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# Sixth International Limnogeology Congress—Abstract Volume, Reno, Nevada, June 15–19, 2015

Open-File Report 2015-1092

6th International Limnogeology Congress
ILIC 2015
Reno - Lake Tahoe

International Association of Limnogeology

U.S. Department of the Interior
U.S. Geological Survey

**Cover:** Photograph of Lake Tahoe looking west to California from Sand Harbor, Nevada. Photograph by Michael Rosen, U.S. Geological Survey, January 19, 2009.

# Sixth International Limnogeology Congress — Abstract Volume, Reno, Nevada, June 15–19, 2015

Edited by Michael R. Rosen, Andrew Cohen, Matthew Kirby, Elizabeth Gierlowski-Kordesch, Scott Starratt, Blas L. Valero Garcés, and Johan Varekamp

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**U.S. Department of the Interior**
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# Preface

Limnogeology is the study of modern lakes and lake deposits in the geologic record. Limnogeologists have been active since the 1800s, but interest in limnogeology became prevalent in the early 1990s when it became clear that lake deposits contain continental environmental and climate records. A society that is focused on limnogeology would allow greater communication and access to research on these important subjects and contribute to providing sound science used to understand rapid global changes in our modern world; thus, the International Association of Limnogeology was founded in 1995 at the first International Limnogeology Congress (ILIC) held in Copenhagen, Denmark.

The Sixth International Limnogeology Congress (ILIC6) was held in Reno, Nevada, from June 15–19, 2015. The ILIC meetings have been held every 4 years since the first meeting in1995 and were subsequently convened in Brest, France (1999), Tucson, Arizona, USA (2003), Barcelona, Spain (2007), and Konstanz, Germany (2011). The Congress in Reno, USA marks the second time the Congress has been held in the United States and more than 150 scientists from every part of the world participated. About one-half of the participants were from North America, together with scientists from Europe, South America, Asia, Africa, Australia, and New Zealand. The format of the Reno Congress followed the format originated at the Tucson Congress (ILIC3), which is unusual for scientific meetings. Nine keynote speakers spread throughout the Congress gave 1-hour talks, with the rest of the time available for viewing posters that were presented by the bulk of the participants. Keynote presentations were diverse and showed the breadth of research that is being done in lake systems worldwide. The abstracts of the keynote speakers and about 140 poster presentations are included in this volume. These posters cover a variety of limnologic, paleolimnologic, and limnogeologic topics including contaminant histories of lakes, the role of groundwater in lake processes, the formation of minerals in lake sediments, terminal lakes, how lakes reveal climate changes and paleohydrologic processes, the impact of volcanic emissions on lakes, as well as the biologic and chemical evolution of lake systems.

The extended abstracts of USGS authors in this Abstract Volume were peer reviewed and approved for publication by the U.S. Geological Survey. Abstracts submitted by non-USGS authors did not go through the formal USGS peer review and approval process, and therefore may not adhere to our editorial standards or stratigraphic nomenclature and is not research conducted or data collected by the USGS. However, all abstracts had at a minimum one peer review, and all abstracts were edited for consistency of appearance in the published Abstract Volume. The use of trade, firm or product names in any extended abstract is for descriptive purposes only and does not imply endorsement by the U.S. Government.

The ILIC6 also included a half-day workshop on using the Bacon age-dating modeling software. The workshop was run by Amy Myrbo and Susan Zimmerman, and was attended by more than 15 participants, many of whom were students. The workshop provided hands-on practice for new and beginning users of the Bacon age-depth modeling software and related tools. Attendees created age-depth models using their own data, with support and advice from Amy and Susan.

Students were a big part of the Congress, with more than 25 students attending. Several students received scholarships to help pay for registration and travel costs and were sponsored by the International Association of Sedimentologists, the University of Kentucky, Northern Arizona University, Queen's University, Canada, and the National Autonomous University of Mexico.

The Congress included a mid-Congress half-day field trip to Lake Tahoe, led by Sudeep Chandra and Alan Heyvaert, illustrated the limnogeologic history of the lake. The participants also learned about the current water resource issues that involve keeping the lake clean, providing potable water to inhabitants, and keeping invasive species out of the lake. A one-day post-Congress field trip to Pyramid Lake, Nevada, led by Brian Wadsworth of the Pyramid Lake Paiute Tribe, Ken Adams, and Alan Heyvaert also was held to discuss water management, cultural, and limnogeological aspects of the lake. The Congress also included four overnight pre- and post-Congress field trips to lakes and lake deposits. The pre-Congress field trips examined outcrops of the pluvial and post-glacial lakes of the eastern Great Basin, led by Paul Jewell, Ben Laabs, Jeff Munroe, and Jack Oviatt, and lake sequences of closed-basin lakes in the Eocene Green River Formation in Wyoming, led by Michael Smith and Jennifer Scott. Post-Congress field trips to Pleistocene deposits and modern lakes in the Great Basin of North America (led by Susan Zimmerman, Ken Adams, and Michael Rosen), and a trip to modern volcanic lakes in Lassen National Park (led by Paula Noble and Kerry Howard) provided participants with a glimpse at a wide variety of lakes in the Western United States. The field trip guides for the four overnight pre- and post-Congress field trips are available at http://pubs.usgs.gov/of/2015/1092.

The U.S. Geological Survey has sponsored each ILIC that has been held in the United States because of the importance of understanding paleoclimate and contaminant histories of lakes, two main themes of the Congress. This volume provides a permanent record of the wide variety of studies that are being conducted in modern lakes and ancient lake deposits worldwide, and it provides a stepping stone for any one desiring further discussion of the work that was presented at ILIC6.

# Acknowledgments

The editors would like to thank Tina Triplett, Executive Director of the Nevada Water Resources Association, and her team (Katie Keating, Kallie Harris, Laura Sedar, and Jackie Schmid) for their dedication in making sure all aspects of the Sixth International Limnogeology Congress ran as smoothly as possible and for their work in collating and distributing the abstracts to the editors. We would also like to thank the ILIC6 organizing committee and the many sponsors (see below) of the meeting for contributing to the success of the Congress. Finally, the stellar work of Linda Rogers and her team at the U.S. Geological Survey Science Publishing Network lifted much of the burden off of the editors.

The list of sponsors for ILIC6 in alphabetical order include:

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LacCore
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National Autonomous University of Mexico, Mexico
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## KEYNOTE ABSTRACTS

### Assessing Natural Hazards with Lake Sediments: Reconstructing Histories of Floods, Earthquakes and Tsunamis

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Natural hazard assessments rely on high-quality time series of catastrophic events in order to constrain their recurrence rates and intensities. In this context, lake sediments provide continuously recording, datable and sensitive geologic archives that are capable of extending instrumental and historic time series towards prehistoric epochs. Such time series allow thus detailed and unprecedented analysis of past hazard activities and their temporal variations, eventually allowing projections into the future.

Ideal hazardous events to be recorded in lake sediments are for instance (1) floods, producing prominent clastic layers intercalated with background sediment (Glur and others, 2013), or (2) earthquakes, inducing subaquatic mass movements, related turbidites, or in-situ sediment deformations (Strasser and others, 2013). The sensitivity and response of each lacustrine system to record such natural hazards, however, are different and lake-specific. The formation of flood layers, for instance, depends not only on the rain-driven runoff signal but is also a function of the sediment-mobilization potential or the lake-basin geometry. In a similar fashion, triggering of earthquake-induced mass movements is dependent on slope geometries and sediment recharging potential, the latter characterized by sedimentation rate. This varying sensitivity implies that (1) each lake record needs to be calibrated with instrumental/historic data, and that (2) lakes should be weighed by their sensitivity before directly compared in regional multiple lake studies.

While recurrence intervals can be determined in a straight-forward manner by identifying and dating event layers, reconstructing the hazard intensity is much more complex. Flood intensity, for instance, is rather reflected in the maximal grain size of a flood layer (proxy for hydrologic energy) and not by the layer thickness (proxy for mobilized sediment). Determinations of the earthquake's epicentral location, magnitude and epicentral intensity are even more challenging and rely on complex local-to-regional analyses within multiple lake records and on empiric attenuation equations of seismic shaking that are furthermore masked by site effects.

Once the reconstructions of past hazard chronicles are achieved, projections into the future can be attempted, considering stable or changing boundary conditions, i.e. different climate states or different tectonic forcings. These projections, moreover, need to include human-induced changes and impacts, such as catchment-wide land-use. Additionally, they should be part of an applied approach and consider increased risk due to increased societal vulnerability. Forward numeric models that consider the external forcings (obtained through the reconstructed time series modulated by the ongoing environmental/climate changes) and the current lake state (for example the amount of sediment-charged slopes) can successfully simulate the hazard in a probabilistic manner. This will be shown with a tsunami hazard analysis, which quantifies the impact of these seismically-triggered lacustrine events on the lake shore communities through sophisticated simulations, providing a timely and societally-significant approach to use lake sediments in a quantitative fashion (Hilbe and Anselmetti, 2015).

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# Late Holocene Environments of Mesoamerica: A Story of Climate Changes and Human Occupation

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Lakes in central and southern Mexico are ideal sites for the study of late Holocene climatic trends. Most of these lakes have high sedimentation rates and their sediments are rich in pollen, diatoms and other biological remains that, together with geochemical proxies, allow reconstructions of past environmental, ecological and climatic changes. Mexico, besides, includes the cultural core-areas of several Mesoamerican civilizations, and its lake records can also give an insight of the interplay between human development and climatic variability in the region. Mexico's (and Mesoamerican) cultural development can be divided in the following episodes: Preclassic (2500 BC–AD100), Classic (AD100–AD900), Postclassic (AD900–1521), Spanish occupation (1521–1810) and Independent Mexico (1810–today). We present a review of late Holocene records from central and southern Mexico which show climatic variability and its impact on tropical ecosystems. In most of these records intense human impact is present since the Preclassic, mostly after *ca.* 1000 BC, and in several modern impact (post-1950) can also be followed. In some of them a clear connection between climate and cultural changes can be inferred, mostly at the transition between the Classic to the Postclassic. The particular response of each record is, however, modulated by its precipitation/evaporation balance. The main climatic trends during the Late Holocene in this region can be summarized as follows: (1) a trend to dryer conditions since the late Preclassic and during the Classic; driest conditions correlate with the late Classic (AD600–900), which is also a time of a major cultural reorganization related with the demise of the Teotihuacan and Maya cultures; (2) relatively moist conditions during the late Postclassic (AD1200–1400) correlate with the Aztec expansion and the maximum development of some sites in Northern Mexico; and (3) cool Little Ice Age, with two dry phases that generally follow the Spörer and Mounder solar minima (1400–1560 and 1650–1750), the first of these dry episodes preceded and correlates with the arrival of the Spanish in Mexico.

## Plio-Pleistocene Climate Variability in the Terrestrial Arctic: Insights from Organic Geochemical Proxies

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The regional response of the high Arctic to past climate variability is little known beyond the brief time period (~120,000 years) covered by Greenland ice cores. In 2009, a 3.6 Ma sediment core was recovered from Lake El'gygytgyn (NE Russia), the largest and oldest unglaciated Arctic lake basin. These sediments thus offer a unique opportunity to examine Plio-Pleistocene high-latitude continental climate variability. Proxy data (e.g., physical properties, bulk geochemistry, pollen, diatom assemblages) generated thus far from the Lake El'gygytgyn drill core indicate the presence of 17 “super”- interglacials occurring in the past 3.2 Ma (Melles and others, 2012; Brigham-Grette and others, 2013), including Marine Isotope Stages (MIS) 11 and 31. Remarkably, pollen-based estimates of temperature and precipitation suggest that MIS 11 and 31 were characterized by summer temperatures approximately 4°C higher than at present with 3 to 4 times the annual precipitation (Melles and others, 2012). Here we present results of ongoing organic geochemical analyses of Lake El'gygytgyn sediments focusing on the mid-Pliocene warm period, the Plio-Pleistocene transition and intensification of Northern Hemisphere glaciation (~2.9 to 2.5 Ma), the mid-Brunhes transition, and warm Pleistocene interglacials. Despite the ultra-oligotrophic nature of Lake El'gygytgyn and generally low sedimentary total organic carbon (TOC) content, we find abundant branched glycerol dialkyl glycerol tetraethers (brGDGTs) throughout the entire record and use the methylation and cyclization indices of branched tetraethers (MBT and CBT, respectively) to reconstruct past temperature (Weijers and others, 2007). We note that overall trends in our MBT/CBT temperature record support the pollen-based temperature reconstructions throughout the entire core. Interestingly, a number of abrupt and relatively short-lived cooling or warming events on the order of 2 to 4°C are noted within several of the interglacial periods, which are the subject of ongoing investigation. Overall, application of the MBT/CBT paleothermometer to Lake El'gygytgyn sediments appears to be a highly promising technique for generating a high-resolution Plio-Pleistocene temperature record from the continental Arctic.

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# Lake Tahoe and A World Water Crisis from Climate Change and Global Warming of Inland Waters

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The global decline of aquatic ecosystem integrity and water quality driven by climate change is in my opinion the most important environmental problem to be faced in this Century. Climate based warming is a major driver of these problems that are affecting aquatic systems from both severe droughts and serious flooding across the globe. Like many of the world's inland freshwaters, Lake Tahoe continues to warm and lose transparency as gradual eutrophication causes increased algal growth. Water shed erosion and fine particulates from atmospheric deposition also cloud the water column. Invasions of both exotic aquatic weeds and fish introductions further threaten the functioning of this sensitive ecosystem. The synthesis of long-term data, new research technologies, exploratory research, adaptive management, and community outreach have been important for better conserving Tahoe's air and water quality. The lessons learned at Tahoe should prove useful for the management of other aquatic resources. Unfortunately throughout the world policy decisions are often based on poorly interpreted data driven by political and industrial agendas. Strong environmental science must be returned to the forefront in developing an improved environmental ethic in order to mitigate and improve adaptive management strategies for sustaining the quality of our limited freshwater resources. The impacts of climatic change and warming continues be denied for political and industrial advantage through a well funded and orchestrated attack on science. The World Water and Climate Foundation (WWCF) was organized in 2012 from an earlier educational network (WWCN) established in Kyoto in 2002. Limnology students were then brought together at four world water conferences. Data presented and recently published from these conferences helped assess the impact on inland waters of climatic change and global warming. Only by developing improved strategies can we hope to meet the world's water, energy and food crises that now threaten future life on our increasingly damaged and over populated planet.

# Recent Advances in the Use of Oxygen Isotopes in Diatom Silica in Lake Research

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Isotope geochemistry is an essential part of environmental and climate change research and over the last few decades has contributed significantly to our understanding of a huge array of environmental problems, not least in palaeolimnology and limnogeology. Amongst the growing applications is the use of the oxygen isotope composition of diatom silica. Key issues are the preparation/purification of the material, the isotope extraction method, and the interpretation of the signal in a variety of lake types.

