{C}$  (energy source) between organisms gives insights in food web structure and energy flow. Here we present a pilot study from Loch nam Fear in the Flow Country, Scotland. The assemblage composition of macrophytes and invertebrates indicated a distinct change in aquatic community around 1990 reflecting the 1986–9 establishment of a conifer plantation 500m from the lake. A 1–3‰ decrease in  $\delta^{15}\text{N}$  of plant and zooplankton remains suggest that the conifer plantation had a strong impact on nitrogen cycling and possibly led to reduced aquatic food chain length.



# Diatom-rich sedimentary archives: production, preservation, and paleoenvironmental potential

*Rosine Cartier, Elodie Brisset, Daniel Conley, Sherilyn Fritz*

## Session 07



# Oral Presentations

## **S07-001 - Spatiotemporal ecology and sedimentary processes in a pristine lake system at the permafrost margin of southern Yakutia (Russia)**

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The Northern hemisphere is strongly affected by on-going global warming since the late 19<sup>th</sup> Century. Recent climate warming and permafrost degradation is threatening the residential areas of the local people and natural northern ecosystems. Lake systems represent the major freshwater resource and act as extremely sensitive sentinels of environmental changes. Lake Bolshoe Toko (56°15N, 130°30E, 903 m.a.s.l., length: 14 km, width: 7 km, maximum water depth: >70 m) is located at the marginal permafrost zone in southeastern Yakutia, Russia. The lake occupies a basin at the foot of the northern slope of the eastern Stanovoi mountain range, composed of Precambrian igneous rocks. At its north-eastern margins the lake is bordered by moraines of three different glacial sub-periods. These geological boundary conditions give way to different depositional environments within the lake and hence cause spatial variability in habitat conditions for species assemblages.

In our study, we analyse the sediment-geochemical properties (organic carbon, nitrogen, mineralogy and grain-size) from a set of 37 surface samples and two long cores. We compare the abiotic system to the taxonomical diatom and chironomid species distribution and the oxygen isotope signal measured from the diatom opal ( $\delta^{18}\text{O}_{\text{diat}}$ ). Our results show significant within-lake variability of the species distribution, influenced by limnological parameters (water depth, habitat conditions, distance-to-shore) and differential catchment properties (i.e. nutrient supply). Sediment cores were radiocarbon dated back to 40.000 cal. years BP and XRF scanned for elemental composition. The composite record provides a better understanding of the spatiotemporal within-lake variability of palaeolimnological proxies as well as insights into the Late Quaternary glaciation history and the coupling between lake system ontogeny and climate forcing on millennial timescales.

## **S07-O02 - Influence of erosion and vegetation changes on diatom deposits in high-altitude lakes of the European Alps**

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Diatom in lakes represent a major sink of Si influencing the global Si cycle and fluxes of this nutrient from continent to oceans. However, processes triggering diatom deposition in lake sediments are not well known as they might involve different mechanisms. One entry to investigate factors controlling diatom deposition is to compare for same physical settings, changing environmental variables over time. Here, we use a large dataset of multiproxy analyses carried out in three Lateglacial to Holocene lake sediment archives (Lake Petit, Lake Allos, and Lake Vens) located in the same range of altitude (2200 to 2300 metres a.s.l.), situated in comparable geological bedrock (crystalline dominated), and where no volcanic sources exist. Thus, in this context Si inputs are restricted to transfer from watershed to lake. BSi has consisted exclusively of diatoms in these records encompassing, all the sites together, concentrations of 0 to 91 wt percent of the total bulk sediment. Our results allow to distinguish three main periods of BSi concentration: minimum from 12,000 to 7000 cal. BP, maximum from 7000 to 2000 cal. BP, and intermediate content from 2000 cal. BP to Present. Comparison to multiproxy analyses carried out on the same records indicates that these periods have been linked to major changes in the lake catchment, that includes change in detrital erosion, soil chemical weathering and vegetation cover. By incorporating all these results in a multivariate component analysis, we propose to discuss the relative influence of these environmental variables to diatom deposition in alpine lakes.

## **S07-003 - Palaeohydrological changes at Yellowstone Lake (Wyoming, USA) during the Holocene inferred from oxygen isotopes in diatoms: preliminary results**

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Continental hydrothermal systems have a major influence on the Earth's thermal (heat) budget and on geochemical cycles, and they represent a significant geological hazard through thermal explosions. Yellowstone Lake's hydrothermal system, located in one of the most active volcanic plateaus (Wyoming, 2357 m a.s.l, USA), is characterized by extensive seismicity and comprises thermal features and hydrothermal explosion craters. Processes triggering hydrothermal activity operate over short timescales, such as earthquakes or daily to annual cycles (climate seasonality), as well as millennial timescales (changes in magmatic activity, regional climate influences).

To better understand the processes driving hydrothermal activities on varied timescales and their implications for environmental change, sediment cores were taken in 2016 in the framework of the "HD YLake research program". As Yellowstone Lake sediments are rich in diatom fossils, past hydrological changes related to climate change are inferred using the oxygen isotope composition ( $\delta^{18}\text{O}$ ) of biogenic silica that comprises the cell wall of the diatoms. One dominant species, *S. yellowstonensis* was extracted from the sediments for isotopic analysis.  $\delta^{18}\text{O}$  variations in palaeoclimatic records usually represent changes in lake water balance related to local properties and regional climatic influences. At Yellowstone Lake,  $\delta^{18}\text{O}$  variations in lake waters are mainly triggered by evaporation processes (depending on the water residence time and the surface area of the lake) and the seasonal activity of the Yellowstone River. A preliminary  $\delta^{18}\text{O}$  record covering the Holocene will be presented and the major factors triggering  $\delta^{18}\text{O}$  variations in the past will be discussed as well as initial inferences of past hydrological changes.

## **S07-O04 - Palaeolimnological analysis of sulphate deposition events following large volcanic eruptions in historical times**

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Major volcanic eruptions may have severe societal impacts as shown by ash dispersal and sulphur emissions from recent Icelandic eruptions. However, ice-core sulphur records demonstrate that these events were minor as compared to historical events of much larger magnitude. We still lack a sufficient understanding of the environmental impacts of such colossal eruptions, which take place on average once per century and can be expected to recur at any time in the future. As part of a newly initiated project, we aim at estimating the extent of such sulphate deposition events in northern and central Europe, their typical duration and effects on aquatic biota, catchment vegetation and soils, including the potential release of highly toxic methyl mercury to lake waters. By freeze-core sampling of varved lake sediments at well-documented sites, we will target some selected volcanic events of known origin during the last millennium, such as Askja 1875, Tambora 1815, Laki 1783, Veidivötn 1477 and Samalas 1257. Their physical, chemical and biological impacts on the local ecosystems will be analysed at annual resolution, if possible aided by the identification of tephra particles from the respective eruptions. Established geochemical and palaeolimnological methods will be applied, including diatom analysis of biogenic varve sequences, and comparisons will be made with historical accounts when available. As part of ongoing efforts to establish instrumentation for synchrotron-based analysis of chemically unaltered, frozen sediment records at the MAX IV facility at Lund University, we will also perform high-resolution S, Fe and Hg speciation analyses of the varve records, using X-ray absorption spectroscopy. Apart from deeper insights into ecosystem responses to massive volcanic sulphur deposition and associated ashfall events, the project will pave the way for future applications of synchrotron-based techniques within palaeolimnology.

## **S07-O05 - Diatom, mineralogical, and geochemical proxies provide a new view of the paleolimnology of Lake Bonneville (western USA) as observed in the restricted Pilot Valley sub-basin**

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Between 30 and 13 ka, pluvial Lake Bonneville (western US) rivaled Lake Michigan in terms of surface area, depth, and volume, and its marls represent an important archive of climate and paleolimnological processes. We report the first diatom record anywhere in the basin for the complete Bonneville cycle from core taken in the Pilot Valley sub-basin, Utah. Combined with geochemical and mineralogical records, the proxies represent closed-basin transgression, the catastrophic Bonneville flood, open-lake conditions, and closed-basin regression and desiccation cycles.

Diatoms record pH and salinity, and vary from alkalibiontic/brackish (early transgression), alkaliphilous/fresh-brackish (deep lake) and back to alkalibiontic/brackish (late regression) conditions, and mesotraphentic to eutrathentic nutrient loads. The Bonneville flood produced freshening recorded in marls by a decrease in the ratio of carbonate minerals to quartz, a decrease in Sr, and minima in carbon and oxygen isotopes after the flood.

Pennate diatoms reveal passage through and back into the euphotic zone during transgression and regression by sufficient light penetration through the water column to support an active benthos. As such, the base of the euphotic zone (~35m depth) can be established through time. However, establishing time-depth relations in the core required an unusual model-based approach because reservoir effects and detrital carbonate influence  $^{14}\text{C}$  activities in marl and detrital Th makes U-series ages impractical.

Restriction and evaporation within the Pilot Valley arm of Lake Bonneville during times of shallow water produced high endogenic carbonate production, an order of magnitude higher than during deep-water phases. This is revealed in the age-depth model, carbon and oxygen isotopes, and relative diatom abundances, requiring a major re-evaluation of the position of the previously published Bonneville flood horizon within the sediments of Pilot Valley. In summary, lacustrine sediments from restricted arms of large pluvial lakes may vary significantly from complementary records from an open basin.

## S07-O06 - Modelling silicon supply during the Last Interglacial (MIS 5e) at Lake Baikal

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Limnological reconstructions of primary productivity have demonstrated its response over Quaternary timescales to drivers such as climate change, landscape evolution and lake ontogeny. In particular, sediments from Lake Baikal, Siberia, provide a valuable uninterrupted and continuous sequence of biogenic silica (BSi) records, which document orbital and sub-orbital frequencies of regional climate change. We here extend these records via the application of stable isotope analysis of silica in diatom opal ( $\delta^{30}\text{Si}_{\text{diatom}}$ ) from sediments covering the Last Interglacial cycle (Marine Isotope Stage [MIS] 5e; c. 130 to 115 ka BP) as a means to test the hypothesis that it was more productive than the Holocene.  $\delta^{30}\text{Si}_{\text{diatom}}$  data for the Last Interglacial range between +1.29 to +1.78‰, with highest values between c. 127 to 124 ka BP (+1.57 to +1.78‰). Results show that diatom dissolved silicon (DSi) utilisation, was significantly higher ( $p=0.001$ ) during MIS 5e than the current interglacial, which reflects increased diatom productivity over this time (concomitant with high diatom biovolume accumulation rates [BVAR] and warmer pollen-inferred vegetation reconstructions). Diatom BVAR are used, in tandem with  $\delta^{30}\text{Si}_{\text{diatom}}$  data, to model DSi supply to Lake Baikal surface waters, which shows that highest delivery was between c. 123 to 120 ka BP (reaching peak supply at c. 120 ka BP). When constrained by sedimentary mineralogical archives of catchment weathering indices (e.g. the Hydrolysis Index), data highlight the small degree of weathering intensity and therefore representation that catchment-weathering DSi sources had, over the duration of MIS 5e. Changes to DSi supply are therefore attributed to variations in within-lake conditions (e.g. turbulent mixing) over the period, where periods of both high productivity and modelled-DSi supply (e.g. strong convective mixing) account for the decreasing trend in  $\delta^{30}\text{Si}_{\text{diatom}}$  compositions (after c. 124 ka BP).

## Poster Presentations

### S07-P01\* - Paleoclimate reconstruction for the transition MIS 6 to MIS 5 from lake Chalco, central Mexico

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The objective of this work is to analyze the sediment between 100 to 122.5m from lake Chalco, central Mexico, using diatoms and X-Ray Fluorescence. We identify two different diatom assemblages indicative of contrasting limnological and climatic conditions. The first is a freshwater assemblage, dominated by *Stephanodiscus niagarae*, and *S. oregonicus*, species that are scarce in modern environments in central Mexico but are common in temperate lakes in USA and Canada, we consider this assemblage indicative of temperate, freshwater conditions. The second is an halophilous assemblage, dominated by *Anomoeones costata*, *Cyclotella meneghiniana* and *Campylodiscus clypeus*, which are common in modern alkaline, subsaline to hyposaline lakes in central Mexico. Extrapolating the chronological model based on  $^{14}\text{C}$  and U/Th dates on the top 63.5 m of the sequence, we consider that the studied section covers the MIS 6 to MIS 5 transition (ca. 130 ka). This transition is recorded by a change from laminated (MIS6) to massive sediments (MIS5) at 106 m. The laminated MIS6 sediments alternate between light diatom ooze lamina, dominated by the freshwater assemblage (*S. niagarae* and *S. oregonicus*) with peaks in Si/Ti and dark laminae dominated by clastic sediments with peaks in Ti. These cyclical laminations show that in central Mexico there was a stronger seasonality in the climate, with cold and dry winters and warm and wet summers. The massive (MIS5) sediments on the other hand are characterized by an increase in Ca/Ti and the halophilous assemblage, which indicate an abrupt change in the hydrology of the basin, with a change towards warmer climates and subsaline to hyposaline conditions in the lake. The presence of 13 layers of micritic mud that are intercalated along the laminated (MIS6) sediments, suggest that the transition between the cooler MIS6 climates to the warmer MIS5 was punctuated by a series of short term warmings events.

## **S07-P02\* - Palaeolimnological evidences for the rise and fall of a star-like planktonic diatom (*Asterionella formosa*) during the Antropocene in Romania**

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High-resolution, multi-core, multi-proxy study was carried out on three sedimentary records obtained from the Lake Ighiel, the largest karst lake of Romania. Lake Ighiel was formed ca. 6000 years ago, and during the evolution of lake-catchment system the siliceous algae were able to preserve in the sediment from ca. 4800 cal yr BP. After dominance by small fragilariales, the Middle Holocene (ca 4.8–4.2 cal kyr BP) is marked clearly by a relative increase in benthic *Navicula* and *Gyrosigma* taxa, indicating habitat diversification. An episodic return to small *Fragilariales* from 2.6 to 2.5 cal kyr BP periphitic taxa are abundant with benthic diatoms. In the last 1000 yrs *A. formosa* increases in relative abundance, but in the last 200 yrs it became dominant, which had been sporadic from the lake's sediment record in earlier intervals. *Asterionella formosa* is known as common and often dominant planktonic diatom in mesotrophic and eutrophic lakes worldwide. Recently it's abundance increases in oligotraphenic lakes as well. We can assume a strong positive correlation between the soil proliferation and impact of global warming to the abundance of *A. formosa*. Contrary the period of II. World War imprinted as decreasing of *A. formosa* in the lake sediment. Global warming related changes, like longer open water periods, changes in lake mixing regimes, and lake thermal properties might have contributed to the increase in the relative abundance of *A. formosa*. In the last couple of years, the "star" of *Asterionella* dramatically and abruptly fall, the small celled Centrales taxa practically extruded it from the lake sediment. To disentangle the influence the nutrient supply and climate related driving factors to diatoms is an unsolved problem. The authors acknowledge support from NKFIH 119208, CRYPTIC project.



## **S07-P03\* - Diatom-records in subalpine lake sediments: opportunities and limits for paleoclimate studies**

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Mountain lakes ecosystems are highly sensitive to global warming. Direct effects such as increasing lake temperature, intensified thermal stratification, and shorter ice cover periods strongly influence the structure of algal communities. Additionally altered catchment processes and precipitation patterns resulting in changing light climate and water level variability especially affect benthic algal assemblages. Diatoms are widely used in paleoclimate studies, as they are particularly sensitive indicators for climate-driven changes in lake processes and dynamics. We used sediment records of a small subalpine lake taken in different depths to identify diatom assemblage dynamics focusing on diatom life form, substrate specificity, nutrient preference and tolerance towards physical disturbance. A high-resolution study of current diatom depth-distribution patterns supports interpretation of subfossil community changes. We found that subfossil diatom assemblages of the sediment core taken in the aphotic zone are highly appropriate to reconstruct a variety of environmental changes. In sediments of well-illuminated littoral zone, however, periphytic diatoms outnumber planktonic diatoms by far. Cores taken in these depths are unsuitable for conclusions derived from planktonic species or from shifts in the ratio of planktonic to benthic diatoms. Small centric diatoms dominate the upper part of the aphotic zone core signifying high lake levels and extended thermal stratification. Assemblages of predominant epipsammic and epipelagic species in deeper parts of the core indicate lower lake levels or higher transparency. Increasing diatom diversity in younger sediments suggests increasing substrate availability and habitat stability.

The study is funded by the Bavarian State Ministry of the Environment and Consumer Protection

## **S07-P04\* - Linking silicon isotopes with diatom communities in small lakes in Lassen Volcanic National Park (CA, USA)**

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The quantitative use of silicon isotope ratios ( $\delta^{30}\text{Si}$ ) as a diatom paleoproductivity proxy in lacustrine systems requires a greater understanding of factors affecting their  $\delta^{30}\text{Si}$  values. We determined  $\delta^{30}\text{Si}$  in modern dissolved Si (DSi) and in modern and sedimentary biogenic silica in Manzanita (ML), Widow (WL), and Butte (BL) lakes in Lassen Volcanic National Park, California (USA). Combined with diatom community data and physicochemical parameters, we aim to characterize patterns of productivity, diatom composition, and BSi retention relative to Si isotope values to better interpret  $\delta^{30}\text{Si}$  observations from small, montane lake systems.

Modern planktonic diatom  $\delta^{30}\text{SiBSi}$  values (-1.1 to -1.3‰) in ML appear to be quite different from periphyton diatom  $\delta^{30}\text{SiBSi}$  values (-0.4 to -0.8‰). The fractionation associated with diatom silica production is larger than previously assumed and is different for each lake. Down-core  $\delta^{30}\text{Si}$  values do not correlate with %Opal-A for all cores over the last century. However, down-core changes in diatom community composition do coincide with changes in  $\delta^{30}\text{Si}$  values and %Opal-A throughout the core record for each lake. Non-metric multidimensional scaling, hierarchical cluster analysis, and indicator species analyses on modern and core samples from the three lakes indicate that sediment BSi  $\delta^{30}\text{Si}$  is linked to diatom growth habitat. In line with our modern observations, samples dominated by euplankton diatom taxa have low  $\delta^{30}\text{Si}$  (< -1.0‰), while samples dominated by littoral, benthic periphyton taxa have higher  $\delta^{30}\text{Si}$  (> -0.3‰). Intermediate sediment  $\delta^{30}\text{Si}$  (-1.0 to -0.3‰) are dominated by mixed tychoplankton and epilithic periphyton taxa. Different  $\delta^{30}\text{SiBSi}$  values by growth habitat likely reflect a combination of different DSi pools coupled with species-specific fractionations. These data suggest that  $\delta^{30}\text{Si}$  records from small lakes are a better proxy for the source of the BSi production rather than paleoproductivity itself.

## **S07-P05 - A 1000-year record of centennial-scale cyclic vegetation change from Maar Lake Sanjiaolongwan in northeast China**

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We present a high-resolution 1000-year pollen record of vegetation change from Sanjiaolongwan Maar Lake (SJML) in northeast China. An age model was established using analyses of  $^{210}\text{Pb}$ ,  $^{137}\text{Cs}$  and AMS  $^{14}\text{C}$ . Our intention was to use the results to examine possible relationships between vegetation change and climate in the study area and variations in solar activity. The pollen assemblages show that during the study interval the vegetation was temperate coniferous and deciduous broadleaved mixed forest. Although *Pinus* is the most abundant pollen type, various line of evidence suggest that it is not temperature-sensitive. However, from an analysis of changes in pollen assemblages over the past 1000 years and a comparison with pollen records from other lakes in the region, we conclude that *Quercus* frequencies can be used as a sensitive temperature index for the study area. Several notable cold periods, with lower *Quercus* frequencies, occurred at approximately 1200 AD, 1440 AD, 1640 AD and 1820 AD. These century-scale cold periods correspond to major minima in solar activity, leading us to conclude that variations in solar activity may have been an important driver of centennial-scale climate and vegetation change in the study area during the last millennium.

## **S07-P06 - Glaciohydrologic effect on diatom assemblage changes in Lake Basomtso on the southeastern Tibetan Plateau during the past two centuries**

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Climate warming since the end of Little Ice Age (LIA), especially after the 20<sup>th</sup> century, has apparently an influence on lake environments of the southeastern Tibetan Plateau (TP). However, a minimal standard deviation (SD=0.47) calculated using diatom data from Lake Basomtso implied insignificant ecological change over the past two centuries. Similar situation has been reported in other lakes of this region, which suggested that regional warming since the LIA is not high enough to exceed the lake ecological threshold. A modest diatom composition change during ca. 1770–1866 AD was identified. It can be speculated, from physical and geochemical aspects, that high-energy water flow in Lake Basomtso was produced by the synthetic effect of glacial melting and short distance between glacier forelands and the lake during the onset of climate warming. It changed water transportation capacity which made contribution to the modest diatom composition change. Increase in abundance of benthic or epiphytic species (e.g. *Achnanthes minutissima*, *A. biasolettiana*, *Fragilaria capucina*, *F. construence*, *F. pinnata*) in the lake sediments deposited during ca. 1770–1866 AD primarily attributed to the enhanced transportation by strong water flow from rivers, swales or littoral zone to profundal zone of the lake. Transportation capacity of meltwater decreased gradually along with glacial recession and increased in transportation distance. Under this context, less benthic or epiphytic diatoms could be transported to the profundal zone after the late 19<sup>th</sup> century. In summary, ecological change in deep lakes of southeastern TP since the LIA is not significant on the whole, but glaciohydrologic process have some impacts on diatom composition changes in lakes fed by glacial meltwater.

## S07-P07\* - Diatom community response to climate change during the interglacial/glacial cycle MIS 17-15 in ancient Lake Ohrid

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Understanding the response of aquatic primary producers to climatic and environmental stressors is important in light of ongoing climate change. This is particularly because trophic states and with it biodiversity are thought to experience significant perturbations due to anthropogenically induced changes in land use and climate. Here, we analyze the diatom response to limnological, environmental and climate change between MIS 17 and 15 (718–557 ka) in a long sediment record (584 m; ca. 1.9 Ma) from Lake Ohrid (Macedonia/Albania). The diatom assemblage throughout MIS 17 is dominated by the hypolimnetic species, *Cyclotella cavitata*, indicative of a high productivity in the lake and warm climate. Increased relative abundance of facultative planktonic and benthic taxa at ca. 703 ka and ca. 693 ka reflects climatic instability, most probably related to higher precipitation. Increase in the relative abundance of the epilimnetic taxa, *Cyclotella* sp. 1 aff. *minuscula* and *Cyclotella* sp. 2 aff. *ocellata*, at the expense of *Cyclotella cavitata* marks the beginning of MIS 16. Towards the end of MIS 16 (ca. 640 ka) epilimnetic taxa establish the highest dominance in the assemblage. This is indicative of restricted stratification in the lake due to cold winter and summer periods, combined with sufficient nutrient input from the catchment. The transition to MIS 15 is noticeable by the presence of *Aulacoseira subarctica*, a mesotrophic species indicative of increased mixing in the lake. During MIS 15 the co-dominant hypolimnetic taxa *Cyclotella cavitata* and *Cyclotella fottii* are representative of high temperatures during this period, especially at ca. 610 ka and ca. 578 ka, when these are present at almost 100% relative abundance. A significant increase in the abundances of *Cribrionella ohridana*, a fossil species close to epilimnetic *Cyclotella minuscula*, indicates the beginning of a gradual cooling towards the end of MIS 15 (ca. 573 ka). The response of the diatom community from Lake Ohrid during the period investigated is thus in tune with global scale climate change and its regional expression thus highlighting the sensitivity of aquatic primary producers to climate-induced changes in limnological parameters.

## **S07-P08\* - Lake Kinneret (Israel): Diatom-based palaeoecological reconstruction for the Holocene**

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Although the Eastern Mediterranean and especially the southern Levant are key regions for paleoclimatological and paleoenvironmental research, our understanding of Holocene environmental variability and its possible drivers is still limited. As diatoms remain one of the least-exploited proxies in paleoclimate research in the Mediterranean region, we would like to present a high-resolution multi-proxy record (special emphasis is given to diatom analysis) from Lake Kinneret (the Sea of Galilee), Israel.

During the Holocene, well-correlated shifts in the diatom, mineralo-geochemical and palynological data indicate marked lake-level variation over time as well as changes in the trophic state of Lake Kinneret. Our results are particularly important in improving the reconstruction of Holocene lake-level variation, and thus past moisture availability. Diatom-inferred lake-level oscillations correlate well with the output from climatic models from the Levantine region and clarify previous uncertainty concerning regional variation in moisture availability. The Early Holocene (from ca. 9,000 cal yrs BP to 7,400 cal yrs BP) was characterized by lake-level shifts due to fluctuating dry-wet climate conditions. During the mid-Holocene (from 7,400 to 2,200 cal yrs BP), a stable, deep lake-level phase persisted due to high humidity. The lake level of modern Lake Kinneret fluctuates seasonally with available moisture, but has also been influenced for ca. 2,000 years by the impacts of water abstraction for human consumption and agriculture.

Over the last 9,000 cal yrs BP, the trophic state of Lake Kinneret has changed from an oligotrophic to a meso- to eutrophic environment, mainly triggered by increased human impact from around 2,200 cal yrs BP onwards. The lake's ecosystem status was not strongly affected by the documented major changes in human occupation patterns during the mid-Holocene, when a relatively stable environment persisted.

## **S07-P09\* - What is diatomite?**

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Geologists, sedimentologists, engineers, and palaeontologists use the term "diatomite" for various types of siliceous sediment that contains diatom fossils. The definition in the literature varies greatly; and, in many cases, authors state no definition at all. In most literature from the first half of the 20<sup>th</sup> century, diatomite is considered to be sedimentary rock with a high percentage of SiO<sub>2</sub> in the form of diatoms. Definitions regarding diatomite as a rock are found primarily in the mining literature and in USGS reports, and the required percentage of SiO<sub>2</sub> varies. In the more recent literature, mostly in palaeoenvironmental reconstructions and palaeolimnology, one can find diatomite defined as siliceous sediment layers or silica-rich sediment, with some variable content of diatoms and clay. The required percentage of diatomaceous content in sediment varies widely throughout this literature, but it is not well defined.

The question arises: What is diatomite really? Is it sediment or sedimentary rock? If it is sediment, what is the threshold of diatomaceous content that justifies calling the sediment "diatomite"? Is the percentage of diatomaceous/silica content the right variable to define diatomite? Could it instead be density, porosity, or stage of diagenesis? This poster aims to summarise the different definitions of diatomite in the literature and stimulate a discussion regarding its definition. Our goal is to standardize the terminology for the use of diatomite and related terminology in different settings.



# Lakes as (isotopic) rain gauges of the past

*Rienk Smittenberg and Christos Katrantsiotis*



Session 08



# Oral Presentations

## **S08-001 - Radiocarbon chronology and paleoclimate reconstruction based on coupled $\delta^2\text{H}/\delta^{18}\text{O}$ biomarker analyses of lacustrine sediments from Garba Guracha, Bale Mountains, Ethiopia**

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East Africa is a region of extreme climate variability in the past. These climate changes are one of the key factors for human dispersal and migration and therefore highly discussed. To contribute to this discussion, we investigate the sediment archive of Garba Guracha in the Bale Mountains, Ethiopia. Garba Guracha is a cirque lake situated at 3950 m altitude at the lower limit of the Afro-alpine biome. It was investigated previously by Umer et al. (2007, QSR 26) and Tiercelin et al. (2008, QSR 27), focusing on pollen and geochemical analyses respectively.

Our work aims at (i) establishing a robust chronology based on radiocarbon dating of bulk sedimentary organic matter, bulk n-alkanes and charcoal, as well as on tephrochronology; (ii) paleoclimate reconstruction based on biomarker and stable isotope analyses.

All four dating techniques yield ages that are in good agreement. We find no evidence for pre-aging of lipids. These results indicate that we can establish a robust Late Glacial and Holocene chronology for the sediments of Garba Guracha.

Compound-specific  $\delta^{18}\text{O}$  analyses of plant-derived sugars (c.f. Zech et al., 2014, JOPL 51) yield more negative values for early Holocene core sections than for the rest of the sedimentary archive. We tentatively interpret this finding in terms of higher rainfall amount associated with the African Humid Period. Ongoing work focuses on compound-specific  $\delta^2\text{H}$  analyses of plant-derived n-alkane biomarkers. We present the first results for Garba Guracha from a coupled  $\delta^2\text{H}$ - $\delta^{18}\text{O}$  biomarker approach (c.f. Hepp et al., 2015, HYDROL 529). The coupled approach enables us (i) to reconstruct the lake evaporation history and/or relative humidity and (ii) reconstruct more robustly the isotopic composition of precipitation than hitherto possible based on  $\delta^2\text{H}$  or  $\delta^{18}\text{O}$  results alone.

This study is part of the Research Group DFG FOR 2358.

## **S08-002 - A global synthesis of water isotope proxies from lake archives through the last 2000 years from the Past Global Changes (PAGES) Iso2k Project**

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Water isotopes provide tracers of changing hydroclimate in space and time and, with their increasing incorporation into climate models, a potential check on climate model skill. We investigate the usefulness of lakes, where isotopes preserved in sedimentary sequences are controlled by multiple parameters, climatic, limnological and geomorphological, as a record of past change in hydroclimate and as a tool for data-model comparisons. We use the new PAGES Iso2k database, a global compilation of  $\delta^{18}\text{O}$  and  $\delta\text{D}$  records collected to investigate spatiotemporal variability and secular trends in global hydroclimate during the past 2000 years. Of 159 lake records identified from the literature as fitting the Iso2k selection criteria, for chronological control and resolution, the database currently holds 117 isotope time series from 83 lakes, a unique resource for paleolimnology. Of these, 78 are time series from sensors of lake water  $\delta^{18}\text{O}$ : including bulk carbonate (37), ostracods (22), and diatom silica (4). 39 records are from sensors of precipitation/soil water  $\delta\text{D}$  (terrestrial biomarkers) or lake water  $\delta\text{D}$  (aquatic biomarkers). We evaluate the spatio-temporal patterns in these records over the past 2 ka, and compare these patterns with isotope-enabled model simulations using Proxy System Models (PSMs). For example, we find latitudinally-dependent patterns in lake carbonate  $\delta^{18}\text{O}$  that are consistent with measured and modelled global patterns in precipitation  $\delta^{18}\text{O}$  and P-E. The global distribution of sites in the Iso2k database allows us to mitigate for challenges posed when comparing individual lakes with grid squares in climate models, whilst the range of lake hydrological settings and isotopic sensors, both included as meta-data in the database, allows investigation of the usefulness of different isotopic proxies in data-model comparisons. Working iteratively with this approach will help improve climate model and PSM skill, and interpretations of down-core isotopic records.

## **S08-O03 - Eastern Mediterranean hydroclimate reconstruction over the last 3600 years based on sedimentary n-alkanes, their carbon and hydrogen isotope composition and XRF data from the Gialova Lagoon, SW Greece**

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The present study aims to reconstruct the late Holocene environmental and hydrological changes in the Gialova lagoon, a shallow and coastal Mediterranean ecosystem in the SW Peloponnese, Greece and also to contribute with new paleoclimate data for the Eastern Mediterranean region. We use a combined analysis of n-alkane distributions and their carbon and hydrogen isotope compositions ( $\delta^{13}\text{C}$  and  $\delta\text{D}$ ) on a 2.6 m long sediment core retrieved from the central part of the lagoon. The age-depth model based on 7 radiocarbon dates suggests that the sequence covers the last 3600 years. Our geochemical multiproxy approach shows that the organic matter in this lagoon is mainly derived from the local aquatic vegetation largely affected by climate changes. Macrophyte-dominated periods correspond to wet episodes, when lower salinity and higher water-level created favorable conditions for aquatic plant growth. Our climate reconstruction (mainly based on the leaf wax  $\delta\text{D}_{31}$ ) shows major shifts from dry and/or warm periods at ca 3600–3000 cal BP and ca 2000–1300 cal BP to wet and/or cold episodes at ca 3000–2700 cal BP and ca 1300–900 cal BP, the latter coinciding with the early MCA. The late MCA at 800–900 cal BP is characterized by relatively drier and/or warmer conditions. The period ca 700–200 cal BP is the wettest and/or coldest in our record and coeval with the Little Ice Age. The climatic fluctuation reported in our study can be explained by the relative dominance of high-latitude atmospheric modes (e.g. North Atlantic Oscillation) and low-latitude atmospheric patterns (Intertropical Convergence Zone shifts and the associated Subtropical High), which suggests an Atlantic-Mediterranean-Monsoon climate link in this area for the late Holocene.

## **S08-O04 - Late Holocene precipitation changes from terrestrial and aquatic biomarkers in freshwater lake sediments in Vanuatu**

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The South Pacific Convergence Zone (SPCZ) is one of Earth's major precipitation features, with mean annual rainfall ranging from 10 mm/day in its northwest portion to 4 mm/day in its southeastern reach. Coral records suggest the mean annual position and precipitation intensity associated with the SPCZ have expanded and contracted on decadal to centennial timescales. Existing data is limited, making these changes difficult to characterize.

The Pacific archipelago of Vanuatu occupies an intermediate position in the modern SPCZ. It should therefore be sensitive to major contractions and expansions of the SPCZ, becoming wetter when it expands southeast, and drier when it contracts. In order to reconstruct changes in precipitation over the past millennium in Vanuatu, we collected sediment cores from White and Red Lakes, two adjacent freshwater lakes on Thion Island (15.03°S, 167.09°E), and measured hydrogen isotope ratios ( $^2\text{H}/^1\text{H}$ ) of lipid biomarkers from terrestrial plants (long-chain n-alkanes and n-alkanoic acids), aquatic plants (mid-chain n-alkanoic acids), and microalgae (dinosterol). For all measured biomarkers in White Lake,  $^2\text{H}/^1\text{H}$  ratios were 20-40‰ higher during the Little Ice Age (LIA, ~1450–1850 CE) relative to the preceding Medieval Climate Anomaly and to the 20<sup>th</sup> century, suggesting drier conditions during the LIA. Although algal lipid  $^2\text{H}/^1\text{H}$  followed a similar pattern in both lakes, leaf wax  $^2\text{H}/^1\text{H}$  ratios from Red Lake diverged sharply from those in White Lake. The leaf wax Carbon Preference Index and Average Chain Length values from Red Lake were consistently lower than in White Lake, suggesting a significant contribution from degraded soil carbon to Red Lake, which is proximal to steep terrain.

This study demonstrates the potential for H isotopes of single lipids from single sites to be dominated by non-hydrologic signals, and highlights the necessity of measuring multiple lipids from multiple sites in order to produce robust paleohydrologic records.

## **S08-O05 - Reconstruction of isotopic composition of palaeoprecipitation from a Middle Pleistocene lake at Marks Tey, Essex, UK**

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Oxygen isotope values of past precipitation are important tracers of past climate. Outside polar regions, where ice cores may be recovered, estimates of past isotopic composition of precipitation are uncommon. Lacustrine carbonate  $\delta^{18}\text{O}$  values offer the potential to reconstruct the past  $\delta^{18}\text{O}$  of lakewater, providing independent estimates of temperature are available. In short-residence time lakes with minimal evaporative enrichment,  $\delta^{18}\text{O}$  of lakewater may approximate that of precipitation. Provisional results are presented of a multi-proxy quantitative ostracod analysis, combining the Mutual Ostracod Temperature Range (“MOTR”) method with stable isotope data from the former lake basin at Marks Tey in Essex. The basin contains an archive of the Hoxnian interglacial (correlated with MIS 11c) and the transition to the next cold period. A sediment thickness of more than 24m overlying the interglacial sediments has been logged and sampled, from which air temperature ranges produced using the MOTR method suggest a cold-warm oscillation overlying the interglacial. These temperature estimates are combined with oxygen isotope values from *Cytherissa lacustris* valves to derive the isotopic composition of the palaeolakewater and potentially palaeoprecipitation. Limitations of the approach include the effects of evaporative enrichment, the impact of quite wide reconstructed temperature ranges on the calculation of water isotope values, and uncertainties about the relationship between air and water temperatures.

# **S08-O06 - A 18,000-year lacustrine high-resolution record of past temperature and hydroclimate dynamics from the Indo-Pacific Warm Pool**

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Deep convection in the Indo-Pacific Warm Pool (IPWP) is a major source of latent heat for the higher latitudes, and therefore plays a key role for climate dynamics. The IPWP is also a main moisture source for the East Asian and Australasian Monsoons. Lastly, it forms a key node in the dynamics of the El Niño Southern Oscillation (ENSO). Despite its importance, relatively little is known about the spatiotemporal evolution of IPWP (hydro)climate over longer timescales; only few high-resolution records exist. Here we present a new 18,000-year long hydroclimate record from Southern Thailand, based on the hydrogen isotopic composition of leaf waxes ( $\delta D_{\text{wax}}$ ), combined with a biomarker-based proxy record of past temperature. The dataset clearly shows that changes in orbital forcing exert a primary control on mean temperature and thereby on atmospheric convection in the region over decadal to millennial timescales. However, clear excursions from this general behavior can be observed during the last glacial termination (18–11 ka BP). The temperature proxy record indicates that our site was several degrees colder during most of this period, rising only significantly between 11.5–10.5 ka BP, when also the Sunda shelf became completely inundated. Maximum temperatures and greatest convective activity were reached in the mid-Holocene (6–4 ka BP) with a subsequent decrease. Our results add an important piece of the puzzle of the spatiotemporal evolution of the IPWP hydroclimate, providing a good testbed for ongoing climate modeling efforts.

## **S08-O07 - Carbonate stable isotope record of middle-to-late Holocene hydroclimate variability in the west-central Guatemala highlands**

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A long-term perspective of past hydroclimate variability for Central America provides important context for evaluating the potential impacts of Northern Hemisphere temperature changes and shifting influences of ocean-atmospheric processes. The isotopic composition of fine-grained endogenic carbonate samples from Lake Kail vary between  $\sim -8.5$  to  $-4.5\text{‰}$  (VPBD) over the last  $\sim 6000$  years. Based on empirical observations, we interpret the  $\delta^{18}\text{O}$  variations as a record of meteoric inputs; principally reflecting variations in the amount of precipitation and secondary influences from evaporation. The  $\delta^{18}\text{O}$  record indicates a trend of wetter conditions through the middle-late Holocene that tracks decreasing Northern Hemisphere insolation. Multi-decadal-to-centennial wetting events generally correspond to decreases in solar irradiance, colder Northern Hemisphere temperatures, and lower North Atlantic and Tropical Pacific sea-surface temperatures (SSTs). There are also centennial-scale wetting events centered on  $\sim 6000$ , 4300, 2800, 1500, and cal yr BP that are coincident with ice-berg discharge (AKA Bond events) in the North Atlantic. The period spanning the Little Ice Age (LIA) is marked by lowest  $\delta^{18}\text{O}$  values of the record.

## **S08-O08 - Interglacial variability in Central Asian (Lake Baikal) precipitation**

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Uncertainty surrounds the prospects for future changes in the hydroclimate across Central Asia in response to a warmer climate state. Lake Baikal, south-east Siberia, provides a unique opportunity to develop new insights into this issue by providing an uninterrupted sediment record that captures previous interglacials that may represent analogues for future hydrological change. Here, using a calibrated relationship between diatom oxygen isotopes and historical observations of precipitation; rates of regional Central Asian precipitation are reconstructed for Marine Isotope Stages 1, 5e and 11c. Through these interglacials, annual precipitation is closely related to the prevailing Milankovitch orbital parameters and summer solar insolation. On the basis of this relationship, mean rates of precipitation are reconstructed for other interglacials over the last 600 ka with MIS 1 (mean = 570 mm/yr) and MIS 11 (mean = 550 mm/yr) displaying the lowest rates of annual precipitation since the Mid Pleistocene Transition compared to values >600 mm/yr for other interglacials. In contrast, typical rates of regional precipitation have been considerably lower at <500 mm/yr through the 20<sup>th</sup> and 21<sup>st</sup> century to date.



# Poster Presentations

## **S08-P01\* - How dry was the Younger Dryas? Evidence from a coupled $\delta^2\text{H}$ - $\delta^{18}\text{O}$ biomarker paleohygrometer approach applied to the Gemündener Maar, Western Eifel, Germany**

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It is well known that the Younger Dryas – named after the alpine-tundra wildflower *Dryas octopetala* – was a cold spell occurring in the Northern Hemisphere during the Late Glacial. By contrast, there is much less clear evidence concerning moisture supply/availability and relative humidity changes during the Younger Dryas. Some studies suggest a two-phasing with humid conditions being succeeded by relatively dry conditions for northwestern and central Europe. More recent studies suggest that the Younger Dryas was overall drier than the preceding Allerød and the succeeding Early Holocene.

For this study, we investigated a Late Glacial sediment core that was retrieved from the Gemündener Maar in the Western Eifel, Germany. We analysed the hydrogen ( $\delta^2\text{H}$ ) and oxygen ( $\delta^{18}\text{O}$ ) isotopic composition of leaf wax-derived lipid biomarkers (n-alkanes) and hemicellulose-derived sugar biomarkers, respectively. Both  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$  are suggested to reflect mainly leaf water of vegetation growing in the catchment of the Gemündener Maar. Taking advantage of the finding that the isotopic enrichment of leaf water due to evapotranspiration depends primarily on relative humidity, we use (i) the coupled  $\delta^2\text{H}$  -  $\delta^{18}\text{O}$  biomarker approach to reconstruct the deuterium-excess of leaf water and (ii) calculate relative humidity (RH) values (corresponding to vegetation period and day-time RH) (c.f. Tuthorn et al., 2015; Hepp et al. 2017; Zech et al., 2013).

The results of our coupled  $\delta^2\text{H}$  -  $\delta^{18}\text{O}$  biomarker paleohygrometer approach (i) support the above-mentioned two-phasing of the Younger Dryas (ii) do not corroborate overall drier climatic conditions characterising the Younger Dryas and (iii) suggest that the amplitude of RH changes during the Early Holocene, including a pronounced Preboreal humid phase, was much higher compared to the Younger Dryas.

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## **S08-P02 - Holocene Arctic precipitation and its response to sea ice extent – using leaf wax hydrogen isotopes as a proxy**

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Climate dynamics in the Arctic are complex due to feedback mechanisms between atmosphere, cryosphere and the oceans. Precipitation is particularly difficult to reconstruct due to lack of good proxies and because of high spatial and temporal variability. Addressing this problem is the starting point of this new project, aiming to use leaf wax hydrogen isotopes in lake sediment cores from Svalbard and North Norway to generate Holocene Arctic precipitation records. Improved understanding of Arctic precipitation is important since it is one of the main controls on glacier mass balance. Furthermore, Arctic precipitation is closely linked to changes in sea ice, a key indicator of Arctic climate change. Loss in sea ice results in larger areas of open water, facilitating moisture transport to the Arctic. Fluctuations in sea ice extent is expected to have influenced precipitation in Svalbard, but not mainland Norway since the sea ice has not reached that far south in the Holocene. By analyzing lake sediments from both Svalbard and North Norway we hope to be able to identify differences in precipitation, possibly connected to changes in sea ice extent in the past. In addition, analyses of leaf wax hydrogen isotope composition in modern sediment from sediment traps and hydrogen isotopes from lake water and precipitation will provide information about the seasonal signal. This will in turn improve our understanding of Arctic precipitation variability, and allow us to place recent and current climate and environmental change into a long-term context.

## **S08-P03\* - Interpreting hydro-isotope records from Patagonia by means of backward trajectories, surface water surveys and refined isotope proxies**

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Very strong and persistent zonal atmospheric flow in the mid-latitudes of the Southern Hemisphere forms the westerly wind belt. This wind belt advects moist air masses from the Pacific Ocean towards the Andes and leads to precipitation on its upstream side due to orographic lifting but aridity on the downwind side due to a foehn effect. Knowledge is scarce about the exact regions of moisture uptakes and their respective movement patterns. Moisture origins have been evaluated by backward trajectories and compared with hydrogen and oxygen stable isotope composition of precipitation of stations from the Global Network for Isotopes in Precipitation. Stations downstream of the Andes show isotopic depletion caused by Rayleigh-type isotope fractionation compared to upstream stations, despite of similar moisture sources. Moisture recycling above the continent plays a major role for a station further east at the Atlantic leading to heavy-isotope-enriched rainfall there.

This information is of high significance for the interpretation of oxygen isotope records from Patagonian lake sediments, peats or tree-rings used to reconstruct past atmospheric and hydrological dynamics. Beside a few GNIP stations, the modern database needed for the calibration of isotope proxies from remote Patagonia areas is extremely poor. To overcome this lack of data, lentic and lotic waters from Chile and Argentina were sampled between 2013 and 2018.

We show that the water balance has a strong influence on the isotopic composition of lentic waters. Bathymetry, exposition to wind, inflows, outflows, and climatic settings influence their water balances, and in turn have a strong influence on the isotopic composition of lakes. Thus, the choice of sites and of reliable proxies for the oxygen isotopic composition of the lake water is especially important. Methodologically refined proxies, such as oxygen isotope ratios of aquatic cellulose and chironomid head capsules, provided promising results in our calibration studies.

## **S08-P04\* - Rising S/Fe ratios in recent lacustrine sediments: post-sedimentary overprint or an indicator of anthropogenic sulphur emissions?**

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Anthropogenic SO<sub>2</sub> emissions have been increasing since the industrial revolution and peaked in Europe about 1975. These emissions can be related to increasing sulphate concentrations, supposedly originating mainly from acid rain, in lakes of the study area of North-Eastern Germany during the last century. Besides acidification, there is a general trend of eutrophication in this area. Our study investigates whether a link between S-emissions and eutrophication can be established and whether the isotopic signature of the source of sulphur in sediments can be tracked.

Rising S/Fe ratios in recent lake sediments were observed in many lakes in the area. In Lake Stechlin eutrophication began roughly in 1990, but S/Fe ratio suggests a much earlier start. The question arises whether the signal has been caused by S-emissions or by eutrophication. If downward diffusing HS<sup>-</sup> caused the post-sedimentary signal formation, vertical isotope fractionation is possible. Because Fe-sulphide formation in lacustrine environments is usually limited by the concentration of sulphur, an isotope fractionation effect is assumed to be small and δ<sup>34</sup>S of Fe-sulphides (acid volatile and chromium-reducible sulphur fractions) is assumed to reflect the isotopic signature of the sulphur source most precisely. Furthermore, due to transformation of Fe-oxide/hydroxides to Fe-sulphides, long-lasting P-retention capability of the sediment could be reduced and eutrophication could be stimulated.

Previous studies about the correlation between anthropogenic S-emissions and eutrophication lack a multi-proxy approach which would account for changes in the depositional environment and which would clarify whether organic matter, Fe, or sulphur was the limiting factor for Fe-sulphide formation. We are going to explain the meaning of S/Fe ratios in lakes of the southern Baltic Sea lowlands by various depositional and redox proxies at a high vertical spatial sampling resolution. Finally, isotopic composition of different S-fractions will be used to describe the timing and source of S-emissions.

## **S08-P05\* - Lakes in Southern Greece and their potential as archaeohydrological archives**

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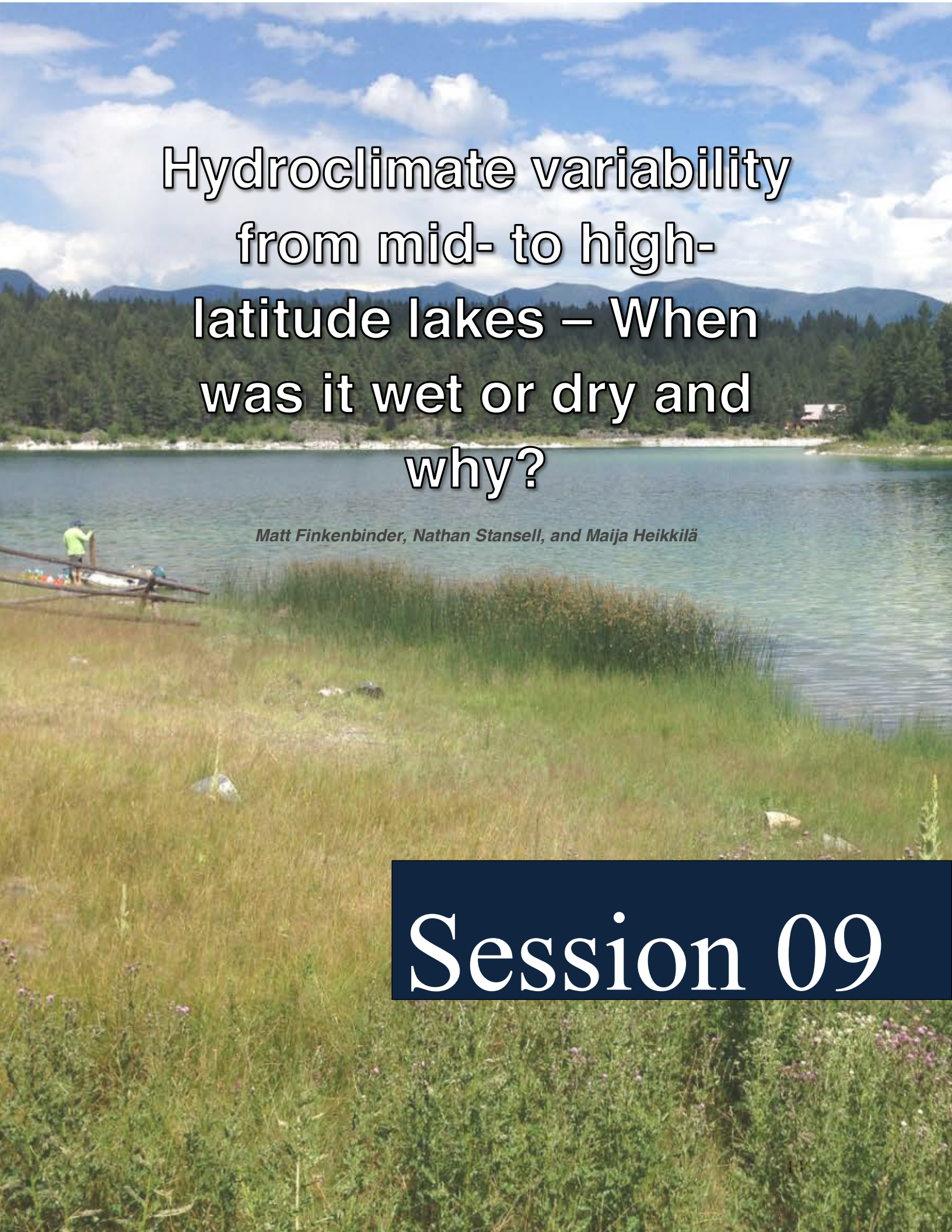
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Environmental and cultural changes and their mutual relationship or influence have long been a subject of research in the Eastern Mediterranean region with its long historical and prehistorical record. However, environmental records with a comparatively high temporal resolution near archaeological sites are still very rare in Southern Greece. We here present a newly started project which aims to reconstruct environmental changes and their influence on the cultural development in the region around the Gulf of Corinth with a temporal focus on the Bronze Age/Iron Age transition (12<sup>th</sup> to 8<sup>th</sup> century BC) based on a complementary study of limnological and archaeological archives. We use inorganic geochemical and sedimentological proxies from selected (palaeo)lakes on the northern Peloponnese (Stymphalia, Pheneos and Kaesari) and from Aetolia-Akarnania (Trichonida). The aims of our project are (a) to reconstruct the changes in hydrological dynamics; (b) to describe reactions of regional hydrology to climate variations reported for the higher latitudes and potentially find coupling mechanisms; (c) to differentiate natural environmental conditions in the region from effects of human influence on the local hydrology, erosion, and sedimentation; (d) to interpret this data in the context of the societal development derived from the archaeological record. The individual aims cumulate into a better understanding of socio-environmental interactions with a focus on water availability and water demand in the past. Combining our geochemical analyses from lake archives with sedimentological and pedological analyses from the catchment(s) promises detailed palaeo-environmental information at a resolution that goes beyond the capabilities of each individual method. The connection with knowledge of social developments derived from archaeological data and the reconstruction of scenarios of transformation will enable us to disentangle and evaluate the role of natural and human-induced environmental changes within societies of changing complexity.



A scenic landscape of a lake with mountains in the background and a person in a canoe on the water. The text is overlaid on the top half of the image.

# Hydroclimate variability from mid- to high- latitude lakes – When was it wet or dry and why?

*Matt Finkenbinder, Nathan Stansell, and Maija Heikkilä*

**Session 09**

## Oral Presentations

### **S09-001 - Hydroclimate variability of northern Patagonia during the last 20 kyr inferred from the bulk organic geochemistry of Lago Castor sediments (Chile, 45°S)**

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Lago Castor (45°S, 72°W) contains a continuous sediment record of the last 20 kyr, which was recently interpreted in terms of past changes in westerly wind strength, based on sediment physical properties and seismic data (Van Daele et al., QSR 2016). Here, we use the bulk elemental and isotopic composition of the organic matter preserved in Lago Castor sediments to reconstruct changes in the supply of organic matter of terrestrial and aquatic origin to the lake through time. Results show that the lake sedimentary organic matter is composed of variable proportions of aquatic plankton, C<sub>3</sub> terrestrial plants, and aquatic macrophytes. Before 17.8 cal kyr BP, aquatic macrophytes were abundant, likely due to the postglacial lake level rise. After 17.8 cal kyr BP, accumulation rates of organic matter of terrestrial origin increased, while those of aquatic macrophytes became negligible, which is interpreted as the densification of the regional terrestrial vegetation due to the evolution of the regional climate towards temperate conditions. From 9.3 cal kyr BP onwards, accumulation rates of both aquatic macrophytes and C<sub>3</sub> plants increased and peaked between 7.5 and 2.7 cal kyr BP. The latter is interpreted as a period of increased precipitation, and is in excellent agreement with the grain-size results previously obtained on the same sediment core. These results, which are broadly compatible with regional pollen records, highlight the potential of bulk organic geochemistry to independently reconstruct hydroclimate variations from lake sediments.



## **S09-002 - East vs West: differing precipitation regimes cause a climatic dipole during the Holocene Thermal Maximum in northern Ontario, Canada**

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The climatic history of the northern Ontario boreal forest region is poorly understood compared to the rest of North America. Specifically, the onset, duration, and character of the Holocene Thermal Maximum (HTM) has not been investigated in this region until recently. Paleolimnological studies examining various biological proxies show that the HTM of northwest Ontario was characterized by high temperatures and functionally low moisture which resulted in regionally low lake-levels, higher lake production, and a shift of the prairie-forest ecotone to the east. The nature of the HTM in northeastern Ontario is almost totally unknown with one palynological study that suggests a delayed and protracted HTM compared to the northwest. In our study, we collected two piston cores from Hogsback Lake; a small, headwater, high elevation, remote lake from northeast Ontario. One core was taken from the deep basin (38 m); the other from the mid-depth slope (21 m) as analysis of surface-sediment diatoms identified this depth as the benthic-planktonic boundary. Preliminary diatom analysis show very different regimes compared to those from the west of the province. Holocene diatom assemblages from Hogsback Lake suggest slightly warm conditions early in the Holocene which dissipated within two thousand years. In northeast Ontario, there is no evidence of a decrease in lake level, however, suggesting that the evaporative conditions of northwest Ontario did not occur in the northeast. This agrees with pollen studies from southern Ontario and the northeast United States which show wet and warm conditions during the HTM. The milder inferred temperature, compared to northwest Ontario, may be due to downwind cooling effects from the remnants of the Laurentide Ice Sheet. The disparity between the HTM climates of northwest and northeast Ontario suggest a climatic dipole which is consistent with results from ocean-atmosphere-vegetation climate models of the Holocene of North America.

## **S09-O03 - The Garden Basin cattail fen, central Utah, USA, reveals a 12.5 ka record change from pond to fen and the attendant magnitude of precipitation change**

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Small pond-wetland systems make excellent archives of climate variability because they oscillate between wet ground (dry climate) and perennial standing water (wet climate) states. Thus, large responses are found diatoms, pollen, biogenic silica (BSi), and organic matter pyrolysis proxies. Such systems may have small catchments, simplifying the quantification of precipitation changes required to convert a wetland into a pond. We report a multi-proxy record from the Garden Basin cattail (GBC) fen (2250 m elevation, 38.516°N, 111.419°W) in central Utah, USA. This wetland, and others nearby, formed in the swales of a large paleo-landslide and have basal sediment ages between 12.9 and 10.5 ka.

The GBC fen pollen, diatoms, and pyrolysis (RockEval) reveal three major climate states: a) a wet but variable episode from 12.5–10 ka, b) a dry period from 10–6 ka and, c) a return to wet conditions after 2.5 ka. Sage/amaranth and sage/ragweed ratios indicate elevated annual and summer precipitation during periods a) and c). The diatom record confirm oscillations between pond and fen as recorded by aerophilic and aerophobic diatoms. Pyrolysis, measuring the balance between sedimentary algal and terrestrial plant organic matter, shows higher algal content during wet (pond) episodes. The BSi record (like pollen, diatoms, and pyrolysis) shows large variations during period a), suggesting that beside variable precipitation, green or blue-green algae may periodically out compete diatoms.

Proxy records, as detailed as they are, can only show relative rather than absolute changes in precipitation. Relative to its size, the GBC fen has a large catchment, suggesting that small changes in precipitation may change the fen to a pond. A simple water budget suggests that a 5-10 cm annual increase in precipitation will change the fen from a state of no standing water to a pond that spills surface water the entire year.

## **S09-004 - 12 kyr record of flood and environmental changes in Southern Alps (Lake Iseo, Italy)**

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The high-resolution sedimentological and geochemical analysis of a 21m sediment sequence from Lake Iseo (Southern Alps, Italy) led to reconstruct the long term hydroclimate variability by the identification of event layers over the last 12 kyr BP. In a previous study undertaken on another core, these layers were attributed to extreme surface runoff events. However, large mass-wasting deposits inducing important hiatus did not permit to establish a continuous record of such events. Our new sediment sequence does not present such disturbances and thus allows us to establish a high resolution continuous Holocene record. Based on the flood chronicle and XRF geochemical analyses, we evidence a major palaeohydrological transition at approximately 4 kyr BP, as previously described in the western Mediterranean region. The first part of the record presents very low frequency of flood events, while since 4 kyr BP the flood frequency increases. This pattern appears to be in phase with Southern Alpine palaeoflood records. This transition is interpreted as a nonlinear climate response to the orbital-driven gradual decrease in summer insolation at 60°N, with the influence of Mediterranean mesoscale precipitation events, typical of the Mediterranean climate. We propose to compare the flood record, with archaeological and historical data coming from the watershed. The human activity attested in the vicinity of the main tributary from the Roman period seems to be one of the key to understand the flood chronicle. This evidences that even in a large Alpine lake, sedimentation process and hydroclimate record can be impacted by the anthropization of the catchment area.

## **S09-O05 - Diatom response to late Holocene climate evolution as recorded in the sediment record of an alpine lake in the Pamir Mountains (Xinjiang Province, western China)**

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In Central Asia the various paleo-climatic archives analyzed so far have provided contrasting results and suggest high regional variability and a complex interplay between the westerlies and Siberian High. Here we present the diatom analysis of the sedimentary records from two neighboring lakes located in the Pamir Mountains (western China) that records climatic changes during the late Holocene.

Diatom assemblages in the two lakes have similar composition. To help interpreting the sequences, the diatom composition in surface sediment samples collected across a water depth gradient was investigated. Three assemblages were identified: (i) a near-shore assemblage composed of epiphytic species (mainly of the genera *Cymbella*, *Encyonopsis* and *Gomphonema*) in association with the planktonic *Pantocsekiella comensis*; (ii) a mid-depth (7-11 m) assemblage dominated by benthic species that include the epipsammic *Amphora indistincta* and small *Fragilariaceae*; and (iii) a deep-water assemblage almost exclusively composed of the planktonic *Pantocsekiella comensis*.

The sequence from the larger lake varies little and is completely dominated by *Pantocsekiella comensis*. By contrast, the smaller lake is marked by the alternation of assemblages dominated by *Pantocsekiella comensis* in association with epiphytic species, and assemblages dominated by *Amphora indistincta* and benthic *Fragilariaceae*. Dominance by the “mid-depth assemblage” is indicative of high water transparency and corresponds with dry intervals. By contrast, low proportions of the “mid-depth assemblages” correspond with lower water transparency during wetter intervals. These wet intervals are also characterized in the grain size analyses by high silt content. Our record shows 7 wet episodes (4950–3950; 3500–3250, 2750–2600; 1700–1580; 1190–1150; 620–570; 300–100 cal. years B.P.) and 7 dry episodes (3950–3500; 3250–2750; 2600–1700; 1580–1190; 1150–620; 570–300; and 100 cal years B.P. to the present).

## **S09-O06 - Holocene hydroclimate variability in the eastern Baltic region inferred from open and closed-basin lake sediment stable isotope records**

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Radiocarbon dated, finely laminated carbonate lake sediments from southern Estonia record late Holocene precipitation and evaporation (P/E) changes. Lake Nuudsaku is an open-basin lake with a seasonally active overflow that is fed by active springs and groundwater. Lake Pangodi is a closed-basin lake making it sensitive to summer evaporation. Lake Nuudsaku water isotope values display pronounced seasonal variability: lower values for winter precipitation and higher values for summer. In contrast, water isotope values from Lake Pangodi are enriched relative to meteoric water, indicating that P/E balance is a strong influence on lake hydrology. Local modern winter and summer precipitation samples have  $\delta^{18}\text{O}$  values ranging from  $\sim -18$  to  $-13\text{‰}$  and  $\sim -8$  to  $-5\text{‰}$  VSMOW, respectively. We interpret the  $\delta^{18}\text{O}$  record from Lake Nuudsaku as principally reflecting variations in the source and seasonality of precipitation rather than overall moisture-balance. The Lake Pangodi record has  $\delta^{18}\text{O}$  values that are consistently  $\sim 3$  to  $9\text{‰}$  enriched relative to modern meteoric water samples, indicating that the lake was sensitive to evaporative enrichment throughout the Holocene. The combined records suggest that the early Holocene was overall drier and the middle Holocene was wetter. The middle-late Holocene transition at  $\sim 4200$  cal yr BP was a shift from higher to lower P/E for much of the late Holocene. Conditions became increasingly drier through the Medieval Climate Anomaly (MCA) until  $\sim 700$  cal yr BP. The Lake Pangodi record also suggests that the last  $\sim 600$  years had the highest P/E (wettest) conditions of the late Holocene. The Lake Nuudsaku record of precipitation seasonality suggests that periods with greater winter precipitation occurred at times of shifting North Atlantic temperature and circulation dynamics. Additionally, the Pangodi and Nuudsaku records suggest that summer P/E changes were affected by both changing North Atlantic conditions and shifts in regional summer temperatures.

## **S09-007 - A 27 ka paleoenvironmental lake sediment record from Taro Co, central Tibetan Plateau: implications for the interplay between monsoon and the Westerlies**

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The interaction of the Indian Ocean Summer Monsoon (IOSM) and the Westerlies is a crucial scientific issue to understand how they impact the climate on the Tibetan Plateau (TP), especially in the geological times. Here we present a lake sediment record retrieved from Taro Co covering the last 27 ka to elucidate how the IOSM and the Westerlies interact.

Taro Co (486 km<sup>2</sup>, Dmax: 132m, 4565 m a.s.l., currently closed), located on the central TP, is a fresh lake with the major supply from glaciers. Two parallel piston cores as well as several gravity cores were retrieved from the deepest parts. These cores were correlated based on high resolution XRF scanning and a continuous 1069 cm-long core was finally integrated. Chronology was determined by <sup>210</sup>Pb, <sup>137</sup>Cs and AMS <sup>14</sup>C measurements. Multidiscipline analyses including grain size, total organic carbon (TOC), total nitrogen, diatom, pollen and n-alkanes were accomplished to reconstruct paleoenvironmental changes.

The lake level of Taro Co was low since 27 cal ka BP indicated by very coarse materials and diatom assemblages. The terrestrial water input decreased continuously reflected by such elements as Si, Ti, Fe, K. It is likely that there was a sedimentation gap between 961–954cm, corresponding to 23.4 to 18.6 cal ka BP probably demonstrated Taro Co was very shallow at that period. The first prominent abrupt change of most proxies was observed at 14.7 cal ka BP showing a great lake deepening which likely indicated an enhancement of IOSM. There were several spells with abrupt changes of cold/warm stages before the Holocene and the Younger Dryas event occurred at 11.8 cal ka BP. During the Holocene, carbonate dissolution was identified at 9.76 to 3.44 cal ka BP which indicated a high moisture availability hence high lake level even the lake became an open system.

# Poster Presentations

## **S09-P01 - Australian subtropical hydroclimate variability 80–40 kyr**

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In Australia, very few continuous sediment records extend beyond 40,000 years before present (40 kyr). As such, understanding of Australian climate during MIS 4 (71–58 kyr) and MIS3 (57–29 kyr) – periods known for climatic instability – is incomplete, and questions remain regarding the presence and impacts (if any) of rapid climate changes observed in this period in ice cores. Yet understanding Australian climates of this period is important as it encapsulates the timing of human arrival on the continent and the demise of its megafauna. Without knowledge of palaeoclimate variability, it is neither possible to fully assess the causes of megafauna extinction, nor the impacts of human arrival.

Here we present a new palaeoclimate record for the 80–40 kyr period derived from the oxygen isotope ( $\delta^{18}\text{O}$ ) composition of aquatic cellulose in sediments from Welsby Lagoon – a freshwater wetland in subtropical eastern Australia. In conjunction with other proxy data, the record indicates a (relatively) stable MIS4, followed by substantial variability in subtropical climates during MIS3. These results contrast with modelled climate data – which suggest some temperature variability in MIS4, though little precipitation change between 80 and 40 kyr – that have been used to support the argument for human agency in megafauna extinctions (Saltre et al., 2016; *Nature Comms.*, 7:10511). Patterns of variability in the Welsby Lagoon data also suggest linkages to remote climate forcing during MIS3, though further refinement of the chronology is required to fully test this. Given the paucity of similar aged records in Australia, these results highlight that significant uncertainties remain with respect to Australian climate variability, with relevance to understanding the mechanisms of SH climate change and their impacts on ecology and human behaviour.

## **S09-P02 - Westerlies Asia and monsoonal Asia: spatial difference in climate change and possible mechanisms on decadal to sub-orbital scales**

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'Anti-phase' or 'out-of-phase' relationships in precipitation/moisture changes between inland arid Asia and eastern monsoonal Asia occurred on different timescales during the Holocene. Moreover, we can propose the existence of a 'Westerlies-dominated climate regime' (WDCR) in mid-latitude Asia in the present interglacial period. In this study, we first review the development of a theoretical framework for the WDCR, and define the boundary of its core area: from the Caspian Sea in the west to the western region of the Hexi Corridor in the east, while the northern and southern limits coincide with those of arid central Asia. This spatial extent approximates to Central Asia and Xinjiang Province in China (36–54°N, 50–90°E). Second, we review all the evidence for the existence of the WDCR on sub-orbital ('multi-millennial' herein) to decadal timescales during the Holocene. Finally, using climate simulation and reanalysis data, we consider the drivers of the WDCR and conclude that external factors (insolation changes induced by orbital factors) dominate the WDCR on a sub-orbital timescale, while a circum-global teleconnection was the most significant factor on centennial and decadal timescales. This study represents a comprehensive summary of the development of our knowledge about the WDCR over the past several decades, which we hope provides an initial theoretical framework for understanding climatic and environmental changes in this arid region, as well as a scientific basis for its environmental management and ecological restoration in the context of global warming.



## **S09-P03\* - Laminated Estonian lake sediment record as an indicator of past precipitation changes**

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Finely laminated lake sediments from Lake Nuudsaku, South-West Estonia, provide a high-resolution sedimentological evidence of the last 7.8 ka. The varves represent interannual and cyclical changes over longer time periods and provide an important link to past precipitation changes. Palaeomagnetic and physical-chemical properties of Lake Nuudsaku are used to help interpret the correlation between organic varve thickness and precipitation.

## **S09-P04 - East Mediterranean hydroclimate over the past 200,000 years as indicated from the Dead Sea sediments**

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An ICDP deep drilling in the Dead Sea Basin recovered a continuous 450 m record covering ~220,000 years. The Dead Sea watershed stretches between the Mediterranean climate zone and the Saharan-Arabian desert belt and its sediments reflect the interplay of the climate in these regions. The sediments comprise of mainly aragonite, gypsum, halite and detritus layers reflecting changes in the fresh water runoff into the lake. The wettest intervals are represented by alternating aragonite and detritus and occur during glacials when lake level was high. The driest intervals are represented by thick halite-rich layers that were deposited during interglacials when lake level was low. We generated a high resolution lake level based on the halite layers (that precipitate in a rate of ~15 cm per 1-meter lake level drop) and the abundance of aragonite interpreted from XRF scanning. Since the lake is enriched in Ca and depleted in  $\text{HCO}_3^-$ , aragonite precipitates when fresh water containing  $\text{HCO}_3^-$  enters into the lake. In addition to the average changes in runoff,  $^{234}\text{U}/^{238}\text{U}$  ratios in the lake, reflected by the ratio in the authigenic minerals (aragonite, gypsum and halite), show significant changes in the water sources around the lake during its driest periods. These are indicated by Pb and Sr isotopes as well.  $^{234}\text{U}/^{238}\text{U}$  activity ratio decreases from its typical value of ~1.5 (the ratio in its main water source – the Jordan River) to values down to ~1-1.2 at the driest interval at the end of MIS 5e, 116 ky ago and for a short while at the beginning of the Holocene. These changes are associated with Peak summer insolation in the Northern Hemisphere and reflect significant shifts in the lake's hydroclimate where the Jordan River becomes insignificant and eastern and southern water sources from the usually dry regions of the watershed become wetter.

## **S09-P05 - Holocene hydrological variability of Lake Ladoga, NW Russia as inferred by diatom oxygen isotopes**

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Lake Ladoga, the largest in Europe, was investigated as part of the German-Russian project 'Paleolimnological Transect' (PLOT) aiming at investigating the Late Quaternary climate and environment history along a transect crossing Northern Eurasia. Samples of sediment core (Co1309) which covers the past 10.5 cal ka BP contained sufficient diatoms to be analysed for oxygen isotope analysis. Our inferences are based on a comprehensive survey of both the modern hydrological system and diatom taxonomy.

The present-day lake water isotope composition (mean  $\delta^{18}\text{O}_{\text{lake}} -9.8\text{‰}$ ), corresponds with the most recent  $\delta^{18}\text{O}_{\text{diatom}}$  of  $+30.7\text{‰}$ , indicating a water-silica isotope fractionation ( $\alpha = 1.0414$ ) in the right order of magnitude for local lake temperatures. However, the diatom isotopic variability is related to changes in  $\delta^{18}\text{O}_{\text{lake}}$  rather than to lake temperature. Changes in  $\delta^{18}\text{O}_{\text{lake}}$  are mainly driven by evaporation effects, and influenced as well by air temperature, hydrological and air-mass changes.

The data indicate that the lake existed as a freshwater reservoir at least since 10.5 ka cal. BP. Variations in  $\delta^{18}\text{O}_{\text{diatom}}$  range from  $+30.7$  to  $+35.1\text{‰}$ , and clearly reflect the Holocene Thermal Maximum as an interval of maximum  $\delta^{18}\text{O}_{\text{diatom}}$  around  $+35\text{‰}$  between 8 and 6.5 cal. ka BP. At 0.8–0.2 cal. ka BP, a prominent minimum around  $+31\text{‰}$  is visible corresponding to the Little Ice Age. A continuous depletion in  $\delta^{18}\text{O}_{\text{diatom}}$  since 6.6 cal. ka BP is in good agreement with late to mid-Holocene cooling. Lake level rise results in lower  $\delta^{18}\text{O}_{\text{diatom}}$ , whereas the lowering of the lake level causes higher  $\delta^{18}\text{O}_{\text{diatom}}$  due to respective changes in the P/E ratio. Generally, overall high  $\delta^{18}\text{O}_{\text{diatom}}$  around  $+33.9\text{‰}$  characterise a persistent evaporative lake system throughout the Holocene. As the Lake Ladoga diatom isotope record is roughly in line with the  $60^\circ\text{N}$  summer insolation, a linkage to broader-scale climate change is likely.

## **S09-P06 - Holocene hydroclimate variability in central Scandinavia inferred from flood layers in contourite drift deposits in Lake Storsjön**

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Despite the societal importance of extreme hydroclimate events, few paleoenvironmental studies of Scandinavian lake sediments have investigated flood occurrences. Here we present a flood history based on lithological, geochemical and mineral magnetic records of a Holocene sediment sequence collected from contourite drift deposits in Lake Storsjön (63.12° N, 14.37° E). After the last deglaciation, the lake began to form around 9800 cal yr BP, but glacial activity persisted in the catchment for about 250 years. Element concentrations and mineral magnetic properties of the sediments indicate relatively stable sedimentation conditions during the Holocene. However, human impact in the form of expanding agriculture is evident from about 1100 cal yr BP, and intensified in the 20<sup>th</sup> century. Black layers containing iron sulfide appear irregularly throughout the sequence. The increased influx of organic matter during flood events led to decomposition and oxygen consumption, and eventually to anoxic conditions in the interstitial water preserving these layers. Elevated frequencies of black layer occurrence between 3600 and 1800 cal yr BP reflect vegetation changes in the catchment as well as large-scale climatic change. Soil erosion during snowmelt flood events increased with a tree line descent since the onset of the neoglacial period (around 4000 cal yr BP). The peak in black layer occurrence coincides with a prominent solar minimum around 2600 cal yr BP, which may have accentuated the observed pattern due to the prevalence of a negative NAO, a longer snow accumulation period and consequently stronger snowmelt floods.

## **S09-P07\* - Reconstructing Late Holocene humidity in C Sweden by high-resolution oxygen isotope analysis of bulk carbonates**

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Stable oxygen isotope records have been used for palaeoclimate reconstructions since the mid-20<sup>th</sup> century, including several studies in central and northern Sweden, and here the method has been applied to bulk carbonates from the sediments of Lake Blektjärnen, Jämtland. The study followed up on previous work in the lake and used bulk carbonates to improve the resolution of the record to c. 15 years per sample, reaching back some 2,350 years. Results were mostly compliant with previous studies in the region and indicated a wetting trend around 2,300–1,300 cal. yrs. BP, a wet Medieval Warm Period, and a dry Little Ice Age. The study demonstrates possible advantages of bulk carbonate sampling for the analysis of stable oxygen isotopes and provides high-resolution data on Late Holocene humidity changes in central Sweden.

## **S09-P08 - Environmental evolution of Xingkai (Khanka) Lake since 200 ka by OSL dating of sand hills**

Ji Shen (1), Yun Zhu (1) and Hao Long (1)

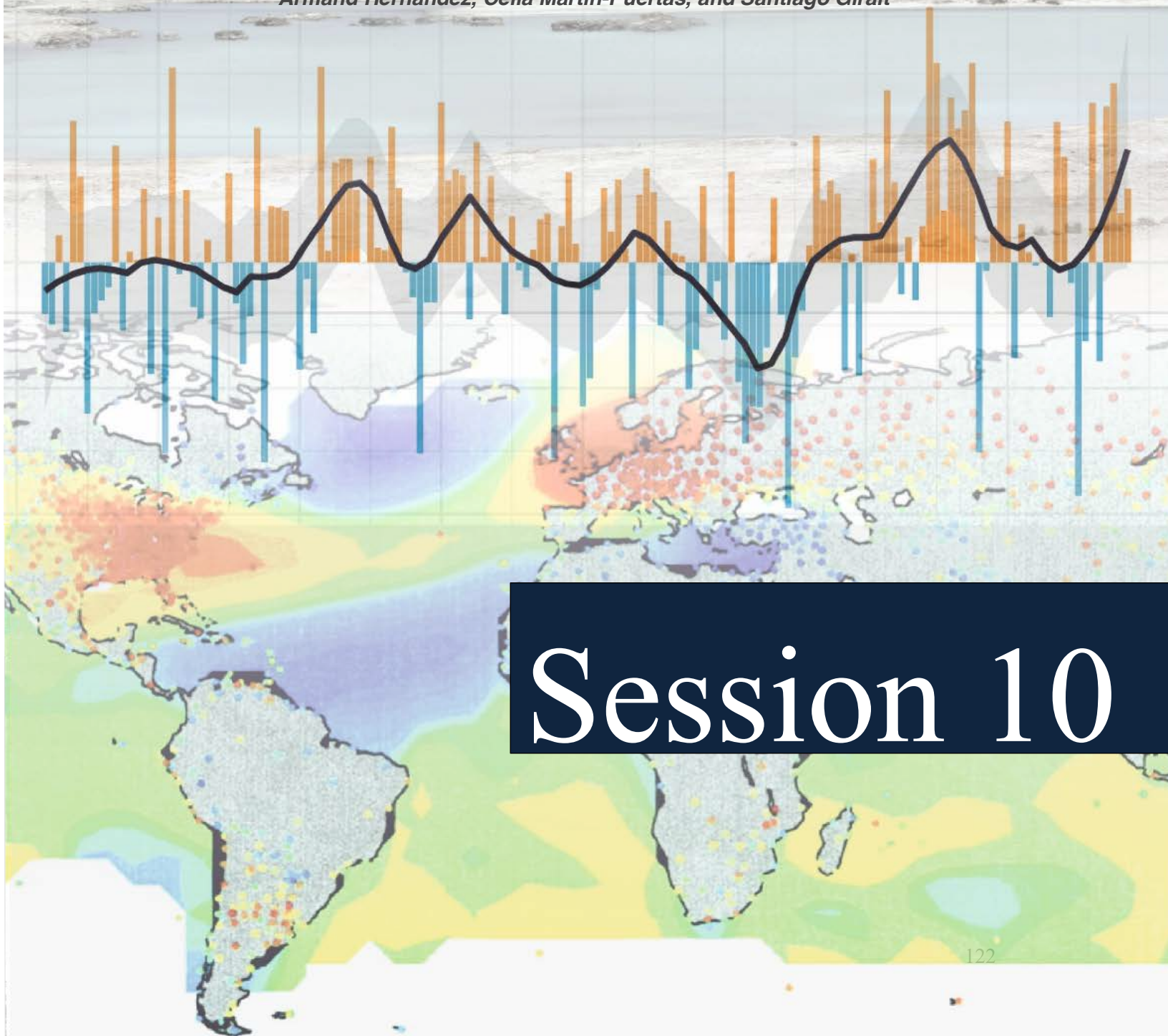
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Xingkai Lake is the largest freshwater lake in Northeast Asia. In addition to the lakeshore, there are four sand hills on the north side of the lake that accumulated during a period of sustainable and stable lacustrine transgression and were preserved after depression. Analysis of well-dated stratigraphic sequences based on 18 OSL datings combined with multiple index analysis of six sites in the sand hills revealed that the north shoreline of Xingkai Lake retreated in a stepwise fashion since the middle Pleistocene, and that at least four transgressions (during 193–183 ka, 136–130 ka, 24–15 ka and since 3ka) and three depressions occurred during this process. The results of this study confirmed that transgressive stages were concurrent with epochs of climate cooling, whereas the period of regression corresponded to the climatic optima. Transgressions and regressions were primarily caused by variations in the intensity of alluvial accumulation in the Ussuri River Valley and fluctuations in regional temperature and humidity that were controlled by climatic change. Moreover, one obvious transgressive process that occurred in MIS3 may have been related to enhanced precipitation that was reportedly widespread in the west of China, while short-term fluctuations in the lake level might well be a direct response to regional precipitation variations on the millennial scale.

# Present and past lacustrine responses to climate modes

*Armand Hernández, Celia Martín-Puertas, and Santiago Giralt*



## Session 10

# Oral Presentations

## **S10-001 - Aquatic ecosystem response to the transition from SWW to ENSO dominant climate during the Holocene**

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Climate change is an important driver of aquatic ecosystem response in temperate regions of the world. However, their response to different climate systems and changes in climate variability need more attention with predicted increases in climate extremes. Using sites from the southwest Pacific we examine how aquatic ecosystems respond to changing climate and climate systems through time. Tasmania is the chosen research area due to an apparent shift in climate systems during the Holocene from south westerly wind (SWW) dominance to El Niño Southern Oscillation (ENSO) driving hydroclimate. Using a palaeolimnology approach from several multiproxy datasets (charcoal, pollen, elemental and isotopic Carbon Nitrogen, XRF geochemistry, pollen, diatoms, and cladocerans) we examine aquatic ecosystem response to long-term climate change and transitions in dominant climate systems. Our results demonstrate that these aquatic ecosystems are indirectly driven by climate via the terrestrial environment during phases dominated by SWW climate. With the onset of ENSO, the relationship between the terrestrial environment and aquatic ecosystems is altered. The increase in climate variability caused by ENSO results in increased fire disturbance and more abundant sclerophyll vegetation causing nutrient depleted terrestrial environments and a change in the aquatic ecosystem and the response to climate.



## **S10-O02 - The link between typhoon precipitation and sedimentation processes in an alpine, subtropical lake.**

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The relationship between typhoon amplitude, frequency, and long-term climate change in late Holocene has drawn attention and previous studies in coastal areas of Northwest Pacific suggested that the number of typhoons increased during La Niña-like periods, including the Little Ice Age. However, there is a lack of modern sedimentological observations comparing typhoon and non-typhoon seasons, limiting our understanding of how typhoons are recorded in the sedimentary record. Cueifong Lake, a small lake with river input during raining season and no outflow is located at altitude of 1,840 meters in northeastern Taiwan in the subtropical western Pacific Ocean. The lake receives 4275 mm of precipitation per year, with 59% of the precipitation delivered by typhoons. In this study, we use the organic and inorganic composition from monthly collected sediment traps to observe the sediment features of dry season, wet season, and modern typhoon events. The observations of modern sediment are used to assess typhoon signals in a 1.85 m long core record which was drilled in the lake center. The typhoon events are identified by comparison to a baseline from the modern trap observations, and sedimentation rate in the core record is determined by  $^{210}\text{Pb}$  dating. The aim of this study is establish how frequency and amplitude of typhoon events have changed during the late Holocene.

## **S10-O03 - Cyclic burial of palaeo-oxidation fronts in sediments of Lago Fagnano, Tierra del Fuego, potentially triggered by oscillations of the Southern Westerlies**

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Lago Fagnano (54°S Tierra del Fuego, Argentina/Chile) is the southernmost ice-free lake outside Antarctica and, as such, a gateway to understand past and present relations between Antarctic, South Pacific and South Atlantic climate changes. The Holocene sediments exhibit a cyclic alternation of light grey clay and dark green to black laminae suggesting a well-stratified lake under certain environmental or climate conditions. However, currently extreme westerly winds impact Lago Fagnano the whole year promoting lake mixing especially during austral summer. Here we aimed at clarifying the mechanism and climatic forcing of laminae formation in Lago Fagnano under well-mixed and oligotrophic conditions. Using high-resolution XRF scanning and mapping, thin section, XRD and SEM analyses of sediment cores, we identified Fe- and Mn-oxides as triggering the lamination on (sub-) decadal timescales. We interpret black and greenish laminae as buried palaeo-oxidation fronts that underwent early diagenetic processes. The burial of redox fronts in Lago Fagnano is most likely promoted by cyclic rapid increases of sedimentation due to higher runoff or mass-wasting events. Increased runoff is related to the strength of the Southern Hemisphere Westerlies that, in turn, is modified by climate oscillations. Therefore, we suggest that the cyclic repetition of the buried palaeo-oxidation fronts, showing periodicities of ~52 and ~4.5 years in the western and eastern sub-basins of Lago Fagnano, respectively, is forced by climate modes. The most likely candidates are the Antarctic Oscillation (AAO) and the El Niño Southern Oscillation (ENSO), both impacting southernmost South America and showing similar sub-decadal modes and multi-decadal variations.

## **S10-O04 - Eemian Interglacjal (MIS 5e) environmental changes recorded in three palaeolakes discovered in Bełchatów Opencast Mine in Central Poland – Cladocera Data**

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The results of Cladocera investigations of the Eemian (MIS 5e) lacustrine sediments of three palaeolakes: Kuców IIc, Parchliny 2014 and Parchliny 2016 are presented. Subfossil Cladocera analysis has revealed detailed results covering the last 13,000 years. From 2000 this method is used in Poland for examination of older sediments from before the last glaciation. Cladocera remains were prepared according to a slightly modified standard procedure (Frey, 1986). The study area is located in central Poland at the boundary of the Szczerców Basin and the Bełchatów Plateau. It extends about 10–20 km to the north from the maximum limit of the Wartanian end moraines or glaciofluvial fans. The studied Eemian palaeolakes were formed at the end of the Warta Glaciation in tunnel and kettle holes. They had preserved a continuous record of environmental changes throughout the Early Eemian Interglacial, until the Early Vistulian Glaciation. The main aim of this study was to reconstruct the development of the Eemian reservoirs unveiled in the Bełchatów Opencast Mine during interglacial climate change. The sediment samples were taken from the Bełchatów field – Kuców IIc section and from the north-eastern part of Szczerców field – Parchliny 2014 and Parchliny 2016 section. The analysis showed that the deposits contained well-preserved fragments of various Cladocera species of age above 100,000 years old. Most of the 18 species identified belonged to the littoral group living among aquatic plants and in bottom sediments. In the analyzed samples, a considerable minority were the open-water species. The identified species were *Ceriodaphnia* sp. and *Daphnia pulex* group and *Bosmina longirostris*. The superiority of the littoral species indicates the shallow nature of the reservoirs. The species composition and the variability in the frequency of specimens of Cladocera made it possible to distinguish zones of the palaeolakes development, which well correlate with pollen data.

## **S10-O05 - Southern Hemispheric Westerly and ENSO-linked climatic variability recorded in the sediments of Laguna Azul (southern Patagonia, Argentina)**

**Bernd Zolitschka (1), Stephanie Janssen (2), Nora Maidana (3), Christoph Mayr (4,5), Torsten Haberzettl (6), Hugo Corbella (7), Andreas Lücke (8), Christian Ohlendorf (1) and Frank Schäbitz (2)**

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Different climatic modes interact across time and space. With lacustrine proxy-based climate reconstructions ideas about the spatio-temporal evolution and interactions of climate modes are developed. Here we present multiproxy and radiocarbon-dated investigations of lacustrine sediments from the Lateglacial crater lake of Laguna Azul (52°S) and introduce high-resolution data of hydroclimatic variability from southeastern Patagonia. These data document a multi-millennial Holocene variability of the Southern Hemispheric Westerlies (SHW) overprinted by centennial warm/dry phases for the last 4000 years. The climatic fluctuations impacted on water-column stratification as well as on the lake-level with feedbacks on lakeshore erosion, algal communities, trophic conditions, lake bottom-water oxygenation and authigenic mineral formation. The lacustrine history started with a cool/wet period from 11,600–10,100 cal. BP followed by an extended Early Holocene dry period (10,100 and 8300 cal. BP) with a shallower lake, ectogenic meromixis, strong anoxia, methanogenesis and high salinity. From 8300 until 4000 cal. BP the influence of SHW weakened resulting in less arid conditions and the development of a deep freshwater lake. Since 4000 cal. BP, regional temperature decreased accompanied by intensification of SHW reaching full strength at 3000 cal. BP. Superimposed on these multi-millennial SHW fluctuations, Laguna Azul experienced century-long warm/dry spells during the Late Holocene contemporaneous with intensification of ENSO. These periods are centered around 3700, 2200, 1000 cal. BP and during the 20<sup>th</sup> century. Although less arid periods are evident between these dry periods, the only pronounced moist period is contemporaneous to the “Little Ice Age”. The record of Laguna Azul compares well with other South American archives documenting SHW variability. Different from variations of the SHW, the observed centennial fluctuations are regionally synchronous for southern South America and the Northern Hemisphere. Changes in solar activity, large volcanic eruptions and/or modulations of ocean circulation are potential triggers.

## Poster presentations

### **S10-P01 - Early human impact in the Azores Archipelago: A Late Holocene high-resolution paleoecological analysis from Lake Peixinho, Pico Island, Portugal**

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Human arrival on oceanic islands causes large-scale habitat alterations and extinctions of local flora and fauna. Understanding the processes of how humans transformed island environments soon after colonization is critical to current conservation and restoration strategies. Only a few islands worldwide provide the opportunity to examine island colonization within a period of recorded history. Such islands enable us to calibrate paleoecological methods and perform comparative analyses with other locales. According to the written sources, the Portuguese officially colonized the Azores Archipelago in the North Atlantic Ocean in the 15<sup>th</sup> century providing a well-documented history of human impact. Paleoecological reconstructions from the Azores thus allow us to compare ecosystem processes and dynamics before and after colonization.

A high-resolution pollen record from Lake Peixinho (Pico Island) provides novel insights into early human impacts in the Azores from the 13<sup>th</sup> century – two centuries prior to the official historical colonization of the archipelago. In addition, the record highlights the role of tephra sedimentation from proximal volcanic eruptions as natural driver of ecosystem dynamics. We compared palynological results to diatom, chironomid, Cladocera and geochemical records from the same lake, as well as other sedimentary records from Pico Island and existing pollen records from other Azorean islands. Ongoing analyses of paleoecological records from other islands in the Azorean Archipelago (Corvo, Flores, Sao Miguel, and Terceira) will help pinpoint the timing and impact of human colonization in the Azores. This research is funded by the Juan de la Cierva-formacion postdoctoral grant (FJCI-2015-26199), the Fundacao LUSO-Americana, and through

the Spanish funded research projects PaleoNAO (CGL2010-15767), RapidNAO (CGL2013-40608-R) and PaleoModes (CGL2016-75281-C2).

## **S10-P02 - The North Atlantic Oscillation in the Azores archipelago: a Holocene high-resolution and multiproxy limnological approach**

**Santiago Giralt (1), Armand Hernández (1), Linda Amaral-Zettler (2), Roberto Bao (3), Stella Birlo (4), Erik Jan De Boer (1), Teresa Buchaca (5), Daniel Castro (6), Rafael Carballeira (3), Vitor Gonçalves (7), Celia Martín-Puertas (8), Sergi Pla-Rabes (9), Ricardo Prego (10), Juan José Pueyo (11), Pedro Raposeiro (7), Nora Richter (12), Valentí Rull (1), Alberto Sáez (13), Helena Sousa-Marques (7), Ricardo Trigo, (14), David Vázquez-Loureiro (3)**

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The two main centers of action associated with North Atlantic Oscillation (NAO) climate variability occur over the Azores archipelago (high) and Iceland (low), respectively. In this context, high-resolution multiproxy characterization of lacustrine sedimentary records can provide useful insights into the NAO evolution at different temporal scales throughout the Holocene. While the Icelandic Low is relatively stable the oscillatory behavior of Azores High is relatively large and, consequently, this displacement tends to define the NAO state and impacts through time. Other atmospheric and oceanic variability modes like the East Atlantic and Scandinavian patterns, and the Atlantic Multidecadal Oscillation, also play a significant role in climate fluctuations of the European North Atlantic region. The coupling and uncoupling of these atmospheric and oceanic modes have shaped the climate variability of Southern Europe for the last 2,000 years (Sánchez-López et al., 2016 QSR, 149: 135–150), however, little is known beyond the Common Era. In order to capture the mid-to-late Holocene evolution of the NAO southern center of action and its potential interactions with other climate modes, we have recovered sediments from lakes over a large transect that spans four of the nine Azorean islands: Lagoa Caldeirão (Corvo), Lagoas Funda, Lomba, and Negra (Flores), Lagoas Caveiro and Peixinho (Pico), and Lagoas Azul and Empadadas (São Miguel). We present preliminary results from high-resolution multiproxy characterizations of these lacustrine sequences. These results suggest complex non-stationary interlinkages between the NAO and other atmospheric and oceanic climate modes on different time-scales, likely reflecting the spatial and temporal displacements of their centers of action. To fully document spatial and temporal shifts throughout

the Holocene, it is crucial to study the southern NAO center of action using multiple paleo-records from this area. This research is funded through the PaleoNAO (CGL2010-15767), RapidNAO (CGL2013-40608-R) and PaleoModes (CGL2016-75281-C2) Spanish projects, and the Fundacao LUSO-Americana.



## **S10-P03\* - The recent multi-annual and quasi-bidecadal fluctuations of lake system in the Pampean Plains from central Argentina and their climate connections**

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The Pampean Plains are located in a large flat area of the subtropics of southeastern South America (SESA), including the most populated and productive area of Argentina. Across the region, the environmental functioning of numerous shallow lakes developed across the region is a product of the water budget and the flat terrain geomorphology. Although several floods and droughts affected the socio-economical activities of lake-shore villages, complete and reliable data-bases of water-bodies fluctuations are scarce. A reliable database lake-area oscillation from 1965 to 2015 was reconstructed for Melincué Lake (ML; 33°43'S/61°28'W); located in the center of the Pampean Plains, in order to better understand the nature of the oscillations and its main forcings. The series was built using satellite Landsat images, and complemented with instrumental data. The lake area internal variability of ML was analyzed in different time-scales, from intra-annual to multi-annual, examining the persistence and the frequencies of the series. Results showed that the lake oscillates with a significant quasi-bidecadal periodicity. A secondary 13 years-frequency signal was detected since the 1970s, when a dramatic increase in ML areas occurred associated to a shift to humid conditions described along the hydrometeorological and sedimentological records of SESA. Precipitation and evaporation controlled the annual lake areas, acting with different time-responses. The comparison of the annual lake area variation with climate indices in the Pacific and Atlantic oceans indicated the largest correlation with Pacific Decadal Oscillation modes. The study provided evidence of the effects of large-scale climate circulation and low-frequency modes on the local shallow lakes dynamics in the Pampean Plains, which is fundamental for anticipating the hydrological response to future climatic changes.

## **S10-P04\* - Impact of large-scale atmospheric and oceanic patterns on south-western European climate for the Common Era**

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Robust knowledge about future trends in climate extremes is crucial for those societies. However, under the current global warming context, there is a high uncertainty on the projected changes in extreme events. Understanding how the current global warming might influence extreme climatic events in the 21st century remains a major challenge. Climate variability within the coupled oceanic-atmospheric system causes variations in the atmospheric flow, which is one of the main reasons for the variability of large-scale modes of climate variability. High-mountain lakes in south-western Europe are particularly sensitive to the influence of North Atlantic large-scale atmospheric and oceanic patterns due to their geographical position and the reduced anthropic disturbances. In this context, Serra da Estrela (Portugal), the westernmost range of the Iberian Sistema Central, constitutes an optimal setting to obtain climate proxies as it represents a physical barrier to air masses coming from the Atlantic Ocean. We present a proxy-based reconstruction of the modes of climate variability impact on south-western Europe for the last ca. 2000 years. We have characterised the sedimentary record of Lake Peixão (1677 m a.s.l.) and compared it to other south-western European records. Above-average rainfall conditions were usually linked to the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO) both in negative phase, whereas background and drought conditions would be concurrent with NAO and AMO in positive phase. In turn, cold periods are likely influenced by negative NAO and AMO, whereas relative warmer conditions would be related to periods in which NAO and AMO phases are both in positive phase. Hence, our results highlight that, although the climate regime in this area is clearly influenced by the NAO, the slow-varying AMO also plays a key role at long-term time-scales.

This research is funded through the PaleoNAO (CGL2010-15767), RapidNAO (CGL2013-40608-R) and PaleoModes (CGL2016-75281-C2) Spanish projects.

## **S10-P05\* - Atmospheric and oceanic patterns influence on mid-to-late Holocene climate from Pico Island (Azores archipelago)**

**Armand Hernández (1), Pedro M. Raposeiro (2), Alberto Sáez (3), Vitor Gonçalves (2), Roberto Bao (4), Juan J. Pueyo (5), Ricardo M. Trigo (6), Santiago Giralt (1)**

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European climate is partly conditioned by a number of atmospheric and oceanic patterns which occur in the North Atlantic sector. The favourable location of the Azores Archipelago (37°–40°N, 25°–31°W) results in a privileged setting to generate high-resolution Holocene climatic proxy data that can contribute to deep our understanding on the evolution of these atmospheric and oceanic patterns. Here, we present a new high-resolution climate reconstruction based on the Caveiro Lake sedimentary sequence in order to fill this gap. Previously, Björck et al. (2006) studied a section of this sequence (the uppermost 4.6 m; 6 Ka cal BP) concluding arid periods occurred during decreased North Atlantic SST and evaporation linked to disturbances in the thermohaline circulation as a consequence of increased drift-ice in the North Atlantic. In turn, the NAO impact was the main atmospheric driver of short-term precipitation changes. The new studied sequence (9.55 m long, 8.2 Ka cal BP) has been analysed at decadal-to centennial time-scale resolution for X-ray diffraction, X-ray fluorescence core scanning and elemental and isotope geochemistry on bulk organic matter. The comparison of the Aridity index of Björck et al. (2006) with the new climate reconstruction carried out in this work for the last 6000 years clearly shows that the arid phases of the index fit with the instantaneous sedimentation events defined by both tephra layers and external loadings deposited into the lake. Therefore, these arid events were not triggered by North Atlantic drift-ice variations but by volcanic eruptions and extraordinary rainfall events. Nevertheless, preliminary data of this study suggest that the decadal to centennial evolution of the Caveiro Lake was dominated by the NAO and the North Atlantic SSTs variations.

Björck et al. (2006) – *Quat Sci Rev* 25,9-32.

This research is funded through the PaleoNAO (CGL2010-15767), RapidNAO (CGL2013-40608-R) and PaleoModes (CGL2016-75281-C2) Spanish projects.

## **S10-P06\* - Paleoclimatic variations in western Amazon based on diatoms from Airo lake (Amazonas State, Brazil) from the last 13,300 years cal BP**

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The aim of this study was characterize climatic variations from the last 13,300 years cal BP in Brazilian western Amazon based on biogeochemistry. To this end, we retrieved a 146cm-long core from a marginal lake disconnected from Negro river (Airo lake; 00°19'37.225''S, 66°08'33.266''W). Using  $^{14}\text{C}$ , seven organic matter samples were dated and age was calibrated (Calib 5.0.2). We counted 500 valves per sample (30cm to top) and 4 slides transects due few diatoms valves (145 cm to 31 cm). Analysis included diatom community (density and %), planktonic/benthonic ratio and sedimentology, bulk and isotope organic geochemistry. The 73 species mostly comprise acidophilic species (ex. >20% in average *Eunotia hirudo*). From ca. 13,300 years cal. to ca. 1,500 years cal BP (Phase 1) presented coarser grains (sand), while diatoms valves density were 'low' (i.e., ranging from 0 to  $37.543 \times 10^3$  valves/g) with mainly benthonic taxa. From ca. 1,500 years cal BP up to top (Phase 2), silt became dominant and concurrently the density of diatom valves increased (between  $30.918 \times 10^4$  and  $14.151 \times 10^6$ ), chiefly by planktonic taxa. Higher silt contribution along with a pronounced decrease in C/N ratios are indicative of the declining influence of the Negro River over Airo lake. Our results suggest that Phase 1 represented Airo Lake area as a lotic ecosystem, characterized by high energy and thereby low diatom sedimentation. On the onset of Phase 2, the Negro River became disconnected from Airo Lake, which is suggested by the predominance of silt, associated with low hydrodynamics. Further along Phase 2, our results suggest an increased of mean water level in Airo Lake (characterized by higher valves/g, planktonic taxa dominance, and  $\delta^{15}\text{N}$  values increase), which was probably the result of higher precipitation regimes in the South American Monsoon System. Funding: INSU-EC2CO, CNPq 479873/2013-5 and FAPESB RED0026/2014.

## **S10-P07 - Climatic oscillation cycles modulating the Río de la Plata estuary fluvial discharge into the adjacent continental shelf, during the Late Holocene**

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The Río de la Plata estuary (RdIP) and adjacent continental shelf exhibit complex hydrographic characteristics leading to highly variable terrigenous input, controlled primarily by climatic forcing. The hydrological setting, resulting from river runoff driven by changing precipitation regimes, reflects the climatic variability during the Little Ice Age and the Medieval Climate Anomaly. This study aims to analyze the cyclicity in such runoff-related continental input and their associated climatic oscillation cycles over the past 1,200 yr. To achieve this, we used a 10-m-long sediment core retrieved from the RdIP mudbelt depocenter, which presents an extremely high mean sedimentation rate of 8 mm yr<sup>-1</sup>. We performed continuous 1-cm XRF scans and run time series analysis on the Fe/K, Ti/Al, Fe/Ca, Ti/Ca and Si/Al element ratios, used as regional proxies for the fluvial input signal. The most significant cyclicalities were recorded at 2, 5-9, 60, 62, 107, 121, 226 and 340 yr. These climate-related cyclicalities are attributed to the Atlantic Multidecadal Oscillation (AMO) and the El Niño Southern Oscillation (ENSO) climatic modes. The 226 and 340 yr cyclicalities are most probably related to solar forcing. We also identified an intensification of the AMO signal followed by a strengthening of the ENSO signal during the past 500 yr. Hence, we provide further evidence on the teleconnections between the Atlantic and the Pacific sea surface temperatures (SSTs), through large-scale atmospheric circulation, and the response of the Southeastern South-American (SESA) precipitation to such atmospheric changes. The AMO SSTs in the North Atlantic seems to strengthen the Pacific SSTs signal at inter-annual and decadal scales, and modulates the changes in RdIP river flow and continental material within the inner shelf at multidecadal, decadal and interannual scales.

## **S10-P08 - Mid-to-Late Holocene environmental reconstruction on Pico Island (Azores, Portugal) based on multiproxy analysis of Lake Caveiro sediments**

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The Azores constitutes the most remote archipelago of the North Atlantic Ocean. Both human colonization and natural changes have significantly modified its ecosystems. To assess the impacts of natural and anthropogenic changes over the last 8200 yr, elemental geochemistry on bulk organic matter, diatoms, Cladocera and chironomid remains were analyzed in a 952-cm long sediment (3.7m depth) from Lake Caveiro.

From 8200 to 650 cal yr BP, climatic and volcanic forcing seem to have been the main drivers of biological change. Between 8200 and 6000 cal yr BP, the sedimentary sequence was characterized by dominance of volcanoclastic deposits and high abundance of aerophilic diatoms and sparse Cladocera and chironomid remains. This interval has been interpreted as indicative of unstable conditions because of intermittent renewal of lake bottom substratum owing to repetitive tephra sedimentation. Between 6000 and 3500 cal yr BP, fossil assemblages were dominated by benthic species, with an increasing trend of the planktonic/benthic (P:B) ratio, suggesting stable substratum and rising lake levels. An increase in planktonic taxa and the presence of deep-water chironomid species was found between 3500 and 1300 cal yr BP, suggesting a highstand phase. Between 1300 and 650 cal yr BP, a decreasing trend of the P:B ratio was recorded, implying a further lake shallowing. Moreover, the appearance of flowing water species suggests a period characterized by climate instability. From 650 cal yr BP to the present, a significant increase in primary production and a decline in species richness likely reflect anthropogenic impacts, such as forest clearance and the introduction of exotic species. These results highlight the impact that human, volcanic and climatic drivers have had on the environmental evolution of the ecosystems of Pico Island. This research is funded by Spanish projects PaleoNAO (CGL2010-15767), RapidNAO (CGL2013-40608-R) and PaleoModes (CGL2016-75281-C2).

## **S10-P09 - Decoupled early Holocene summer temperature and monsoon precipitation in southwest China**

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Proxy-based reconstructions of Holocene temperature show that both the timing and magnitude of the thermal maximum varied substantially across regions. Climate-model simulations indicate that early Holocene summers were substantially cooler in areas influenced directly by the Laurentide ice sheet, whereas elsewhere in the Northern Hemisphere temperatures were dominated by orbitally forced insolation. Because summer temperature inferences for low-latitude regions (e.g., SW China) dominated by the Indian summer monsoon are lacking, spatial differences in Holocene summer temperature and their underlying forcing mechanisms are unclear. We developed a well-dated, pollen-based summer temperature record (mean July; MJT) for the last 14,000 years from Xingyun Lake, southwest China. MJT decreased during the Younger Dryas, increased slowly to high values during the period 8000–5500 yr BP, and decreased thereafter. MJT record differs from that inferred using carbonate oxygen isotopes ( $\delta^{18}\text{O}$ ) from the same sediment core. The latter record reflects variations in monsoon precipitation, with highest precipitation having occurred in the early Holocene (11,000–6500 yr BP). We propose that summer temperature and precipitation in southwest China were decoupled during the early Holocene. Both MJT and monsoon precipitation decreased after the middle Holocene, tracking the trend in boreal summer insolation. We suggest that greater cloud cover, associated with high precipitation, generated by a strong summer monsoon, may have depressed early Holocene temperatures that would otherwise be related to greater summer insolation. Melting ice sheets in high-latitude regions and high concentrations of atmospheric aerosols during the early Holocene may have contributed, in part, to relatively cool summer temperatures.

## **S10-P10 - Different responses and driving mechanisms of H1 event in the Asian Monsoon domination and its marginal region**

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The Tibetan Plateau is affected by the westerlies and the India monsoon, of which the influence is able to be reflected through climate change signals in sedimentary records in the transition regions. The Nam Co Lake is located in the transitional region between the westerlies and the Indian monsoon (Indian monsoon margin) on the Tibetan Plateau. Sedimentary records of the Nam Co Lake shows that climate shifted from cold-dry to warm-humid, and from westerly domination to Indian monsoon domination reflected by pollen discriminant function since 16.5 kaBP. There are same changes reflected by pollen records of Tangra Yumco Lake and biomarker records of Mang Co Lake in this monsoon margin area. However, unlike the dry condition appeared in H1 event period in East Asia typical monsoon region during this shifting period, lake records in Indian monsoon margin area of the Tibetan Plateau showed that climate performed more humid in H1 period than in Last Glacial Maximum. By comparing results of full\_forcing TraCE experiment and Freshwater hosing experiment, it is found that the weakening of AMOC results in southward shift of the ascending branch of Hadley circulation. It enhances north toward trans-equatorial wind at upper layer of the troposphere, which transit to the upper-level westerly jet in middle latitude of northern hemisphere. Although the enhancement of upper westerly jet is limited due to warming effect of greenhouse gas and solar radiation in northern hemisphere, there is a structural change similar like convergence center in upper troposphere in East Asia typical monsoon regions. It limits convective activity below and reduces precipitation, while in high elevation area of monsoon margin, it is difficult to limit influence of Indian monsoon by increasing upper westerly wind, which leads to the stability of precipitation in Indian monsoon marginal region.





# The Varied Response of Lakes to Global Warming Based on Sediment Records and Modern Process Studies

*Jasmine E. Saros and Daniel R. Engstrom*

## Session 11



# Oral Presentations

## **S11-001 - Historical diatom community and productivity shifts help predict the sensitivity of boreal lakes to climate change**

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The boreal region covers over 15% of the earth land surface, contains over 60% of the world fresh surface waters, and holds over 3 million lakes. Multiple lines of evidence suggest that boreal-lake ecosystems are changing rapidly due to human-induced climate warming. Current research, however, has demonstrated variable ecological responses to climate change among lakes. We predict that the sensitivity of boreal lakes to climate change will vary primarily along two physical gradients with one reflecting direct, in-lake climate effects and the other reflecting indirect, watershed effects. To test this framework, we investigated 25 undeveloped boreal lakes using paleolimnological analysis and showed the lakes are changing rapidly, with significant shifts in diatom and other algal communities, unprecedented appearances of noxious cyanobacterial blooms, and increased carbon burial in lake sediments. Here we focus on the historical response of diatom communities to direct and indirect climate drivers to test our two-dimensional sensitivity framework. Historical diatom response in each lake was summarized by measures of community turnover, changes in diagnostic functional and taxonomic groups (e.g., tychoplankton, deep chlorophyll layer communities), and measures of algal production (biogenic silica). Diatom response metrics were estimated across time periods from the mid-1800s to present and projected on the sensitivity framework to determine whether physical characteristics of lakes and watersheds could serve as predictors of lake sensitivity to climate change. To determine potential mechanisms of lake response to climate, we recreated historical trends in thermal structure at daily timesteps from 1960–2011 in four shallow and four deep wilderness lakes using the MINLAKE model.

## **S11-002 - Linking changes in chemistry across different time scales - from Holocene sediment records to four-hourly logger data**

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Aiming at reconstructing the impact of Holocene climate change on a small high Alpine lake, we sampled piston cores and short gravity cores from Rasass See (2686 m a.s.l., Eastern Alps, max. depth 8.5m). We obtained a composite sediment record that was 120 cm long and reached back over the last 10 000 years. We measured bulk chemistry, organic content, and minerals in discrete, continuous 1cm intervals. Expecting strong changes in the chemical composition of the sediment, we started monitoring the lake twice every year in 2010, the time of coring. The changes in limnochemistry were stronger than expected, and we started logging temperature and conductivity four-hourly along a depth profile in 2011. Logging data allowed us to follow the timing of ice break and ice on, as well as the onset of mixing and stratification. Mixing regime triggered changes at the sediment water interface, and thus the sediment chemical signature. We were particularly interested in targeting the driver for changes in sulfur concentration in the sediment.

We observed a strong increase in sulfate and conductivity in the lake water since the onset of monitoring. We matched this trend to sulfur increase by 5000  $\mu\text{g/g}$  in the top sediment record which occurred over the last century. Going back to the early Holocene, sulfur trends were more variable and also much stronger (up to 45 000  $\mu\text{g/g}$ ). Linking the logging and monitoring data to changes in the sediment record allowed us to put the current increase in solutes and conductivity into perspective. The changes in chemical composition during the early Holocene were of a manifold magnitude compared to the changes observed over the last decade. Thus the monitoring of the water chemistry provided hints how to interpret Holocene sediment composition.

## **S11-O03 - Lake monitoring and sediment trapping reveal large inter-annual variations of seasonal responses recorded in annual diatom sediment records**

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A major effect of global warming on lake ecosystems is manifested in changes to temperature-driven seasonal processes. We investigated the influence of seasonality on the formation of diatom sediment signals by comparing continuous diatom records collected by a sequential sediment trap with the diatom record in the annually laminated (varved) sediment of a boreal lake (Nylandssjön). Using high resolution water column monitoring over three consecutive years and a decadal sequential sediment trap record, we identified large year-to-year variation in the seasonal formation of the annual diatom sediment signal. The annual diatom record in the sediment trap corresponded well with the annual record in the varved sediment. Throughout the decadal record, relative diatom abundance was mainly dominated by either *Cyclotella glomerata* or *Asterionella formosa*. Year-to-year differences in relative abundance of these two taxa could be explained by (i) seasonal weather anomalies, (ii) catchment processes, and (iii) specific timing of seasonal thermal structure of the lake. The detailed physico-chemical lake monitoring suggests that the timing of physical in-lake process has a large influence on the build-up of *Cyclotella glomerata* blooms before spring over-turn, particularly in warm winters. In addition, the decadal monitoring identified anomalies in autumnal discharge and the combined effect of forestry and air temperature to be related to the relative abundances of *Cyclotella glomerata* vs. *Asterionella formosa*. For these two dominant taxa, the timing of nutrient delivery from the catchment during stratified conditions under ice (late winter) or before autumn over-turn were most important. Inter-annual variation of seasonal weather, catchment and in-lake processes highlight the importance of specific seasonal mechanisms opposed to e. g. mean annual temperature for the understanding of biological sediment formation.

## **S11-004 - Spatio-temporal changes in diatom communities in shallow subarctic lakes**

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Diatom (*Bacillariophyceae*) communities constitute powerful indicators of climate change. Their responses to climate perturbations are largely dependent on environmental context, and as yet remain insufficiently understood in relation to shallow subarctic lake ecosystems. These shallow waterbodies are sensitive to changes occurring in their airshed and catchment, such as warming temperatures or altered flux of terrestrial carbon and nutrients. We explored diatom responses to changing environmental conditions at the Fennoscandian treeline, employing both spatial and temporal approaches to address direct and indirect climate impacts on shallow subarctic lakes. With a focus on the concentrations and optical characteristics of catchment-derived carbon, spatial variability in benthic diatom communities was investigated in 31 lakes spanning the treeline transect. To evaluate varied climate controls on the long-term development of the benthic communities, fossil diatom shifts in a shallow tundra lake were examined in connection to centennial temperature variability and inferences of terrestrial influence over the past ~600 years. In these shallow systems, terrestrial carbon concentrations and associated changes in underwater irradiance regimes appeared to have little influence on diatom community composition over space and time. Lake water pH imposed primary control over diatom distribution across the treeline, linked to catchment geomorphology, soils and vegetation cover. Species shifts through time occurred concomitantly with centennial temperature fluctuations, attributed to changes in the length of the ice cover period and related effects on lake water chemistry, nutrient regimes, and habitat availability. The findings suggest that diatom communities in shallow subarctic lakes may be resilient towards climate-induced changes in terrestrial carbon input, while implying sensitivity to other potential climate effects mediated via changes in catchment vegetation and hydrology, nutrient dynamics, or physical habitats.

## **S11-O05 - Integrating modern and paleolimnological data to assess hydroecological conditions in a high-latitude floodplain landscape**

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Climate-driven decline in freshwater supplied by rivers draining the hydrographic apex of western North America has ramifications for downstream ecosystems and society. For the Peace-Athabasca Delta (PAD) in northern Alberta, floods from the Peace and Athabasca rivers are critical for sustaining abundant shallow water habitat, but their frequency has been in decline for decades over much of its area. Here, we assess current hydrological and limnological status in the PAD by integrating spatial and temporal perspectives. Based on analysis of water isotope compositions and water chemistry measured at numerous lakes across the delta, we show that hydrological and limnological effects of the large-scale ice-jam flood event of 2014 failed to persist into 2015. Multi-centennial isotope-inferred paleohydrological records from five hydrologically-representative lakes in the PAD indicate that periodic desiccation during the early Little Ice Age occurred at the most elevated basin in response to locally arid climatic conditions, yet other lower elevation sites were influenced by high water level on Lake Athabasca owing to increased snowmelt- and glacier-derived river discharge. In contrast, water isotope monitoring data during the past 15 years at all five lakes consistently document the strong role of evaporation, a trend which began in the early to mid-20<sup>th</sup> century according to the sediment core records. Our evidence suggests the PAD has entered a new hydrological regime – one characterized by widespread evaporative influence unprecedented during the past 400 years. Integration of hydrological and limnological approaches over space and time is crucial to inform assessment of contemporary lake conditions in large, complex floodplain landscapes.



## **S11-O06 - Exploring variable links among climate, ice out and thermal stratification: implications for diatom response to warming**

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Climate-driven changes in sedimentary diatom assemblages over the past 150 years in mid-to high latitude lakes of the northern hemisphere are linked to altered ice out timing and thermal stratification. Variable response across lakes and regions raises the need to better understand mechanistic links between specific features of climate and physical lake characteristics. We compared lakes in boreal versus Arctic areas, assessing factors that control the timing of ice out and strength of links to thermal stratification. Subsequent effects on diatom assemblages over different time scales were also investigated. We discuss how mean air temperatures during different months drive ice off in the two regions, with links to summer thermal stratification varying in strength across the two areas. Effects of earlier ice out and subsequent deeper lake mixing on diatom assemblages in Arctic lakes were stronger than those in the boreal lake. These climate-lake linkages revealed by modern process studies are used to refine interpretation of variable patterns across lake sediment records.

## S11-O07 - A diatom assemblage change in Lake Nam Co (Tibetan Plateau) caused by recent global warming?

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Paleoclimate and paleoecological studies from Lake Nam Co (4718 m a.s.l., ~2030 km<sup>2</sup>), located on the southern Tibetan Plateau (TP), hint at a continuous change in the diatom assemblage during the last five decades. In 2012 and 2013, sequential and integral sediment traps were installed in the lake to investigate the seasonal diatom succession. *Stephanodiscus medius* and planktonic *Fragilaria*-species dominated the diatom plankton in all trap samples. *Cyclotella ocellata*, the most abundant species during the last 4000 years, was detected with a maximum abundance of only 10.9%. The seasonal succession shows *Stephanodiscus medius* dominance in spring and autumn during thermal mixing phases, whereas planktonic *Fragilaria*-species were frequently found during the summer stagnation. Compared to the paleorecords, the development of diatoms differed considerably in 2012/2013. For this reason, the diatom development was analyzed in a multidisciplinary approach using a sediment short core, obtained in 2012, to clarify a) when did this change in the diatom assemblages start and b) what were the underlying causes?

Our results clearly document a gradual replacement in species dominance from *Cyclotella ocellata* to *Stephanodiscus medius* since the beginning of the 1960's. Simultaneously, the abundance of benthic diatoms decreased and planktonic *Fragilaria*-species became more frequent since the mid-1990's. Recent studies clearly demonstrate the impact of global warming on the TP, which is reflected in Lake Nam Co by rising lake levels and increasing water temperatures over the last decades. Higher water temperatures triggered longer-lasting and earlier stratification as well as a shortening of ice cover, which is in good agreement with higher occurrences of *Stephanodiscus medius* und planktonic *Fragilaria*-species. Additionally, despite the very low population density on the TP, increasing P and N contents in the sediments already indicate signs of anthropogenic influence on Nam Co, possibly caused by atmospheric input originating from South Asia.



## **S11-O08 - Diatom response to climatic warming over the last 200 years: A record from Gonghai Lake, North China**

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Annual monitoring data and centennial and millennial-scale paleolimnological records have revealed an increase in small-celled planktonic diatom species relative to heavier tycho-planktonic and small benthic diatoms in many high-altitude lakes, presumably in response to recent climatic warming. In addition to changes in the composition and structure of lacustrine diatom assemblages, there have also been changes in diatom biodiversity; however, these changes are not regionally consistent. In this study, we chose a temperate mid-latitude lake to explore the response of changes in diatom assemblages and biodiversity to recent climatic warming. The diatom record spans the past ca. 200 years and reveals that since 1966 CE the small-celled *Cyclotella ocellata* + *stelligera* has replaced the previously dominant, large-celled phytoplankton *Cyclotella schroeteri*. These changes are in accordance with the increasing trend in global mean surface temperature. Biodiversity increased remarkably from 1966 CE, but began to decline after 1990 CE, presumably in response to rapid climatic warming. Our findings indicate that the response of diatom biodiversity to climate change was a nonlinear process.

## Poster Presentations

### **S11-P01 - Do nutrient subsidies to alpine lakes amplify warming-driven changes in diatom community turnover?**

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We assess whether nutrient subsidies in glacial meltwater alter the sensitivity of diatom communities in alpine lakes to regional warming using a combination of paleoecological and experimental methods. North American lake sediment records demonstrate increased diatom community turnover since 1850 in glacially fed (GF) alpine lakes, yet it is unclear whether glacier meltwater nutrients alone, or an interaction between rapidly increasing temperature and glacier meltwater inputs, control these changes. To assess whether interactive effects of nutrient enrichment and climate warming influence diatom community structure, we quantify diatom sediment records ( $n = 6$ ) from paired GF and snow and groundwater fed (SF) lakes in the northern US Rocky Mountains. Preliminary results demonstrate cohesive increases in key diatom taxa between GF lakes (*Discostella stelligera*,  $\rho = 0.74$ ; *Asterionella formosa*,  $\rho = 0.82$ ; *Fragilaria tenera*,  $\rho = 0.83$ ), but less directional change and cohesion of SF lake diatom responses. Lack of diatom community changes in SF lakes suggests that low-nutrient alpine lakes may be insensitive to warming because of strong nutrient resource constraints. To refine interpretation of the sedimentary diatom records, we conducted an incubation experiment that measured the individual versus interactive effects of nitrate, temperature, and average light exposure on alpine lake phytoplankton communities. By integrating contemporary and past ecological responses to nutrients and temperature, this study will clarify how nutrient enrichment increases lake sensitivity to regional-scale climate warming across mountain landscapes.

## **S11-P02\* - Large and deep perialpine lakes: a paleolimnological perspective for the advance of ecosystem science.**

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The large perialpine lakes are important component of the Alpine landscape. Due to their piedmont location in the most densely populated and productive region of the Alps, they play a crucial socio-economic role as resource for drinking water, irrigation, industry, tourism, hydroelectric production, and biodiversity conservation. They are exposed to multiple human pressures, and, as their catchments extend to the glacial Alpine range, they are particularly sensitive to global warming effects. Limnological surveys outlined coherent responses by large perialpine lakes to the massive nutrient enrichment during the 1950s–1970s, while recent trajectories are rather heterogeneous. Past and ongoing paleolimnological studies confirmed the coherence of the lakes' evolution at a secular perspective, but outlined individual trends resulting from local management policies, lake morphology, and superimposed effects of climate change. A survey of the paleolimnological literature, published from 1975 to April 2017 on perialpine lakes from north and south of the Alps, was performed to review current knowledge of large and deep perialpine lakes obtained by sediment studies, and summarize how paleolimnological studies can effectively contribute in defining past ecological status of lakes from several lines of evidence. A further objective of the review work was to present how paleolimnological studies can assist limnological research in outlining lake sensitivity to present and future human impacts. This is particularly important when defining trophic and ecological reference conditions, because inappropriate restoration targets might prove unachievable within the present context of global change.

## **S11-P03 - Recent oxygen decline relates to organic carbon in subarctic ecotonal lakes**

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Northern lakes play a significant role in the ongoing climate change through their functions in carbon release and sequestration. The cascading effects of climate change in these lakes, nonetheless, make it difficult to assess the carbon balance. A key question in aquatic elemental cycling is related to the influence of bottom water oxygen conditions in regulating the burial and release of nutrients under climate warming. In this study, we used head capsules of benthic chironomid (Diptera: Chironomidae) larvae to assess community and diversity change between the Pre-Industrial period and the present and to reconstruct changes in hypolimnetic oxygen conditions from 30 subarctic ecotonal lakes (northeastern Finnish Lapland) using the top-bottom paleolimnological approach. Subsequently, we tested the findings against dissolved organic carbon (DOC) concentration of the sites. We found that the benthic communities were distinctly dissimilar between the past and the present with largest changes in the more transparent oligo-mesohumic lakes. However, murky polyhumic lakes displayed uniformly a decrease in diversity. The chironomid-inferred oxygen values showed a general decrease towards the present, with largest shifts in low DOC lakes but no significant changes were found in the hypolimnetic oxygen conditions of high DOC lakes, often located in wetland areas. These findings suggest mechanisms that prohibit oxygen decline in lakes associated with constant organic carbon inputs making them more resilient toward climate-induced reductions in hypolimnetic oxygen. Accordingly, the results show that low DOC lakes of the northern treeline are more prone to climate change impacts with increasing potential of carbon release under reduced bottom water oxygen.

## **S11-P04\* - Lake primary production response to wildfire and climate warming in the western boreal forest, Northwest Territories, Canada**

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In sub-Arctic and Arctic regions of Canada, widespread climate warming is thought to be affecting the natural disturbance regime of wildfires. The 2014 wildfire season in Northwest Territories was notably severe with ~390 reported wildfires burning nearly 3.5 million hectares of forest cover. Wildfires can increase lake primary production through increased transport of nutrients from the burned catchment area, but can also potentially decrease lake primary production through a reduction in light. The purpose of our research is to determine the impact of wildfires on aquatic systems in the southern Northwest Territories. Our research is using a multi-proxy, paleoecological approach to reconstruct recent (~200 years) records of wildfire and lake primary production. Lake primary production is an important measurement as increases in lake primary production can lead to a degradation of freshwater quality. Lake sediment records from four boreal lakes in southern Northwest Territories were analyzed for macroscopic charcoal and sedimentary chlorophyll a (Chl a). Charcoal analysis was used to determine the timing and frequency of past wildfires. This analysis allows us to determine specific links between fire frequency and climate. Historical Chl a was reconstructed for lakes in burnt and unburnt catchments to determine the magnitude and direction of change in lake primary production in response to warming temperatures and recent wildfires. Preliminary results indicate that peaks in charcoal, indicating recent wildfire events, do not lead to changes in lake primary production as indicated by Chl a. Reconstructions of Chl a from the shallowest lakes (~1–2 m depth) that were sampled show recent increasing trends in Chl a. This suggests that lake primary production in shallow boreal lakes in southern Northwest Territories is increasing in response to long-term warming.

## **S11-P05 - Depositional and geochemical dynamics of Mediterranean Watershed-Lake Systems (WLS) during the Anthropocene: disentangling human and climate forcings in the Iberian Peninsula during the last millennium**

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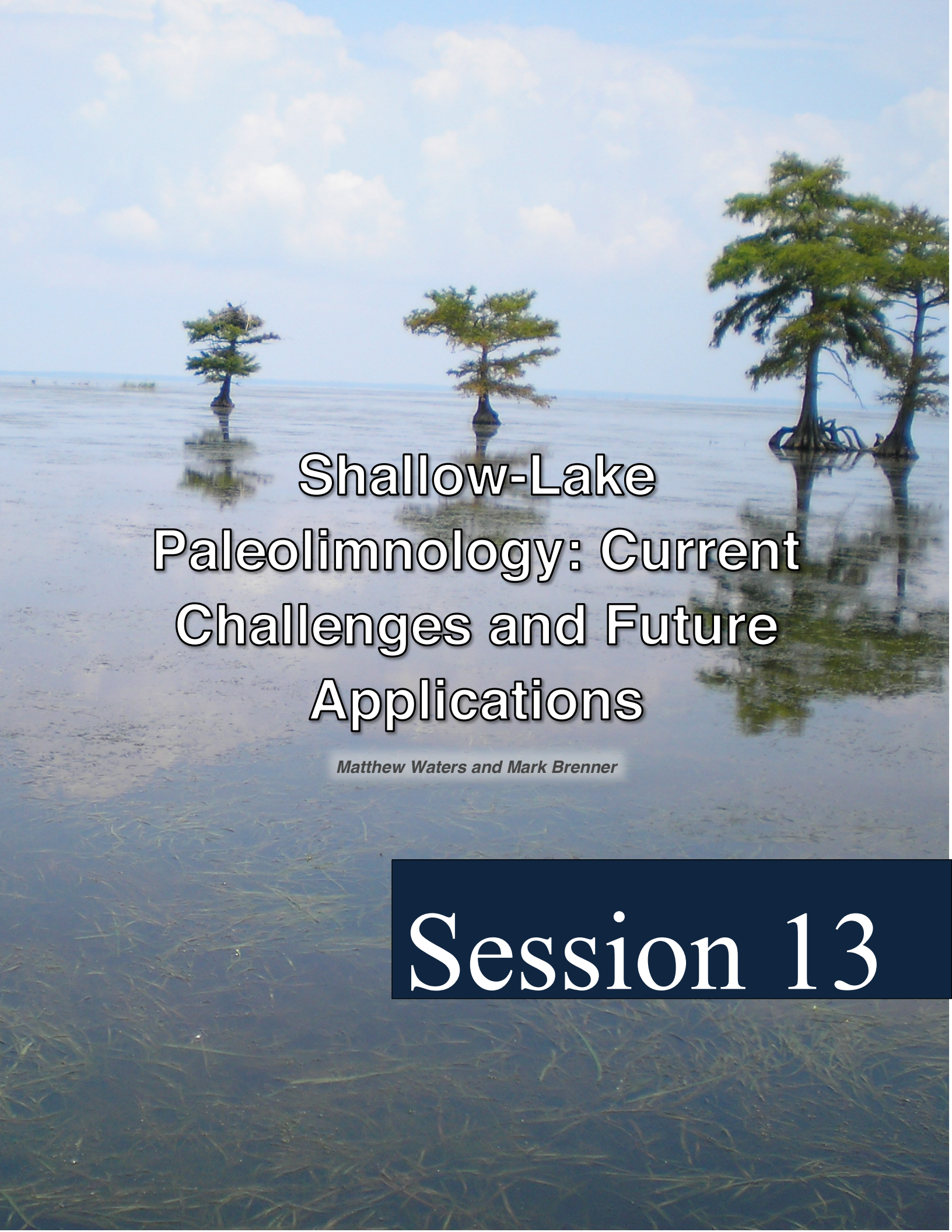
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In the context of sustainable socio-economic growth, water availability, soil conservation and land degradation are key factors in the Mediterranean regions of the Iberian Peninsula. Our knowledge of Mediterranean Watershed-Lake Systems (WLS) dynamics in the context of recent Global Warming and the Great Acceleration is hindered by the absence of integrated studies that include varied geographic contexts and long term time series. In the Mediterranean regions of the Iberian Peninsula disentangling climate and anthropic factors is more complex due to the long history of human impact. The forecasted intensification of the hydrological cycle (flood intensity and frequency) associated to global warming will likely lead to higher sediment mobilization and sediment delivery to the lakes, increase in carbon fluxes and bioproductivity and also in metal and other pollutant mobilization from the watersheds. The MEDLANT project applies a multidisciplinary approach to understand environmental, paleohydrological and climate dynamics in WLS during the Anthropocene based on high resolution lake records for the last millennium. We use a transect of lake paleorecords from NE Iberian Peninsula to test these hypotheses by comparing recent changes with those occurred during other warmer periods - as the end of the Little Ice Age and during the Medieval Climate Anomaly - and also during the main phases of human impact (Roman, Medieval, late 19th- Early 20<sup>th</sup> century). Available data suggest that synergetic effects between climate and humans have intensified erosion, heavy metal mobilization and C storage in Mediterranean WLS. However, increase in extreme events caused by climate change and reforestation due to rural exodus have had opposite impacts in sediment delivery in recent times. Dynamic models for Mediterranean WLS will include their response during climate and anthropogenic disturbances and the complex synergetic effects obtained from paleolimnological records.





# Shallow-Lake Paleolimnology: Current Challenges and Future Applications

*Matthew Waters and Mark Brenner*

## Session 13

## Oral Presentations

### **S13-001 - Multi-proxy investigations highlight ecosystem response to hydrological change in wetland shallow lakes**

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Floodplain wetlands are highly productive systems between freshwater bodies and their terrestrial watersheds, and may be comprised of up to 50% by shallow lakes. Important drivers of ecological change within these shallow lakes include hydrological regime and climate, both of which can influence biodiversity and ecosystem functioning. The Selenga Delta is a floodplain wetland and the transition between Lake Baikal (UNESCO World Heritage Site) and its main tributary, the Selenga River, in southeast Siberia. The Selenga Delta is comprised of floodplain meadows and hundreds of shallow lake and pond environments, with varying levels of hydrological connectivity to the Selenga River. It is internationally recognized for providing critically important habitat for migratory birds, waterfowl, and other species endemic to Lake Baikal. The Selenga Delta was declared a Ramsar site in 1994. Paleolimnological analyses were undertaken on two shallow lakes within the Selenga Delta, unofficially named SLNG04 and SLNG05. Multi-proxy investigations using algal pigments, diatoms, and microfossils determined ecological dynamics within the shallow lakes to be strongly driven by natural and anthropogenically induced changes in hydrological regimes since the 19<sup>th</sup> century. A decline in abundance and diversity of macrophytes, and an increase in the diatom planktonic:benthic ratio and diatom Hill's N2 occurred in the 1960s at SLNG05. The major ecological shift was likely the response to a change in connectivity between SLNG05 and the floodplain, resulting from the construction of a hydroelectric dam along the Angara River. Multi-proxy investigations also proved to be crucial in the assessment of these shallow systems, as connectivity-related changes to the abiotic environment at SLNG04 through the 19<sup>th</sup> and 20<sup>th</sup> centuries led to preferential preservation/dissolution of some biological remains, including diatoms and pigments.



## **S13-002 - A paired paleolimnological study on contrasting large shallow lakes provides perspective on land use, point source pollutants, climate, and lake recovery**

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The mid-continent USA-Canada border is characterized by several large, shallow, relict basins of Glacial Lake Agassiz, which are important resources for regional economies. Only 70 km apart, Lake of the Woods and Upper and Lower Red Lakes are limnologically similar with respect to size, depth, and frequent cyanobacteria blooms. Upper and Lower Red Lake are still surrounded by natural forest and peatland, whereas Lake of the Woods has a long history of human-mediated nutrient loading and remediation. Multiple Pb-210-dated cores were taken from each lake to contrast their post-European histories. Multiproxy analysis targeted sediment character, P inventory and cycling, and algal communities. Lake of the Woods showed increased productivity and cyanobacterial blooms through the 1970s when point sources were curtailed, however the lake has continued to have high nutrient levels from cycling of legacy sediment P. Algal communities reorganized after the 1970s, but did not return to pre-European structure. In contrast, large areas of Upper and Lower Red Lake had nonconformable sedimentation, likely a consequence of physical mixing of sediments by wind. Total P and Fe-bound P concentrations increased upcore, indicating increased burial and high potential for internal loading.

Corresponding to the increased nutrients, biogenic Si and chlorophyll-a increased while  $\delta^{13}\text{C}$  and C:N decreased, indicating greater algal productivity upcore. Diatom communities were dominated by tychoplanktonic taxa, though planktonic diatoms increased subtly with damming, and a recent shift from tychoplanktonic to benthic diatoms was observed. Corresponding to the recent shift in the diatoms, pigment analysis revealed that nitrogen-fixing and toxin-producing cyanobacteria increased. Comparisons between lakes tell us that we have to select carefully where to recover undisturbed stratigraphies in large shallow lakes. Upper and Lower Red Lake paleoecology provides a unique opportunity to understand trends among the remnant Agassiz lakes, trends that may be obscured by anthropogenic disturbance.

## **S13-O03 - Understanding the effects of industry on the Peace-Athabasca Delta (Canada): developing baseline hydrological conditions and sediment metal concentrations using paleolimnology**

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The Peace-Athabasca Delta (PAD) in northern Alberta, Canada, is recognized internationally for its ecological, historical, and cultural significance (UNESCO World Heritage Site, Ramsar Wetland of International Importance). The construction of the WAC Bennett Dam (1967) and the Site C Dam (ongoing, 2024) on the Peace River and expansion of the Alberta Oil Sands industry along the Athabasca River have raised concerns over water quantity and quality in the delta. We are using paleolimnological techniques to assess current environmental and hydrological conditions of the PAD in the context of a pre-industrial baseline. Research focuses on lakes very near to the Peace River to reconstruct past hydrological conditions and to characterize sediment metal deposition derived from Peace River floodwaters. At Lake PAD 65, organic matter and  $\delta^{13}\text{C}_{\text{org}}$  increases, whereas C/N ratios decrease after 1970, which aligns with changes in the Peace River hydrograph caused by river regulation. Notably, this is the first site (of 31) with paleolimnological evidence that attributes hydroecological change in the delta to the Bennett Dam, which suggests these effects are only evident in close proximity to the Peace River. Analysis of sediment metal concentrations from PAD 65 and PAD 66, normalized to aluminium, reveal that key metals of concern (e.g. Ni, V) are enriched relative to pre-industrial baseline concentrations in sediments supplied by Athabasca River floodwaters. This reflects that sediment carried by the Peace and Athabasca Rivers are derived from different geological sources and, therefore, river-specific baselines need to be incorporated for interpreting sediment metal concentration data from lakes across the delta. These findings will be of interest to multiple stakeholders, and will inform stewardship and lake ecosystem monitoring of the delta.

## **S13-O04 - Multiple negative consequences of sulfate pollution in freshwater shallow lakes, and recognition of sulfate loading in the (neo)paleorecord**

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Anthropogenic sulfate loading to lakes and wetlands occurs by a number of processes, and is often considered benign; however, experimental and field survey results demonstrate that in freshwaters with organic-rich sediments, addition of dissolved sulfate causes a cascade of related and deleterious ecosystem consequences. Microbial reduction of sulfate in anoxic sediment porewater produces sulfide, which may precipitate with iron and other metals, or, in metal-poor sediments, can accumulate to phytotoxic levels. Many aquatic rooted plants have mechanisms to partially reoxidize and “detoxify” sulfidic sediments, but their growth and reproduction may also be affected negatively by porewater sulfide, leading to local extirpations and shifts in plant community composition. Even if sulfide does not accumulate to toxic levels, “extra” decomposition of organic matter occurs in anoxic environments when added sulfate is available as a terminal electron acceptor: the constituents of organic matter, including N, P, dissolved organic and inorganic carbon, and mercury, are released to the water column by this mechanism, instead of being sequestered in the sediments. Nutrient enrichment supports phytoplankton growth, and DOC and alkalinity can alter ecosystem structure. The release of P is further exacerbated when sediment iron is tied up as a sulfide.

The capacity of sulfate loading to alter aquatic ecosystems should thus be considered as a possible cause of changes seen in shallow lake paleorecords, especially under human influence, such as macrophyte community composition changes or shifts from macrophyte to algal domination (especially without obvious changes in water depth). Sulfate addition may be recognized in the paleorecord by black color of the split core face that disappears over hours as weak iron monosulfides oxidize, pyrite in smear slides, or increased acid-volatile sulfur (AVS). Because sulfate reduction occurs in sediment porewater, this evidence is likely to occur stratigraphically in sediments that predate the true time of sulfate addition.

## **S13-O05 - Sediments from shallow ponds on islands in Lake Ontario archive waterbird population dynamics, limnological change, and biovector-mediated pollution**

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Long-term population data for waterbird species in the Laurentian Great Lakes of North America are sparse, with most censuses having taken place in the last 30–40 years. Sediments from shallow ponds on summer nesting islands in eastern Lake Ontario provided a unique archive to extend census data by tracking the arrival and population shifts of waterbirds, as well as their associated ecological impacts. Here, we focus on Double-crested Cormorants (*Phalacrocorax auritus*) and Ring-billed Gulls (*Larus delawarensis*), both of which are of primary management concern for many areas. We collected sediment cores from four ponds that were impacted differentially by cormorants and gulls, including a non-impacted reference site. Multiple biological proxies (diatoms, chironomids, sedimentary chlorophyll a), as well as biogeochemical markers (stable nitrogen isotopes, trace elements, sterols/stanols) were used to identify the arrival and impact of these birds on the islands, in comparison with available historical species data. Challenges associated with dating shallow ephemeral pond sediments were evident in some sites, though using a top-bottom approach with mixed sediment records still enabled us to observe broad-scale changes that acted as a proof-of-concept for this multi-proxy approach to tracking birds using paleolimnology. Sediment records showed concomitant increases in  $\delta^{15}\text{N}$ , sedimentary chlorophyll a, eutrophic diatom species, as well as sterol biomarkers that coincided with known bird-nesting events. Water chemistry and surface sediments from a larger survey of seven sites in eastern Lake Ontario showed that trace elements were elevated in bird-impacted sites relative to reference sites, including some heavy metals that exceeded Canadian guidelines for the protection of aquatic life. Diatom and chironomid assemblages also appeared to reflect high levels of heavy metals in bird-impacted sites. These findings have implications for wildlife management decisions, as well as the role of these bird species as vectors of contaminants in freshwater foodwebs.

## **S13-O06 - Evidence for multiple drivers of eutrophication in shallow, subtropical lakes of the southeastern USA**

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In recent decades, many shallow lakes worldwide have experienced rapid ecological changes in response to multiple stressors. Nutrients (P, N) are considered the primary driver of trophic state change (e.g. primary productivity), but factors such as water depth, water residence time, dissolved color, temperature, salinity and contaminants have also been identified as potential drivers. Future projections suggest that agricultural, industrial and climate impacts on shallow lakes will increase, creating the need to identify secondary drivers of ecological change. We studied sediment records from several shallow, subtropical lakes in the southeastern USA and identified drivers of eutrophication during periods of recent human impact and during times prior to substantial human disturbance (mid-late Holocene). We inferred past allochthonous inputs of organic matter, nutrients, and metals, and identified autochthonous, primary producer communities using photosynthetic pigments and cyanotoxins in sediment cores from Lakes Mattamuskeet and Pungo (North Carolina), Apopka and Griffin (Florida), and Long Pond (Georgia). Sediment records from all five lakes display evidence of eutrophic conditions that predate intense human disturbance, and these episodes of eutrophy are linked to shifts in climate, hydrology, and land-water connectivity. Whereas nutrient inputs have been identified as the primary driver of eutrophication in shallow lakes, our findings suggest that other environmental drivers strongly influence lake trophic status. Most management and restoration plans for eutrophic shallow lakes focus on nutrient reduction, but such schemes might prove more effective if additional drivers were considered.

## Poster Presentations

### **S13-P01 - Long-term dynamics of aquatic plant succession reconstructed from a palynological record in a shallow, freshwater lake, China**

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Aquatic plants in shallow freshwater lakes play a key role in stabilizing ecological function and providing valuable ecosystem services, yet they are under severe degradation worldwide. An improved understanding of long-term aquatic plant succession is critical to investigate the potential driving mechanisms and to facilitate ecological restoration. We reconstructed changes in the aquatic plant community over the past century based on palynological records from Changdang Lake, Lower Yangtze River Basin, China. Our results reveal that aquatic plants in Changdang Lake have undergone three clear phases: emergent macrophytes dominated in ca. 1900s–1970s, submerged macrophytes dominated in ca. 1970s–1990s, and floating macrophytes increasingly dominated after the 1990s. Increasing multiple anthropogenic pressures, mainly altering nutrient input and hydrological condition have caused this significant change. We argue that Changdang Lake is currently in a transition phase between a macrophyte-dominated and an algae-dominated state. Our palynological records are not consistent with many contemporary studies, which suggest submerged plants were dominant before the 1950s in most lakes across this region. We argue that the return of aquatic plants to their 1970s–1980s state would be a realistic target for lake restoration. Our results demonstrate the great potential of palynological records for revealing the long-term dynamics of macrophytes in shallow lakes for sustainable lake restoration and management.

## **S13-P02 - A shallow-lake record from high-altitude environments of the Eastern Cordillera, Central Andes, Argentina**

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Deposits from a shallow (~1 m depth), closed-basin lake at high-altitude in the Eastern Cordillera of Argentina were investigated with the aim of establishing the relationship between sediment changes and past environmental variations. The study area is located >4000 m a.s.l., and is characterized by low (<400 mm yr<sup>-1</sup>) seasonal precipitation (December to March), scarce vegetation cover, large thermal amplitudes and high radiation. In this extreme environment, Laguna Salada Grande (23°S/65°W) provides a valuable record of paleoenvironmental and paleohydrological changes. Around this lake, paleoshorelines several meters above the present lake level indicate the existence of a deeper paleolake. The physical properties (magnetic susceptibility, particle size) and geochemical composition (organic and inorganic carbon, XRF elemental composition) of laminated and massive sedimentary units were analyzed. Sedimentary features, such as organic-rich sediments and tuff deposits, can be traced into outcrops, enabling the reconstruction of the past paleolake configuration. Despite its altitude, the Laguna Salada Grande basin has not been glaciated since the Late Pleistocene, permitting comparison of the paleolimnological record with reconstructions of the cooler and wetter events driven by glacial fluctuations at the Eastern Cordillera. Results from this research will also be compared with high-altitude limnogeological records in the Santa Victoria range (in the Eastern Cordillera, north of the study site) and the Altiplano-Puna region, west and north of the study site. This reconstruction will enable a better understanding of past regional atmospheric circulation, and its effect in Late Quaternary mountain lake environments in the eastern part of the Central Andes.

## **S13-P03 - Field testing cellulose-water $\delta^{18}\text{O}$ relations in periphytic algae for paleohydrological reconstructions**

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The oxygen isotope composition of aquatic cellulose extracted from lake sediment cores has long been used to reconstruct past hydrological change. A key aspect of this method assumes a constant oxygen isotope fractionation factor between aquatic cellulose and lake water. This project field-tested the cellulose-water oxygen isotope fractionation factor across broad gradients of hydrology and algal community composition in lakes of the Peace-Athabasca Delta (PAD), where numerous paleohydrological reconstructions have been carried out using cellulose-inferred lake water  $\delta^{18}\text{O}$ . In May 2015, periphyton samplers were deployed at 48 lake sites within the PAD where they accrued algal biomass until collection one month later. Samples for lake-water oxygen composition were collected at the same time as deployment and collection of periphyton samplers. Periphyton was removed from the samplers and subjected to multiple chemical extractions to isolate the cellulose fraction. Cellulose-inferred lake water  $\delta^{18}\text{O}$  overlaps with lake water  $\delta^{18}\text{O}$  in ~70% of sites using a fractionation factor of  $1.028 \pm 0.0015$ . Overlap improves to ~83% based on cellulose samples that appeared pure after extraction. On average, cellulose-inferred lake water  $\delta^{18}\text{O}$  was more closely aligned with May lake water  $\delta^{18}\text{O}$ , suggesting rapid spring colonization and periphyton growth. Lower cellulose-inferred lake water  $\delta^{18}\text{O}$  values than measured lake water  $\delta^{18}\text{O}$  at some sites may be attributable to influence of relatively isotopically depleted rainfall that occurred between deployment and collection. Overall, high agreement between the cellulose-inferred and the directly measured lake water  $\delta^{18}\text{O}$  supports a constant cellulose-water oxygen isotope fractionation factor and lends confidence to paleohydrological reconstructions.



## **S13-P04 - Unexpected stability of a shallow lake ecosystem (Lake Komorany, Czech Republic) despite rapid climate change at the Late Glacial/Holocene boundary**

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Sediments of central European lowland lakes are valuable, but little studied natural archives. The image of postglacial landscape development was mostly formed by study of alpine lake records. Our study investigated the response of a large shallow lake ecosystem (former Komorany Lake, 50.53°N, 13.53°E, surface area ~25 km<sup>2</sup>) to abrupt environmental changes at the Late Glacial/Holocene boundary. Sediment cores obtained in the 1980s by rescue sampling were subsampled and four bulk samples were selected for AMS radiocarbon dating. Analyses of biological variables (diatoms, chironomids, pollen) were accompanied by XRF and LOI. The age-depth model provided evidence for a continuous Late Glacial to early Holocene record, supported by the palynostratigraphy. The alkaliphilous tychoplanktonic diatom *Staurosira* dominated throughout the studied profile. They were, however, partly excluded from counting and analyses considering their low indicator value. Although algal productivity rose distinctly with amelioration of climate conditions at the start of the Holocene, no remarkable change in diatom species composition was observed. The only significant changes in the diatom and chironomid assemblages occurred slightly before the onset of the Holocene: the tychoplanktonic diatom *Staurosira venter* that dominated the basal part of the profile was replaced by *Staurosira construens*. The abundance of *Chironomus plumosus*-type and *Chironomus anthracinus*-type decreased and *Procladius*, *Einfeldia dissidens/natchitochae* and *Glyptotendipes pallens*-type were established. Palynological data indicated the presence of aquatic macrophytes since the Late Glacial. Our results suggest very consistent in-lake conditions, with high nutrient availability that enabled the aquatic community to maintain a stable structure at the Late Glacial/Holocene boundary. The trophic status even decreased slightly in the Holocene. During the Late Glacial/Holocene transition the eutrophic lakes likely represented very stable ecosystems despite drastic changes in the surrounding landscape.

## **S13-P05 - Environmental changes since the mid-19th century, related to water-level fluctuations and anthropogenic pressures in large, shallow Lake Liangzi, Yangtze floodplain, China**

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Macrophyte composition and abundance affect the overall ecological structure and function of shallow lakes. Information on the nature and timing of changes in these plant communities are therefore crucial for understanding the impact on the wider lake ecosystem. We examined plant macrofossils, diatoms, cladocerans as well as physical and geochemical variables in two sediment cores from Lake Liangzi, a large shallow lake on the Yangtze floodplain in SE China, to assess trajectories of environmental change. We also used historical records of environmental changes in the lake and its catchment. This lake is of particular interest because, unlike most lakes in the region, it has maintained a macrophyte-dominated state in modern China. Results revealed a shift in the lake during the past ~160 years, from a clear-water, low-growing submerged macrophyte community (e.g. *Najas minor*, charophyte species), dominated by planktonic diatoms and planktonic cladocerans, towards a pollutant-resistant, tall-growing macrophyte community (*Potamogeton* spp., *Ceratophyllum demersum* and *Myriophyllum spicatum*), with dominance by benthic and epiphytic diatoms and littoral cladocerans. A pronounced increase in abundance of planktonic *Bosmina* spp. at the expense of a decrease in littoral species, and a decline or disappearance in macrophyte abundance in surface samples, suggests that the lake recently entered a new, unprecedented state. Redundancy analyses identified major hydrology changes and moderate anthropogenic pollutant inputs as the main drivers of changes in the lake. Our study demonstrated that plant macrofossils in short, radionuclide-dated sediment cores provide reliable information on the nature and timing of changes in the macrophyte community in shallow Yangtze lakes. Furthermore, our study provided information on the composition of the plant community prior to strong recent perturbations, and shed light on the trajectories and drivers of ecological and environmental changes, thus offering valuable information for lake managers.