Diatom silica is a form of biogenic opal, and is comprised of an inner tetrahedrally bonded silica skeleton (Si-O-Si) with an outer, hydrous layer. The hydrous layer is freely exchangeable and must be removed prior to oxygen isotope measurement. Analysis of the oxygen isotope composition of diatom silica requires samples that are almost pure diatomite since extraction techniques will liberate oxygen from all the components in the sediment. There is a generally acceptable protocol involving chemistry and physical techniques although some material has proved impossible to purify and therefore geochemical mass balancing techniques have been employed. Even a small proportion of contaminant can have a significant influence on the oxygen isotope value. When robust preparation and analytical methods are used, the oxygen isotope composition of diatom silica offers an important palaeoclimate proxy, providing an additional complementary, rather than an alternative, host of oxygen isotopes in carbonates.

# Limnogeology in the Central Andean Foreland, or
# *How I Learned to Stop Worrying and Love Project FBOM*

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The Convergent Orogenic Systems Analysis (COSA) initiative at the University of Arizona was a large, industry sponsored research project that endeavored to rethink the evolution of Cordilleran mountain belts and associated basins from a holistic multi-disciplinary perspective, aided by new tools in geology, geochemistry, and geophysics. A great number of faculty and students participated in the project, using the complex extant central Andes of northern Argentina as the primary target field area. Later, the project would revisit a number of classic localities within the Mesozoic Sevier fold-and-thrust belt of the western United States. The conceptual underpinning of the project was initially discussed in DeCelles and others (2009), which posited that crustal shortening and magmatism in Cordilleran systems were parts of a cycle that was largely driven by processes impacting the upper (continental) plate. This new model challenged previous hypotheses on Cordilleran mountain building, which had placed greater emphasis on time-transgressive deformation and processes dictated by dynamics of the subducting (oceanic) plate. The DeCelles and others (2009) concept of orogenic cyclicity has important implications for the creation of accommodation and patterns of sedimentation, both within partitioned retroarc foreland basins and atop the orogens themselves. My colleagues and I began investigating different aspects of convergent syn-orogenic sedimentation from this perspective – and thus the Foreland Basins of Mercosur (FBOM) project came into existence.

ILIC6 provides a lovely backdrop to highlight some of the key learnings that have been obtained from FBOM since ILIC4, where the project was first introduced when I was a graduate student. In the intervening eight years, an important theme of the research program has been comparative modern and ancient limnogeology. Numerous field campaigns (some more newsworthy than others; Arini, 2009) to examine lacustrine deposits were conducted in different foreland depozones of both the Andean and Sevier systems. South America contains a great diversity of inland aquatic ecosystems, yet large and deep tectonic lakes are relatively rare. Fundamentally, this is because continental foreland basins adjacent to thin skinned fold- and-thrust belts frequently overfill with sediment, and as a consequence topographic closure (a prerequisite for lake formation) is difficult to preserve over expanded intervals of geologic history. Observations of modern foreland geomorphology and insights from models suggest that lake persistence requires favorable environmental conditions, which may include: (1) topographic isolation due to interaction of the migrating flexural wave with pre-existing structures; (2) climate characteristics that promote sediment starvation; (3) differences in hinterland bedrock composition that encourage greater solubility with weathering, thereby limiting bedload exported by rivers to the basin; and (4) short-lived interactions partially coupled to the tectonic setting, such as competitive aggradation on fluvial megafans or eolian deflation. The various paleoenvironments associated with the global record of foreland basin lake strata appear to validate the importance of these controls (Cohen and others, 2015).

In my view, some of the most interesting lacustrine strata accumulate in the distal foreland depozones, which are represented in the modern Andean system by lakes of the Pantanal and Chaco lowlands, and in the ancient Sevier system by Cretaceous rocks (Minnewaste Limestone; Zaleha, 2006) beautifully exposed in South Dakota. Ultimately, a primary objective of FBOM was to use the distribution of modern lakes, coupled with lake sediment core data, to improve our understanding of the rock record. Some headway has been made towards this goal, particularly in the Andes. Massively bedded, organic-rich, green silty clays recovered from the floodplain lakes of the humid Pantanal in Brazil (McGlue and others, 2011) present an intriguing analog for key Paleogene lacustrine strata from Argentina, which some authors argue is reflective of deposition in a back-bulge depozone (DeCelles and others, 2011). The prevailing geodynamics associated with the early Cenozoic evolution of northwest Argentina (rift to post- rift sagging versus subsidence linked to flexural wave migration) have been vigorously debated, but the many shared lithofacies characteristics between modern and ancient lake deposits strongly supports the interpretation of a convergent paleogeographic setting.

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## A Question of Scale: Understanding the Climatic, Tectonic and Geomorphic Signatures in Eocene Strata of the North American Cordillera


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The application of modern geochronologic methods to the study of Paleogene lake deposits in the Western United States. has revolutionized our understanding of the processes that led to their deposition. This talk will explore the Paleogene record from two scales: (1) individual beds and bed set within the Wilkins Peak Member of the Green River Formation (5–500 kyr); and (2) the large-scale Eocene stratigraphic packaging across the Cordilleran foreland and hinterland (0.5–5 Myr).

Part (1): The Wilkins Peak Member of the Green River Formation is a complex amalgam of lacustrine and alluvial lithofacies deposited in a closed basin at the center of the Laramide broken foreland during the Early Eocene (51.6–49.8 Ma). Facies analysis and correlation of surface sections and core document remarkable lateral continuity within the Wilkins Peak Member. This correlation extends the Wilkins Peak Member into a region directly adjacent to the Uinta Uplift. Calcite-rich lacustrine lithofacies along the southern basin periphery interfinger with quartzose Uinta Uplift-derived fan delta deposits, which differ strongly from the dolomite marl, evaporite and arkosic alluvial facies of the basin interior.

Despite the compositional dissimilarities between the peripheral and interior facies belts, strata across both record a regular 4–30 meter oscillation between two facies associations: (1) a lacustrine association, which typically record rapid (precession-scale) expansions and contractions of Lake Gosiute; and (2) an alluvial mode, associated with low lake level and a basin-ward shift in alluvial depositional environments. Radioisotopic geochronology suggests that lacustrine-alluvial cycles likely were driven by 100 kyr (and possibly 405 kyr) eccentricity. Lacustrine intervals record the greatest hydrologic and insolation variation, and are hypothesized to have occurred during eccentricity maxima when insolation variation due to precession would have been most pronounced.

Part (2): Two major episodes of hydrologic drainage closure are recorded by Eocene terrestrial strata in the western United States. The first occurred in the retroarc foreland during the early Eocene, and resulted in the deposition of the Green River Formation. The second occurred in the hinterland during the late Eocene and resulted in accumulation of the Elko Formation. In both regions, lake strata overlie fluvial strata and become progressively more evaporative up-section, and are overlain by volcaniclastic strata. Both successions were then truncated by regional unconformities that extend until the Oligocene.

These succession are hypothesized to record trenchward propagation of a regional topographic wave caused by rollback of the Farallon flat slab. Regional surface uplift resulting from advection of asthenosphere initially caused ponding of lakes, then volcanism and volcaniclastic sedimentation, then ultimately the development of regional unconformities. Radioisotopic geochronology of Green River Formation ash beds suggest this topographic wave migrated trenchward (SW) across the foreland from 53 to 47 Ma at a velocity of ~6 cm/yr. Single crystal sanidine $^{40}Ar/^{39}Ar$ ages for Elko Formation ash beds indicate hydrologic ponding of the hinterland between 43 and 38 Ma. The 4 Myr gap between Green River and Elko Formation deposition may represent the time required for the rollback wave to transit the steep eastern slope of the Sevier fold-thrust belt.

# Canaries in the Coal Mine: Northern Lakes as Sentinels of Environmental Change

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High latitude lakes offer important opportunities for paleolimnologists to study long-term environmental changes using lake sediments. For example, Arctic regions are often the first to show signs of climatic change and often to the greatest degree. In particular, paleolimnological studies from many Arctic lakes and ponds have recorded striking and ecologically significant shifts in diatom assemblages. In addition, changes in these primary producers have now been supplemented by data from many other proxies, clearly showing that many of these changes are most closely linked to recent climatic change, often through indirect mechanisms (e.g., longer ice-free periods, enhanced thermal stability, etc.). It is important to acknowledge, however, that there are many environmental variables that can influence northern lakes. Despite considerable progress being made in our understanding of the physiology and ecology of key indicator proxies, it appears to be increasingly "fashionable" to state that fundamental processes are still very poorly understood or have not been studied (frequent wording it seems on many grant proposals). My thesis is that considerable progress has been made in many of these areas, due largely to the efforts of physiologists, chemists, ecologists, limnologists and other scientists, but that this information has not always been fully assimilated into many paleolimnological studies. Paleoenvironmental assessments are also challenged by the fact that, as we are a historical and inferential science, true experimental hypothesis testing is rarely possible. Nonetheless, a reasonable alternative is to conduct carefully designed comparative paleoenvironmental studies, where *a priori* questions can be answered using the sedimentary record. Paleolimnological methodologies have continued to gain strength and credibility over the years—my view is that we should not shy away from addressing complex issues. This presentation will include examples showing how our lab has attempted to disentangle the effects on northern lakes of multiple-stressors, such as industrial activities (e.g., the expanding petrochemical industry in some northern regions), the limnological repercussions of marine intrusions linked to decreased sea ice cover, and other environmental stressors within the context of a rapidly changing climate.

# Episodes of Environmental Stability Versus Instability in Late Cenozoic Lake Records of Eastern Africa

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Episodes of environmental stability and instability may be equally important for African hominin speciation, dispersal and cultural innovation. Three examples of a change from stable to unstable environmental conditions are presented on three different time scales, (1) the Mid Holocene (MH) wet-dry transition in the Chew Bahir basin (Southern Ethiopian Rift) (between 1.1 and $0.4\times10^4$ yr), (2) the MIS 5–4 transition in the Naivasha basin (Central Kenya Rift) (between 1.6 and $0.5\times10^5$ yr), and (3) the Early Mid Pleistocene Transition (EMPT) in the Olorgesailie basin (Southern Kenya Rift) (between 1.25 and $0.4\times10^6$ yr). A probabilistic age modeling technique is used to determine the timing of these transitions, taking into account possible abrupt changes in the sedimentation rate including episodes of no deposition (hiatuses). Interestingly, the stable-unstable conditions identified in the three records are always associated with an orbitally-induced decrease of insolation: the descending portion of the 800 kyr cycle during the EMPT, declining eccentricity after the $1.15\times10^5$ yr maximum at the MIS 5–4 transition, and after ~$1.0\times10^4$ yr. This observation contributes to an evidence-based discussion of the possible mechanisms causing the switching between environmental stability and instability in Eastern Africa at three different orbital time scales ($10^4$ to $10^6$ yr) during the Cenozoic. This in turn may lead to great insights into the environmental changes occurring at the same time as hominin speciation, brain expansion, dispersal out of Africa and cultural innovations and may provide key evidence to build new hypothesis regarding the causes of early human evolution.

## POSTER ABSTRACTS

### Using Tree-Ring Records to Simulate Annual Lake-Level Fluctuations at Tulare Lake, California, over the Last 2,000 Years

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Tulare Lake in the southern San Joaquin Valley of California was a sensitive recorder of long term climate fluctuations prior to water diversions and the lake itself being drained for agricultural purposes in the late 19th century. Lake levels in this quasi-closed basin fluctuated according to the water balance of its contributing watershed (~37,400 km$^2$), which includes four major tributaries that drain the southern Sierra Nevada. Here, we present results of paleohydrologic modeling using moisture-sensitive tree-ring chronologies to derive annual stream flow that in turn, is routed to a Tulare Lake water balance model that results in annual lake-level fluctuations over the last 2,000 years.

Tulare Lake occupied a broad, shallow basin that began to overflow into the San Joaquin River when the lake surface reached an altitude of about 64 m (Atwater and others, 1986). In particularly wet years, the lake surface reached an altitude of about 66 m, which corresponds to a surface area of about 1,860 km$^2$, a depth of about 10 m, and a volume of about 10 km$^3$. The climate of the basin floor is arid with hot summers and cool winters, mean annual precipitation (MAP) of about 20 cm/yr, and mean annual evaporation of about 140 cm/yr. About 95% of the water that flows into the lake is derived from spring snowmelt in the Sierra Nevada, where MAP ranges from about 100 to 150 cm/yr in the higher parts of the range, and is delivered by the Kings, Kaweah, Tule, and Kern Rivers. Total discharge in these streams is highly variable from year to year but averages about 3.7 km$^3$/yr and ranges from < 1 to >10 km$^3$/yr over the period of record (AD1894–2001). On average, about 1.85 km$^3$/yr of water is lost due to infiltration as the rivers flow across alluvium on their way to Tulare Lake after they exit the mountain block, but this value is higher during wet years and lower during dry years (Harding, 1949).

Simple regression modeling of annual discharge versus Palmer Drought Severity Index (PDSI) values from moisture-sensitive tree-ring chronologies contained within the Living Blended Drought Atlas (LBDA) of Cook and others (2010) for each of the four principal tributaries for the period AD1894–2001 yield $R^2$ values ranging from about 0.52 to 0.61. Routing the LBDA-derived discharge to the lake-water balance model for the early historic period (AD1850–1880) effectively simulates observed lake-level fluctuations, which serves as validation for our approach.

This approach was then used to simulate annual Tulare Lake-level fluctuations over the last 2,000 years, which revealed multiple decadal-scale droughts alternating with relatively wet periods. The most severe droughts in the simulation occurred just before and during the Medieval climate anomaly (~AD800–1160). The longest and most consistently wet period occurred during the onset of the Little Ice Age (~AD1300–1450), which is broadly consistent with the geologically-derived lake-level curve of Negrini and others (2006).

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# North American Rocky Mountain Hydroclimate: Holocene Patterns and Variability at Multi-Decadal to Millennial Time Scales Based on Lake Sediment Oxygen Isotope Records

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Existing long-term Holocene proxy records from the North American Rocky Mountain region have documented broad, multi-millennial-scale climate states. However, until recently there have been only hints about changes in hydroclimatic variability at multi-decadal frequencies or about past changes in the seasonality of precipitation. Changes in precipitation seasonality that diminish snowpack have significant implications for semi-arid ecosystems with snow-dominated precipitation balances in mountainous regions. And although multi-decadal climate variations are incompletely understood, there is agreement that their spatial structures are related to higher frequency ocean-atmosphere interactions. Oxygen isotope archives provide direct evidence for changes in past surface and atmospheric water and are obtained from well-dated and continuously deposited lake sediments throughout western North America. They provide a means for investigating regional hydroclimatic changes over periods when changes in global energy balance due to solar insolation are known to have occurred. Such comparisons provide the longer-term context for understanding recently observed change and climate model simulations of the future.