## **S13-P06 - Subfossil Cladocera response to environmental variables in dystrophic lakes of NE Poland**

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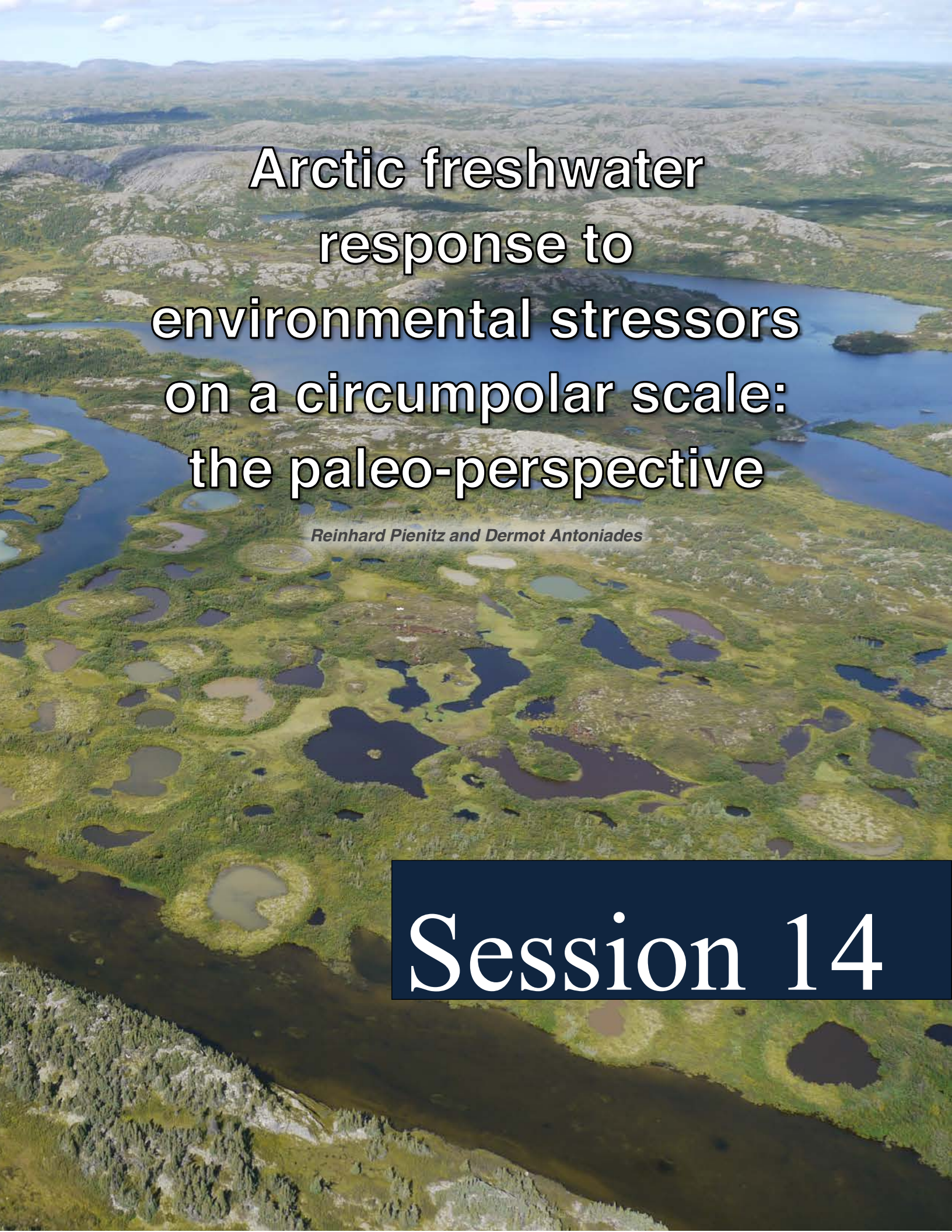
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The main focus of this study was to evaluate the relationship between subfossil Cladocera community composition and environmental properties of dystrophic lakes. Dystrophic lakes are unique ecosystems and have several distinctive features: high amounts of organic acids, brown-coloured water, low pH, visibility and conductivity. They are rare in the Middle European Lowlands, but in Poland they occur in northern part of the country, most commonly in the coldest NE part. We present results of subfossil Cladocera analysis conducted on surface sediments from dystrophic lakes located in Wigry National Park (WNP). We hypothesize that Cladocera species composition depends on the dystrophication index (HDI); thus, Cladocera assemblages change with the degree of dystrophication. HDI takes into account water pH, conductivity and DOC/DIC ratio; lakes with an HDI value greater than 40 are considered dystrophic. In our study we also aimed to create an inventory of the main Cladocera species that inhabit these unique ecosystems and determine species composition for dystrophic lakes. Non-metric multidimensional scaling (NMDS) was used to evaluate similarities among samples in cladoceran community composition and structure. Statistical analyses showed that Cladocera assemblages in all the studied lakes were similar, and individual Cladocera species responded to the measured environmental parameters (e.g., pH, lake size and depth). Results suggest that in dystrophic lakes, Cladocera community composition is an emerging characteristic of individual species responses to the environment. Our results also show a cladoceran community more diverse and abundant than previously thought. The composition and structure of the studied Cladocera assemblages resemble those of the boreal region, reflecting the climatic disconnect that exists between the Polish lowlands and similar environments in the rest of Europe.

This study is a contribution to project 2016/23/D/ST10/03071 funded by the National Science Centre.





**Arctic freshwater  
response to  
environmental stressors  
on a circumpolar scale:  
the paleo-perspective**

*Reinhard Pienitz and Dermot Antoniades*

**Session 14**

# Oral Presentations

## **S14-001 - Local versus regional controls on aquatic production in two adjacent low-arctic lakes in SW Greenland**

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Arctic aquatic ecosystems are nutrient-limited and are therefore affected by the recent anthropogenic disruption of biogeochemistry as much as by climatic changes. The impacts of these processes are difficult to predict and separate due to collinearity in external drivers (e.g. climate, nutrients, catchment changes), inherent ecosystem complexity and a wide range of in-lake processes (e.g. thermal stratification, nutrient recycling, species competition) that respond differentially to external forcing. Sediment records can be used to determine natural responses to past climate forcing, but it remains difficult to separate local from regional processes and it is still unclear to what extent climate drives ecological change and production in lakes. Here, we aim to separate local (in-lake, nutrient supply) from regional (climate) controls statistically by using a multi-proxy palaeolimnological paired-lake study, where the two adjacent sites differ in morphometry and lake depth but reflect the same regional climate forcing. The two lakes (SS2, SS1590) are located near Kangerlussuaq in Southwest Greenland, a well-studied, lake-rich region that allows the research to be placed in a wider regional context. This study highlights the complexity of ecological changes over centennial timescales and emphasizes the importance of nutrient supply and limnological controls on community structure and aquatic production, rather than direct climate forcing.



## **S14-002 - Inferring Holocene climate change in Greenland: Potential for improvements using modern chironomid (Diptera: Chironomidae) assemblages identified with increased taxonomic resolution**

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Given the influence of the Greenland Ice Sheet and feedbacks from Arctic sea ice on global climate, quantitative paleotemperature records from Greenland provide a critical context for understanding global change. Records from areas beyond the ice sheet allow for an understanding of climate-driven changes in this sensitive region. However, proxy calibration data for Greenland is rare, representing a knowledge gap regarding spatial variability in high-latitude climate. Here, we explore the potential of chironomid assemblages from the uppermost sediments of 170 lakes spanning the Canadian Arctic Archipelago and northern Labrador to inform interpretations of Holocene subfossil chironomid assemblages from Greenland lakes. This calibration-set was developed by re-identifying previously-collected specimens at a higher taxonomic resolution than originally published and increases the number of modern analogues available for downcore paleoenvironmental reconstructions. Direct gradient analysis of modern environmental parameters confirmed that temperature explains the largest amount of variation in the training set species data. Both high- and low-resolution transfer functions for reconstructing quantitative chironomid-based paleotemperatures were compared for several non-glacial lakes in a wide range of climate zones across Greenland over the Holocene. We interpret assemblage change in the context of the suitability and applicability of regional chironomid-based transfer functions for reconstructing quantitative temperatures in Greenland and other northern North American regions. Results show that modern chironomid assemblages from non-glacial lakes in Greenland are often dominated by taxonomic groups that were merged in earlier calibration-sets (e.g., *Psectrocladius*, *Micropsecta*), and many such groups also show interesting variability over time in Holocene records. Thus, the development of high-resolution calibration-sets may allow for better interpretations of paleo environments, especially for regions where diversity is low throughout the Holocene and assemblage change is subtle. We assess the potential for improved paleoclimate reconstructions in Greenland and surrounding regions based upon these principles.

## **S14-O03 - Western Canadian Arctic lakes impacted by permafrost thaw exhibit higher sedimentary concentrations of metals and PAH contaminants**

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High-latitude lake ecosystems across the circumpolar north are increasingly impacted by environmental changes associated with thawing permafrost. In addition, many northern regions are underlain by significant proven and predicted reserves of hydrocarbons. Even in the absence of direct human exploitation of these resources, there is the potential for an influx of contaminants to lakes associated with terrestrial geomorphic disturbances, such as occur with thawing permafrost. In these remote ecosystems the translocation of materials from the catchment following thermokarst might represent an important, but as yet uncharacterized, source of contaminants to lakes. We assessed the potential for permafrost thaw to act as a natural source of polycyclic aromatic hydrocarbons (PAHs) and metals to lakes using sediment cores in the ecologically sensitive, and hydrocarbon rich western Canadian Arctic. We examined 4 lakes with retrogressive thaw slumps, and 4 nearby undisturbed reference lakes, focusing on PAH deposition and composition in the sediment. Total organic carbon (TOC)-normalized concentrations for parent and alkylated PAHs were higher in sediments of slump-affected lakes than the reference lakes. Diagnostic ratios of specific PAHs suggested the sediment of slump-affected lakes had greater influence from petroleum-based PAH sources. Thaw slump-affected lakes were enriched in metals derived from shale-based, Quaternary deposits when compared to reference lakes where these surficial materials were not exposed by thermokarst activity. Higher PAH concentrations and the composition indicative of petrogenic sources observed in sediment of slump-affected lakes were best explained as a combination of low TOC availability, a pattern previously observed for persistent organic pollutants, and increased inputs of previously bound hydrocarbons from the catchment due to permafrost erosion. These findings demonstrate that, to avoid misinterpreting the scale and nature of the impact of hydrocarbon development in northern landscapes, monitoring of sediment PAHs must be assessed in the proper framework of these dynamic freshwater systems.

## **S14-004 - Environmental impact of early Sadlermiut settlements at Native Point (Southampton Island, Nunavut, Canada)**

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Based on archaeological and genetic studies, the Arctic was first populated by Paleo-Eskimos (Dorset culture) and eventually succeeded by the arrival of the ancestors of present-day Inuit (Thule culture). The first Thule forager groups settled successfully in the Hudson Bay region of the Canadian Arctic starting ca. 1050 CE. At Native Point on Southampton Island (Nunavut), first evidence of settlements dates prior to 1200 CE by Sadlermiuts, a Thule group that adopted Dorset culture elements. The village consisted of numerous sod and winter houses which framed a small shallow freshwater body (c. 20,000 m<sup>2</sup>). Numerous butchered carcasses of mainly walrus, seal, bowhead whales and caribou remained in the pond and further decayed in the water.

Here, we present results from a paleolimnological study of three short sediment cores taken from the bottom of the settlement pond. Sedimentological, geochemical and micropaleontological analyses show an abrupt change at c. 1150 from pristine aquatic environments to eutrophic conditions, alongside shifts in chironomid faunal assemblages that infer changes in the pond's aquatic vegetation as well as a dominance by the detritivore *Tanytarsus gracilentus* during this period. Likewise, variations in  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  isotopes of the organic matter suggest that this shift is related to the first butchering activities of Sadlermiuts in the area.



# **S14-O05 - Terrestrial and aquatic responses to Holocene climate changes in northernmost Sweden - identifying the magnitude and direction of changes in the subarctic catchment of Torneträsk**

**Hendrik Vogel (1), Carsten Meyer-Jacob (2, 3), Matthias Thienemann (4), Benedikt Ritter (4), Christian Bigler (2), Richard Bindler (2), Stephanie Kusch (4), Melanie J. Leng (5, 6), Enno Schefuß (7)**

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Terrestrial and aquatic environments in high northern latitudes will experience substantial change in response to predicted future warming. To provide a better account of the possible magnitude and direction of these changes requires understanding past responses of these environments to climate changes. Here we present hydro-acoustic data and sedimentary records from the 330-km<sup>2</sup> Lake Torneträsk (N Sweden) that enable catchment-scale reconstructions of terrestrial and aquatic responses to Holocene climate changes. We employed a suite of sedimentological, biological, and inorganic-, organic-, and isotope-geochemical techniques to extract quantitative and qualitative information on climate changes, and associated landscape and ecosystem responses.

Molecular proxies for summer temperatures show a long-term Holocene cooling trend of ~2°C due to isostatic uplift and decreasing summer insolation, similar to other regional reconstructions. Stable water isotope indicators for precipitation amount and source lack significant variability for most of the Holocene but suggest a significant change, possibly in precipitation source, commencing at ~1500 cal BP. This shift is accompanied with an increase in flood frequency, indicating more frequent heavy precipitation events during summer. Indicators for chemical weathering and soil formation show a long-term trend towards deeper weathering horizons and thicker, more organic-rich soils throughout the Holocene. While most of our data show long-term trends associated with the overall climate pattern and landscape development following deglaciation we note a significant perturbation of terrestrial and aquatic ecosystems during the last ~1500 years. Neoglacial cooling and reorganization of atmospheric circulation led to a significant erosion pulse in the Torneträsk catchment along with substantial mobilization and export of organic carbon from catchment soils. Considering the magnitude and direction of change, our data suggest that cooling and associated changes in atmospheric circulation exerted the strongest perturbation of terrestrial ecosystems in the subarctic catchment of Torneträsk during the Holocene.

# Poster Presentations

## **S14-P01\* - Creating a data analytics system for lake sediment records in the Russian Arctic**

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Arctic lake archives exceeding the era of the last glacial maximum are limited to a few exemplary lake sediment records. There are big research gaps especially in the Russian Arctic and the palaeolimnological records that have been published are not easily comparable to each other in advanced statistical applications. We therefore find that a standardized data set of available proxy data from lake sediment cores in the Eastern Arctic will greatly facilitate a better understanding of relationships between lake system ontogeny and millennial climate forcing on a continental scale. Our objective is to develop a state-of-the-art data analytics system that allows to detect coupling mechanisms of inherent ecosystem dynamics and external climate changes and their spatiotemporal pattern in dependence to lake and catchment attributes. Over the last decades we generated an archive of a high number of radiocarbon dated sediment cores with published or unpublished data. The high complexity of data types and the increasing amount of measurements requires a big-data approach to generate data synthesis products. One single lake sediment record comprises ca. 100 000 sample measurements attributed to >100 different biotic (e.g. organic sediment properties, diatoms, pollen, chironomids) and abiotic (e.g. XRF scanner data, XRD mineral composition, grain-size distribution) proxy data. Detection of ecosystem-climate relationships in a three-dimensional large dataset, requires close interdisciplinary collaboration between field-based polar research providing the original data and their interpretation and data science expertise that guides the management, standardization, quality-control, and big-data statistical methods. Here we present statistics on the spatial distribution, age coverage and availability of palaeolimnological parameters of lake sediment records in the Russian Arctic.

## **S14-P02 - Cladocera assemblages in lake sediments from the Russian Arctic**

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Cladocera (Branchiopoda, Crustacea) is a key component of aquatic ecosystems, which is widely used in paleoecological reconstructions of climatic and environmental changes. Their chitinous exoskeletal components are usually well preserved in lake sediments. Information about the ecology exists for most species, and they are sensitive to changes in climate and environmental variables such as trophic state, conductivity, saline transgressions and predation intensity. This study presents the results of Cladocera remains data collected along four tundra-to-taiga transections in central (Khatanga river catchment area, south of Taymyr Peninsula) and eastern Siberia (Lena River Delta and New Siberian Islands, Indigirka and Anabar river catchment areas). Subfossil Cladocera from surface sediments (0–2 cm) of 90 lakes and from five short cores were analyzed. The aim of the present investigation was to examine the taxonomic and ecological diversity of cladoceran microfossil assemblages from northern part of Russia. Differences in the cladoceran assemblages were related to limnological features and geographical position, climate and water chemistry. There are just a few paleolimnological study has been previously done on Cladocera remains in Russian Arctic.

## **S14-P03\* - Seasonality of chrysophyte cyst assemblages in varved Lake Nautajärvi implications for palaeolimnological studies**

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Although chrysophyte cysts are widely used as palaeobioindicators in palaeolimnological studies, only recently have attempts been made to use their modern deposition from sediment trap data to provide more detailed, seasonal-based environmental reconstructions.

In this study sediment traps were used to record seasonality of chrysophyte cysts during two climatically different years 2009 and 2010 in an annually laminated Lake Nautajärvi, Finland, and this seasonal data was then compared with the fossil record derived from the surface sediment of the lake. The overall changes in cyst assemblages between years and seasons are subtle. No clear connection to any particular season could be detected in the sediment surface. Despite the climatological differences between the study years, the inter-annual accumulation rates of cysts were surprisingly similar, whereas the intra-annual accumulation rates differed substantially. This and the high amount of taxa occurring from spring to autumn in the trap samples implies that primary producers are more dependent on prevailing seasonal limnological conditions than on rapid, shortly lived episodes.

Redundancy analysis (RDA) revealed that chrysophyte cyst assemblages from the spring sediment trap are mainly controlled by the spring discharge intensity, a surrogate variable of spring weather conditions, whereas precipitation and air temperature have the strongest impact on the summer assemblages. However, only discharge explains statistically significantly the variance in the cyst data. The similarity between cysts found in the sediment traps and surface sediment sample suggests that within small and shallow lakes without any extreme environmental settings the surface sediment sample represents well the lake's overall algal composition and can thus be used in palaeolimnological studies.

## S14-P04 - Pollen investigation of annually laminated sediments from Lake Kevo, Finnish Lapland

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The pollen accumulation in annually laminated sediments of lake Kevo (Finnish Lapland) investigated using two sources of data: the pollen from lake core and the series of annual pollen traps observations. The deepest part of the Lake Kevo was cored in the April of 2017. The annual lamination allows precise dating of every level and link the particular layer with annual ground observations. The core covers potentially the latter part of the Little Ice Age (LIA) and the transition from LIA to recent warming. The series of long term ground pollen observations has been collected in Kevo research station since the 1970s by Prof. Sheila Hicks. The data are available through Pollen Monitoring Program network (<http://www.pollentrapping.org/>).

Short pollen diagram of 20 levels of pollen counting with near annual resolution will be produced from the same lake sediment core that was analyzed by other methods (physical and chemical sediment properties and diatom analyses). The pollen from upper part of the core is well preserved, easy to count and reflects the diversity of regional vegetation. The spectra are mostly dominated by pollen of *Pinus*, *Betula*, *Ericaceae* and *Poaceae*. The similarity between pollen from lake sediment and the ground observations will be investigated by numerical methods (clustering and correspondence analysis).

The results of that study will bring better understanding of subarctic climatic variability using high resolution multiproxy approach. Comparison of pollen from lake sediments and ground pollen observations will add the information to the sediments deposition in the lakes. The past variation in the catchments erosion can be reconstructed from the physical sediment properties. Pollen data from Lake Kevo will provide valuable information from the catchments and its changes in order to better understand the driving forces of erosion changes and subarctic lake-catchments dynamics.

## S14-P05 - Paleo-optics of tundra lakes

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Underwater irradiation regimes control fundamental ecosystems functions, such as food web structure, auto- versus allochthonous production, and carbon sequestration in transparent and shallow high latitude and high altitude lakes. A recent method for measuring ultraviolet UV radiation absorbance of fossil cladoceran (Branchiopoda) remains (UV-ABS), indicative of the relative content of UV protective melanin pigment, has proven to be useful when tracking past underwater UV regimes and their connection to solar forcing in High Arctic lakes. However, the role of light- and UV-attenuating dissolved organic carbon (DOC) and intensity of DOC photodegradation are crucial for UV transparency in subarctic tree line lakes, which are more prone to vegetation-driven DOC alterations. We examined sediment records of two adjacent lakes (Loazzejavri and Nammajavri) in subarctic Finnish Lapland for fossil Cladocera and UV-ABS to track ecotonal differences in paleo-optics since ~1300 Current Era (CE). The UV-ABS records indicated consistently increased underwater UV during the late 15<sup>th</sup> century, ~1700–1800 CE and the late 20<sup>th</sup> century. The earlier peaks of UV exposure were likely responses to more transparent water column through climate forcing on in-lake production and allochthonous DOC input during the cold Little Ice Age, whereas the increase in UV exposure during the late 20<sup>th</sup> century may reflect increased UV irradiance caused by ozone depletion of the 1970–80s. The records further suggest reductions in UV exposure during the early 21<sup>st</sup> century that may be associated with increased allochthonous DOC load under warming climate. To refine paleo-optical interpretations and the role of DOC and its photodegradation on sedimentary UV proxies, our future studies will focus on the impacts of irradiation on UV-protective pigment composition of aquatic biota and biogeochemistry of sediments through experimental paleolimnology.

## **S14-P06 - Palaeoecological and palaeoclimatic reconstruction of the Holocene in the South of the Taimyr Peninsula (Russia) based on chironomids analysis of lake sediments**

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The study aims to explore the palaeoclimate and palaeoenvironment during the last 7100 yr. on the Taimyr Peninsula - the most northern part of Russia. Arctic regions are highly sensitive to climate changes, and the reconstruction of past Holocene environments of those regions is important for understanding of the background of natural climate variability underlying anthropogenic influences on climate change. The 131.5 cm-long lake sediment core from Khatanga-12 lake (72.4°N, 102.29°E; 60 m a.s.l.) has been studied. We performed a multy-proxy reconstruction of palaeoclimate and Holocene environment. Quantitative reconstruction of mean July air temperature and the water depth of the lake have been performed using Northern Russia chironomid based inference models (Nazarova et al., 2011, 2015). The analysis of changes in the species composition of subfossil chironomids communities made it possible to identify four statistically significant ecological zones. The period from 7100 to 6250 cal. years BP is the early stage of the lake development. Thermokarst processes caused by high humidity and relatively warm climatic conditions influenced the lake ecosystem. The period after 6750 cal. years BP is characterized the higher than the modern reconstructed temperatures and corresponds to a final stage of Mid Holocene warming. Between 6500 and 4750 cal. years BP chironomids show climate cooling corresponding to a Neoglacial cooling which was observed in different regions of Eurasia and Northern America. From 2000 cal. years BP the reconstructed climatic conditions are unstable, reconstructed T July are close to the modern.

This project was financed by the RSF (project no. 16-17-10118)

## **S14-P07\* - Unravelling Late Quaternary palaeoenvironmental change in Chukotka, Arctic Russia: Insights from a multi-proxy approach**

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Understanding palaeoenvironmental change within arctic environments is of critical importance owing to the rapidity of change that can occur due to arctic amplification. This is of particular significance within the remote regions of north Eastern Siberia where data coverage in palaeoenvironmental records is low and the effects of climatic changes are high. In such regions the coupling between climatic forcing and limnic processes is yet to be thoroughly understood but is crucial to improving predictions of future climatic scenarios. In this study a 292 cm and 194 cm lake sediment core was obtained in July 2016 within the Chukotka Autonomous Okrug region of arctic Siberia from 31 m water depth in Lake Rauchua'gytgyn and from ca. 25 m water depth in Lake Illerney, respectively. The Rauchua'gytgyn and Illerney cores were dated back to 10,500 and max. 32,900 cal. yrs BP. Here we present calibrated and log ratio transformed XRF elemental data. In both cores, principal component analysis performed in R indicated that Br, Fe and Mn evidence redox conditions, whilst Zr and K function as coarse detrital and clay mineral indicators. Highest temporal fluctuations were observed in the Holocene, but major changes appeared at the Pleistocene/Holocene transition.

A follow-up expedition is scheduled for summer 2018 to retrieve extended sediment cores and to conduct seismic measurements to gain insights into the spatial sedimentation history of the lakes. Multiple abiotic and biotic proxies will be analysed from these long cores to fill an important research gap by providing data for the first time on the Late Quaternary glacial history in this remote area. The data will feed into a palaeolimnological compilation of polar terrestrial proxy data as part of the PALMOD project.



## **S14-P08 - An Overview and First Results of the PLOT (Paleolimnological Transect) Project in the Russian Arctic**

**Volker Wennrich (1), Raphael Gromig (1), Andrej Andreev (1,2), Marlene Baumer (1), Dmitri Bolshiyarov (3,4), Grigory Fedorov (3,4), Svetlana Kostrova (5), Sebastian Krastel (6), Elodie Lebas (6), Anna Ludikova (7), Hanno Meyer (5), Lyudmila Pestryakova (8), Larisa Sevelieva (4), Lyudmila Shumilovskikh (9), Dmitry A. Subetto (10), Bernd Wagner (1), Martin Werner (11) and Martin Melles (1)**

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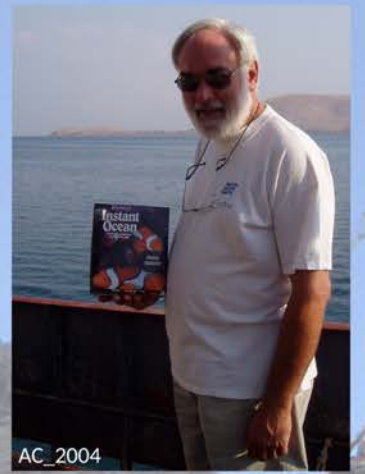
The joint Russian-German project "PLOT - Paleolimnological Transect" aims to recover lacustrine sediment sequences along a >6000 km-long longitudinal transect across the Eurasian Arctic in order to investigate the Late Quaternary climatic and environmental history. The climate history of the Arctic is of particular interest since it is the region, which is experiencing major impact of the current climate change. The project is funded for a duration of three years by the German and Russian Ministries of Research. Since 2013 extensive fieldwork, including seismic surveys, coring, and hydrological investigations, was carried out at lakes Ladoga (NW Russia), Bolshoye Shuchye (Polar Urals), Emanda (Verkhoyansk Range), Levinson-Lessing, and Taymyr (both Taymyr Peninsula). Fieldwork at lakes Bolshoye Shuchye, Levinson-Lessing, and Taymyr was conducted in collaboration with the Russian-Norwegian CHASE (Climate History along the Arctic Seaboard of Eurasia) project. A major objective of the PLOT project was to recover preglacial sediments. A multiproxy approach was applied to the analytical work of all cores, including (bio-)geochemical, sedimentological, geophysical, and biological analyses. First data implies the presence of preglacial sediments in the cores from all lakes except Lake Emanda. Age-depth models, based on radiocarbon dating, OSL dating, paleomagnetic measurements, identification of cryptotephra, and varve counting (where applicable), are in progress. The records shall be correlated to that of Lake Elgygytgyn (NE Russia), which represents the master record for the Siberian Arctic. The outcome of the PLOT project will be a better understanding of the temporal and spatial variability and development of the Arctic climate. Here, we present the major results and first key interpretations of the PLOT project. We also give an outlook on the future strategy and foci of the project. First results will culminate in a special issue in spring 2018 comprising publications about Lake Ladoga and Lake Levinson-Lessing.



JIT\_1974



MS\_2005



AC\_2004



RR\_1996



JIT\_1976

# Lakes of Africa through space and time: a tribute to Jean-Jacques Tiercelin

*Mathieu Schuster, Andy Cohen, Tom Johnson, Robin Renaut, and Chris Scholz*

# Session 15



RR\_2013



TJ\_2013



MS\_2004

# Oral presentations

## **S15-001 - Plio-Quaternary evolution of the Omo river delta (Shungura Formation, Omo Group, Northern Turkana Depression, EARS): facies analysis and sedimentary architectures**

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The Shungura Formation is a major site to study Plio-Pleistocene vertebrate (including hominid) evolution and contemporary environmental changes. Indeed, it provided an exceptional array of data (radiometric chronology, faunal assemblages, early Oldowan stone tools and paleoecological markers). It also offers an outstanding opportunity to investigate the sedimentary record of the evolution of an axial system in a rift basin.

The Shungura Fm. is a ca. 800 m thick succession covering a period between ca. 3.6 Ma and 1 Ma. It is made of volcano-clastic sediments deposited in a wide range of depositional environments ranging from deep lake to meandering river. In this work, a newly documented section spanning almost all the Shungura fm. (550 m thick) and covering a period between ca. 3.6 Ma and 1.76 Ma is investigated. From a sequence stratigraphy perspective, we propose to explore fluctuations of Turkana Paleolake and variations in the sedimentary supply that came from the Ethiopian uplands by investigating the evolution of the Omo Delta through time and space.

First, depositional environments are interpreted based on sedimentary facies analysis. Then, the identification of stacking patterns allow progradational and retrogradational trends to be delineated, revealing several Transgressive-Regressive cycles. Finally, reconstructed sequences are confronted to previous paleo-environmental reconstructions.

These elements will provide a better constrained framework for understanding the interrelations between local faunal evolution (including that of human ancestors) and its environmental factors.



## **S15-002 - Palaeoenvironment of the Angamma Delta, Lake Megachad, and its implications for lake-level history at the end of the African Humid Period**

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During the early Holocene African Humid Period (AHP) there was a dramatic increase in the area of lakes and wetlands over the northern and central part of the continent. The AHP came to an end during the mid Holocene, although the exact timing and nature of AHP termination has been disputed with studies variously suggesting abrupt, gradual and fluctuating endings, and regionally-synchronous versus time-transgressive patterns. Lake Megachad was one of several huge lakes that existed during the AHP. We present stratigraphical, sedimentological, palaeoecological and isotopic evidence from sediments of the Angamma Delta for fluctuations in the level of Lake Megachad at the end of the AHP. The Angamma Delta lies on the northern margins of the Bodele Depression and in the former north-eastern part of the megalake. Delta slope deposits were deposited over 7000 cal BP at the height of the AHP. Overlying bioclastic sediments, from 4300–4800 cal BP and an elevation of 285–290 m, lie below the palaeolake highstand (339 m) but close to the elevation of the Bahr el Ghazal sill, which divided the two sub-basins. Ostracod oxygen-isotope values indicate that the waters of the northern sub-basin were evaporated to an extent similar to that in modern Lake Chad. Palaeoecological evidence suggests that the lake was perennial and evaporative enrichment is attributed to restricted circulation of lake waters as the sill emerged. The age and elevation of the bioclastic sediment, coupled with published lake level reconstructions from elsewhere within the basin, suggest a complex lake-level history at the end of the AHP involving rapid and large vertical fluctuations in lake level at this time. The new data provide support for other geological records from northern Africa, and some modelling experiments, that suggest abrupt changes in climate at the end of the AHP.

## **S15-003 - Variation in clastic-fraction sediment properties of Lake Chala, East Africa: Understanding the source-to-sink processes and temporal changes**

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The clastic fraction of lacustrine sediments provides valuable information about the dynamics of sedimentation in lakes, and can be used to define distinct terrestrial source areas and transport mechanisms from source to sink. Along-core variation in the clastic fraction yields indications of temporal changes in the terrestrial environment surrounding the lake. However, to successfully exploit these terrestrial proxies in palaeo-environmental interpretations, we first have to understand and quantify the modern conditions at the study site.

In this study we test if the grain-size distribution and mineralogical composition of the clastic fraction of sediments from Lake Chala can be used to infer source-to-sink processes into the lake. Lake Chala is a deep freshwater lake situated inside a steep-sided volcanic crater basin on the eastern slope of Mt. Kilimanjaro. Situated close to the equator, the lake provides one of the few sedimentary archives worldwide allowing the study of inter-hemispheric climate dynamics over long time scales. Because of its restricted crater catchment, the fine-grained and finely laminated sediments of Lake Chala are mainly composed of organic matter, biogenic silica and authigenic carbonate, with a relatively small detrital mineral component. In order to identify the modern dynamics of this terrestrial sediment input (i.e., aeolian vs. run-off) into Lake Chala, and to map differences in sedimentological properties, core and surface-sediment samples as well as on-shore samples from several locations within and outside the catchment were investigated.

The observed spatial variation in grain-size distributions and mineralogy can be linked to distinct terrestrial source areas, whereas the down-core trends give information about past changes in transport dynamics towards and into the lake during the last 25 000 years. The results of this study will be applied on the 215 m long ICDP DeepCHALLA record to describe changes in terrigenous sediment input into the lake further back in time.

## **S15-004 - Quaternary outcrop and core stratigraphy of the Magadi Basin, South Kenya Rift**

**Bernhart Owen (1), Robin Renaut (2), Tim Lowenstein (3), Veronica Muiruri (4), Emma McNulty (3), Nathan Rabideaux (5), Kennie Leet (3), Dan Deocampo (5), Andrew Cohen (6), Christopher Campisano (7), Anne Billingsley (6), Mark Sier (8), Shangde Luo (9), Alan Deino (10) and Anthony Mbuthia (11).**

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Cores from Lake Magadi (South Kenya Rift) contain a nearly-continuous sedimentary sequence that rests on trachyte (1.08 Ma). Fifteen major facies were laid down in a series of fresh to highly saline lakes, wetlands and playas. The sediments are distinctive in lacking pedogenic horizons, which are common in other lacustrine rift sequences. This reflects the basin's location in a tectonic sump where continuous aquatic environments were maintained by geothermal and/or meteoric springs even during dry periods.

Five geochemical zones and sixteen subzones can be distinguished based on major and trace elements and mineralogy. An upward decline in Ca:Na ratios and rise in  $(K_2O+NaO)/Al_2O_3$  ratios reflect increasingly saline and alkaline palaeolakes. Rare Earth Element data become more varied upwards reflecting the evolution of strongly alkaline carbonate brines. Calcite and Mg-calcite give way to zeolites above 98 m core depth (~325 ka) with zeolites and trona dominating above 60 m (~98 ka), reflecting a transition from moderately saline to strongly saline lakes. Seven diatom zones can be distinguished with well-preserved floras dated to 472–18 ka. Pollen are present throughout most of the core, reflecting the presence of anoxic environments through much of the 1-million-year record.

The geochemical, diatom and pollen data suggest progressive aridification since about 510 ka superimposed on many wet-dry cycles and with increased variability during periods of high eccentricity-modulated precession. Particularly intense aridity developed between 455–325 ka that may correlate with calcrete formation between the poorly dated Oloronga and Green beds, in outcrop. The transition to extremely arid conditions in the Magadi Basin coincides with a global shift in climate patterns at the Mid-Brunhes Event, partially overlaps with mammalian extinctions in the South Kenya Rift (500–400 ka), and corresponds with a change from Acheulean to Middle Stone Age tools in the nearby Olorgesailie Basin.

## **S15-005 - Geothermal contributions to lacustrine sedimentation in the Kenya Rift**

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Geothermal fluids flow into many Kenya Rift lakes from shoreline springs or from the lake floor, either from vents or diffusively. Their influence on sedimentation varies from lake to lake, but they can be a major influence on lacustrine sedimentary records and their paleoenvironmental interpretation, especially in small closed lakes. Most spring fluids are alkaline. Gases from the mantle and lower crust (mainly carbon dioxide) discharge into some lakes. The impact of geothermal fluids can be direct or indirect. The most important role of deeply sourced springs is to maintain surface water in lakes that would otherwise desiccate during dry periods (e.g., at Magadi, Nasikie Engida, Logipi, Bogoria). Some springs leave a local sedimentary record as sublacustrine carbonate chimneys (Magadi) and unusual sinters (Baringo, Bogoria). Other fluids (saline alkaline with little Ca or too cool in the reservoir for silica precipitation where discharged) leave no record. Some evidence is indirect. Spring fluids with unusual compositions (e.g. high Si, F, sulfate) recharge lakes that in evaporative settings may precipitate silica as chert precursors including gels (Magadi) or form mixed salts (Suguta). Deeply-sourced carbon dioxide is important in trona precipitation. Shallow circulating geothermal fluids passing through lake sediments also precipitate high-temperature minerals (e.g., thermonatrite) or accelerate diagenetic reactions including zeolitization and formation of fluorite. Where springs help to maintain lakes during dry periods, they help to preserve continuous sedimentary records (Nasikie Engida, Bogoria). In turn, they can preserve microbial organic matter by inhibiting oxidation, producing favourable hydrocarbon source rocks. Shoreline spring deposits and hydrothermal alteration can sometimes be used to reconstruct lake-level changes. Though often ignored, thermal springs and gases can be major influences in sedimentation in closed rift lakes.

## **S15-O06 - A 550,000 yr lacustrine environmental record from Chew Bahir, south Ethiopia: towards an understanding of climatic influences on early human populations**

Henry Lamb (1), Asfawossen Asrat (2), Christopher Bronk Ramsey (3), Andrew Cohen (4), Sarah Davies (1), Jonathan Dean (5), Alan Deino (6), Walter Duesing (7), Verena Foerster (8), Annett Junginger (9), Melanie Leng (10), Emma Pearson (11), Helen Roberts (1), James Russell (12), Frank Schaebitz (8), Martin H. Trauth (7), and the Chew Bahir Science Team

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Chew Bahir is one of six sites in eastern Africa currently under investigation as part of the Hominin Sites and Paleolakes Drilling Project (HSPDP), in which Jean-Jacques Tiercelin was a much-valued colleague. At 4°40'N, 36°50'E and 600 m a.s.l., Chew Bahir is a 30 x 70 km area of playa mudflats overlying >4 km of unconsolidated sediments in the Broadly Rifted Zone between the Main Ethiopian and Kenya-Turkana Rifts. It lies ~80 km east of Omo-Kibish, site of 195 ka *Homo sapiens* fossils, the earliest known from eastern Africa. In November 2014, we drilled duplicate 280 m cores, aiming to determine the major climatic and environmental changes during the last 500 kyrs, and to test the hypotheses that periods of directional change or heightened climatic variability drove key events in human cultural and biological evolution.

The composite core record represents >90% recovery, verified through multi-proxy inter-core correlation, and analysed with high-resolution  $\mu$ XRF, XRD, stable isotope, biomarker and sedimentological data. An initial age model, based on radiocarbon and OSL ages from the uppermost 80 m and three  $^{40}\text{Ar}/^{39}\text{Ar}$  single-crystal K-feldspar ages, shows that the record extends to ~550 ka. We focus here on the last 200 kyrs, in which mineralogical, geochemical, and colour reflectance data document pronounced hydroclimatic variability. This variability is similar to Indian Ocean sea-surface temperature and atmospheric CO<sub>2</sub> variations, as a consequence of orbital (mostly precessional) forcing, and to wet-dry oscillations elsewhere in northern and eastern Africa. These climatic changes may have implications for understanding early human population dynamics in the region, including multiple 'Out of Africa' dispersal events.



## **S15-007 - Basin Evolution and Source-to-Sink History of the Central Lake Malawi (Nyasa) Rift**

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Long-lived continental rifts are influenced by surface processes that include footwall erosion, drainage development and fragmentation, and margin uplift. In the Central Basin of the Lake Malawi (Nyasa) Rift a complex and long-lived system of sublacustrine fans has developed. An extensive suite of crustal-scale seismic reflection data was acquired in 2015 as part of the SEGMeNT project, which produced superb images of the syn-rift section. These deep images are augmented by legacy single-channel high resolution reflection data that provide detailed information on facies geometries and stacking architecture of the deep-water siliciclastic systems. The ages and lithologic character of the stratal surfaces observed in the reflection seismic data are constrained by ties to the 2005 scientific drill cores acquired during the Lake Malawi Scientific Drilling Project. The South Rukuru River is an eastward flowing regional drainage (11,900 km<sup>2</sup>) that enters Lake Malawi through an incision in the western border fault of the rift's Central Basin. The Ruhuru River drainage (17,230 km<sup>2</sup>) enters the eastern side of the lake at an accommodation zone margin between the North and Central Basins. Both are antecedent drainages that prior to rifting may have delivered sediments to the Indian Ocean continental margin. Both systems now deliver sediment to a highly confined and focused depocenter in the Central Basin. The complex interplay of extension, mainly on the border fault systems, and high-frequency and high-amplitude lake levels shifts, has led to unique coarse sediment facies stacking architectures, with vertical stacking controlled by hydroclimate, and lateral positioning localized by fault behavior. Focused deep-water (700 m) deposition has resulted in overpressure within the sedimentary section in the localized depocenter, producing high-relief mud diapirs. Long-lived channel-levee systems observed in the seismic data demonstrate that both drainages systems have been operative for the past several million years.

# **S15-O08 - Lake Turkana fluctuations during the Plio-Quaternary : a sequence stratigraphy perspective from the Nachukui Formation (Plio-Quaternary, East African Rift System, Turkana Depression, Kenya)**

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Understanding lake-level variations through time and space is of major importance for reconstructing paleohydrological conditions in continental basins, notably in rifts.

During the last few decades sequence stratigraphy proved a powerful tool to reconstruct sea-level variations at geological time scale. Here we propose to use this method to reconstruct past lake-level fluctuations in a continental rift basin, and then to deconvolute their genetic climate- and tectonic-related origins.

The Nachukui Formation (Omo Group) is a sedimentary succession that represents the syn-rift sedimentary record of the North Lake basin. This Formation, associated to the main border fault of the half-graben is exposed on the western shore of Lake Turkana and constitutes a 700 m thick fluvio-lacustrine sediment pile that ranges from ca. 4.2 to 0.7 Ma. One of the major advantage of the Nachukui Fm, apart from excellent outcrops conditions, is a very robust absolute chronological framework based on tephras, as a consequence of the major paleoanthropological discoveries in all of the Turkana Depression over the last decades.

Building upon facies and sequence analyses, the successive depositional environments are interpreted (e.g., alluvial fans, mouth bar, beachface, shoreface) and major stratigraphic surfaces are identified (maximum flooding surface, emersion, incision) allowing successive prograding and retrograding trends to be defined.

Finally, two main types of sedimentary paleolandscapes alternatively characterize the western graben margin: one dominated by aggrading-prograding fan-delta sequences, and one dominated by prograding-retrograding paralic sequences. Additionally, we show that high-amplitude (> 70 m) lake level variations were mostly controlled by eccentricity parameters as revealed by ca 400 ka cycles. Cycles related to precession (ca. 20 ka) are identified and investigated from ca. 1.9 and 1.7 Ma, however they show low-amplitude (<15 m) variations indicating that they only modulated the long-term lake level evolution.

## **S15-009 - The Lake CHAd Deep DRILLing Project (CHADRILL) – Targeting ~10 Million Years of environmental and climate change in Africa**

**Florence Sylvestre (1), Mathieu Schuster (2), Hendrik Vogel (3), Moussa Abdheramane (4), Daniel Ariztegui (5), Ulrich Salzmann (6), Antje Schwalb (7) and Nicolas Waldmann (8)**

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Covering almost 8% of the continent, the Lake Chad Basin (LCB) is the largest endorheic drainage basin in Africa ( $2.5 \times 10^6 \text{ km}^2$ ) and one of the largest intracratonic basins on Earth. With a sedimentary infilling extending back to ~10 Myr and located at the interface of the African tropics and subtropics, it provides a unique opportunity to trace back changes in moisture variability and associated changes in environmental conditions in so far unprecedented detail. With the discovery of *Sahelanthropus tchadensis*, the LCB has been recognised as one of the cradles of humanity. The findings demonstrate that human evolution was not restricted to the East African Rift, thus posing important questions about the origin of mankind while strengthening the debate concerning the environmental triggers for human evolution. Understanding the routes of hominin dispersal “Out of Africa” becomes increasingly important. Many studies consider the Sahara Desert as a natural obstacle to human migration with the Nile as the only optimal corridor. Some studies suggest, however, another potential corridor, following drainage systems, between the LCB and the Mediterranean Sea for latitudinal migration. In addition, obtaining long sedimentary records from the LCB may help to assess the dynamics of intracontinental basins through time and space. Sediments outcropping around Lake Chad show intriguing similarities to those discovered by the on-going Curiosity Mars mission. This striking similarity makes the LCB a promising analogue for similar freshwater systems that were once present on Mars.

To this end, the CHADRILL science team has recently requested ICDP funds to realize a scientific drilling project in the LCB. If funded, this initiative aims at generating a unique sedimentary record of climatic and environmental changes potentially extending back to ~10 Myr. Such a record will not only provide important new insights into long-standing fundamental research questions but also address important societal challenges.

## Poster presentations

### **S15-P01 - $\delta^{13}\text{C}$ record from Plio-Pleistocene lacustrine fish fossils from an HSPDP drill core from Tugen Hills, Kenya: Implications for fish habitats and the timing and extent of lake level fluctuations**

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$\delta^{13}\text{C}$  values of fish fossils from an HSPDP drill core from Tugen Hills, Kenya are used to infer fish habitats in response to lake level fluctuations during the Plio-Pleistocene in East Africa. This study offers insight on how regional environments responded to external climatic forcing such as orbital cycles, local insolation changes and global climate events. These data can also allow us to constrain the timing and extent of high-lake stands during the earliest appearance of *Paranthropus* sp. and *Homo* sp. as well as the important Plio-Pleistocene climate transition, when global climate began to cool and East Africa climate became drier and more variable. Modern  $\delta^{13}\text{C}$  values of fish bone and teeth from Lakes Turkana and Malawi provide a valuable modern analogue for understanding the paleolake. Initial  $\delta^{13}\text{C}$  values of the fish fossils (-20‰ to -26‰) show that fluvial fish are present along with pelagic species, but there are no obvious shallow lacustrine fish communities. This may suggest that there were open-water phytoplankton communities available as a food source even in the most arid phases of East African climate. Furthermore, the lack of shallow, benthic lacustrine fish communities may indicate that the rate of change from low-lake stands to deeper lake phases may have been fast enough to preclude shallow water species from becoming established at the core site. These results suggest that lake level responses to climate variability in the East African Rift may have been abrupt during the Plio-Pleistocene transition.

## **S15-P02 - A 550 kyr hydroclimate record from Chew Bahir, southern Ethiopia, reconstructed from oxygen isotope analysis of lacustrine sedimentary carbonates**

Jonathan R. Dean (1,2), Melanie J. Leng (2), Asfawossen Asrat (3), Melissa S. Chapot (4), Andrew S. Cohen (5), Alan Deino (6), Verena Foerster (7,8), Henry F. Lamb (4), Helen M. Roberts (4), Frank Schaebitz (8), Martin H. Trauth (7), Finn A. Viehberg (8) and the Chew Bahir Science Team

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There are few long, continuous, terrestrial Pleistocene records from eastern Africa, so it has been difficult to establish the relative influences of different climate forcings on the region's hydroclimate and to understand the climatic conditions through the time interval of anatomically modern human (AMH) origin and dispersal out of Africa. To address these gaps in our knowledge, the Hominin Sites and Paleolakes Drilling Project cored lake sediments from Chew Bahir in southern Ethiopia, close to the Omo-Kibish, site of the oldest known eastern African AMH fossils. A preliminary chronology for the 298 m core based on OSL and Ar-Ar ages suggests that the record covers the past c.550 kyr. Here we use the oxygen and carbon isotope composition of endogenic calcite to reconstruct changes in hydroclimate. The data suggest significant fluctuations in water balance, with seemingly more evaporative conditions during glacial periods and less evaporative conditions during interglacials. As well as precessional-scale variability at times of higher eccentricity, we demonstrate a sawtooth structure to the data, which we argue suggests the importance of factors other than local insolation changes in influencing Ethiopian hydroclimate. We also make inferences about the possible correlation between the stability of climate and the dispersal of anatomically modern humans out of Africa.

## **S15-P03 - Late-Holocene sedimentation and sodium-carbonate deposition in saline alkaline Nasikie Engida, southern Kenya Rift Valley**

**Gijs De Cort (1,2), Dirk Verschuren (2); Robin W Renaut (3), Matthias Sinnesael (4); Thijs Van der Meeren (2); Anthony Mbuthia (5); Edward Keppens (4); Steven Goderis (4) and Florias Mees (1)**

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Continental rifts are often characterised by geothermal activity and associated hydrothermal discharge, phenomena which can play a substantial role in depositional systems on the rift-basin floor. Water and solute budgets of hydrothermally fed lakes are often complex. At the same time, hydrothermal inflow can be a major buffer against desiccation, especially in shallow closed lake basins in arid environments. This is because, even though especially shallow groundwater flow is ultimately dependent on replenishment by meteoric waters, its lagged response time can attenuate climatic fluctuations on shorter time scales. Therefore, hydrothermal lakes are potential candidates to provide paleoenvironmental records in regions where other archives might be compromised by frequent drought. This is illustrated in Nasikie Engida, a shallow hypersaline lake in the arid southern Kenya Rift Valley, where geothermal groundwater has maintained a shallow (currently 1.5 m) but permanent water column and continuous deposition of highly authigenic laminated sediments during times when larger and deeper Rift-Valley lakes stood dry. Here we present the first data on the late-Holocene sediment composition of this remarkable system, including a history of the lacustrine deposition of the sodium-carbonate mineral nahcolite ( $\text{NaHCO}_3$ ). Our data includes bulk-sediment and mineralogical composition, the former corrected for systematic anomalies induced by large amounts of sedimentary sodium carbonate. We also present a stable-isotope time series of  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of authigenic nahcolite, and of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  of bulk organic matter. The potential roles of hydroclimate change and geothermal activity as driving processes behind the observed patterns are discussed, resulting in a first paleoenvironmental reconstruction from Nasikie Engida over the time period from ca. 2,700 cal yr BP to the present.

## S15-P04 - Ancient algae and crater chemistry: a 5,000-year record of environmental change from an Ethiopian crater lake

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Babogaya is a small (~500 m diameter), 60 m-deep maar lake, one of the Bishoftu Crater Lakes located at ~1900 m asl, ~50 km south-east of Addis Ababa, Ethiopia. Environmental conditions at Bishoftu promote a seasonal cycle of lake mixing (dry season; November–February) and stratification (wet season). This cycle stimulates varying levels of nutrient circulation leading to the intermittent deposition of light-coloured, aragonite-rich laminae formed in the dry season, alternating with darker, more organic layers deposited in the wet season. Analysis of the sediments of this lake will therefore allow determination of past inter- and intra-annual climatic variability in a region influenced by both Indian Ocean and Atlantic air masses.

Diatom analysis of a ~15 m partially-laminated core, retrieved from near the deepest central part of the lake, combined with bulk geochemistry (C/N and  $\delta^{13}\text{C}$ ) and micro-XRF core scanning, is used to infer past environmental changes in the area. An outline chronological framework from radiocarbon dating of micro-charcoal fragments reveals a high sedimentation rate, with a basal date of ~5,500 cal BP.

Laminated units of the core (1500–1250 cm; ~5550–4000 cal BP, and 625–67 cm; ~3200–600 cal BP) are characterised by organic rich, aragonitic sediments, dominated by small *Nitzschia* cf. *vanoyei*. *Fragilaroid* species (*Pseudostaurosira brevistriata* and *Staurosirella pinnata*) are more abundant towards the base of the core. The middle unit (1250–625 cm; ~4000–3200 cal BP) is characterised by minerogenic sediment, bounded at the base by a Gastropod shell layer. Lithogenic element counts (Ti and Fe) are higher in the middle unit, with lower biogenic silica (Si/Ti) content, interpreted as resulting from enhanced erosion from the crater sides.

## **S15-P05 - The Middle Pleistocene Sr-isotope stratigraphic record of paleo-Lake Suguta (N-Kenya): A proxy for paleo-climate variability or active tectonics?**

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Several studies of the Quaternary Sr-isotope composition of paleo-lake Turkana in the East African Rift System (EARS) show changing Sr-isotope values in lacustrine fossils from paleo-lake deposits. Such isotope changes are interpreted to be the result of a changing contribution of run-off from different sub-catchments of lake Turkana, as climate change shifted regional rainfall patterns due to orbital-forced insolation cyclicality. Unfortunately, paleo-lake deposits through the entire Pleistocene in the Turkana region are patchy, and especially those from the Mid-Pleistocene are almost absent. We here present a first set of data from the Mid-Pleistocene lacustrine sediment sequence RUPA in the Suguta Valley. The Suguta Valley, located just south of Lake Turkana in the EARS, formed around 1.8 Mio years ago and is separated from the Turkana basin by the Barrier volcano complex since approximately 50,000 years ago. Before that, both paleo-lakes formed a mega lake that deposited up to 40 m thick lacustrine sequences in the Suguta Valley. According to preliminary ages, the RUPA sequence was deposited between 840,000 and 740,000 years ago and spans five sedimentological cycles that potentially represent precession-forced lake level variation reflected by alternating diatomite and fluviatile deposits. The Sr-isotope data set is complemented by diatom, grainsize, stable isotopes, XRF and XRD analyses. In this setting, the Sr-isotope data do not vary pronouncedly in phase with these sedimentological cycles, but demonstrate a long trend of Sr-isotope change, which may be related to an increase in volcanic activity rather than climate. This may suggest that the catchment configuration of the Suguta Valley in the Mid-Pleistocene was less suitable to record precession-forced hydro-climate change in lacustrine Sr-isotope ratios. These findings would have an important impact on the interpretation of Turkana's Sr-isotope values between 1.8 Mio years and 50,000 years, the time when the two basins formed mega-lake Turkana.



## **S15-P06 - Paleolimnological changes during the past 25,000 years of Lake Nakuru, Kenya**

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Lake Nakuru in Kenya, located south of the equator on the East African Plateau, is one of the many modern, shallow saline lakes in the East African Rift System (EARS). 15,000 to 5,000 years ago during the African Humid Period (AHP), many of these lakes were instead deep, freshwater lakes because of a change in earth's precession, causing increased moisture in the region. Due to their sensitive reaction to even moderate moisture changes, those lakes belong to so-called "amplifier lake" systems. Beyond the existence of such lakes during the AHP, little is known about them, especially regarding their internal stability/instability during the AHP as well as the transitional speed in and out of wet phases. Here we present a high-resolution multiproxy record for the last 25,000 years including diatom identification and geochemical and physical parameters. Samples were retrieved from the upper 8 m of two duplicate, 17 m drill cores taken by the Lake Naivasha Coring Project (LNCP) in 2004. The chronology of the cores is based on 11 AMS  $^{14}\text{C}$  ages measured on charcoal and two  $^{40}\text{Ar}/^{39}\text{Ar}$  ages from separate tephra layers. The outcome of the study will contribute to knowledge regarding the impact of moisture changes during and along the transitions of dry-wet-dry cycles on the sensitive lake systems of the EARS. Furthermore, the new record will resolve a regional data gap regarding the synchronicity of lake level changes and its associated impact on humans living in the region.

## **S15-P07 - Garba Guracha revisited: testing the Mountain Exile Hypothesis**

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Garba Guracha is a cirque lake located at 3950 m altitude in the Bale Mountains National Park, Ethiopia, at the boundary between the Afro-alpine and sub-alpine Ericaceous vegetation belts. Jean-Jacques Tiercelin and Mohammed Umer cored its sediments in about 2002, leading to publication of one of the longest, best-dated, and most continuous Late Pleistocene-Holocene palaeoenvironmental records from above 3000 m in Africa. Their 2007 and 2008 papers document the vegetation and deglaciation history of the Bale Mountain plateau, which supports the most extensive area of Afro-alpine vegetation on the planet, and an exceptionally rich endemic biodiversity. However, those publications revealed little about human exploitation of the Bale Mountain environment.

We again cored Garba Guracha ('Black Lake' in the Oromo language) in February 2017, as part of a major DFG-funded research unit ("The Mountain Exile Hypothesis - How humans benefited from and re-shaped African high altitude ecosystems during Quaternary climate changes") that aims to test the hypothesis that human settlement of the Bale Mountains dates from at least the late Pleistocene. We also drilled cores from seven other sites in the area in early 2018, in partnership with archaeological, glacial geological and pedological investigations. Here we attempt an early synthesis of the results of  $\mu$ XRF geochemistry, stable isotope, biomarker, pollen and charcoal analyses of the Garba Guracha sediments with a new age model based on radiocarbon and  $^{210}\text{Pb}$  ages, and suggest an initial interpretation of anthropogenic impact on the Bale Mountains.

## **S15-P08 - U-Th Disequilibrium Dating of Chert from Lake Magadi Sediment Cores**

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Lake Magadi was cored to igneous bedrock in 2014 as part of the Hominin Sites and Paleolakes Drilling Project (HSPDP) to furnish paleoenvironmental context for human evolution in East Africa. Two cores (1A, B and C: 137 m and 2A: 198 m) composed of zeolitic mud, chert, trona, calcite, and sand/gravel, contain a record of Pleistocene/Holocene closed-basin paleoenvironments and paleoclimates in a tectonically-active rift basin.

Early syndepositional cherts formed by replacement and cementation of siliceous gels, magadiite, evaporites (trona, gaylussite), diatomaceous deposits, and carbonate fossils (ostracodes and gastropods). Early chertification is demonstrated by randomly-oriented plant and insect fragments, and labyrinth patterns that show lithification of uncompacted siliceous gels. Magadi cherts were dated by uranium-thorium disequilibrium techniques. Cherts incorporate significant uranium (0.6-11 ppm) and minor initial  $^{230}\text{Th}$  ( $^{230}\text{Th}/^{232}\text{Th}$  atomic ratios of 6-600  $\times 10^{-6}$  and  $^{238}\text{U}/^{232}\text{Th}$  concentration ratios of 3-33). Ten cherts in core 1A (24 to 88 m), range in age from 11.8 to 285 ka. Nine cherts from core 2A (36 to 107 m), range in age from 12.4 to 267 ka. Chert dates, along with radiocarbon ages, Ar-Ar dates of tephras, and paleomagnetic dating, provide a robust one-million-year chronology of the HSPDP Magadi cores. The sediment cores record a shift from an early, shallow freshwater lake stage, evolving to a narrow, at times anoxic, meromictic saline lake stage. The assemblage of chemical sediments (zeolites, chert, magadiite, trona, nahcolite) indicates alkaline saline conditions for much of the history of the Magadi basin. One major dry period, from ~455 to 325 ka, overlaps OIS Stage 11, the longest, warmest interglacial of last 500 kyr. Chert dates from trona layers show the first evaporites were deposited in the Magadi basin ~119 ka, much earlier than previously thought.

## **S15-P09 - Paleohydrological reconstruction based on lacustrine deposits: the Lake Chala record, equatorial East Africa**

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Lake Chala, a 92-m deep crater lake on the Kenya-Tanzania border near Mt. Kilimanjaro, has been identified as an excellent site for reconstructing ~250,000 years of past climate and environmental change in easternmost equatorial Africa. Under the umbrella of the ICDP DeepCHALLA project, a ~215-m long and continuous sedimentary sequence with ~95% recovery was obtained in November 2016 from the lake's depocenter. Here, we present the first results of amalgamating down-hole and along-core logging data with high-resolution seismic reflection data in order to produce a record of Lake Chala's limnogeological evolution through time. Lake Chala sediments are finely laminated throughout most of the recovered sequence, suggesting the persistence of a tranquil, anoxic to sub-oxic profundal depositional conditions. The sequence is occasionally interrupted by event deposits such as turbidites (up to 108 cm thick) and tephtras (2–9 mm thick). Combining preliminary interpretations of the lithological record and the seismic stratigraphy allows to identify 18 major stratigraphic units, deposited in varying sedimentological conditions related to climate-driven fluctuations in lake level. Evidence for these fluctuations includes major changes in saturated bulk density, natural gamma-ray values, and organic carbon content. During inferred lowstands, bulk-density values increased from 1.0 g/cm<sup>3</sup> to 1.25 g/cm<sup>3</sup>. Major peaks in gamma-ray values correlate with sharp lithology changes. Cm-scale depth matching of gamma-ray measurements from down-hole and down-core logging indicate that the offset is likely due to changes caused by sediment expansion, especially in the lower half of the sedimentary infill. Detailed inspection of the geophysical record confirms our assumptions on an oscillatory lake level. Combining the results of this study with the preliminary chronology provides valuable information as for the hydrological evolution of Lake Chala over the past 250,000 years and serves as a base for understanding long-term climate variability in easternmost equatorial Africa.

# S15-P10 - Sr isotope record of palaeo-hydrology for the last 120 ka from Chew Bahir, Southern Ethiopian Rift

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The earliest *Homo sapiens* fossils are located in Africa. Human dispersal out of Africa first occurred ~270,000 years ago and continued over different phases (e.g. 270 ka, 120 ka, 80-40 ka). The reasons for these expansion waves are still unclear, however, increasing aridity, higher moisture availability, or abrupt climatic shifts might have played a role. Reconstructing the palaeo-environment in the close vicinity of hominin sites during these periods is key to understanding whether climate change had a role in the evolution and dispersal of anatomically modern humans. The Hominin Sites and Paleolakes Drilling Project (HSPDP) and related pilot drilling campaigns retrieved several sediment cores near key hominin fossil sites in Ethiopia and Kenya, which are presumably along an important migrational corridor.

Here we present preliminary strontium isotope ratios ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) from lacustrine fossils and microfossils in cores from Lake Chew Bahir, extending back to 120 ka. Sr isotope ratios preserved in biogenic carbonates are derived from lake water, which reflects the lithology of the drained catchment area. During humid periods 'amplifier lakes' Chamo and Abaya, dominated by volcanic lithology, overflow into Chew Bahir. During the African Humid Period (~15-5 ka, AHP) a slow decline in Sr isotope ratios suggests palaeo-connectivity of these lake systems to Chew Bahir was greater during humid episodes. We aim to develop an isotopically-enabled hydro-balance model to quantify past lake levels using the relationship between Sr isotope ratios in humid versus dry periods. This will provide much needed data of the palaeo-environmental conditions in an important migrational corridor in eastern Africa during key periods of human dispersal.

# **S15-P11 - Lake Chala turbidites produced by surficial slope sediment remobilization: A mechanism to bring near-shore macrofossils to the deep basin with only limited time offset**

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In paleoclimate and paleoenvironmental studies, turbidites are usually considered as interruptions of the sedimentary sequence and therefore ignored. However, turbidites are composed of sediments from the (shallow) slopes along the lake's periphery where fossil assemblages are often different to those in the deep basin. Turbidites may thus be valuable as carriers of this near-shore proxy information to a profundal core site. However, as turbidites are composed of reworked (older) sediments, their fossil content can only be exploited if their "mean time offset" can be readily estimated or ascertained to be minimal.

Here we study the turbidite record of the 215 m (~260 kyr) long composite core of Lake Chala in the framework of the ICDP project DeepCHALLA. We analyzed its sediment color at 0.5-cm interval using a spectrophotometer. The composite core contains at least 1262 turbidites. For each of the 391 thickest turbidites (>~1.7cm) we determined the average color in the L\*a\*b\* color space, and plotted it against the average color of different intervals (2–55 cm) of laminated sediment matrix below the turbidite. For each combination of paired values, the highest R<sup>2</sup> values are found for the upper 7–15 cm of matrix sediment below the turbidites, which can thereby be interpreted as the average remobilization depth. These results are mainly based on the a\* value, which is most constant in sediments from across the basin as determined by short-core transects.

Our results show that the sediments of most Lake Chala turbidites are 100–200 years older than the laminated sediments upon which they are deposited. We conclude that the turbidites can be used as 'sampling windows' to study temporal trends in macrofossils such as ostracods, chironomids and fish teeth, which are much more common along the basin periphery than in the deep basin.

## **S15-P12 - Holocene rainfall runoff in the central Ethiopian highlands and evolution of the River Nile drainage system as revealed from a sediment record from Lake Dendi**

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A 12 m long sediment succession was recovered from the eastern Dendi Crater lake, located on the central Ethiopian Plateau and in the region of the Blue Nile headwaters. 24 AMS radiocarbon dates indicate that the sediment sequence spans the last 12 cal kyr BP. Sedimentological, geochemical and initial diatom data from the sediment succession indicate only moderate change in precipitation and catchment runoff during that period, probably due to the elevated location of the study region in the Ethiopian highlands. Less humid conditions prevailed during the Younger Dryas. After the return to full humid conditions of the African Humid Period (AHP), a ~2 m thick tephra layer, probably originating from an eruption of the Wenchi crater 12 km to the west of the lake, was deposited at 10.2 cal kyr BP. Subsequently, single thin horizons of high clastic matter imply that short spells of dry conditions and significantly increased rainfall, respectively, superimpose the generally humid conditions. The end of the AHP is rather gradual and precedes relatively stable and less humid conditions around 3.9 cal kyr BP. Slightly increasing catchment runoff led to sediment redeposition, increasing nutrient supply, and highest trophic states in the lake until 1.5 cal kyr BP. Since then, a highly variable increase in clastic matter indicates fluctuating and increasing catchment runoff. The data from Lake Dendi show, in concert with other records from the Nile catchment and the Eastern Mediterranean Sea, a relatively high Blue Nile discharge between 10.0 and 8.7 cal kyr BP. Subsequent aridification peaked with some regional differences between 4.0 and 2.6 cal kyr BP. Higher discharge in the Blue Nile hydraulic regime after 2.6 cal kyr BP is probably triggered by more local increase in rainfall, which is tentatively caused by a change in the influence of the Indian Ocean monsoon.



# Tropical lakes in the Anthropocene

*Sarah Metcalfe, Suzanne McGowan, Margarita Caballero, Peter Gell, Keely Mills,  
David Ryves, David Taylor*

Session 16



# Oral Presentations

## **S16-001 - Assessing the impact of aquaculture in the Philippines using palaeolimnology**

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In the Philippines, aquaculture in freshwater lakes contributes significantly to its economy, food security and employment. However, intensive aquaculture often leads to degradation in the lake ecosystem integrity because of nutrient fertilisation resulting in harmful algal blooms (HABs), introduction of toxins and invasive species. The few limnological studies carried out on Philippine lakes demonstrate a link between aquaculture activity and degraded water quality but there is a lack of information to help define how lakes have reacted over time to changing intensities of aquaculture and other catchment effects. This research, adopts a palaeolimnological approach to assess the impact of aquaculture on the Seven Lakes of San Pablo (Luzon Island). These lakes are ideal for study as they are all within a small geographical area but have each been subjected to different timings and intensities of aquaculture allowing comparisons between the 'more developed' and 'pristine' lakes, with respect to aquaculture, to be made. A multi-proxy approach is employed to reconstruct environmental change in the sampled lakes over the last c. 100 years, specifically, using chlorophyll and carotenoid pigments as indicators of algal communities (including possible HAB taxa) and carbon and nitrogen isotopes with C/N ratios to link ecosystem state with organic matter cycling. Preliminary results indicate that significant degradation has occurred in the 'more developed' of the lakes since the introduction of intensive aquaculture in the 1970's. Lake Sampaloc, a small 'highly developed' lake with respect to aquaculture shows a four-fold increase in chlorophyll a and a two-fold increase in the pigment canthaxanthin, from potentially HAB-forming cyanobacteria, compared with Lake Mohicap, a 'less developed' lake, which shows only a two-fold increase in chlorophyll a and HAB-associated pigments (canthaxanthin, echinenone). Further work aims to disentangle aquaculture impacts from other anthropogenic activities by studying lakes spanning a gradient of farming intensities.

## S16-002 - Modern vs. recent conditions in a deep tropical lake in western Mexico

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Alberca de Tacambaro, is a small (0.08 km<sup>2</sup>), relatively deep (30 m) volcanic lake on the southwestern sector of the Trans-Mexican Volcanic Belt. It is a freshwater, eutrophic lake, with HCO<sub>3</sub> - Mg-Ca waters. Given its depth, small area and the fact that this lake is protected by high crater walls, Tacambaro is an ideal site for evaluating changes in water column mixing due to human impact in its catchment, modern warming trends and ENSO events. Therefore, limnologic and paleolimnologic data are used to track the effects of human impact and climate change on this lake since the arrival of the Spanish settlers in AD 1530. Our results show a very intense human disturbance in the lake and its basin related with the arrival of the Spanish settlers by AD 1540, with a diatom assemblage dominated by *Cyclotella stelligera*. A similar to modern diatom assemblage dominated by *Achnanthes minutissimum* was established by 1900 and remained relatively stable until 2000 when needle shaped species (*Ulnaria nanana*, *Ulnaria delicatissima*) became more abundant and *Cyclotella ocellata* appeared in the record as temperature anomalies start to show warmer years. *Cyclotella ocellata* showed low abundances until the 2009 ENSO event, when it became the dominant taxa as a response to warmer conditions, a more stable stratification and nutrient limitation. Modern limnologic surveys of the lake show a tendency to meromictic conditions with a very shallow epilimnion and a water column that is stratified during most of the year, showing only a short winter mixing season.

## **S16-003 - New insights on Anthropocene fire management from pre-Columbian Amazonian Dark Earth forests**

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The Anthropocene Epoch is characterized by significant human alteration of Earth's geology and ecosystems including increased carbon emissions, soil degradation, deforestation, and mega-fires. However, the history of human occupation remains poorly characterized in many parts of the world which are known to have long histories of intensive indigenous land use (e.g. the Amazon Basin). To examine the history of human occupation in the eastern Amazon, we analyse a ~8,500 year-old sediment core record from Lake Caranã, providing new evidence of the history of human occupation. The onset of pre-Columbian activity in the region (~4,500 cal yr B.P.) is associated with the beginning of fire management and crop cultivation. Selective forest enrichment of edible plants and low-severity fire activity began after ~2,500 cal yr B.P. and was followed by the formation of the anthropogenic Amazon Dark Earth (ADE) soils ~2,000 cal yr B.P. The change in forest composition altered the structure of forests growing on ADE soils (ADE forests) making them more drought susceptible and fire-prone. This legacy persists in modern ADE forest despite modern land use histories. The Amazon rubber boom (mid-1700s to 1920 A.D.) is associated with record-low fire activity despite regional climate drier than present indicating fire exclusion strategy. The formation of FLONA Reserve in 1974 A.D. is accompanied by the relocation of indigenous populations and continued fire suppression. Despite these efforts, recent biomass burning and fire severity is higher than any other period in the record. This is attributed to combined climate and human factors which create optimal conditions for mega-fires in ADE forests that threaten to transform the Amazon from a net carbon sink to a net carbon source. To mitigate mega-fires in fire-prone ADE forests, a fire management policy reducing fire-use and more careful fire management for farming may help to reduce fuel loads and the occurrence escaped wildfires. As both natural and anthropogenic pressures are projected to increase in the Amazon, this study provides insights into the legacy of past human land use on modern ADE forest composition, structure, and flammability that can inform future forest management and conservation efforts in the upcoming century.

## **S16-O04 - Fly-ash particles as a stratigraphic marker for the Anthropocene in tropical lakes of Central and South America**

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The Anthropocene is a term that is now increasingly widely used in both scientific and broader literature but has yet to be formally ratified and continues to generate considerable scientific controversy especially regarding where to place its starting point. Although it is now likely that the recommended start date will lie in the mid-20<sup>th</sup> century, the recognition of an unambiguous and globally synchronous stratigraphic marker with which to define the lower boundary of the new epoch and so underpin the required Global Boundary Stratotype Section and Point (GSSP or 'golden spike') or alternatively a Global Standard Stratigraphic Age (GSSA) is essential to the definition of the Anthropocene itself.

Spheroidal carbonaceous particles (SCPs), a component of fly-ash, are produced solely from the high-temperature combustion of coal and oil and may provide such a reliable stratigraphic marker. They are derived from a key driver of anthropogenic change, preserve well in the natural archives and show a consistent and significant increase in accumulation from 1950 resulting from the rapidly increasing demand for electricity, and consequent accelerated coal and oil use following the Second World War. However, while historical records of SCPs in lake sediments appear to show globally synchronous patterns, records from tropical regions are very sparse.

Here, we present SCP lake sediment profiles from a number of lakes from tropical regions of Central America, the Caribbean and northern South America. Although outside the tropics, for comparison, we also include data from the southern USA. We show that despite these cores coming from a broad range of lake types, the mid-20<sup>th</sup> century increase in SCP input is present at all sites. We compare these data with other regions from around the world to show the extent to which SCPs can provide a useful global stratigraphic marker for the proposed Anthropocene Epoch.

## **S16-O05 - Mercury as a useful proxy for Palaeoenvironmental Reconstruction**

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Mercury has been used by human society over thousands of years and has left a signature in the sedimentary record that points to expanding trade, land clearance, and industrialisation (mining and coal burning) - all characteristics of the Anthropocene. This study applies a multiproxy approach (geochemistry, pollen and charcoal data) to reconstruct past environmental changes in Papua New Guinea (PNG) and test the usefulness of mercury (Hg) as a palaeoenvironmental proxy. Sediment cores from Lake Kutubu and Lake Sondambile were retrieved, spanning the last 4,500 years and encompassing the period before and during agricultural development and industrialisation. These lakes are in the highlands of PNG and support thriving agricultural communities. Pollen and charcoal data demonstrates that human disturbance increases in highland PNG with the gradual spread of agriculture after 7,000 cal BP; however, it only influences the remote areas of Lake Kutubu after ~1,500 cal BP. Mercury concentrations change from stable to variable at this time, and correlates to the increase of sago plantation and fire frequency in the highlands. Agricultural activities associated to land clearing have increased lake productivity, demonstrated by chlorophyll a. Higher Hg concentrations coinciding with higher primary productivity suggest that bush fire and Hg scavenging and sedimentation by algae are the major drivers of mercury variation in these lakes. Mercury has demonstrated to be a useful proxy for human impacts, with increases correlated to increase in bush fire and primary productivity linked to agriculture and land clearing.

## **S16-O06 - A 150-year record of polycyclic aromatic compound (PAC) and heavy metal deposition from high Andean Cajas National Park, southern Ecuador**

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Polycyclic aromatic compounds (PACs) and heavy metals released from anthropogenic sources have been long recognized as environmental threats. Only few studies exist for the Southern Hemisphere. High-altitude environments favor the trapping of volatile species (PACs, possibly Hg, ‘cold condensation’) which may lead to enhanced deposition in remote, high mountain-areas. Here, we compare the pollution history reconstructed from sediments of high-altitude lake Fondococha (4130 m, remote) with lower-altitude lake Llaviucu (3150 m, near the city of Cuenca), southern Ecuador. We asked the following questions: (i) How did the depositional fluxes develop over the last ca. 150 years? (ii) Is there a difference between the high-altitude and the lower-elevation lake? (iii) Do the PACs / heavy metals originate from short- or long-range transport?

The PAC-fluxes in high-elevation Lake Fondococha increased after 1950 suggesting a delayed pollution-onset compared to the Northern Hemisphere. Moreover, the dominance of Low Molecular Weight compounds indicates mainly local biomass-burning (natural, agricultural) and transformation products (oxygenated PACs) suggest admixtures of long-range atmospheric transport. The lower-elevation Lake Llaviucu recorded 4-5 times higher PAC-fluxes than Lake Fondococha and points to a mix of local urban (industry, traffic) sources and local biomass burning. The wet climate at lower altitudes (precipitation-maximum at 3500 m) efficiently scavenges PACs from the atmosphere. Apparently, topographic effects and micro-climatic conditions are important factors.

Heavy metal fluxes (Cr, Ni, Cu, Zn, Cd, Pb, Th, U, and Hg) stay constant between 1850 and 1950, and increase afterwards (1950–2014) by a factor of 2.5–3 (Lake Llaviucu) and 3–4 (Lake Fondococha). More than 80% (Cu, Zn, Pb, Th, U) or even more than 95% (Al, Ni and Cr) of the post-1950 increase is attributed to increased soil erosion. Atmospheric deposition is small. In contrast, >55% of the post-1950 deposition increase of Hg is attributed to atmospheric deposition.

## **S16-007 - Subfossil Cladocera and Chironomidae from freshwater lakes of Central America and the Yucatan Peninsula: estimating ecological requirements for future palaeolimnological research**

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Palaeolimnological research in Central America is rudimentary. Beside logistic issues and lack of appropriate lakes, the reason is the insufficient knowledge of taxonomy and ecology of aquatic biota. Thus, we studied surface sediments from lakes in Central America (Guatemala, El Salvador, Honduras) and Mexico (Yucatan Peninsula). The material was collected in 2013 by means of Ekman grab from a wide range of lakes located in lowlands to mountain regions. Concurrently, environmental variables were measured. Here, we present the taxonomic composition and distribution of subfossil Cladocera and Chironomidae. Cladocera were represented by both planktonic and littoral species. Among planktonic taxa Bosminidae and Daphniidae families were the most abundant. Daphniidae were restricted to water bodies in mountain regions, whereas Bosminidae were widely distributed in lakes with different abiotic conditions. Moreover, Bosminidae also occurred in highly mineralized waters ( $> 900 \mu\text{S cm}^{-1}$ ). The great majority of the identified Cladocera species belonged to the littoral family Chydoridae. *Chydorus cf. sphaericus* was the most common species, which probably reflects its tolerance to a wide spectrum of habitat conditions. Chironomidae were represented by  $>100$  taxa belonging to four subfamilies. The vast majority of remains ( $\sim 95\%$ ) were *Chironominae* and *Tanypodinae*; Orthocladiinae were restricted to high altitudes. Taxa richness per lake varied from 4 to 25, averaging 10.8 taxa. The most common genera were *Ablabesmyia*, *Polypedilum*, *Goeldichironomus*, *Labrundinia* and *Chironomus*, present in more than half of the lakes. The study revealed high variability in the qualitative and quantitative composition of subfossil Cladocera and Chironomidae. Some of the remains were recorded for the first time in the region, while others might represent species new for science.

The project was funded by the National Science Centre, Poland, 2014/13/B/ST10/02534 (Cladocera) and 2015/19/P/ST10/04048 (Chironomidae) and the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 665778.

# Poster Presentations

## S16-P01 - Tracing anthropogenic changes in the Pacific Islands of Vanuatu

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Small islands are paradigmatic cases of anthropogenic impacts on ecosystems. Using lake sediment cores to reconstruct past human activities can help retrieving information on the environmental responses to different rates and degrees of change on these vulnerable ecosystems.

On Remote Oceanic Islands, first human settlements came along with major landscape modifications as demonstrated by archaeological, palaeontological, palynological and geomorphological investigations. However, few sedimentological studies have been conducted so far on this topic in the area.

In our study, we used a multiproxy approach, combining geochemical tools based on biomarkers (fossil molecules of known origin) with traditional sedimentological methods (total organic carbon, biogenic silica, grainsize) on cores from two lakes of the west coast of Espiritu Santo, Vanuatu, dating back ~ 1000 years. The catchments of lake Nopovois and lake Wunawae are under different anthropogenic influence. Lake Nopovois is located near a village, while lake Wunawae has no human settlement nearby.

From the results of lake Nopovois, it is possible to identify different phases of human occupation. At the bottom of the core (60–80 cm) we identified an undisturbed baseline. Starting from 60 cm all proxies indicate a modification in the catchment, here interpreted as human induced changes (*i.e.* soil erosion – increase in total organic carbon and grainsize; lake eutrophication – increase in biogenic silica; changes in vegetation – *n*-alkanes results indicating a shift towards a less forested area and an increase in macrophytes on the lake surface). This trend is interrupted by the occurrence of two volcanic eruptions, confirmed by preliminary observations of tephra layers as well as by a sharp decrease of mean grain size.

The results from the undisturbed lake Wunawae will allow us to compare two catchments with different histories of human occupation and trace anthropogenic impacts caused by land use changes in the area.



## **S16-P02\* - Human influence on crater lakes in western Uganda**

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Tropical freshwater lakes are critical natural systems of global importance. In eastern Africa, crater lakes and their catchments provide vital ecosystem services (e.g., potable water, aquaculture, and ecotourism) to some of Earth's fastest growing and most vulnerable human populations. However, these services are under increasing threat due to the impact of human activities. Previous research on crater lakes of western Uganda has focused upon the use of the sediment records as palaeoclimatic archives, with little attention given to the impact of human-driven changes and the impact it can have on the lake ecosystem. The crater lake catchments are experiencing rapid changes as a result of clearance and land use alteration, as well as other environmental changes related to recent climate change (e.g., 0.9°C temperature rise in the last 20 years). The impacts of such changes on ecosystem function and biogeochemical functioning is largely unknown.

This research will use a multi-disciplinary approach combining satellite technology, limnology, and palaeolimnology. The contemporary data will be used to develop a pollen-land cover calibration set for understanding landscape change over the past 20 years, and for application to the palaeolimnological aspect of this work. From a palaeolimnological perspective, this research will target a number of lakes with differing catchments (i.e., natural vs impacted). Sediment cores from the lakes (spanning the last c. 200–400 years) will be analysed for pollen, charcoal, diatoms and pigments to study the impact of human activity and recent surface water warming, on biogeochemical cycling and its associated impacts on the ecological functioning of the lake systems.

## **S16-P03 - A 3800-year paleoenvironmental record from the Lacandon region of Mexico, inferred from testate amoebae and element concentrations in a sediment core from a mid-elevation solution lake**

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We used a combination of testate amoebae and element concentrations (Sr, Ti, Fe, Ca) from a sediment core from Amarillo Lake, Chiapas, Mexico, to infer past climate and environmental conditions. The lake lies in a karst basin at 830 masl in the mid-elevation Lacandon Forest. We retrieved a 3.6-m core using a modified Livingstone piston corer. The base of the core dates to 3815 cal yr BP, and an age-depth model was constructed using four <sup>14</sup>C dates. Samples were taken at 10-cm intervals along the length of the core from which 1-cm<sup>3</sup> sub-samples were collected for analysis of testate amoebae. Testate amoebae are abundant and have great potential as paleobioindicators, especially because they are poorly studied in the northern Neotropics. Element concentrations were measured by X-ray fluorescence (XRF). Detrended correspondence analysis (DCA) identified trophic state and conductivity as the main factors that influence relative abundances of testate amoeba taxa in this lake. Stratigraphic shifts in concentrations of major elements provide insights into past climate variability; periods of high Ti and Fe are associated with high rainfall and therefore higher water levels, possibly linked with changes in El Niño activity. Lower Ti and Fe concentrations during the last ~1000 years, however, indicate generally low lake level, an inference supported by results from testate amoebae assemblages. Higher relative abundances of the testate amoeba *D. oblonga* var. *oblonga* indicate mesotrophic conditions, whereas higher proportions of *Centropyxis aculeata* var. *aculeata* are indicative of eutrophic conditions. *Arcella discoidea* is an indicator of higher conductivity, whereas *C. aculeata* var. *discoidea* indicates lower ionic strength.

## **S16-P04\* - Holocene trophic state changes in relation to sea level variation in Lagoa Encantada (Brazil) inferred from diatom community**

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Here, we test the hypothesis that, during the Holocene, the aquatic ecosystems of the South American east coast increased in mean trophic level, concurrently with declining sea level. We analyzed a 602cm sediment core that was collected in Lagoa Encantada, located on the South American East Coast of Brazil (14°36'39.03"S e 39°08'33.30"O), which we sliced at 5 cm intervals. Thereafter, we sampled the diatom community (that was characterized by 174 species distributed in 24 genera) which we compared across the core. Radiocarbon dating revealed that sediments at the core's base (i.e., 600cm) to be  $1,530 \pm 30$  years cal B.P. Precisely, the depths of 602 and 600 cm were characterized by the presence of degraded valves of freshwater and estuarine species, suggesting the merging of distinct communities. From 600 to 550 cm, we found a clear dominance of *Cyclotella* spp. However, from 550 up to 480cm, we observed that *Cyclotella* spp.'s dominance was replaced by *Aulacoseira* spp., the latter occurring in high abundance from 480cm to 140 cm. Thereafter, from 140 to 30cm, *Eunotia* spp. established itself as the dominant taxon, only to be replaced by *Aulacoseira* spp., which once more became dominant, from this point to present days. This detailed core assessment reveals that 1,500 years cal B.P., Lagoa Encantada was connected to the sea but lost this connection thereafter. Following its isolation from the sea, this system became lentic, eutrophic, and well mixed, as suggested by the dominance of the species *A. granulata* and *A. granulata* var. *angustissima*. This period was followed by an acidification phase, evidenced by the domination of *Eunotia* spp. until 150 years ago. Thereafter, the planktonic environment was once again dominated by *Aulacoseira* spp. We therefore conclude that during the Holocene this coastal ecosystem was generally characterized by relatively high productivity. Funding: CNPq: 485672/2013-8.

## **S16-P05 - Palmitone as a biomarker for the agricultural plant *Colocasia esculenta***

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The arrival of humans on remote Pacific islands drastically changed their pristine environments and left traces in lake sediments that can now be used to reconstruct past anthropogenic impacts. However, the timing and subsequent development of human activity in this part of the world is still debated. The analysis of lipid biomarkers preserved in the sediment can potentially provide some answers to these questions. New species-specific plant biomarkers relevant to the region would be a useful tool to reconstruct vegetation and land-use changes, especially in cases where pollen is poorly preserved in the sediment. This study addresses this gap by developing a biomarker for the culturally important agricultural plant *C. esculenta* (taro).

The neutral lipid composition of 162 agricultural and uncultivated plant samples representing 87 genera from the Pacific archipelago of Vanuatu was characterized by Gas Chromatography – Mass Spectrometry (GC-MS). The lipid composition of the samples was heterogeneous and there was no correlation between phylogeny and lipid composition. However, the compound palmitone (16-hentriacontanone) was unique to the six *C. esculenta* samples in this sample set with a mean concentration of  $402 \pm 63 \mu\text{g/g}$  dry sample. Palmitone has been identified in few other plants to date, and no plants prevalent in the western tropical Pacific are known to produce it in such high quantities as *C. esculenta*. The suitability of palmitone as a biomarker for taro was tested by measuring its concentration over the past millennium in a sediment core from Vesalea Lake on the West Coast of Espiritu Santo, Vanuatu, where taro is known to be cultivated today.

Validating palmitone as a biomarker for taro would not only be useful for reconstructing the introduction of this plant in Vanuatu, but would be useful for clarifying the complex interplay between humans and remote tropical environments throughout Oceania.

## **S16-P06 - Understanding human-driven ecosystem change in a tropical Southeast Asian wetland: a multi-proxy lacustrine record from Tasik Chini, Malaysia**

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Tropical areas are becoming increasingly vulnerable to rapid environmental change as a combined result of climate change and human impact on the landscape, which significantly threatens the quality and biodiversity of freshwater ecosystems. Tasik Chini, a flood pulse wetland ecosystem located on the Malaysian Peninsula, is a critically endangered site that consists of twelve interconnected lake basins. The natural vegetation of the lake's catchment and surrounding area has become increasingly influenced by rubber and oil palm plantations, mining, fruit farms, logging, and tourism in recent years, which has resulted in pollution, soil erosion, and external nutrient loading to the lake. In addition, the main outflow river was dammed in 1995 to help stabilise the lake's water level. These activities have collectively changed the hydrological balance of the lake, influenced biodiversity through species and habitat loss, and affected the sustainability of the ecosystem due to eutrophication. To understand the influence of anthropogenic catchment change on the lake and to investigate the key drivers of ecosystem change, gravity cores were recovered in 2015 from different sub-basins of Tasik Chini. Chronologies based on  $^{210}\text{Pb}$  dating show that each gravity core dates back to the late 19<sup>th</sup> century and covers the transition to enhanced human impact within the catchment. The cores have been analysed for organic geochemistry, diatom assemblage, and sedimentary pigments to infer past environmental conditions within the basin. Data show how past variability compares to recent anthropogenic-induced environmental change and define how different catchment disturbances have contributed to ecological change at this internationally important wetland site. This information is vital to assess ongoing human impacts at the site as a means to provide future science-based management and conservation strategies and thereby counter the main drivers of ecosystem degradation.

## **S16-P07\* - Maori's arrival in North Island, New Zealand: Does the archaeological evidence match with the sediment archive?**

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Based on archaeological evidence, Maoris landed New Zealand around 700–800 cal BP. Their arrival brought tremendous environment modifications in the island including clearing of forests by burning. They also started horticulture and pasture practices in the island, introducing non-native animals. These environmental changes can be traced back in time using sedimentary archives. But will the sediment record match the archaeological evidence?

Here we present downcore fecal biomarker (coprostanol) and leaf wax records from Lake Pupuke in the North Island of New Zealand spanning 1718 cal yr BP. Coprostanols (5 $\beta$ -coprostanol plus 5 $\beta$ -epicoprostanol) are found in human wastes and can be used as tracers for prehistoric human presence. Leaf wax data (n-alkanes and n-carboxylic acids) will allow us to evaluate changes in horticultural and pastoral activities. Tracking these biomarkers in the sediment record will help us unravel when Maoris started pastoral activities around the lake. These biomarker footprints will also help us to further define the timing of the arrival of Polynesians in the North Island of New Zealand as well as possible implications of concurrent climatic changes.

## **S16-P08 - Seasonal biogeochemical monitoring at Tasik Chini, Malaysia: a case study of a tropical flood pulse wetland**

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Tasik Chini is a shallow, lowland flood-pulse wetland and UNESCO-designated site in the state of Pahang in Peninsular Malaysia. Wetland sites are rare in this region and therefore of great conservation and cultural importance. The lake's catchment has seen rapid development since the late 20<sup>th</sup> century due to the conversion of forest for palm oil and rubber plantations, mineral extraction and increased tourism. We provide a comprehensive limnological monitoring study over the course of one year as a means to understand the biogeochemical functioning of the lake, to better constrain the effects of catchment disturbance via palaeolimnological techniques. Monitoring of nutrients (phosphorous, nitrate, silicate), major ions, algal biomass (Chlorophyll-a), algal biomarkers and isotopes ( $\delta^{30}\text{Si}$  and  $\delta^{18}\text{O}$ ) was conducted on a monthly basis for one year (from November 2016). Sampling was conducted at dominant inflows, the outflow and at four basins across the lake, which encompass sites from close to catchment disturbance or more pristine. Lake  $\delta^{18}\text{O}$  data capture compositions derived from the monsoonal rain system in the region during months December-February. Lake nutrient concentrations increase (N, P) during the rainy season (DJF), which is later followed by an increase in algal biomass during the dry season. Lake water silicon compositions ( $\delta^{30}\text{Si}$ ) concomitantly increase ( $>+1\text{‰}$ ) with algal biomass, reflecting the uptake of Si via diatom biomineralisation during the region's dry season.

## S16-P09\* - Environmental history of tropical reservoirs and implications for management

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Tropical reservoirs are sensitive to eutrophication but long-term impacts of impoundment on their productivity and biota are poorly understood. We studied the environmental history of five reservoirs in Brazil with different productivities, using sediment records spanning the last ~50 to 90 years. Our main objectives, based principally on the analysis of organic geochemistry (TOC, TN, TP, C:N), stable isotopes ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ), and diatoms, were to reconstruct and compare the magnitude of environmental changes and to determine the conditions prior to any eutrophication. The geochemical data were in good agreement with the diatom shifts and supported the ecological interpretations. The history of environmental change was reservoir-specific and reflected local and regional stressors. The diatom assemblages prior to enrichment were composed of two groups. The oligotrophic phases were characterized by several benthic species with low abundances, mainly *Eunotia* and *Brachysira*, while in three reservoirs the early assemblages were characterized by taxa associated with mesotrophic conditions, namely *Aulacoseira ambigua*, *A. tenella*, *Discostella stelligera*, and *Spicaticriba rudis*. Diatoms and geochemistry revealed varying degrees of environmental change. We inferred that Ribeirão do Campo reservoir has remained oligotrophic since its construction, Itupararanga and Paineiras have both remained mesotrophic, and Salto Grande has been eutrophic since its construction in 1949. In Rio Grande reservoir, which was originally oligotrophic, the eutrophication began in the 1950s, with a slight improvement in water quality after its separation from Billings Reservoir, followed by a subsequent decrease in quality since ~2001. The use of the squared chord distance (SCD) dissimilarity coefficient to evaluate the extent of biological change proved to be suitable also for reservoirs and provides a valuable tool for informing management. This work provides information on the baseline conditions, the natural variability of non-degraded reservoirs, and the degree of ecological change in degraded ecosystems.



## **S16-P10\* - A multi-proxy survey of recent environmental changes from the sediments of lake Apastapeque (El Salvador, Central America)**

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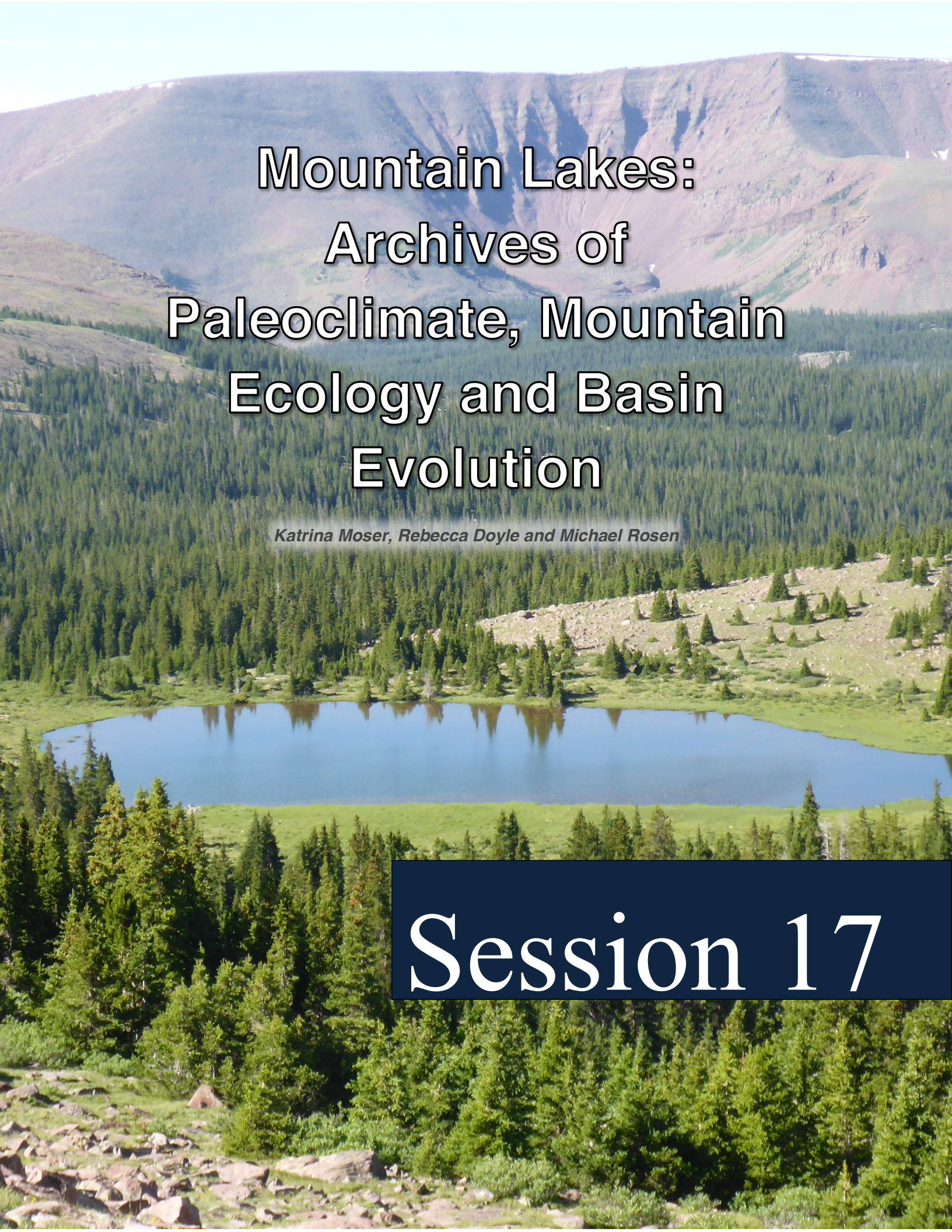
Paleolimnological research in Mesoamerica concentrates on lakes situated in Mexico and Guatemala; only few surveys have been carried out in El Salvador. These studies noted a great variability of climate over the last 1500 years and a significant environmental transformation during the 19<sup>th</sup> century. Unfortunately, there is very little information about the impact of these events on aquatic ecosystems. Therefore, we analyzed Cladocera, Chironomidae, Bacillariophyceae, Ostracoda and Testate amoebae remains from sediments of lake Apastapeque (El Salvador, 509 m a.s.l., 13°41'32.84"N 88°44'42.41"W) to examine environmental changes during the last ~620 years.

Three main zones were identified based on biological indicators, geochemical data and spheroidal carbonaceous particle (SCP) concentration. The oldest period (~1392–1500 AD) was characterized by potentially high water level (dominance of planktonic cladocerans and diatoms) and increased trophicity (higher percentages of *Bosmina longirostris*, higher Fe/Ca). Consequently, the decrease in abundance of both fauna and flora reflects deterioration of environmental conditions corresponding to the onset of Little Ice Age. During this period, littoral cladocerans appeared and benthic diatoms dominated indicating a lake level drop probably caused by drier conditions. The increase in abundance of both cladocerans and chironomids after ~1950 and SCPs suggests enhanced human influence.

The most recent period (2001–2013 AD) is characterized by a major and sudden environmental change. Bosminidae were replaced by *Daphnia longispina*-group (Cladocera), the abundance of *Labrundinia* type 3, *Goeldichironomus* types 1 and 2 increased (Chironomidae), and the relative abundance of *Aulacoseira granulata* var. *granulata* (Diatom) increased dramatically. We suggest that an earthquake that occurred in 2001 may have caused a dramatic environmental change that affected the structure of fauna and flora.

The project was funded by the National Science Centre (2015/19/P/ST10/04048 and 2014/13/B/ST10/02534), the EU Horizon 2020 research and innovation programme under the MSC grant no. 665778 and grant Schw 671/16-1 by the Deutsche Forschungsgemeinschaft.x\_y





# Mountain Lakes: Archives of Paleoclimate, Mountain Ecology and Basin Evolution

*Katrina Moser, Rebecca Doyle and Michael Rosen*

Session 17



## Oral presentations

### **S17-001 - Alpine environmental change on High Plateaus of central Utah: detecting the influence of glaciation, seismic activity, and hydroclimate on lake sediment records**

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The High Plateaus of central Utah are prominent physiographic features that delineate the boundary between the Bonneville Basin and the Colorado Plateau. With upper elevations between ~2700 and 3500 m, these alpine ‘islands’ have vertical relief of ~1300 to 2100 m above surrounding desert ecosystems. Small, relatively shallow alpine lakes are abundant within Pleistocene glacial margins, whereas larger lakes occupy tectonic basins. Since the late Pleistocene, humans have been attracted to the abundant water, game, and relatively cool climate that the High Plateaus provide. Today, runoff from the relatively pristine ecosystems are the primary water resource for local and regional communities, yet relatively little is known about past variations in climate, water, and environmental change during the Pleistocene and Holocene. Long-term perspectives provide the necessary context to better understand recent trends and future projections. We present High Plateau lake sediment records from two sites; a small cirque lake on the crest of the seismically active Wasatch Plateau, Emerald Lake (3030 m a.s.l.), and a large, deep graben lake within the Fish Lake plateau, Fish Lake (2700 m a.s.l.). Their geochronology, sediment structures, accumulation rates, bulk properties, mineralogy, and stable isotope geochemistry provide evidence for the timing of glacial and seismic activity and hydroclimatic trends. Preliminary results from the ~12 m Fish Lake record, from the >200 m lake sediment package, indicate glacially influenced sedimentation between ~25 and 12 ka. Emerald Lake sedimentation developed by 9.5 ka, with landslide induced seismic activity indicated at ~9 ka and between ~3 and 1 ka. Lake levels were near modern by 6 ka. Oxygen and carbon isotope stratigraphies from intact sequences of endogenic carbonate occur between 6 and 3 ka and from the mid-1750s AD to present. Variations are interpreted to reflect the combined effects of changes in net-precipitation amounts (drought) and seasonal balance.

## **S17-002 - Lake-System Response to Late Quaternary Climate and Catchment Dynamics on the northern Tibetan Plateau**

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Lake-catchment interactions are important processes that control climatic and non-climatic responses along sediment cascades in mountain lake systems, such as at Lake Heihai, a typical hard-water lake system on the northern Tibetan Plateau. The 10 km long, 4 km wide, and 22 m deep lake is situated at 4440 m a.s.l. within an intermontane basin along the Kunlun Fault. A prominent lake terrace with frozen fossil lake sediments gives evidence of an up to 6 m higher lake level than present in the early Holocene. Spatio-temporal variations in detrital sediment provenance and directions of hydrological runoff are documented by mineralogical and geochemical signals in the lacustrine sediment records. Sparse sediment supply from northern sources was basically associated with cold spells and aeolian supply in the late Glacial and the late Holocene that went along with the formation of endogenic aragonite in the lake. Distal fluvial sediment supply fed by glacial meltwaters and rainfall discharge from the Kunlun Mountains in the south prevailed throughout the Holocene. Alluvial sediment supply and runoff, directly from nearshore hills at the southern margin of Lake Heihai, added to overall sediment fluxes and led to lake-level rise between 10.7 cal. ka BP and 7.9 cal. ka BP. This is indicated by detrital dolomite and the formation of metastable Mg-rich monohydrocalcite on the expense of endogenic calcite in the deep and stratified lake. The implication is that the proximal alluvial fans only influenced the depositional environment during times, when precipitation was not blocked by the otherwise persistent mountain barrier of the Kunlun Mountain Range to the south, preventing the northward spread of summer-monsoon moisture. The temporal pattern of hydrological changes at Lake Heihai fits the change in summer insolation intensity and the trend in the north-south summer-insolation gradient.

## **S17-003 - Quantifying the effect of flood-events and land-use change on erosion rates in an Alpine catchment**

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Quantifying baseline values for natural and anthropogenically forced soil-erosion rates is critical when considering future climate change and population-growth predictions. Soil erosion is closely linked to precipitation regimes, extreme run-off events, and anthropogenic impact changing vegetation cover and, consequently, soil erodability. As it is still highly uncertain, how the occurrence of floods will be modified through ongoing climate change, soil erosion and sediment yield in the future are difficult to predict. It is thus essential to study patterns of soil erosion in the past over extended time-scales so that they can be compared with the reconstructed flood history and land-use changes. In this study, the sediments of Lake Grossee (Flumserberg, Switzerland) are targeted to provide a several thousand years long record of flood- and soil-erosion history. Grossee is an Alpine lake at an elevation of 1617 m a.s.l. with a surface area of 0.05 km<sup>2</sup> and a maximum water depth of 11.5 m. The lake catchment of 2.2 km<sup>2</sup> lies in the Helvetic Alpine nappes of the Swiss Alps and consists partly of the Permian volcanoclastic Verrucano and the Triassic Quarten formations, which together provide the characteristic reddish color of many parts of the catchment. During a flood event, these sediments are mobilized from the catchment and carried into the lake where they form distinct reddish flood layers providing thus ideal conditions for a flood-event reconstruction. Quantifying and dating the detrital particles in the lake sediments will moreover produce a soil-erosion history that can be compared with other independent records of climate change and human impact.

In 2017, several short and one long sediment core have been retrieved allowing to establish a composite section of 773 cm length. Dark, organic-rich sediment sections are interpreted as hemipelagic background sediments, whereas reddish siliciclastics beds are interpreted as turbidites deposited during flood-events. Over hundred flood-event layers ranging from 1–15 cm in thickness have been identified in this unit, the upper ones coinciding with some documented flood events of the area. The Grossee sediment record emphasizes a strong increase in flood-event occurrence as well as in soil-erosion rate around 4000 yrs BP. This increase is also accompanied by an increase in background erosion rate, which occurs independently of major floods. A quantitative comparison shows that steady background erosion rate, over the entire Holocene period, is a more efficient agent to erode soils in the catchment, providing three quarters of the total sediment yield, whereas the remaining one quarter being mobilized during extreme events. The change in erosion regime around 4000 yrs BP is interpreted to be related to an overregional climate signal towards colder and wetter conditions, but might additionally be enhanced by human land use, as Alpine farming was initiated around that period.

## **S17-004 - From a landslide lake to a football pitch – a multi-proxy view on 11,000 years of landslide depression development in the Polish Western Carpathians**

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Mineral and organic deposits accumulated by lake and mires in landslide depressions are important archives of ecosystem changes in mountainous areas. The usually small size of such lakes and mires makes them very sensitive to local ecosystem changes and various disturbances. Our study focused on a palaeoecosystem reconstruction inferred from deposits accumulated in a small depression (smaller than 1ha) formed in the Bogdanówka landslide (Polish Western Carpathians). In the period of ca. 11,230–10,730 cal. BP a shallow lake was slightly overgrown by submerged macrophytes and floating vegetation with poor Cladocera and Chironomidae fauna. The lake was surrounded by woodlands, dominated by *Pinus sylvestris*, *Betula* and *Ulmus* with an admixture of *Picea abies*, which were subjected to frequent and/or intense wildfires. From ca. 10,720 cal. BP a rich fen developed. After the Sphagnum spread (from ca. 7320 cal. BP), the rich fen probably transformed into a poor fen that functioned until ca. 1300 cal. BP. The water table probably rose during the periods of ca. 10,710–10,140, 8200–7540 and 4200–1790 cal. BP and during these periods coincided with Bond's climate events centered at ca. 10.3, 8.2 and 4.2 ka cal. BP. The topmost 60 cm of the deposits (covering the last ca. 400 years) consist of clayey silts rich in micro- and macrocharcoal. This layer probably reflects increased erosion stimulated by a human-induced deforestation and fire, probably accelerated by the Wallachian migration. This impermeable sediment layer limited vertical drainage of the depression contributing to the appearance of the seasonal lake after heavier rainfalls and snow cover melting. At present, during drier periods, the depression is exploited as mown meadow and football pitch.

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## **S17-O05 - Mountain lake diversity reflects multiplicity of climate change effects – paleolimnological studies in various Alpine lakes**

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Mountain lakes constitute highly sensitive ecosystems, which are adapted to extreme conditions. Its characteristics vary widely and thus, the influence of climate warming may differ. The basic hypothesis states that the bigger the water body the better the ability to buffer the impact. The lake set of the study consists of 15 mountain lakes in the Bavarian Alps with a wide range of altitudes, surfaces, depths, and even geological origins. To investigate the individual history and climate warming-related change in a lake we used sediment cores and its subfossil diatom assemblages. Each centimeter layer was ‘scanned’: diatoms were counted, the dry weight was measured and the diatom density/biomass out of the two former proxies was estimated. Additionally the sediment layers’ age was determined. The climate in the Alps indicates the onset of a significant warming approximately 30 years ago. In our sediment cores, this is characterized by an onset of a shift in the diatom assemblages and an increasing dissimilarity among adjacent layers. This fact occurred in each studied sediment core. Nevertheless, the extent of this change varied considerably across the mountain lakes. Apart from the sedimentation rate, the onset of the impact of global change was detected in different sediment depths and the diatom transition in bigger lakes was much smoother than in those of small shallow water bodies, confirming our hypothesis. Furthermore, the geological origin is very decisive. The diatom assemblages of a montane doline lake, which is exclusively fed by ground water, acts highly probable like an alpine lake in context with the climate warming. The mere altitude’s effect is less important than changes in the catchment, e.g. vegetation like the climate change-related uphill-movement of the tree line.

The study is funded by the Bavarian State Ministry of the Environment and Consumer Protection

## **S17-006 - Contrasting the ecological responses of shallow and deep lakes to recent climate warming in the tropical Andes**

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Andean lakes are hotspots of biodiversity and serve as critical freshwater resources for millions of people. However, little information is available regarding their ecological responses to anthropogenic climate change, which is occurring rapidly in the Andes. Recent paleolimnological work has revealed marked shifts in diatom species in relation to enhanced water column stratification, caused by warming air temperatures and declining wind speeds. However, the response of higher trophic order consumers in the lakes is not well understood. A paleolimnological examination of Cladocera community composition from four lakes in Cajas National Park, southern Ecuador, recorded relative increases in pelagic taxa *Daphnia* and *Bosmina* during the period of recent warming, when these lakes transitioned from being polymictic to increasingly thermally stratified. In three shallow (<5 m) non-stratified Cajas lakes, climate-related cladoceran shifts did not occur, though long-term assemblage changes appeared to track size of the littoral area, perhaps reflecting past water level shifts. To determine climate change impacts elsewhere in the Andes, three non-stratified lakes were examined from the Cordillera Vilcanota, Peru. The cladoceran assemblages from the two deepest lakes showed marked shifts in the past (i.e., >150 years ago), possibly related to glacier activity and water level changes. However, none of the three lakes experienced marked cladoceran shifts over the past century, despite steadily increasing air temperatures recorded at climate stations ~60–70 km away. The relatively stable assemblages over the last century may be due to the lack of thermal stratification in these lakes, caused by a climate-moderating effect from nearby glaciers. This research provides among the first paleolimnological cladoceran data from the Andes, and highlights the potential importance of lake stratification and related limnological changes in driving cladoceran assemblage composition.



## **S17-007 - Water depth and salinity as drivers of chironomid assemblage composition in two large lakes on the Tibetan Plateau**

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The Tibetan Plateau stores Earth's third largest amount of ice and provides water for a major part of Asia, home to almost two thirds of the world's population. To better predict water availability under global warming, it is important to reconstruct past lake levels, which are coupled to salinity in many closed lake systems. Chironomids are known for their sensitivity to water depth and salinity, but little attention has been paid to changes in the relationship between chironomids and water depth in deep lakes and under different salinities. The Tibetan lakes Taro Co and Selin Co provide a unique opportunity to study these interdependencies, because both lakes are large, closed lake-systems located at similar elevation. While Taro Co is a freshwater lake (0.5 ppt salinity), Selin Co is characterized by saline water (7–10 ppt salinity).

A total of 62 (Taro Co) and 72 (Selin Co) surface sediment samples were collected from the lakes and surrounding contributories with water depths ranging between 0.3 and 125 m, and between 0.2 and 52 m, respectively, and analyzed for their content in chironomid remains. Chironomid head capsule concentrations and biodiversity are higher in the freshwater lake. While the lakes differ in their faunal composition, they both show similar significant zonal boundaries which define a splash zone (0–0.5 m), a littoral (0.5–16 m) and a profundal zone (>16 m). Concentrations of chironomid remains are highest in the profundal zones of each lake. We conclude that depth exerts a strong control on the chironomid assemblages even under different salinities. This suggests that changes in fossil chironomid records from deep lakes on the Tibetan Plateau can be used to reconstruct past changes in water depth.

## **S17-O08 - Rapidly changing environmental conditions during MIS 3 in the northern Alps reflected in the Nesselstalgraben paleo-lake record**

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The Nesselstalgraben (NTG) site (47°39.4'N, 13°02.8'E, 555-595 m a.s.l.) provides a unique sedimentary sequence exposed on ravine slopes in the northern Alps. Geoelectric surveys suggest a basin width of at least 300 m and >30 m sediment filling. In 2016, 40 sections were sampled from the exposed parts of the sequence. The smoothed sediment surface was scanned with an X-ray-fluorescence core scanner in 2 mm resolution. Based on marker layers and XRF scans, a continuous 21 m long profile has been compiled. The sections were split into 2 cm samples, which were used for ongoing analyses of pollen, ostracods, bryophytes, element contents, isotope geochemistry, and grain-size. Radiocarbon analyses on wood, monocotyledons and bryophytes provided median ages between 30 and >50 ka cal BP and indicate that the complete Marine Isotope Stage (MIS) 3 is probably covered in the sampled record.

Towards the top of the profile, fluvial interaction is indicated by increasing sand and gravel intercalations, capped by fluvio-glacial gravels of the Last Glacial Maximum. The part of the section dating to MIS 3 varies lithologically between laminated to non-stratified pure carbonate silts and organic-rich to peaty silts. Element contents obtained from XRF scans show a high variability reflecting lithological variations. Ca is antagonistic to most other recorded elements and is of detrital origin. Ca maxima are considered to reflect cold and dry stadial periods when chemical weathering was subordinate, but intense physical weathering of Mesozoic carbonates occurred in the catchment. In contrast, elements resistant to chemical weathering (Ti, Zr) prevail during warmer and more humid interstadials with more intense carbonate dissolution and accumulation of organic matter. Varying proportions of arboreal and non-arboreal pollen occur in the lower part of the section (MIS 3). Increased *Pinus* and *Picea* pollen represent interstadial conditions, while stadials show higher values of *Poaceae*.

## **S17-O09 - 6600 years of earthquake record in the Julian Alps (Lake Bohinj, Slovenia)**

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Sequences of lake sediments often form long and continuous records that may be sensitive recorders of seismic shaking. A multi-proxy analysis of Lake Bohinj (526 m a.s.l) sediments associated with a well-constrained chronology was conducted to reconstruct Holocene seismic activity in the Julian Alps (Slovenia). A seismic reflection survey and sedimentological analyses identified 29 homogenite-type deposits related to mass-wasting deposits. The most recent homogenites can be linked to historical regional earthquakes (i.e., 1348 AD, 1511 AD and 1690 AD) with strong epicentral intensity [greater than ‘damaging’ (VIII) on the Medvedev–Sponheuer–Karnik scale]. The correlation between the historical earthquake data set and the homogenites identified in a core isolated from local stream inputs, allows interpretation of all similar deposits as earthquake related. This work extends the earthquake chronicle of the last 6600 years and indicates 29 events occurred. The early Holocene sedimentary record is disturbed by a seismic event ( $6617 \pm 94$  cal yr BP) that reworked previously deposited sediment and led to a thick sediment deposit identified in the seismic survey. The period between 3500 cal yr BP and 2000 cal yr BP is characterized by a major destabilization in the watershed as a result of human activities that led to increased erosion and sedimentation rates. These changes increased the lake’s sensitivity for recording an earthquake (earthquake-sensitivity threshold index) with the occurrence of 72 turbidite-type deposits over this period. The high turbidite frequency identified could be the consequence of this change in lake earthquake sensitivity and thus these turbidites could be triggered by earthquake shaking, as other origins are discarded. This study illustrates why it is not acceptable to propose a return period for seismic activity recorded in lake sediment if the sedimentation rate varies significantly.

## **S17-O10 - Paleolimnological records of tropical African mountain temperatures, glaciers, and lapse rates since the last ice age**

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In the coming century the world's high tropical mountains are predicted to experience a magnitude of temperature change second only to the Arctic. Glaciological data suggest that large changes in tropical mountain temperatures also occurred during the last glacial maximum (LGM), despite evidence for relatively small changes in low elevation tropical temperatures. Large changes in high-elevation temperature alongside small changes in low elevation temperature suggest that the gradient of temperature with elevation (the lapse rate) was different during the LGM from today. However, climate models are unable to simulate such large lapse-rate changes, and the glaciological data have been questioned due to the influence of temperature, radiation, and precipitation on glacier mass balance. New records are therefore needed to understand the sensitivity of tropical mountain climates.

Here we present new quantitative temperature reconstructions from organic geochemical analyses of sediment cores from high-elevation lakes on Mt. Kenya and the Rwenzori Mountains, tropical East Africa, as well as equilibrium line altitude estimates of temperature from newly-dated glacial moraines. These records both indicate at least 6°C cooling on these mountains during the LGM. Through comparisons to low-elevation lake records, we show that LGM cooling was amplified with elevation and hence that the lapse rate was significantly steeper than today. We also observe similar (~2°C) changes in temperature during the mid-Holocene at all elevations, indicating little change in Holocene lapse rates. As changes in the lapse rate are intimately linked to atmospheric water vapor concentrations, we attribute the steeper lapse rate to drying of the tropical ice-age atmosphere. This implies that Holocene changes in water vapor concentrations were modest, yet Holocene temperature changes had significant impacts on tropical mountain systems, including the potential complete deglaciation of mountains less than 5000 m elevation.

## **S17-O11 - Mid- to late Holocene environmental changes inferred from multi-proxy-studies of lacustrine sediments from the Dayan Nuur region in the Altai Mountains, Mongolia**

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The ‘Altai Tavan Bogd’ National Park, located between 2,000 m and 4,000 m a.s.l. in the north-western part of the Mongolian Altai, is a montane forest-steppe-ecosystem which is very sensitive to natural variations. The area is influenced by extreme continental and alpine climatic conditions which provide a unique vegetation mosaic, mainly composed of dry steppe, meadow steppe and forests. Annual precipitation rate and the nomadic inhabitants in the region are important impact factors. Starting with early human occupation of the area from the Middle Palaeolithic and the introduction of cattle breeding in the Late Neolithic, the Mongolian Altai has been influenced by various nomadic tribes. Diverse cultural and political structures have led to changes in land use and animal husbandry over time. As the inhabitants still maintained their simple and traditional way of life, the Mongolian Altai is a suitable investigation area to examine the interactions of vegetation, climate and human activities over time.

The presence of high mountains, steep slopes and deep basins provide a characteristic landscape which favors, despite the extremely low precipitation, the formation of small lakes. Hence, lake records may be the most suitable sedimentary archive to do research on past environmental conditions.

Our objectives are to detect changes in the vegetations’ biodiversity and the sensitivity of Mongolian Altai’s forest-steppe-ecosystem to natural and anthropogenic environmental changes. We aim to quantify the extend of this natural and anthropogenic impact. Further, we want to focus on the dynamics and stability of the forest edges, the role of fires in the past and the conditions for lake formation in the area. Multi-proxy analyses of the radiocarbon dated lake record D3L6 have been performed. The profound analyses comprise pollen, non-pollen palynomorphs, micro- and macro-charcoal, diatom and XRF data.

## **S17-O12 - Climate-induced changes in carbon resources since the Last Glacial Maximum sustaining Lake crustean zooplankton in a deep alpine lake (Lake Lugu, southwest China)**

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Secondary production in lakes can be heavily subsidized by input of terrestrial carbon, which reflects vegetation structure, production and hydrology but it remains unclear what role climate plays. Here we use a ~26 kyr multi-proxy palaeolimnological record from a monsoon-dominated lake in SW China to show how allochthony has responded to climate forcing at millennial timescales. The shift in  $\delta^{13}\text{C}$  in Cladocera to more negative values from the LGM to the Holocene reflects changing catchment vegetation and a dietary shift from organic matter mainly from C4 plants during the LGM to C3 plants during the Holocene. The  $\delta^{13}\text{C}$  value of zooplankton was high (approximately  $-24.8\text{‰}$ ~ $-18\text{‰}$ ) in LGM, suggestive of an increase in the proportion of organic detritus derived from plants using the C4 pathway, which would have increased in response to the drier climate or lower atmospheric  $\text{pCO}_2$ . The  $\delta^{13}\text{C}$  value of Cladocera during the Holocene ( $-34\text{‰}$ ~ $-22\text{‰}$ ) are in the range typical of terrestrial C3 plants. The comparison between our data and proxies of regional paleoclimate suggests that the decline of the cladoceran  $\delta^{13}\text{C}$  value after the LGM was due to the large decline of C4 plants linked to a combined increase of atmospheric  $\text{CO}_2$  and humidity levels. *Bosmina*  $\delta^{13}\text{C}$  tracked atmospheric  $\text{CO}_2$  following the Last Glacial Maximum and the Dongge  $\delta^{18}\text{O}$  isotope record (a measure of monsoonal intensity) ( $r = 0.81$ ,  $p < 0.0001$ ) suggesting a first order climatic control of lake-carbon dynamics. Zooplankton production increased from 10 cal kyr BP with strengthening of the SW monsoon and expansion of Tsuga-dominated forest in the early Holocene reflecting the input of terrestrial C and the importance of terrestrial subsidy of the lake for lake production.

# Poster Presentations

## **S17-P01\* - The REPLIM Project: A lake and wetland network to monitor global changes in the Pyrenees**

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REPLIM is a network of global change observatories located in lakes and peat bogs and includes scientists, managers and citizens from Spain, France and Andorra. The REPLIM objectives are to monitor main physical, chemical and biological variables, to characterize the watersheds and the lake/wetland basins, with the main objective of documenting present trends and model future responses.

Because of the complexity of climate fluctuations during the Holocene and the long history of human interactions with the Pyrenean landscapes the Project also looks back at the evolution of each site during the last 2 millennia. Available data show the impact of known climate phases and recent global warming, but the timing, nature and synergies with cultural changes show temporal and spatial variability at a Pyrenean scale that are not yet well described. During periods of intense human disturbance - the Medieval Ages and the 18<sup>th</sup> to mid 20<sup>th</sup> centuries – alpine watersheds were significantly impacted (increased soil erosion, carbon fluxes, heavy metal loads, bioproductivity changes). Periods of higher heavy metal deposition occurred in Roman times and since the Industrial Revolution, with a decline after the late 20<sup>th</sup> century. Deforestation and grazing activities lead to the development of “cultural landscapes” since Medieval times.

Against the backdrop of global warming, the Great Acceleration during the 20<sup>th</sup> century led to rural abandonment and a decline of farming and grazing in the Pyrenees, replaced by hydropower generations and tourism.

REPLIM aims to increase awareness about global change in the high mountains environments and the need for comprehensive management strategies integrated with the socio-economic development of the Pyrenees.

REPLIM is funded by the European Regional Development Fund (FEDER) through the Interreg-POCTEFA 2014-2020 program. Results contribute to the development of the strategy of the Pyrenean Climate Change Observatory (OPCC) forming part of the Work Community of Pyrenees (CTP).

## **S17-P02\* - Reconciling diverse diatom-based lake responses to climate change in four mountain lakes in the South-Carpathian Mountains during the last 17 kyrs**

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Climatic changes were studied using siliceous algae (diatoms and Chrysophyta stomatocysts) analyses in four mountain lakes in the Retezat Mountains in the South-Carpathian Mountains with the aim to search for synchrony in aquatic ecosystem responses. According to the basal radiocarbon dating of the lake sediment cores, these lakes were formed around 17,000–15,000 cal yr BP. High resolution diatom analyses were carried out together with loss-on-ignition (LOI) and biogenic silica (BiSi) measurements. Comparison of the proxy results suggests that despite the different slope aspect, water-depth and basin parameters, diatom assemblage changes show clear synchrony. The most remarkable changes in the aquatic ecosystems were observed around 6500 cal yr BP on the northern slope and around 6100 cal yr BP on the southern slope during the Holocene. Evidences for sharp concomitant shifts were found between 9200–9000 and 3200–3000 cal yr BP in the siliceous algal communities on both slopes. The Late Glacial/Holocene boundary was not pronounced in the shallow lakes, but was significant in a deep lake. The signs of a dry and bipartite Younger Dryas (GS-1) were evident, but floristic changes differed in the lakes. Principal component analyses explained very similar variances along the first and second axes for three lakes, while the fourth lake (Lake Bucura) proved less sensitive to climate change due to the dominance of moss-inhabiting diatom assemblages. Lake level changes have only been reconstructed on the basis of diatom life forms in one of the deep lakes (Lake Gales). High lake levels were inferred between 9300–9000 and 3000–1700 cal yr BP. In addition to LOI, biogenic silica content (BiSi) was measured on the sediments of the northern slope and pointed to different seasonal biological productivities; increasing LOI was often coupled with low BiSi values. The authors acknowledge support from NKFIH 119208, CRYPTIC project.



## **S17-P03\* - Investigating the efficacy of bulk and compound-specific isotopic compositions, and n-alkane abundances, as indicators of organic matter source to alpine lake sediments**

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Accurately identifying shifts in organic matter sources is fundamental for investigating paleoenvironmental changes using lake sediments. Wet conditions, for example, can be inferred by identifying periods when the lake received higher proportions of allochthonous to autochthonous inputs, whereas arid conditions can be inferred when the opposite is true. Shifts between predominately allochthonous and autochthonous sources are typically identified using the ratio of organic carbon (C) to total nitrogen (N) (i.e., C:N) of sediment organic matter. This proxy is confounded, however, by the fact that terrestrial soils and autochthonous sources can have similar C:N ratios.

We are therefore seeking tools to better discriminate between origins of organic matter in lake sediments. Our initial focus is remote alpine lakes since such systems receive few organic inputs from anthropogenic sources (e.g., sewage) relative to lowland lakes. We have compiled a baseline of bulk and compound-specific isotope compositions, and n-alkane distributions, of probable organic matter sources to Uinta Mountain (Utah, U.S.A.) lakes and their sediments. To date, nine functional groups of organisms have been analyzed for their bulk C and N isotope compositions: krumholtz trees, graminoids, semi-emergent angiosperms, terrestrial bryophytes, shrubs and subshrubs, lichen, submerged bryophytes, submerged angiosperms and algae. We found significant overlap between the bulk C and N isotope compositions of autochthonous and allochthonous sources, indicating that bulk C and N isotopes are not useful for differentiating among these sources in this environment. To improve discrimination among these sources, we have begun quantifying the relative abundances of n-alkanes from allochthonous and autochthonous sources and measuring their compound-specific C and hydrogen isotope compositions. Results to date have focused on allochthonous sources, which exhibit significant overlap in n-alkane isotope compositions and relative abundances. Our next efforts are focused on lacustrine algae, submerged angiosperms and submerged bryophytes in the search for a unique n-alkane signature.

## **S17-P04 - Holocene depositional evolution of Laguna del Maule (central Andes, Chile, 36° S): volcanic and paleoclimate implications**

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The Laguna del Maule (LdM) volcanic field is one of the most seismically and volcanically active areas in the central-southern Andes, with intense postglacial and Holocene activity. We performed a seismic survey and collected a transect of sediment cores to study the depositional evolution of the lake located in the LdM caldera. This new high-resolution centennial-scale multi-proxy record provides insight into environmental and eruptive dynamics over the last 13.0 ka BP. Up to 18 ash and 5 lapilli layers mark volcanic events, which mostly cluster in the early and late Holocene with an extensive volcanic event at ~ 4.0 ka. Sedimentary facies and geochemical indicators (TOC, C/N, Br/Ti and Fe/Mn) are used to infer higher (lower) organic productivity during early and mid-Holocene (late Holocene) associated to lower (higher) water levels and dominant anoxic (oxic) conditions at the bottom of the lake. We attribute decreased lake levels between ~ 8.0 and 5.0 ka in part to lowered winter precipitation, which is coeval with a southward shift in the Southern Westerly Winds documented in other records, and a strengthening of the Pacific Subtropical High. Higher fluctuations in lake levels after 4.0–3.0 ka BP are indicative of increased ENSO variability. Several important global climate transitions (LIA, 4.0, 8.0 and 11 ka) are well represented in the LdM sequence showing the importance of this record for reconstructing regional paleohydrology. Finally, periods of higher lake productivity during early and mid-Holocene were synchronous with elevated frequencies of volcanic events suggesting a climatic-volcanic synergy in limnological processes.

## **S17-P05 - Little Ice Age reconstructed from sediments of a mountain lake in Central Europe using chironomids, cladocerans and diatoms**

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The period with significantly altered climate conditions during the 15<sup>th</sup>–19<sup>th</sup> centuries, known as the Little Ice Age (LIA), was probably the most pronounced climatic interval in the Northern Hemisphere during the last millennium, with serious impact on biota but also human society. The timing and nature of these variations, however, show great regional variability. Climate proxies provided by lake sediments are excellent high resolution sources of information on past oscillations. Alpine lakes are especially sensitive indicators of environmental change that respond significantly to even small events, what is usually not the case of aquatic ecosystems situated at lower elevations.

We analyzed the remains of chironomids, cladocerans and diatoms from a 35 cm long sediment sequence, dating back to 1340 AD, obtained from a mountain lake in the Tatra Mts. (Popradské pleso, 1494 m a.s.l.). Our goal was to reconstruct the LIA and its main events in the southern part of the Tatra Mts. for the first time and to compare its effect to different elements of the lake ecosystem, such as plankton and benthos.

In all analysed proxies, two main zones were identified and divided into sub-zones. The bottom zone lasted until ca. 1830 and most likely refers to the LIA. The second zone suggests gradual increase of temperature and increased trophy. Sub-zones differed in the proxies, reflecting climatic oscillations and changes in fish stock dynamics. However, the most dramatic changes over the whole analyzed period in all proxies co-occur with the most severe human impact in the catchment of the lake. Our results suggest that even local human influence can alter environmental conditions of a lake more than the climate fluctuations during the LIA.

The paleolimnological research of Popradské pleso was supported by grants APVV-15-0292, VEGA 1/0341/18 and ITMS 26210120024.

## **S17-P06\* - Geochemical and palynological data revealing the Early Pleistocene evolution of the Lake Ohrid Basin (Albania, Macedonia) and its habitats**

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Lake Ohrid in the Western Balkans (Albania, Macedonia) is the oldest extant lake in Europe, dating back 1.4 million years (Ma). About 450 meters of continuous, undisturbed limnic sediments represent an outstanding archive of environmental change spanning across the mid-Pleistocene transition (MPT). Due to tectonic subsidence throughout the Pleistocene and to the present day, the lake has developed into a deep (average water depth: 155 m) and oligotrophic waterbody, with the post-MPT sediments recording environmental changes driven by 100ka glacial-interglacial cycles and showing a strong influence of North Atlantic climate. In the early Pleistocene, however, the aquatic and terrestrial habitats of a shallower basin were likely affected very differently by the then obliquity-controlled climate dynamics. We present data from biomarker and pollen analyses of the lowest section of the ICDP DEEP core, covering obliquity cycles between 1.4 and 1.2 Ma. Carbonate precipitation in Lake Ohrid appears strongly controlled by temperature, which is confirmed by closely correlating temperature-sensitive ratios of glycerol dialkyl glycerol tetraethers (GDGTs) from soil bacteria. The composition of the vegetation in the catchment adapts accordingly, which is reflected in the pollen data as well as the changing composition of leaf wax-derived biomarkers. However, we also find evidence for long-term changes and short-term disturbances that appear independent of the climatic development. This includes, for example, a lasting shift in leaf-wax derived n-alkane distributions coinciding with a reduced input of potentially littoral Poaceae pollen, shifts in the relative amounts of aquatic biomarkers suggesting a change in nutrient cycling between sediment and surface water as well as evidence for a tectonically induced lake-level drop and associated erosion of wetland soil and siliciclastic alluvium. It thus appears that, during its first 100 ka, Lake Ohrid was an entirely different ecosystem: shallow, with more extended littoral zones, including wetlands, and significantly more productive.

## **S17-P07 - A 100-year record of environmental change inferred using a sediment core from alpine Lake Sayram, northwest China**

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Lake Sayram is a deep, hydrologically closed alpine lake in the Tianshan Mountains of northwest China. We inferred recent environmental changes in the region using a 30-cm sediment core from the lake center. Core chronology for the last ~100 years was established with  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  dating. Past environmental conditions were inferred using sediment pigments, source-specific biomarkers, metal and nutrient contents,  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of bulk carbonate, and polycyclic aromatic hydrocarbon (PAH) concentrations. Sedimented pigments and nutrients provide insights into the lake's past trophic status. The ratio of evaporation to precipitation controlled the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of dissolved inorganic carbon (DIC) in the lake water and is likely responsible for the stratigraphic covariance of  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  in bulk carbonate. Alkenone unsaturation indices are associated with climate conditions, and PAH and metal concentrations reflect the intensity of human activities. Constrained cluster analysis of the multiple variables in the Lake Sayram core was used to distinguish three periods of sediment deposition. Prior to 1960, the climate was dryer, evaporation was greater, and the lake water was more saline. The vertical distribution of PAHs changed little and low molecular weight PAHs were dominant. In the early part of the sediment record, an episode of drier climate in the 1920s was identified from the presence of aeolian dust. From the 1960s to the 1990s, delivery to the sediments of high molecular weight PAHs and heavy metals increased slowly, associated with a period of limited economic development in the Xinjiang region. Thereafter, pigments and geochemical variables in the sediments indicate enhanced trophic state of the lake and greater phytoplankton productivity. Before the 1960s environmental changes in and around Lake Sayram were controlled largely by natural, i.e. climate drivers. Since that time, human activities have had a profound influence on the lake and surrounding environment.

## **S17-P08 - Climate and catchment processes modulated the impact of atmospheric deposition on nitrogen cycling and algal shift in a subtropical alpine lake, SE Tibet**

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Mountain regions have been widely recorded to be impacted by regional warming and atmospheric deposition, however, their relative roles on ecosystems existed strong spatial heterogeneity. Moreover, their independent role and interaction have been rarely identified. Lake sediments, as important natural archives, can record abundant information of environment changes. The low-latitude alpine regions along the southeast margin of Tibet Plateau dotted many lakes. Herein we used multiple proxies (i.e. nitrogen stable isotope) from a well-dated sediment core collected from an alpine lake (Taiji Lake) from this region to track the signal of atmospheric deposition, so that the role of regional warming and atmospheric deposition could be teased out in driving biogeochemical processes and biotic changes over the past three centuries. The results showed that a moderate depletion of bulk sediment  $\delta^{15}\text{N}$  starting from the 1820s was followed by an enriching trend after  $\sim 1976$  AD. Furthermore, this profile of  $\delta^{15}\text{N}$  variation was strongly associated with the fluctuation of sediment organic matter (OM) and catchment processes that collectively accounted for 55.9% of the isotopic variation over time. Lake productivity (as inferred by Chlorophyll  $\alpha$  pigments) showed a significant increase from  $\sim 1967$  AD which was synchronous with an increased input of autochthonous OM as evidenced by a consistent decrease in sediment C/N ratio. The algal production was significantly related to total nitrogen (98.7%), which was predominantly driven by both atmospheric deposition (44.0%) and regional warming (37.3%). In contrast, these processes only accounted for 11.4% of diatom community variation despite this proxy significantly shifting  $\sim 1929$  AD. Overall, our sediment evidence revealed the strong link among climate, atmospheric deposition and catchment processes in driving biogeochemical cycling and lake production, and highlighted the impact of external forcing in modulating sediment signals such as  $\delta^{15}\text{N}$ .

## **S17-P09 - Distribution of diatoms, chironomids and cladocera in surface sediments of mountain lakes in south-Carpathian mountains, Romania**

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Surface sediments from forty mountain lakes in South-Carpathians were analyzed for subfossil diatom, chironomid, and cladoceran assemblages. Samples were collected from three mountain regions (Retezat Mts, Parang Mts, and Fagaras Mts). Ordination techniques were used to identify relevant physical and chemical environmental parameters that best explain the distribution of these biota in the studied lakes. Distribution of diatoms showed a strong relationship with physical (e.g., lake area, lake depth, transparency) and chemical (e.g. lake-water pH, alkalinity, calcium and silica concentrations) variables of lake water and sediment. The greatest variance in chironomid and cladoceran assemblages is explained by lake elevation and lake area. Increasing lake depth is reflected in diatom and cladoceran assemblages by higher percentages of planktonic species, whereas chironomid assemblages are characterised by a high proportion of cold stenothermous taxa. Diatom and cladoceran communities differed between mountain regions, whereas chironomid assemblages were similar in all regions.

## **S17-P10 - Late Holocene vegetation and climate change on the southeastern Tibetan Plateau, Implications for the Indian Summer Monsoon and links to the Indian Ocean Dipole**

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The Indian Summer Monsoon (ISM) is one of the most important climate systems, whose variability and driving mechanisms are of broad interest for academic and societal communities. Here, we present a well-dated high-resolution pollen analysis from a 4.82-m long sediment core taken from Basomtso, in the southeastern Tibetan Plateau (TP), which depicts the regional climate changes of the past millennium. Our results show that subalpine coniferous forest was dominant around Basomtso from ca. 867 to ca. 750 cal. yr BP, indicating a warm and semi-humid climate. The timberline in the study area significantly decreased from ca. 750 to ca. 100 cal. yr BP, and a cold climate, corresponding to the Little Ice Age (LIA) prevailed. Since ca. 100 cal. yr BP, the vegetation type changed to forest-meadow with rising temperatures and moisture. Ordination analysis reveals that the migration of vegetation was dominated by regional temperatures and then by moisture. Further comparisons between the Basomtso pollen record and the regional temperature reconstructions underscore the relevance of the Basomtso record from the southeastern TP for regional and global climatologies. Our pollen based moisture reconstruction demonstrates the strong multicentennial-scale link to ISM variability, providing solid evidence for the increase of monsoonal strengths over the past four centuries. Spectral analysis indicates the potential influence of solar forcing. However, a closer relationship has been observed between multicentennial ISM variations and Indian Ocean sea surface temperature anomalies (SSTs), suggesting that the variations in monsoonal precipitation over the southeastern TP are probably driven by the Indian Ocean Dipole on the multicentennial scale.



## **S17-P11\* - A late Holocene multi-indicator paleoproductivity record for the Eastern Sierra Nevada (California): New Insights from June Lake**

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Paleoproductivity indicators in a recently collected sediment core from June Lake (Mono County, CA) exhibit marked fluctuations over the last ~4500 years, suggesting pronounced sensitivity to environmental forcings. The lake is a mid-elevation, surficially-closed system situated near the boundary between the Sierra Nevada and the Basin and Range, and within a few kilometers of the active Mono-Inyo Craters. The core consists of three distinct lithologies: a dominant diatom-rich, laminated biogenic ooze, subordinate intervals of thinly bedded carbonate mud, and a series of coarse-grained tephra interspersed throughout the record. Productivity indicators, including total organic carbon (TOC), total nitrogen (TN), and Si/Ti, exhibit sharp declines immediately following deposition of volcanoclastic layers, suggesting a reduction in primary productivity in response to short-term environmental stressors accompanying local volcanism. However, at intervals not obviously correlated with volcanic activity, productivity and/or preservation declines sharply, coincident with increases in total inorganic carbon (TIC) and Ca/Ti. We attribute this difference in mineralogy to carbonate precipitation during intervals of lake level lowering. C:N and  $\delta^{15}\text{N}_{\text{org}}$  values show little variability throughout the record (generally 9–10 and 3.5–5.5‰, respectively), which implies little change in organic matter source over the late Holocene. As an exception to this trend,  $\delta^{15}\text{N}_{\text{org}}$  values show a marked decline over the last ~200 years, which may reflect anthropogenic influences. This study marks a new step in discerning Holocene hydroclimate fluctuations in the Sierra Nevada, which may prove consequential as California resource planners attempt to project future water needs. Forthcoming  $\delta^{13}\text{C}$  and biogenic silica data will further illuminate this productivity story, and additional  $^{14}\text{C}$  dates will enhance our ability to interpret the resolution of the record.

## **S17-P12\* - Impacts of human activities and climate on Lake Morenito, Northern Patagonia, Argentina**

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For more than 50 years, Lake Morenito, located in the city of Bariloche in the Nahuel Huapi National Park (Argentina), has been exposed to anthropogenic impacts including damming, house-building, species introduction, tourism, and probably climate change. An 80 cm-long sediment core spanning more than 100 years from L. Morenito was studied for chironomid larvae, stable isotopes, and organic geochemistry to resolve how natural and anthropogenic stressors impacted the lake. The core chronology is based on  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  activities. Chironomid assemblages display major changes around AD 1950. The appearance of the warm adapted *Chironomus* and the replacement of *Apsectrotanypus* by *Ablabesmyia* indicate a shift to warmer conditions. Chironomid composition changes again in AD 1960, post-damming and after the deposition of volcanic tephra, followed by slow recovery of several taxa. At this time, a change in the sediment accumulation took place possibly linked to increased erosion during and after damming. However, for most of the core, low TOC/TN values (<10) were recorded indicating a predominant algal source of organic matter with only little terrigenous input. The increasing trend of  $\delta^{15}\text{N}$  coupled with the decrease of  $\delta^{13}\text{C}$  from AD 1950 to present day, points to shifts in the carbon and nitrogen cycles of the lake associated with human activities. It is evident that damming of Lake Morenito in AD 1960 played an important role in the history of the lake. However, human activities such as fish introduction and tourism linked to the climate warming of the 20<sup>th</sup> century, especially during the 1950s, possibly had a greater effect on the lake ecosystem. Indeed, climatic warming and increase of the human impact in all the areas of the National Park already started 70 years ago and coincided with a general trend of regional increasing air temperatures.

## **S17-P13\* - Late Glacial and Holocene landscape history of the Sanetti Plateau, Bale Mountains (Ethiopia), as deduced from biogeochemical properties of lacustrine sediments**

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The Bale Mountains were one of the three extensively glaciated higher elevation areas in Ethiopia during the last glacial maximum. After deglaciation, several small depressions on the Sanetti Plateau turned into shallow lakes. Today, some of these lakes dry out seasonally due to the alternation between monsoonal precipitation in summer and dry north-easterlies in winter. With this study we aim at contributing to the reconstruction of the Late Glacial and Holocene environmental history of the Bale Mountains, particularly sedimentation, fire and vegetation history.

We investigated partly laminated lake sediments at high-resolution from a catchment located at an altitude of 4115 m a.s.l. on the Sanetti Plateau. According to the results of radiocarbon dating, the 2.55 m sedimentary archive represents particularly the period from 18 to 5.4 cal. ka BP. Total organic carbon (TOC) concentration reaches almost 8% during the time between 16 and 18 cal. ka. and low concentration of TOC (~1%) is recorded at about 5 cal. ka BP. Low odd-over-even predominances (OEP) of n-alkane lipid biomarkers as well as low TOC/N ratios corroborate the interpretation of highly degraded organic material building up the upper 70 cm. Fire reconstruction is assessed using the n-alkane proxy C18 as well as black carbon analyses. The results suggest that there are several periods of clearly increased accumulation of charred residues (during the LG lacustrine period) as well as periods when the relative contribution of charred residues to TOC increased (when frequent desiccation started during the Mid Holocene). The Late Glacial – Holocene transition is furthermore characterized by a major shift in the long-chained leaf wax-derived n-alkane patterns. These changes in average chain length (ACL) are interpreted in terms of vegetation changes. More positive  $\delta^{13}\text{C}$  values in the lower part of the sediments (-20 to -14‰) moreover likely reflect a LG expansion of C4 grasses.

## **S17-P14 - The anthropocene in the southern central Pyrenees: The Urdiceto lake record**

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The multidisciplinary study of the sedimentary record of a high mountain lake (Urdiceto, 2369 m a.s.l.) located at the headwaters of the Cinca River (southern, central Pyrenees, Spain) has allowed the reconstruction of sediment fluxes, bioproductivity, carbon cycles and deposition of heavy metals during the last millennium.

Depositional dynamics are reconstructed from detailed sedimentary facies analyses, X-ray fluorescence scanner, elemental geochemistry (Total Organic Carbon, Total Inorganic Carbon and Total Sulfur Content) and an age model based on  $^{210}\text{Pb}$  and  $^{14}\text{C}$  dates. The sediments are alternations of fine and coarse silts that reflect the changes in the runoff and sediment transport from the basin. Comparison with climate data indicates increased runoff and sediment delivery during colder and wetter periods, and deposition of finer silts with higher organic content during warmer phases. However, after the lake was dammed in the 1930s for hydroelectric power, the exploitation regime controls its dynamics, characterized by higher water depths, large seasonal lake levels fluctuations and sedimentation of finer silts. The occurrence of Pb in the sediments marks an intense period of heavy metals pollution at the end of the 19<sup>th</sup> century and during the first half of the 20<sup>th</sup> century associated with a greater intensity of mining and metallurgy at local and regional scale, and a decrease at the end of the century probably due to the prohibition of lead fuels.

The Urdiceto sequence demonstrates the sensitivity of sediment fluxes in high altitude watersheds to climatic changes on a decadal or centennial scale during the last millennium and the high impact of dam construction in depositional dynamics.

## S17-P15\* - Multi-proxy evidence of the abrupt 8.2 ka paleoclimatic event from a small mountain lake in the Czech Republic

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The 8.2 kiloyear event was the most abrupt climatic cooling to occur during the Holocene. Currently there are very few detailed records describing ecosystem responses to the event from inland Central Europe. Here, we present multi-proxy evidence from a sediment profile from Prasilske Lake, a small tarn in the Bohemian Forest, Czech Republic (49°05'N, 13°24'E; 1079 m a.s.l.; 4.2 ha; max. depth 17 m; catchment area 0.65 km<sup>2</sup>; anoxia near bottom). In a 2.2 m long sedimentary sequence, we identified a series of erosion events correlated with the 8.2 ka cooling identified by increases in Ti and Rb (microXRF), decreases in LOI, and increases in magnetic susceptibility. To reconstruct the lake-catchment response, water invertebrate fauna remains (chironomids, caddisflies, alderflies, bryozoans), diatoms, water and terrestrial plant macroremains, bark beetle remains, pollen and charcoal were analyzed. An initial phase of erosional activity likely began with a fire event within the catchment ~8500 cal. yr BP, which allowed for the rapid succession replacement of an open *Pinus-Betula* dominated landscape to a more enclosed *Picea* dominated system. Our results document a subsequent increase in the presence of primary attack bark beetles (*Ips typographus*, *Pityogenes chalcographus*, *Pityophthorus pityographus*, and *Polygraphus poligraphus*) and changes in water fauna and diatom assemblages. The 8.2 ka event was characterized by sharp increase in both littoral and profundal chironomid taxa (genus *Heterotrissocladius*, *Microtendipes*, *Procladius*, *Tanytarsus*, and *Zavreliomyia*), higher diversity in the other macrozoobenthos, and dominance of heavily silicified planktonic diatoms (*Aulacoseira* spp.) suggesting intensive mixing of the lake water and improvement of oxygen conditions near the bottom. Based on this sensitive natural archive, we conclude that the climatic deterioration likely had a greater environmental impact in inland Central Europe than previously assumed.

The study was supported by the Czech Grant Foundation (Project 16-06915S - EUROPIA).

# S17-P16 - Paleoenvironment and paleoclimate since 5000 cal a BP in the southeastern margin of Qinghai-Tibet Plateau revealed by a high-resolution lacustrine sediment record from an alpine lake

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Shadecuo Lake, a closed lake located at an altitude of 4446 m, is located in the southeastern margin of Qinghai-Tibet Plateau, and belongs to Kangding city, western Sichuan Province. The lake is very sensitive to climate change. A 121-cm-long sediment core was recovered in a water depth of 8 m using a UWITEC piston corer from the central part of Shadecuo Lake. The core chronology was established using  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  dates of a short core and the AMS  $^{14}\text{C}$  dates of three plant remain samples. High-resolution pollen and other proxies such as grain size, TOC, TN, and magnetic susceptibility from the core were analysed to reconstruct vegetation and climate histories since ~5000 years in the southeastern margin of Qinghai-Tibet Plateau. The results show that seven significant vegetation changes are recorded, which are responses to climate changes. During the period 5040~4500 cal a BP, *Pinus* forest was distributed in the lower altitude mountainous region, and a small amount of *Picea/Abies* and *Tsuga* were mixed in this forest. Evergreen broadleaved forest dominated by evergreen oaks was distributed above the *Pinus* forest. Around Shadecuo Lake, sparse herb vegetation grows in rock debris. This vegetation distribution indicates that climate between 5040–4500 cal a BP was relatively moderately warm and humid conditions. From 4500 to 2640 cal a BP, the area of *Pinus* forest in the lower altitude mountainous region decreased with the number of *Tsuga* in this forest decreasing, whereas the sparse herb vegetation in rock debris around Shadecuo Lake expanded. This vegetation change reflects that temperature and humidity decreased. Between 2640 and 2290 cal a BP, *Pinus* forest in the lower altitude mountainous region expanded markedly, while the area of evergreen oak forest and the sparse herb vegetation in rock debris around Shadecuo Lake decreased evidently, indicating that the temperature and humidity during this period are the highest during the past 5000 years. During the period of 2290~1620 cal a BP, *Pinus* forests shrank significantly, and the area of evergreen oak forest and the sparse herb vegetation in rock debris around Shadecuo Lake increased, denoting that the climate cooled and dried. From 1620 to 660 cal a BP, *Pinus* forest in the lower altitude mountainous region expanded, while the area of evergreen oak forest and the sparse herb vegetation in rock debris around Shadecuo Lake decreased, which reflects that the temperature rose and the humidity slightly increased. During the period of 660~10 cal a BP (1290~1940 AD), *Pinus* forest shrank, whereas evergreen oak forest and the sparse herb vegetation in rock debris around the lake expanded slightly, indicating that the climate during the period was relatively cool and dry. After 1940 AD, *Pinus* forest expanded significantly, and the area of evergreen oak forest and sparse herb vegetation in rock debris decreased, which reflect that the temperature and humidity all increased.

The sediment core from Shadecuo Lake recorded well some important climatic events such as the end time of “Holocene Optimum”, “late Holocene cooling period”, “Medieval Warm Period”, “Little Ice Age”, and “20<sup>th</sup> century warm period”. This study has an important reference significance to understand the evolution of vegetation and the process of climate change since the middle and late Holocene in southwestern China.

## **S17-P17\* - Increased glacier melt water led to lake expansion on the western Tibetan Plateau since the late 1990s: isotopic ( $\delta^{18}\text{O}_{\text{carb}}$ ) evidence from Aweng Co**

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Glacier-fed lakes in the Tibetan Plateau (TP) have undergone a dramatic expansion since the late 1990s, in parallel with the changing climate. However, the dominant factor that may have led to an increase in glacier-fed lake area is still controversial. Here we present a case study of Aweng Co, a glacier-fed lake in the western TP, the surface area of which has increased since the late 1970s and most rapidly since the late 1990s. A water balance model was established to clarify the reasons for increased lake water mass, combined with meteorological data and the recent sedimentary record. The output of the model suggests that although precipitation contributed more than 55% of the lake water budget, increased glacier melt water was probably the main factor (extra water) that led to rapid lake area change between 1997 and 2007. From 2007 to 2010, precipitation was the main factor causing an increase in lake area as the supply of glacier melt water probably decreased. The water balance model was verified by the sedimentary record. The oxygen isotopes of carbonates ( $\delta^{18}\text{O}_{\text{carb}}$ ) are sensitive to water source changes, therefore providing an indicator of water budget for glacier-fed lakes in recent decades, a model which can now be used for the interpretation of longer core records.

## S17-P18 - Seasonal diatom variability of Yunlong Lake—a case study based on sediment trap records

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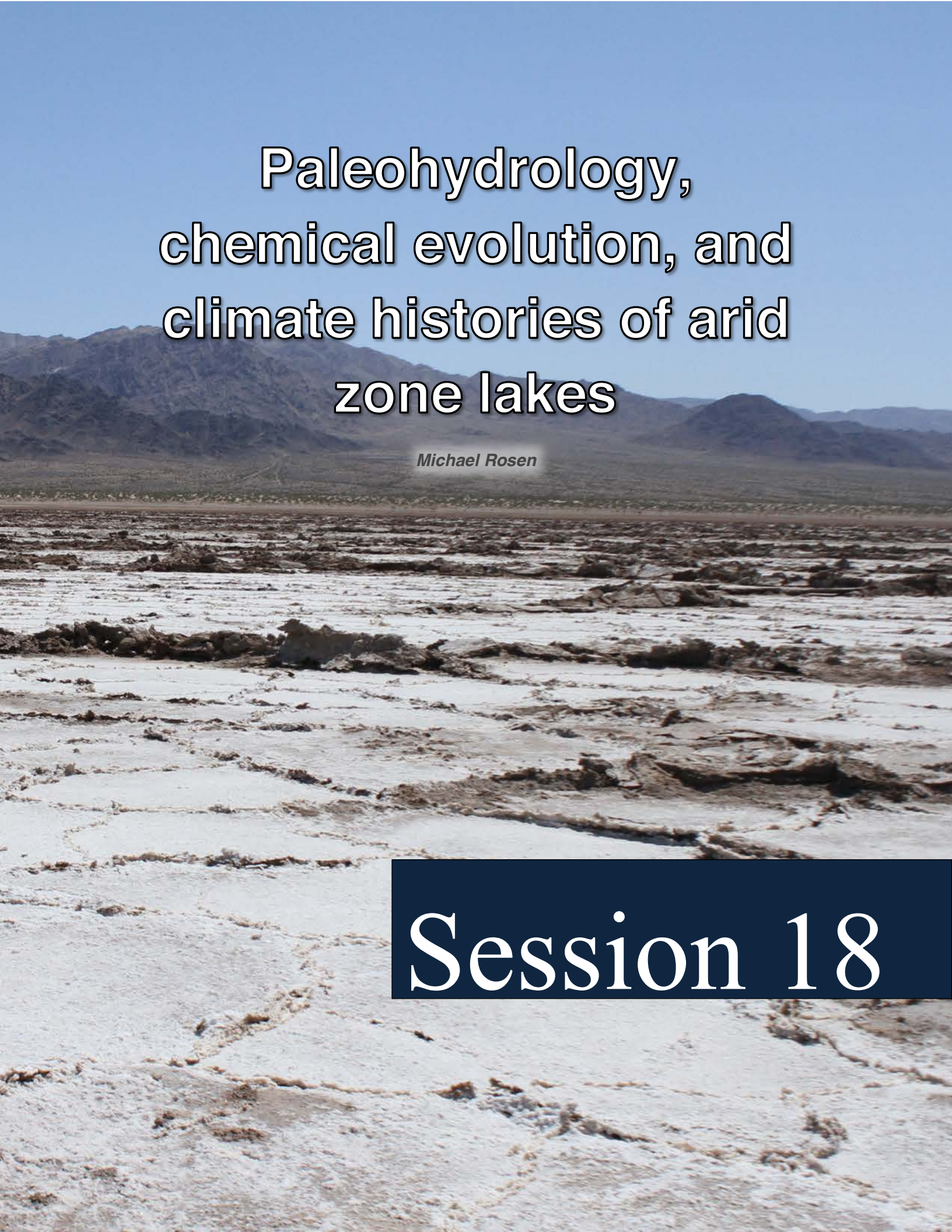
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Seasonal patterns of diatom succession can provide an important reference for paleolimnological interpretations, and lakes in the monsoon region, with distinct seasonal variations, are well-suited for this type of study. Yunlong Lake, a subtropical alpine lake in southwest China, was selected for a sediment trap diatom study during the interval from September 2013 to August 2015.