This poster will present a review of recently obtained sediment-carbonate oxygen isotope records with multidecadal-to-century resolution from lakes within the North American cordillera. Individually, the records reflect some degree of variance related to their respective regional hydroclimate, whereas their comparison elucidates patterns that are best explained by broader climate mechanisms. The overview provides new insights into Holocene hydroclimatic shifts on multidecadal to millennial time scales that coincide with changes in seasonal solar insolation and other proxy evidence for past changes in the North American Monsoon and Pacific ocean-atmospheric patterns. Additional comparisons are made with new speleothem records. Recognizing and understanding internal Pacific ocean-atmosphere variations are of particular importance for western North America and are needed to improve climate model ability and evaluations of future water availability, forest ecosystems and disturbance, including fire. Advances in our understanding internal climate variability will require a long-term perspective that oxygen isotope proxy records of hydroclimate can provide.

# Regional Climate and Land Use Change Recorded in the Sedimentary Record of Lago Lungo and Ripasottile, Rieti Basin, Lazio, Italy

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A 15 m sediment core recovered from Lago Lungo, in the Rieti Basin, central Italy, provides a high-resolution 2,700 year record of environmental change related to climatic influence and anthropogenic landscape alteration. Another 10 m core was also recovered from Lago di Ripasottile, located ~1.5 km to the west. The Rieti Basin is a ~250 km$^2$ intrapenninic extensional basin located ~80 km north of Rome within the Tiber River watershed. Pollen analyses corroborated with historical records of land-use change delineate the major shifts in forest composition and their historical context. Here we focus on sedimentological and geochemical data (scanning XRF) from the Roman Period through the Little Ice Age (LIA) in Lago Lungo while the Ripasottile core is used for correlation of major events. Though geographically close to Lungo, Ripasottile is fed by a different groundwater source and has a direct outflow, the Velino River. The base of the Lungo core (ca. 680 BCE- 1 CE) is marked by a steady increase in fine-grained sediment, rich in detrital elements Ti, Rb, and K, and corresponding decrease in Ca, representing a transition from the unaltered system after the Romans cut the first channel that drained the larger lake filling the basin. The Medieval Period interval (MP; 900–1350 CE) is lithologically distinct, composed of varicolored bands of alternating silt, clay, and calcareous concretions. Low counts of Ca, high detrital elements and frequent abrupt peaks in levels of the redox elements Fe and Mn indicate episodic clastic influx. Pollen data indicates that the greatest degree of deforestation and erosion occurred during the MP, supported by mean sedimentation rates of ca. 1 cm/yr, over twice the rate of the underlying interval. The Medieval climate was warmer and more stable than before 900 CE, causing population and agricultural land-use to increase. The influence of the Velino River on Lago Lungo increases during the MP through channel migration, increased flooding, and/or increased overland flow across a less forested landscape. The next transition (1350 CE), marks the start of the LIA and is coincident with the Black Plague. Historical records also document a large earthquake in 1350 CE, which may have caused rapid adjustments to the lake's depositional and hydrochemical regime and contributed to widespread land-abandonment. Clastic input abruptly ceases at the start of the LIA, and peaks in Sr,

Ca, and S may be attributed to changes in lake inflow. The core from Ripasottile was correlated with Lungo using a high magnetic susceptibility peak occurring between the LIA and the MP. The same sedimentary character and differences between these two intervals are seen in both lakes. The peaks in S and Sr during the LIA in Ripasottile correspond to those in Lungo, suggesting a basin-wide event that affected the deep regional groundwater flow. Results of the core analyses, confirmed with historical documentation, provide new insights into the basin history and the underlying causes of environmental change.

# Giant Stromatolites of the Green River Formation, (Laney Member, Sand Wash Basin), Colorado

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The Eocene Green River Formation of Colorado, Utah, and Wyoming is one of the most studied ancient lacustrine systems. The system covers 77,000+ $km^2$, is over 2,000 m thick, and has the richest microbialite record of any lake system. The microbialites are dominated by stromatolites, with oncoids, shrubs, and thrombolites also occurring.

Giant stromatolites from the Laney Member (Sand Wash Basin, Colorado), provide a unique example of large lacustrine microbialites. The stromatolites are multi-meter in size, and individual columns are up to 5.5 m high and 7 m wide. They are composed of carbonate layers (some silicified) that can be traced from the base to the top of the column. Hence they grew in water at least 5.5 m deep. These are the largest individual lacustrine columnar stromatolites reported in the scientific literature. Unlike most lacustrine stromatolites, these have distinct layers a few to several centimeters thick, composed of one to several different kinds of microbialites, including planar to wavy laminated stromatolites, centimeter-size columnar stromatolites, laterally linked domical stromatolites, ooidal boundstone, and microbial shrubs. The stromatolites initiated on vertical tree trunks of a flooded woodland. These giants were the result of a combination of factors including an abundant supply of calcium-rich spring and surface water that mixed with saline-alkaline lake water, subsidence rates and climate influenced lake-depth changes that were balanced with stromatolite upward growth rates, and tree trunks that provided stable substrates and initial vertical relief above the lake floor.

The presence of acicular aragonite within the stromatolites, as well as laminated lake sediments composed of aragonite (basinward from the giant stromatolites) provide another important element to understanding the environment. The lake was saline-alkaline (pH>9), and enriched in $CO_3^{--}$, Si, Mg, and Na. Carbonates rapidly precipitated during mixing of inflow waters with lake waters, resulting in deposition of aragonitic "whitings". Precipitation of aragonite within the stromatolites was induced by infiltrating spring-water that mixed with the saline-alkaline pore waters. Silica cementation occurred as the pH of the pore water dropped. Fresh inflow also diluted saline-lake waters, producing a lateral chemical gradient within the lake, as indicated by an increase of dolomite within microbialites and laminated carbonates in a basinward direction. Depleted $\delta^{18}O$ values (average -8.00) of the near-shore stromatolites, as well as their primarily calcitic composition, are consistent with an interpretation of a very fresh-water input. In contrast, a basinward increase in salinity-alkalinity is supported by the enriched isotopic values in the aragonite laminated lake sediments ($\delta^{18}O$ value of -5.90 and $\delta^{13}C$ value of +3.33). At the near-shore, giant stromatolite location, lake chemistry was dynamic and fluctuated frequently, depending on the amount of surface inflow and spring-water entering the lake.

The world's largest known lacustrine columnar stromatolites are not only worthy of attention as unique fossils, but they provide insight into the critical paleoenvironmental, climatic, and chemical suite of factors conducive to the development of microbialites in lacustrine environments.

# Relationship of Copper Mineralization to the Conditions of Lacustrine Sandstone Formations in Stratiform Deposits in Kazakhstan

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Zhezkazgan deposits are located in Central Kazakhstan in the basin of the proto-Zhezkazgan River, which had flowed into the ancient Lake Teniz. The ore-bearing strata of the Zhezkazgan ore district have a cyclic structure. Each cycle begins with layers of coarse-grained rocks and sandstone and ends with finely dispersed clastic rocks. Sedimentation in the study area occurred in a large river valley, controlled by a series of deep faults. It changed its direction from the meridional (Zhezkazgan syncline) to the southeast (Zheskazgan Sarysu-depression) in the area of the Taskora and Jaman-Aibat fields. This is confirmed by the typical association of fluvial sediments: alluvial fans (deposited in the foothills) with the local bedrock erosion, floodplains, coastal plains, coastal and underwater deltas. River flow was seasonal and floods alternated with periods of drying.

The cycles began with tectonic activity, creating a more or less dissected relief and an increasing humidity of the climate. Moderate intensity streams eroded pre-existing sandy material surrounding the river valley land areas. Due to the significant potential geomorphological relief in the early periods of each cycle flood waters caused erosion, which was preserved in the form of layers and lenses of conglomerates and breccias composed of sand bodies. Relatively stable periods are expressed by the formation of aleurolite and argillite layers in the composition of the sand layer. Grey-coloured rocks formed at the beginning of each regressive cycle as a result of the accumulation of the products of physical weathering in shallow water pools with underwater currents.

The sedimentation cycle completed stabilisation of the tectonic regime, and the medium sand intervals changed to fine-grained material. The sedimentary environment then moved from underwater sections of the basin to its coastal areas. Further long periods of sedimentation occurred in alluvial plain settings, and here the material accumulated predominantly under the influence of chemical weathering from the source rocks. Small-amplitude oscillatory processes lead to the accumulation of horizons of interbedded grey and red coloured rocks that are usually characteristic of coastal areas of sedimentary basins.

Accumulation conditions in the ore-bearing strata of Zhezkazgan series incorporate 12 lithogenetic rock types. We established that the mineralization was associated with sandstone facies deposited on the underwater part of the delta, which has favourable reservoir properties to infiltrate solutions and for ore formation.

# A Hypersaline Environment for Stromatolite Growth in the Mesoproterozoic Sibley Group, Ontario, Canada

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The Mesoproterozoic Sibley Group is a dominantly clastic red bed succession, exposed in the Nipigon area along the north shore of Lake Superior in Ontario. Within the Rossport Formation, the Middlebrun Bay Member comprises a meter-scale carbonate-chert unit, containing both stromatolitic and massive carbonate. Previous work has established that the overall environment was lacustrine (Rogala and Fralick, 2005); this study examines the particular environment in which the Middlebrun Bay carbonates formed, in order to understand the relationship between stromatolite growth, lake history, and water chemistry.

On Channel Island and mainland Ontario, the Middlebrun Bay Member is characterized by cherty, dolomitic stromatolites (fig. 1). These stromatolites are stratiform to columnar, with synoptic relief typically less than 2 cm. Both black chert and dolomite preserve depositional carbonate textures, including fine-scale laminae and clotted and precipitated stromatolitic textures. Trace element concentrations, measured by ICP-MS, are strongly elevated compared to average Proterozoic carbonates.


**Figure 1**

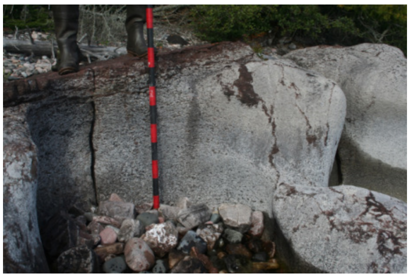
**Figure 2**

In contrast, the Middlebrun Bay Member on Copper Island is a coarsely crystalline limestone (fig. 2), lacking chert or internal stromatolitic lamination. This massive white limestone has a texture similar to chicken-wire evaporite and contains sandstone clasts derived from the overlying bed, reminiscent of collapse-related brecciation. In thin section, this unit has large subhedral to euhedral crystals, abundant stylolites, and zonation apparent by cathodoluminescence. Both stylolites and crystal boundaries contain accumulations of insoluble residue, indicating that dissolution and reprecipitation processes were important in generating the final texture. Trace element concentrations are generally elevated, compared to average Proterozoic carbonates, and broadly similar to other Proterozoic carbonates interpreted as calcitized evaporites (Manning-Berg and Kah, 2013).

Observations of both the massive limestone and stromatolitic dolomite-chert facies of the Middlebrun Bay Member are consistent with deposition in a strongly hypersaline environment with low clastic influx. The massive limestone is best interpreted as a calcitized evaporite, based on field, textural, and geochemical evidence. The stromatolites likely formed in very shallow areas laterally adjacent to evaporite deposition, as observed in some modern hypersaline lakes.

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## H-Isotopic Composition of Leaf-Wax *n*-Alkanes of Lake Van Sediments as Hydrological Proxies over the Past 150 ka in Turkey

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Lake Van lies at 1,640 m altitude in eastern Anatolia and is, by volume (607 $km^3$), the third largest endorheic lake on Earth. It is characterized by saline (22 ‰) and alkaline waters (pH 9.2). The ICDP PALEOVAN drilling operation in 2010 allowed the recovery of a 220 m-long sedimentary record from the Ahlat Ridge spanning the last 600 kyrs. Previous studies resulted in the establishment of a reliable age model (Stockhecke and others, 2014). This exceptional climatic archive was investigated for relevant organic molecular proxies on orbital and millennial-time scales in order to reconstruct lake level trends and changes in humidity over the catchment.

The hydrogen isotopic composition of the $n$-$C_{29}$ alkane in Lake Van sediments co-varies with the measured pore water salinity profile. High ACE index (ACE = Archaeol/(Archaeol + GDGT-0) x 100) values are in agreement with high salinity conditions (Turichand Freeman, 2011) during MIS 4 to MIS 2. The ACE index has been proposed by Turichand Freeman (2011) as a paleosalinity indicator, as biological precursor organisms for archaeol include halophilic archaea. The δD variations of $n$-$C_{29}$ might have been partly induced by a shift from a C3 to C4 plant dominated vegetation (Sachse and others, 2012). However, pollen data and minor variations of $\delta^{13}C$ values of the $C_{29}$ $n$-alkane in the range of 2 ‰ argue against a dominant influence of changes in paleovegetation.

Also, the δD values of long-chain ketones $C_{37}$ follow these trends in salinity and δD of leaf wax $n$-alkanes in general. These results confirm that the lake level lowering, as indicated by the pore water salinity increase, was caused by a sustained period of aridity. Deviations in δD $C_{37}$ from the trends might be due to changes in haptophyte composition. Differences in haptophyte species composition has been confirmed in Lake Van through the analysis of fossil DNA (Randlett and others, 2014). A 10 kyr offset is observed between proxies documenting the lake level decline (ACE and pore water) and aridity within the catchment (reflected by δD of $n$-$C_{29}$ and pollen).

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## A Facies Interpretation of the Hominin Sites and Paleolakes Drilling Project West Turkana Core: Dynamic Fluctuations on a Shallow, Lacustrine Margin

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The West Turkana Kaitio leg of the Hominin Sites and Paleolakes Drilling Project targeted a lacustrine interval from ~2 Ma to 1.5 Ma. The conventional model of the geometry of the Turkana Basin projected that the drill site would primarily represent deep, lacustrine conditions. However, upon splitting and describing the cores it was discovered that the drill site was actually located on a shallow, highly dynamic margin. One of the goals of this project was to create a facies interpretation of the WTK13 core to assist in the interpretation of the paleoclimate and paleoenvironment by quantifying the sensitivity of this fluctuating lacustrine margin. Two facies models (Primary and Secondary) were produced from the data collected during the HSPDP-WTK13 sampling party in November 2013 (core images, smear slide descriptions, etc) and the stratigraphic column compiled by Henderek in May 2014. The Primary Facies model defines units on the basis of the lithology, sedimentary structures, and fossils present at the time of deposition. The Secondary Facies model goes into more detail by further distinguishing units based on secondary process, precipitation, reworking/concentration of existing material, or diagenesis that occurred post-primary disposition. This frequently subdivides Primary Facies units but gives a more complete picture of everything that the sediments have undergone since being deposited. Each unit was described in detail and the thickness to the centimeter was recorded in a spreadsheet to generate the facies models.