Combining the results with the analyses of meteorological records, water temperature monitoring and monthly water chemistry sampling, we made the following conclusions. First, the whole-year normal growth pattern of both tychoplanktonic and euplanktonic diatom species, as well as the overall high abundance of benthic species, reflects the unusually strong mixing characteristics of the lake, which is ensured by the entire upper 7-m of the water body throughout the year. Second, we found a biannual warm-cold season diatom response pattern, which was mainly controlled by water temperature. The warm season was from May to November, with an overall higher water temperature, and the representative species were *Aulacoseira granulata* and *Achnanthes catenata*; and the cold season was from December to April, with a lower water temperature and stronger turbulent mixing, which induced the blooming of species such as *Cyclotella asterocostata*, *Cyclotella balatonis* and *Aulacoseira ambigua*. Third, changes in the concentration of silica also influence the succession of diatom assemblages, causing planktonic species to bloom in the sequence of *A. ambigua* - *C. asterocostata* - *Cyclotella stelligera* - *C. balatonis* - *Cyclotella pseudostelligera* during the first cold season. This indicates that smaller-sized diatom species are more successful in obtaining nutrients. Fourth, there were interannual differences in the diatom assemblages, especially in the abundance of *C. balatonis* and the occurrence of *Asterionella formosa* during the second cold season, which was probably related to the significantly increased lake trophic status in the second year.





# Paleohydrology, chemical evolution, and climate histories of arid zone lakes

*Michael Rosen*

Session 18

## Oral presentations

### **S18-001 - Quantitative Reconstructions of Past Lake Level Changes from Tufas and Paleoshorelines in the Central Andes**

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Paleoshorelines and tufa deposits of closed-basin lakes provide unequivocal evidence for past variations in the balance between precipitation and evaporation. Here we demonstrate the descriptive power of combining (1) precise uranium-thorium (U/Th) ages on tufa and other shoreline carbonate deposits with (2) geologic interpretations of depositional context at all scales--from outcrop to the microscale---and (3) elevational measurements of paleoshorelines. By integrating these data, we can pair the timing of past lake level variations with corresponding quantitative constraints on water volume changes.

To illustrate our process, we present new U/Th dating constraints on lake level variations from a north-south transect of closed-basin, high-altitude paleolakes in the central Andes (21–27°S, 3800–4400 m a.s.l.). This region contains several small (<40 km<sup>3</sup>) basins surrounded by well-preserved paleoshorelines and tufas that indicate previous periods of much wetter conditions. Recent advances in analytical techniques allow us to U/Th date small (<10 mg) aliquots of powder to avoid sampling detrital materials requiring large age corrections. With improved sample selection and high U concentrations, we can acquire U/Th dates on shoreline carbonates that are precise to within ±50 to 300 years.

Our initial ages suggest that these lakes were higher than present levels during these periods: 12–10 kyr BP, broadly coincident with the Younger Dryas; 15.5–14.5 kyr BP, coincident with Heinrich Event 1; and at some period before 100 kyr BP. These lake expansions correspond to 4- to 19-fold increases in lake surface area relative to modern. In addition, the depositional context of dated carbonates suggests that some of these wet periods are also associated with large magnitude lake level fluctuations occurring within sub-millennial timescales.

These data are the first precise shoreline ages for this broad section of the central Andes and significantly expands the region of known wet conditions during HE1 and the YD.

## **S18-O02 - Paleo-limnological reconstruction of the late Quaternary Dead Sea from pore-fluid compositions in the ICDP deep drilled core**

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Major ion and isotope pore-fluid compositions from a deep ICDP sedimentary core drilled at the bottom of the Dead Sea are used for reconstructing the composition of the deep lake and to understand the geochemical and limnological processes over ca. 200 ka. Conservative ion concentrations from the pore-fluids ( $Mg^{2+}$  and  $Br^-$ ) were diluted and concentrated over glacial and interglacial periods, respectively, and are correlative to the net water changes in the deep-lake. Long term precipitation and dissolution of halite had occurred in the lake leading to changes in Na/Cl and  $\delta^{37}Cl$  of the brine. During the last interglacial (ca. 132 to 117 ka) lake levels dropped and halite layers precipitated accompanied by a decrease in the Na/Cl ratio and in  $\delta^{37}Cl$  in the pore-fluids. Conversely, during the last glacial, when lake levels increased and transgressed over the adjacent salt diapir of Mt. Sedom, pore-fluid Na/Cl ratio increased and  $\delta^{37}Cl$  became enriched, suggesting contribution of  $Cl^-$  via dissolution of halite. The dissolution of the Mt. Sedom salt resulted in local increase in the density of the brine which then sank to the hypolimnion/monimolimnion and led to its change in composition.

## **S18-O03 - Dynamics of East Asian summer monsoon over the past two glacial-interglacial cycles revealed by lake sedimentary archives in north China**

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Determining the drivers of past East Asian summer monsoon (EASM) activity can help understand patterns of monsoons in the present and future. Two competing factors, high-latitude ice-volume and low-latitude solar insolation, have been proposed as the primary triggers of the long-term variation in EASM, but the relative importance of these factors remains unclear. Here, lake-level variations of two closed lakes (Zhuyeze and Huangqihai, at a distance of 800 km) from the north periphery of present EASM dominated area are used as a proxy of EASM intensity over the past two glacial-interglacial cycles. Mainly based on optically stimulated luminescence dating of the sedimentary deposits associated with rise and fall of lake-level, our results indicate three major highstands at the periods within 250–200 ka, 130–100 ka, and 12–6 ka. Correspondingly, low lake-levels occurred during the last and penultimate glacials. Over the past 12 ka, the two lakes sustained high water level during the first half of Holocene (12–6 ka) with a peak level at 9–7 ka, and retreated rapidly at ~6–5 ka. The overall relevance of lake-level fluctuations to marine isotope record demonstrates a dominant ice-volume forcing of the EASM variations on the glacial-interglacial timescales. As for the modern interglacial, the EASM intensity was strengthened during the early Holocene and weakened through the middle to late Holocene, which appears to indicate that the monsoon intensity was regulated by the insolation on the sub-orbital timescales. Thus, EASM variation is likely to have been modulated by both global ice-volume and solar insolation forcing, but each played a different role on different timescales. However, the rapid fall of the lake-levels at ~6–5 ka, indicating an abrupt decline of monsoon precipitation, indicates a nonlinear response of EASM variation to insolation forcing.

## S18-O04 - Paleohydrological evolution of a saline wetland in arid NW Australia: Insights from groundwater dolomite

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Extensive chemical deposits dominated by dolomite occur within the Fortescue Marsh, a 1000 km<sup>2</sup> wetland in the semi-arid inland Pilbara region of northwest Australia. Given, dolomite precipitation is strongly controlled by reaction kinetics and is inhibited at surface temperatures and pressures, the presence of dolomite indicates specific hydrochemical conditions occurred to overcome kinetic barriers to precipitation, associated with elevated Mg/Ca, salinity and alkalinity. We analysed the geochemistry and stable isotopic compositions of carbonates and groundwater from various depths and locations across the Marsh to reconstruct the hydrochemical conditions involved in dolomite formation and provide paleoenvironmental and paleohydrological records for the Quaternary period. Two major phases of groundwater dolomite formation are apparent from the presence of two distinct units, based on differences in depth,  $\delta^{18}\text{O}$  values and mineral composition. Group 1 (G1) occurs at 20-65 m depth and contains stoichiometric dolomite with  $\delta^{18}\text{O}$  values of -4.02 to 0.71‰. Group 2 (G2) is shallower (0–23 m depth) and contains Ca-rich dolomite +/- secondary calcite with a comparatively lower range of  $\delta^{18}\text{O}$  values (-7.74 to -6.03‰). Modelled  $\delta^{18}\text{O}$  values of paleogroundwater from which G1 dolomite precipitated indicated highly saline source water, which had similar  $\delta^{18}\text{O}$  values to relatively old brine groundwater within the marsh, developed under a different hydroclimatic regime. The higher  $\delta^{18}\text{O}$  values suggest highly evaporitic conditions occurred at the Marsh, which may have been a playa lake to saline mud flat environment. The younger G2 dolomite precipitated from comparatively fresher water, and modelled  $\delta^{18}\text{O}$  values suggested formation from mixing between inflowing fresher groundwater with saline-brine groundwater within the Marsh. In contrast to the modern hydrology of the Marsh, which is surface water dependent and driven by a flood and drought regime, past conditions conducive to dolomite precipitation suggest a groundwater dependent system, where shallow groundwaters were influenced by intensive evaporation.



## **S18-O05 - A new Dead Sea pollen record reveals the last glacial paleoenvironment of the southern Levant**

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The Dead Sea is a salt lake that occupies the lowest depression on Earth. It witnessed a dynamic history with strong lake level variations and salinity changes since the last glacial. In addition, the Dead Sea region is a key site for investigating the history of mankind because it accommodates important archaeological remains of modern humans and Neanderthals. Yet, our knowledge about the paleoenvironment and particularly the vegetation history of the Dead Sea region was still fragmentary.

Here, we present a new palynological study inferred from sediments of Lake Lisan, the last glacial precursor of the Dead Sea. The sediments were recovered from the center of the modern Dead Sea in the frame of an ICDP campaign. They represent the longest continuous sediment record of the southern Levant. The study combines pollen data revealing the regional vegetation history, microscopic charcoal data to reconstruct fire activity in the past, and a pollen-inferred climate reconstruction. The palynological results indicate that Irano-Turanian steppe and Saharo-Arabian desert vegetation prevailed in the Dead Sea region during the last glacial. Nevertheless, Mediterranean woodland elements significantly contributed to the vegetation composition during most of the investigated period suggesting moderate amounts of available water for plants. Our results suggest that modern humans, who eventually colonized Europe, settled in the southern Levant during a climatically stable period with low fire activity. However, during the Late glacial, a strong environmental change occurred: A considerable shift of the vegetation went along with a major lake level decrease.

The study gains new insights into environmental responses of the Dead Sea region to climate variations in the past. It contributes towards our understanding of paleoenvironmental conditions in the southern Levant, which functioned as a corridor for human migration processes.

## S18-O06 - The large and brackish lake Lop Nur in the early Holocene, Tarim Basin (NW China)

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Lop Nur was the terminal lake of the Tarim Basin until its final desiccation in the late 1930s and early 1940s. Sediments from a dug section (YKD0301) in the “Great Ear” basin of the dried lake were investigated to reconstruct the Holocene lake history. Silty early Holocene sediments (ca. 9.4–9.0 ka ago) contain abundant shells of the ostracods *Cyprideis torosa* and *Eucypris mareotica*, Ruppia seeds, charophyte remains and tests of the foraminifer *Ammonia tepida*. Stable oxygen isotope values of ostracod shells are significantly higher than  $\delta^{18}\text{O}$  values of bulk carbonate in this part of the dug section. The relatively high difference between both  $\delta^{18}\text{O}$  records gradually diminishes afterwards, probably indicating a significant water depth and thermal stratification of the water column in the summer half of the year in the early Holocene. The recorded fossils suggest that Lop Nur was a stable brackish-water lake with a depth of at least several metres during this time. Afterwards, a unit of fossil-barren sediments probably results from a relatively short period of reduced inflow and fluctuating saline conditions. Freshwater ostracod shells of *Ilyocypris* sp., *Darwinula stevensoni*, *Limnocythere inopinata*, *Candona neglecta*, *Pseudocandona* sp., *Herpetocypris* sp. and *Cypridopsis vidua* indicate increased run-off entering the lake ca. 8.7–7.2 ka ago. Stable isotope values for both ostracod shells and bulk carbonate are low and in the same range, reflecting the significant contribution of inflows to the lake and a shallow water depth without temperature stratification in the water column. Almost barren sediments afterwards indicate low inflow again. Lop Nur experienced the largest water depth and permanently stable brackish-water conditions in the early Holocene before 9.0 ka. It remains open whether the early Holocene Lop Nur received significantly more run-off as a result of larger meltwater contribution during the post-glacial warming or due to higher precipitation in the lake’s catchment.

## S18-007 - The Hydrology of Lithium Brines in Playas

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Many playas throughout the world have high concentrations of lithium in the basin center brines. High concentrations of lithium in these brines may result from several different mechanisms. Potential sources of lithium include, geothermal fluids, dissolution of lithium from tephra, lithium-bearing clays, or pegmatites, and groundwater that collects lithium over long flow paths. Brines with the highest concentrations of lithium are believed to form from evapoconcentration of geothermal fluids; a well-known example is the brine at Salar de Atacama, Chile, with lithium concentrations ranging from 1,000 to 4,000 mg l<sup>-1</sup>. In the western United States, lithium brines rarely exceed 100 mg l<sup>-1</sup> except at Clayton Valley, Nevada, USA, where lithium concentrations range from 60 to 400 mg l<sup>-1</sup>. At Clayton Valley, the source of lithium is a subject of debate, where one possibility is the lithium-bearing tephra and clays present in the subsurface. Long groundwater flow paths from outside Clayton Valley may also contribute lithium. In the Bristol Trough, California, USA, 3 playas in separate closed basins vary in lithium concentrations: less than 5 mg L<sup>-1</sup>) at Danby Dry Lake, 20–80 mg l<sup>-1</sup> at Cadiz Dry Lake, and 71–110 mg l<sup>-1</sup> at Bristol Dry Lake. Although it has been postulated that geothermal fluids supply the Na-Ca-Cl brine and the lithium to Bristol and Cadiz closed basins, there is little to no evidence for geothermal fluids, except for a young 80,000-year-old volcanic crater in Bristol Dry Lake. All the Bristol Trough basins are old (>3 million years old), which gives considerable time for the evapoconcentration of lithium. Ongoing research is investigating whether evaporation of discharging groundwater from the surface of the playa center, with potentially low permeability halite and clays, can support sufficient flow to allow for evapoconcentration of brines at the center rather than at the playa margin.



## **S18-O08 - Late-Holocene hydrological variability of iconic oasis lakes at Ounianga in the central Sahara (Chad)**

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The Ounianga basin in northeastern Chad, listed as a World Heritage Site by UNESCO, hosts two clusters of unique desert oasis lakes. These lakes range from freshwater to hypersaline, and all of them are sustained against the strong climatic moisture deficit by continuous inflow of fossil groundwater from the Nubian Sandstone Aquifer (NSA). The paleolimnological record of Lake Yoa in the Ounianga Kebir cluster has provided key insights on the transition from the African Humid Period towards the current hyperarid climate regime (Kröpelin et al. 2008, Francus et al. 2013). However, the large volume of Lake Yoa and its state of hypersalinity throughout the late Holocene has limited the paleohydrological proxy signature of climatic moisture-balance changes (Eggermont et al. 2008). Here, we present paleolimnological records from three shallow lakes in the Ounianga Serir cluster, which reveal their paleohydrological response to late-Holocene climatic perturbation. Our records document site-specific but semi-synchronous paleohydrological shifts, suggesting that relatively modest variation in the Late-Holocene climate regime, e.g. in temperature or wind strength, resulted in basin-wide lake-level fluctuation notwithstanding a most likely fairly constant groundwater recharge from the NSA. In the two more dilute lakes (Edem and Agouta), lower lake level promoted a greater cover of rooted or floating reed-mats, whereas in hypersaline Lake Teli it resulted in more frequent disruption of the water column's density stratification. This study provides a long-term reference frame for the resilience of Ounianga's lacustrine ecosystems to future climatic change.

Eggermont H., Verschuren D., et al. 2008. *Quaternary Science Reviews* (27) 2411-2425

Francus P., von Suchodoletz H., et al. 2013. *Sedimentology* (60) 911-934

Kröpelin S., Verschuren D., et al. 2008. *Science* (9) 765-768

## **S18-O09 - Precipitation history of the central Atacama Desert since the Miocene as reconstructed from clay pan records of the Coastal Cordillera/N Chile**

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Hyperaridity is a major limitation of Earth-surface processes and biological activity in the Atacama Desert of N Chile, one of the oldest and the driest deserts on Earth. But even the hyperarid core of the Atacama Desert of N Chile has experienced severe precipitation events, e.g., during the flash floods in 2015. On geological timescales, the overall aridity that is postulated to have lasted at least since the early Miocene was punctuated by distinct pluvial events. Such wetter conditions, e.g. during the Miocene, caused widespread lake-formation in the Central Depression and Coastal Cordillera, but also caused amplified surface processes, changes in vegetation dynamics, and enabled the dispersal of species. Unfortunately, due to the limited number and heterogeneous appearance of climate archives from the central Atacama, its longer-scale precipitation history is still a matter of controversy.

This study aims to study continuous long-term (Quaternary-Miocene) paleoclimatic/environmental records from the hyperarid core of the Atacama Desert covering the last >10 Ma. Therefore we investigated clay pan records from endorheic basins in the Coastal Cordillera mostly formed by blocking of drainage by tectonic movement. The clay pans under study are located along a latitudinal transect across the hyperarid core of the Atacama, and thus, are assumed to have recorded local and regional precipitation variations on different timescales. The investigated sequences exhibit significant changes in the sedimentological, geochemical, and mineralogical properties due to changes in precipitation, but also in the weathering and erosion in the catchments. Diatom and phytolith remains preserved in these records clearly point to significant water bodies during the wettest periods and a significant vegetation cover. The results shed a new light on the timing, frequency, and the driving mechanisms of the intervening pluvial phases.

## Poster presentations

### **S18-P01 - Hydro-climatic variability in western Iran since the Lateglacial: subfossil chironomids, a new promising proxy for palaeohydrological reconstructions in the Middle-East**

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Although Iran is an interesting area, few palaeoclimatic records are available from it. Iran is a climatic and biogeographic crossroad and one of first areas of civilization. Subfossil chironomids, have recently proved their high potential as seasonality indicators in the Neor region with a dominant continental Mediterranean climate. We present here two chironomid records from northwestern Iran (Lake Neor) and southwestern Iran (Dasht-e Arjan Wetland). Based on subfossil chironomid evidence, these records allow documenting the hydroclimate history of the last 15000 years. Major hydroclimatic changes have been detected, particularly at Neor, including the alternating occurrences of stronger (e.g. 15000–13400 and 2500–1500 BP) and weaker summer droughts (e.g. 8700–7500 and 4000–2500 BP). The Younger Dryas at Arjan and Neor lake systems was marked by higher lake levels and more permanent lacustrine conditions (suggested by high percentages of *Chironomus plumosus/anthracinus*-type and *Micropsectra* sp). During the early Holocene, wetland water tables and lake levels decreased in both sites, marked by the appearance of shallow water and macrophyte dependant taxa (such as *Polypedilum nubeculosum*-type) at Arjan and by dominance of (semi)-terrestrial taxa (such as *Paraphaenocladus/Parametriocnemus*) at Neor. These major hydroclimate changes were probably caused by a strengthening of the Indian Ocean Summer Monsoon leading an Inter Tropical Convergence Zone northward shift, consequently obstructing rainfall coming from the North Atlantic and Mediterranean area by Mid-latitude Westerlies. The 4000–2500 BP wet time interval (revealed at Neor), could favor the nomado-pastoralism activities of the Elamites at high elevations during summers. Dryness between 2500 and 1500 BP, could explain the hydraulic building (e.g. Dam, Qanat) built by Achemenids to manage water resources to farming and irrigation during rarefaction time. Our studies, highlight the high potential of chironomids to reconstruct the climate seasonality in the semi-arid regions.

## **S18-P02\* - Variability of the North American monsoon during the last 20,000 years reflected in limnic sediments from the Chihuahua Desert**

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Over the last glacial-interglacial cycle lateral shifts of the North American Monsoon (NAM) caused significant changes in precipitation patterns over subtropical northern Mexico that are reflected in lacustrine environmental archives across the region. The main aim of this study is to reconstruct late Pleistocene and Holocene hydrological and climatic variability in Central North Mexico, using organic matter (OM) inputs to lake sediments and the carbon and oxygen isotopic composition ( $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ ) of endogenic carbonates, allowing a better understanding of the spatiotemporal variability of the NAM.

The study area includes two paleolakes, Santiaguillo and El Potosi, located at the western and eastern fringes of the Chihuahua Desert, respectively. The Santiaguillo record spans the last 27 ka, and the El Potosi record spans the last 20 ka. We determined the abundances and distributions of lipid biomarkers in 62 sediments (31 from each lacustrine basin), as well as  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values of bulk calcite in 122 sediments (61 from each basin).

Significant differences in biomarker composition over time, as well as between the sites, reveal contrasting environmental dynamics along the mountain ranges bordering the Chihuahua Desert. In the East (El Potosi), a change from mainly terrigenous OM to aquatic/bacterial OM suggests that the deglaciation was associated with a switch to drier climate and/or reduced terrestrial productivity, whereas the opposite occurred in the West (Santiaguillo catchment). The carbon and oxygen isotope records of endogenic carbonates also corroborate this premise.

Overall, the data reveals clear compositional changes that appear related to changes in hydrology and climate. We determine that the response of the vegetation (lacustrine and terrestrial) to the same global climatic events was different in Santiaguillo and El Potosi lacustrine environments. This can be a reflection of how variable the NAM was during the last glacial-interglacial period in the north of Mexico.

# **S18-P03 - Investigating the sensitivity and complexity of salt lake catchments during periods of climatic variability: A 12,000 year geochemical and palynological record from Alicante, Spain**

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This paper examines a 12,000-year record from a former salt lake in the upper Vinalopó Valley in south-eastern Spain. The investigation was part of a Marie Curie fellowship which aimed to investigate the potential impact of climate variability on prehistoric communities, from the Iberian Peninsula, between the Mesolithic and Bronze Age. Methods have included high resolution multi-proxy analysis: pollen, non-pollen palynomorphs, grain-size analysis, X-ray fluorescence (mineral identification) and X-ray diffraction (geochemistry). The results show strong sensitivity to both long term and small changes in the evaporation/precipitation ratio, affecting the surrounding vegetation composition, lake-biota and sediment geochemistry.

## **The key findings include:**

1. An expansion of mesophilic woodland taxa, lake infilling and the establishment of a more perennial lake system at the onset of the Holocene due to increasing wetness and temperatures.
2. An increase in solar insolation after 9 ka cal BP which saw the re-establishment of pine forests
3. A continued trend towards increasing dryness (climatic optimum) at 7 ka cal BP but with continued freshwater input
4. An increase in sclerophyllous open woody vegetation (anthropogenic?), but with increasing wetness (climatic?) represented in the lake record, between 5.9 and 3 ka cal BP
5. The identification of several short aridity events, the most prominent corresponding to the 8.2 ka cal BP event, which likely impacted the carrying capacity during the Mesolithic-Neolithic transition, in terms of fresh water supply for human/animal consumption, wild plant food reserves and suitable land for crop growth.

## **S18-P04\* - Diatoms in the Arabian Desert: Early to mid-Holocene paleolake development at the oasis of Tayma, NW Saudi Arabia**

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Although well-dated high-resolution paleoclimatic data from sensitive arid areas are important to understand patterns and forcing of climate variations as well as prehistoric human migration, only few records exist in northern Arabia. Laminated lacustrine sediments from a paleolake nearby the oasis of Tayma provide a valuable archive for reconstructing environmental change during the early-to-mid Holocene in the nowadays arid to hyperarid region.

Diatoms were analyzed for detailed information about the characteristics of the paleolake development and thus smaller-scale climate fluctuations. Distinct changes in diatom assemblages, concentrations and taxa dominances point to highly variable lake conditions over the analyzed time period (9200–4200 cal yr BP). The initial phase (9200–8700 cal yr BP) is characterized by low diatom concentration, poor to moderate valve preservation and a dominance of benthic taxa indicative of a shallow, fluctuating water body with high salinity. Around 8600 cal yr BP, diatom concentration significantly increased and, together with moderate preservation, suggests first stabilization of the lake. This coincides with the beginning of maximum grassland expansion inferred from pollen analyses. Continuously high concentrations and abundances of planktonic taxa (mainly *Cyclotella choctawatcheeana*) depict highest lake levels and maximum humidity around 8300–8000 cal yr BP, likely coinciding with shoreline deposits mapped up to 17 m higher along the basin margins. Results are supported by increased TOC values and the deposition of varved sediments. Despite the elevated lake level, the diatom assemblage as well as other microfossils preserved still point at a brackish water body during that time. After 7950 cal yr BP, a sharp decline in planktonic taxa and decreasing diatom concentrations hint at an abrupt lake level drop, followed by a long-term aridification trend and a sabkha development since 4200 cal yr BP.

This study is a contribution to the research project “CLEAR – Holocene Climatic Events of Northern Arabia” (<https://clear2018.wordpress.com/>).

# **S18-P05\* - High-resolution sediment-geochemistry of the Tayma palaeolake record as unique archive of the Early Holocene Humid Period in northern Arabia**

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Within today's hyperarid interior of the northern Arabian Peninsula, an exceptional sequence of early- to mid-Holocene, partly varved lake sediments is preserved in the continental sabkha basin of Tayma. The Tayma palaeolake evolved as a consequence of enhanced moisture supply during the orbital insolation-driven Early Holocene Humid Period (EHHP). As yet, our knowledge about the magnitude and timing of the EHHP in northern Arabia was hampered due to a lack of robust proxy data. We used an ensemble of high-resolution sedimentological and geochemical data to trace the evolution of the Tayma palaeolake in great detail, and to infer the hydroclimatic variability during the EHHP for northern Arabia. Lithological changes were characterized by thin section analyses, elemental  $\mu$ XRF scanning, and XRD measurements. We found pronounced seasonal variability during the lake's evolution, which we reconstructed through micro-facies analyses of the varved sediments. Changing lake water evaporation and lake-internal productivity were inferred using stable oxygen and carbon isotope compositions ( $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ) of carbonates, supported by total organic carbon (TOC) and calcium carbonate ( $\text{CaCO}_3$ ) contents. Our detailed floating varve chronology is anchored through  $^{14}\text{C}$  dating of pollen concentrates and a precisely-dated cryptotephra associated with the S1 tephra that originates from the central Anatolian volcanic province. Our results show that slightly wetter conditions started at Tayma at ca. 9300 yrs BP. The highest moisture availability was only achieved during a ca. 600 years lasting deep-lake phase from ca. 8500 to 7900 cal. yr BP, when varves formed in the lake. Thereafter, prolonged aridification prevailed, leading to sabkha development at ca. 4200 cal. yr. BP. Furthermore, we found a complex regional hydrological pattern during the EHHP on centennial time-scales.

This study is a contribution to the research project "CLEAR – Holocene Climatic Events of Northern Arabia" (<https://clear2018.wordpress.com/>).

## **S18-P06 - Constructing a Plio-Pleistocene climate history for the playa Lake George, Australia**

**Bradley N. Opdyke (1), Bradley Pillans (1), and Michael McPhail (2)**

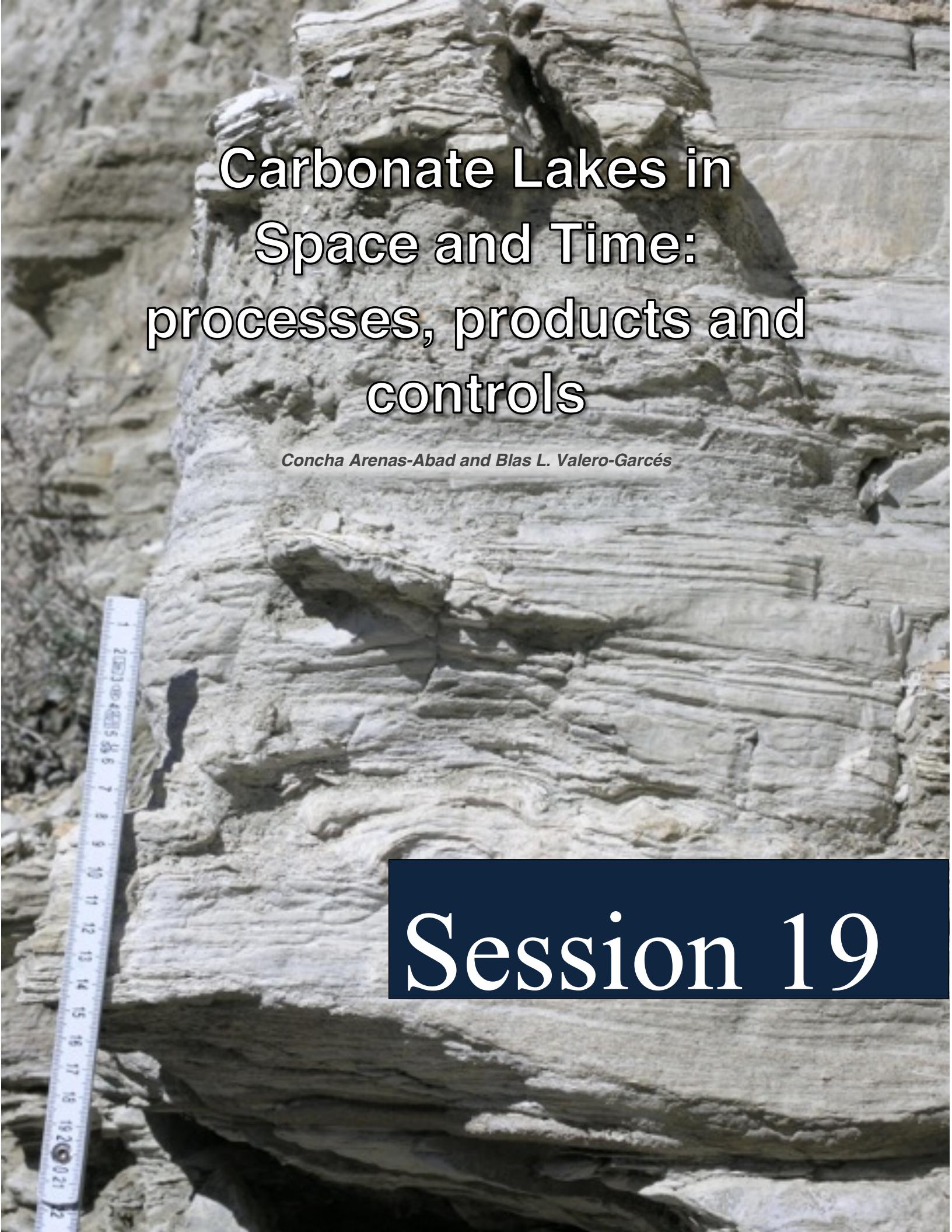
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Lake George is a playa lake 40 kilometres from the centre of the City of Canberra in the Australian Capital Territory. The Lake basin contains sediment and a climate record begins nearly 4 million years ago. Lake George sits in an isolated basin catchment that acts as a rain gauge through time. The overall record is one of steady aridification. Recent data that support this observation include pollen data support a transition from a *Nothofagus* rainforest + sclerophyll woodland to a *Casuarina/Allocasurina* sclerophyll woodland across the Plio-Pleistocene boundary. Sediments are commonly laminated until the mid-Pleistocene transition at close to a million years old when the laminations cease. Sedimentological and XRF data indicate the Lake begins to periodically dry with great regularity after 500,000 years. The best indications of this in our most recent cores are thin (cm scale) horizons of carbonate rich sand that punctuate a clay rich sedimentary record. We propose that the record of humid phases in the Lake George basin correspond to a cooling of tropical surface waters in the Indo-Pacific over the same time interval. Within the latest Pleistocene the Lake George basin appears to be totally dry throughout the Last Glacial Maximum and reaches its maximum post-glacial depth at roughly the same time as the maximum surface water temperatures are reached in the tropical east Indian ocean early in the Holocene. These data point towards a more humid trend for south eastern Australian climate as the planet warms into the near future.





# Carbonate Lakes in Space and Time: processes, products and controls

*Concha Arenas-Abad and Blas L. Valero-Garcés*

Session 19

## S19-001 - The deep sigh of Lake Bénît

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Alpine lake acidification and eutrophication have been intensively studied in the context of global change. Although these processes may influence greenhouse gas (GHG) emission, much less research has been devoted to this question.

Lake Benit is a small (0.041 km<sup>2</sup>) monomictic shallow (8 m depth) hard water mountain (1400 m a.s.l.) lake, whose trophic level increased since the fifties when the lake water level was artificially raised by about 2m. Carbon dioxide and methane concentrations and fluxes were measured from August 2016 to July 2017. Carbon dioxide concentrations in the lake increased during winter below ice (up to 450 µmol CO<sub>2</sub>/l) and during summer, especially in the deepest layer. Methane concentrations increased as well during winter but especially during summer stratification (up to 310 µmol CH<sub>4</sub>/l in the deepest layer), but most of the methane was oxidized in the oxycline. Lake Benit emitted 3200 kg C yr<sup>-1</sup>, that is about 78 g C m<sup>-2</sup> yr<sup>-1</sup> to the atmosphere by diffusion, mostly as carbon dioxide, during spring ice melt and autumn overturn. Even in summer and near the shore, in the Potamo belt, was measured a CO<sub>2</sub> efflux. A whole lake Carbon budget showed that the main source of carbon entering the lake was spring water alkalinity (3565 kg C yr<sup>-1</sup>) but this flux entirely leaved the lake with discharge. Maximum additional input fluxes of about 700 kg C yr<sup>-1</sup> and 1500 kg C yr<sup>-1</sup> were estimated for carbon released from flooded soils, and macrophytes (*Equisetum*) annual litter respectively. Lake sediment accumulated about 800 kg organic C yr<sup>-1</sup> and 200 kg C-CaCO<sub>3</sub> yr<sup>-1</sup>. Overall, there was a large disequilibrium between carbon outputs and inputs. Two mechanisms may contribute to explain the large carbon efflux: a carbon release from sediments, and a recycling of carbonates produced in the littoral zone. This high efflux may vary from year to year in relation to climate.

## **S19-002 - The role of Mg-bearing clay in Cenozoic dolomite formation within saline wetlands of semi-arid NW Australia**

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Dolomite has been increasingly recognised within various modern and ancient lacustrine, alluvial and groundwater deposits in semi-arid to arid regions worldwide, although the mechanisms of dolomite precipitation are often unclear. The role of Mg-bearing clays has been recognised as a potential precursor for dolomite precipitation in addition to high viscosity smectites providing substrate and promoting incorporation of Mg into carbonates. We analysed the mineralogy and geochemistry of three dolomite profiles from ancient wetlands in the semi-arid Pilbara region of NW Australia, using XRD, XRF, and stable C and O isotope analysis. Hylogger3 hyperspectral scanning was used to produce continuous high resolution mineralogy of the profiles and identify changes in clay mineral composition. SEM-EDS analysis was completed to confirm clay mineral identification and establish textural relationships with carbonate facies. Mg-bearing clays were the most dominant component after dolomite and included palygorskite, saponite, montmorillonite and occasional sepiolite. Palygorskite was the most abundant clay mineral and occurred as fibrous bundles finely intermingled with dolomite rhombs and suggested precipitation from Mg-rich pore waters between dolomite. Dissolution of earlier formed smectite likely promoted precipitation of both dolomite and palygorskite, increasing Mg and Si and pore waters. The  $\delta^{18}\text{O}$  values (-6.99 to -3.84‰ V-PDB) indicated precipitation from brackish to moderately saline waters (28-74 g/L TDS) and suggests concentration of Mg-rich alkaline inflowing waters promoted dolomite formation. However,  $\delta^{13}\text{C}$  values (-6.27 to -4.84‰ V-PDB) did not suggest processes were driven by microbial mediation and no evidence of organic matter or microbes was identified. The interaction with authigenic Mg-bearing clays may play an important role in the nucleation of abiotic dolomite within these settings. Further SEM work and Hylogger3 data analysis, currently being undertaken will provide further information on the relationship of smectites with dolomite and the environmental conditions of formation.

## **S19-003 - Sedimentary coeval aragonite and calcite with contrasting isotopic signals: Implications for lacustrine stable isotope analysis**

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Bulk carbonate  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  analysis is a commonly applied analytical method in palaeolimnology. However, in some cases the interpretation of the isotopic signal of bulk carbonates, is far from straightforward. In case of terminal, alkaline Lake Van, positive bulk  $\delta^{18}\text{O}$  values appear in both, cold arid periods such as the Younger Dryas and in warm wet periods such as the Last Interglacial (MIS 5e). We systematically analysed the mineralogical (XRD, SEM, Raman spectroscopy and electron microprobe analysis) and isotopic (isotope mass spectrometry) composition of Lake Van's fine fraction. Our interval of interest covers the last ca. 150 kyr. Samples containing diagenetic dolomite were excluded from the study.

While the Mg/Ca ratio of Lake Van water is unfavourable for calcite precipitation, analysis of varved sediments documents presence of both aragonite and calcite spatially separated between light and dark laminae. Based on this observation we propose that calcite precipitation under close to freshwater conditions within river plume whittings (mainly in spring) is followed by aragonite precipitation in basin wide whittings in late summer. The precipitation of these polymorphs within chemically contrasting surface water (i.e., freshwater-influenced and evapoconcentrated) may explain  $^{18}\text{O}$  and  $^{13}\text{C}$  enrichment of aragonite relative to calcite, much larger than one inferred from aragonite-calcite fractionation factors. Isotopic composition of both lake water and inflowing freshwater and the timing of the mixing process are related to changes in the regional hydrological cycle and likely variable at millennial to centennial time scales. Understanding the dynamics of this interaction is the key for interpreting isotopic signatures of Lake Van bulk carbonates. Our temporally-separated carbonate precipitation model has a potential to refine environmental reconstructions by taking not only differences in isotopic fractionation between aragonite and calcite into account but also carefully considering the processes favouring the precipitating polymorph.



## **S19-004 - Responses of low-elevation carbonate lakes on the Yucatan Peninsula to climatic and human forcings**

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Carbonate lakes of the low-lying Yucatan Peninsula display marked variability in sediment lithology, both spatially and temporally. This variability is expressed by differences in sediment type within and between lakes, between seasons, and over interannual and centennial/millennial timescales. Even in this area of limestone geology, lakes switch between carbonate and non-carbonate accumulation in response to changes in carbonate supersaturation, which may be driven by changes in climate (E/P), biological productivity (algae and cyanobacteria), and inputs to the lake of catchment material. A switch from carbonate-dominated to primarily organic sediment after ca. 4000 BP has been observed in cores from lakes across the peninsula, but drivers of this change are not yet clear.

Across the Yucatan Peninsula, both catchment and in-lake processes were affected in the late Holocene (ca. 3500–1000 BP) by ancient Maya land use practices, including agriculture and urbanisation. These activities confound interpretation of standard palaeoclimate proxies in carbonate systems such as  $\delta^{18}\text{O}$ , and were responsible for shifts in sediment type in some lakes. Understanding carbonate dynamics in these systems has also been hindered by a lack of regular, year-round lake monitoring and the absence of seasonally resolved sediment records. We illustrate the diversity of lacustrine carbonate sedimentation on the Yucatan Peninsula using records from Lakes Peten Itza (Guatemala), Punta Laguna, Esmeralda and Yaal Chac (Mexico). Yaal Chac is unique in having been monitored sub-annually for water chemistry, including oxygen isotope analysis, and sediment deposition and possesses sediments that are laminated, including early Holocene varves, thereby preserving a record of past intra-annual (seasonal) change. We use this contemporary understanding of carbonate systematics from Yaal Chac, and additional work from Punta Laguna, to test hypotheses of human and climate driven changes in carbonate precipitation across the region.

## **S19-005 - Holocene and Pleistocene Karst Lakes of Dalmatian coast (Eastern Adriatic Sea)**

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The Croatian coastal region (Dalmatian type of coastline) is a part of Maritime Dinaric Alps which coincides with the Adriatic Carbonate Platform (AdCP). Some of the coastal karst depressions/basins developed into larger lakes. Sediment core records show a tight correlation between sea level rise and lake formation during early Holocene. Terrestrial sequences in the Croatian coastal karst regions are often incomplete due to erosion or nondeposition. Therefore, accumulation of lake and marine sediments offer complete and well-dated archives spanning throughout most of the Holocene. Since a part of the karstified AdCP is drowned and its palaeo-dolines, depressions of variable size, as indicated by seismic data, contain up to 400 m of well stratified sediments (Kvarnerić bay, N. Adriatic) allowing insight to earlier periods of the Quaternary. Generally larger karst depressions lie between the islands at present day water depths from -40 m to -90 m. These karst basins contain archives of climate change and have experienced repeated relative sea-level cycles during the Quaternary. Coring and geophysical data of a 40m thick sediment sequence indicate at least two glacial (lake sediments) and three interglacial (marine) cycles are present in Lošinjski kanal, due to submerged sills at -50 m. Most of the present day lakes along eastern Adriatic coast formed during the early Holocene (Bokanjačko blato, Vransko jezero near Biograd, Veliko jezero- Mljet). Vransko jezero on the Island of Cres survived from the Pleistocene as probably did lake Crniševo (Baćina lakes). The LGM lakes of Lošinjski kanal and Valun bay were flooded at onset of the Holocene, while the Pleistocene lake in Pirovac bay was flooded by the sea 8 ky cal BP and Veliko jezero on Mljet Island at 3 ky cal BP.

## **S19-O06 - Clastic carbonates in Quaternary Iberian lakes: facies, processes and depositional environments**

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Carbonates are main components of Quaternary lake sediments and they also occur in sequences and rock formations from all geological ages. There are many processes controlling carbonate deposition and that results in a large variability of sedimentary facies, depositional environments, and carbon –related fluxes in the lakes. Understanding carbonate formation processes is key to quantify the variability in carbon fluxes and characterized global sinks and sources. In most lacustrine facies, endogenic and clastic carbonates occur and their identification is key to detangle climate versus watershed-related processes and to provide robust interpretation to other data obtained from geochemical analytical techniques. A review of carbonate occurrences in Quaternary and extant lakes in the Iberian Peninsula show that clastic carbonates are dominant in lake sequences located in carbonate bedrocks with carbonate-rich surface formations and soils. However, low temperatures and dilute meteoric waters seem responsible for the low carbonate content of sediments in high elevation lakes in the glaciated terrains, even when carbonate formations are present in the watersheds. In small karstic lakes, sediment infill is dominated by fining upward sequences deposited during flood events. Turbidite sequences in deeper lakes also contain carbonates. In lakes with intense subaquatic spring discharge, large remobilization and re-suspension of the sediments accumulated in the deepest areas lead to the deposition of thick homogeneous layers (homogenites). Clastic carbonates are also generated in shallow areas due to re-working processes and deposited in-situ or transported by currents and floods to deeper areas.

The occurrence of clastic carbonates in these sequences provides opportunities to identify carbonate sources and provenance, past watershed dynamics and their relationships with in-lake depositional processes and improves the reconstructions of past global changes based on lake sequences.

# Poster Presentations

## **S19-P01 - Carbonate deposition in small karstic lakes in central Spain during the last two millennia**

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The sediments from karstic, funnel-shaped lakes in the Iberian Range (Central Spain) are characterized by a large variability of carbonate facies, despite of their small size, that reflect the varied lake processes, watershed geology and climate and land use changes.

During the last 2000 years, sedimentation has been mainly controlled by hydrology and modulated by lake parameters (morphology, water chemistry and thermal regime), surface hydrology, watershed size, climate and erosional processes in the catchment.

During relatively more arid periods, as the last phase of the Iberian-Roman Humid Period (IRHP, 650 BC–CE 350), the Dark Ages (DA, CE 500–900) and the Medieval Climate Anomaly (MCA, CE 900–1300), lower lake levels were conducive to enhance shallower environments and more development of littoral facies. Wetter phases and higher lake-levels during the Little Ice Age (CE 1200–1850) resulted in deposition of laminated facies and higher endogenic carbonate production.

A noticeable characteristic of these lakes is the large increase in clastic (carbonate and silicate) input during historical times, particularly since the Medieval epoch, mainly caused by large socio-historical changes in the Mediterranean mountains in deforestation, grazing, land uses, and population. Detailed facies and lake basin analyses during these periods of higher clastic input have allowed identification of carbonate source areas and quantification of sediment yields and fluxes during extreme events.

Similar trends and processes have been documented in other Iberian karstic lakes located in carbonate terrains. Lake morphology and hydrology are main controls on carbonate depositional dynamics in these systems, modulated by Mediterranean climate fluctuations and variable human impact in their watersheds.



## **S19-P02 - Microbialite-coated rafts (giant "oncoids") from the Late Triassic lacustrine succession in the Jameson Land Basin, East Greenland**

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Microbialite-coated rafts occur as a thin unit in the Late Triassic Edderfugledal Member in the Jameson Land Basin, East Greenland. The rafts' central nuclei comprise thin-layered siltstones, mudstones and microbial carbonate sheets. They are ~3–10 cm thick, reach up to 1 m in length and have sharp edges. They are coated by microbialites, commonly 3–5 cm thick, giving rise to a giant, flat-shaped "oncoidal" appearance. On the upper side of the rafts, the microbialite crusts commonly have columnar forms. On the underside of the rafts, the crusts are less well developed, and display shrub- or thrombolite-like structures that have a peloidal-like texture in thin section view. Some microbialite-coated rafts are folded and overturned.

The rafts were generated under high energy conditions. Their sharp broken edges indicate partial lithification at the time of formation. However, the folding and buckling of the rafts, including their microbialite coatings, demonstrate that they also acted in a flexible manner. This may have been aided by the presence of microbial laminations that could have formed a cohesive and leathery carpet, rich in water and EPS. The complete microbialite coating suggests that the rafts were subject to regular re-mobilisation. This would require significant energy. The common differences between the microbialite developments on the upper and underside of rafts suggest that the microbialite coatings could have formed in-situ. In-situ growth of oncoid coatings have been documented by a number of studies from lakes and rivers. These studies suggest that the microbial coatings of oncoids do not necessarily require strong or repetitive turning. The columnar microbialites formed on the upper side of the rafts may result from photosynthetic cyanobacterial activities. The peloidal microbialites that usually occur on the underside of the rafts may be formed by microbes that could grow in dim light conditions.

## **S19-P03 - Carbonate and evaporite minerals in lake sediments: a new approach to reconstruct paleoprecipitation in northern China**

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Authigenic carbonate and evaporite minerals in lake sediments are widely used to qualitatively reconstruct climate. However, uncertainties still remain about their quantitative relationship to climate. In this study, we first investigated 86 modern lakes in northern China to establish the relationship between mineral formation, lake water chemistry, and climate, and then precipitation during the Holocene were reconstructed using this relationship and compared with pollen-based reconstruction from a lake core in this region. Investigations from the modern lakes show that from east to west, with increasing salinity and ionic concentration, calcite, dolomite, and evaporite minerals (gypsum and halite) occur in sequence. Their eastern boundaries approximate modern isohyets, and we define for the first-time rainfall thresholds of 600 mm, 400 mm, and 350 mm for the formation of calcite, dolomite, and evaporite minerals, respectively. In addition, the modern 600 mm and 400 mm isohyets are located at the transitions between forest and forest steppe and between forest steppe and steppe in the study region, occurrence of calcite and dolomite may also reflect vegetation types. The quantitative reconstruction of precipitation based on mineral analysis from the lake core is consistent with results from pollen-based reconstruction from the same core. As carbonate and evaporite minerals are widely found in ancient lake sediments in northern China, our findings enable a new approach for the quantitative reconstruction of past precipitation from geological records.

## **S19-P04 - Environmental significance of lacustrine stromatolite lamination using textural and stable-isotope variations (Miocene, central Ebro Basin, Spain)**

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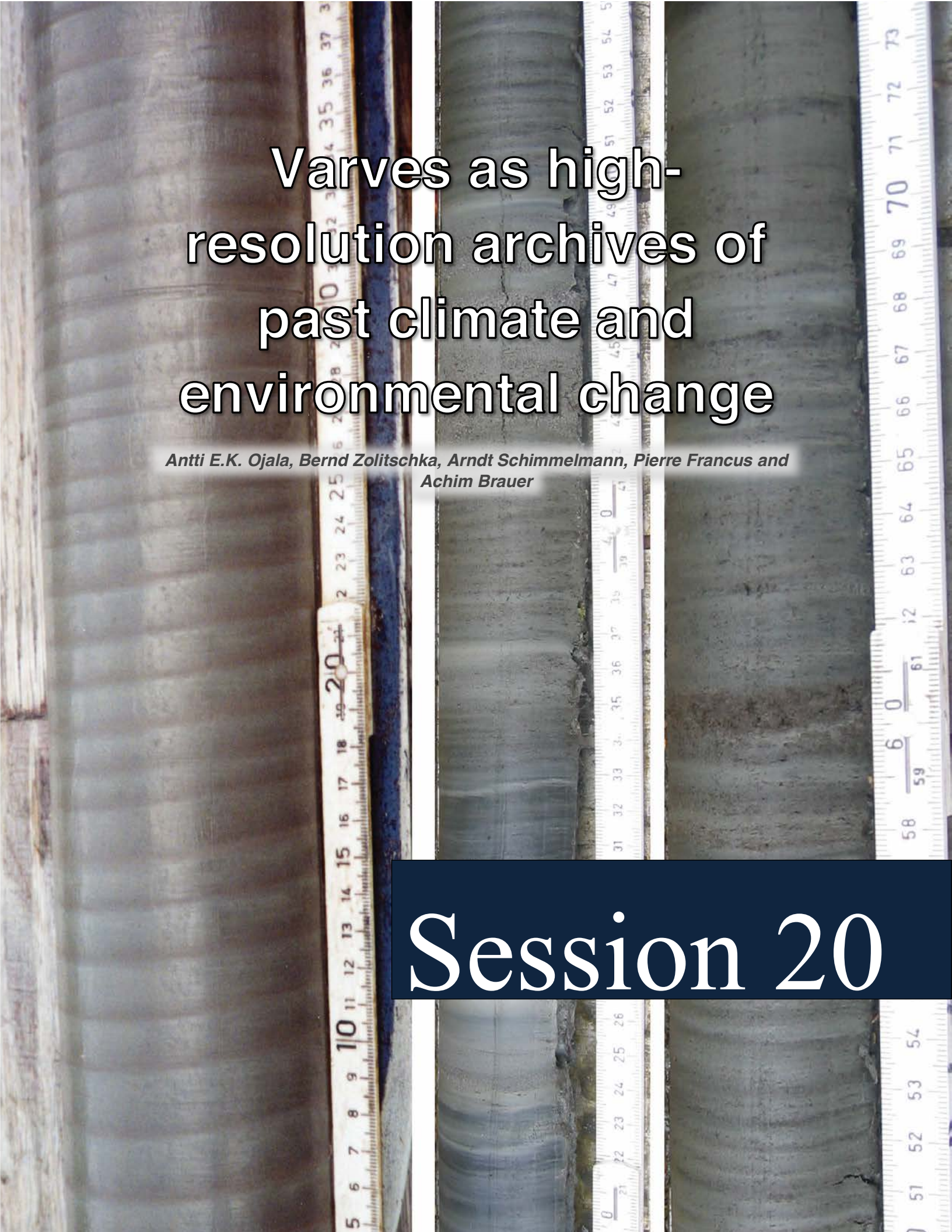
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This contribution explores the environmental and temporal significance of Lower and Middle Miocene stromatolites that developed in a closed lake-basin (central Ebro Basin). The lake fluctuated between sulphate-depositing and freshwater carbonate-depositing conditions, driven by changes in the precipitation/evaporation ratio (P/E), also expressed as lake level changes. The calcitic and dolomitic, fine-grained stromatolites formed at intermediate, saline carbonate-depositing conditions. They are composed of several laminae types and orders. Simple laminae are: dark dense micrite (0.04 to 0.5 mm thick), light dense micrite-microsparite (0.11 to 1.89 mm thick), light porous clotted micrite-microsparite (0.1 to 1.35 mm thick), and fibrous calcite (0.01 to 0.34 mm thick). Simple laminae can be grouped into dark (0.28 to 2.76 mm thick) and light (0.65 to 6.36 mm thick) composite laminae. The combination of the several types of simple and composite laminae results in different lamination patterns. Stable-isotope analyses of consecutive composite laminae in five calcite stromatolites (70 laminae) show cyclic isotopic variations that parallel textural changes through time. The light laminae have lower values (mean  $\delta^{13}\text{C}_{\text{light-lam}} = -1.36$ ,  $\delta^{18}\text{O}_{\text{light-lam}} = -4.56\text{‰}$  V-PDB; N= 36) than the dark laminae (mean  $\delta^{13}\text{C}_{\text{dark-lam}} = -1.09$ ,  $\delta^{18}\text{O}_{\text{dark-lam}} = -4.03\text{‰}$  V-PDB; N= 34), with  $r = 0.42$ . In mid-latitude closed basins affected by evaporation, light laminae are interpreted as corresponding to more humid conditions, with larger soil-derived  $\text{CO}_2$  input, whereas dark dense laminae formed in drier conditions. As temperature and evaporation produce opposing effects on the oxygen isotope record in carbonate, the mean  $\delta^{18}\text{O}$  range between light and dark laminae (0.53‰) should represent the minimum range of temperature variation (2.2°C). Stable isotopes from high-resolution sampling are consistent with the above interpretations and indeed reflect shorter cyclic changes within each composite laminae, compatible with seasonal changes in P/E. Thus, isotopic and textural variations represent both seasonal and pluriannual changes mainly linked to P/E.

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The image shows three vertical sediment cores, likely from a peat bog or lake, used for climate and environmental reconstruction. Each core is placed next to a ruler for scale. The leftmost core is light brown and shows distinct horizontal layers. The middle core is dark grey and also shows horizontal layering. The rightmost core is dark grey and shows horizontal layering. The rulers are marked in centimeters and millimeters, with some numbers visible such as 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100. The text is overlaid on the image in a white, bold, sans-serif font with a black outline.

# Varves as high-resolution archives of past climate and environmental change

*Antti E.K. Ojala, Bernd Zolitschka, Arndt Schimmelmann, Pierre Francus and Achim Brauer*

## Session 20

## Oral presentations

### **S20-001 - Changing flood frequencies during late Pleistocene climate change in the eastern Mediterranean**

**Yoav Ben Dor, Moshe Armon, Marieke Ahlborn, Efrat Morin, Yigal Erel, Achim Brauer, Markus J. Schwab, Rik Tjallingii, Yehouda Enzel**

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Floods make up a dominant hydroclimatological phenomenon in arid lands and bear significant implications for humans, infrastructure design, and landscape evolution worldwide. However, determining flood frequency during changing climate is rarely achieved because modern and paleoflood records, especially in arid regions, are often too short or discontinuous. Yet, coeval independent climate reconstructions and paleoflood records are required to further understand the impact of climate change on flood generation. Changes in the hydrological balance in the Dead Sea watershed result from centennial-millennial climate changes, reflected by Dead Sea lake-level changes, whereas floods in the large watersheds draining directly into the Dead Sea are linked to specific synoptic circulation patterns, capable of developing flood-inducing rainstorms. In this study, two 700-year-long seasonally-resolved flood time series were extracted from late Pleistocene (25–15 ka) Dead Sea varved sediments, coeval with significant Dead Sea lake-level variations, reflecting long-term changes of the hydrological budget. These series demonstrate that changes in mean centennial precipitation in the eastern Mediterranean are coupled with drastic changes in flood frequencies. In addition, floods cluster into periods of intense flood frequency. Within flood clusters, flood occurrences increase by +75% (+20%) above their respective background frequencies during rising (falling) lake-level. These drastic changes in flood frequency are linked to changes in the track, depth, and frequency of eastern Mediterranean cyclones during wetter and drier regional climatic conditions.

## **S20-O02 - A micromorphological assessment of Lateglacial Swedish clay varves from Svinstadsjön, Östergötland**

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During the last deglaciation (ca. 16–10 ka BP) glacially-forced global sea level changes and regional isostatic movements resulted in isolation of the Baltic from the north-eastern Atlantic. This led to the formation of the Baltic Ice Lake (BIL), which was ice-dammed by the Fennoscandian Ice Sheet during the Lateglacial Interstadial and Stadial periods. Glacial sediments accumulated in the BIL and are now exposed across the Baltic region. De Geer (1884) identified annual cycles in the sedimentation pattern, and through the construction of overlapping varve-thickness diagrams he established the Swedish Timescale (STS). The STS was the first model of ice retreat across Sweden and has since been extended to the present day. There are, however, sections of the 13,257 year-long STS where varves are missing. In particular, 700–900 years are missing either during the Younger Dryas - Pre-Boreal period (12.9–11.35 ka BP) or the early Holocene. One explanation for the missing years is a lack of precision in macroscale varve counts, which are the traditional means of developing site chronologies.

Here we combine macroscale counts,  $\mu$ -XRF analysis, and thin section micromorphology on a 9 m Younger Dryas age varve record from Svinstadsjön, Östergötland. Three varve microfacies were identified from thin section analysis. Melt season characteristics vary from complex microfacies, typically >10 mm thickness with multiple sediment inputs, to simple single-layered melt seasons in thinner, <1 mm thickness, varves.

Varve count data show differences between counting methods due to two key reasons: 1) more varves are counted under thin section due to the presence of thin (<1 mm) varves, and 2) deformation structures, overlooked during macroscale counts, cause double counting. Ultimately, micro-scale sediment analysis may provide a revised estimate of the number of years in the Lateglacial part of the STS, and more precise reconstructions of Fennoscandian Ice Sheet retreat and palaeoenvironmental change.

## **S20-O03 - Phases of human expansion and abandonment in laminated lake sediments along a Central European transect.**

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Beside climate and natural succession humans are the strongest force for environmental change in the Holocene. Since mid-Neolithic times, human induced changes in the landscape and in the lake system often conceal natural developments so that they are hard to disentangle. The presentation will give examples for high resolution pollen records from annually laminated lake sediments along a transect from Northern Germany to Central Poland. High dating accuracy with a combination of  $^{14}\text{C}$  and varve counts and with tephra layers as means for absolute linkage of the records enable precise and high resolution inter-site correlation and comparison of human impact. The palynological results are contrasted with independent archaeological proxies for settlement intensity in order to identify when environmental change operated as trigger for cultural transformations or when environmental change was the result of human activity.



## **S20-004 - Lake Odensjön - a new varved sediment record from southern Sweden**

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Annually laminated (varved) sediments provide opportunities to reconstruct climate change and human impact on the environment with high temporal resolution. Depending on the character of the varves, such sediments can provide insight into the delivery of both autochthonous and allochthonous material from the lake and its catchment. Here we present a new record of laminated sediments from the small dimictic Lake Odensjön in southern Sweden. The sampled sequence, collected with a freeze-corer at 20 m water depth in the central, deepest part of the lake, spans the uppermost 91-cm part of the sediment succession. Dating with  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  in combination with identification of the distinctive and well-documented pollution Pb peak associated with the use of leaded petrol in the mid 1970's confirms that the laminations represent varves. Radiocarbon dating of the lower part of the record demonstrates its extension to around 450 years before the present. X-ray fluorescence, loss-on-ignition and microscopic analyses indicate high contents of biogenic silica and organic matter, abundant diatoms and low minerogenic content, demonstrating that the varves are of biogenic origin. The conditions for varve formation have changed through time and substantial variations in the content of macroscopic plant remains give evidence of pronounced changes in catchment land-use. In the late 19<sup>th</sup> century the catchment most likely was completely deforested, while rapid colonization by beech, *Fagus sylvatica*, occurred during the following century as demonstrated by abundant well-preserved leaves. This new record of varved sediments, which is the most southerly of its kind in Scandinavia, will be subject to additional sampling and analyses by a range of methods, potentially contributing to increased understanding of past environmental changes in southernmost Sweden.



## **S20-O05 - Rise and Fall of the Tibetan Empire at 7–9<sup>th</sup> century in response to climate change**

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The Tibetan Empire was the only unified and powerful empire that ruled an area considerably larger than the Tibetan Plateau from the 7<sup>th</sup> to 9<sup>th</sup> centuries AD. The sudden rise and fall of the Tibetan Empire remains an enigma for historians. Here we present precisely dated multiple proxy records in a varved lake sediment core in the center of the Tibetan Empire. The records show that a warm and humid period coincided with the existence of the Empire. The ameliorated climate likely increased livestock and food production supporting the rise of the Empire, which made it possible that a small tribe at Yarlung River expanded to a mighty empire able to fight with the Tang Dynasty to the east and the Arabians to the west. The deteriorated climate during the middle of the 9<sup>th</sup> century may have contributed to the collapse of this mighty empire.

## **S20-O06 - Using the sedimentology of distal glaciolacustrine varve sediments to understand changes in former proglacial lake systems.**

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Glaciolacustrine sediments formed in proglacial lakes represent a key archive for reconstructions of past environmental and climate change. Perhaps most important are annually-laminated (varved) sediments, as these deposits facilitate precise estimates of the rates and duration of palaeoenvironmental events, through counts of successive annual layers, and detailed analysis of their internal structure. Critically, such sediments are one of only a few environmental archives to provide insights into the dynamics of abrupt climate events and resolve subannual structures. However, in (palaeo)lakes characterised by low biological productivity, it can be difficult to discern a 'true' varve structure. Instead, independent-age determinations are required to corroborate the seasonal cycle of sedimentation. This is possible in lakes where varve sedimentation extends to the present-day, but in the palaeolake systems this is often not the case, and more reliance is placed on robust, process-based sedimentological models to evaluate potential varve structures.

Glaciolacustrine varves range in thickness from >1000 mm in ice-proximal areas, to <1 mm in ice-distal locations. A variety of analytical techniques are available to examine the detailed sedimentary structures preserved at these different scales, with micromorphological techniques, such as thin section analysis, essential for robust analyses of the fine sediment structures (<5 cm thickness) typical of the more distal parts of glaciolacustrine basins. Typical glaciolacustrine varves are composed of texturally-distinct couplets comprising (i) a coarse sediment component (very fine sand and silt) deposited during the melt season, and fine sediment component (very fine silt and clay) that settles during the non-melt season. At the microscale, these couplets can exhibit a complex range of sedimentary structures, which are not recognisable with the naked eye, and reflect variations in the nature and/or frequency of sediment-laden meltwater pulses to the lake basin during the melt season, either from (i) the glacier margin; (ii) nival melt streams from the immediate catchment; (iii) precipitation events; and (iv) stochastic slump or surge deposits resulting from on-off events.

This talk uses observations made from a range of former glaciolacustrine basins (e.g. NW Europe, Patagonia) to outline protocols for the recognition of complex varve microfacies, how it might be possible to use varve microfacies to distinguish between the relative contribution of glacier-fed sediment as opposed to nival inputs and their differentiation from non-annual (irregular) sediment structures. This should enable improved understanding as to the drivers of varve thickness variations in palaeo-glacier lakes.

## **S20-O07 - Annually-resolved reconstruction of hydroclimate from Nar Gölü, Turkey over the last 2.6 ka BP**

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In southwest Asia, the wet-dry seasonality and semi-arid climatology increases societal vulnerability to drought. Long, continuous records of hydrology from the region are therefore important to contextualise past societal change, and to benchmark natural variability in water availability. We present the longest annually-resolved record of south-west Asian climate to date, spanning the last 2,589 years. We reconstruct hydrological change from a climatically sensitive lake, Nar Gölü, Turkey using varve sedimentology. Organic-calcareous varve deposition is driven by the wet-dry seasonality, and varve microfacies analysis has developed an inter- and intra-annual record of the resultant limnological variability. Calibration using meteorological data identified the March-May evaporation/precipitation ratio as the primary control on carbonate sublayer thickness. Combining these analyses with previous stable isotope, pollen and diatom records from the same cores further develops a holistic environmental record able to gauge past and present hydrology, including drought severity. An inferred abrupt hydrological change to the spring growing season is well-dated at  $535 \pm 15$  AD, coinciding with the onset of the Late Antiquity Little Ice Age (LALIA). Carbonate mineralogy indicates generally fresher water conditions during the following 871-year long period, with a multi-decadal dry period at 850 AD broadly coinciding with regional land abandonment and marking the start of regional, long-term aridification. By reconstructing high resolution hydroclimate, this annual record of past water availability provides a unique context for understanding climate change and its potential impact in this vulnerable region.

## **S20-O08 - Uralian varves - glacial varves across the LGM in the Polar Ural Mountains**

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Here we present a partly varved and exceptionally well dated continuous sediment record spanning the last ca. 24,000 years from lake Bolshoye Shchuchye in the Polar Ural mountains of Arctic Russia. In addition, we present some preliminary results from the adjacent and seemingly also varved sediment record in lake Malshoye Shchuchye. The varved part of the sediment record in Bol. Shchuchye stretches across the LGM from the bottom of the core at 24 to 18.7 cal. ka BP. We consider the varved sedimentation in the lakes to be a glacial signal from the catchment, i.e. that they are glacial varves. Our results suggest that the lake basins have remained ice free throughout the LGM and most likely since the preceding glaciation in MIS 4. However, glaciers were present in the lake catchments during the LGM. In Bol. Shchuchye, a decrease of glacial varves suggests that the glaciers started to retreat ca. 18.7 cal. ka BP and the last glaciers had disappeared by 14.35 cal. ka BP. We infer a distinct climatic amelioration at the onset of the Holocene and an early Holocene thermal optimum between 10–5 ka in both lakes. The combination of AMS  $^{14}\text{C}$ - and varve chronologies in this study has provided a valuable contribution to constrain the age models for ongoing palynological-, paleomagnetic, DNA- and compound specific isotope ( $\delta^2\text{H}$ ,  $\delta^{18}\text{O}$ ) analyses also conducted within the framework of the CHASE- (Climate History of the Arctic Seaboard of Eurasia) project. Our combined efforts will provide long sought after continuous and high resolution records that supplement the existing, more fragmentary data from moraines and exposed strata along river banks and coastal cliffs around the Russian Arctic.

# **S20-O09 - High-precision radiocarbon dating of laminated sediment sequences reveals synchronous vegetation succession trajectories during the Neolithic in Southern Central Europe**

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Varved sediment chronologies with best possible time control are essential to compare palaeoecological studies with independent high-precision climatic or societal data (e.g. ice cores, tree rings, stalagmites). We present two new sites with partly varved sediments that cover the period of first increasing human impact during the Neolithic (7000–4200 cal. BP). The two small lakes are Burgäschisee (465 m a.s.l., 21 ha) and Moossee (521 m a.s.l., 31 ha), both located on the Swiss Plateau in Southern Central Europe. The chronologies are based on constant year sampling (9–11 years per sample) for radiocarbon dating on terrestrial plant macrofossils and Bayesian models for wiggle matching. The high precision chronologies in combination with the high-resolution sampling for all palaeoecological analyses allow identifying even short-term settlement phases. Cultural indicator pollen such as *Cerealia*-type, *Plantago lanceolata*-type, and others, light-loving shrubs such as *Corylus avellana* (indicator for more openness of the landscape), macroscopic charcoal (indicator for local fires), green algae (e.g. *Tetraedron minimum*) as well as cyanobacteria such as *Anabaena* and *Aphanizomenon* (indicator for eutrophication) point to several local occupation periods. We use our data to thoroughly check the Central European succession theory by analyzing post-disturbance patterns at subdecadal to millennial time scales. Regional afforestation usually starts synchronously with *Betula* as a pioneer tree. The climax forest was a mixed beech forest with mainly *Fagus sylvatica* and other deciduous together with *Abies alba*. The new data provide ample evidence of strong vegetation reorganizations, eutrophication and marked fire regime shifts in response to human impact with a precision and resolution that has never been reached before in Southern Central Europe. This allows us to assess linkages between palynologically-inferred high-resolution land-use reconstructions (e.g. crop production, fire) with dendrochronologically dated archaeologically inferred societal dynamics. Similarly, an accurate comparison with highly resolved climate data will now be possible.

## **S20-O10 - Varves as a chronometer for clastic sediment influx into a small lake catchment in central Anatolia since 13.8 ka BP**

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There has been long-standing debate about the relative roles of climate change and human impacts upon long-term changes in lake-catchment ecosystems. These agencies can be difficult to disentangle in the absence of highly resolved chronologies. On the other hand, with varved sediment records it is possible to establish controlled experimental conditions and test different causal mechanisms more rigorously. In this paper we reconstruct the erosion history of a small lake catchment in Cappadocia (Turkey). Because most of its sediments are annually laminated, it is possible to date precisely clastic inwash layers and to calculate recurrence intervals and flux rates. Lake cores have been analysed for XRF elemental geochemistry, along with proxies for hydro-climate (oxygen isotopes) and land cover (pollen), thus avoiding the need for external correlation. Peaks in titanium and other detrital elements, along with changes in clastic layers, indicate two main phases of increased sediment influx into Nar Lake, namely 9300 to 8000 Cal BP (Neolithic, when obsidian mining took place nearby) and again during the last 2600 years (Iron Age to modern). Multi-proxy comparisons show that these phases were associated with periods of increased human impact on vegetation and soils in the lake catchment. Most sediment influx has been in the form of turbidites, linked to the presence of a fan-delta at the lake edge, although this store does not appear to have delayed significantly sediment delivery from eroding hillslopes to the lake bed. The marked increase in detrital influx during the late Holocene implies that badland development in the lake catchment is recent and anthropogenic. The record also shows that sediment influx diminished markedly at times when the environmental footprint of human populations was lightened, which in turn indicates that catchment degradation is reversible with appropriate land management.

## **S20-O11 - Separating regional and local drivers in landscape development using two lake sediment records from northern Sweden**

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Single sediment profiles are excellent for assessing landscape development on a local scale. However, if we want to separate regional drivers – e.g., climate – from local processes – e.g., soil development – it is necessary to compare records from at least two sites. In this study we used varved sediment records from two lakes of different age situated close to the coast in northern Sweden, with the aim to determine if changes in geochemical composition reflected local or regional drivers. Because the two lakes are situated in an area with land up-lift (currently about 80 cm in 100 years), Sarsjön and Kassjön emerged from the Bothnian sea c. 9000 and 6000 years ago, respectively.

The changes in sediment geochemical composition in the early part of the records are relatively similar for the two lakes. Both show expected signs of vegetation development and soil stabilization (increasing LOI and decreasing Ti, Al and Rb). Simultaneously, soil formation and weathering affects the quality of the minerogenic material, and the K:Ti-ratio decreases with time. These changes do not occur synchronously in the two lakes, and hence, they reflect local processes. However, around 3500 years ago there is a synchronous change, and both sediment records become more minerogenic (e.g., higher Ti, Al and Rb). The common timing suggests that this change reflects a regional driver, e.g., climate. It has been suggested that the climate became more humid during this period (increased erosion), and this is also the period when spruce takes over as the dominant tree species in the region. Taken separately these records would not allow us to say whether this shift was driven by a local or regional driver, however, by using two records it is possible to come to that conclusion.

## **S20-O12 - Climatic and anthropogenic forcing on catchment erosion inferred from annually laminated lake sediments in central and eastern Finland**

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Six annually laminated (varved) lake sediment records were studied in eastern and central Finland. Each record is continuously varved until the present day and extends more than 100 years back in time. Sediments of the lakes are of clastic organic varve type. A varve year consists of three laminae. The first, clastic minerogenic lamina, results from increased erosion caused by spring snow melt. The second and third laminae consist of mostly organic matter produced during growing season and settling down under ice cover. The lakes are observed to be sensitive to climatic forcing but during the past 100 years the catchments are actively cultivated following the intensified anthropogenic land use. The erosional changes were observed with respect to climatic and anthropogenic variation.

Both minerogenic and organic matter accumulation are related to precipitation, during winter and growing season, respectively. In general, the amount of erosion is controlled by the amount of accumulated snow during the previous winter and the length and intensity of the melting episode. However, three of the lakes are located in catchments rich in fine grained tills and the erosion on these catchments was observed to be more sensitive to frost formation than to snow accumulation. The changes in availability of erodible material is altered due to human actions, however the erosional events caused by land use changes seem to be quite short lived, only from few to ten years, and then a return to pre-disturbance level was observed. The frost sensitive soil type of fine grained tills seems to have a strong influence on the lake response compared to lakes located in catchments rich in sand moraines and such lake-catchment systems seem to be sensitive to different climatic forcing factors than those on sand moraine rich catchments.



## **S20-O13 - Tracing lake mixing regimes using sedimentological and geochemical proxies in varved sediments: 2000-years-long record from Lake Żabińskie (NE Poland)**

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Recent spread of hypoxia calls for understanding of long-term drivers and factors influencing changes of lake bottom water oxygenation. This study provides an insight into changes in mixing regime of Lake Żabińskie during the last two millennia. We used annually resolved sedimentological and geochemical record as well as pollen data to explain character, timing and reasons of changing conditions. Analyses of microfacies and grain-size provided information about sediment composition, structure and erosion rates. Geochemical data (XRF and elemental analyses) shed light on behavior of both redox sensitive (Fe, Mn, TS) and conservative (Ti, K) components. Furthermore, their relationships are explained by commonly used ratios (Fe/Mn, Mn/Ti, TOC/TS, TOC/TN). Analyses of the proxy dataset allowed for distinction of five main phases of different lake mixing regimes related mainly to land-use changes. However, no significant relationship between erosion rates (Ti, grain-size) and redox proxies (Fe, Mn, TS) was found. During periods of increased human activity and landscape opening, Fe/Mn ratio and TS concentrations remained low and indicated more intensive lake mixing and at least seasonal oxygenation of bottom waters. Periods of weaker human impact and forest restoration led to lake sheltering. Elevated Fe/Mn and TS contents reflect weaker mixing and meromictic conditions. Transitions between these periods were characterized by highly variable conditions and short-term changes. Our study shows that Fe/Mn ratio can be used to reconstruct water column mixing and hypolimnetic oxygen conditions despite substantial changes in the catchment land-use.

# Poster Presentations

## **S20-P01 - Varve Sequences from Windermere, UK: New Insights into the Deglaciation of the Lake District**

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The interval from the end of the Last Glacial Maximum around 19 ka to the start of the Holocene at 11.7 ka was marked by rapid climate oscillations that ultimately led to the complete demise of the British, Irish and Fennoscandian Ice Sheets. Understanding the dynamics of Earth system behaviour through this period relies on the development of records of sufficiently high resolution to capture the relative timing of change. Annually laminated sediments or varves provide an appropriate temporal resolution but are rare in the early part of the deglaciation. Here we present a new glaciolacustrine varve record, close to the Eurasian Ice Sheet and prior to the rapid warming of the Lateglacial Interstadial (GI-1), from Windermere in the Lake District of Northwest England.

Evidence from varved sequences from four cores in the Windermere North and South Basins are integrated with seismic stratigraphic records to reconstruct the regional deglaciation. The final phase of ice retreat commenced abruptly within 250 years of the main Interstadial transition and led to a change from cm-scale glaciolacustrine varves to nival varves within 36–40 years in the South Basin, and a change in mineralogy as the main ice sheet was lost and fragmenting valley glaciers receded. Rapid ice retreat up the North Basin was recorded by a series of De Geer moraines and chaotic outwash sediments. The new cores, combined with the seismic evidence, show the potential for a centuries-long varve chronology and climate history through Heinrich Stadial 1.

## **S20-P02\* - Varved lake sediments from Lake Gościąg (Central Poland) as a high-resolution archive of past environmental and climatic changes**

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Lake Gościąg is a well-known study site since the 1980's. It is a part of the Na Jazach lake system in the Płock Basin (Central Poland). The lake consists of a smaller northern basin (Tobyłka Bay) and a main basin with a maximum depth of 22.1 m. The ongoing, multidisciplinary project focuses on modern sedimentation monitoring, paleoenvironmental and paleoclimatic reconstructions, catchment investigation and a study on a landslide at the southern slope of the lake basin.

To decipher past environmental and climatic changes, a set of sediment cores was retrieved from the deepest part of Lake Gościąg in September 2015. Three parallel sediment cores (A, B and C) and two surface cores (S1 and S2) were obtained during the survey. The cores were drilled with an UWITEC Piston Corer in the deepest part of the lake bottom. They cover a length of 1818 cm (A), 1849.5 cm (B) and 1282 cm (C), 95 cm (S1) and 97 cm (S2).

The record presents, except of the topmost part, a continuous sequence of varved deposits down to glacial sand. The new varve chronology and its uncertainty based on multiple varve counting is supported by radiocarbon dating and palynological analysis. The detailed varve microfacies analysis and data obtained from  $\mu$ XRF core scanning revealed several distinct shifts in sediment structure and elemental composition.

The most pronounced one is observed around 13.5 m of the sediment composite profile and, in respect to the preliminary data, can be linked to the 8.2 ka event. The first results of subfossil zooplankton assemblages (Cladocera) confirms a distinct change at this depth and points to several pronounced ecological turnovers during the entire lake history.

This study is a contribution to scientific project financed by the National Science Centre, Poland – No. UMO-2015/19/B/ST10/03039.

## **S20-P03\* - Sediment transfer in German lowland lake catchments - Erosion on the slopes and input into annually laminated lake sediments**

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Holocene annually laminated lake sediments are perfect archives recording the soil erosion history of their catchments. A comparison of quantitative data of erosion (truncated soils, gullies) and sedimentation on the slopes (colluvial layers, gully fills) with the input of detrital components into the lake enables a more precise reconstruction of timing erosion and a more complete inventory of sediment budgets in the different sediment stores. Additionally, specific processes, like high-energy (gullying) events that cross thresholds of connectivity between the different stores are detectable.

The Holocene hydro-sedimentary connectivity was found to be very slow (<10% of eroded material reach the lake) at the investigated lakes and thus questioning data reported from other archives (namely alluvial systems). Extraordinary high-energy runoff events in the central European lowlands were detected during the 18<sup>th</sup> and 14<sup>th</sup> century as well as at ca. 200 BC. The potential of the reconstruction of high-resolution chronologies of extreme precipitation events (recurrence intervals) as well as the reconstruction of data for the central European lowlands and the estimation of thresholds of hydro-sedimentary systems are discussed.

## **S20-P04\* - Climate or men? The quest for drivers of multidecadal to centennial palaeolimnological processes during the Neolithic in Northern Germany**

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Multiproxy investigations of annually laminated lake sediments included palynological, geochemical and micro-morphological analyses. They allow for a comparison of lake internal processes such as lake mixing or productivity with proxies for human activity and climate/weather history. By comparing data from two different sites in Northern Germany, Lake Belau and Lake Woserin, it was possible to identify even short-termed, i.e. multi-decadal to centennial signals. Synchronous changes of human activity in the pollen records indicate drivers of supraregional importance. Changes in human impact are also reflected in geochemical proxies related to lake productivity. In order to test the role of climate, the signals were compared with independent climate proxies: For older phases (pre-neolithic) a strong relation between climate proxies and hydrological/sedimentological features, as for instance recorded in the Fe/Mn-ratio, is visible. However, distinct changes in human activity associated with major climatic events (Bond 3, 4, Piora oscillation) raise the question of climate or human activity being the main driver for the observed lake internal changes. Furthermore, short-termed supraregional synchronous changes in human impact during the Younger Neolithic – also reflected in increased lake productivity – also seem to point at a large-scale driver for settlement intensity. This poster will present first results of trying to disentangle the different factors and to identify primary and secondary drivers.

## **S20-P05 - Central Asian Holocene paleoenvironmental and paleoclimate changes derived from a varved sediment record of the high-altitude Lake Chatyr Kul (Tian Shan/Kyrgyzstan)**

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The endorheic Lake Chatyr Kul is located at 3530 m a.s.l. in the high-relief southern Tian Shan ranges. This position is at the intercept of large-scale hemispheric climate systems: the Westerlies, the Siberian High and the Asian Monsoon. The Lake is potentially sensitive to variations of climate system interactions and thus displays a key region to study their impact on Holocene climate development.

Sediment cores were retrieved in 2012 from the deepest part of the lake at ~20 m water depth and a composite profile of 6.25 m length was established. The basal age is ~11.800 cal a BP based on an age model derived from 9 AMS <sup>14</sup>C ages of terrestrial plant remains and varve counting. It is the first record in this region comprising seasonal laminated sediments almost throughout the entire profile.

The early to mid-Holocene (~10.500–4500 cal a BP) shows frequent alternations between minerogenic (high sedimentation rates) and organic-minerogenic (low sedimentation rates) varves, whereas the mid to late Holocene shows more pronounced system shifts at ~4500 and ~2000 cal a BP. The interval between 4500 and 2000 cal a BP is characterized by organic – minerogenic varves (lowest sedimentation rates) with high amounts of aquatic plants and benthic diatoms indicating reworking processes. After 2000 cal a BP minerogenic varves dominate with highest sedimentation rates.

Changes of microfacies structures,  $\mu$ XRF element scanning and geochemical data indicate changes of environmental parameters such as erosional processes, limnological changes and variations in the amount and source region of precipitation. Non-climatic processes like active tectonics and surface deformation could have influenced the hydrographical system. A high-resolution digital elevation model based on satellite data will help to trace these as well as paleo-shorelines and permafrost processes to better understand the lake basin development.

This is a contribution to the BMBF-funded project CAHOL.

## **S20-P06 - The potential of annually laminated lake sediments in northern Poland for distal Icelandic cryptotephra investigations**

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Volcanic ash (tephra) from explosive eruptions can be distributed over long distances from the source and may be used for dating and synchronising sedimentary sequences for detailed palaeoenvironmental reconstructions. Numerous tephra studies have shown that northern and central Europe was regularly impacted by large-scale eruptions from Iceland and the Eifel Volcanic Field in Germany since the Late Glacial. So far, tephra studies in Poland are limited to only a few sites due to the distal to ultra-distal position to European volcanoes that reduces the probability of deposition of macroscopic visible ash layers. However, observations of recent eruptions of Eyjafjallajökull (AD 2010) and Grímsvötn (AD 2011) on Iceland have demonstrated that volcanic ash fall could occur in Poland.

We used the potential of annually laminated sediments from selected lakes along a W-E transect in northern Poland in order to extend the knowledge about the occurrence and dispersal of cryptotephra (non-visible tephra) deposited during the last two centuries. We investigated short gravity cores and focused on the detection of tephra from Askja (AD 1875) and the most recent Eyjafjallajökull (AD 2010) and Grímsvötn (AD 2011) eruptions. The results allow to update existing tephra dispersal maps in Central Europe. Moreover, the combination of high-resolution proxy studies with independent dating methods (varve chronology, tephrochronology) will enable detailed spatiotemporal reconstructions and comparisons of palaeoenvironmental changes over a large area.

### **Acknowledgements**

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## **S20-P07 - Water temperature and geochemical sediment monitoring of two neighbouring lakes with varved sediments in northern Poland**

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Local factors like catchment morphology and lake basin bathymetry have an influence on lake sedimentation responses to external forcing like climate change. Understanding these local processes is crucial for robust sediment proxy interpretation. One suitable approach to disentangle local and regional climate factors is an in-depth monitoring of lake sedimentation processes.

Here, we apply a specific dual-lake monitoring of neighboring Lakes Głęboćzek (JG) and Czechowskie (JC) located within a radius of 2 km. These lakes are located in the Tuchola Pinewoods in northern Poland and were formed by glacial-hydrodynamic processes at the end of the last glaciation. The catchments mainly consist of outwash plane deposits composed of sandy, fluvio-glacial sediments. The lake sediments are annually laminated (varved).

The monitoring setup consists of a sequential trap (two-week sample interval), a 4-cylinder trap (monthly sample interval) and a water temperature logger chain (0.5 h resolution), installed in the profundal zones of the lakes. Measured and analyzed parameters comprise stable oxygen and hydrogen isotopes of lake water and sediment, total organic carbon (TOC), calcite (CaCO<sub>3</sub>), diatoms and water temperature. Despite a general similarity of autochthonous sediment formation processes, we observed differences in total and seasonal sediment flux. These differences are partly related to specific circulation patterns of these lakes determined by local factors. We further compare the observed seasonality of recent sediment deposition with the varve structure of sub-recent sediments to provide a sound base for interpretation of varve micro-facies.

This study is a contribution to the BaltRap project "WP2: Holocene annually laminated lake records" founded by the Leibniz Association.



## **S20-P08\* - A 45 kyr record of flash-floods from a deep rift lake: The Dead Sea**

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The sedimentary sequence in the Dead Sea depocenter is characterized by alternating aragonite and detritus laminae interbedded by centimeter- to meter-thick detritus layers, e.g., turbidites and homogenites. The location of the Dead Sea Basin within the Dead Sea transform fault zone makes the seismic shaking, apart from the flooding, another major agent for the generation of these thick detritus layers. While the deposition of millimeter-thick aragonite and detritus laminae is mainly the product of runoff processes controlled by climate, these laminae have long been considered to represent seasonal variation and thus have the potential to serve as hydrologic record of flash-floods. We present a thickness record of aragonite and detritus laminae couplets of the past 45 kyr from the ICDP deep drilling in the Dead Sea depocenter. The aragonite and detritus laminae are thin and occur at high frequency during the last glacial period, while during the Holocene they are thick and less frequent. We interpret this observation as the result of high frequency and small-magnitude flash-floods during the last glacial period, and low frequency but large-magnitude flash-floods during the Holocene. This frequency-magnitude distribution supports Monlar (2001), who proposed that the increased aridity associated with global climate change may have increased the frequency of large floods in arid regions.

## **S20-P09 - Increased sedimentation following the Neolithic Revolution in the Southern Levant**

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The Dead Sea drainage basin offers a rare combination of well-documented substantial climate change, intense tectonics and abundant archaeological evidence for past human activity in the Southern Levant. It serves as a natural laboratory for understanding how sedimentation rates in a deep basin are related to climate change, tectonics, and anthropogenic impacts on the landscape. Here we show how basin-wide erosion rates are recorded by thicknesses of rhythmic detritus laminae and clastic sediment accumulation rates in a long core retrieved by the Dead Sea Deep Drilling Project in the Dead Sea depocenter. During the last ~11.5 kyr the average detrital accumulation rate is ~3-4 times that during the last two glacial cycles (MIS 7c-2), and the average thickness of detritus laminae in the last ~11.6 kyr is ~4.5 times that between ~21.7 and 11.6 ka, implying an increased erosion rate on the surrounding slopes during the Holocene. We estimate that this intensified erosion is incompatible with tectonic and climatic regimes during the corresponding time interval and further propose a close association with the Neolithic Revolution in the Levant (beginning at ~11.5 ka). We thus suggest that human impact on the landscape was the primary driver causing the intensified erosion and that the Dead Sea sedimentary record serves as a reliable recorder of this impact since the Neolithic Revolution.

## **S20-P10 - Interpreting Soft Sediment Deformation and Mass Transport Deposits as Seismites in the Dead Sea Depocenter**

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We have studied the history of earthquakes over the past 70 kyr by analyzing disturbed sedimentary layers around the margins of the Dead Sea. However, we know little about disturbances in the basin depocenter, where water depth is ~300 m, and accessible only by drilling. In this study, we compare disturbances from the Dead Sea depocenter, with the contemporaneous earthquake record (~56–30 ka) that was recovered on the western margin of the lake. This comparison allows us to discern the characteristics of disturbance in the different subaqueous environments and identify the source and sedimentary process of mass transport deposits. Our observations indicate that (i) the long disturbance sequences in the Dead Sea depocenter are composed of in situ deformation, slump, and chaotic deposits; (ii) earthquake-triggered Kelvin-Helmholtz Instability is a plausible mechanism for the in situ deformation in the lake center; (iii) the slump is slope area sourced; (iv) the unit of chaotic deposits is lakeshore sourced; and (v) earthquake-triggered slope instability is a viable mechanism for the slump and chaotic deposits. We further suggest that long sequences of disturbance in seismically active lake depocenters can be used to infer earthquake clusters.

## **S20-P11\* - Varve counting, radiocarbon and tephrostratigraphy of annually-laminated sediments from Diss Mere (East Anglia, UK).**

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Diss Mere (Norfolk) is one of the few known lakes in the UK that provides an annually-laminated (varved) sediment record of the Holocene. Here we show the first independent Holocene chronology for the site based on varve counting, radiocarbon analyses and validation by tephrochronology.

The Diss Mere sedimentary record is 17 m long. The sediments consist of calcite mud and silt with a high organic matter content. 35 radiocarbon dates along the sediment sequence show that the Diss Mere record covers the entire Holocene. The first 9 m are faintly laminated and a total of 8,535 varves are well preserved from 9 to 14 m of sediment depth. The lower three metres display a transition from calcite mud to grey sand. According to the  $^{14}\text{C}$ -based age-depth model, the varves date between 2000 and 10,600 cal. a BP, which is in close agreement with the floating varve counts. In addition, 8 cryptotephra layers corresponding to Early-Holocene (4), Mid-Holocene (1) and Late Holocene (3) volcanic eruptions have been identified along the varved sequence and used to validate the Diss Mere chronology. The discovery of these tephra layers combined with the precise varve chronology provides opportunity to revise the age estimates of less securely dated tephra and is a major contribution to the ongoing development of a Holocene tephrostratigraphic framework for Europe. The combination of tephrochronology and varved sediments also has important palaeoclimatic applications. For example, this approach makes it possible to synchronise the Diss Mere record with that of the equally high-resolution Meerfelder Maar record in Germany and to compare and contrast the climatic signals from both sites, which is an essential requisite in understanding the regionality of abrupt climate change during the Holocene.

This research is funded by the Royal Society (Dorothy Hodgkin Fellowship) and the European Commission (MSCA-IF-705633).

## **S20-P12 - Climatic and environmental variability during the Younger Dryas cold phase in Lake Gościąż, central Poland**

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The warming at the end of the last glaciation in the northern hemisphere was interrupted by several short climatic oscillations with the Younger Dryas (YD) as the most pronounced cold setback. The YD is an about 1100-year long period with an internal variability that provides insights into climate evolution towards a major change in climate, such as the abrupt warming at the transition to the Holocene. Since this climate change occurred at very fast rates, high resolution climate archives like annually laminated (varved) lake sediments are crucial for deciphering climate mechanisms and landscape responses at major climate change points.

The well-known varved lake sediments from Lake Gościąż (central Poland) are of particular interest, as they represent one of the longest and best-preserved sequences in Europe. Five new sediment cores have been obtained to re-investigate this record applying a combination of high-resolution microfacies analyses, micro-XRF element core scanning and mapping and stable oxygen and carbon isotope analyses. This study has a special focus on the YD/Holocene transition.

Two varve chronologies of the deep main basin and a shallow secondary basin (Tobyłka Bay) have been established. Both cover the YD/Holocene transition, defined by biostratigraphy. YD varves consist predominantly of diatom frustules, calcite and re-suspended material, whereas the Holocene varves mainly are composed of calcite and organic material. In general, the YD exhibits higher year-to-year variability and complexity due to less stable climate conditions. Higher bioproductivity and detrital input indicate windier conditions during the YD.

$\delta^{18}\text{O}_{\text{carb}}$  values increase and  $\delta^{13}\text{C}_{\text{carb}}$  values decrease, while the chemical elements show either a sharp shift or a sequence of oscillations around the biostratigraphic YD/Holocene boundary. The proxies show different responses and also a successive shift at the YD/Holocene boundary.

This study is a contribution to a scientific project financed by the National Science Centre, Poland – No. UMO-2015/19/B/ST10/03039.

## **S20-P13 - Preliminary Results of Volcanic Impacts on Ecological Systems Based on Annually Laminated Sediments from Lake Van, Turkey**

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Volcanic eruptions are well-known drivers of short-term climate variations and thus responsible for rapid changes in local vegetation. Ecological research about volcanic impacts is mostly based on observations made several decades after the eruption. Studies of the environment following the Mount St. Helens eruption have shown that the affected vegetation outside the blast zone recovers rapidly within years (Del Moral and Bliss, 1993).

In this preliminary study, we examine the response of terrestrial and aquatic vegetation to environmental perturbation of major volcanic events on the basis of a high-resolution time-scale (mean resolution: 3.5 years). We used the annually laminated Lake Van sediments with precise time control (e.g., tephra layer V18;  $32.7 \pm 2.5$  ka BP). In this highly sensitive region, the Nemrut volcano has been the most frequent source of tephra for the last 400 ka. Such disturbances provide the opportunity to study past ecological dynamics with respect to the rate of vegetation change, reaction time, and plant regeneration. Based on this, we want to know how the semi-arid steppe vegetation at Lake Van responds to volcanic impacts. Do we see, as expected from other ecological research of volcanic impacts, an increase of light-demanding taxa (e.g., *Juniperus*) and steppe elements (e.g., *Artemisia*, *Chenopodiaceae*), a reduction in biodiversity or perhaps a positive correlation to fire events? Do we recognize an immediate reaction in abiotic proxies, such as an increase in erosion by XRF measurements or even a significant change in annually accumulated sediment?

This preliminary study at Lake Van can help to evaluate the course and mechanism of vegetation changes after volcanic disturbances in a sensitive climatic region.

## **S20-P14\* - Laminated lake sediments as an indicator of recently induced anoxia in lakes of northern Poland**

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Annually laminated (varved) lake sediments can provide a precise chronology of past environmental changes. Although the number of lakes with recognized varved sediments is growing, still little is known about the conditions for laminae formation and preservation. Especially interesting in this respect are lakes with laminations preserved only in the topmost sediments, because they offer the possibility to track conditions responsible for this change. The issue of the occurrence of lamination in recent sediments is usually associated with worsening of oxygen conditions in the water column. Possible causes of this situation are seen in stronger stratification of lake waters caused by climate change or anthropogenically induced eutrophication.

Identification of factors affecting past oxygen conditions in lakes can be carried out with detailed investigations of sediment profiles with clear transitions from homogenous (massive) to laminated structures. Such transitions are observed in the topmost sediments of lakes Dubie, Salno and Wąsoskie, located in northern Poland. In order to determine the mechanisms responsible for the sedimentation of laminated sediments in those lakes we developed a research project with the following goals:

1. Identification of climatic, catchment-related and limnological conditions responsible for the change in sediment structure from homogeneous to laminated.
2. Identification of processes and mechanisms leading to changes in the sedimentation process.
3. Determination of precise chronologies and dynamics of observed changes.

Using geochemical proxies, diatoms and cladocerans we want to verify opposing hypotheses of climatic or local causes of laminae formation. The chronology of observed changes will be determined by three dating methods: varve chronology, Pb-210 and Cs-137. Finally, obtained results will be compared with existing cartographic materials and documentary sources.

## **S20-P15 - Temperature seasonality control on halite layers in the Dead Sea: In situ observations**

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Layered halite sequences have been deposited in deep basins throughout the geological record. However, analogues of such sequences are commonly studied in shallow environments. Here we study active precipitation of halite layers from the only modern analog for a deep, halite-precipitating basin, the hypersaline Dead Sea. In situ observations in the Dead Sea link seasonal thermohaline stratification and halite saturation to the characteristics of actively forming halite layers. The spatiotemporal evolution of halite precipitation in the Dead Sea was characterized by means of monthly observations of the i) lake thermohaline stratification (temperature, salinity, density), ii) degree of halite saturation, and iii) textural evolution of the active halite deposits. We present the observed relationships between textural characteristics of layered halite deposits (i.e. grain size, consolidation, roughness) and the degree of saturation, which in turn reflected the limnology and hydro-climatology. The lake floor is divided into two principle environments: A deep, hypolimnetic and a shallow, epilimnetic lake floor. In the deeper hypolimnetic lake floor, halite continuously precipitates with seasonal variations: (a) during summer, consolidated coarse halite crystals form rough surfaces under slight super-saturation. (b) During winter, unconsolidated, fine halite crystals form smooth seafloor deposits under high supersaturation. The observations also emphasize the thought regarding seasonal alternation of halite crystallization mechanism. The shallow epilimnetic lake floor is highly influenced by seasonal temperature variations and by intensive summer dissolution of part of the previous year's halite deposit, which results in thin sequences with annual unconformities. This emphasizes the control of seasonal temperature on the characteristics of precipitated halite layers. In addition, precipitation of halite on the hypolimnetic lake floor, to the expense of dissolution of the epilimnetic floor, results in lateral focusing and thickening of halite deposit in the deeper part of the basin and thinning of deposits in shallow marginal basins.



## **S20-P16\* - A local clay-varve chronology of glacial Lake Onego, NW Russia**

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Glacial Lake Onego (GLO) developed in front of the receding Late Weichselian ice margin in Russian Karelia. Widely spread glacial varves formed in GLO have been earlier studied by means of palaeomagnetism, varve counts and <sup>14</sup>C AMS dates from the northern Lake Onego area and from the bottom of the lake. Changes in magnetic parameters and a similar stratigraphy of the varve record together with the existence of a basin wide marker interval of pink colored varves have been used for core to core correlation and palaeogeographic interpretations (Saarnisto and Saarinen 2001). Unfortunately, there are missing varve to varve correlations between the cores. We will present a 1100-yr long local varve chronology based on three parallel cores from two small lakes in the Zaonetsky Peninsula of the northern Lake Onego area. Varve counts and correlation of varve series were provided from digital images. Thickness changes exhibit rapid upward thinning from several tens of mm to 5–15 mm within first 150 yrs which can be interpreted as rapidly increasing distance from the retreating ice margin. The slightly fluctuating varve thickness then decreases to 3–10 mm for the period 150–500 yrs above the bottom indicating a rather stable retreat of the ice margin. The varve thickness of 3–5 mm in the ‘pink horizon’ with 108 varves decreases to 2–3 mm at the end of the period. Above the ‘pink horizon’, a sudden decline in varve thickness to 1 mm and less takes place and continues within the following ca 250 yrs. According to the earlier AMS chronology of Saarnisto and Saarinen (2001), which places the deglaciation of Lake Onego basin between 14,250 and 12,750 cal yrs BP, this interval of micro-varves may have been climatically controlled during the Greenland Interstadial 1b. The final slight thickening of varves (ca. 350 yrs) indicates increased erosion due to a lowering of the ice-lake level.

The study is financially supported by the Russian Scientific Foundation (#18-17-00176).

## **S20-P17 - Different responses of sediment fluxes in lakes to meteorological conditions: preliminary results from process studies in the Masurian Lakeland, Poland**

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Lake sediments are widely used in reconstructions of climate change but still little is known about the preservation of climate signals in sediments. Documentation of these processes requires comprehensive process studies that combine limnological monitoring and sediment trapping. Here, we present results from two varved lakes located in northeastern Poland (Lake Żabińskie and Lake Łazduny), which provide ideal conditions for tracking how climate signals are preserved in the sediments, modified or overprinted by different processes. During the first year of the monitoring program we observed limnological conditions (water temperature, oxygen concentrations and chlorophyll-a concentrations), chemical composition of water samples (epi- and hypolimnion), as well as sediment fluxes. Sediment samples collected in different seasons were analyzed for major components by inspection of smear slides and measurements of TOC, TIC, TN, and TS contents. Our results show that, despite similar meteorological conditions, substantial differences between the lakes occurred in terms of sediment accumulation rates and sediment composition. Much higher sediment accumulation rates were recorded in Lake Żabińskie, which may be explained by the more eutrophic character of the lake. Moreover, one prominent maximum in sediment accumulation was observed in Lake Żabińskie while in Lake Łazduny we recorded several minor maxima during the whole ice-free period. In both lakes, calcite precipitation is very important for seasonal variability of sedimentation which constitutes the majority of the total annual flux. At this stage, differences in timing of enhanced calcite accumulation in sediments between the lakes are difficult to interpret and need verification during the coming years.

## **S20-P18\* - Combining Hyperspectral Imaging and $\mu$ XRF data to link varve-formation processes with meteorological data, Lake Zabinskie, Poland**

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Varved lake sediments are a valuable resource for paleoclimatological investigations due to the ability to produce proxy records at high-resolution with annually resolved chronologies. New advances in Hyperspectral Imaging (HSI) and Micro X-Ray Fluorescence ( $\mu$ XRF) provide opportunities to study the composition of varves at very high resolution ( $\mu$ m scale), with the potential to yield new insights into sub-varve scale depositional processes, and relationships with limnological and meteorological phenomena.

HSI has been demonstrated to be an effective method to measure the abundance of chloropigments in sediment at much higher resolution than would be possible with conventional pigment analysis using liquid chromatography (Butz et al., 2017). In this study we use HSI to determine the abundance of chloropigments (Chlorophyll-a and diagenetic products) in the sediments of Lake Zabinskie, Poland at a spatial resolution of 60  $\mu$ m (equivalent to approximately 70-80 data points per varve). The sediments of Lake Zabinskie contain well-preserved biogenic varves defined by the deposition of calcite and diatom remains in spring and summer, with clay and fine-grained organic matter deposited in winter. Previous work at Lake Zabinskie, has demonstrated a relationship between chloropigments and spring (March to May) temperatures during the period 1907–2008 (Amann et al., 2014). In this study, we extend the calibration to the period 1779–2016 using higher resolution pigment data inferred from HSI. Additionally, we use HSI and  $\mu$ XRF data to investigate sub-varve scale structures and composition including multiple calcite lamina, multiple algal blooms within a single varve year, and the seasonal timing of sulfur burial, which is possibly related to hypolimnetic hypoxia. These sub-varve scale features will be compared with meteorological and limnological data to understand the mechanisms driving the internal biogeochemical structure of varves.

## **S20-P19 - Multiple varve chronologies for the last 2000 years from the annually laminated sediments of Lake Żabińskie (northeastern Poland) – assessment of strategies for varve counting and uncertainty estimations**

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In this study we compared different methods to count biogenic varves. We used the 2000-year-long varved sediment record from Lake Żabińskie (northeastern Poland). This lake was chosen because of well-preserved varves as well as independent age controls, i.e. 29 AMS C-14 dates, Cs-137 activity peaks and volcanic glass shards (AD 1875 Askja cryptotephra). Microscopic investigations of thin sections led to identification of six major varve microfacies present in the sediment profile. Using these microfacies, we tested three counting methods and different approaches of estimating counting uncertainty. These three methods provided comparable numbers of varves (A: 1943 +/- 30, B: 2034 +/- 34, C: 2028 +/- 34/-53) and similar shapes of age-depth relations. However, two methods were found to suffer from arbitrary assumptions and subjective decisions in the process of chronology building. Procedures led either to the age underestimation or problems with reliable and objective estimation of counting uncertainty. To counteract these problems, we propose a method which includes analyses of major varve microfacies and three independent countings free from the need of varve-by-varve microscopic investigations. This method provided acceptable results and was more objective and less time-consuming. Additionally, we present a semi-automatic approach for varve counting using the XRF Ca record. It was tested and provided results that may serve as a first approximation of the number of varves. In this study we emphasize that different counting strategies will lead to different uncertainty estimations, which in turn may be important for the reliability of proxy data interpretation.

# Ecosystem recovery from environmental stressors

*Jennifer Korosi and Josh Kurek*

## Session 21



## Oral presentations

### **S21-001 - The decline, extinction, and potential for re-introduction of the rare aquatic plant *Najas flexilis* at Esthwaite Water, UK**

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Esthwaite Water is a shallow, moderately alkaline lake in the English Lake district, and has drawn various forms of legal protection because of its high conservation interest. Historically, the lake supported a diverse aquatic plant community, including the rare macrophyte *Najas flexilis*. However, eutrophication of the site has caused significant ecological change over the past 50 years, including the loss of *N. flexilis*. Esthwaite Water is one of the most intensively monitored lakes in the world, with water chemistry monitoring data dating back to the 1940s. Despite their importance, aquatic plants are one of the few ecosystem components that have not been subject to regular monitoring. Nevertheless, attempts are being made to reintroduce *N. flexilis* at Esthwaite Water following recent observed recoveries in nutrient concentrations. Comparing existing monitoring data with paleoecological reconstructions of plant macrofossils, diatoms and Cladocera reveals that, although *N. flexilis* finally disappeared from Esthwaite Water in the 1980s following extensive eutrophication, the plant has not been abundant at the site since ~1915. At this time, it was associated with species typical of a clear-water, oligo-mesotrophic, mildly alkaline conditions; conditions which pre-date the long-term monitoring records. Furthermore, there is no evidence for ecological recovery from eutrophication in the paleoecological records at Esthwaite Water. This contra-indicates reintroduction of the species at Esthwaite Water, and instead suggests that further restoration of the habitat should be prioritised.

## **S21-002 - A paleo-limnologic study of the effects of hydropower exploitation on a subalpine lake.**

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Many high mountain lakes in remote and protected areas are managed in order to produce hydroelectricity. This study uses a paleolimnological approach to describe the ecological dynamic of a small natural lake on granite, before and after 1976, when hydroelectric management was initiated. The change in management included the building of a small dam (+2 m) allowing littoral soil flooding and erosion, addition of water from another lake, and winter drawdown (-8 m) to supply water to the turbines. This experiment provides a test of the trophic upsurge theory (Turgeon, 2016) in a high mountain environment.

The Corne lake (2098 m a.s.l., 7.3 ha) is formed of a shallow cove (4 m depth, 1/3 of the total area) and a deep (28 m) depression. Sediment cores were taken in both units, dated ( $^{14}\text{C}$ ,  $^{210}\text{Pb}$ ,  $^{137}\text{Cs}$ ) and analysed for carbon, nitrogen content and isotope ratios, mineral elements (X-ray fluorescence), phosphorus and microalgal communities (diatoms and chrysophytes). Surrounding soils were mapped and analysed.

Since 1976, we observed a large and long lasting increase in the deposition of terrigenous material attributed to littoral soil and sediment erosion. This input was followed by a eutrophic phase (surge).  $^{14}\text{C}$  dating of bulk sediment carbon suggests that the lake processed much younger carbon after 1976 than before. In addition, a large change in the diatom community structure occurred. The present trophic status of the lake appears much lower than the one prevailing before 1976. Hence hydroelectric management may influence the trophic status of high mountain lakes, at least on the mean term.

## **S21-O03 - Sediment DNA helps revealing ecosystem collapse and recovery post-rabbit invasion on Sub-Antarctic Kerguelen Islands**

**Gentile Francesco Ficetola (1,2), Jérôme Poulénard (3), Pierre Sabatier (3), Erwan Messager (3), Ludovic Gielly (1), Anouk Leloup (3), David Etienne (4), Jostein Bakke (5), Emmanuel Malet (3), Bernard Fanget (3), Eivind Storen (5), Jean-Louis Reyss (3), Pierre Taberlet (1), Fabien Arnaud (3)**

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Dropping rabbits to uninhabited islands was a common practice in 19<sup>th</sup> century to avoid sailors starving in case of shipwreck. On Sub-Antarctic pristine islands, devastating effects of such human-induced alien species invasions were amplified by the lack of predators, ecosystems simplicity and harsh climate. However, such a scenario is mostly an a posteriori reconstruction as no observations were led contemporaneously, nor prior, to the initial invasion.

Here we investigate the effects of rabbit invasion on remote Sub-Antarctic Kerguelen Islands. Through the combination of sedimentology, geochemistry, pollen, non-pollen palynomorphs and sediment DNA data, we were able to reconstruct the timing of major ecological changes that affected a small lake-catchment area following rabbits first arrival.

Prior to rabbit invasion, the landscape was dominated by two plants: *Acaena magellanica* and *Azorella selago*. Rabbits were first introduced on the Archipelago in 1864 AD, however, rabbit sedDNA become detectable in the lake catchment only ca. 1940 AD, which is consistent with direct historic observations and further confirmed by the concomitant detection of coprophilous fungi. At that time the sedDNA plants record presents a peak in *Azorella selago* followed by a dramatic drop accompanied by a rise in *Acaena magellanica*. Since then, *Acaena magellanica* dominates the sedDNA record whereas the landscape is virtually free of any *Azorella selago*. Meanwhile, the erosion rate was progressively tripled over the 20 years following the first rabbit DNA detection and then dropped to nearly pre-rabbit values after 1990 AD.

Rabbits invasion rapidly provoked an environmental crisis: increased erosion and *Azorella selago* disappearance. Over a longer perspective *Acaena magellanica* regain, a potentially decline in rabbit population, and climate change toward dryer conditions permitted a drop in erosion, but no sign of *Azorella selago* recovery has been observed. This detailed example will permit to refine alien species invasion models.



## **S21-O04 - Long-term fire regimes define Afroalpine and Afromontane vegetation in tropical mountains: the case of the Bale Mountains, Ethiopia.**

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Fire plays a critical role shaping both the distribution and composition of the Afroalpine and Afromontane ecotone. Some communities are resilient to certain fire regimes, presenting post-fire traits such like resprouting, as evident in the Ericaceous zone, while others are more fire-prone. Fire regimes are also driven by vegetation as some parameters defining fire regimes – frequency, type or intensity – are often regulated by plant communities structure, flammability and connectivity.

While understanding fire-vegetation, spatio-temporal relationships is a critical topic in the preservation of these communities, current research is mostly focused over relatively short time scales. However, if we aim to define conservation baselines, resilience trajectories and human impact thresholds in tropical mountains, we need to look at centennial to millennial time-scales.

We present a preliminary, high-resolution Afroalpine fire record from lake Garba Guracha (3950 m a.s.l.), one of the sites cored within the DFG-funded unit “The Mountain Exile Hypothesis – How humans benefited from and re-shaped African high altitude ecosystems during Quaternary climate changes”. Aiming to provide information relevant to conservation of the Afroalpine and Afromontane vegetation, our main goals are: 1) Identifying changes in fire regime throughout key climate phases such as the Lateglacial-Holocene transition or the African Humid Period, 2) Defining the role of human agency, if any, on fire regime changes, and 3) Assessing fire regime changes on the long-term response of the Afroalpine zone at different time scales.

Our record shows a relatively low fire frequency during the Lateglacial-Holocene transition, followed by a rapid increase in fire activity at the Holocene onset. Fire intensity was further enhanced from ca. 8500 cal BP until the fire regime changed at ca. 4500 cal BP, when both frequency and intensity diminished. We explore the interactions of climate, fire and human impact on vegetation in the light of these shifting fire regimes.

## **S21-O05 - Resilience and recovery of lake ecosystems on the Swiss Plateau to prehistoric human impact (7000–4200 cal yr BP)**

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In Central Europe, human societies changed from hunter-gatherers to societies increasingly relying on crop cultivation and animal husbandry during the early Neolithic period (7500 to 6700 cal yr BP). Though Neolithic agrarian societies were still strongly influenced by natural environmental changes (e.g. climate), they significantly changed their surroundings by settlement construction, forest clearance and agricultural activities.

Lowland lakes around the Alps are well-known for Neolithic pile-dwellings and lake-shore settlements, which provide unique records of long-term human-climate-environment interactions. The proximity of lake villages and local agricultural activities (e.g. crop cultivation, animal husbandry) might have influenced the water quality of these ecosystems. Therefore, multi-proxy palaeolimnological analyses of lake sediments can reveal their resilience and recovery during and after prehistoric human impacts.

The sediments of two lakes (Burgäschisee and Moossee) on the Swiss Plateau were studied at exceptionally high temporal resolution for diatoms. Results were compared with available analyses of pollen and non-pollen palynomorphs to determine whether human settlements coincided with changes in lake hydrology and to provide information on the resilience of lake ecosystems to repeated human-induced disturbances.

Preliminary results show remarkable changes in diatom assemblages along with the first notable occurrence of human indicator pollen together with increased microscopic charcoal influx values in the sediments of Burgäschisee (5740–5560 cal BP). Planktonic *Pantocsekiella pseudocomensis*, *P. costei* and *C. radiosa* are replaced by periphytic diatoms, such as *Gomphonema parvulum* and *Navicula vulpina*, which might indicate nutrient enrichment due to anthropogenic impact or climate-driven lake level lowering. The subsequent increase of planktonic diatoms, such as *P. pseudocomensis* and *C. radiosa* could be indicative of ecosystem recovery from human induced disturbances, as well as lake level rise.

The obtained information is relevant for understanding lake ecosystem responses to climatic and anthropogenic change and also for predicting future ecosystem responses to ongoing global change.

## **S21-006 - Old sins in new fins – Legacy pollution from French mining and potential bioavailability in mountain lakes**

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Although we largely associate impacts from mining on the surrounding environment with the industrial era, historical mining has a millennial scale history on the globe leaving a long-lasting imprint on the environment. Pollution from pre-industrial times caused by mining activities such as ore exploitation and processing, when there were few if any environmental controls, could be substantial. Many of such historical mine sites are located in mountainous areas, which are also impacted by enhanced deposition of inorganic contaminants due to orographic enhancement. Combined, these areas are therefore of outmost concern in a legacy pollution aspect. Results on trace metal concentrations in the Central Pyrenees, where extensive mining (Ag, Fe) occurred from the Antiquity to the 19<sup>th</sup> century, indicates that  $\geq 600$  tons of anthropogenic lead (Pb) is stored in peat and organic soils in the Haut-Vicdessos area. The Pb-isotopic signature measured in soils, peat bogs and sediments indicates various sources of Pb deposition; i.e. both natural sources and from mining activities during the Antiquity, medieval and recent periods, but also Pb derived from industrial and vehicle/transportation sources. The effects of this legacy pollution can also be seen in the contemporary freshwater aquatic food chain. Based on geochemical data, i.e. total concentration and isotopic signatures of Pb in brown trout (*Salmo trutta fario*) and common minnow (*Phoxinus phoxinus*) caught at five sites and in three different adjacent valleys, we found that although mining in the area ceased over 100 years ago, trout and their prey still show a large range of Pb isotopic signatures including both modern deposition and mining related Pb. This reflects the long-lasting impact of human-environment interaction, and that ecosystem conditions may remain impaired centuries after activities have ceased.

## **S21-O07 - Defining the natural range of variation and extent of metal pollution of the Athabasca River in the Alberta oil sands region: an approach using floodplain lake sediments**

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Alberta oil sands began operations in 1967, but onset of environmental monitoring for pollution of the Athabasca River and adjacent floodplain lakes began 30 years later. Consequently, no pre-industrial baseline exists upon which current river sediment quality can be compared. This undermines our ability to determine the relative importance of contaminants supplied by natural versus industrial processes to downstream environments and hinders the ability to quantify the extent of Athabasca River pollution by rapid growth of oil sands development. Here, we address this critical knowledge gap by analyzing sediment cores from flood-prone lakes located upstream and downstream of oil sands operations within the Alberta oil sands region (AOSR). Radiometric, loss-on-ignition, and organic carbon and nitrogen elemental and isotope analyses were used to identify stratigraphic intervals of flood-supplied sediment and periods without flooding. These periods were further validated by a pre-1967, binary mixing model to understand the relative influence of river-derived sediment to these flood lakes. When compared to the pre-industrial baseline, normalized metals concentrations in recently deposited flood-derived sediment do not show evidence of pollution of Athabasca River sediment. There is, however, a clear signal of metal enrichment in recent decades in non-flood sediment in floodplain lakes located closest to mining operations, indicating local atmospheric pollution. These pre-industrial baselines provide an estimate of the natural range of variability of metal concentrations in Athabasca River sediment for assessment for evidence of pollution of the Athabasca River in the AOSR. Paleohydrological and contaminant analyses of stratigraphic records of flood-prone lakes along the Athabasca River provide a promising approach to establish baselines, reference conditions, and to discern natural and pollutant pathways of contaminant deposition.

## **S21-O08 - Recovery of lake invertebrate communities from organochlorines associated with historic forest management**

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Forest stakeholders in New Brunswick (NB), Atlantic Canada, operated arguably the world's largest aerial insecticide spray program during the latter half of the 20<sup>th</sup> century. Over 12 million lbs of DDT, a persistent organochlorine insecticide that bioaccumulates and concentrates in food webs, was used between ~1950 and 1970. In aquatic ecosystems, many pelagic and benthic invertebrates are sensitive to organochlorines when probable effects levels are approached or exceeded. We used sedimentary measures of DDT, including its major breakdown products (DDD and DDE), and remains of zooplankton (Cladocera, chaoborids) and benthic invertebrates (chironomids) preserved within dated sediment cores from 5 remote NB lakes to assess responses to and recovery from historic DDT use. Within our remote, oligotrophic study lakes, invertebrate community composition and concentration suggest marked shifts in response to insecticide stressors and presumably other environmental changes in recent decades. The timing of biological changes suggest an individual lake response to cumulative stressors. Overall, ecological recovery of aquatic invertebrates has not occurred at the most DDT-impacted lakes. This research highlights potential legacy effects of persistent pollutants used over 60 years ago.

## **S21-O09 - Assessing the recovery from eutrophication in the near-shore regions of a large, fluvial lake on the St. Lawrence River**

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The St. Lawrence River in eastern North America connects the Laurentian Great Lakes to the Atlantic Ocean, supplying millions of people along its waterfront with drinking water, aquatic recreation, and fishing opportunities. Since industrialization, the health of this river has been subjected to numerous stressors, including a variety of anthropogenic inputs. The addition of these pollutants over decades and the resultant environmental degradation led to the designation of part of this river as an Area of Concern (AOC), where beneficial uses of the system have been impaired by high nutrient concentrations and industrial pollution. Remedial actions designed to reduce nutrient inputs to the river have been implemented since the early-1990s, though little monitoring was carried out to assess the impacts of these efforts. Recent surveys suggest that high nutrient concentrations continue to occur in this region, with associated high algal biomass and occurrences of toxin-producing cyanobacteria. A paleolimnological assessment of diatoms, photosynthetic pigments, and stable isotopes ( $\delta^{15}\text{N}$ ,  $\delta^{13}\text{C}$ ) was completed to evaluate the change in water quality and algal community structure in this AOC since the early-1990s, when remedial actions were first implemented. Results indicate that overall algal abundance has increased in the past few decades, including increases in potentially toxin-producing cyanobacteria in recent years. Nutrient influx also appears to have increased steadily since the mid-20<sup>th</sup> century, despite remediation efforts. Though non-point source nutrient pollution from local agricultural watersheds seems to be driving these increases, it remains unclear if and how other stressors, such as climate change and non-nutrient anthropogenic pollution, have impacted algal biomass and community composition. The results of this study will be discussed in conjunction with plans for ongoing research to assess the influences of climate and non-nutrient pollution on eutrophication and the presence of undesirable algae in this system.

## **S21-O10 - Reshaping the landscape - Environmental impacts of a millennium of mining and metallurgy in central Sweden**

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With the first firing of the iron blast furnace at Lapphyttan in the late 12<sup>th</sup> century, the economic and political landscape of Sweden began a profound reshaping. The first firing also led to the reshaping of the landscape of central Sweden itself; this new era in mining and metallurgy led to an unprecedented exploitation not only of mineral, forest and water resources in a 100,000 km<sup>2</sup> geographic region known as "Bergslagen". This exploitation impacted terrestrial and aquatic systems through a wide range of activities: cultivation of the sparse tillable soils, mire haymaking, forest grazing, charcoal kilning, water regulation, mining and smelting, taking place at thousands of sites.

We have analysed sediments from several lakes in different regions associated with historical agriculture and metallurgy and present data on pollen, diatom assemblages (including inferred pH and TP), VNIR-inferred lake-water total organic carbon, geochemistry (LOI, WD-XRF), and FTIR-measured biogenic silica. These boreal forest lakes share similar baseline conditions: pH ~5.5, LW-TOC >15 mg L<sup>-1</sup>, and oligotrophic diatom communities. The first clear change occurs ~1000 y ago, when pollen, charcoal particles and sediment geochemistry indicate both agriculture and mining and metallurgy. The most pervasive impact is a significant decrease in LW-TOC (~50%), even in lakes without direct connection to cultivation or metallurgy. The most intensive impact is on the lakes directly connected to cultivation or smelting, with increasing sediment concentrations of e.g. Fe and Zn, large changes in diatom assemblage composition and increasing Di-pH. During the last 100–200 y the smelters closed, agriculture declined, and lakes immediately begin to recover, diatom assemblages revert and Di-pH decreases. A rebound in LW-TOC is less consistent, with some lakes showing an initial recovery, while others remain at historically low concentrations until the present.

## **S21-O11 - Response and recovery of boreal lakes to historic and modern disturbances**

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Poorly buffered, oligotrophic, clear-water lakes are some of the most well-studied systems in limnology and paleolimnology. However, limnologists are now shifting focus towards humic lakes, as many lakes are currently becoming more humic and there is a need to understand how this will affect ecosystem function. Humic lakes are also an important component of the global carbon cycle and it is still uncertain how climate change will impact the carbon balance in these lakes. Unlike clear-water lakes, very few paleolimnologic studies have addressed the long-term evolution of humic lakes and how they respond to both natural and anthropogenic stressors, even though such information can serve to guide contemporary research and the future management of lake ecosystems. We synthesize chemical and biological data from the sediment records of clear-water and humic lakes in southern and central Sweden into respective schematic models to illustrate similarities and differences in their long-term evolution, responses to environmental stressors (climate, land use, acidification) and subsequent recovery. Both lake types have experienced long-term, natural acidification and increases in lake water carbon (LW-TOC), and in the past c. 1000 years land-use related declines in LW-TOC. However, only clear-water lakes experienced an alkalisation phase with historic land use and ultimately a greater degree of acidification in the late-20<sup>th</sup> century. Our aim is to bring to attention the legacy of past land use on boreal lake ecosystems because future environmental stressors will act on lake ecosystems that may have long since deviated from their natural baseline trajectories.



## **S21-O12 - A Great Lake is still not so great: long-term hypolimnetic oxygen conditions in Lake Erie inferred from chironomid assemblages.**

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The Laurentian Great Lakes of North America are one of world's greatest freshwater lake systems, and its watershed is home to approximately 34 million people. Lake Erie, the shallowest and smallest (by volume) of the Great Lakes, experienced noxious algal blooms and widespread hypolimnetic oxygen depletion in the 1960s, leading to international legislation and action to reduce nutrient inputs into Lake Erie. Water quality improvements were observed in recent decades, with a recent re-occurrence of algal blooms, possibly due to climate change. A mid-basin sediment core was collected to examine chironomid assemblages to assess long-term changes in hypolimnetic oxygen conditions. The occurrence of *Chironomus* spp and *Procladius* in assemblages suggest that Lake Erie has experienced periods of hypoxia and anoxia since 1850 CE, however, the disappearance of oxic-type taxa such as *Micropsectra* and *Heterotrissocladius* suggest that the extent and duration of low hypolimnetic oxygen conditions has worsened since the 1950s. There is no observed recovery in chironomid assemblages despite reduced phosphorus loads to Lake Erie over the last 40–50 years. Variance partitioning analysis suggests that a combination of changes in climate and nutrient inputs from agricultural land-use are influencing chironomid assemblage composition.

## **S21-O13 - Understanding shallow coastal lake response to gradual long-term and episodic salinity increase: a multi-proxy approach**

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In marginal marine areas worldwide, complex and unstable shallow lakes are subjected to multiple pressures. Over the instrumental period coastal-wetland salinisation has occurred at unprecedented rates due to anthropogenic catchment modifications, complex hydrogeology, climate change and sea-level rise. The shallow coastal lakes of the Upper Thurne catchment (Norfolk, England) are seriously threatened by these multiple drivers. Currently, effective management decisions are limited by the short timescales covered by observations and measurements. However, 130-year instrumental time-series complemented by multi-century palaeolimnological reconstructions suggest shifts between macrophyte abundance and loss concurrent with long-term and episodic rising salinity (1.8–8.7 PSU) and eutrophication (TP >100 microgram<sup>-1</sup>). Further understanding of interactions between drivers is limited by the lack of robust palaeosalinity and palaeoproductivity reconstructions. Here, a more reliable reconstruction has been achieved through combining ostracod faunal assemblage analysis with shell geochemistry (Sr/Ca, Mg/Ca,  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ), providing simultaneous information about salinity and productivity. The fossil ostracod assemblage is oligohaline and does not clearly reflect the trends of gradual long-term salinity increase inferred from archival evidence, suggesting controls additional to salinity. However, future management of land drainage and macrophyte management relies upon knowledge of the rate of, or lack of, recovery of the system from past high intensity storm surge events. The combined use of faunal assemblages and shell chemistry has, however, helped to identify intense salinity events associated with storm surges. Alongside macrofossil assemblages, these reconstructions will facilitate better understanding of recent salinity forcing in the Norfolk Broads and other coastal wetlands over longer (multi-millennial) time-scales.

## **S21-O14 - Applying a midge-based model to reconstruct hypolimnetic oxygen in two productive Canadian lakes that support cold-water fisheries**

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Deep-water oxygen is an important water quality parameter for biota and is a regulator of internal nutrient recycling. Hypolimnetic hypoxia, often related to cultural eutrophication, is a threat to aquatic biodiversity, ecosystem function, and ecological recovery, as low oxygen concentrations can persist after nutrient inputs have been reduced due to internal nutrient loading and the influence of climate warming. Lake management decisions or the development of water quality targets for hypolimnetic oxygen are difficult without knowledge of reference conditions, which is often limited by a lack of long-term monitoring data. Here we use sedimentary assemblages of benthic chironomid (Diptera: Chironomidae) subfossils to reconstruction of deep-water oxygen conditions in two lakes that support cold-water fish separated by a broad latitudinal gradient impacted by eutrophication and intensive watershed development. We examine chironomid-inferred oxygen conditions in both Osoyoos Lake, an important rearing lake for Okanagan River Sockeye Salmon (*Onchorhynchus nerka*) in British Columbia and Muskrat Lake, an Ontario Lake Trout (*Salvelinus namaycush*) lake that experiences annual cyanobacterial blooms and worsening late-summer anoxia. Chironomid-inferred deep-water oxygen conditions in Osoyoos Lake have remained suboptimal for Sockeye and below the modern management target for the past ~150 years. Subtle changes in the sedimentary chironomid assemblages show minor responses to increased primary production and changing climate. In contrast, inferred deep-water oxygen and chironomid taxa with high oxygen optima (e.g. *Micropsectra*) in Muskrat Lake have decline through time, with a large decline between ~1898 and ~1940 which is likely related to development in the watershed. In both lakes, paleolimnological analyses provide the long-term context necessary to assess whether current management targets reflect pre-impact conditions, which typically assume that water quality and oxygen habitat degradation has occurred after eutrophication and climate warming. Understanding long-term trends in deep-water oxygen is critical in assessing cold-water fish habitat and recovery after eutrophication.

## **S21-O15 - Assessing the cumulative effects of mining and land-use changes on climatically-sensitive lakes in the Canadian subarctic**

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Natural resource extraction has a long history in Arctic and subarctic environments, including Canada's Northwest Territories (NT). However, very little long-term environmental monitoring information is available on the ecological impacts of these industrial operations on climatically-sensitive northern aquatic environments. An extreme example of large scale subarctic mining activities was the gold extraction operations around the City of Yellowknife, NT between 1938 and 1999, which led to the contamination of many nearby lakes by a variety of contaminants but especially arsenic. Additionally, other environmental stressors, including raw sewage inputs, accidental tailings spills, urbanization, and climate warming have been affecting lakes around Yellowknife. We analyzed sedimentary diatom assemblages and concentrations of chlorophyll-a (using visible reflectance spectroscopy) to assess biological responses to mining activities (and other land-use changes) and to determine if any biological recovery has occurred in the context of multiple stressors. Specifically, we examined the surface diatom assemblages from 33 lakes along a large gradient of arsenic concentrations (1.5–2780  $\mu\text{g/L}$ ), as well as down-core diatom and chlorophyll-a concentrations from 5 lakes. Our data provides strong evidence that the primary producers from lakes around Yellowknife have been altered by mining operations, as well as local land-use changes, over the past ~100 years. However, the biota of these lakes have not returned to pre-disturbance conditions, as the contaminant concentrations are still high at some sites, and regional warming appears to be impeding the biological recovery. The timing and nature of the biological changes in these lakes affected by multiple environmental stressors highlight the interactive effects of industrial contaminants, local land-use changes, and climate warming on the algal assemblages of lakes in climatically-sensitive subarctic regions.

## **S21-O16 - The long-term effects of contamination from arsenic-rich mine tailings on a shallow lake ecosystem in Northeastern Ontario**

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A silver mining boom in the early twentieth century near the Town of Cobalt in northeastern Ontario, Canada, has left a legacy of arsenic-rich mine tailings spread across the landscape including being deposited in many lakes and rivers. Mining and the dumping of mine tailings ended in Cobalt in the early 1930's but these tailings remain largely unmanaged and continue to move around the environment contaminating lake ecosystems with arsenic and other metals. The objective of this study was to investigate the impact, if any, of arsenic-rich mine tailings on a shallow lake ecosystem (Ibsen Pond) and to assess if any natural recovery of the ecosystem has occurred since mining activity ceased in the 1930s. Mine tailings were clearly visible in the sediment record ( $^{210}\text{Pb}$  dated to ~1930) as a band of gray clay to silt material with elevated metal concentrations including arsenic levels of ~1800 mg/kg. A significant shift in the diatom assemblage occurred in response to the tailing contamination driven by an increase in the relative abundance of *Fragilaria construens f. construens* to nearly 60% of the diatom assemblage and the loss of benthic diatom diversity and a reduction in planktonic diatom abundance. Arsenic concentrations in the surface sediments remains elevated (~3200 mg/kg) and there is no evidence of recovery in the diatom community nearly a century after mining activity has ceased. These results suggest that shallow lake ecosystems are slow to recover from severe mining impacts and that remediation efforts are required in these systems as natural recovery is not occurring at timescales relevant to human society.

## **S21-O17 - Using macrofossils to understand the palaeoecology of farmland ponds and inform conservation efforts**

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The majority of UK farmland ponds are in a state of poor ecological health and suffering from low biodiversity. Many small (30 m max. diameter) farmland ponds were created over the 17<sup>th</sup>-19<sup>th</sup> centuries in eastern England and it is thought that traditional pond management practices (periodic scrub and mud removal) arrested terrestrialisation in these ponds until at the least the 1950s–70s period. The termination of management (likely linked to agricultural intensification) is thought to be a central driver of pond terrestrialisation leading to ecological degradation. Conservation efforts have sought to re-introduce management at ponds to reduce the impact of terrestrialisation, thus re-instating species-rich and macrophyte-dominated systems. However, questions remain over how man-made farmland ponds have changed over their life history in response to management and how effective this is as a conservation tool. Palaeoecological studies of lakes have proved an effective means of informing conservation efforts, but no such work has been undertaken for small ponds. In this study sediment cores were collected from two heavily overgrown farmland ponds in eastern England prior to conservation management. Plant and animal-based macrofossil analysis was used to reconstruct the ecological history of the ponds and to determine if historical expansion of scrub around the ponds impacted the biodiversity and structure of aquatic communities. Aquatic communities observed at the two ponds after the re-introduction of management practices were also compared with the macrofossil record. Our results show strong impacts of terrestrialisation and management on pond biological assembly, thus affording considerable support for on-going landscape-scale conservation work in UK farmland.

## Poster presentations

### **S21-P01 - From plowing to grazing: An example of land-use relaxation and its effect on soil stabilization and the recovery of Lake Lavijärvi, Russia Karelia**

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The region of Sortavala in the Russian Republic of Karelia has witnessed severe changes in land-use in the last century. Since the Industrialization and especially during World War II, intensive field cultivation with regular plowing occurred in the catchment of Lake Lavijärvi, initiating soil erosion and consequently lake eutrophication. In the post-war period, the arable fields were mostly converted to pastures as the land was ceded to the Soviet Union by Finland.

The study site offers an ideal testbed to investigate lake system behavior and soil stabilization processes after relaxation of human pressure by offering an example of change resulting from a sudden change from plowing to grazing agriculture. Magnetic susceptibility and detrital element distribution (XRF Ti) show substantial soil erosion at the start of the industrialization and mechanization of agriculture in the region (1900). At the same time radiocarbon ages of bulk sediment increasingly deviate from the modeled deposition age, indicating mobilization of old soil OC from surrounding fields. Enhanced nutrient input stimulated primary production and triggered a period of eutrophication, visible by a peak in C/N, biogenic silica and increased pollen percentages of aquatic plants and high abundance of middle-chained leaf wax n-alkanes ( $P_{aq}$  ratio). In the post-war period, soil erosion indicators are decreased suggesting soil stabilization processes in the catchment due to a change towards pastoral activity. These findings demonstrate the influence of different land-use practices on soil stabilization and provide additional background for sustainable soil management and freshwater renaturation.

## **S21-P02\* - Validation of a TP transfer function for the purposes of a water quality index development**

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Lake Erie is again under the threat of cultural eutrophication, mostly due to the runoff of nutrients from the surrounding farmlands. Therefore, it is an issue of high importance to continue monitoring efforts in Lake Erie to assess further deterioration or progressive changes due to the restoration management practices. This study validates a diatom total phosphorus (TP)-transfer function for monitoring of the Lake Erie's pelagic zone. Indices of water quality based on diatom transfer functions are often used without a careful examination of their performance because model validation is, unfortunately, not an issue of primary funding importance. Therefore, we present a validation of a planktonic diatom index (PDI) based on a large, independent dataset from the Western and Central Basins of Lake Erie. The results of the regression model of PDI scores and measured total phosphorus were robust ( $r^2=0.34$ ,  $r^2=0.63$  after the removal of three high chloride-sulfate outliers). However, we need to take into account several differences in the morphology and nutrient loading of the two basins. The Western Basin is very shallow, with an irregular mixing regime and high nutrient and sediment load. Turbulent conditions hamper our ability to find any significant relationship between PDI and snapshot TP measurements. On the other hand, the Central Basin is deeper, with less nutrient enrichment, and stratification occurring regularly during the summer. Less variability enables more precise measurement of TP, making a link between PDI and TP indubitably stronger. The functionality of PDI relies on the assumption that TP is instrumental in the structuring of diatom communities. Although the effect of TP is often obscured by other variables (e.g. TN, alkalinity, conductivity), there is usually a high degree of correlation. However, seasonal changes, encompassing the mixing regime and changing light penetration, exert a large effect on the ultimate diatom composition.



## **S21-P03\* - Maintenance of meromixis in a boreal lake receiving waters from a closed metal mine**

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Mine waters are a significant point source stressor for the environment. Acid mine drainage has long been considered a big environmental issue, but recent studies suggest that the salinity of mine waters may also be harmful particularly to small, dimictic lakes which are abundant in e.g. Finland. The denser saline mine waters may cause a shift in the mixing regime of a lake, leading to a permanent stratification of the water column, i.e. meromixis. As the mining industry in Finland continues to grow, policy makers and environmental regulators need to be more aware of these harmful effects of saline mine waters.

In this study, the boreal mining-impacted Lake Valkeinen is investigated. Lake Valkeinen is situated in Eastern Finland near the now-closed Kotalahti nickel-copper mine (active 1959–1987). The waters from the mine have been managed according to the permit conditions and are primarily discharged elsewhere. The present limnological condition of the lake is studied to determine what maintains the meromixis in this lake. Water column samples were collected and field measurements (e.g. pH, temperature, specific conductance, O<sub>2</sub>, redox potential) from the water column were carried out approximately twice per month in February–October 2017. Element concentrations and other water column properties are analysed from the water samples. Preliminary results suggest that the water column of Lake Valkeinen is indeed permanently stratified. The lake is ca. 16 m deep and the chemocline is situated around the depth of 8 m. In future, sediment samples from the lake will be investigated to obtain a view of past changes, such as the period of active mining, the onset of meromixis, and the development of the meromixis in the lake basin.

## **S21-P04\* - Slow recovery in mining impacted subarctic lakes in northern Sweden**

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Metals and minerals are important components of our modern society. However, mining activities pose threats to our ecosystems, both during and after mining at a specific sites has ceased. One problem is related to acid mine drainage, where lakes receive acidified, metal-rich water from leaching mine tailings. Post-treatment of mine sites are thus necessary to prevent acid mine drainage to reach the aquatic environments. In this study we compared three lakes in the vicinity of an abandoned, post-treated lead- and zinc-mine, in order to assess the recovery of lakes with different pollution history. One of the lakes was a settling pond, receiving mine drainage during the whole period of mining (AD 1943–2001), the other lake received drainage during the early stages of mining and the third received only runoff from the tailings. In all three lakes, there was a clear impact of the mine during ongoing production, but lead and zinc concentrations decreased after mining stopped. However, surface sediments from lakes receiving mine drainage still had elevated zinc and lead concentrations, exceeding the European environmental quality standards for inland waters. Those lakes also exhibited other severe effects on the ecosystems, for example lead poisoned birds. Further remediation is thus needed to enable complete ecosystem recovery.

## **S21-P05 - The impact of century old arsenic-rich mine tailings on sedimentary diatom and zooplankton assemblages in Cobalt, Ontario, Canada**

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Silver mining in the early 1900s has left a legacy of arsenic-rich mine tailings around the town of Cobalt, in northeastern Ontario. Due to a lack of environmental control and regulations at that time, it was common for mines to dump their waste into adjacent waterbodies and land depressions, concentrating metals and metalloids in sensitive aquatic ecosystems. In order to examine what impact these century-old arsenic-rich mine tailings are having on present day aquatic ecosystems we sampled diatom assemblages in lake surface sediment in 24 lakes along a gradient of arsenic contamination (<0.1–972  $\mu\text{g/L}$ ). In addition, we examined open water zooplankton abundance and community composition and chlorophyll-a concentrations over 10 of these study lakes on a gradient of arsenic contamination (0.8–1180  $\mu\text{g/L}$ ). Our results show that while present-day arsenic concentrations are not having a major influence on diatom community assemblages lakes contaminated by mine tailings have generally lower zooplankton abundances. These results suggest that while legacy contamination may not be greatly altering community composition it continues to reduce zooplankton and algal abundance and thus lake productivity nearly a century after mining activity has ceased.

## **S21-P06 - Postglacial biogeography of aquatic quillworts in the Bohemian/Bavarian Forest lakes, Central Europe: a review and extension of current knowledge**

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Modern relic populations of quillworts *Isoetes echinospora* and *I. lacustris* inhabit two of the eight glacial lakes in the Bohemian/Bavarian Forest, Central Europe. *Isoetes echinospora* occurs in Plešné Lake only, *I. lacustris* in Černé Lake only. Previous paleoenvironmental reconstructions, however, documented presence of both quillworts also in some other paleo-lakes in the region during the Holocene. Nonetheless, the ecological range and distribution of quillworts remain unclear. We investigated ecological range and the expansion timing of *I. echinospora* and *I. lacustris* from micro- and macrospore dynamic patterns in the sedimentary records of five glacial lakes (Černé Lake, Plešné Lake, Prášílské Lake, Rachelsee, Stará Jímka Lake) to assess environmental drivers responsible for the local decline or extinction of the species. We also estimated quillwort population size in the past from calculated microspore productivity using abundance data of recent plant stands and microspore influxes from the youngest part of the sediment profiles from Plešné and Černé Lakes. Our results showed that quillworts established populations in all five lakes between 10,500–9,500 cal yr BP and reached maximum abundances between 9,500–7,500 cal yr BP. Both species deteriorated across the entire region between 6,000–4,000 cal yr BP as documented by sharp declines in microspore influxes. Microspore influx values were continuously low and/or sporadic thereafter. Declining trend was probably associated with changes in vegetation cover and/or soil conditions as indicated by the expansion of *Abies alba* in the catchment documented by increasing pollen influxes to the lakes. After 1950, quillworts become locally extinct in Prášílské Lake, Stará Jímka Lake and Rachelsee, as there were no more spores in the sedimentary records.

## **S21-P07\* - Paleolimnological record of ecological changes of a humic lake following hydrological alternation and supply with carbonate- and nutrient-rich allochthonous waters.**

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In the 1960's, in Eastern Poland, the extensive Wieprz-Krzna Canal system was put into operation. The Canal and ditch system, delivered to the western and central part of Łęczna-Włodawa Lakeland (Western Polesie, Eastern Poland), water that has contributed to the severe ecological deterioration of many waterbodies. To fulfill the role of storage reservoirs, some natural lakes were connected to the system. The humic Lake Czarne Sosnowickie was one of these. As the alkalinization of humic lakes is a rarely studied phenomena compared e.g. to the brownification of hardwater lakes, we used this unique opportunity to investigate the reaction of the ecosystem of a moderately deep (max. depth 15.6, mean 5.1 m), polyhumic lake to the increased carbonate and nutrient supply resulting from an over 40-year period of Canal operation. The conducted analysis of subfossil Cladocera and Chironomidae, together with the chemical analysis of a 210-lead dated sediment profile, documented a severe near-bottom oxygen decline and an ongoing eutrophication which was notable already 10–15 years after the first water injection. The ecosystem response manifested itself within both studied invertebrate groups as a decline in the species richness and a diminished Shannon diversity. Among Cladocera, the most remarkable change of community were the increased of total abundance due to dominance of *Bosmina longirostris*, *Chydorus sphaericus* and *Alona rectangula* with parallel decline of *Alonella excisa*, *Latona setifera*, *Rhynchotalona falcata* and *Alonopsis elongata*. For Chironomidae, the very evident decline of total abundance and change in species composition (decline of *Chironomus antracinus*, *Cladopelma*, *Procladius*, *Ablabesmyia* and midge *Ch. flavicans* and shift toward taxa of lower oxygen demands) indicate deteriorated (hypoxic) conditions. As the analysed core covered over 150-yrs of lake history, we were able to track back the ecosystem reference conditions (the natural state of a seepage, low trophy, humic lake) and now observe first signals of its recovery.

## **S21-P08\* - Paleorecord of the pre-historic settlement and hemp retting practices in hardwater lakes and their ecosystems recovery following severe eutrophication and anoxia**

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Although human impact on lakes is easily readable since the industrial revolution began, the state of some lakes was anthropogenically disturbed earlier. Indeed, their lasting ecological status was already re-defined in the pre-historic period. We tracked the influence of ancient and historical settlement and climate on the shape of lake ecosystems (trophy, oxygen conditions, aquatic vegetation), based on multi-proxy sediment studies of four small, hardwater lakes situated in close vicinity within the Chełm Hills Region, Eastern Poland. Due to favorable natural conditions, the region strongly attracted early settlement. Our analysis (palynology, subfossil Cladocera, Ostracoda, C and O stable isotope ratios, radiocarbon and 210-lead dating) revealed that, starting from the subboreal chronozone, neolith settlers significantly shaped the landscape. In these lakes, human influence is reflected as elevated trophy visible from biotic and geochemical proxies. By studying several sites and the cores from different parts of the sedimentary basins, we disentangle the local and regional factors in the development of these waterbodies, and we identify intensified settlement phases, followed by regeneration phases. Especially distinguishable in all lakes was the impact of hemp retting practices, noticeable in the IV–V centuries and intensified in the Early Medieval, resulting in severe eutrophication and deterioration of oxygen conditions. The record of these was visible in the subfossil Cladocera, which show the alike succession, with subsequent abrupt decay of taxa vulnerable to oxygen deficits. The early episodes of eutrophication led to ecosystem turnover from which only one lake successfully recovered, remaining nowadays in a good ecological, macrophyte-dominated state. Based on derived geological, hydrological data, and chemical analysis of contemporary sediment, we unraveled the possible mechanisms for successful recovery to good ecological state (Lake Słone), and the causes for the remaining to be in poor ecological condition (the other lakes).

# Limnogeology: the past and future of lakes: a tribute to Elisabeth Gierlowski-Kordesch

*Blas Valero-Garcés, Michael Rosen and Antje Schwalb*

## Session 22



# Oral presentations

## **S22-001 - Microbial communities from modern and ancient lacustrine sediments – Unravelling their significance in paleoenvironmental studies**

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Lacustrine sediments are ideal targets for paleoenvironmental studies. Given the specific characteristics of each system, a good understanding of the sedimentation and post-depositional processes is necessary to carry out this kind of reconstructions. However, disentangling primary signals from diagenetic overprinting remains complex.

The main actors of early diagenesis in lake sediments are microbial communities. They play a critical role in the precipitation-dissolution of minerals, remineralization of organic matter and isotopic fractionation of the corresponding elements. While they have always been acknowledged, only recently they became the target of dedicated research, integrated within multidisciplinary efforts to resolve past climatic changes.

The pillars behind Beth Gierlowski-Kordesch endless enthusiasm for science were her scientific curiosity and interest for new approaches to study lake sediments. In this contribution, we provide an overview of the recent advances made in the field of lake sediments applied geomicrobiology. By combining the analysis of past and present microbial activities in sediments retrieved from scientific drilling, we show how limnogeological studies can benefit from a better understanding of microbial turnover and biogeochemical cycling. The revolution guided by omics techniques allows tracing the taxonomy, functions and activities of subsurface microbial populations with the prospect to shed light on the much-discussed deep biosphere composition. Approaches including environmental DNA, lipid biomarkers, isotopic fingerprints and organic/inorganic mineralization traces have been implemented in several lake studies, encompassing a wide variety of lake systems and limnological regimes. Beyond the insights that can provide these analyses to joined reconstructions, these studies have also shown that the deep biosphere of lake sediments is active and diversified, and that it responds to past environmental conditions, possibly involving differential overprint in relation with climatic shifts. These results call for a generalized effort to integrate microbial ecology to paleoenvironmental reconstructions in order to resolve symbiotic biological and geological processes.



## **S22-O02 - Climatic and limnologic dynamics of Lake Chalco, central Mexico, during the last 35 ka**

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Diatom-based transfer functions for salinity, annual temperature and precipitation were developed using a training-set of 40 lakes in central Mexico, and were applied to the Chalco diatom sequence, to generate a ca. 35 ka cal BP quantitative paleolimnologic and paleoclimatic reconstruction which allows assessing the intensity and speed of environmental change in central Mexico since the late MIS-3, including the impact of millennial scale events like Dansgaard-Oeschger interstadials (D-O) and Heinrich stadials (HS).

Orbital scale variability is recorded, showing the late MIS-3 as a period of variable but generally high salinities during the peak in summer insolation ca. 36–29 ka cal BP. MIS-2 (27 to 11.5 ka cal BP) shows low salinities, that relate with the lowest evaporation and summer insolation. The last glacial maximum (LGM) is a two-phase event reaching the lowest temperatures (-4.5 C) by 26–25 ka cal BP and 20–19 ka cal BP. The onset of the deglaciation is recorded by 19 ka cal BP and represents the wettest period in the record. The early Holocene shows positive temperature anomalies (+3 C) and high salinities during the peak in seasonality and summer insolation at 10–9 ka cal BP. Millennial scale events are evident, with a patten of warm-wet D-O interstadials and cool-dry HS, in agreement to other tropical sites in the Northern Hemisphere (NH). The Chalco data therefore fits with the model that during HS cold-freshwater inputs to the North-Atlantic slowed deep-water formation, reducing meridional heat transport and favoring a southerly location of the Inter-Tropical Convergence Zone and a reduced activity og the NH monsoons. However, on an orbital scale Chalco shows opposite moisture trends when compared to Petén Itzá, which shows a dry deglacial and wet LGM and early Holocene, these trends can be explained by the latitudinal differences between both sites, under a scenario of increasing moisture advection as summer insolation increases during the deglaciation and early Holocene.

## **S22-O03 - A U/Th age model for the continuous, >600-kyr-long lacustrine sediment record of Lake Junin, Peru**

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We present a uranium-thorium (U/Th) age model for the ~100-m-long sediment core extracted from Lake Junin, Peru, a record unprecedented amongst deep lacustrine records in its dependence on U/Th ages throughout its length. The sediment core is characterized by alternating packages of glaciogenic siliciclastic sediment and authigenic carbonate marl. We applied U/Th dating to ~150 bulk carbonate marl samples representing the array of carbonate sedimentological facies observed in the core. With this suite of analyses, we developed a framework for evaluating U/Th dates alongside corresponding sedimentological, elemental, and geochemical data to enhance our ability to make "age" interpretations from "dates" calculated from measurements. As a result of this framework, improved sample selection, and recent advances in analytical techniques, the Lake Junin record is the first continuous, U/Th-dated paleolake record spanning multiple glacial-interglacial cycles in the tropical Andes.

The carbonate marls have high uranium concentrations (0.3–4 ppm) and low detrital content, with ratios of radiogenic  $^{230}\text{Th}$  to initial  $^{230}\text{Th}$  that are 10–20 times greater than sediments from Lake Titicaca (Fritz et al., 2007) and the Great Salt Lake (Balch et al., 2005). These qualities allow us to date these sediments to within  $\pm 200$ –800 years in the Holocene and  $\pm 6000$ –8000 years between 280 and 400 kyr ago.

We compare all of our U/Th analyses to corresponding radiocarbon dates, high-resolution X-ray fluorescence (XRF) data, magnetic susceptibility measurements, sediment carbon data, and sedimentological facies descriptions to evaluate the robustness of a U/Th date for any given sample. Consequently, we also demonstrate the influence of detrital carbonate (eroded limestone bedrock) on U/Th dating.

Ultimately, our results indicate that the Lake Junin record spans ~7 glacial-interglacial cycles, complementing the long records from Sabana de Bogota, Lake Titicaca, and local speleothems and making it well-positioned to yield critical insights on past climate changes in South America.

## **S22-004 - Climate variability and palaeoenvironments during the transition from MIS6 to MIS5e in Lake Chalco Mexico**

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Information of past climates is preserved in the sedimentary continental sequences. Previous interglacial can be seen as analogue of the present interglacial and studies of this warmer period, without human impact, can provide insights of climate variability. The basin of Chalco located near Mexico City has a long and continuous sedimentary record and in recent years the upper section has been extensively studied providing data about climate variability and environmental changes for the last 40 kyr in this high altitude tropical basin. Several cores were drilled up to 122 m depth and the core correlation was based on magnetic susceptibility, tephra markers and lithology features. The sedimentary sequence covers the last ca. 150 kyr based on the age model constructed by 13  $^{14}\text{C}$  and one  $^{230}\text{Th}/\text{U}$  dates. Here we present a detailed record of the stratigraphy, palynomorphes, and diatom assemblages for the MIS 6 to MIS 5e transition. The lithology of the MIS 6 section is characterized by light/dark fine laminae with diatom ooze with *Stephanodiscus niagarae* and *S. oregonicus* in the lighter laminae. During this period, *Quercus*, *Cupressus*, *Alnus*, *Picea* and *Pinus* were the main components of the forests. Within the non-pollen palynomorphes (NPPs), several species of *Pediastrum* and *Botryococcus* are present. A freshwater lake and diverse forests are reconstructed for the late MIS6. Sandy-silts sediments with a different diatom assemblage composed of *Anomoeis costata*, *Campylodiscus clypeus* and *Cyclotella meneghiniana* mark the transition to MIS 5e. The vegetation record also showed a change in the forest composition with *Pinus* as the main element and the absence of *Picea* in the record. Among the NPPs abundant concentration TXA-1 type indicative of alkaline saline waters characterizes the MIS 5e. The multiproxy data suggests a transformation towards a saline lake with regional vegetation dominated by *Pinus* forests in the MIS 5e.