Silts and clays (Lam Scram Primary facies) dominate the core with a few intervening sandy intervals. Evidence for erosion is fairly limited but the record does include some faults with cm-scale offset that are associated with a hydrothermal interval near the base of the core. From the Secondary facies model, 91 cycles of laminated lacustrine sediment (Lac Lam facies) to weakly pedogenically modified clays (Soil facies) are preserved in this core. This observation supports findings from a parallel outcrop section measured to the decimeter at Kaitio in the summer of 2013 which documented ~33 transitions from lacustrine clay to paleosols. However, the core presents the unique opportunity to resolve this record on a previously unprecedented scale. The environment interpreted as dynamic fluctuating lacustrine margin that was subaqueous during transgressive events but sub-aerially exposed and forming weak soils during regressions. Ultimately, this setting may prove extremely sensitive to fine-scale paleoclimate cycles that might have been obscured in a deeper water record.

# Carbonate Rich Paleolakes of the Triassic Cuyana Rift Basin

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The Santa Clara Arriba Formation consists of Triassic continental deposits found in the Santa Clara sub-basin, located in the middle area of the Cuyana rift basin of west-central Argentina. This Triassic rift is composed of several asymmetric half-grabens with sedimentary fill representing diverse lacustrine systems from the post-rift phase of the basin (fig. 1). Paleolakes in other sub-basins of the Cuyana rift (e.g., Cerro Puntudo and Potrerillos sub-basins, respectively located north and south from the Santa Clara Arriba Formation) developed on the passive margins of the rift during the synrift stage, provide limnogeologic data for comparison. Interestingly, most of the paleolakes show carbonate sedimentation. This allows for a detailed comparative study of carbonate accumulation within different settings of the rift during synrift and post-rift phases.

The Santa Clara Arriba Formation contains finely laminated shales with sandstone and limestone interbeds that are finely stratified as well. An aggradational stacking pattern of parasequences points to a constant sediment + water supply with continuous subsidence during sedimentation in this lacustrine system. The shales contain bioturbation features and they have been secondarily cemented by carbonates (spar). Thin section analysis shows limestones with well-laminated micrite, and also show features linked to biogenic activity, including fenestrae. Laminae are planar or crenulated and average 40 µm in thickness. Diagenesis consists of voids and cracks replacements by sparry calcite. Abundant siliciclastic mud aggregates composed of brown reddish clays are dispersed within the limestones. These aggregates measure 5–10 µm in diameter and can be interpreted as pedogenic in origin.

Biogenic limestones are present in the paleolakes of the post-rift stage of the Cuyana Basin in the high accommodation zone of this rift (Santa Clara sub-basin) as well as in the synrift stage in the low accommodation zones (Cerro Puntudo and Potrerillos sub-basins). This strengthens the hypothesis that provenance and hydrology are the main controls in carbonate accumulation within rift systems.

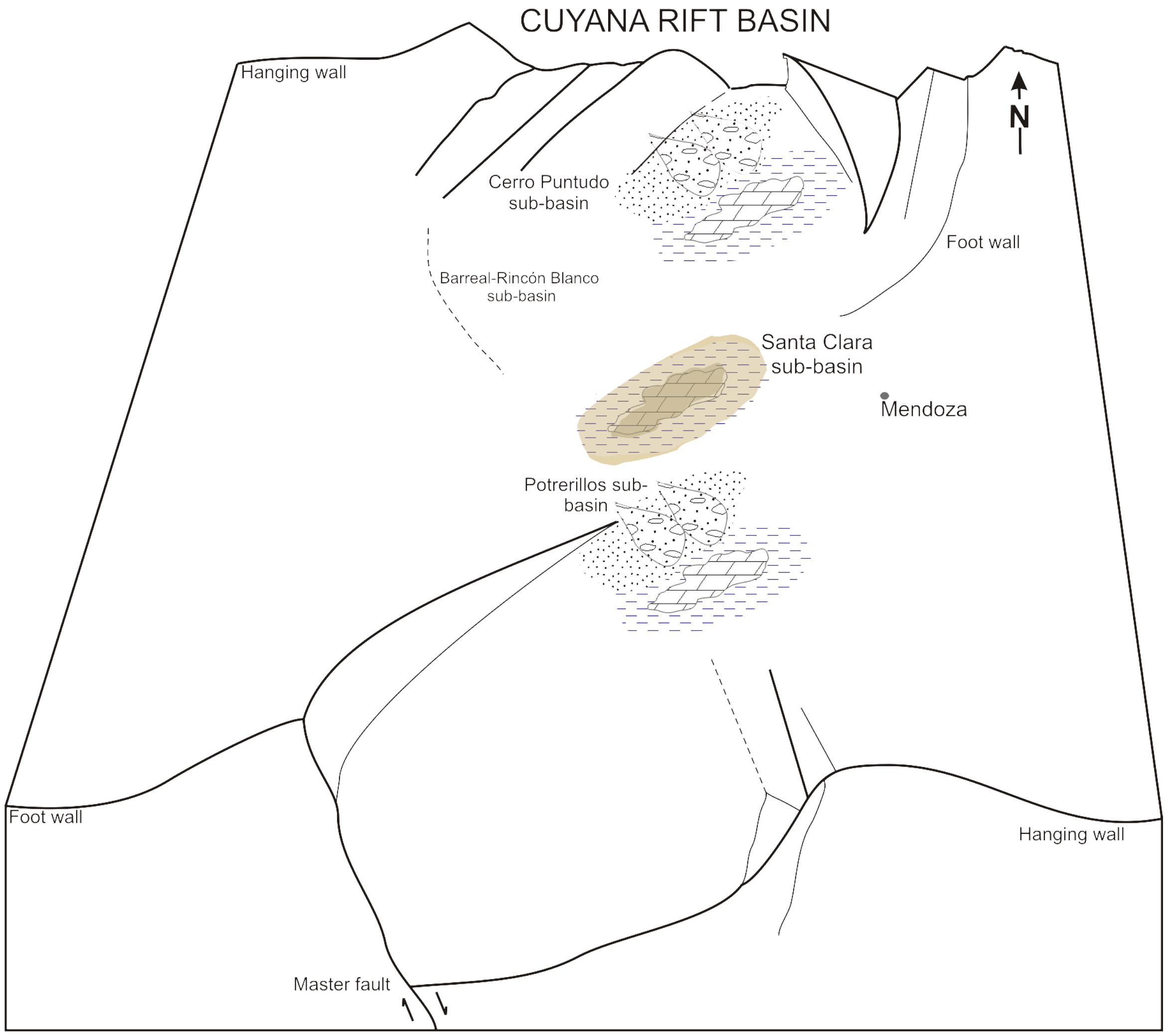


**Figure 1**. Triassic Cuyana rift basin showing the asymmetric half-grabens and the location of the two low accommodation zones: Cerro Puntudo (N) and Potrerillos (S) during synrift, and the high accommodation zone: Santa Clara (center) during post-rift.

# Time Series Analysis of the HSPDP Drill Core from the Tugen Hills, Kenya to Determine Effects of External Forcing on Local Climate in the Context of Hominin Evolution

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The Hominin Sites and Paleolakes Drilling Project (HSPDP) is an international collaboration aimed at collecting high-resolution record of paleoclimate and paleoenvironmental changes from East African Rift paleolake deposits, and through these records, develop a more comprehensive understanding of the environmental context of human origins. As part of this project, a 227 m drill core was collected from the Tugen Hills in the Baringo Basin of the Central Kenya Rift Valley.

The upper 130 m of the Baringo Basin core records transgressive and regressive phases of paleolakes, with diatomites and mudstones indicative of deep lake phases and silty, sandy and gravelly beds (often with paleosol alteration) indicating changes to fluvial and terrestrial environments. The core spans a period of between approximately 3.33–2.55 Ma. Magnetic susceptibility, gamma density, color greyscale, and total inorganic/organic carbon content have been analyzed for this core and reveal variability in hydrologic patterns which correlate well with diatomite cycles observed in the upper portion of the core. We are currently conducting time series analyses of the geophysical log and TOC/TIC data to characterize cyclicities that may be related to specific external forcings, such as fluctuations in insolation, and global climate events, such as the onset of Northern Hemisphere glaciation, which may have influenced the climate of equatorial Africa and ultimately lacustrine cycling in the Baringo Basin.

# Alpine Lakes, Mapping and Geologic Significance Case Study: North Auresian Sebkhas (Ne Algeria)

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The area study is located at the south of the eastern Algerian alpine belt allochtonous foreland. Geologic study linked to mapping from remote sensing data has allowed us to determine that the distribution of the lakes in the area study is controlled essentially by four factors, which are tectonics, diapirism, reservoir rocks, and climate.

Lake distribution is related to the intersection of the Pan-African basement faults with north-south directional faults and northwest-southeast dextral strike slips, which creates local depressions. We can observe that recent lakes that are localized generally at the forefront of diapiric Triassic outcrops are formed by the ascension of saline fluids from dissolved salt. The dissolution of the salts creates in-situ depressions that form the lakes.

The underlying siliciclastic layers come into play in the role of reservoir rocks, while the arid to semi-arid climate gives an evaporitic nature (Sebkhas) to some lakes.

# The Lacustrine Record of Pleistocene Super Interglacials and the Warm Pliocene at Lake El'gygytgyn, Northeastern Russia, with Possible Links to Antarctica


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The coastal regions of central Beringia contain a well-studied sequence of marine shorelines consisting of barrier beach sequences and broad coastal plans of superposed marine sediment. These sequences include shorelines associated with two Pliocene high sea stands, and lower shorelines dated to MIS 31, MIS 11, and MIS 5e. All these shorelines correspond with super interglacials identified in the Lake El'gygytgyn paleoclimate record (Lake E), northeastern Arctic Russia. However, not all super interglacials correspond with a recorded high sea level event in the western Arctic. We argue that most of the high sea stands in central and northern Beringia, especially the northwestern coast of Alaska, likely require at least the partial demise of Greenland, or WAIS, or EAIS, or some combination of the three. How do we evaluate what melted and why?

MIS 31 and several other interglacials are remarkably warm events found in the ANDRILL and other marine records around Antarctica. Half a recession cycle after this warmth in Antarctica, we see a super interglacial in Lake E. Because of unconformities in the ANDRILL record, MIS still provides the best match with Lake E but we postulate that other intervals marked by the deposition of diatomaceous ooze in that record may also correspond to many of our interglacials. The challenge has been to determine what would force warmth in the south followed by warming in the north. Here we explore this relationship starting with the observation that most super interglacials with highest insolation correspond with extremely low eccentricity but with a significant lag. We explore how orbital conditions may have preconditioned the polar regions to a large response linking changes in polar ice sheet size to sea level and interglacial extremes recorded at Lake E. Ongoing work continues to test these ideas.

# Abrupt Hydrologic Change During Deposition of the Southern Bouse Formation Recorded by Stable Isotopes and Microfauna: Implications for an Estuarine or Lacustrine Origin

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Controversy about the processes involved in integration of the ancestral Colorado River and when it flowed into the Gulf of California continues despite nearly a century of study. Current debate focuses on the depositional environment of the ~ 5-Ma southern Bouse Formation (SBF) in Blythe basin, Arizona and California. The SBF contains a moderately diverse marginal-marine fauna, including marine-obligate foraminiferans, which are puzzlingly found in limestones and marls that have geochemical signatures, including $^{87}Sr/^{86}Sr$ ratios, permissive of either a lacustrine or estuarine origin. Resolution of the debate as to whether these deposits formed in marginal marine, lake, or estuarine conditions has been hindered by the relatively small number of samples placed in a detailed stratigraphic framework and analyzed for both faunal and geochemical indicators. Here we present the results of the first continuous high-resolution sediment and ostracode stable isotope ($\delta^{18}O_{SED}$, $\delta^{13}C_{SED}$, $\delta^{18}O_{OST}$, $\delta^{13}C_{OST}$; VPDB) and microfaunal study of a key series of outcrops in Hart Mine Wash (33.291 °N, 114.636 °W) that collectively span much of the SBF, and have been argued to record a transition from marine to saline-lake conditions.

At our study site, the SBF consists of a basal 5-m-thick limestone comprised of alternating bioclastic and calcarenite units. The basal limestone is overlain by roughly 15 m of white marl, followed by about 4 m of interbedded marl and clayey marl with a 3-cm-thick distinctive clay layer (DCL) about 1 m below the top. The marl and clayey marl is capped by ~2 m of dense green claystone followed by ~20 m of red claystone, siltstone, and fine-grained sandstone.

The majority of $\delta^{18}O_{SED}$ and $\delta^{13}C_{SED}$ values fall between -8 and -10.5‰ and -1 and +1‰, respectively. Both $\delta^{18}O_{SED}$ and $\delta^{13}C_{SED}$ abruptly decrease by 3‰ across the DCL. $\delta^{13}C_{SED}$ increases again in the overlying meter of interbedded marl and clayey marl; $\delta^{18}O_{SED}$ does not. Four genera of ostracodes from below the DCL have stable $\delta^{18}O_{OST}$ of about -3 ± 1‰, roughly 6 to 7‰ higher than the encasing sediments. Above the DCL, $\delta^{18}O_{OST}$ abruptly falls to -10 ± 2‰, identical to the encasing sediments. $\delta^{13}C_{OST}$ does not appreciably change from below (-2 ± 2‰) to above (-3 ± 3‰) the DCL.

Various combinations of marginal-marine ostracodes (*Cyprideis*, *Cytheromorpha*) and continental fresh- to brackish-water ostracodes (*Candona, Heterocypris*?) are found in all units. The marine-obligate planktic foraminifera *Streptochilus* occurs in large numbers about 1 m below the DCL. Fresh- and brackish-water continental ostracodes are absent in this interval, but abruptly reappear above the DCL in association with *Cyprideis, Cytheromorpha* and low numbers of *Streptochilus*.

The Blythe basin water column supported continental, marginal-marine, and marine-obligate organisms, and was isotopically stratified ($\delta^{18}O$) prior to the deposition of the DCL. After deposition of the DCL, the water column abruptly freshened and the isotopic stratification abruptly ended. Reasonable estimates of sedimentation rate suggest this transition across the DCL occurred over decadal to century time scales. Implications for marine, estuarine, and lacustrine interpretations are complicated and the subject of ongoing work.

## Diatom Paleoecology of the Paleolake at West Turkana (HSPDP)

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We present preliminary fossil diatom data in association with the Hominid Sites and Paleolakes Drilling Project (HSPDP) from the western bank of the modern Lake Turkana. What story will paleoecology tell us about relationships between the environment and human evolution? The West Turkana site is one of several locations chosen by the HSPDP, because of their great potential for reconstructing environmental variables in the northeast African region during early hominid activity. This 216 (m) core was acquired at Lat: 4.10972 Lon: 35.87178 in Kenya from the western margin of the modern Lake Turkana in July 2014. The presence of developing soil profiles in the core description implies multiple lake water level changes throughout the core. Fluctuating lake levels were also suggested by preliminary (smear slide) analyses of fossil diatom assemblage transitions downcore. Diatom preservation worsens as pH varies, which appears to coincide with the changing lake water levels through ionic concentration. This region has been subject to frequent tectonic activity and vegetative land cover may have changed significantly in the past. Local stream channels, including the Omo River, have the potential to migrate over great distances in response to these changes. Our preliminary results from the fossil diatom assemblages suggest at least one cycle from lacustrine-dominated to riverine-dominated conditions (and back) has occurred at the core site.

# Changes in Landuse and Environmental Conditions Recorded in Lake Malawi (East Africa) Sediments

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Changing agricultural practices—increased application of fertilizer and enhanced irrigation—have the potential to lead to significant enhancement of agricultural yields in many areas of the world, including east Africa (Mueller and others, 2012). However, changes in land use can affect lake processes and these effects are recorded in lake sediments. In Malawi there have been significant increases in agricultural production, with accelerated conversion of forest land to agriculture since 1990 and a government fertilizer subsidy program since the early 2000s; these have led to large increases in crop production over the past 20 years. Understanding the impacts of these changes on Lake Malawi is a critical issue in this region where lake fisheries are the largest single source of animal protein for human consumption.

Annually laminated sediments from the north basin of Lake Malawi provide a high-resolution record of regional environmental history in a region where climate records are scarce. The Lake Malawi Scientific Drilling Program recovered core (MAL05-2A) from this basin that yielded an 80 kyr record showing a tropical component of millennial scale climate fluctuations during MIS 3 and 4 (Brown and others, 2007; 2008). In addition, northern Lake Malawi sediments recorded decade-to-century scale variations during the "Little Ice Age" (Brown and Johnson, 2005). To evaluate the response of this system to 21st century changes in climate and shifts in regional land use, a series of multicores was recovered in January 2012 from *RV Ndunduma* at 10.018°S 34.191°E (close to the site of MAL05-2A).

The varve-counting chronology for these cores is consistent with earlier studies of cores from nearby locations, including the additional 14 years of sediment accumulated since previous field programs. Bulk elemental composition of sediments, evaluated using an ITRAX XRF core scanner yielded proxies for fluxes of terrigenous and biogenic sediments, as well as provenance indicators for the terrigenous material. The uppermost sediments (deposited since ~1995) are markedly different from underlying material—darker, denser, and with higher clay contents. This is likely to be the result of changing land use in the basin, including conversion of hill-slope forests to tilled agriculture The increased clay fluxes observed during the 21st Century is unprecedented in the 80,000 year context of other lacustrine records.

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# Diatom-Inferred Stratification and Fire History of Island Lake, Wyoming

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Island Lake, an alpine lake of glacial origin, is located in the Beartooth Mountains near Cody, Wyoming, at an elevation of 3,048 m. Like many alpine lakes, Island Lake is highly transparent with a deep chlorophyll maximum and has a maximum water depth of 33 m. Thus, it is ideally suited for researching the relationships between ecological bioindicators for mixing depth and fire. Fire is an integral ecosystem function within the Rocky Mountains. Two common fire reconstruction methods include sedimentary charcoal and fire-scarred trees.

In this study, we explore preliminary paleolimnological data from a sediment core measuring 1.54 m, which was collected in the summer of 2013. Radiocarbon analysis revealed the core dates back to 10,000 BP. Diatom assemblages were counted for the length of the core. Two planktonic diatom genera, *Discostella* and *Aulacoseira*, were abundant throughout. Both of these genera have known ecological associations with stratification and mixing, respectively, in low-nutrient lakes from this region. Based on the relative abundances of fossil diatom species in each group, we created a diatom-inferred stratification index to reconstruct changes in lake stratification patterns over the Holocene. This stratification index was compared to dendrochronology fire history records of the area over the last 500 BP to assess whether mixing depth changes can be correlated with terrestrial fire events. Together, these paleo-environmental indicators show substantial changes throughout the Holocene at Island Lake and provide context for other regional records of fire history.

## Paleoenvironmental Implications of Lacustrine Ostracodes (Crustacea) from the La Cantera Formation (Early Cretaceous), San Luis, Argentina


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The La Cantera Formation is part of the infilling of the San Luis Basin (San Luis Province, Argentina). During the Cretaceous, as a result of the reactivation of a previous Triassic rift, the basins were developed. The La Cantera Formation is characterized by greenish-gray finely horizontal laminated claystones and siltstones interbedded with gray ripple-laminated sandstones that were interpreted as a lacustrine environment. The laminated mudrocks present freshwater fossils as crustaceans, fish and insects. The aim of this work was to analyze the ostracode (Crustacea) associations from the La Cantera Formation, from a paleolimnologic point of view, and to compare the results with those obtained from other groups of organisms from the same unit and other coeval formations.

Three samples bearing ostracodes from different levels of the La Cantera Formation Type Locality were processed (M1, M2 and M3). The ostracode extraction process was mechanical and manual and cleaning of the sediment surface was done under binocular low-magnification microscope. The specimens were photographed in the Scanning Electron Microscope (SEM) of the Laboratorio de Microscopía Electrónica y Microanálisis of the Universidad Nacional de San Luis (LabMEB, UNSL). Furthermore, Energy Dispersive Spectrometer (EDS) microanalysis was performed on specimens and sediment. The studied material is housed in the Fossil Collection (MIC) from the Facultad de Ciencias Físicas, Matemáticas y Naturales, UNSL.

Three different taxa of the Class Ostracoda were recognized: *Limnocytherinae* sp. and Podocopida indet (Family Limnocytheridae) and *Pattersoncypris angulata* (Family Cyprideidae) (Bustos Escolana, 2015). Limnocytherinae sp. and Podocopida indet. were found in Level 10 and presents good preservation. *Pattersoncypris angulata* was found at levels 29 and 30, but they are more abundant in level 29. The preservation of the ostracodes from these levels is poor, with broken shells and sometimes only the molds are preserved.

Microanalysis showed differences in elemental composition between the 3 levels; particularly between level 10 (sample M1) and the levels 29 and 30 (samples M2 and M3, respectively) (table 1). In the M1, a high concentration of Si is observed, with a particular absence of Ca in the shells, but not in the bearing substrate. The samples M2 and M3 differ with M1 due to the presence of a high concentration of Ca in the shells and the absence of Si. The M2 substrate shows a higher concentration of Ca than Si, and in M3 the substrate has a similar concentration of Ca and Si.

**Table 1**: Microanalysis performed in M1, M2 and M3 for shells and substrate. Measures Wt%.

| Samples | Shell | | Substrate | |
|---|---|---|---|---|
| | WT%Si | WT%Ca | WT%Si | WT%Ca |
| M1 | 59.74 | - | 22.09 | 14.43 |
| M2 | - | 59.91 | 5.96 | 41.67 |
| M3 | - | 53.49 | 37.63 | 37.13 |

The ostracode microfauna from the La Cantera Formation appears to be a low diversity association characterized by two species of freshwater ostracodes distributed in two families. Representatives of Limnocytherinae are distributed in different continental Cretaceous basins of Argentina. *Pattersoncypris angulata* is recorded in Cretaceous successions in Brazil and Argentina. Singularly, the ostracode associations of the two lacustrine successions of the San Luis Basin have no similar elements. The association recorded in the La Cantera and the microanalysis suggests that the ostracodes were developed in freshwater environments with strong changes throughout its temporal evolution in their evaporation and salinity rates, mainly in the lacustrine shoreline.

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# The Behavior of the Calcium Ion in Saline and Alkaline Lake Complexes Revealed by Statistical Techniques


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Many endorheic wetlands consist of temporary playa-lakes characterized by specific hydrochemical conditions and mineral paragenesis. This is the case of two lake complexes which occupy areas located to the N and S of the Central mountain range in Spain. Systematic water measurements carried out since 2011 indicate that one of the wetlands, located in La Mancha region, with conductivity values ranging from 4 to 121 mS/cm, is a mesosaline complex, whereas the second, located to the north (Duero basin), with values ranging from 0.8 to 19 mS/cm, is comprised of alkaline (soda) lakes.

The concentrations of ions vary from one season to another. Table 1 shows the maximum and minimum values of the main ions for both lake complexes. Calcium usually presents the lowest concentration of all the ions and any slight change is perceptible. The Piper-Hill-Langelier water classification diagram shows a $SO_4^{2-}$-($Cl^-$)-$Mg^{2+}$-($Na^+$)-($Ca^{2+}$) trend for the first group of lakes and $Cl^-$-($SO_4^{2-}$)-($HCO_3^-$)-$Na^+$ for the second group.

**Table 1**. pH and ion concentration in the two wetlands.

| | | $Cl^-$ (meq/L) | $SO_4^{2-}$ (meq/L) | $CO_3^{2-}$ (meq/L) | $HCO_3^-$ (meq/L) | $Ca^{2+}$ (meq/L) | $Mg^{2+}$ (meq/L) | $Na^+$ (meq/L) | $K^+$ (meq/L) | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| South (La Mancha) | Max | 2294.35 | 3699.86 | 45 | 14 | 44.71 | 4061.92 | 2752.11 | 145.92 | 10 |
| | Min | 4.79 | 30.39 | 0.2 | 0.72 | 13.82 | 13.91 | 6.53 | 0.58 | 8 |
| North (Duero) | Max | 107.36 | 75.84 | 37.36 | 37.36 | 1.1 | 62.38 | 166.61 | 21.4 | 11 |
| | Min | 2.07 | 0.36 | 0.39 | 2.3 | 0.22 | 2.44 | 8.25 | 0.3 | 8 |

In both complexes, the flat surfaces of the playa-lakes are covered in microbial mats, which comprise a green layer (mainly cyanobacteria), a dark red or purple layer, and a deep, black layer, caused by bacterial sulphate-reduction processes. The mat types and related sedimentary structures change seasonally according to a variety of processes which affect the mineral precipitation and distribution. As a result of the interactions between bio-geochemical parameters in the two lake complexes, more than thirty minerals are formed. The authigenic minerals are comprised of sulfates, carbonates, chlorides and silicates. Gypsum is the most abundant mineral in the south and it is present in smaller amounts in the north. It occurs throughout all mats embedded in the lake brine. The contact of the gypsum with the microbial mats is established to control their lenticular morphology. However, the other sulfates only precipitate at high concentrations (conductivity > 70 mS/cm) at the water-air interfaces, forming thin crusts over the surface. Petrographical and biological observations indicate that the precipitation of carbonates (calcite and hydromagnesite) is aided by microorganisms within the microbial matrix.

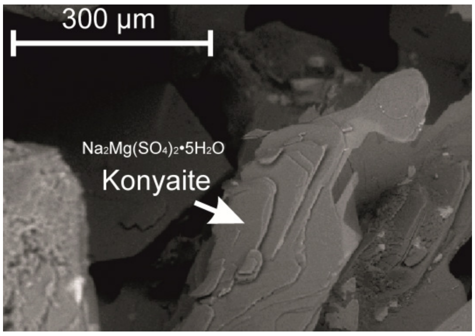


**Figure 1.** - Mg-Na sulphates precipitating in Altillo Grande lake.

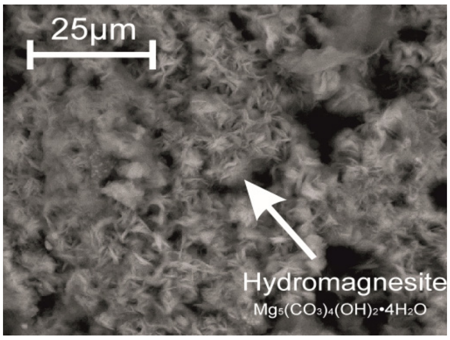


**Figure 2.** - Mg-Ca carbonates being formed in Las Eras playa.

In general, gypsum is more abundant in winter whereas the Na-Mg sulfates and Na chlorides are dominant in summer, as determined by XRD and SEM analyses of surface samples in the more saline complex. The sulfates and chlorides include hexahydrite, epsomite, starkeyite, pentahydrite, konyaite, blödite (fig. 1.), halite, mirabilite and thenardite among others. In the alkaline complex the main minerals are thenardite, halite, blödite, hexahydrite, starkeyite, nesquehonite, hydromagnesite (fig. 2.) and natron.

Several statistical tests have been performed as a complementary tool to refine the hydrochemical conditions and to better discriminate the biological influence in the mineral precipitation. The preliminary results show that the main ions vary in a similar way, except calcium which exhibits the opposite behavior (decreasing concentration to higher conductivity values in both lake complexes). A plausible explanation for the reduction in the concentration of $Ca^{2+}$ in dissolution could be the high electrostatic attraction of the microbial mats to the negatively charged divalent ions, such as $Ca^{2+}$. The presence of complexing ions (e.g., $SO_4^{2-}$) and acidic organic molecules can lead to the precipitation of gypsum and calcite in the microbial mats at high water concentrations.

**Acknowledgments**

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# Stable Isotopes ($\delta^{18}O$ and $\delta^{13}C$) in Ostracod Shells as Palaeoclimate Tools in a Chilean Altiplano Lake

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Ostracods in lacustrine sediments provide information on the magnitude and variability of the environment and climate. Carbon and oxygen stable isotopes in ostracod shells shed light on past water temperature, salinity, ionic and isotopic composition. Geochemical signatures in hydrologically closed-basin lakes, especially in dryland regions can be interpreted as changes in effective precipitation, air temperature, lake water-level or atmospheric circulation.

The objective of this study is to determine the climatic variability in the Inca Coya Lake (Chilean Altiplano) by analyzing stable isotope $\delta^{18}O$, $\delta^{13}C$ from ostracod shells and sediment samples. Inca Coya (22º, 20'S; 68º, 35'W) is a small and shallow (17 m) lake located 2,534 m a.s.l. The modern climate in the area is cold and dry, with a rate of precipitation less than 200 mm/yr, which makes it one of the driest areas of the world and highly sensitive to study climate reconstruction.

A 100 cm long sediment core was collected from Inca Coya Lake using an Uwitec gravity corer. Three ostracod species were identified along the sedimentary sequence: *Limnocythere* sp., *Limnocythere elongata* and *Cyprideis lengae*. The first two species, the most dominant and abundant, were used for isotopic analysis. Sedimentological analyses were also made to determine organic matter (LOI 550°C), carbonates (LOI 950°C) and magnetic susceptibility.

*Limnocythere elongata* shows good preservation and is broadly distributied throughout the study core. However, its abundance alternates with *Limnocythere* spp. Ostracod fossil species assemblages can be divided in four groups (fig. 1): (a) Zone I is characterized by low ostracod abundance and fluctuations in the proportion of organic matter and carbonates, (b) Zone II displays a slight increase of ostracod valves and low concentrations of organic matter and carbonates, (c) Zone III presents high percentage of carbonates and a stable ostracod abundance, and (d) Zone IV displays an abrupt decrease in the percentage of carbonate down to 5%, and an increase in the abundance of ostracods.

The isotopic profile (fig.2) shows fluctuations with high $\delta^{13}C$ values of +4.63 to +10.00‰ and $\delta^{18}O$ +0.83 to +2.95‰. Although both species belong to the same genus and present similar trends, the signal of $\delta^{18}O$ in *L. elongata* displays a slightly broader range (+0.83 to +2.95). Results evidence a high environmental variability in the past, with periods characterized by high evaporation and dryness (high percentage of carbonates and high $\delta^{18}O$ values), alternated by short periods of moisture.