## **S22-O05 - Climatic and sedimentological variations during the last ~600,000 years in the large, ferruginous Lake Towuti, Indonesia**

**James Russell (1), Hendrik Vogel (2), Satria Bijaksana (3), Martin Melles (4), Towuti Drilling Project Team Members**

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Lake Towuti is the largest and one of the oldest tectonic lakes in Indonesia. The lake's location provides an outstanding opportunity to reconstruct long-term changes in terrestrial climate in the Western Pacific warm pool. Moreover, Lake Towuti is housed in the ultramafic East Sulawesi Ophiolite which provides extraordinarily high concentrations of iron and other metals to the lake and its sediments, resulting in the deposition of a variety of iron minerals. In 2015 the Towuti Drilling Project recovered over 1,000 meters of new sediment core, including cores through the lake's entire sediment column to bedrock to investigate paleoenvironmental changes and their influence on this unique lake system. The upper 100 m of section consists of fine-grained clay, indicating continuous lacustrine environments over the last ~600 kyr BP.

Within this unit, we observe alternations between greenish-grey and reddish-grey clays that reflect orbital-scale changes in climate. Geochemical, mineralogical, and isotopic analyses all suggest that the alternations between green and red clays represent shifts between wetter and drier climates and changes in lake mixing. Our current age model indicates that these transitions exhibit a complex relationship with orbital-scale climate forcing, with indications of precessional, half-precessional, and glacial-interglacial influences on western Pacific climate. Water column modelling indicate that lake mixing requires large changes in temperature, surface radiation, and latent heat fluxes, providing quantitative bounds on orbital-scale variations in western Pacific climate. Interestingly, despite their oxidized appearance, the reddish clays are characterized by high concentrations of reduced iron minerals such as magnetite and siderite. We suggest that lake mixing promotes the deposition of reactive iron oxides that are subsequently transformed into siderite and magnetite in the sediment, suggesting a new mechanism for siderite formation that could apply to ancient ferruginous systems.

## **S22-006 - Post-Variscan (Stephanian and Permian) and Post-Alpine (Quaternary) lake sequences from Pyrenean basins: sedimentary facies and models from old rocks and new sediments**

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A large variety of lacustrine facies occur in the Stephanian (Upper Carboniferous) and in the Permian Pyrenean basins developed after the Variscan orogeny. The Stephanian formations include coal-bearing, clastic and carbonate sequences from freshwater to saline conditions and in a range of depositional environments from volcanic to strike-slip settings. Permian lacustrine facies are minor occurrences, as dolomite, calcrete and palustrine facies intercalate within fine-grained clastic red facies. The Aragon - Bearn Permian Basin (western Pyrenees) contains the thickest (some tens of m) carbonate units intercalated among clastic red beds, and the only gypsum outcrop of all Pyrenean Late-Variscan basins. Quaternary lakes in the Pyrenean domain occur in: i) glacial basins located at high altitudes, ii) karstic sinkholes developed in the Pre-Pyrenean range and iii) saline lakes in the central Ebro Basin generated by karstic and deflation processes since the Pleistocene.

Post Variscan and Quaternary facies and depositional models share some similarities in spite of quite different tectonic and volcanic settings. Although limnogeological methodologies applied to the study of rock outcrops and sediment cores are not the same, the integration of both types of tools is the best strategy to have a better understanding of lake processes through space and time. These post Variscan and post Alpine Pyrenean sequences contain examples of how environmental, climate and basin dynamics (tectonic, progressive infilling, drainage network changes) factors have controlled lake depositional processes as i) facies variability and ii) carbonate, sulphate and organic matter production and preservation. These interactions between field stratigraphy and sedimentology, comparative case studies from varied geological ages and diverse analytical tools for rock and sediments are beneficial for both, global change studies based on recent lake records, and past environmental reconstructions based on geological records. As Elizabeth Gierlowki- Kordesch would say: “It is about the rocks (and sediments!)”.

## **S22-O07 - The environmental history of Lake Ohrid (FYROM/Albania) based on the 1.4 Ma SCOPSCO DEEP site record**

**Bernd Wagner (1), Alexander Francke (1,2), Thomas Wilke (3), Timme H. Donders (4), Janna Just (1,5), Sebastian Krastel (6), Jack H. Lacey (7,8), Niklas Leicher (1), Melanie J. Leng (7,8), Konstantinos Panagiotopoulos (1), Eleonora Regattieri (9), Laura Sadori (10), Hendrik Vogel (11), Giovanni Zanchetta (9), and the SCOPSCO science team**

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The four main aims of the SCOPSCO (“Scientific Collaboration on Past Speciation Conditions in Lake Ohrid”) deep drilling project are to infer (i) the age and origin of Lake Ohrid, (ii) its regional seismotectonic history, (iii) volcanic activity and climate change in the central northern Mediterranean region, and (iv) the drivers of biodiversity and endemism. The Ohrid basin formed by transtension during the Miocene and opened during the Pliocene and Pleistocene. The lake history is recorded in a 584 m long sediment succession, which was recovered within the framework of the International Continental Scientific Drilling Program (ICDP) from the central part (DEEP site) of the lake in spring 2013. To date, 50 tephra and crypto-tephra horizons have been found in the sediment succession. Tephrochronology and tuning biogeochemical proxy data to orbital parameters revealed that the upper 247.8 m represent the last 637 kyr. We now extended the age model with support of magnetostratigraphic data down to 456 m of the sediment sequence. The new data indicate that the lake established de novo in the still relatively narrow valley almost 1.4 Ma ago. Deep-water conditions in Lake Ohrid were fully established at 1.2 Ma, when there is also a significant change in vegetation around the lake. The mountainous setting with relatively high water availability provided a refugial area for temperate and montane trees during the relatively cold and dry glacial periods. The sedimentological data from Lake Ohrid show long-term variability in temperature, in tune with orbital-scale and millennial-scale climate fluctuations. Despite these environmental changes the microgastropod phylogeny and the diatom fossil record show no major extinction events in Lake Ohrid. The potential high resilience of the ecosystem together with relatively low extinction rates may explain the extraordinary degree of endemic biodiversity in the lake.

## Poster presentations

### **S22-P01 - High-resolution climate reconstruction for the last 250,000 years established from continuous Auckland Maar Lake records**

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Micro-XRF elemental core scanning methods developed in recent years provide quantitative geochemical data at sub-millimetre resolution leading to an expansion of the proxy database and improved interpretation of sediment records. In particular, micro-XRF element scanning of epoxy resin-impregnated sediment slabs commonly produced for thin-section fabrication, have been demonstrated to allow precise linking of thin-section observations and high-resolution elemental data produced by micro-XRF scanning. This approach has also significantly improved our ability to detect abrupt climatic shifts as well as short to long-term changes in seasonality.

In this context, well-laminated and continuous maar lake sequences from the Auckland Volcanic Field are well suited to the application of this integrative approach in New Zealand. Long and high-resolution terrestrial paleoclimate archives from this region are commonly few, often show low resolution and suffer from age controversies. The main objective of this project, therefore, is to generate the most thorough and continuous high-resolution terrestrial record from the Southern Hemisphere at an annual to perhaps seasonal resolution for climatically-forced environmental changes spanning ca 9 ka to ca 245 ka BP. In the context of the geographic setting of the North Island of New Zealand, this will allow to investigate and evaluate how inter- and intra-hemispheric climate dynamics are linked at high-precision stretching from the present day back over at least the last two glacial cycles, last ca 243 ka.

## **S22-P02\* - DeepCHALLA: Using isotopes in diatom silica to detect historical Megadroughts in the tropics**

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The International Continental Scientific Drilling Program (ICDP) project DeepCHALLA aims to reconstruct ~250,000 years of climate history in East Africa, using a ~214-metre sediment sequence retrieved from the bottom of Lake Chala on the eastern flank of Mt Kilimanjaro. Analysis of oxygen isotopes in fossil diatom frustules will play a critical role in reconstructing past changes in hydroclimate in particular locating periods of drought. Specifically, the exact timing and severity of the so-called African Megadroughts which occurred between ~130–90,000 years BP and are believed to have been critical in the dispersal of early modern humans out of Africa. Parallel analysis of carbon isotopes of the organic matter occluded within the diatom frustules will provide important insight into changes in the sources and biological demand of carbon in the lake system. Here, we compare the last 25,000-year record of oxygen isotopes in diatom silica from the DeepCHALLA sequence to that from an earlier core (CHALLACEA; Barker et al. 2011), to confirm the replicability of this paleohydrological proxy in sediment cores from different locations within Lake Chala. The success of diatom isotope analysis from Lake Chala is due to: 1) ease of sample purification from the diatom-rich Lake Chala sediments; and 2) reduced likelihood of species-specific effects because of the very low diversity of fossil diatom assemblages. Challenges in sample preparation mostly involve the detection and removal of tephra and minerogenic deposits. Ultimately, the stable isotope records from Lake Chala diatoms will provide insights into African climate history and lake-carbon cycling over two glacial-interglacial cycles. This project highlights the utility of diatom isotopes in reconstructing environmental history, particularly in cases where ecological knowledge of the diatom taxa may be limited.



## **S22-P03\* - Petrological characteristics of lava flows underlying the lacustrine sequence of Chalco basin, central Mexico**

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The Trans Mexican Volcanic Belt (TMVB) is an E-W-trending volcanic arc located between 19° and 20°N in central Mexico, which has been active from the Oligocene to the present. Its origin is related to the subduction of the Cocos plate beneath North America. The Basin of Mexico is a hydrological closed basin located in the central-eastern part of the TMBV, where a lacustrine system developed from the closure of the basin by the emplacement of the Chichinautzin monogenetic volcanic range in the southern part, nearly 1.3 Ma ago. The basin has been populated since pre-Hispanic times, and nowadays houses Mexico City megalopolis and its nearly 22 M inhabitants. Monogenetic volcanic activity poses an important hazard for the region, as lava flows, ash fallout, phreatomagmatic activity and pyroclastic flow emplacements. Numerous works of volcanic stratigraphy and petrology have been carried out in the exposed units; however the characteristics of the older deposits covered by the products of the most recent activity are little known. The International Continental Drilling Program in Chalco basin recovered ca. 420 m long lacustrine and alluvial sedimentary sequence overlying a series of ca. 100 m thick lava flows. The petrological characteristics of these deposits will allow understanding the geologic history of the Basin of Mexico.

Five lava flow units were recognized according to the burned contacts between them. Lava flows show different degrees of crystallinity (holocrystalline - hypocrySTALLINE), characterized by porphyritic, glomeroporphyritic, optic, trachytic, and pilotaxitic textures. Phenocrysts of olivine and plagioclase with simple twins and concentric extinction are presented. The alteration phases in the olivine and the plagioclase are iddingsite and epidote, respectively. Zeolites are also present. The vesicles vary in size and shape, and some of them are filled with calcite. TAS diagram shows that the lavas are basalt-basaltic andesite in composition.

## **S22-P04\* - The sedimentary architecture of the lacustrine successions between Chalco and Xochimilco basins, central Mexico.**

**Beatriz Ortega (1,6), Sandra Garcia (2), Guadalupe Cruz (3), Matthias Bucker (4), Marco Albarran (2), Margarita Caballero (1), Lizeth Caballero (2) Yoselyn Gomez (1), Luis Placencia (5) and Socorro Lozano (6)**

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The sedimentary sequences of lakes in central Mexico have provided detailed records of past climatic and environmental variability. However, in this region the active volcanism and tectonism may also influence the lacustrine sedimentation. The Basin of Mexico is a hydrological closed basin located in the central-eastern part of the Trans Mexican Volcanic Belt (TMVB). The TMVB is an E-W-trending volcanic arc located between 19° and 20° N in central Mexico, which has been active from the Oligocene to the present. Its origin is related to the subduction of the Cocos plate beneath North America. In the Basin of Mexico, several sub-basins developed in response to volcanism, tectonism and subsidence. A lacustrine system developed from the closure of the basin by the emplacement of the Chichinautzin monogenetic volcanic range in the southern part, nearly 1.3 Ma ago. The basins to the south are the Xochimilco basin to the W and the Chalco basin to the E. The lacustrine / volcanoclastic sequences of both basins were recovered in drilled cores close to their depocentres. A 122 m long sedimentary sequence analyzed in Chalco basin spans the last ca. 150 kyr. The sedimentary components and physical properties vary markedly in response to climatic and environmental fluctuations. At 106 m depth, the Chalco sequence record the end of the MIS6 (150–130 kyr), where a relatively deep, stratified, freshwater lake is recorded. After the MIS6/MIS5 transition (130 kyr) and until the MIS3/MIS2 transition (29 kyr), the lake changed to alkaline-subsaline, and variations in carbonate precipitation suggest in general relatively low lake levels. Xochimilco sequence also show this general pattern; however, these main phases are recorded at shallower depths (> 30 m difference), suggesting a higher subsidence in Chalco basin. The changes in the architecture of lacustrine sequences are caused by tectonic subsidence.

## **S22-P05 - Paleolimnological and geophysical studies in mid-elevation lakes of the Lacandon Forest, Chiapas, Mexico**

**Liseth Pérez (1), Matthias Bücker (2), Adrián Flores Orozco (2), Jakob Gallistl (2), Carlos Pita (3), Emilio García (3), José Alberto Razo (3), Paula Echeverría (4), Karla Rubio (5), Anaís Cisneros (6), Azálea Pérez (6), Martín Garibay (6), Itzel Sigala (6), Fernanda Charqueño (7), Julieta Massaferró (8), Christoph Mayr (9), Alexander Correa-Metrio (1), Juan Felipe Franco-Gaviria (10), Mark Brenner (11), Antje Schwalb (4)**

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Most paleolimnological studies in the northern Neotropics, especially in Mexico, have been carried out in either low- or high-elevation lakes. The Lacandon Forest of Chiapas, southern Mexico, hosts a number of mid-elevation (~500-900 m a.s.l.) karst lakes. We carried out paleolimnological studies in these solution lakes using multiple aquatic (ostracodes, cladocerans, chironomids, gastropods, testate amoebae) and terrestrial bioindicators (pollen, charcoal) and geochemical variables (element contents, stable isotopes). Ecological information was lacking for most taxonomic groups. We therefore studied modern species assemblages in combination with selected limnological variables to better understand the ecology of each taxon. Lakes Lacandón, Metzabok, Nahá, Tzibaná, and Ocotalito yielded sediment records that enabled high-resolution inferences for Holocene climate and environmental changes. The oldest record we obtained came from Lake Ocotalito (~9,540 cal yr BP). Our multi-variable study across an altitudinal transect in the Lacandon Forest enabled us to make robust inferences about the Holocene history of this region. It also provided us with a better understanding of aquatic and terrestrial species optima and tolerances, as well as the timing of their responses to past climate and environmental changes.

Our results highlight the importance of these mid-elevation lakes for constructing a regional picture of climate and environmental change across the northern Neotropics. Until now, we have only been able to retrieve cores of Holocene age from these basins and it remains unclear whether the study lakes contain older deposits. We applied geophysical exploration methods (high-resolution bathymetric surveys, sub-bottom seismic profiling, waterborne electric and electromagnetic surveys) to obtain more information about the general geologic settings of the lakes in the study area and, in particular, to determine the thickness of their lacustrine sediments.

These geophysical datasets contain information about the geology, hydrology, and even archaeology of these sites, and illustrate the value of such methods for paleolimnological studies.

## **S22-P06 - Late Holocene environmental history of karst Lakes Nahá and Metzabok, Lacandon Forest, Chiapas, Mexico**

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Karst Lakes Nahá (area = ~57 ha,  $z_{\max} = 30$  m) and Metzabok (area = ~77 ha,  $z_{\max} = 25$  m) are located in the biodiverse Lacandon Forest, in the state of Chiapas, southern Mexico. We present high-resolution paleoenvironmental inferences for the last ~300 years, using invertebrate remains (ostracodes and gastropods) and geochemical variables in sediment cores from the two water bodies. We collected a short, mud-water-interface sediment core from Nahá (60 cm) and Metzabok (46 cm). Uppermost sediments in the cores were dated using  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$ , and the bottom was dated by  $^{14}\text{C}$ . Ostracodes and snails were identified to species level and their abundances quantified. Concentrations of metals (Ca, Sr, and Fe) were determined by XRF. All analyses were carried out at 1-cm intervals. Preliminary results suggest that changes in ostracode assemblages are associated with fluctuations in water level, whereas gastropod community composition is related primarily to temperature. These biologically based inferences are confirmed by the geochemical record, as Ca and Fe concentrations are evidently related to the ratio between evaporation and precipitation. Interpretation of Fe stratigraphy is complicated because the metal is redox-sensitive, but its co-variance with other terrigenous indicators (i.e. Ti, Zr) shows that it, too, is a terrigenous input proxy. The geochemical records show fluctuations throughout the cores. However inputs of terrigenous materials increase upcore, except in the last ~17 years, when these decrease. Although these general relations were detected in both lake records, the record from Nahá displays abrupt variations, whereas the record from Metzabok appears to have been less variable. Overall, the sediment records from both Lakes Nahá and Metzabok indicate an upcore trend toward drier conditions, as inferred from an increase in relative abundance of the ostracode *Cytheridella ilosvayi* and a general decrease in all gastropod species in the most recent sediments.

## **S22-P07\* - Hipercorig – The new coring tool for sediments in operation**

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A new, very compact rig on a barge system to recover continuous sediment cores down to 100 m depth in water depths of up to 300 m is currently being released for use by the scientific community. The device will close the critical gap between simple, man-powered piston corers reaching max. 20 m coring depth versus professional water-well or exploration type drill rigs capable of retrieving hundreds of meters of core.

A crucial issue of small piston corers is the loss of power from the top drive along the drill string due to dampening effects. Hipercorig utilizes a down-the-hole water hammer directly above the piston. This novel design integrates advanced, inexpensive piston coring with field-proven, hydraulic hammer techniques powered by a high-pressure pump in a modular, mobile system. It includes a modular barge platform, the complete coring system, iron roughneck, winches, service boat and other auxiliary equipment, all transportable in four 20-foot standard containers. Areas of operation do not only include lakes, estuaries and shallow marine areas, but also bogs, environmental sites and similar on land sites. The system has been constructed and tested on Lake Mondsee and Lake Constance in Spring 2018. Barge deployment can be achieved manually without docks and heavy cranes due to its modular, light-weight design. Cost of operations depend mainly on mobilization, consumables and staffing with two coring experts plus at least two helpers.

Hipercorig will be available for funded scientific projects capable to cover expedition costs plus a maintenance fee guaranteeing to sustain the rig functionality including repairs, spare parts and improvements. Decisions for utilization will be made upon a written proposal to the German Scientific Earth Probing Consortium, GESEP e.V.

## **S22-P08 - Unravelling the Holocene environmental history of Lake Chad**

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The Lake Chad basin (LCB) is an intracratonic basin dating from the Phanerozoic located in central Africa, at the northernmost boundary of the semi-arid Sahel belt and south of the Sahara desert. Lake Chad, which occupies the LCB, lies in the direct path of the Inter-Tropical Convergence Zone (ITCZ) seasonal migration. While over 80% of the water input to the lake comes from the Chari-Logone River system that drains waters from the tropical Savannah in the south, the remaining 20% of water input enters from direct rainfall and from the Komadougou Yobe River system from the west. The water outputs are mainly through evaporation (95%) and lake-floor seepage (5%). Therefore, Lake Chad is ideally situated to study the temporal and spatial variability of summer monsoons in West Africa.

The current study shows results from a high resolution Chirp geophysical survey complemented by coring on Lake Chad. The results show that the sedimentary infilling of the lake can be divided into five internal seismic units identified by their distinctive different seismic facies. Petrophysical and sedimentological measurements carried out on the cores allow calibrating the different seismic units into chronologically-confined lithological units. The results of this study show important fluctuations during the Holocene, including those of the Mega-Chad Lake (African Humid Period) and throughout the receding interval into the current conditions.

## S22-P09 - The oldest chitinous fossil remains of Cladocera from Miocene (12–8 million years ago) oxbow lake (Central Poland)

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Well preserved Cladocera remains were found in samples of Neogene (Miocene, stage Serravalian and Tortonian) deposits collected in outcrop of the Bełchatów Lignite Mine, Central Poland (51°15'46,4"N 19°18'49,2"E). They were accompanied by numerous plant macroremains (mainly leaves) and sporomorphs (pollen grains and spores) plus algal microremains (*Botryococcus*, *Closterium*, and *Zygnemataceae*). In the studied samples were found Cladocera taxa belonging to the genus *Alona* and *Camptocercus*, as well to genus *Chydorus* (*Chydorus* cf. *sphaericus*). All taxa were determined on preserved shells, head shells and postabdomens. The conducted analyzes are preliminary and will be continued. The latest middle Miocene to late Miocene age (ca. 12–8 Ma BP) has been considered for these deposits presumably formed in an abandoned channel of a meandering or braided river with stagnant or slowly moving water which is suggested by presence of leaves and pollen of *Potamogeton* as well as pollen of *Alisma*, *Nuphar* and *Typha/Sparganium*. Results of palaeobotanical investigations suggest warm temperate and moderately wet climate, comparable to the Cfa climate type (warm temperate, fully humid with hot summer) in the Köppen-Geiger climate classification. The mean annual temperature of 13.5–16.5 °C was estimated on the basis of plant macroremains.




## **S22-P10 - The characteristics and origin of unifite in organic rich mudrock in the Eocene Jiyang Depression, Bohai Bay Basin, China**

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Unifite refers to mudrock with internally homogeneous characteristics and an absence of laminae. Previous studies were primarily conducted in the marine environment, while notably few studies have investigated lacustrine environment. Based on core observation in the lacustrine environment of the Jiyang Depression, Bohai Bay Basin, China, unifite is common in deep-water organic-rich mudrock. The unifite are sharply delineated at the bottom and top contacts, abundant in angular terrigenous debris, and associated with oxygen rich but lower water salinities in comparison to adjacent black shales. Unifite exactly distributes in the distal part of deep-water gravity driven sandstone units, and shows scoured bases, high angle mineral crystals, and fining-upward trend. It is suggested that it is a turbiditic mudrock deposited by settling from dilute turbidity currents. A warm and humid climate and high subsidence rate are two main triggering events. Dilute turbidity currents are able to greatly entrain biochemically formed micrite and planktonic organisms from the water column, and deposit them in the turbiditic mudrock. The turbiditic mudrock is able to be a potentially effective source rock. The minerals in the unifite are disorganized and chaotic, which cause fractures to develop in various directions, thereby, enhancing the vertical migration of oil and gas molecules to horizontal wellbore in shale reservoir exploitation.



Landscape  
paleolimnology: a  
powerful approach for  
examining pressing  
environmental problems  
facing lakes at regional  
and global scales

*Irene Gregory-Eaves, Katherine Griffiths and Jean-Philippe Jenny*

Session 23



## Oral presentations

### **S23-001 - Linking contemporary species distribution maps and palaeoecological data to locate refugia for aquatic flora and fauna in the modern landscape**

**Helen Bennion (1), Ambrose Baker (1), Carl Sayer (1), Carole Roberts (1), Simon Turner (1), Viv Jones. (1), Paul Wood (2), Malcolm Greenwood (2) and Neil Rose (1)**

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Connectivity, by which energy, materials and genetic resources move within and between hydrological units of the landscape ('hydroscape') is a fundamental property of aquatic systems. However, connectivity also exposes fresh waters to multiple stressors. Thus, to manage fresh waters sustainably into the future, there is an urgent need to understand better how altered connectivity affects stressor delivery and determines biological response. Connectivity can influence the timing, trajectory and potential for biological recovery yet the endpoints of such recovery are unclear because the source of organisms required to achieve restoration targets, and the constraints on their dispersal, are often unknown. If former inhabitants no longer exist in the contemporary regional species pool, a novel ecosystem may result.

Using examples from selected UK lakes, analysed as part of a large interdisciplinary research programme (Hydroscape), we link contemporary species distribution maps to palaeoecological data (pre-1850) and determine how restoration endpoints are influenced by connectivity. We present plant and animal macrofossil records for the selected lakes to assess biodiversity loss over time and explore contemporary data to locate biodiversity refuges in the surrounding landscape. We focus on macrophytes and caddis flies and determine from which locations in the modern hydroscape species must be sourced to achieve restoration goals when stressors are reduced. The implications of restoring sites which are spatially separated from source populations of desirable colonists are considered, along with the possibility of identifying functionally equivalent alternative species; we determine if, without such species, restored ecosystems are likely to develop novel assemblages.

## **S23-O02 - Landscape Paleolimnological Insights from the Canadian Lake Pulse Network (lakepulse.ca)**

**Irene Gregory-Eaves (1), Alexandre Baud (1), Rebecca Garner (2), Katherine Griffiths (1), Adam Jeziorski (3), Paul MacKeigan (1), Cindy Paquette (4), Brigitte Simmatis (3), Marc Amyot (5), Dermot Antoniadis (6), Pierre Francus (7), Beatrix Beisner (4), Yannick Huot (8), Alex Poulain (9), David Walsh (2) and John Smol (3)**

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Canada is the steward of many of the world's lakes. Surprisingly, though, there has never been a systematic, national limnological or paleolimnological study to date. To address this gap in scientific knowledge and provide essential data to enable stakeholders to make informed decisions, the Lake Pulse Network was launched. The Lake Pulse Network is a multi-year, collaborative initiative investigating the health and functioning of Canadian lakes. Lakes larger than 0.1 km<sup>2</sup> are being selected at random across 13 different Canadian ecozones, using a blocked design to control for three different levels of watershed land use and three different ranges of lake surface area. In summer 2017, the first 217 lakes from across eastern Canada were sampled for ~100 different parameters by five teams trained to follow a standardized protocol. An additional two years of sampling will allow for the collection of data from a total of 680 lakes across Canada. An important theme of the Network is to assess "where, by how much and why have Canadian Lakes changed due to human activity." Our team is investigating this theme by employing paleolimnological methods to assess how lakes have changed over the past ~200 years. We are conducting comparative analyses of contemporary and pre-industrial sediments (i.e. a "top-bottom" approach) across a large suite of network lakes and employing a breadth of different indicators including chironomids, chlorophyll a, cladocerans, diatoms, DNA, and mercury. Full core analyses from a subset of lakes are also being performed. For example, high-resolution instruments (XRF and CT-scanners) are providing novel estimates of the enrichment of heavy metals since pre-industrial times. Lakes sampled in 2017 captured a wide range of morphometry, water clarity and water chemistry across Eastern Canada. Our preliminary findings will be presented within this limnological context and historical landscape changes.

## **S23-O03 - Inferring past environments across the Lake Pulse Network: Tracking diatom changes across four Canadian ecozones**

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Canada is a land of lakes, but these waterbodies are increasingly under strain from anthropogenic stressors. The Lake Pulse Network ([lakepulse.ca](http://lakepulse.ca)) is a collaborative, systematic investigation of lakes spanning 13 ecozones, with the objective of creating the first nationwide database of Canadian lake health. To that end the network has committed to sampling 680 lakes, across a range of sizes and varying degrees of anthropogenic impacts, over three years. Intrinsic to the network is the question of "where, by how much and why have Canadian lakes changed due to human activities?" To address this objective, we are conducting top-bottom analyses on sediment cores from a subset of the sampled lakes, while maintaining the blocked design of the original survey by selecting sites with a variety of size classes and watershed impacts. Here we present top-bottom analyses of diatoms from 50 lakes from 4 ecozones in eastern Canada (Atlantic Maritimes, Atlantic Highlands, Boreal Shield, and Mixedwood Plains) sampled during the first field campaign. Preliminary analyses suggest that the lakes from the Mixedwood Plains experienced, on average, significantly ( $p < 0.05$ ) greater shifts in the diatom assemblages than the other ecozones. The diatom assemblage shifts from the pre-industrial (bottom) to contemporary period (top) from the Mixedwood Plains are reflective of nutrient enrichment. This observation is consistent with the current land-use/land cover patterns of Mixedwood Plains, which is characterized by extensive agricultural development and has the greatest human population density relative to all other Canadian ecozones. In contrast, deeper lakes from the Boreal region with low to medium anthropogenic impacts showed more muted shifts in diatom assemblages. Ultimately, this landscape-level survey of Canadian lakes will provide stakeholders the tools and information necessary to better manage these vital aquatic ecosystems.

## **S23-004 - Using paleolimnological baselines to assess sources and pathways of metals in surface sediment of floodplain lakes (Peace-Athabasca Delta, Alberta, Canada)**

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The Peace-Athabasca Delta (PAD), northern Alberta, Canada, is the world's largest freshwater boreal delta. The ecological integrity of the delta is strongly tied to river floodwaters that are critical for replenishing the delta. The floodwaters also transport sediment, nutrients and contaminants from upstream sources. Since the PAD is located downstream of the Alberta oil sands, concerns have been raised over the potential transport of metal pollutants to the PAD via the Athabasca River. However, metals may be transported to the PAD by several pathways, including the Athabasca and Peace rivers and atmosphere, but their origin and distribution remain unknown. To address this knowledge gap, surface sediment samples (top ~1-cm) were collected in September 2017 from 62 lakes throughout the delta to provide a snapshot of metal (Be, Cd, Cr, Cu, Pb, Ni, V, Zn) concentrations that have accumulated during recent years. Despite concerns about the potential for Athabasca River transport of metal contaminants to the PAD, raw concentrations of metals are higher in the surface sediment of lakes located in the Peace sector than those within the Athabasca sector. To assess for pollution, metal concentrations were normalized to aluminum and then compared to baseline metal-aluminum relations for the Athabasca and Peace sectors developed from pre-1920 measurements in lake sediment cores. Apart from a few lakes in the delta that show a slight enrichment of zinc values, most metal concentrations plot consistently within the 95% prediction interval of the pre-1920 baselines including vanadium and nickel which are metals most commonly associated with oil sands production. Thus, results presented here show no clear evidence of recent oil sands derived metal pollution in lakes in the PAD. This study demonstrates the usefulness of paleolimnological approaches for developing baseline reference conditions necessary for the interpretation of lake surface sediment metal concentrations.

## **S23-O05 - Regional paleolimnology reveals widespread stressors**

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Long-term records of environmental condition are critical for diagnosing region-wide anthropogenic impacts and establishing best management practices. Extending paleolimnology from single lakes to large regions should enable detection of widespread stressors such as climate change and atmospheric deposition. Using assemblage similarity analysis on diatom paleorecords from 100 Minnesota lakes we characterized periods of spatially consistent change over the last 150 years. While we expected localized stressors such as agriculture and urban development to drive assemblage reorganization in specific lakes, overarching stressors such as climate change should be discernable in the regional analysis. We hypothesized that this overarching shift would manifest as diatom assemblage reorganization from low-nutrient to higher-nutrient taxa and, more recently, species that indicate warmer atmospheric temperatures, warmer surface waters, and shifts in lake thermal structure. We specifically test whether diatom communities are stronger indicators of multiple regional stressors than other common paleolimnological proxies.

## **S23-O06 - Using palaeoecology to examine the controllers of state and sensitivity in Australian billabongs (floodplain lakes)**

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Billabongs are diverse and productive elements of riverine landscapes and play an important functional role as refugia in these highly variable environments. There is strong historical evidence that billabongs in Australia have been negatively affected by human activities such as catchment disturbance and river regulation. Improved catchment management and delivery of environmental water have potential to mitigate the effects of land use and hydrological change, however, the effectiveness of these measures requires a good understanding of the critical stressors and of how and why their influence varies in the diverse array of billabongs that exists in riverine landscapes. Many palaeo records from the Murray-Darling Basin show evidence of abrupt loss of submerged plants associated with the beginning of European occupation, however, this change is not consistent. Some billabongs show loss of macrophytes; others show persistence of macrophytes; while third group shows an unstable character with no evidence of submerged macrophyte communities persisting for long periods. It is unclear whether this pattern reflects spatial variation in stressor intensity or underlying variation in the resilience of individual billabongs due to hydro-geomorphological or landscape setting. This study explores the relationships between billabong ecosystem states prior to and following European occupation and the degree of change in states and a range of morphological, landscape and climate measures in an effort to determine the critical factors controlling resilience to the effects of land use and hydrological change.



## **S23-O07 - Land-lake interactions of trace metals in UK lake landscapes**

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Metal concentrations observed in lake biota and sediments reflect both contemporary inputs but also, often overlooked, catchment re-mobilised (legacy) metals. Resolving the balance of inputs between current and legacy sources is critical in both our understanding of the flow of trace metals into lake ecosystems, improving our interpretation of metal contaminant palaeolimnological records and predicting future inputs. Landscape-scale aquatic connectivity is an important factor of trace metal concentrations found in lakes; influencing both the transport of metals through catchments, uptake by biota and subsequent storage in lake sediments. Enhanced lake-land interactions in relation to legacy and contemporary metal contaminants may not always be beneficial to lake ecosystems.

Data from multiple lakes with different connectivity metrics are being studied as part of a large interdisciplinary programme (NERC Hydroscape) in three contrasting aquatic landscapes in the UK (Norfolk Broads, Glasgow and the Lake District). These landscapes have a considerably varied history and intensity of land-use changes due to industrialisation, urbanisation and agriculture. Radiometrically dated sediment cores are being used to produce historical inventories of trace metals (Hg, Pb, Zn, Cd, Ni and Cu) to assist in distinguishing between legacy and contemporary sources of contaminants. Radionuclide and trace metal inputs are also evaluated by measurement of catchment soils, atmospheric deposition and lake biota (aquatic plants, zooplankton and fish).

We present multi-metal sediment, soil and biota data from across the three UK aquatic landscapes that assess historical metal loadings and the extent that geographical location and connectivity within the landscape has influenced both the palaeolimnological record and contemporary ecological effects due to continued legacy metal inputs.

## **S23-O08 - Destruction of associated wetlands as a contributing driver of lake eutrophication in Florida USA: Integrating modern and historic studies for landscape-level ecological assessments**

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Florida USA represents a district of 8000 warm-temperate and subtropical lakes. Approximately 50% of the state's area was freshwater wetlands prior to 1800 A.D. (83, 916 sq. km), but 50-66% of those wetlands were destroyed since c. 1800 by drainage and filling, and by engineered alteration of lake levels that left fringing wetlands stranded and subject to drying. Loss of associated wetlands was particularly extensive from residential and urban development on lake shorelines in the 20<sup>th</sup> century, but long-term written documentation is poor to non-existent. Allogenic colored dissolved organic carbon (C-DOC) from fringing wetlands exerts well-recognized effects on primary productivity, particularly at lower levels of limnetic nutrient concentrations. Analysis of several large data sets, however, shows lower chlorophyll *a* levels per unit phosphorus in high-C-DOC lakes across a wide range of water quality. Loss of color, therefore, is likely to have exacerbated algal production as nutrient loading proceeded in eutrophied lakes. Diatom assemblages that suggest wetland presence are nearly ubiquitous at the base of cores we've studied from Florida lakes. Paleolimnological evidence shows that many poorly buffered lakes experienced alkalization, which we interpret as partly due to the loss of allogenic inputs of humic and fulvic acids from loss of fringing wetlands. We use Geographic Information System Mapping Technology (GIS) to examine the distribution of fringing wetlands and their apparent loss for selected areas with dense lake distributions, and present paleolimnological evidence about the loss of wetlands, changes in C-DOC, and alkalization for several case-study lakes. We examine the use of biological indicators (e.g., diatoms, pollen) for assessing changes in color and pH, and spectrophotometric methods for detecting sediment markers. Our studies suggest that the protection and restoration of fringing wetlands are of considerable importance for effective management and conservation of freshwater lakes in this region.

## **S23-O09 - Lake ecosystem shift caused by social-economic transitions: case from Yangtze River Basin, China**

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Globally, many freshwater lakes have undergone rapid degradation over the past century. Lake scientists and managers are struggling with enhancing lake ecosystem resilience to cope with escalating anthropogenic pressures. A better knowledge on how lakes and social systems evolved up to the present is vital for understanding, modeling and anticipating the current and future ecological status of lakes. By integrating paleoenvironmental, instrumental and documentary sources at multi-decadal scales, we demonstrate how typical shallow lake socio-ecological systems evolved over the last century in the Yangtze River Basin, a biogeographic region containing hundreds of shallow lakes. We find that an abrupt ecological shift, expressed as a significant reorganization of lake aquatic species and communities, occurred around the AD 1970s. Land reclamation, hydrological modification, and pollution seem to have acted directly and synergistically to cause this shift. We argue the lake socio-ecological systems went through three stages as society transformed from a traditional agricultural to an urbanized and industrialized society. The dominant feedback has changed from conventional farmer-ecosystem feedback to newly formed socio-economic and ecosystem feedback, due to increasing population, social wealth and resource demand during the last decades. Our results highlight the importance of accounting for the long-term dynamics and feedbacks between ecological, social and economic changes when defining safe operating spaces for sustainable freshwater ecosystem management.

## Poster presentation

### **S23-P01 - A quantitative synthesis of the dynamics and drivers of lake sedimentation over the past 150 years**

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Sediment accumulation rate is a key metric of lake functioning that has a wide range of ecological implications, from lake infilling to carbon sequestration. Lake sediment records and the rates at which sediment accumulates also reflect complex changes in hydrological and anthropogenic processes occurring within the ecosystem. For this study, data published in the *Journal of Paleolimnology* between 1989–2016 were digitized to gather records from over 500 sites worldwide. In particular, data on sediment infill rates (measured as  $\text{mm}\cdot\text{year}^{-1}$ ) and mass accumulation rates ( $\text{g}\cdot\text{cm}^{-2}\cdot\text{year}^{-1}$ ) were collected over the past 150 years. For each site, key watershed variables including watershed size, slope and land-use metrics were also extracted to quantify the relative importance of these parameters. Based on previous work, we hypothesized that geographic variables would be important predictors but expected that watershed morphometry and land use would also be significant predictors. General additive models applied to mass accumulation rate data provided evidence of temporal increases in lake sedimentation, showing a general pattern of steeper increases following 1950. Furthermore, preliminary regression tree analyses of the sediment infill rates showed that 35% of the variance was accounted for and important predictors included cropland density in the watershed and altitude. Interestingly, urban density was observed to account for only 3% of the variance when considering watersheds on a global scale, but nonetheless exhibited strong positive and localized effects on lake sedimentation when considering a subset of watersheds with high urban densities. Our current work shows that despite a wide range of natural variability, sedimentation is increasing in lakes around the world and appears to be the result of increases in cropland and urban density in lake watersheds.

## **S23-P02 - Discerning the effects of major energy projects, climate and change in distributary flow paths on hydrology of lakes in the Athabasca Delta, Canada**

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The Peace-Athabasca Delta (PAD) in northern Alberta, Canada, is the world's largest boreal freshwater delta. For the past 50 years, there have been many unresolved concerns over the potential effects of major energy projects, climate change and reduced river discharge on lakes in the delta. In 2017, a report by UNESCO/IUCN has reignited these concerns by declaring that hydroelectric regulation of the Peace River by the Bennett Dam has reduced flood frequency and lowered lake levels in the PAD. In response to concerns about drying in the PAD, paleolimnological analyses at three lakes along the unregulated Athabasca River previously identified that hydrological conditions in the southern Athabasca sector of the delta are strongly influenced by recent geomorphic changes in distributary flow. Yet, uncertainty remains regarding the extrapolation of these results over space and time across the Athabasca Delta, given its hydrological complexity. Consequently, sediment cores were collected in summer 2015, 2016 and 2017 from eight lakes along a ~45 km transect in the Athabasca Delta to assess spatial and temporal patterns of variation in hydrological conditions and their drivers. Results from loss-on-ignition analyses on <sup>210</sup>Pb-dated sediment profiles, a simple and effective proxy for river floodwater influence, show directional hydrological change in recent decades to reduced flooding in the Athabasca Chipewyan First Nation Reserve and adjacent regions, and increased flooding along a reactivated distributary. The timing and patterns pinpoint the 1982 Embarras Breakthrough, a natural geomorphic event that diverted flow northward and away from the First Nation Reserve at the Athabasca Delta terminus as the principal cause, not the widely perceived Bennett Dam.

## **S23-P03 - Interaction of climate and morphology in the evolution of a proglacial lake in the south of Kamchatka**

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Lake Sokoch lies at the upper boundary of stone birch forest in the Central Kamchatka Mountain Chain in the south of the central Kamchatka depression (53°15.133'N, 157°45.489'E, 495 m a.s.l.). The lake consists of two lake basins connected with a 500 m channel cutting a moraine arc between the two basins. The main lake basin (Lake Sokoch) is 1000 / 750 m in size, with a maximum water depth of 7 m. The smaller lake basin (Lake Maly Sokoch) is situated to the north of the main lake and is now ca 300 m in diameter but was likely larger in the past. The lake was formed at about 9.4 cal ka BP. This interval was characterized by glacial meltwater runoff with a high detrital sediment supply, a low biological productivity, and conditions that were alkaliphilous, meso- to eutrophic, and shallower than today. Between 9.0 and 6.2 cal ka BP lake-level rise, biological productivity enhances, and trophy level decreases to meso- to oligotrophic conditions. The interval between 6.2 and 3.0 cal ka BP was probably strongly influenced by climate conditions and a volcanic eruption that temporarily changed the water chemistry at about 4.1 cal ka BP. The wetter conditions led to an enhanced fluvial runoff, stronger nutrient influx and increased trophy level. Temperature cooled after 3.1 cal ka BP, consistent with glacier advances in the wider catchment. Between 2.7 and 1.6 cal ka BP, limnology returned to more oligotrophic conditions. The youngest interval, since 1.6 cal ka BP, was characterized by shallow-water conditions. Climate cooling culminated during the Little Ice Age. The inferred long-term climate trend for Kamchatka is consistent with the typical pattern of mid-latitude Asian climate through the Holocene, with a prolonged early Holocene warming, a climate optimum in the mid-Holocene and climate deterioration towards the late Holocene.

## **S23-P04 - Pre- to post-human disturbance water quality and diatom community changes in clay vs. fine-grained till catchments**

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Boreal freshwater ecosystems are facing many environmental problems, such as eutrophication. Water quality monitoring programs often postdate anthropogenic disturbances and, thus, paleolimnological methods are commonly used for defining past environmental conditions. However, these studies have mainly concentrated on examining temporal changes from single lakes leading to a lack of spatial studies about the interaction of lakes and their catchments. Shallow and naturally eutrophic lakes, in particular, require further studies.

In our spatial paleolimnological study, we used top-bottom diatom sampling and multivariate statistics to examine the pre- and post-human disturbance conditions of 70 mainly small and shallow lakes. The lakes are located on two geologically contrasting regions that have different land use histories. Till-dominated Eastern Finland was permanently inhabited as late as in the 16<sup>th</sup> century, while the clay-rich Southern Finland has a long land use history. However, both regions currently display notable total phosphorus (TP) gradients. Our aims were to examine the spatial distribution of naturally eutrophic lakes and its relation to surficial geology as well as the pre- to post-disturbance changes in diatom assemblages and water quality in the two regions.

Our results show that, despite the contrasting geologies, relatively similar pre-disturbance TP gradients exist in Eastern and Southern Finland. Naturally oligotrophic lakes are located on coarse-grained till-dominated areas, whereas fine-grained till (Eastern Finland) and clay (Southern Finland) are abundant in the catchments of naturally eutrophic lakes. Many lakes show similar pre- to post-disturbance diatom assemblage changes and water quality trajectories towards eutrophication, salinization, alkalinization, and brownification. Shallow, naturally eutrophic lakes with short water residence times have been particularly susceptible to these changes. Our results suggest that variation in glacial landforms can result in a steep natural TP gradient, while lake morphology is important in explaining the sensitivity of a lake to anthropogenic disturbances.



# Lakes in the geologic record

*Sila Pla-Pueyo and Mathieu Schuster*



Session 24



## Oral presentations

### **S24-001 - Paleo-Rivers and the Origins of the World's Largest Na-Carbonate Evaporite Deposit: Eocene Green River Formation, Western U.S.**

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Sodium carbonate evaporite deposits are relatively rare because they require nonmarine parent waters with  $[\text{HCO}_3^- + \text{CO}_3^{2-}] > [\text{Ca}^+ + \text{Mg}^{2+}]$ . Modern deposition of trona, nahcolite, and other sodium carbonate minerals is commonly associated with nearby active volcanism, suggesting that excess alkalinity may be derived from magmatic  $\text{CO}_2$  in waters emanating from hydrothermal springs. Paradoxically, deposition of the world's largest commercial sodium carbonate evaporite deposit, contained within the Eocene Green River Formation in Wyoming, was not associated with nearby active magmatism. Coeval magmatism was active ~200 km southeast in the Colorado Mineral Belt however, and rivers draining this area could have supplied excess alkalinity to Eocene lakes. Field studies along the course of a proposed paleo-river confirm deposition of fluvial and deltaic sandstone bodies with generally northwest-directed paleocurrents. Sandstone compositions are consistent with a sediment source in central Colorado, and include granitic, metamorphic, and volcanic rock fragments. U-Pb detrital zircon ages ( $n=567$ ) also show prominent spectral peaks that are consistent with derivation from the Colorado Mineral Belt and its host rocks. The youngest detrital age peak occurs at 58 Ma, ~5-6 my prior to the onset of trona deposition. Several factors could account for this apparent discrepancy however, such as variable zircon fertility in the parent rocks, time required to unroof and transport zircon grains, persistence of hydrothermal systems after magmatic zircons cooled through their U-Pb closure temperature, slight temporal mismatches between the sandstone and evaporite deposits, or dating errors. The results of this study thus are consistent with the hypothesis that riverine transport of alkalinity from the Colorado Mineral Belt contributed to trona formation in Wyoming. Paleo-rivers draining different segments of the Colorado Mineral Belt may also have contributed to deposition of nahcolite in the Piceance basin in northwest Colorado, a hypothesis that remains to be tested.

## **S24-O02 - Dynamics Study of Windfield of Middle Eocene Lacustrine Depositional Systems in the Dongying Sag, Eastern China**

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The windfield is one of fundamental factors to influence and control the development of depositional systems. Wind does not only directly act on the eolian sediments, it can also drive waves and currents to move and affect the distribution of the aquatic sediments. However, limited work has been on the restoration of paleo-windfield. This study proposes a technique to recover the paleo-wind direction and paleo-wind strength using the beach-bar sediments. The paleo-wind direction is obtained on the basis of the assumption that the trend of offshore bar is almost perpendicular to the propagation direction of waves, with steep and short leeward side and gentle and long windward side in the cross section. The paleo-wind strength is calculated using the following parameters: (1) the sedimentary thickness of the isolated offshore bar or gravelly beach ridge; (2) the average water depth; (3) the paleo-fetch; (4) the paleo-gradient; and (5) the angle between wind direction and the normal shoreline. The Dongying Sag is a half-graben lake basin during middle Eocene epoch located in the Bohai Bay Basin, eastern China. The study strata include upper Shahejie 4 Formation and lower Shahejie 3 Formation from bottom to top. The result indicates that the north wind with speed of 6.4–21.9 m/s and the southeast wind with speed of 6.3–14.6 m/s co-existed about 45 Ma ago. This study also found the strength of winds are decreased in the upper Shahejie 4 Formation from bottom to top and few thin beach-bars in the lower Shahejie 3 Formation could be used to reconstruct paleo-windfield. Therefore, the upper Shahejie 4 Formation containing beach-bar sediments is related to a strong windfield, while the lower Shahejie 3 Formation containing gravity flows sediments and mudstones belongs to a weak windfield.

## **S24-O03 - Composite stratigraphy and preliminary age model from Orakei Maar Paleolake (Auckland, New Zealand)**

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The Southern Hemisphere mid-latitudes are a key to understanding interhemispheric climate teleconnections, drivers and processes in the global climate system. However, long and high-resolution terrestrial paleoclimate records spanning the last glacial cycle from this region are few due to ocean dominance. Auckland maar (paleo-) lakes in New Zealand are a solution to this dilemma – providing well-laminated, continuous and high-resolution sedimentary records of terrestrial paleoclimate from which reliable chronologies are being developed beyond the <sup>14</sup>C dating limit.

The longest and highest-resolution sediment core has been recovered from Orakei maar which spans ca. 9 to 135 ka BP. The base of the record is Miocene Waitemata Group sandstone overlain by volcanic ejecta interpreted to be the product of the maar-forming eruption. The record is comprised of ca. 85 m lacustrine sediment below the marine/freshwater transition developed following the crater rim breach at ca. 9 ka associated with post-glacial sea-level rise. The sediment sequence covers the onset of finely-laminated lacustrine sediment and includes a multitude of basaltic, andesitic and rhyolitic tephra layers that enable the establishment of robust core correlation – within and between Auckland maar lakes as well as robust chronology development. We present the full composite stratigraphy for the Orakei maar paleolake (Auckland, New Zealand) which was established based on visual matching of stratigraphic markers between overlapping cores and aided by stratigraphically-based matching of time-series of magnetic susceptibility and  $\mu$ -XRF core scanning data.

Based on the Orakei maar lake composite stratigraphy and the identification of known-age tephra layers a preliminary age-model was established. The average sedimentation rate for this crater lake below the Rotoehu tephra (ca. 46 ka) is approximately 0.4–0.5 m/ka, and by extrapolation of the latter to the base of the composite record, an Orakei eruption age of ca 135 ka is proposed.

## **S24-004 - Controls on sedimentation of carbonate ephemeral lakes in fluvial systems: examples from the Pliocene-Quaternary in southern Spain.**

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The main controls that affect carbonate deposition in continental basins are widely recognised as climate, base level and tectonism. In the specific case of carbonate lakes related to siliciclastic fluvial systems, studies by other authors show that topography (linked to base level and spring level) and provenance have proved to be crucial for the precipitation of carbonate. On the other hand, climate is regarded as a minor factor, as these kind of lakes are found under all types of climatic conditions.

As continental carbonates are common occurrence in Neogene-Quaternary fluvio-lacustrine basins in southern Spain, several examples of carbonate ephemeral lakes developed in the medial-distal part of a number of fluvial systems have been selected in the Alcalá Basin, the Guadix-Baza Basin and the Granada Basin. Ephemeral carbonate lakes developed in connection to these Pliocene and Quaternary fluvial systems, either as part of their main course (as in the case of the fluvial-tufa systems of Frailes and Cubillas), as transverse systems (as in the case of the fluvial-tufa system of Rambla Becerra) or as carbonate lakes in a siliciclastic floodplain (as in the case of the Guadix Basin).

The combination of sedimentological studies, isotopic data and some available provenance studies from the literature are used to compare the ephemeral carbonate lakes forming in each system. Special attention is given to the proximity of carbonate-rich source areas, together with the potential supply of carbonate from the surface runoff vs. the groundwater. The main conclusion supports the importance of surface water and the presence of carbonate in the source areas as the main factors affecting the deposition of carbonate in the ephemeral lakes developed in connection with fluvial systems.

## **S24-O05 - Mantle driven drainage disruption and lake basin formation in the North American Cordilleran hinterland**

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The Cordilleran hinterland of northeast Nevada has been interpreted to have overlain a flattened Farallon slab from the Late Cretaceous to Eocene, and experienced lake basin formation coincident with slab removal. Slab removal and advection of asthenospheric mantle beneath Nevada have been invoked to explain a southwestward migrating wave of Eocene to Oligocene volcanism and topographic uplift. However, the timing of slab removal and subsequent delamination of North American lithospheric mantle can only ambiguously be related to the surface record. Subsequent Neogene extension and basin filling have complicated the correlation and interpretation of relevant strata. We apply single crystal sanidine  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology to more than 20 ash beds in northeast Nevada to reconstruct Paleogene landscape evolution, and use these new ages and legacy geochronology to assess competing tectonic interpretations for lake basin formation. Lakes formed locally at ca. 48.7 Ma, coeval with foreland lakes of the Green River Formation. The most expansive phase of lacustrine deposition occurred between ca. 43.4 and ca. 40.8 Ma, leading to onlap of fluvial deposits and paleovalleys cut in folded Paleozoic bedrock. A basin-wide transition from fluvial-lacustrine to fluctuating profundal lithofacies at ca. 42.7 Ma suggests a shift towards regional hydrologic closure. The stromatolitic upper Elko Formation is intercalated with ash fall tuffs and several partially welded to unwelded ignimbrites. The Elko Formation and overlying volcanic strata are overlain regionally by a pronounced unconformity of  $\sim 20$  m.y. We interpret the overall record of drainage ponding and paleovalley inundation, progressively evaporative conditions, increasingly proximal volcanism, and subsequent Oligocene unconformity to reflect the surface effects of progressive NE to SW removal of the Farallon slab at the end of the Laramide orogeny.

## **S24-O06 - An Early Pleistocene (1.9–1.7 Ma) lake-wetland sequence in southern Israel: greening the path of hominin migration Out of Africa**

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Several studies were previously carried out on this sedimentary sequence, with the aim of reconstructing the paleoenvironmental settings, mainly through methodological investigation of the microfauna assemblages. These previous studies show that the lacustrine sequence consists of chalky limestone with some banks of massive limestone alternating with marly to sandy-marly beds rich in gastropods, ostracods, fish remains, and charophytes. The fossil assemblage indicates a freshwater to hypersaline environment with salinity ranging between 0.5‰ and 70‰. Based on archeological artifacts corresponding to the Acheulean culture found on a nearby alluvial terrace, the top of the lacustrine sequence was assigned with a Lower Paleolithic age (~2.6–1.7 Ma).

The current study presents new results that expand our knowledge on the chronology and environmental settings of this lake system. Paleomagnetic measurements show a lower, normal polarity zone and a reverse interval in the upper part of the section. Considering previous exposure ages between 1.9 and 1.6 Ma measured on the pavement at the top of the columnar section, we correlate the observed polarity pattern with the top of Olduvai and the lowermost part of chron C1r. Hence, the Kuntula lacustrine sequence can be dated to approximately 1.9–1.7 Ma.

New analysis of the biological diversity show that the sequence mainly contains remains of very few species of ostracods, mostly recrystallized steinkerns of the euryhaline *Cyprideis torosa* and few shells of *Ilyocypris* (which is typical for freshwater and running water) or *Candona* (freshwater environments). The current study is further complemented by elemental analysis of the lithological sequence ( $\mu$ XRF), and allows to better understand the environmental settings prevailing in the region during the Early Pleistocene and to propose several mechanisms for the expansion of humid conditions at these latitudes.

## Poster Presentations

### **S24-P01 - Holocene deglaciation, isostatic uplift, and relative sea level changes in Lützow-Holm Bay, East Antarctica**

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The East Antarctic Ice Sheet (EAIS) is probably the largest unknown in identifying regional contributions to global sea-level rise since the Last Glacial Maximum. This is because geological constraints on its dynamics are still sparse, and the data that do exist indicate that the response of various sectors of the EAIS differs both in timing and rate of ice-mass change. Here we analysed fossil pigments, siliceous microfossils, sedimentology and geochemistry of radiocarbon-dated sediment cores from isolation and glacial lakes along an 80 km transect (from Skallen to Skarvsnes, Langhovde and the Ongul Islands) in Lützow-Holm Bay (East Antarctica) to determine the timing of deglaciation and regional isostatic uplift, and to develop Relative Sea Level curves (RSL). The geological constraints of the RSL were compared with output from two Glacial Isostatic Adjustment (GIA) models. The minimum radiocarbon age for regional deglaciation is c. 11,240 cal. yr BP on West Ongul Island with progressively younger deglaciation ages approaching the main regional ice outflow at Shirase Glacier. Marked regional differences in the magnitude and timing of RSL change were observed. In Skarvsnes a minimum marine limit of 32.7 m was inferred, which is c. 12.7 m higher than previously published evidence, and 15 m higher than that reported in the other three ice-free areas. Current GIA model predictions slightly underestimate the rate of Late Holocene RSL fall at Skallen, Langhovde, and West Ongul, but provide a reasonable fit to the reconstructed minimum marine limit at these sites. GIA model predictions are unable to provide an explanation for the shape of the reconstructed RSL curve at Skarvsnes. We consider a range of possible explanations for the Skarvsnes RSL data and favour an interpretation where the anomalously high marine limit and rate of RSL fall is due to reactivation of a local fault.



The background of the slide is a photograph of a vast, open landscape. The foreground and middle ground are filled with tall, dry grasses in shades of yellow, tan, and brown, suggesting a wetland or prairie environment. In the distance, a dark line of trees marks the horizon. The sky is filled with large, dramatic clouds, ranging from light grey to dark, stormy grey, with patches of blue sky visible.

# From Coast to Continent: Wetlands as Archives of Environmental Change

*Antonio Martinez Cortizas, Timothy Mighall, Malin Kylander and Richard Bindler*

Session 25



# Oral Presentations

## S25-001 - Making the quantitative link between the peat record and monitoring – why does “downwash” matter?

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Accumulation records of pollutant metals in natural archives, such as peat and lake sediment, have frequently been used to reconstruct past atmospheric deposition rates. To ensure that we extract not only a qualitative record from peat, we should also establish a quantitative link between the archive and the few decades of data that are available from contemporary monitoring. Herein, however, lies the challenge. While there is good support for peat as a record of relative changes in e.g. metal deposition over time, there has been limited critical examination of accumulation records in quantitative terms. For instance, some studies have reported difficulties in establishing a valid chronology due to displacement and/or suspected smearing of the radionuclide signatures ( $^{210}\text{Pb}$ ,  $^{241}\text{Am}$ ,  $^{137}\text{Cs}$ ). Others have shown that under certain conditions post-depositional downward movement of atmospherically deposited metals may also occur, which adds complexity to establishing reliable chronologies, as well as inherent problems of estimating accurate accumulation rates of peat and past metal deposition. Of the processes that can potentially influence the quantitative record, downwashing is particularly pertinent, as it would have a direct influence on how and where atmospherically deposited metals are accumulated in peat. By using a combined field and experimental approach, and by comparing our records to that of biomonitoring- and direct deposition data, we have investigated the potential downward mobility of metals (Pb, Hg, Cu, Zn) and radionuclides ( $^7\text{Be}$ ,  $^{241}\text{Am}$ ,  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$ ) in both ombrotrophic and nutrient-poor fen peat cores. This allowed us to successfully trace the depth to which downwash may occur and quantify the implications on estimates of peat mass accumulation rates and metal (Pb and Hg) deposition. More importantly, in order to link the peat archive to contemporary monitoring data, our data clearly shows that the phenomenon of downwashing – primarily driven by rainfall intensity and duration – must be taken into account.

## **S25-002 - Non-pollen palynomorphs provide new insight into the history of three ombrotrophic bogs from N Poland**

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Ombrotrophic mires are important archives of past environmental changes. Analyses of pollen, testate amoebae and plant macrofossils, supported by radiocarbon (AMS  $^{14}\text{C}$ ) dating provide information about peatland's development, past hydrological dynamics and forest succession. Such palaeoenvironmental reconstructions have been done for three Sphagnum bogs located in N Poland: Mechacz Wielki, Gązwa and Kusowskie Bagno. These reconstructions were carried out on cores dating back to 2000, 6000 and 4000 cal. yr BP, respectively and their age-depths models were recalculated according to an enlarged set of AMS dates. Moreover, the profiles were additionally supplemented with a new proxy – non-pollen palynomorphs (NPPs). NPPs, despite their increasing popularity in palaeoecological research, are still a poorly recognized group due to their heterogeneity. They represent microfossils of animal, plant and fungi origin, and most NPPs are still not identified to the genus level. However, the efforts to find the indicative value of particular types were undertaken. Hence, the main goal was to link different NPP types with environmental changes, by combining the obtained results with available qualitative and quantitative reconstructions. The NPP content was compared with the water level and pH derived from testate amoebae analysis, as well as local vegetation (reconstructed on the basis of plant macrofossil) and climate changes. The results show that NPP data are in agreement with other biotic proxies and help to improve the interpretation of environmental changes. We concluded that HdV-10 and HdV-90 are related to dry phases or water level fluctuations, whereas HdV-13, HdV-30 and HdV-37 occur mostly during wet shifts. Higher pH promotes the presence of HdV-29, HdV-77A and HdV-96A, whereas lower pH the appearance of HdV-35.

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## **S25-O03 - Predicting peat properties using FTIR-ATR and PLS: an application to Swedish peatlands (Store Mosse and Draftinge Mosse)**

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In peat research a decision is sometimes to be made of choosing between single (i.e. intensive) and multiple (i.e. extensive) peat cores studies. Sample and time constraints are also common when destructive and time consuming methods are applied. In this context, infrared spectroscopy is a promising alternative as it is non-destructive, easy to apply, requires none or minimum sample preparation and can yield valuable information on peat properties.

Using FTIR-ATR, we analysed two peat cores: one from Store Mosse (SM) and one from the adjacent, smaller, Draftinge Mosse (DM). Total C and N contents and isotopic ratios ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) were also determined ( $n=106$  and  $76$  samples, respectively). Partial least squares (PLS) modelling was applied using the SM spectra as predictors and the other properties as response variables. Validation was assessed in two ways: i) two thirds of the SM samples were used as training set and one third as validation set, and ii) all DM samples were used as validation set.

Highly significant models ( $R^2$  0.97–0.99), with 2–10 latent vectors (LV), were obtained for SM. Validation coefficients were very high ( $r^2 > 0.80$ ) for C, N and  $\delta^{15}\text{N}$  and high ( $r^2$  0.77) for  $\delta^{13}\text{C}$ . For DM, models were highly accurate for C ( $r^2$  0.92, 2 LV) and N ( $r^2$  0.94, 3 LV) and accurate for the isotopic ratios ( $\delta^{13}\text{C}$   $r^2$  0.69, 1 LV;  $\delta^{15}\text{N}$   $r^2$  0.70, 2 LV). Despite the lower performance, the predicted  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values reproduced the main features of the isotopic chronologies.

Our results indicate that FTIR-ATR combined with PLS i) is able to accurately predict peat properties in the same bog (helpful for multiple cores studies), and ii) the models can be transferred to similar peatlands of the same region, although the accuracy may vary between peat properties.

## **S25-004 - Peaty colours: 9000 years of wet and dry cycles at Store Mosse (Sweden)**

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Peat colour is commonly considered as an informative property, with its changes related to the degree of humification (DPH) and/or plant remains composition. Traditionally, the DPH is determined by the colour of alkaline peat extracts and has been largely used to infer bog wetness: darker indicating drier and lighter wetter conditions. Since the method is both time consuming and destructive, it is worth investigating non-destructive and easy to use alternatives.

With this aim, we measured colour on dried and milled peat samples from a core collected from Store Mosse, spanning ca. 9000 years. Usual CIELab parameters: L\* (luminosity), a\* (green to red), b\* (blue to yellow), C\* (chroma) and h\* (hue), were obtained with a Konica-Minolta CR-5 colorimeter. Other peat properties available for this core include total C and N, C/N ratios, isotopic composition ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ), and a FTIR degradation index (Cb/Lg, carbohydrates/lignin), which allow us to assess the colour results.

All colour parameters, with the exception of h\*, were negatively correlated (-0.51 to -0.83) to C,  $\delta^{15}\text{N}$ , DPH and age, and positively correlated (0.69 to 0.75) to the Cb/Lg index: the colour gets darker and less chromatic as C,  $\delta^{15}\text{N}$ , DPH and age increase, and Cb/Lg decrease. Superimposed on this long-term trend is a see-saw pattern (for L\*, a\*, b\*, C\* and h\*), shared with the Cb/Al record, which suggests shorter-term variations also related to peat decomposition.

As a preliminary interpretation, we hypothesize that the colour is controlled by (i) the long-term decomposition that occurs as the thickness of the peat deposit increases and peat ages, and (ii) by climatic-controlled decomposition that occurred under decreased or increased wetness, when the peat section was at, or near, the surface of the bog. The detrended records show seven sections interpreted as wetter periods: 8.8–8.2, 7.6–7.2, 5.7–4.8, 4.0–3.6, 3.2–2.9, 2.2–1.6 and 1.2–0.4 ka.

## **S25-O05 - Long-term (ca. 57 ka) controls on the accumulation of organically bound elements in Pinheiro mire (Minas Gerais, Brasil) evaluated using structural equation modelling**

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Using principal components analysis (PCA), Horák-Terra et al. (2014) identified four main drivers of peat geochemical composition in Pinheiro mire: catchment mineral fluxes (MF), atmospheric dust deposition (AD), long-term climate change (LTC) and peat decomposition (PD). Through partial least squares modelling (PLS), Pérez-Rodríguez et al. (2015) showed they influenced mercury accumulation during the last ~57 ka. But PCA and PLS assume independence between factors, which is seldom the case in natural systems, and fail to identify mediating (i.e. indirect) effects.

As structural equation modelling enables to predetermine interactions, we evaluated its applicability by using the bromine and mercury records and SmartPLS (Ringle et al., 2015). The previous models were complemented by including time (TM, i.e., peat age) as predictor. TM and LTC were defined as mediating as well as direct factors. The final models suggest high time-dependence of PD (-1.12), MF (0.86), LTC (0.62), and low dependence of AD (0.35). PD (0.53) and AD (-0.55) also showed a moderate climate dependency. The evolution of the mire's catchment (i.e. progressive growth of the peat deposit and soil erosion), long-term and climate controlled peat decomposition, and periodic changes in atmospheric circulation may account for these interactions.

The Br model explains 92% of the variation in concentrations, the largest effects corresponding to TM (-0.46) and AD (0.68). The Hg model explains 76% of the variance and is dominated by MF (-0.85) and PD (-0.74), with moderate direct effect of TM (-0.57) and a lower effect of AD (0.39). The chronology of the residuals (i.e. unexplained variation) suggests increased Hg content under cold and decreased Hg and Br contents under warmer Pleistocene-Holocene climate phases.

References:

Horák-Terra et al. (2014), *Geoderma* 232-234, 183-197; Pérez-Rodríguez et al. (2015), *Environ Sci Tech* 49, 1356-1364; Ringle et al. (2015), *SmartPLS 3*. Boenningstedt: SmartPLS GmbH, <http://www.smartpls.com>.

## **S25-O06 - Response of two Mediterranean coastal wetlands (Corsica, France) to Holocene relative sea-level rise and land-use changes revealed by fossil Coleoptera records**

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Coastal wetland-based archives have an exceptional scientific potential to infer past biodiversity changes and identify key thresholds for particular ecosystems facing relative sea-level rise (RSLR). In this presentation, we focus on the fossil Coleoptera analysis – supplemented by pollen and geochemical data – of two <sup>14</sup>C-dated cores from Corsican back-barrier wetlands: the Grecu pond located on a low-laying island (S. Corsica) and the Cannuta marsh situated on a deltaic floodplain (N. Corsica).

The respectively 7000- and 5900-year sedimentary records from the two sites show contrasted ecosystem trajectories, stemming mainly from their different geomorphological features. Regarding the Grecu pond, by comparing the beetle fauna present on the island today with fossil beetle assemblages, we find that 60% of past wetland beetle fauna became locally extinct because of the increase in salinity caused by marine intrusions. Most of this diversity loss occurred 3700 years ago, when relative sea-level reported in the region was at ~1.5 meters below present sea level. These local extinctions have been exacerbated by the intensification of human pressures over the last decades, with the artificial reduction of the wetland surface area. Regarding the Cannuta marsh, fluctuations of calcium and sulphur (used as tracers of Gypsum), show evolution from a brackish lagoon to a freshwater environment. This transition, marked by a diversification of wetland beetle fauna 1000 years ago, is possibly due to relative sea-level stability and floodplain progradation. It is consistent with evidences of soil erosion (inferred from titanium abundance) and pastoral practices in the watershed.

We demonstrate the efficacy of fossil beetles for reconstructing the environmental changes in coastal lagoon ecosystems, their resilience, and their response to the Holocene RSLR in the western Mediterranean. This retrospective approach also provides a foreshadowing of potential future insect diversity changes along Mediterranean coastal lagoon ecosystems.

## **S25-007 - Constraining the timing and magnitude of paleodust deposition from mid-Holocene to the present in south-central Sweden from multi-element datasets coupled with mineralogy**

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Atmospheric mineral dust plays a dynamic role in the climate system acting both as a forcing and a feedback mechanism. The majority of paleodust studies to date have been conducted on marine sediments or polar ice cores, while terrestrial deposition has been less studied, leaving large regional gaps. Scandinavia is currently only represented by one paleodust study, conducted at Store Mosse, southern Sweden (Kylander et al. 2013; 2016). Within this project the overall aim is to compare the magnitude and timing of dust deposition at three sites located in a west to east transect in southern Sweden. Here, early results from two rain-fed bogs; Draftinge (57°06'27.6 N 13°42'54.1 E) and Gällsered Mosse (57°10'27.4 N 12°35'52.3 E) are presented. The respective sequences have been analysed for botanical composition, bulk density, loss-on-ignition (LOI), organic chemistry (elemental C, N, and  $\delta^{13}\text{C}$ ), and dated by AMS radiocarbon dating. Downcore elemental concentrations have been analysed by quantitative WD-XRF analysis every 3-5 cm coupled with mineralogical analysis by X-ray diffraction (XRD). Based on the concentrations of soil dust elements (Si, Al, and Ti), four episodes of increased dust deposition are recorded at Draftinge Mosse whereas six dust events (DEs) are noted at Gällsered Mosse. Three of these DEs are co-occurring at the two study sites, and two are recorded at all three sites. The mineralogy throughout the Draftinge sequence is dominated by quartz and feldspars, with the exception of sample from ca 5.6 ka BP where a distinct mineralogy of calcite, clays and quartz is noted. By comparing dust deposition at several study sites, based on multi-elemental datasets coupled with mineralogy, magnitude and timing of regional paleodust deposition can be constrained and an increased knowledge of past dust dynamics obtained.

# Poster Presentations

## **S25-P01\* - Using chironomids to constrain Early Lateglacial climate trends on the Swiss Plateau (Central Europe)**

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For Central Europe very limited information is available about temperature changes during the early Lateglacial period, particularly compared with the better studied time intervals after the major warming at the onset of the Bølling (ca. at 14,500–14,700 cal BP). This represents a significant gap in our understanding of early Lateglacial climate dynamics in this region. This knowledge gap is exemplified by recent work wherein pollen evidence suggests an early warming in Northern Switzerland at ca. 16,000 cal BP without any reliable local independent climatic records with which to compare.

We present a new fossil chironomid record covering the earliest Lateglacial period from Burgäschisee, a small lake on the Swiss plateau, for which vegetation change (birch expansion) suggests early Lateglacial warming at 16,000 cal BP. Sediments from Burgäschisee have been re-examined and sampled for chironomid remains to assess whether major changes in assemblage composition can be detected between ca. 18,000 cal BP and 14,700 cal BP suggesting major climatic events. The Burgäschisee record will also be compared with new pollen and chironomid records from Rotsee, Switzerland, for the same time interval.

This is one part of a larger project which aims to produce the first Central European July air temperature reconstruction encompassing an entire interglacial-glacial-interglacial cycle from the beginning of the Eemian interglacial to the Lateglacial.



## **S25-P02\* - The CHERISH project – developing archives of North Atlantic storminess from coastal wetlands in Ireland and Wales**

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CHERISH (Climate, Heritage and Environment of Reefs Islands and Headlands) is a five-year project, funded by the EU Ireland Wales Territorial Co-operation Programme (2014–2020). It is a partnership between the Royal Commission on Ancient and Historic Monuments of Wales, the Geological Survey of Ireland, the Department of Geography and Earth Sciences at Aberystwyth University and the Discovery Programme: Centre for Archaeology and Innovation Ireland. Interdisciplinary research is focusing on risks to cultural heritage around the coasts of Wales and Ireland from climate change, sea level rise and extreme events. A key element of our research involves investigation of the record of past storm events in the Irish sea area, to place contemporary risks within a long term context.

Whilst there are a number of studies of storm activity over the late Holocene around the Irish sea coast, the record is far from complete. Data available indicate notable episodes of increased storminess in the mid 1300s and during the Little Ice Age. However, records that extend beyond the last 1,000 years are sparse and have largely focused on geomorphological evidence, such as sand dunes. In order to identify the driving mechanisms of periods of increased storminess across the region, continuous palaeoenvironmental sequences are required.

Here we present preliminary results from a series of coastal wetland sites in West Wales and southern Ireland. A combination of geochemical, physical and biological proxies is used to identify periods of increased sea spray and aeolian influx as well as direct evidence of overwash caused by storm activity. Chronological control is provided through a combination of radiocarbon and luminescence dating. The localised nature of some storm impacts, combined with the complexities of reconstructing environmental change in dynamic, coastal environments necessitates a regional, multi-site approach.

## **S25-P03\* - Environmental analysis at the monastic site of Iona – interpreting the impacts of social transformations and crisis during the early medieval period using wetland records**

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Iona Abbey was founded in 563 AD by St. Columba on the island of Iona, western Scotland. The abbey enjoyed almost two centuries of peace and prosperity; it quickly became a renowned centre for learning, although it is best known for its role in the spread of Christianity throughout Scotland. Later Viking raids had a drastic impact on the monastic community during the 8<sup>th</sup>–9<sup>th</sup> centuries, although some form of activity may have continued on the island. Much later during the 13<sup>th</sup> century a Benedictine order and Augustinian nunnery were founded and flourished throughout the medieval period.

This study aims to better understand the social transformations and impacts of crisis which took place during the early-later medieval period using an environmental perspective. A 1.05 m core was extracted directly south of the Benedictine abbey church, and two small monoliths were extracted from a wetland deposit from a ditch on the periphery of the site and the inner banks of the vallum. Pollen, non-pollen palynomorphs and microscopic charcoal have been used to reconstruct environmental changes taking place from the pre-Columba era through to the Benedictine-Augustinian period in order to:

1. To determine whether human activity can be identified in the environmental record prior to Columba settlement.
2. To better understand the timings of monastic construction and the environmental impacts of the Columba monastic community.
3. To better understand the impacts of Viking attacks on the island community.

To better understand the environmental transformations of the later Benedictine-Augustinian community.

## **S25-P04\* - Wet but dry: interpreting contrasting proxy evidence during a high accumulation event in Draftinge mosse (Sweden)**

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Reconstructing surface wetness in peatlands is a challenging issue that, more often than desired, gives contrasting proxy evidence, making it difficult to clearly differentiate between dry and wet periods. The differences inherent to the different methods and their intrinsic weaknesses may be behind this situation. However, other circumstances such as seasonal contrast or microtopography development could account for some of the apparent disagreement.

Draftinge Mosse is a raised peat bog located in south-central Sweden close to the extensively studied “Great Bog” (Store Mosse). Here, contrasting proxy evidence for moisture conditions was found for the period between ~5600 and ~4600 cal. BP. At this time, a high peat accumulation event (HPAE, with a maximum of  $294 \text{ g m}^{-2} \text{ y}^{-1}$ , also found at Store Mosse by Kylander et al., 2013) was accompanied by increased carbohydrates/lipids ratio indicating less decomposed peat and pointing to wetter conditions. In contrast, in the same peat section supposed dry NPP indicators also showed a large increase in abundance, suggesting that drier conditions prevailed. To complicate the interpretation further, suggested wet NPP indicators also increase from ~5000 cal. yr BP to present (with ups and downs). The sudden boost in peat accumulation, that started coinciding with warming in the North Atlantic right after the termination of Bond Event 4, suggests that changes in microtopography might have played a role in the creation of different microhabitats (drier hummocks and wetter hollows) and this would explain the variable response in some of the proxies. Although other factors affecting the ecological behavior of the detected NPP cannot be neglected, our hypothesis is that during the HP AE, despite generally wetter conditions in the region, the surface of the peatland might have been locally isolated of the water table because of the rapid peat growth, resulting in the creation of dry microhabitats.