This research was financially supported by several projects: Fondecyt project N° 3120082, Fondecyt 1120807, Proyecto CRHIAM CONICYT.

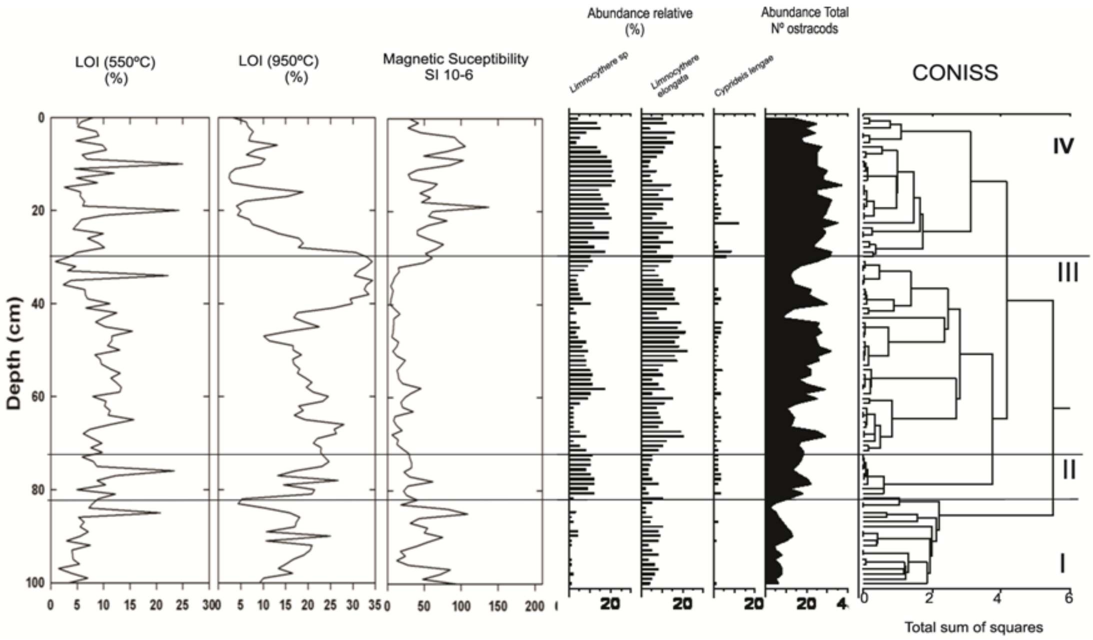


**Figure 1**. Sedimentological analyses and relative abundance (%) of ostracod species. Data were clustered using CONISS.|

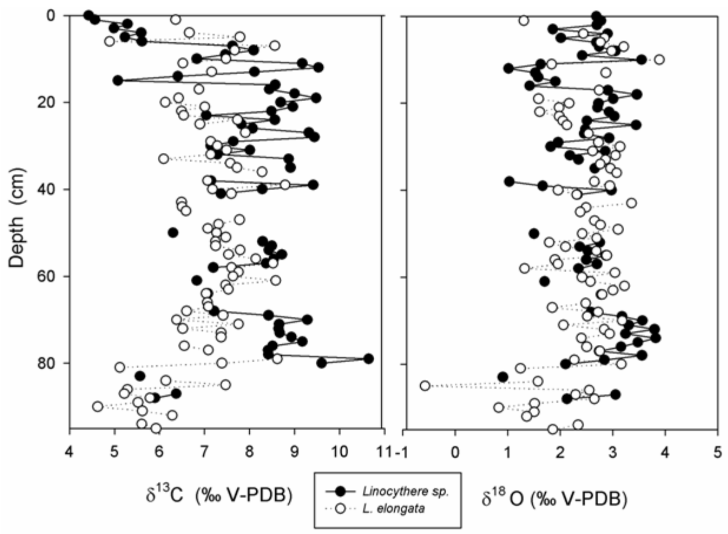


**Figure 2**. $\delta^{18}$O and $\delta^{13}$C isotope profiles of Inca Coya Lake.

## Xenoconformities in Lake Deposits: Examples from the Eocene Green River Formation, Western United States

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Lacustrine and related terrestrial strata commonly exhibit abrupt, basinwide shifts in lithofacies, stratigraphic packaging, biota, and geochemistry, which are not associated with unconformities or other evidence for significant hiatuses or periods of erosion. Such changes are the defining stratigraphic feature of some lake basins, and often form the basis for formal stratigraphic division of their deposits. Adjacent units separated by such transitions may record fundamentally different depositional states of the basin ("lake types"). For example, the Wilkins Peak Member of the Green River includes voluminous evaporite deposits deposited in a hypersaline lake, an environment that did not exist within the basin during deposition of the conformably underlying Tipton Member or overlying Laney Member. The superposition of these successive units therefore appears to violate Walther's Law, which holds that "only those facies and facies areas can be superimposed primarily which can be observed beside each other at the present time." (Walther, 1894, as translated by G. Middleton, 1973). Furthermore, no existing stratigraphic terminology appears adequate to fully describe such transitions. The term xenoconformity is therefore proposed herein, and provisionally defined as a conformable surface or gradation that marks a fundamental, synchronous, persistent change in facies across a large area. Recent work has shown that xenoconformities in the Green River Formation generally record rapid reorganizations of watersheds that drain the surrounding Laramide foreland. For example, the onset of underfilled conditions appears to have resulted from tectonic diversion of a major river that previously entered the Lake Gosiute from the north. Approximately 1.5 Ma later the basin shifted back to balanced-fill conditions, due to expansion of the lake's watershed to the east. A third major transition to overfilled conditions occurred about 0.7 Ma later, coincident with capture of a river that drained rising volcanic topography in central Idaho. Xenoconformities within Eocene lake deposits therefore provide a unique perspective on the dynamic geomorphorphic evolution of the western U.S. Laramide foreland. More broadly, xenoconformities might also record episodes of geologically rapid climate change, if those changes result in permanent modification of lacustrine depositional systems.

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# Resilience of Aquatic Communities in Naturally Fishless Lakes in Yellowstone National Park to Fish Stocking

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Resilience (Holling, 1973) describes the ability of a system to buffer disturbances without significantly changing in structure or function. From the perspective of resilience, we are investigating how aquatic communities of naturally fishless lakes responded to a 100-year fish-stocking program in Yellowstone National Park, Wyoming. Since the stocking program ended, some lakes have returned to a fishless state, whereas other lakes continue to maintain populations of non-native fish.

Lake sediment cores catalog approximately 300 years of history: 140 years of natural variability prior to fish stocking, 100 years of repeated non-native fish introductions during the fish-stocking program, and 60 years of post-fish-stocking recovery. Using fossil assemblages of diatom algae, zooplankton, and macroinvertebrates, as well as historical records of fish stocking, we are reconstructing food webs to examine how the introduction of new predators impacted the existing food web in terms of its community structure and ecosystem productivity and nutrient cycling. We hypothesize that communities that did not maintain a fish population were more resilient to repeated introductions than communities that maintained fish, because the communities did not significantly change in structure and function to include the new species.

Various bedrock types of volcanic and glacial origins characterize the Yellowstone region, within which lie a series of non-geothermal freshwater lakes. Yellowstone also lies at the convergence of two climate regimes, resulting in variable regional microclimates within a relatively small area. The lakes in this study are grouped into paired replicates to evaluate the relative importance of abiotic characteristics, such as bedrock, lake morphology, and regional microclimate in fundamentally determining the resilience of the abiding community. Understanding the fundamental factors that determine community resilience can inform invasive species management and ecological restoration.

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# Is Lake Tahoe Terminal?

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Lake Tahoe, an iconic ultra-oligotrophic lake in the central Sierra Nevada, has been studied intensively since 1968, with the goal of understanding and ultimately controlling its eutrophication and loss of clarity. Research on the lake has included (a) periodic profiles of primary productivity, nutrients, temperature, and plankton; (b) Secchi depth; (c) nutrient limitation experiments; (d) analysis of sediment cores; (e) radiocarbon dating of underwater in-place tree stumps; (f) analysis of long-term temperature trends. Work in the watershed of the basin has included (a) monitoring of stream discharge, sediment and nutrients at up to 20 stream gaging stations; (b) monitoring of urban runoff water quality at selected sites; (c) development of a GIS data base, including soils, vegetation, and land use. Based on these studies, we know that (a) primary productivity in the lake is co-limited by phosphorus and nitrogen, and continues to increase; (b) the loss of clarity continues, but at a declining rate; (c) the lake has been warming at least since 1970, and its resistance to deep mixing is increasing; (d) historically the lake level drops below the outlet elevation about one year in seven; (e) the date of the peak snowmelt runoff is shifting toward earlier dates; (f) after accounting for annual runoff, annual loads of nutrients and suspended sediment have declined significantly in some basin streams since 1980.

Downscaled outputs from GCM climatic models have been used recently at Tahoe to drive hydrologic models and a lake clarity model, and thus evaluate future trends in the lake and watersheds. Results show (a) the temperature and thermal stability will likely continue to increase, with deep mixing shutting down in the latter half of this century; (b) the lake may drop below the outlet for an extended period beginning about 2085; (c) the annual snowpack will continue to decline, with earlier snowmelt and shift from snowfall to rain; (d) the climatic water deficit will increase, especially at high elevations that will be most affected by the loss of snow, with likely consequences for existing vegetation and fire frequency.

Limnologically, the lake is almost terminal; in a medical sense it is not yet terminal, but its condition—especially its valued clarity and deep blue color—is serious.

# Glacial Stratigraphy Beneath Lake Superior: Unique Views of Glacial Sedimentation Provided by High-Resolution Seismic-Reflection Profiles


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Glaciation of the Lake Superior basin left behind a variety of glacial deposits and landforms, especially during the final retreat of Laurentide ice from the basin. Prominent among these features are moraines and thick glacial lacustrine varve sequences in the central part of the lake. Because these features are now beneath deep water, they can be well imaged by modern marine seismic-reflection methods, providing a variety of insights into glacial processes and history.

Three prominent moraines occur east of Isle Royale, and the moraines are as much as 75 m high, continuous, asymmetric, and locally concave down-ice in plan view. The moraines relate to the Marquette advance of the Laurentide ice sheet, but they are difficult to directly correlate with the terrestrial deposits used to define that advance. Air-gun seismic-reflection data show that the moraines are underlain by thick, acoustically massive deposits (till) over a smooth bedrock surface, and that, in front of the moraines, the till grades laterally into increasingly stratified deposits interpreted as glacial lacustrine outwash. Such lateral relations between till and outwash are rarely displayed so well in natural exposures.

Overlying the till and moraines is a thick sequence of glacial lacustrine varves, which is well imaged by high-resolution CHIRP seismic-reflection profiles. Although the CHIRP data cannot resolve even the thickest of the individual varves, the section comprises distinct acoustic packages. The CHIRP data show that the base of the varve sequence becomes younger to the northeast, the direction of ice retreat. Throughout the varved sequence are lenses of acoustically massive material and local features interpreted as iceberg plow marks, which are especially concentrated at one horizon. Limited 3-D seismic data show the curvilinear plan view of the plough marks at this horizon, and the horizon can be mapped throughout the central part of the basin. These features indicate that ice retreat from the basin was not instantaneous or simple in detail.

# A Refined Lake Evolution and Stratigraphic Record of the Hartford Basin

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The Mesozoic Hartford Basin of Connecticut and Massachusetts is one of nearly 40 rift basins of the Newark Supergroup along the east coast of North America, produced by crustal extension from the breakup of Pangaea. Sediment from eroded Paleozoic crystalline rock interlayered by three basalt flows filled the Hartford rift. As a result, the Hartford Basin fill is 4–5 km thick with sedimentary rocks and tholeiitic basalt that is separated into seven stratigraphic units (Demicco and Gierlowski-Kordesch, 1986). The four sedimentary units of the Hartford Basin, from oldest to youngest, are the New Haven, Shuttle Meadow, East Berlin, and Portland Formations. The Talcott, Holyoke, and Hampden Basalts separate these sedimentary units.

Basin-wide research of these stratigraphic units has been limited by few exposures within the Hartford rift. Past studies have identified lacustrine, playa, and alluvial depositional environments composed of shales, mudstones, siltstones, sandstones, conglomerates, and limestones, some of which underwent pedogenesis, in the southern and northern regions of the basin (Demicco and Gierlowski-Kordesch, 1986). Recent coring within the previously unexposed central region of the basin, however, has provided new insight into the facies distribution and thickness of lacustrine deposits related to lake type and basin evolution.

The lake-basin type model predicts a sequence of fluvial basin to over-filled, balance-filled, and under-filled lacustrine conditions as basin accommodation space exceeds water and sediment supply; as subsidence slows, however, balance-filled through fluvial basin facies return (Carroll and Bohacs, 1999). Fluvial basin facies in the lower New Haven and upper Portland Formations, the oldest and youngest units of the Hartford Basin, respectively, enclose lake deposits in the upper New Haven (?), Shuttle Meadow, East Berlin, and lower Portland Formations. Despite this pattern, identifying the predictable evolution of lake types remains nebulous as the balance between tectonics and climate shifted during the development of the Hartford rift (Carroll and Bohacs, 1999). While no black shales have been found in the New Haven Formation, pillow-like basalts are recognized in the upper New Haven, suggesting possible waterlogged conditions. The lower Shuttle Meadow Formation represents over-filled lake deposits (Wolela and Gierlowski-Kordesch, 2007). Past studies hypothesized balance-filled lacustrine conditions from the upper Shuttle Meadow through the middle Portland Formations because of rare dispersed evaporites. These thin evaporites may be the product of closed surficial flow with open groundwater hydrology, preventing the precipitation of thick evaporites (Gierlowski-Kordesch and Finkelstein, 2012). However, recent analyses suggest a gradient of balance-filled to under-filled lacustrine conditions from the lower East Berlin into the lower Portland Formations; balance-filled and over-filled lacustrine conditions are hypothesized to resume within the Portland before grading back into fluvial basin facies. Understanding the evolution of lake types through time yields insight into the interplay between tectonics and climate in a rift punctuated by tholeiitic basalt flow events.

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# The Last Millennium in the Panamanian Midlands: High-Resolution Multiproxy Evidence from Lake San Carlos


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The last millennium has been characterized by relatively high global climatic variability, most evident in the warm conditions that characterized the Medieval Climate Anomaly (MCA) and the cooling of the Little Ice Age (LIA). Such variability has been well documented in high latitudes and in tropical lowlands and highlands. However, there is an information void regarding tropical altitudinal midlands, regions that probably played an important role at providing refugia for natural and human populations during times of extreme environmental conditions. Their importance derives from their heterogeneous topography and the steep environmental gradients they harbor. Here we report on a high-resolution analysis of a ~1,100-year-old sedimentary sequence from Lake San Carlos (780 m asl), Panamanian midlands. Sediments were analyzed for pollen, charcoal, and diatoms at a resolution of 5-cm, whereas isotopes of carbon, oxygen and nitrogen were analyzed in bulk sediment at a 1-cm resolution.