## **S25-P05 - Assessing potential of coastal sediments from the mangrove forest in the Arabian Gulf for paleoenvironmental reconstruction**

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Mangrove forests are bio-diversity hotspots in the United Arab Emirates (UAE) providing habitat to a variety of bird, fish, crustacean and algal species. One of the largest natural and undisturbed mangrove forests in the UAE is located in the Khor al Beida, Umm al Quwain. Siniya island, which is located within the Khor, hosts the largest colony of Socotra cormorant (*Phalacrocorax nigrogularis*) with an estimated 15 500 breeding pairs. A part of Siniya island will be soon developed into a resort, and this is likely to have a profound effect on the whole Khor al Beida ecosystem. In this context, mangrove sediments may provide necessary record of the past undisturbed environmental conditions, which will become useful in the future conservation efforts.

In this study water, intertidal surface sediments and short (up to 10cm) sediment cores were collected from 6 sites along a north-south transect from the mangrove forest in the Khor al Beida. The water and sediments were analysed for diatoms, organic and carbon content and a range of trace metals. Diversity of diatom algae was estimated quantitatively using Simpsons' diversity index and species richness. Diatom diversity and degree of preservation were also analysed in two short sediment cores. Both diatom diversity and species richness show an overall decline down the core; however, diatom frustules remain well-preserved (no symptoms of dissolution). The overall water and sediment chemical quality of the sampling sites appears to be within the accepted ranges. Although diatom assemblage composition and diversity vary along the transect, they are largely similar to the coastal assemblages found in Kuwait and Iran with *Cocconeis placentula*, *Mastogloia* (especially *Mastogloia citrus*) and *Palibellus* spp being the most frequent taxa. This is the first quantitative assessment of surface diatom assemblages in the UAE.

## **S25-P06\* - Glacial Lake Outburst Flood frequency in Chilean Patagonia during the late Holocene: Evidence from Valle Grande floodplain sediments (47°S)**

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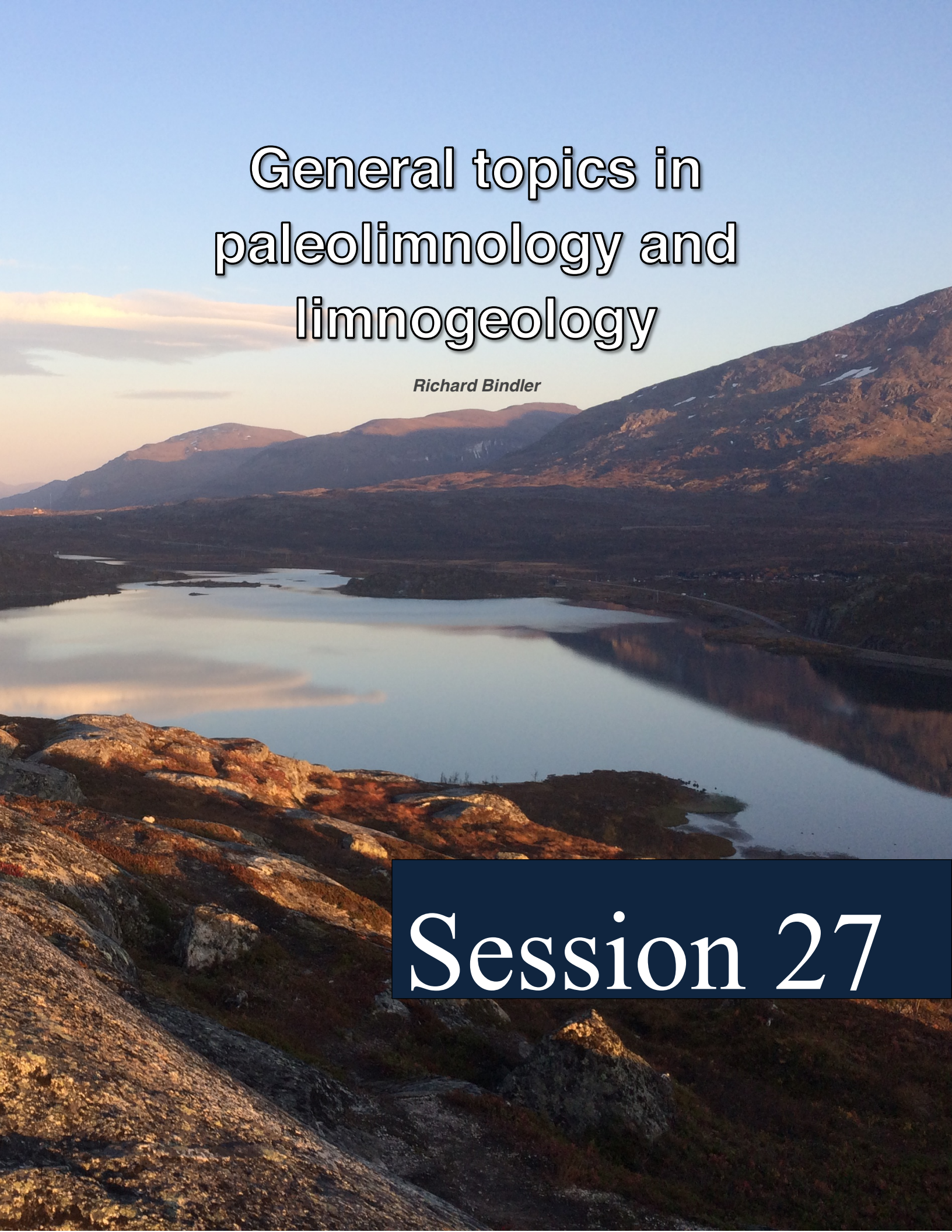
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Glacial Lake Outburst Floods (GLOFs) constitute a major threat in glacier-covered regions. These catastrophic events occur when a lake dammed by a glacier or moraine suddenly empties, resulting in abrupt flooding. In Patagonia, these events are particularly pronounced in the Baker region (47–48°S), where 21 GLOFs were documented in the last decade. They all initiated by the emptying of Cachet 2 lake into Colonia river, a tributary of Baker river. Cachet 2 GLOFs mostly affect the Valle Grande floodplain, located along Baker river immediately upstream of Colonia river. There, backwater flooding results in the inundation of approximately 30 km<sup>2</sup> of pasture lands. Although GLOF frequency seems to have increased worldwide in the last decades, there is currently no reliable scientific evidence supporting this claim, largely due to a lack of flood records on timescales that extend beyond gauged river-flow datasets.

To examine changes in GLOF frequency in Patagonia, four sediment cores were collected in the Valle Grande floodplain. Loss-on-ignition was measured continuously at 5 mm resolution, and cores were scanned on a Geotek MSCL at 2 mm resolution for magnetic susceptibility, gamma density, and sediment color (spectrophotometry). Additionally, radiocarbon ages were obtained at the base of the two most promising cores. All cores indicate the occurrence of fine-grained organic-poor material with high MS and density values, alternating with organic-rich deposits. It is hypothesized that the fine-grained material is deposited during floods, whereas the organic-rich sediments represent periods of quiescence. Although additional radiocarbon dating and charcoal analysis are required to improve core chronology, the records seem to display three periods with higher frequency of floods during the last 2300 years. Once precise core chronologies are available, the results will be compared to historical chronicles and glacier variability reconstructions to assess the possible relationship between GLOF frequency and climate change.





# General topics in paleolimnology and limnogeology

*Richard Bindler*

Session 27

# Oral Presentations

## S27-001 - Biogeochemistry and Paleolimnology of Lake Bafa (Western Anatolia)

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This paleolimnological study investigated the middle to late Holocene paleo-environmental transition (marine/lagoon/lake) around Lake Bafa (coastal Aegean Sea, Western Anatolia), using salinity (diatoms) and vegetation markers (isotopes and chemical composition of organic matter). The lake record (core BAF-37 core) reflects the last 2300 years of sediment accumulation, based on the AMS  $^{14}\text{C}$  dates. *Cocconeis placentula* var. *lineata*, *Coscinodiscus asteromphalus*, *Cyclotella meneghiniana*, *Cyclotella ocellata*, *Cyclotella rossii*, *Thalassiosira fluviatilis*, *Thalassiosira oestrupii* were the dominant diatom species throughout the core. Organic matter types and stable isotope measurements enabled us to determine past vegetation changes driven by arid and humid climate periods. Lake sediments exhibit hydrogen index values (HI) between 70 and 316  $\mu\text{g HC/gTOC}$ , indicating the dominance of Type-II and Type-III kerogens.

The last 800 years (Unit-1) are characterized by relatively  $^{13}\text{C}$ -enriched values, (mean  $\delta^{13}\text{C}$  organic carbon = -24‰), indicating relatively dry climate conditions. Diatom in this unit reflect a permanent, fresh-brackish lacustrine environment. Unit-2 (0.8–1.75 ka BP) indicates more negative  $\delta^{13}\text{C}$  values (mean = -28‰). Diatoms in this unit contain marine or fresh-brackish indicators. Unit-3 (~1.75–3.0 ka BP) is also characterized by relatively negative isotopic composition of organic carbon (mean  $\delta^{13}\text{C}$  org = -28‰) and predominantly type-II organic matter. This could be an indication of higher productivity ranges within the water column. Diatoms in this unit, however, indicate mainly marine conditions, interrupted by floods events, sourced either from the nearby fluvial prograding delta (Buyuk Menderes) or marine (Aegean Sea) environments.

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## **S27-O02 - Late Pleistocene environmental and climate variability inferred from sediments at the open-air archeological site Jordan River Dureijat (Israel)**

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Northern Hemisphere climate variability during the late glacial may have influenced the development of human culture and society in the Levant. However, a shortage of well-dated, high-resolution proxy records from the region impedes attempts to understand the relationship between climate change and socioeconomic change during this time period. Furthermore, proxy reconstructions of late glacial environmental conditions have produced conflicting precipitation histories for this region. Here, we have undertaken a multi-proxy examination of lacustrine sediments collected from the open-air archaeological site Jordan River Dureijat (JRD), located on the east bank of the Jordan River in the Hula Valley (NE Israel). A three-meter sedimentary sequence exposed during the archaeological excavation was sampled continuously at a vertical resolution of one centimeter and composes alternating units of homogenous dark grey silt approximately 10–40 cm thick and horizons rich in mollusk remains (3–7 cm thick), dominated by freshwater mussels of the genus *Unio*, freshwater snails (genus: *Melanopsis*) and cultural artifacts including stone tools and carved bone fish hooks. This is interpreted as fluctuating water level at the site. Thirteen new AMS radiocarbon dates obtained from terrestrial plant material (charcoal) constrain the ages of the horizons rich in mollusk and cultural remains, interpreted as periods of locally reduced water level, and provide the basis for a robust, high-resolution age model for the site between 20 and 10 cal ka BP. Subfossil ostracod remains are present in all samples, with the most abundant species being *Ilyocypris bradyi*, followed by *Candona neglecta* and *Candona angulata*. Total organic carbon concentrations are low (1–4%) and the dark color of the sediments comes from high concentration of clastics derived from the surrounding basalts and, in some samples, abundant microcharcoal; increasing TOC may correlate with rising water level in units devoid of mollusk remains.



## **S27-O03 - Holocene Annual Temperature Change and summer temperature Across the Tibetan Plateau: Paradox**

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Holocene temperature changes have been more controversial because of the apparent discrepancy between global temperature reconstructions and climate modeling, i.e., the Holocene temperature conundrum. We hypothesize this is likely attributed to seasonal biases in the temperature proxy records and a lack of in-depth understanding of mechanisms for climate change in models. Here we present independently dated records of mean annual air temperature (MAAT) based on branched glycerol dialkyl glycerol tetraethers (brGDGTs) at three lake sediment cores and two loess sections across the Tibetan Plateau (TP), where the temperature variability is highly sensitive because of very high elevation. One of the most prominent features in the composite MAAT records is relatively cool Mid-Holocene (7.5–4.0 ka),  $\sim 2^{\circ}\text{C}$  lower than the Early and Late Holocene, which coincided with the apparent advance of glaciers and presence of ice cores on the TP. The MAAT variation on the TP are consistent with the modelling results that shows increasing regional temperature since the Mid-Holocene, but in clear contrast with global temperature reconstructions that mainly reflect summer temperature variation. Our results suggest that changes in boreal summer insolation that leads to variation in precipitation patterns and vegetation dynamics over the TP are the key factor to modulate annual mean temperature evolution since the mid-Holocene, while Greenhouse Gases additionally cause warming trend since then. Our study sheds further lights on paths to solve the Holocene temperature conundrum and implies future loss of glaciers on the TP with the currently increasing temperature.

## **S27-O04 - A multi-proxy assessment of water quality in oligotrophic lakes impacted by cyanobacterial blooms in Ontario, Canada**

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The fouling of freshwaters by nuisance algal blooms, especially those dominated by cyanobacteria, has amassed public concern globally over the putative environmental, economic, and social implications. Since the 1990s, there has been a significant increase in confirmed reports of cyanobacterial blooms in Ontario (Canada) lakes. Many of these lakes are remote, nutrient-poor and have not experienced changes in nutrient status in recent years, suggesting cultural eutrophication is not the primary cause. The manifestation of these cyanobacterial blooms may be associated with recent climate change and positive feedback mechanisms as they occur during the warmest air temperatures on record. To investigate the potential environmental triggers for bloom events in four affected lakes, we examine sedimentary diatoms, chironomids, cladocerans, spectrally-inferred chlorophyll-a, and cyanobacterial akinetes in sediment cores dated using Pb-210. These proxies are used to assess 200-year trends in water quality parameters relevant to bloom dynamics including nutrients, hypolimnetic oxygen, primary production, and lake thermal properties. Diatoms show a variable magnitude of response among the study lakes, with remote lakes showing minimal change throughout the sediment sequence and more developed lakes indicating nutrient enrichment in the early twentieth century and enhanced thermal stratification over the last two decades. Increasing whole-lake primary production in recent decades in all study lakes is consistent with known bloom occurrences. Trends in the paleo proxies are considered in the context of regional climate change and interactions among multiple stressors that favor bloom formation through increases in internal phosphorus loading, air and water temperature, declines in wind speed, and a reduced period of ice-cover. Collectively, paleolimnological inferences suggest that the recent development of cyanobacterial blooms in the study lakes are the result of threshold-type responses to accelerated climate change, with blooms likely to become a more common feature of Ontario and other temperate lakes in the coming years.

## **S27-O05 - Late Holocene high resolution sediment record of environmental change in a karst lake: the Blue Lake (Modro jezero), Croatia**

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The Red (local name Crveno jezero) and Blue (local name Modro jezero) Lakes near the town Imotski (central Dalmatia, Croatia), only approximately 500 m away from each other, represent impressive karst geomorphological forms in the Dinaric karst, collapsed doline, with extreme dimensions. These systems are very sensitive to regional hydrological balances, resulting in considerable lake level, water chemistry and biological fluctuations in response to change in climate, particularly precipitation. The Blue Lake has dried out 7 times through the 20th century based on historical records. The recent drought period (October 2011 to February 2012) provided access to the lake bottom and possibility of drilling an 8-meter-long sediment core. The Blue Lake sediment core covers the last 2400 years, with the sedimentation rate ranging between 0.2 and 0.5 cm/yr. The sedimentary sequence shows evidence of a shallower phase of the lake from 2400 cal BP, and progressive deepening of the lake from app. 2000 cal BP, reaching its maximum during the Medieval Warm Period (MWP). The shallow-water sequence is interrupted by several deeper-water phases and indicates evolution from a wetland prior to 1960 cal BP (lithological zone A). Within this zone, needle-shaped vivianite-rich (iron phosphate mineral) layers occur, which is stable under anoxic conditions, evident in anomalous P-enrichments in this zone. A deeper carbonate-producing lake was formed from 1960 to 1390 cal BP (zone B) with frequent drought periods. The deepest lake period, with no visible discontinuities in sedimentation, lasted for the next 850 years (zone C, between 1390 and 540 cal BP). During the LIA and modern periods (zones D and E, from 540 to the present) the frequency of drying out of the lake increased but their duration was much shorter without significant organic carbon accumulation.

## **S27-O06 - The holocene history of the chironomid fauna from boreal lakes in Lapland (Nellim, Finland)**

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The boreal forest ecosystems represent almost 30% of the world forest area. These ecosystems characterized by a complex forest mosaic are mainly structured by climate (temperature and precipitations) and fire regime. The predictive ability of forest fires is essential to mitigate their impacts on forest ecosystem dynamics, considering related ecological and social-economic aspects. Under global warming (IPCC 2014), changes in climatically-driven fire regime (frequency and severity) are expected, which could represent a potential threat to boreal ecosystems. Consequently, it is necessary to better investigate past relationships between fire and climate in order to apprehend the natural variability of ecological processes. The analysis of chironomid larval headcapsules sequestered in lacustrine deposits allows to reconstruct past environmental and climate changes. It is well known that chironomid assemblages are an efficient proxy for palaeoecological study, giving valuable information on trophic status and lake levels. The present study investigates, at high sampling resolution, two lacustrine records from Nellim region (Lapland, Finland). The Holocene palaeolimnological history of these two sites has been reconstructed.

## **S27-O07 - Landslide fen deposits as specific paleolimnological archives of the Late Glacial and Holocene paleoenvironmental changes: Polish Western Carpathians case study**

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Organic-mineral deposits of landslide fens (landslide peat bogs), which fill small sedimentary basins (paleolakes) formed in landslide depressions, are sensitive indicators of mountainous paleoenvironmental changes in the Late Glacial and Holocene. Mineral horizons inserting organic deposits, as well as mineral covers overlying peat bogs, were related to the long-lasting climate humidity growths. Supplies of allogenic material to the basins with higher water table, which caused temporary termination of peat sedimentation and formation of lacustrine mineral sediments, were caused by slope wash or furrow processes due to repeated downpours or continuous rains during humid climatic phases. Similar (but short-term) sedimentary processes are nowadays observed in some landslide fens after extreme precipitation events.

Erosion accelerated by extreme hydro-meteorological events caused also the removal of parts of deposits, and therefore hiatuses often occur within the depositional sequences. Apart from climatic factors, the depositional sequences reflect also human activity (causing usually acceleration of erosion), as well as the specificity of the sedimentary environment of each studied landslide fen, e.g. morphological position of basin, hydrology of landslide, or type of mineral matter delivery. The interpretation of the paleoenvironmental changes recorded in landslide fen depositional sequences basing on multi-proxy analyses, allowed to reconstruct global climate humidity growths during the Late Glacial (permafrost melting in the Bolling and Allerod Phases), at the beginning of the Holocene, during BO/AT transition and in the Holocene climate optimum, AT/SB and SB/SA transition, as well as during the Little Ice Epoch. Bond events, as pluvial equivalents of the Holocene climate coolings, are also reflected in landslide fen deposits.

## **S27-008 - Si cycling in transition zones: a study of Si isotopes and BSi in Chesapeake Bay sediment cores through the Holocene**

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Coastal marine ecosystems form the transition zone between the terrestrial and the marine Si cycles. Short residence times make them sensitive to environmental changes.  $\delta^{30}\text{Si}$  records may help detect variations in terrestrial Si fluxes and utilization driven by climate or human activity.

The Chesapeake Bay, an estuary on the North American East Coast, is a well-studied environment with a constrained settlement history (European settlement around 250 a BP). A suite of different sedimentary proxies document the influence of climate variations, land-use changes and altered nutrient fluxes since the LGM.

The terrestrial Si pool drained by rivers and ground water flows regulates the availability of dissolved silica (DSi) in the Chesapeake Bay. Changes in catchment Si pools and fluxes caused by e.g. variation in precipitation patterns or land use changes are likely to have both transient and long-term effects on Si inputs to the estuary. To investigate variations in Si fluxes in the Chesapeake Bay during the Holocene we measured sedimentary biogenic silica concentrations and  $\delta^{30}\text{Si}$  in hand-picked diatoms from two sediment cores: one located proximal to the main inflow (the Susquehanna River), the other closer to the Atlantic.

Our results show BSi fluxes and  $\delta^{30}\text{Si}_{\text{diatom}}$  values increased simultaneously with European settlement, and with sea-level rise around 7000 BP when the estuarine ecosystem developed. They indicate similar influences but differing magnitudes of response between the two cores, due to their location in the estuary. Increased BSi concentrations since ~2000 a BP in the proximal site relative to the distal site suggest a greater sensitivity to changes in Si fluxes from the watershed. Mixing with ocean waters seems to buffer the nutrient fluxes from the continent in the distal core. Deforestation since ~250 a BP has a distinct impact, causing higher BSi and large amplitude variation in  $\delta^{30}\text{Si}$  values.

## **S27-O09 - Palaeoenvironmental reconstructions in Central Kamchatka: deep lake vs shallow lake**

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We compared chironomid assemblages and chironomid-based palaeoecological inferences from well-dated sediment cores taken in small seepage lake Sigrid (SL) and 28-m-deep Two-Yurts Lake (TYL), both situated at the eastern slope of the Central Kamchatka Mountain Chain, Far East Russia. The chironomid faunas show distinct taxonomic differences between the two lakes, although they are only approximately one km apart. Water depths (WD) were reconstructed, using a modern chironomid-based temperature and water-depth calibration data set (training set) and inference model from East Siberia (Nazarova et al., 2011). Mean July air temperatures (T July) were inferred using a chironomid-based temperature inference model, based on a modern calibration data set for the Far East (Nazarova et al., 2015). The temperature profile reconstructed from SL exhibits similarity with that from neighbouring TYL, but with some inconsistency in the timing of cold and warm periods and smaller amplitude of reconstructed temperature fluctuations. The reaction of the mainly littoral chironomid fauna of SL to climate variations could possibly have been biased by the stronger effect of other ecological factors, like WD fluctuations, acidification and increased macrophyte coverage, which is much weaker in the TYL because of its larger size and volume, higher freshwater input from inflow streams, and better dilution of the natural humic acids that enter the lake from the catchment area. Prevalence of littoral chironomids over profundal taxa makes chironomid communities of SL more sensitive than TYL communities to fluctuations in water level. We suggest that the influence of climate conditions on aquatic fauna in shallow SL can be overprinted by WD fluctuations related to shifts in moisture availability in the region, and lead to a weaker response of the fauna to T changes.

## S27-O10 - Long-term water quality trends in Canadian Lake Trout lakes

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Lake trout (*Salvelinus namaycush*) is an ecologically important fish species that inhabits cold, deep lakes across Canada and the northern United States. Depletion of hypolimnetic dissolved oxygen (DO) is believed to be threatening many lake trout populations by reducing the amount of optimal habitat within the water column. Nutrient loading, regional warming, and changing inputs of dissolved organic carbon can influence hypolimnetic DO concentrations. Understanding how hypolimnetic DO has varied through time and the influence that multiple stressors have on DO dynamics requires long-term data. Gravity cores spanning ~150 years were collected from nine study lakes across Ontario, Canada, all of which support lake trout populations. Three study lakes were selected due to the availability of recent monitoring data, which could be compared to paleolimnological reconstructions, and the remaining six lakes were selected due to previously identified water quality problems. We use sedimentary diatom assemblages to reconstruct total phosphorus (TP) concentrations and evaluate the influence of climate warming, and chironomid assemblages to reconstruct end-of-summer hypolimnetic DO conditions. In addition, visual reflectance spectroscopy (VRS) was used to track whole-lake primary production and lake-water total organic carbon (TOC) concentrations over time. Preliminary results suggest that VRS-inferred chlorophyll-a and TOC have increased alongside stable or decreasing diatom-inferred TP trends in most of the study lakes. Eight of the study lakes exhibit diatom assemblage shifts indicative of water-column changes associated with regional climate warming, although the timing and magnitude of these responses were site-specific. In only one lake, diatom assemblage changes indicated increased nutrient loading and no response to regional warming. Chironomid assemblage changes were less coherent than diatom assemblage shifts, and suggest the influence of site-specific factors, rather than regional stressors. These data will improve our understanding of long-term trends in Lake Trout habitat quality and the stressors driving these trends.



## **S27-O11 - Updates from CSDCO and LacCore: Facilities for Drilling and Coring**

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The Continental Scientific Drilling Coordination Office (CSDCO) and the LacCore Facility, both hosted by the University of Minnesota, are facilities for the global continental scientific drilling and coring community. The CSDCO provides coordination, leadership, and technical support for coring and drilling projects on Earth's continents, for all project phases. The CSDCO coordinates a) project development and execution, leveraging both facility and commercial resources as needed, b) community infrastructure and cyberinfrastructure advancements, c) cross-cutting initiatives, and d) deeply-embedded outreach, diversity, and education activities. The LacCore Facility supports field operations and provides a fully-appointed lab for core processing, scanning, description, and subsampling, and a repository for sample and data curation and dissemination. In the past five years, CSDCO and LacCore have supported nearly 4,000 researchers from nearly 1,000 institutions, for more than 800 projects in total. These projects range in scale (cost, samples, data) by a factor of 10,000, from projects with a few short cores, to the 34 ICDP deep drilling projects executed or in preparation. The core repository now curates cores from ~7,900 sites worldwide and distributes ~36,000 subsamples annually, several pollen reference collections, project publications, and a data archive from supported projects. Any researcher can rent or purchase coring equipment or supplies, leverage facility staff expertise to develop project operational and outreach plans and budgets, request field support, scan and process cores, accession collections, utilize software applications, request subsamples from curated cores, or discuss concepts for development of novel tools, instrumentation, or cyberinfrastructure. In its new prime location on campus, the facilities enjoy larger spaces designed by staff for better core workflows and experience for visitors. Staff now seek community input to the process of combining these partner facilities under a single NSF Cooperative Agreement in 2019.

## **S27-O12 - Diatom assemblage responses to industrial airborne pollution, wildfire, and climate change in the Athabasca Oil Sands Region, Alberta, Canada**

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The shallow lakes of the Athabasca Oil Sands Region (AOSR) in northern Alberta, Canada, are exposed to ongoing environmental stress from development of the local bitumen deposits and climate change. Additionally, a major wildfire in 2016 burned ~1.5 million acres in the region. Shallow lakes, like those in the AOSR, can be early responders of environmental change, or they can demonstrate limited response to an environmental stress until an ecological threshold is surpassed. Our work characterizes the change in diatom assemblages over time in the region's lakes, and assesses the potential roles of industrial airborne pollution, the 2016 fire, and regional climate change in structuring the diatom communities. We investigated the diatom assemblage responses to industrial airborne contamination using a top-bottom analysis of 18 shallow lakes up to ~100 km away from the main industrial area, and a detailed downcore assessment on a subset of 6 strategically selected lakes. We assess the diatom assemblage responses to the major fire by analyzing the top 3 cm of sediment at 0.25-cm resolution in a subset of 7 strategically selected lakes (4 with burned catchments, 3 with unburned catchments). We find muted changes in the majority of diatom records since the beginning of airborne industrial pollution (~50 years) and the major wildfire (~1 year). The nature and timing of the subtle floristic changes are not consistent with industrial airborne pollution or the wildfire. Rather, the changes match an expected response of shallow lakes to warming air temperatures. We conclude that the diatom assemblages in the majority of shallow lakes in the AOSR are, for now, demonstrating relative resiliency to environmental stress. As industrial development, climate change, and increasingly extreme events are forecasted to continue, it remains possible that ecological thresholds may be surpassed in these lakes in the future.

## **S27-O13 - Using paleolimnology to establish baseline conditions for metal contaminants in advance of proposed mining, Marian Watershed, Northwest Territories, Canada**

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The Marian Watershed Stewardship Program (MWSP), a community-driven aquatic ecosystem monitoring program, was developed by the Tłı̨chǫ Government to address concerns regarding the cumulative impacts of multiple potential stressors. In particular, the MWSP aims to develop methods that will be effective for detecting pollution from the proposed cobalt-gold-copper-bismuth NICO mine within Tłı̨chǫ Lands. In collaboration with the MWSP, we are using paleolimnological approaches to establish baselines of lake sediment metals concentrations across the Marian Watershed prior to mine development, which can be used to assess for pollution from surficial sediment once the mine becomes operational. Here we present  $^{210}\text{Pb}$ -dated stratigraphic metal concentration results from four lakes. Results show metal concentrations are substantially higher in lakes on or adjacent to the ore body compared to lakes located in the surrounding granitic bedrock terrane. Variations in the concentrations of many metals of concern are small, which provide values that can effectively serve as baselines for ongoing monitoring. An exception is arsenic, a metalloid of major concern, which increases variably in the latter half of the 20<sup>th</sup> century. There are multiple possible explanations to explain this trend, including far-field atmospheric emissions of  $\text{As}_2\text{O}_3$  from Giant Mine in Yellowknife, increase in erosion of arsenic-bearing sources in the lake catchments, and/or post-depositional diagenetic mobilization in the lake sediment profile. Notably, increases in arsenic concentrations also occur in the early part of the past millennium likely indicating the potential for variation in the catchment-derived supply of arsenic to these lakes. Additional studies are required to further characterize processes that cause arsenic variations in these lake sediment records. Variation in sediment metals concentrations on both temporal and spatial scales in this region demonstrate the need for lake-specific baselines for accurate interpretation of contemporary sediment monitoring data.

## **S27-O14 - Rainfall- fire-vegetation-soil-lake linkages in the Australian subtropics**

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Australia is the most fire prone continent on the Earth with fire frequency intrinsically linked to climate. However, the relationship between rainfall and fire frequency and severity is complex. High rainfall on decadal to centennial scales may increase the likelihood of high fire severity because it promotes high biomass, but on shorter time scales high rainfall prevents high fire severity. This phenomenon in part explains why the most extreme historical fires have occurred in some of the wettest south-east Australian forests and highlights the need for long term perspectives on fires.

In this study we investigate the nexus between rainfall, vegetation and catchment soil through a study of lake sediments from freshwater Swallow Lagoon, North Stradbroke Island (NSI). NSI is a large sand island and nutrients are tightly cycled in forests and woodlands. We use a unique quantitative rainfall record (derived from the carbon isotope discrimination in leaves of a single tree species preserved in the sediments) and compare it to the vegetation, fire and soil erosion history (derived respectively from pollen, micro and macro-charcoal analysis and micro-XRF core scanning). Our study shows that in the mid-Holocene higher rainfall was associated with greater burning in the catchment and the delivery of plant macronutrients (e.g. Ca) to the lake. In the late Holocene a shift to a more El Niño-like climate resulted in lower and more variable rainfall and fire reduction and reduced loss of catchment macronutrients. This study highlights the importance of fire in influencing the vegetation composition in both a direct and indirect manner.

## S27-O15 - Multi-proxy responses to increasing road salt concentrations in a small shallow lake from Ontario, Canada

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De-icers are applied to roads in many north-temperate regions to improve winter road safety. Sodium chloride (NaCl) is the most commonly used de-icer in North America, however, applications may consist of several different compounds including chloride brines/salts (i.e., calcium chloride (CaCl<sub>2</sub>), potassium chloride (KCl) and magnesium chloride (MgCl<sub>2</sub>)), organic compounds, and abrasives (i.e. sand). Road salt was first applied as a de-icer in the 1940s, with usage escalating dramatically with urbanization, road development, and the establishment of highway safety programs. As a consequence of increased road salt application, many North American lakes have experienced a rise in chloride concentrations since the mid-20<sup>th</sup> century. Jevins Lake, located in south-central Ontario, Canada, and within sight of a major twinned highway, has the highest recorded chloride concentration (90 mg/L) in the region. To assess whether biological changes in this 'worst-case' lake are coincident with historical road salt applications, high-resolution cladoceran and diatom records from a <sup>210</sup>Pb-dated lake sediment core were examined. Subtle increases in salt tolerant cladocera taxa (*Chydorus brevilabris* and *Alona circumfimbriata* (rectangula)) and declines in sensitive taxa (*Bosmina* spp.) around the 1950s suggest that road salt application may have triggered this response. Principal components analysis axis 1 sample scores plotted against age indicate that the most substantial assemblage-scale change in cladoceran composition occurred at the onset of road salt application in the region (ca. 1950). The nature and timing of diatom assemblage changes corroborate the changes observed in zooplankton. Most notably, *Achnanthes minutissimum*, a taxon that has been associated with higher chloride concentrations in the area, appears in the record around 1940 and dominates the assemblages from the mid-1950s to present. In contrast to the changes in biological proxies at this highly affected site, minimal compositional changes in cladoceran and diatom assemblages were recorded in a nearby minimally impacted site.

## **S27-O16 - Temperature fluctuations during the Common Era inferred from brGDGTs in an alpine lake in high-elevation southwestern China**

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Documenting climate change over the past 2000 years is an important first step to understand how the climate system evolved from natural background to anthropogenic forcing. However, global and regional temperature changes during this interval are still poorly understood, largely due to the limited geographical coverage and short of data for the first millennium. Here we report a ~10-year resolution, well-dated, quantitative mean annual air temperature (MAAT) record for the past 2000 years derived from a sediment core collected at a small alpine lake (Tiancai Lake) in remote subtropical southwestern China, based on a site-specific temporal calibration between down-core analyses of brGDGTs and instrumental data for the interval 1959–2015 AD. We find distinct multicentennial-scale temperature fluctuations, including a general cold condition at 0–800 AD, the Medieval Climate Anomaly (MCA) at 800–1400 AD, the Little Ice Age (LIA) at 1400–1900 AD, and the Current Warm Period (CWP) after 1900 AD. On top of this general pattern, we also observe three cold events, centered on ~280 AD, ~600 AD and ~1820 AD. These variations are consistent with historical documents and regional and global paleoclimate records, likely driven by both solar activities and volcanic eruptions before 1900 AD, and then greenhouse gases (GHGs) thereafter. We also find large-magnitude (up to 4 degrees) centennial-scale temperature variations in this high elevation site, which are possibly related with multiple non-linear radiative feedbacks such as seasonal snow cover, cloud, water vapor, and aerosols. We conclude that anthropogenic GHGs have been on top of natural solar and volcanic changes as the primary forcing for global warming since the 20<sup>th</sup> century, and that centennial-scale climate variations in high-elevation areas are quite sensitive to forcing factors.

# Poster Presentations

## **S27-P01 - SEASIDE - A multidisciplinary study of maritime environmental history**

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Changes in sea level occur over timescales ranging from minutes to millennia and have, and will also in the future, influence coastal societies. Presently only instrumental records ranging the last couple of hundreds of years and any reconstructions of sea level changes beyond this must be based on geological and archeological reconstructions.

Our aim is to understand how human societies have responded to changes in the configuration of the landscape (e.g. shifting shorelines). This study utilizes a combination of expertise in Earth Science and Archaeological Landscape analyze. Our intention is to apply a case study in the Gamlebyviken area, situated at the Baltic Sea coast in south-eastern Sweden. The isostatic rebound (today c. 2 mm/year) has resulted in a transition between landscapes and new hunting grounds, pastures and farmlands have emerged from the sea, waterways and fishing grounds have changed.

The study area is exceptionally rich in human sites and ancient monuments since the early Mesolithic. During the Bronze Age it was one of Scandinavia's most significant places, visible today through large burial mounds and rock carvings. The Iron Age and Viking era are also rich represented. The area is relatively little exploited and influenced by modern infrastructure and thus highly suitable for our study.

Research questions:

1. What changes in the landscape are recorded since Neolithic in the study area and how have these affected the humans living along the seaside?
2. How and in what way have human societies adapted to changing Baltic Sea shoreline levels.

By studying when lake basins situated at various altitudes were isolated from the Baltic Sea basin using diatom stratigraphy, a shore displacement curve will be constructed. These data combined with the results from offshore multibeam profiling will enable us to make high-resolution paleogeographical 3D reconstruction of different time-slices.

## **S27-P02 - Groundwater monitoring within catchment areas of three lakes with varved sediments in northern and central Poland**

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Characteristics of sediments and the course of sedimentary processes are considerably individual. Therefore it is important to recognize - as fully as possible - the factors influencing the formation of the deposits and the way individual characteristics of a particular lake and its catchment area get recorded in sediments. This is why the monitoring of water supply and delivery of solid and dissolved matter into the lake is so important.

The monitoring carries out in the catchment areas of the Lake Czechowskie, the Lake Głęboczek (both in Tuchola Pinewood Forest) and the Lake Gościąg (Gostynin-Włocławek Landscape Park) since mid-2012. The study includes measurements of meteorological parameters in the catchment areas of the lakes, as well as hydrological, hydrogeological (24 piezometers) and hydrochemical measurements (samples of water have been collected in a monthly interval).

The groundwater fluctuations in analyzed period (2012–2018) ranged from 0.17 m to 2.14 m. The lowest ones were recorded in piezometers located in watershed zones. The greatest dynamics of fluctuations of the groundwater table was found in the shallow-lying groundwater of the lake terraces (with high influence of anthropoppression). As a result of the high stability of the deeper levels of groundwater, which are the main source of supply for measured lakes, there are only slight fluctuations in water levels in these lakes (below 0.5 m).

Hydrochemical studies showed that the zones of water enrichment in salts are associated with paleolake basins filled with the organic-carbonate sediment, while the salt precipitation zones with the modern lakes.

This study is a contribution to the project No. 2015/19/B/ST10/03039: “New high-resolution and integrated analyses of environmental response to climate change over the last 15,000 years from the Lake Gościąg record within the frame of a W-E European transect” financed by the National Science Centre.



## S27-P03 - Testate amoebae as proxies for water depth in lakes of the Yucatan Peninsula, Mexico

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Paleolimnological inferences that rely on biological proxies require knowledge of the modern ecology of the organisms. Unfortunately, the ecology of groups such as testate amoebae (*Thecamoebians*) is poorly known, especially in lakes of the northern Neotropics. Elsewhere, these protists have been used to infer pH and water table depth. We set out to evaluate whether testate amoeba communities are informative about water depth in the solution lakes of the karst Yucatan Peninsula. We collected surface sediment samples from multiple water depths in 12 lakes, using an Ekman dredge. Littoral-zone samples were taken with a net. Hierarchical agglomerative cluster analysis distinguished littoral, mid-water-depth, and deep-water samples by testate amoebae total abundance. Separation of samples by water depth was confirmed using relative proportions of species. Of the 34 taxa identified, 20 were found only in the littoral zone, the most common being *Arcella vulgaris*. Species such as *Diffflugia oblonga* “spinosa” and *Diffflugia protaeiformis* “acuminate” were more abundant in greater water depths (10–30 m). *Centropyxis aculeata* “aculeate”, however, was found across the water-depth gradient. Shannon Diversity Index values for the littoral zones of the lakes had values between 0.82 and 2.53, whereas all samples from deep water had values <1.40, suggesting deep areas are stressful sites for many testate amoebae taxa. Although multiple variables may determine amoebae distributions in Yucatan lakes, water depth appears to be one of the most important factors. For this reason, it is possible to use testate amoebae assemblages in lake sediment cores from the region to infer past changes in lake water depth.

## **S27-P04 - Groundwater-lake interaction: using ostracods as potential indicators of groundwater influxes in Lake Constance, Germany**

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Lake Constance is the second largest lake in Central Europe and belongs to the largest and one of the most important drinking water reservoirs in Southern Germany. Recently, structures at the bottom were found that may indicate groundwater (GW) inflows into the lake. In order to investigate GW seeps and their potential threats to water quality and biological communities, as well as their temporal dynamic, we assessed the seasonal variation in diversity and distribution of ostracods in sediments. Redundancy analysis (RDA) was performed to analyze the relationship between organisms and environmental variables. One hundred fifteen surface sediment samples were taken using a van Veen grab between June 2016 and June 2017 at three “hot spots”: Mehrerau, Birnau and Birnau-West, ranging between 2 m to 115 m water depth. Water temperature (°C), conductivity ( $\mu\text{S cm}^{-1}$ ), water depth (m) and dissolved oxygen ( $\text{mg L}^{-1}$ ) were measured in situ with a multi-parameter CTD (Rosette) sonde. Two sediment cores were taken in February and June 2017 from Mehrerau and Birnau, respectively. Overall, stygophilic species such as *Darwinula stevensoni*, *Herpetocypris reptans* and *Prionocypris zenkeri* were found in low abundances (1% to 6%) in several sampling sites. The occurrence of two stygobiont species, *Cavernocypris subterranea* and *Pseudocandona marchica*, indicate groundwater inflow into the lake and were mainly found at Birnau region. Statistically significant correlation ( $p \geq 0.01$ ) between water temperature, conductivity and ostracods was found. Variable temporal groundwater input was detected by the occurrence of stygophilic species in both sediment cores. This study is part of the “ReWaM Joint Project - Using tracers to identify groundwater and surface water input to lakes and the importance for water quantity and quality: Case study from Lake Constance (SEEZEICHEN)” supported by the German Federal Ministry of Education and Research (BMBF).

## **S27-P05 - Using lake sediment records to examine productivity in a hypereutrophic karstic lake**

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Lough Gur, a small, shallow hypereutrophic lake located on karstic limestone bedrock in southwest Ireland is in a target area for priority action in the River Basin Management Plan (RBMP) for the second cycle of the Water Framework Directive. The lake has no surface inflow and water level is maintained by groundwater and surface runoff. Questions regarding the balance of the contribution of the inherent natural geographical conditions and the onset of anthropogenic human influences on the lake have prevailed for some time. Two short sediment cores were radiometrically-dated and physical (LOI), geochemical (TN and TP) and algal pigments were examined. Results suggest that the lake may have been productive as early as the mid-1600s, but a marked increase occurred in all proxies between 1950 and 2000. Interpretations, however, must be treated cautiously as radionuclide concentrations were very low.

## **S27-P06 - Differential proxy-responses to Younger Dryas cooling recorded in the sub-decadally resolved record of Lake Hämelsee (Germany)**

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Recent high-resolution palaeolimnological studies have highlighted the potential for differences in response time of individual physical, geochemical and ecological proxies to external forcing such as abrupt climate deteriorations. Response times can theoretically range from an instant response (e.g. change in  $\delta^{18}\text{O}$ -record as a result of a change in atmospheric circulation patterns) to a distinctly delayed response of decadal to centennial scale (e.g. reorganisation of local vegetation following climate cooling). Unfortunately, many palaeolimnological records lack the required age control or the sampling resolution needed to analyse lags in proxy-response to environmental change, hampering a detailed analysis of past ecosystem and climate dynamics.

Here we present the results of a high-resolution multiproxy study from Lake Hämelsee (Germany) that spans the Late-Glacial interval, with a focus on the transition from the Allerød into the Younger Dryas. The chronological framework for the core is based on a combination of varve counting, radiocarbon dating and tephrochronology, which are combined within a Bayesian age model. We applied subdecadal-resolution sampling to the record and combine sedimentological, palaeoecological and biogeochemical analyses to reconstruct ecosystem dynamics during the Allerød-Younger Dryas transition. We use Ramp-Fit Analysis to objectively assess the onset-of-change for each proxy record.

Our preliminary results reveal differential proxy responses to climate cooling and atmospheric circulation reorganisation associated with the onset of the Younger Dryas. The first changes are seen in the n-alkane and GDGT records, followed by transitions in the chironomid, loss-on-ignition and pollen records. In exploring the patterns of proxy-variability we reveal that the first onset of change is detected several decades prior to the biostratigraphically defined onset of the Younger Dryas. Our findings highlight the potential to disentangle environmental and ecosystem dynamics when using sub-decadal resolution analyses.

## **S27-P07\* - Taxonomical versus functional diversity: spatial patterns and temporal trends in chironomid records**

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Anthropogenic changes to the environment are leading to dramatic changes in the structure and composition of biological communities from the local to the global scale. In many natural settings it has been difficult to disentangle natural variability from the effects of human-induced ecosystem change, partly because of the short time scales typically used in ecological studies on trends in biodiversity. Palaeoecological data can provide new insights into the relationship between biodiversity and ecosystem functioning as such records can predate the period of human impact.

Subfossil chironomid assemblages preserved in lake sediments represent a local biodiversity signal, integrating millennial-scale changes in the fauna within a lake. As such, they add a unique perspective on (past) biodiversity change. Here we explore the potential of chironomids as palaeoecological indicators of invertebrate biodiversity.

Our preliminary results show that taxonomic diversity linearly increases with temperature in a Norwegian chironomid-environment calibration dataset. Second, subfossil chironomid records obtained from a set of British lake sediment sequences covering the late-glacial interval indicate that taxonomic diversity was higher during the Allerød interstadial than during colder intervals such as the Younger Dryas. However, these results do not allow to assess whether it was only the numbers of species that changed with changing climate conditions, or if there were fundamental changes to the past fauna, e.g. through changes in the food web. As an ongoing part of our project, we are critically assessing a number of ways in which chironomid assemblages can be assigned to functional types, including but not limited to feeding guilds, habitat requirements and life cycle characteristics. We will determine whether taxonomic diversity or functional diversity is the most appropriate factor to study current and past ecosystem dynamics using chironomid datasets.

## **S27-P08 - A 1.4 million-year palaeoenvironmental reconstruction from Lake Ohrid using stable isotopes**

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Lake Ohrid is an ancient lake situated on the Balkan Peninsula, which has a world-class degree of endemic biodiversity and an extensive sedimentary archive. In 2013, an ICDP drilling campaign was conducted as part of the Scientific Collaboration on Past Speciation Conditions in Lake Ohrid (SCOPSCO) project. The main drill site provided a 584-m record, comprising hemi-pelagic sediments in the upper 447 m that span the last 1.4 million years. We present oxygen and carbon isotope data ( $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ) from carbonate for the entire lacustrine sequence spanning Marine Isotope Stages (MIS) 41-1, based on chronological information derived from tephrostratigraphy, palaeomagnetic analyses, and orbital tuning of biogeochemical proxies. Monitoring data suggest variations in  $\delta^{18}\text{O}$  are a function of changes in regional water balance. This is confirmed through the Holocene where isotope data show a progression from wetter to drier climate conditions, which is consistent with a pattern of regional aridification. At the onset of deep-water lacustrine conditions at 1.4 Ma, low  $\delta^{18}\text{O}$  are comparable to modern values for surface inflow and indicate that Lake Ohrid most likely had a reduced residence time and water volume. Relatively rapid shifts in long-term average  $\delta^{18}\text{O}$  to higher values, observed during MIS 41, 38, and 23, are most likely associated with lake ontogeny and the progressive deepening of the lake. Following MIS 10, there is an increased variability in  $\delta^{18}\text{O}$  between glacial and interglacial phases suggesting a greater sensitivity to hydroclimate change, probably associated with a lower lake level. Higher interglacial  $\delta^{18}\text{O}$  through this time frame most likely reflects the development of a warm and dry Mediterranean climate regime. This dataset is one of the most extensive and highly-resolved terrestrial isotope records available for the Mediterranean, and highlights the significance of Lake Ohrid sediments as a valuable archive of Quaternary palaeoclimate and palaeoenvironmental change.

## **S27-P09\* - EarthArXiv: a free preprint server for the Earth Sciences**

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A preprint is an as-yet, non-peer-reviewed version of a scholarly paper that precedes publication in a peer-reviewed journal; a preprint server, such as the community-led EarthArXiv ([www.eartharxiv.org](http://www.eartharxiv.org)), is an online platform purpose-built to host preprints. A preprint may represent the same manuscript eventually submitted to a peer-reviewed journal, although other content, which may currently be difficult to publish (e.g. datasets, method papers), can also be uploaded and, if appropriate, explicitly linked to the associated manuscript. In this way, preprints provide access to important scholarly content that would otherwise be lost. Preprints speed up dissemination, utilisation, and citation of scholarly outputs. Furthermore, because they are timestamped and receive a DataCite-minted DOI, preprints provide an undeniable record of priority and ownership, which all but eliminates the chance of being "scooped". Preprints also allow for no-cost publishing, are Open Access (OA) on submission, and are indexed by Google Scholar and discoverable by web-tools such as Unpaywall. EarthArXiv, like several other preprint servers, also hosts and can thus act as a repository for postprints (i.e. published articles), helping facilitate (Green) OA and meeting the needs of the many researchers who lack an institutional and/or national scholarly publications repository.

A group of international volunteers, organised by the Earth Science Information Partners (<http://www.esipfed.org/>), recently built EarthArXiv a community-led preprint service for the Earth Sciences, which is built on infrastructure provided by the non-profit Center for Open Science (<https://cos.io/>) Open Science Framework. Since launching in October, EarthArXiv has received more than 270 submissions, with material spanning a range of Earth and Environmental Science disciplines, some of which is relevant to IPA-IAL delegates. If you have any questions, please do not hesitate to contact either Chris Jackson ([c.jackson@imperial.ac.uk](mailto:c.jackson@imperial.ac.uk)) / Tom Narock ([tnarock@ndm.edu](mailto:tnarock@ndm.edu)), two of the co-founders of EarthArXiv, or Anson Mackay ([a.mackay@ucl.ac.uk](mailto:a.mackay@ucl.ac.uk)), an EarthArXiv ambassador and conference delegate.

## **S27-P10\* - The charcoal analysis in a lacustrine sequence of lake Chalco, basin of Mexico: the record of fire events and volcanic activity**

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Forest fires, considered as a free and spontaneous vegetation burn, can change ecosystems significantly. Charcoal particles as a result of the vegetation burn can be deposited in lake basins. Factors such as the climate and vegetation type can be drivers in the fire generation. Previous fire events research in a lacustrine sequence of lake Chalco, which covers the last 85 kyr, has pointed out that the main driver for triggering the fire events was the climate. Nevertheless, they observed that volcanic activity seems to be an important factor in the charcoal production in the basin. We present a high-resolution charcoal analysis, before and after two volcanic deposits, the Tutti Frutti Pumice with an age of 17 kyr and the Upper Toluca Pumice at 12.3 kyr from the CHA11-VII sequence of Chalco lake. We inferred that climate variability was the main factor before and after in the extension, severity and recurrence on the fires for each eruption. Also, climate can impact indirectly during the volcanic activity, because of the available combustible depending on the vegetation type. We observed that not only local eruptions, within the basin, are able to export great quantities of charcoal particles as in a forest fire, but this is related to the kind of volcanic activity. Our data indicate that regional fires are capable to be registered as a local fire event in the lacustrine sequences but without a tephra associated. Within a active volcanic region this observation is important because the interpretations of past forest fire intensity based on charcoal analysis can be different in a no volcanic region. Finally, the establishment of glaciers or high humidity in vegetal structures could function as damping mechanisms, decreasing fire severity during the volcanic activity.



## **S27-P11\* - Response of primary producers to long-term changes in a small sub-alpine lake: L. Pusiano, Italy**

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Lake sediments constitute natural archives of past environmental changes. Long-term environmental records are useful to establish ecosystem reference conditions, enabling comparisons with current environments and potentially allowing future trajectories to be more tightly constrained.

Lake Pusiano is a eutrophic, subalpine, medium-sized (surface area 5.26 km<sup>2</sup>) shallow ( $Z_{\max}=20$  m) water body, formed in the Quaternary moraine deposits of the great Valtellina Glacier (north Italy). Anthropogenic inputs from land clearing, marked hydrological variation, agriculture, highway development and urbanization in the surrounding area, have resulted in strong impacts on the limnology of the lake throughout the past 80 years. In the 1990's this lake has experienced severe eutrophication, including persistent cyanobacterial blooms. Due to the well-documented human impact in its catchment, this lake allows a reconstruction of the relationship between anthropic pressures and primary producer community.

A detailed fossil pigment and diatom analysis were used to assess the magnitude and direction of change in the autotrophic community in response to eutrophication processes in the lake, the timing and appearance of cyanobacterial blooms and their subsequent variability.

To evaluate the relative influence of human intervention on ecosystem dynamics and regime shifts, we examined the algal response, based on specific carotenoids, to diatom-inferred total phosphorus and to the hydrological regime-changes, connected to the river regulation, occurred at the beginning of the nineteenth century.

We found that an abrupt shift in phytoplankton composition towards cyanobacteria and eutrophic diatom taxa followed the increases in agricultural phosphorus use in the catchment.

The human intervention on the hydrological regime had no effect on the productivity level but results in a more oxygenated system and a change on the species composition.

This study highlights the challenge of defining appropriate baselines or reference conditions and the utility of multiple analyses of lake sediments for identifying the timing and magnitude of anthropogenic impacts.

## **S27-P12 - Combination of radiocarbon and OSL dating suggests young age of Lake Esmeralda sediments, Antarctic Peninsula**

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Lake Esmeralda, located in the deglaciated area of Cape Lamb on Vega Island, north-eastern part of the Antarctic Peninsula, offers a unique palaeoenvironmental record thanks to the sediment thickness of ~2 m and very fine lamination. Despite the promising potential of the lake, its sedimentary archive has been poorly studied. The only published works are mainly concerned with palaeomagnetic and radiocarbon dating (Sinito et al. 2011, Irurzun et al. 2013, 2017). In these studies, two bulk  $^{14}\text{C}$  dates supported by relative magnetic palaeointensity suggest that the sedimentary record spans 10.2 ka BP, and reservoir effect is determined at 5.2 ka.

We studied 178-cm long core ESM3 with combination of the following methods: XRF, XRD, determination of magnetic susceptibility, cation exchange capacity, grain size analysis, geochemical analysis (TIC, TOC, TS), high pressure liquid chromatography (HPLC) and diatom community analysis. Our  $^{14}\text{C}$  ages, derived from carefully selected filamentous macroremains of aquatic mosses, however, indicate much lower age of the sediment, only about 1–1.5 ka BP, but with chronostratigraphic reversals. Therefore, nine samples were further subjected to single aliquot regenerative optically stimulated luminescence (SAR-OSL) dating. All OSL apparent ages are younger than 0.5 ka BP and indicate extremely high accumulation rates and very young history of the sediments, probably less than 400 years. Our preliminary laminae counting together with the value of sedimentation rate lead us to conclusion that the lamination is mostly formed on (quasi-)annual basis and thus represents varves. Our multi-proxy study of such high temporal resolution is advancing the precision of regional palaeoreconstructions. In the next step we plan to perform micro-XRF scanning on the parallel core to obtain more information on the nature of the laminae and possibly to geochemically identify cryptotephra which would enable correlation of our records with regional volcanic eruptions.

## **S27-P13\* - Using paleo-lake model simulations to test proxy reconstructions under late-glacial conditions**

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The late-glacial climate (~15.000 to 11.000 years before present) is dominated by rapid shifts between warm (interstadial) and cold (stadial) climate states. These shifts are linked to rapid warming/cooling of the North Atlantic Ocean and related atmosphere-ocean-sea-ice feedbacks in response to excess freshwater fluxes from melting ice sheets. So far, many paleolimnological climate proxies (e.g. chironomids) suggest a direct link between cold/warm North Atlantic Ocean states and cold/warm European summer climates during (inter-)stadials – notwithstanding much higher summer insolation than today.

However, cold summer proxies during late glacial stadials appear to be inconsistent with some terrestrial summer climate proxies and climate model simulations. The latter suggests that rather the winter-spring seasons undergo extreme changes, which may explain some of the divergences between limnological and terrestrial proxies.

Here we test how extreme changes in seasonality during the late glacial affect lake-physical parameters like lake temperatures, ice season and stratification by running two freshwater lake models (FLake, PROBE lake). We use (sub-)daily meteorological forcing data for late glacial conditions from new high-resolution climate model simulations. With these forcing data, we can simulate lakes under different (inter-)stadial climate conditions which took place under different orbital and greenhouse gas forcing. We will show that extreme changes in seasonality, i.e. a shortening of the warm season, will affect different lakes in a very different way depending on lake depth and/or stratification/mixing during summer. The simulated lake-physical changes raise important questions about the stationarity of modern-day empirical transfer functions, which are typically used to infer ambient air temperatures from aquatic proxies but are then applied to fundamentally different climatic conditions of the past.

## S27-P14 - The transport and mass balance of fallout radionuclides in Brotherswater, Cumbria (UK)

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Although lake sediment archives are widely used for reconstructing historical records of atmospherically delivered pollutants, the quantitative relationship between fallout levels and their record in the sediments is complex and not well known. One of the most commonly used radionuclide to date sediments and trace pollution is  $^{210}\text{Pb}$ . Since  $^{210}\text{Pb}$  is strongly attached to particulates, the principle mechanisms controlling its redistribution following deposition on the landscape will be soil erosion within catchments and sediment transport within water bodies.

The purpose of the present research is to study the transport processes controlling the fate of  $^{210}\text{Pb}$  deposited on the catchment of Brotherswater in the English Lake District, UK, and in particular the impact of these processes on the supply of  $^{210}\text{Pb}$  to the sediment record in the lake. The site is unique in that it has been the subject of a number of multi-core studies of fallout  $^{210}\text{Pb}$  (and also the artificial radionuclide  $^{137}\text{Cs}$ ) since the early 1970s. The information gained by comparing and combining results from the present study with those from earlier studies offers the possibility of yielding not only a better understanding of the long-term fate of fallout radionuclides in the catchment but also evidence as to the long-term stability of lake sediment records as natural environmental archives.

Our first objective was to establish a mass balance for fallout  $^{210}\text{Pb}$  in Brotherswater. The mean atmospheric flux ( $183 \text{ Bq m}^{-2} \text{ y}^{-1}$ ) was determined from records in soil cores collected from stable undisturbed sites in the catchment. Estimates of transport rates into the lake and through the water column were made by measuring  $^{210}\text{Pb}$  concentrations on samples collected in sediment traps placed in the main inlet stream and at different depths in the water column. The mean  $^{210}\text{Pb}$  supply rate to the bottom sediments was determined from records in a suite of cores collected from different depositional zones spanning the entire bed of the lake. Collating all the data from this and earlier studies, the total annual input of  $^{210}\text{Pb}$  to the water column of Brotherswater was estimated to be between  $9.05\text{--}11.5 \times 10^7 \text{ Bq y}^{-1}$ , with  $3.30 \times 10^7 \text{ Bq y}^{-1}$  coming from direct fallout and between  $5.75\text{--}8.20 \times 10^7 \text{ Bq y}^{-1}$  by transport from the catchment. Outputs to the sediment record were  $4.29 \times 10^7 \text{ Bq y}^{-1}$ , with the balance ( $4.76\text{--}7.21 \times 10^7 \text{ Bq y}^{-1}$ ) being lost via the outflow. The relatively large catchment inputs are attributed to the large catchment/area ratio of Brotherswater (72). They represent no more than between 2.4–3.4% of annual fallout onto the catchment. A significant fraction of catchment inputs were deposited at sites close to the main inflow.  $^{210}\text{Pb}$  supply rates at parts of the lake remote from the inflow were comparable to the atmospheric flux.

## **S27-P15 - The role of humans in past landscape change over the last 2000 years in southeastern Sweden**

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During the last two millennia Sweden has experienced fluctuations in climate such as the Medieval Climate Anomaly, Little Ice Age and now the Modern Warming, all reflected in paleorecords. Over this same period, the region of southern and central Sweden was also characterised by major fluctuations in population density and the development of more efficient agricultural practices. Since the Neolithic time, the region has been actively exploited for agriculture, however with periods of abandonment or decrease in activity, and reforestation as a consequence. Eventually, there was a transition to modern agricultural practices based on intensive usage of artificial fertilisers starting from 1940–1950's.

What has been the long-term role of humans in changing the landscape? To what extent did changes in land-use contribute to modifications of the Baltic Sea's coastal environmental status?

A case study which aims at getting an insight into influence of changes in land-use on the Baltic Sea coastal zone during the past 2000 years has been carried out and links to the SEASIDE project. Our study area is in the Gamleby region in southeastern Sweden. The area is rich in archeological findings that evidence human activity from the Mesolithic time onwards. Sediment cores from Lake Lillsjön and Lake Skarpegöl are used to reconstruct vegetation and land-use activity history over the last two millennia based on pollen and charcoal analyses. Magnetic susceptibility and core density measurements are used for erosion indication.

The Landscape Reconstruction Algorithm and its two models REVEALS (1) and LOVE (2) will be applied for quantitative reconstruction of, respectively, regional and local plant cover in order to estimate the degree of human impact on the landscape and link it to the archaeological record and the environmental history of the Baltic Sea as recorded offshore from our study region. Preliminary results from this study will be presented.

(1) Sugita, S. 2007a. Theory of quantitative reconstruction of vegetation I: pollen from large sites REVEALS regional vegetation composition. *Holocene* 17:229-241.

(2) Sugita, S. 2007b. Theory of quantitative reconstruction of vegetation II: all you need is LOVE. *Holocene* 17:243-257.

## **S27-P16 - YOUNG ISDR, a new international platform for early career diatomists**

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During the last International Diatom Symposium held in Quebec City (Canada) in 2016, the Young ISDR section within the International Society of Diatom Research (ISDR) was launched. The idea behind this formation is to (a) address the interests of early career diatomists directly to the ISDR committee by an elected early career representative, and (b) assist early career researchers to build collaborations and develop skills needed for career enhancement. A better exchange with experienced diatomists should be facilitated providing workshops dealing with key topics of diatom research within future congresses, such as the next International Diatom Symposium held in Berlin in June 2018. The Young ISDR also tries to improve global networking with other international scientific organisations and related diatom research topics. Here, we would like to present a newly created socializing network of Young ISDR members including an interactive forum and a blog (<https://youngisdr.blogspot.de/>), which both highlight job offers, possible funding, future workshops and conferences, research reports and key publications within the field of diatom research.

## **S27-P17 - Lacustrine pockmarks as hot spots of subaquatic groundwater discharge: case studies from peri-alpine lakes in Switzerland**

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Acquisition of high-resolution swath bathymetric data in peri-alpine lakes allowed the mapping of so-called pockmarks. Pockmarks are crater-like depressions on the floor of oceans and lakes created by focused upward migration of fluids (groundwater and/or gas such as methane) originating from deeper sediment layers or from the bedrock. In this contribution, we will present pockmarks in Lake Neuchatel and Lake Thun (Switzerland) that are presently characterized by active subaquatic groundwater discharge, or that are interpreted to represent spots of groundwater discharge in the past.

In Lake Neuchatel, most prominent are four “giant” pockmarks (80 to 160 m in diameter) located along the northern lakeshore in the extension of NW-SE or NE-SW oriented faults of the calcareous Jura Mountains. Using a Remotely Operated Vehicle (ROV), evidence for present groundwater discharge is provided by (i) positive anomalies in temperature and electrical conductivity detected when cruising just above the surface of the sediment suspension filling a 60 m-deep pockmark crater, as well as by (ii) mini mud volcanoes characterizing the suspension surface. In addition, the analysis of major ions and stable water isotopes of discrete samples from the interior of the pockmark crater show properties characteristic for karst groundwater. In Lake Thun, one site located on gypsum-carrying bedrock along a tectonic fault zone is also characterized by positive anomalies in electrical conductivity, indicating present groundwater discharge. In contrast, a similar karst setting as described above for Lake Neuchatel shows presently no signs of active groundwater discharge.

Hence, in both lakes evidence for presently active subaquatic groundwater discharge via pockmarks was found. Upcoming research efforts will tackle the quantification of this detected groundwater flux using lake-floor monitoring installations. In addition, presently dormant sites will be investigated for activity in the past in concert with hydroclimatological changes and earthquake events.

## S27-P18 - Taxonomic structure of Cladocera and Chironomidae assemblages from Central America and the Yucatan Peninsula based on lacustrine sediments

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Knowledge on the diversity and structure of Cladocera and Chironomidae communities of the Neotropical region, especially Central America, is still insufficient. Due to limited information about taxonomic composition and characteristic features of particular species/taxa, the paleolimnological surveys are hindered in the region. Here we bring the first results of a taxonomic study conducted in surface sediments from waterbodies of Mexico (Yucatan Peninsula) and Central America (Guatemala, El Salvador, Honduras). The recorded cladocerans represent five families (*Sididae*, *Bosminidae*, *Daphniidae*, *Macrothricidae* and *Chydoridae*). Most of the identified taxa belong to the littoral family Chydoridae. However, due to their uncertain taxonomic state, it is often problematic to recognize the members of *Chydoridae* at species level. Some taxa were restricted to specific area, such as *Ephemerophorus archboldi* and *Anthalona verrucosa pectinata* to Mexico while some ones had wide geographical and ecological range. Both planktonic families *Daphniidae* and *Bosminidae* were represented by only three taxa but usually appeared in significant amounts. With 60 taxa, *Chironominae* was the most specious subfamily of chironomids, followed by *Orthoclaadiinae* (26), *Tanypodinae* (16) and *Podonominae* (1). Numerically, *Chironominae* and *Tanypodinae* dominated, representing 63% and 31% of all remains, respectively. The most common taxa were *Ablabesmyia*, *Polypedilum*, *Goeldichironomus*, *Labrundinia* and *Chironomus*, occurring in >50% of the lakes. Diversity per site varied from 4 to 25 taxa. Number of *Orthoclaadiinae* increased and *Chironominae* decreased with altitude, while *Tanypodinae* remained indifferent. Total chironomid diversity did not show any relationship to altitude.



# Author list

First author in alphabetical order. ID number includes session (S) number, if it is a oral presentation (O) or a poster presentation (P) and if there will be a poster speed talk (\*).

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		Blanchet, C	S03-P01
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Cohen, A	Award winner	Felix-Faure, J	S21-O02
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Diekmann, B	S17-O02	Gregersen, R	S03-O05
Doerfler, W	S20-O03	Gregory-Eaves, I	S23-O02
Domaizon, I	Plenary Speaker	Griffiths, K	S23-O03
Doyle, RM	S17-P03*	Grudzinska, I	S21-O05
Dreibrodt, S	S20-P03*	Guerra, L	S10-P03*, S13-P02
Driessen, T	S16-P02*	Guo, L	S19-P02
Duda, MP	S06-O02	Gushulak, CAC	S09-O02
Echeverria, P	S16-P03	Haas, M	S05-O01, S21-P01
Eensalu, M	S09-P03*	Hamerlik, L	S17-P05
Eklund,	S11-O01	Hammarlund, D	S07-O04
Engels, S	S27-P06, S27-P07*	Hansson, SV	S21-O06, S25-O01
Epp, LS	S03-O03	Hazukova, V	S21-P02*
Faber, J	S13-O03	Heiri, O	S05-O02
Favot, E	S27-O04	Hennekam, R	S01-O05
Feeser, I	S20-P04*	Hepp, J	S08-P01*

Hernández, A	S10-P04*, S10-P05*	Kiro, Y	S09-P04
Hertzman, H	S20-O04	Kivilä, HE	S05-O04
Hofmann, A	S07-P03*	Kjellman, S	S08-P02
Holmes, JA	S15-O02	Klaminder, J	S03-O06
Holtvoeth, J	S17-P06*	Klemt, W	S21-O07
Hou, J	S20-O05	Koinig, KA	S11-O02
Howard, K	S07-P04*	Kolaczek, P	S17-O04
Huang, J	S01-P03	Korkonen, S	S14-P03*
Ibrahim, A	S03-P02*	Korosi, JB	Award winner, Plenary Speaker
Ilijanić, N	S27-O05	Korponai, J	S17-P09
Jacq, K	S01-P04	Kostrova, SS	S09-P05
Jenny, J-P	Award winner	Krahn, KJ	S18-P04*
Jeremie, G	S19-O02	Krentscher, C	S16-P05
Jiang, W	S19-P03	Kuefner, W	S17-O05
Jiang, Z	S24-O02	Kurek, J	S21-O08
Jinglu, W	S17-P07	Labaj, A	S17-O06
Jones, MD	S08-O02	Labuhn, I	S09-P06
Jones, SE	S18-P03, S25-P03*	Lacey, J	S16-P06, S27-P08
Junginger, A	S15-P05, S15-P06	Ladd, NS	S08-O04
Juutinen, S	S05-O03	Laeuchli, B	S22-P01
Kalanke, J	S20-P05	Lamb, H	S15-O06, S15-P07
Kang, W	S17-P08	Lami, A	S11-P02*
Karpińska-Kolaczek, M	S25-O02	Larsson, S	S09-P07*
Katrantsiotis, C	S08-O03	Laug, A	S17-O07
Kay, M	S01-O06, S23-P02	Leng, M	S05-O05
Kehusmaa, K	S21-P03*	Levy, E	S18-O02
Kinder, M	S20-P06	Li, J	S07-P05

Li, K	S17-P10	Martínez Cortizas, A	S25-003, S25-004, S25-005
Liao, M	S07-P06	Mather, C	S18-004, S19-003
Lidman, J	S21-P04*	Mauad, M	S17-P12*
Lin, TW	S10-O02	Mayr, C	S08-P03*, S17-O08
Lindemann, C	S20-P07	McCormack, J	S19-004
Lisitsyna, O	S14-P04	Medeiros, AS	S14-002
Little, AJ	S21-P05	Mekonnen, B	S17-P13*
Lloren, RB	S16-P07*	Metcalfe, S	S19-005
Long, H	S18-O03	Meyer-Jacob, C	S05-O07
Lowenstein, TK	S15-P08	Meyer, I	S15-003
Lozano-García, S	S22-O04	Miebach, A	S18-O05
Lu, Y	S20-P08*	Miko, S	S19-006
Lu, Y	S20-P09, S20-P10	Mischke, S	S18-O06
Luoto, TP	S11-P03	Moguel, B	S03-O07
Lyon, E	S17-P11*	Moir, KE	S21-O09
Mackay, AW	S05-O06, S27-P09*	Moorhouse, H	S22-P02*
Maezumi, SY	S16-O03	Moravcová, A	S21-P06
Magne, GK	S27-O06	Morlock, MA	S01-P06*, S04-O02
Maier, DB	S11-O03	Moyle, M	S06-O03
Maitituerdi, A	S15-P09	Musazzi, S	S27-P11*
Makri, S	S01-P05*	Müller, D	S20-P12
March, A	S08-O05	Myrbo, A	S13-O04
Margielewski, W	S27-O07	Myrstener, E	S21-O10
Markowska, M	S15-P10	Nantke, C	S27-O08
Martin-Bello, L	S19-P04	Nazarova, L	S23-P03, S27-O09
Martin-Puertas, C	S20-P11*	Nelligan, C	S27-O10
Martinez Abarca, LR	S27-P10*	Nelson, ST	S07-O05, S09-O03

Neugebauer, I	S10-O03, S18-P05*	Reavie, ED	S23-O05
Nevalainen, L	S14-P05	Regnell, C	S20-O08
Nilsen, AB	S06-O04	Reid, M	S23-O06
Ninnes, S	S21-O11	Remmer, CR	S11-O05, S13-P03
Niska, M	S10-O04	Renaut, RW	S15-O05
Noren, A	S27-O11	Rey, F	S20-O09
Opdyke, BN	S18-P06	Riedinger-Whitmore, MA	S01-P09
Ortega, B	S22-P03*, S22-P04*	Rioual, P	S09-O05
Ossyssek, S	S04-O03	Roberts, LR	S21-O13
Owca, T	S23-O04	Roberts, N	S20-O10
Owen, B	S15-O04	Roberts, S	S01-P10*
Palmer, AP	S20-O06	Roethlin, RL	S01-P11*
Panizzo, V	S07-O06, S16-P08	Roman, M	S27-P12
Patrocínio, L	S10-P06*	Rose, NL	S16-O04
Pearson, E	S01-P07*	Rosen, M	S18-O07
Perez, L	S10-P07, S22-P05	Rouillard, A	S03-O08, S05-O08
Peti, L	S01-P08*	Rubio, K	S22-P06
Peti, L	S24-O03	Russell, F	S01-O07, S05-P01
Pickarski, N	S20-P13	Russell, JM	S17-O10, S22-O05
Pla-Pueyo, S	S24-O04	Rydberg, J	S20-O11
Poher, Y	S25-O06	Saarni, S	S20-O12
Poraj-Górska, A	S20-P14*	Sanchini, A	S06-P01
Primmer, N	S20-O07	Saros, J	S11-O06
Quinlan, R	S21-O12	Schenk, F	S27-P13
Rantala, MV	S11-O04	Schneider, L	S16-O05
Raposeiro, PM	S10-P08	Schneider, T	S16-O06
Rapuc, W	S09-O04, S17-O09	Scholtyski, G	S08-P04*

Scholz, C	S15-O07	Tammelin, M	S23-P04
Schuster, M	S15-O08	Telford, J	S27-O13
Schwalb, A	S22-P07*	Telford, RJ	S04-O05
Schwarz, A	S11-O07	Thienpont, J	S14-O03
Scott, JJ	Plenary Speaker	Tibby, J	S27-O14
Seguin, J	S04-P01*	Ticha, A	S13-P04
Semertzidou, P	S27-P14	Tofilovska, S	S07-P07*
Shen, J	S09-P08	Tu, L	S06-P02*
Sia, ME	S11-P04*	Turner, S	S23-O07
Silva-Sanchez, N	S25-P04*	Tylmann, W	S20-P17
Simmatis, B	S21-O14	Unkel, I	S08-P05*
Simpson, G	S04-O04	Unkelbach, J	S17-O11
Sirota, I	S20-P15	Valero-Garces, B	S19-O07, S22-O06
Sivarajah, B	S21-O15	Valleau, RE	S27-O15
Sjöström, J	S25-O07	Van Daele, M	S15-P11
Smith, ME	S24-O05	Van der Meeren, T	S18-O08
Smittenberg, RH	S08-O06	van Hardenbroek, M	S03-O09, S06-P03*
Solovieva, N	S25-P05	Vandekerkhove, E	S25-P06*
Stansell, ND	S08-O07, S09-O06	Verleyen, E	S24-P01
Stewart, E	S13-O05	Vermaire, JC	S21-O16
Stoof-Leichsenring, KR	S03-P03*	Vicente de Vera, A	S11-P05, S17-P14
Subetto, D	S20-P16*	Viehberg, F	S14-O04
Suchora, M	S21-P07*, S21-P08*	Vinogradova, O	S27-P15
Summers, JC	S27-O12	Vogel, H	S14-O05
Swann, GEA	S08-O08	Vondrak, D	S17-P15*
Sylvestre, F	S15-O09	Vossel, H	S07-P08*, S27-P16
Syrykh, L	S14-P06	Vyse, S	S14-P07*

Wagner, B	S15-P12, S22-O07	Yang, X	S13-P05
Waldmann, N	S22-P08, S24-O06	Zahajska, P	S07-P09*
Walton, R	S21-O17	Zander, P	S20-P18*
Wang, J	S09-O07	Żarczyński, M	S20-O13, S20-P19
Wang, Q	S17-O12	Zawisza, E	S13-P06, S16-O07, S22-P09
Waters, MN	S06-O05, S13-O06	Zech, M	S01-O08
Wengrat, S	S04-P02*, S16-P09*	Zeng, L	S06-O06
Wennrich, V	S14-P08, S18-O09	Zhang, J	S22-P10
Whitmore, TJ	S23-O08	Zhang, K	S23-O09
Winther Pedersen, M	S03-O10	Zhang, Y	S17-P17*
Wirth, SB	S27-P17	Zhao, C	S27-O16
Wojewódka, M	S16-P10*, S27-P18	Zhu, L	S10-P10
Wu, D	S10-P09	Zimmerman, SRH	Plenary Speaker
Xiao, X	S17-P16	Zolitschka, B	S10-O05
Yan, Y	S11-O08	Zou, Y	S17-P18
Yang, B	S05-P02		