From 870 to 1170 AD, vegetation was dominated by grasses, which together added up to more than 60% of pollen taxa, suggesting open vegetation. Although the diatom record was dominated by *Fragilaria crotonensis*, other taxa such as *Aulacoseira* spp. appeared within this period. Thus, the diatoms that characterized this period suggest water turbulence, which could be the result of the lack of a tall canopy to protect the water mirror from the mixing effect of the winds. Charcoal microparticles concentration reached its maxima during this time period, pointing at fire as the most likely mechanism for maintaining open vegetation. Highly-disturbed vegetation has been reported for other areas in Panama and Costa Rica during this time period, and has been attributed to human influence. However, the first appearance of maize pollen took place much later (~1530 AD), and the open vegetation dominance coincided with high El Niño activity. Thus, it is probable that the vegetation shown by the pollen assemblages were in reality reflecting the result of a highly seasonal climate.

From 1170 to 1530 AD, the evidence suggests the progressive formation of a dense tropical forest, which reached maximum diversity and structure by the end of this period. A substantial decrease of diatom diversity to form an assemblage dominated by *Fragilaria crotonensis* offers further support to our interpretation of the development of a dense forest canopy around the lake. Although this dense forest persisted until 1670, the period between 1530 and 1670 was marked by increasing percentages of montane pollen taxa. The latter was likely the result of decreasing temperatures as the result of the global LIA. The appearance of maize pollen at 1530 AD and it persistence towards present indicates intensive human activities, which could have been associated with the progressive decline of tropical forest taxa. Ultimately, the presence of *Achnanthes exigua*, *A. minutissima* and *Nitzschia amphibia* in the diatoms assemblage during the last 100 years were likely associated with eutrophication derived from intensive human activities.

# Abrupt Ecological Changes in the Vegetation of the Guatemalan Lowlands during the Last 210 000 Years: Evidence from Lake Petén-Itzá

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Modern abrupt climate change poses the urgent need to understand ecological responses and community dynamics associated with it. Throughout the Quaternary, climate change has been a constant condition; however, records that are long enough to study climatic variability within this period are scarce. The sedimentary record of core PI-1 from Lake Petén-Itzá in the Guatemalan lowlands spans the last 210,000 years, offering a unique possibility to study ecological responses linked to climatic variability within the late Quaternary. Pollen analysis of P-I1 reveals that vegetation in the area experienced abrupt changes at different time scales. Abrupt changes in vegetation occurred during the glacial-interglacial transitions, corresponding in time and direction with climate regime changes in other regions. Thus, it is very likely that such changes were associated with change in the global climate dynamics. However, abrupt ecological changes that were not directly associated with abrupt global climate changes were also observed. Given the ecological traits of the latter and their apparent decoupled nature from other latitudes, it is possible that they originated from internal vegetation dynamics or from regional variability. Both global and local changes allowed to discern tipping points in the responses of the vegetation and nonlinear responses of the ecological system to global climate change of progressive or abrupt type. Our data demonstrate the resilience of Central American vegetation to sudden climatic changes. However, the high sensitivity and vulnerability of the regional ecosystems to climate change is also clear, especially under the modern fragmented landscape.

# Magnetic Fabrics Preserved by Lacustrine Sediment in Two New York Finger Lakes (USA) Revealed Evidence for Deformation during Coring and Changes in Paleoenvironmental Conditions

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Few paleolimnological studies utilize the anisotropy of magnetic susceptibility (AMS) to infer primary and post-depositional conditions as well as sediment deformation during core collection and sampling. The AMS provides, as a first approximation, the preferred orientation of all the grains in a sample, called the magnetic fabric, and therefore can be used as a proxy for the sedimentary fabric that results from depositional and post-depositional conditions. The combined use of AMS with geochemical and physical analyses permits differentiation of primary depositional conditions from sediment disturbance associated with post-depositional processes and core collection. Detailed analysis of piston cores from Seneca Lake and Owasco Lake (NY, USA) revealed most samples exhibited relatively weak anisotropies that resulted from normal lacustrine sedimentation. However, numerous instances of anomalous magnetic fabrics were also preserved in post-glacial sediment. Anomalous magnetic fabrics resulted from core collection, subaqueous slides, and development of an unconformity associated with a mid-Holocene lowstand. Stratigraphic disruption ("flow-ins") that formed during coring were typically recognized by vertically oriented laminae or soupy sediment and confirmed by magnetic fabric measurements. However, "flow-ins" throughout the uppermost 1–2 meters of three of the four cores could only be identified by a gradual shift in the dominant magnetic fabric. Vertical strain during likely produced overthickened sections without destroying the stratigraphic integrity or the geochemical or physical properties of the sediments. Subaqueous slides were recognized by abrupt changes in lithology, bulk magnetic susceptibility, and magnetic fabrics. A mid- to late Holocene lowstand was recognized using a combination of the alignment of the magnetic ellipsoid with geochemical and physical properties. AMS proves to be a powerful tool to assess core integrity prior to paleoenvironmental reconstruction in lacustrine settings.

# The Dead Sea Depositional Sequence as a Proxy for Ancient Atmospheric and Seismic Events

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The Dead Sea, approximately 80 km east of the Mediterranean Sea and bordering Jordan, Israel, and Palestine, is an endorheic salt lake whose shores occupy the lowest land elevations on earth. It is located in a pull-apart basin along the Dead Sea Transform Fault (DSTF), which flanks the Arabian and African plates, and drains the Jordan River watershed to its north and northeast. In the absence of distributaries and with decreased inflow due to climatic aridity and diversion of water from the Jordan River for agricultural purposes, the average rate of evaporation now exceeds that of inflow. This has led to a loss of total volume, at a current rate of approximately 1 meter per year, resulting in newly exposed areas of the basin floor along the shoreline and on the Lisan Peninsula to the south.

The region is arid, with evaporation generally exceeding freshwater inflow rates, causing the lake to supersaturate with ionic species that precipitate out of the water column forming layers of salts at the bottom of the basin. These precipitate layers are inter-bedded with detrital clay, which is deposited during times of increased precipitation and resultant inflow, or through settling of atmospheric particulates on the lake surface. These particulates migrate through the water column and settle on the basin floor, where they are preserved in the depositional sequence as possible elemental markers for past climatic and atmospheric events. Additionally, due to the propinquity of the DSTF, the sequence may also archive regional seismic events through deformational features known as seismites, which appear as convoluted and brecciated layers interrupting a generally planar mode of deposition. Previously, these features have been dated through varve-counting; however, there is disagreement as to whether these laminae actually constitute an annual depositional pattern. Due to the potential of the Dead Sea depositional sequence as a proxy for past environmental events, determination of this method as a sound dating practice is critical for future studies.

With this as its purpose, the project began with the collection of an approximately 67 cm long section from the newly exposed Lisan Peninsula during a trip to Jordan in January 2014. The sampled section begins at 12 cm below the current ground surface and ends at a total depth of 79 cm. Once in the lab, the sample was photographed and analyzed for sedimentation trends and other features. Several deformational layers were identified that may be indicative of seismic activity and an initial varve count does correspond, within the margin of error, to a radiocarbon date of 1874 (±30), established at 55 cm below the current ground surface. However, deformational layers within the section made the varve count difficult, bringing in to question whether accurate varve counts can be completed across deformed layers. Future studies will include statistical comparison of sedimentation patterns with local precipitation and lake level records to investigate the practice of varve-counting, instrumental dating of additional samples to improve temporal resolution, and qualitative and quantitative analyses to examine possible markers for ancient environmental events.

# The Hominin Sites and Paleolakes Drilling Project: Testing Hypotheses of Climate-Driven Human Evolution and Dispersal at Chew Bahir, Ethiopia

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**Chew Bahir Project members** http://hspdp.asu.edu/

The Hominin Sites and Paleolakes Drilling Project aims to produce palaeoenvironmental records from five sites in east Africa, each being close to globally significant hominin sites. In December 2014, we drilled Chew Bahir, an area of playa mudflats in southern Ethiopia close to the site of the oldest known anatomically modern human (AMH) fossils, to a depth of ~280 metres.

There is currently a lack of long, continuous, Pleistocene records from this region, so these cores will be important in allowing us to investigate the relative influence of low- vs. high-latitude forcing on east African climate and to establish climatic conditions at the time of AMH origin and subsequent dispersal.

Based on sediment accumulation rates estimated from pilot cores, the new core sequence is projected to cover at least the last 500 ka. The core chronology will be constructed from $^{14}C$, OSL, palaeomagnetics, $^{40}Ar$-$^{39}Ar$ of tephra and tephrochronology. Besides geochemical, geophysical and biological proxies, we will use $\delta^{18}O$ and $\delta^{13}C$ of carbonates to reconstruct environmental changes, first at millennial-scale resolution through the whole record, and then at centennial-scale resolution through key periods of interest, e.g., Termination II, 135-125 ka, when AMH may have dispersed from Africa for the first time. Here we present initial stable isotope data from Chew Bahir, to provide a preliminary palaeoenvironmental reconstruction and to help test the various hypotheses concerning AMH dispersal.

# Review of Eemian Transgression Data in the Baltic Region with Special Focus on Lake Ladoga: New Insights for an Old Story

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The Eemian transgression of the Baltic Sea corresponds to the last interglacial period before the Holocene (MIS 5e, ca 124–119 kya). New data obtained from deep coring in Lake Ladoga (Andreev and others, 2014) has resurrected an old question about sediments at the bottom of Lake Ladoga, situated just east of the Baltic Sea. Eemian marine sediments have never been found in the lake although Eemian deposits have been found along river terraces, in some small lakes and as detached lenses. A new coring in Lake Ladoga reached a depth of 22 m, and has found marine diatoms and dinoflagellates that might correspond to the Eemian transgression.

At present, the Lake Ladoga depression appears to be a good depository for the transgressed Eemian Sea. However, this is unlikely because subsequent glacial advances and retreats filled the depression with glacial and periglacial sediments and mostly destroyed previous deposits. In this presentation, we provide a comprehensive picture of the distribution of Eemian deposits around Lake Ladoga. There is very little published data about these deposits (Miettinenand others, 2014). We have assembled known, but never published or published only in Russian, data. An attempt to gather the data from the eastern Baltic territory, particularly from the St.-Petersburg area was made by Malakhovsky and Delusina (2000).

The number of studied marine Eemian sequences described in the Russian literature exceeds 70. They occur more frequently here than on other Baltic coasts, because of the low position of the eastern Baltic territories above the sea level. This meant that they were not destroyed by isostatic uplift, which resulted in the deposition of thicker layers of sediment than in mountainous Fennoscandia.

The typical Eemian sediment comprises a black clay layer with *Yoldia arctica,* having a strong sulfurous odor. The sediments have a monotonous appearance and are easily distinguished from other interglacial sediments. Our goal in describing these Eemian sections around Lake Ladoga is to point out specific features of these sediments and the characteristics of their diatom and pollen assemblages so they can be used in future correlations with new coring from Lake Ladoga. The modern elevation of these sections implies that the elevation of the Eemian Sea could not have exceeded +17 m and probably was very uniform. The distant section near Petrozavodsk as well as the Peski section on the Baltic coast (Miettinenand others, 2005, 2014) correlates with the Prangly Island section in Estonia, which supports the idea of a uniform marine transgression in Eemian time. The similarity of diatom and pollen diagrams reinforces this conclusion while the interglacial vegetation history was quite different from the western regions. The aim of continued work is determination of the lower and upper boundaries of the Eemian transgression in the Baltic region and their dating, with comparisons to the effects of modern interglacial warming.

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# Authigenic Lacustrine Clay Minerals


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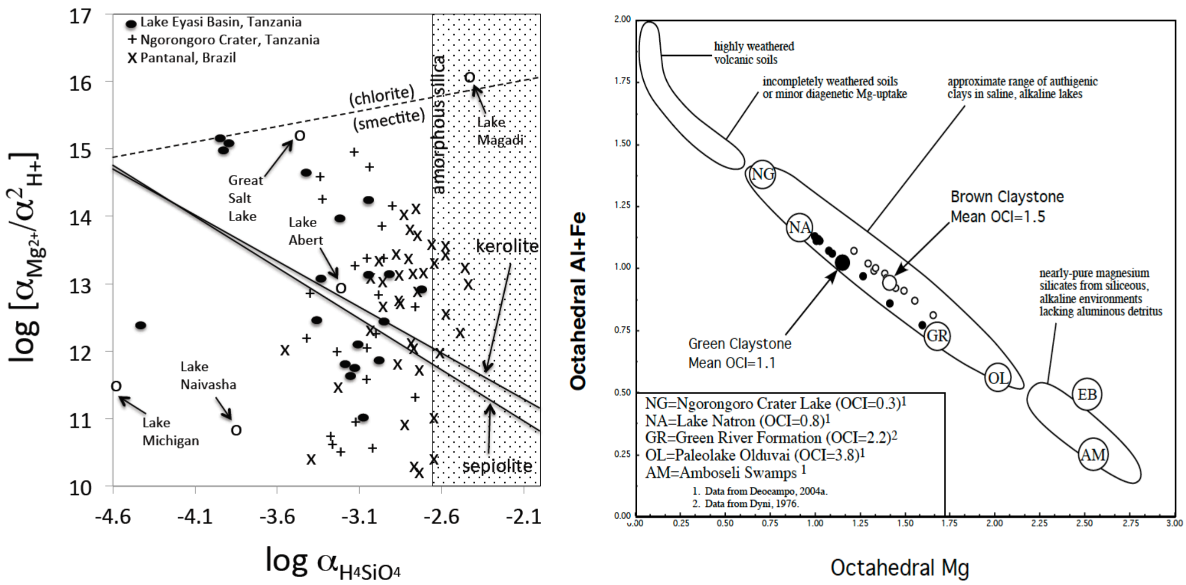
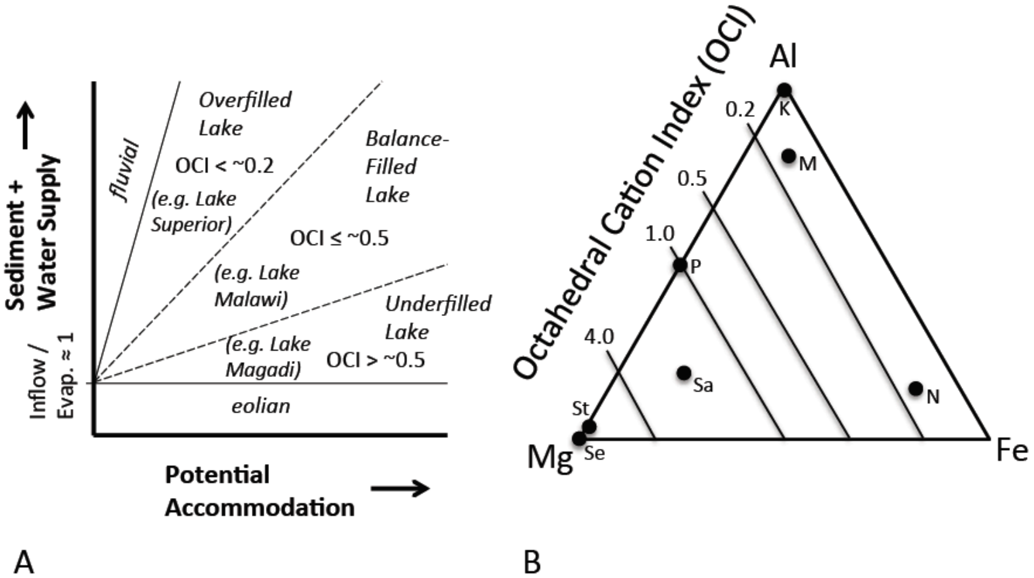
Substantial amounts of authigenic clay minerals can accumulate in terrestrial basins where the following conditions are met: surface or pore waters are alkaline, aqueous silica activity is high, at least some dissolved Mg is present, and detrital input is relatively low. Availability of Al- or Fe-rich detrital clays likely leads to Mg-rich smectite formation, whereas sepiolite or kerolite is favored in environments with no detrital substrates. Geochemically this can be represented with the Octahedral Cation Index [Mg/(Al+Fe)], reflecting the molar proportions of cations in the octahedral sheet of the clay minerals.




**Above, Left**: Mg-silicate stability of several lacustrine systems. **Right**: The range of octahedral cation compositions in lacustrine muds, including Brown and Green claystones from the Miocene Barstow Formation. Data sources for both figures are reported in Deocampo (in press).

Surface waters of the Ngorongoro Crater, Tanzania, provide a good example of alteration of incoming detrital clay minerals into authigenic sediments with strong partitioning of Mg into silicate rather than carbonate phases. Quaternary deposits of Olduvai Gorge, Tanzania, and Olorgesailie, Kenya, provide end-members for comparing processes in highly saline and alkaline settings (Olduvai) versus those in diatomaceous fresher-water environments (Olorgesailie).

Authigenic clays from around the world suggest that illitization and octahedral alterations are decoupled, and therefore indicative of different processes, emphasizing the need to supplement traditional basal layer XRD analyses with analyses of *hkl* reflections and geochemistry of purified phases. Ideally, analyses of these materials would include both oriented (i.e., glass-slide) and randomly-oriented XRD, electron microprobe analyses, and HR-TEM. FTIR can be used to confirm crystallographic expression of the geochemical composition, and stable isotope geochemistry of crystal water can confirm inferred paleosalinity.




**Above, Left**: Lake classification of Carroll and Bohacs (1999), with predicted ranges of Octahedral Cation Index values. **Right**: Octahedral Cation Index values with some common clay minerals, K=kaolinite, M=montmorillonite, N=nontronite, P=palygorskite, Sa=saponite, St=stevensite, Se=sepiolite. Both figures from Deocampo (in press).

In general, authigenic clay minerals are more common in underfilled lake basins, usually associated with evaporitic basins with siliceous input from volcaniclastics or hydrothermal discharge. These models of authigenic clay mineral neoformation are now being tested on lacustrine sediment collected in collaboration with the Olorgesailie Drilling Project (Koora Plain Core) and the Hominin Sites and Paleolakes Drilling Project (Lakes Magadi, Baringo, and Turkana in Kenya, and the Northern Awash in Ethiopia). Preliminary results suggest wide fluctuations in paleosalinity. These data will provide important perspectives on environmental change, particularly in those intervals devoid of biotic or other proxy records.

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# The Impact of Cattle Grazing on California's Sierra Nevada Alpine Watershed: A 10-Year Study

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The Sierra Nevada (Sierra) serves as California's most important watershed with over 50% of the state's surface water originating from the snowpack feeding its alpine lakes and streams. In addition to this important function, the mountain range is also utilized for summer grazing by nearly 40,000 head of open range cattle, at elevations up to 3,000 m. As a result, cattle manure is directly deposited into bodies of water, or is washed into surface water during thundershowers. Cattle grazing is believed to have a harmful impact on aquatic ecosystems on multiple levels, including nutriment stimulation of algae growth causing eutrophication and introduction of pathogenic bacteria.

Beginning in 2003, we have conducted a 10-year study of alpine lakes and streams along the most northern 300 mile segment of the 400 mile Sierra. Water and adjacent periphyton growth was sampled from sites ranging from 1,600 to 3,000 m in elevation. We compared data between grazed areas, and non-cattle grazed areas.

A total 441 samples were collected, including 126 samples of water from lakes and streams at cattle grazed (C) sites, and 315 samples from non-grazed (NG) sites.

We found that aquatic coliforms and *E. coli* significantly increased at C sites where 98% had coliform bacteria and 94% had suspended aquatic *E-coli* levels > 100 CFU/100 mL. These compared with 12 and 0%, respectively, at NG sites ($p<0.01$). Algal biomass was estimated at each site. The algal taxonomy was examined together with analysis of microbes suspended or attached to the algae. Mean benthic periphyton coverage area of the lakes and streams was 31% at C sites compared to only 2% at W sites ($P < 0.01$). Ten genera of algae were identified including Cladophora, Chlorella, Spirogyra, Zygnema, Ulothrix, and a mix of Diatoms. Although density differences were great no significant difference in algae diversity was noted between C and NG.

Larger numbers of bacteria are found attached to algae at C sites compared to NG sites. The prevalence of both coliforms and *E. coli* attached to algae was 100% each at C sites. In contrast, the prevalence at NG sites was 18 and 0%, respectively ($p<0.01$). Mean coliforms and *E. coli* CFU/gm of algae was 388,000 and 265,000, respectively, at C sites. In contrast, at NG sites coliform and *E-coli* CFU/gram algae was 68,000 and 0, respectively ($p<0.01$).

In conclusion, cattle grazing degrades water quality as evidenced by the presence of fecal *E. coli* in suspension in water at nearly all cattle grazed sites, but rarely at non-grazed sites. Significantly higher periphyton biomass and uniform presence of algae-attached *E. coli* was detected in the grazed watersheds. Summer cattle grazing has a significant negative impact on water quality in California's important high Sierra watershed and should be restricted to lower elevations.

# Ostracode-Based Holocene Environmental Inferences from Mid-Altitude Lake Ocotalito, Chiapas, Mexico

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This study provides insights into Holocene climate and environmental changes at mid-altitudes in the northern Neotropics. The Lacandon Forest, Chiapas, Mexico contains numerous karst lakes, which are characterized by high abundances of paleo-bioindicators, including ostracodes, cladocerans, chironomids and thecamoebians. We used ostracodes in a 5.39-m-long sediment core from Lake Ocotalito (920 masl, 7.4 ha, $z_{max}$ = 23 m) as indicators of Holocene climate and environmental change. The core was collected in 20 m of water and has a basal age of ~9,500 cal years BP. We made paleoenvironmental inferences using: (1) fossil ostracode species assemblages and their relative abundances, (2) stable isotope analysis ($\delta^{18}O$, $\delta^{13}C$) of the most abundant and dominant ostracode taxon throughout the core (*Cytheridella ilosvayi*), (3) concentrations of selected elements (Fe, Ti, Ca, Sr), and (4) magnetic susceptibility ($\chi$). Ostracode relative abundances, along with Sr and Ti concentrations and $\delta^{18}O$ values in ostracode valves indicate past changes in the balance between evaporation and precipitation, i.e. periods of dry climate and low lake levels, and times of wetter conditions with high lake levels. $\delta^{13}C$ values in ostracode shells were used as a proxy for lake productivity. The early Holocene (~9,500–-6,000 cal years BP) was characterized by low numbers of ostracode valves and high magnetic susceptibility values, suggesting wet conditions and higher lake levels, except at ~7,500 cal years BP, when *C. ilosvayi*, *Cypridopsis okeechobei* and *Potamocypris* sp. were present, and $\delta^{18}O$ and Sr values were relatively greater, indicating lower precipitation and lake levels. Large lake level fluctuations and high species richness characterized the middle Holocene (~6,000–2,500 cal years BP). Periods of low lake level are suggested by the presence of the littoral species *Heterocypris punctata*, and higher $\delta^{18}O$ and $\delta^{13}C$ values indicate drier climate conditions and higher productivity, respectively. Drier conditions are also inferred from high Sr and low Ti concentrations. The late Holocene, since ~2,500 cal years BP), is characterized by increasing productivity and both lower numbers and diversity of ostracodes. The dominant species was *C. ilosvayi*, followed by *Typhlocypris* sp. and *C. okeechobei*. A decreasing trend in Ti values and slight increase in $\delta^{18}O$ values suggests drier conditions. Ostracode genera that are typically dominant in the lowlands of northern Guatemala and the Yucatán Peninsula, such as *Paralimnocythere* and *Cypria*, were not encountered in Lake Ocotalito sediments. Combined study of biological and geochemical variables in the Lake Ocotalito core enabled reliable paleoenvironmental inferences.

# Controls on the Chemical Evolution of Till-Derived Lakes in the Seneca Lake, NY (USA) Watershed

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Typically lakes are thought to evolve from initially dilute water chemistries to higher concentrations resulting from evaporation or basin leakage or both. Aqueous geochemical studies of lake water usually focus on natural lakes that record a balance between the regional hydrologic budget and the bedrock geology. We focused on examining constructed and natural ponds hosted only in glacial till, creeks in both till and bedrock, natural springs and groundwater wells drawing water only from tills, and Seneca Lake, all within the same watershed in western New York. Determining the contribution of solutes to lake chemistry from weathering of glacial till requires the characterization of water chemistries from constructed lakes whereby rainwaters can interact with fresh tills and release their cation and anion suites. The Hanley Biological Preserve, located in a rural, agriculturally dominated setting in western New York, has undergone significant change in land use from open fields to a landscape dominated by small ponds constructed over 40 years ago. Sampling and characterization of water chemistries from these till-lined ponds as well as comparisons to the natural creeks flowing through the preserve and the tributaries and waters of Seneca Lake define the role that tills play in delivering solutes with weathering. The weathering of the till provides a different suite of cations than the local bedrock geology. The weathering of dolomite, high-Mg and low-Mg carbonate provides magnesium and calcium in the till derived waters. In contrast, calcium is the dominant cation in the Seneca Lake tributaries compared to sodium in Seneca Lake. Minor amounts of sulfate present in the till-derived waters suggest pyrite was oxidized to provide sulfate ions. What actual role freshly weathered tills play as a source of solutes in the chemical evolution of lakes remains unknown. Examination of till-derived waters across the Finger Lakes Region from water wells, natural springs and creeks all sourced from tills documented a wider range of water chemistries fitting the trends at Hanley and encompassing the tributaries feeding Seneca Lake. Given the widespread nature of tills in the region and their mineralogical heterogeneity, till derived waters can range from dilute to brackish. If this mineralogical heterogeneity controls the total solutes then early chemical evolution of lakes need not start as dilute. It seems reasonable that the initial chemical composition of proto-Seneca Lake as well as other till hosted lakes, immediately after glaciation, reflected a till- rather than a bedrock-derived cation chemistry.

# Towards a Half Million Year Environmental Record from the Hominin Sites and Paleolakes Drilling Project in Chew Bahir, Southern Ethiopia


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Chew Bahir, a deep tectonically-bound basin in southern Ethiopia, today covered by ~2,000 km$^2$ of saline mudflats, is a newly explored and recently ICDP-cored climatic archive, containing a several kilometer thick infill of fine lacustrine deposits. The site lies in close proximity to the Lower Omo, site of the oldest known fossils of anatomically modern humans. The duplicate sediment cores, HSPDP-CHB14-2A and 2B, were obtained as part of the HSPDP (*Hominin Sites and Paleolakes Drilling Project*) deep drilling campaign in Oct–Dec. 2014. They are expected to provide valuable insights about East African environmental variability during the last >500 kyrs, in the source region of modern humans. As a key part of HSPDP, which aims at understanding the role of environmental changes in human evolution, the long Chew Bahir record will also contribute to an understanding of the environmental context of the transition into the Middle Stone Age, and the origin and dispersal of *Homo sapiens*.

We present here the initial outcome of the recent core opening and sampling party of the 278.58 m and 266.38 m parallel Chew Bahir cores. The duplicate cores have been merged to one continuous composite core that is currently under further multi-proxy investigation, following HSPDP protocols. Recovery for both cores exceeds 85%. Based on extrapolation of sedimentation rates from short cores (Foerster and others, 2012; Trauth and others, in press) taken in a NW-SE transect across the basin, we anticipate a record covering at least the last 500,000 yrs. First results from the MSCL logging and the initial core description will be presented here, providing an overview of the core composition, and the likely proxy analyses to follow. Low-resolution investigations with a FlowCam and classic smear slide analyses will provide additional information about microfossil (pollen, diatoms, charcoal, phytoliths, etc.) and mineral content, including potential tephra occurrences, crucial for establishing a reliable geochronology. The good recovery and anticipated high time resolution of the cores promise a continuous record of environmental fluctuations on decadal to orbital timescales, that will allow tests of climate-evolution hypotheses relevant to human origins.

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# Holocene Climate and Vegetation Dynamics in the Maya Midlands

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During the last decade environmental reconstructions of the Maya lowlands have proliferated. However, little is known about the environmental dynamics of the midlands, a region that probably played a critical role at providing refugia for natural and human populations during times of critical environmental transitions. Here we report on the sedimentary analysis of a 9,500-year-old core retrieved from Lake Ocotalito (920 m asl), southeastern Mexico. Geochemistry and pollen analyses on the sedimentary record were used to evaluate regional climate and vegetation dynamics. Our geochemical results showed high moisture availability during early Holocene, which favored the development of dense tropical rain forest. Between 8200 and 7800 AP, a major transition towards dry and highly variable conditions occurred and, according to the palynological record, was dominated by seasonal vegetation. These conditions prevailed up to 3500 AP, when human-induced forest clearance and subsequent soil erosion took place. During the past 600 years, the forest cover showed a trend towards recovery, probably as the result of increasing moisture availability and a reduction of human activities in the area.

The sedimentary evidence showed that environmental and vegetation dynamics from early to mid Holocene were likely the result of climate changes at different geographic scales. Differently, during the late Holocene human impacts on the landscape dominated environmental dynamics over climatic forcings. Despite substantial climatic changes, the region was continuously forested and responded to climatic instability by recruiting key species, maintaining a high diversity. Moreover, paleoclimatic reconstruction suggests that in the long term, the climate system in the Maya midlands has been highly variable and maybe associated with the Atlantic Ocean dynamics, expressed through the latitudinal displacements of the Intertropical Convergence Zone. At shorter time scales, it is likely that ENSO system activity has introduced high regional climate variability.

# Late Quaternary Stratigraphic Framework, Seismic Stratigraphy, and Paleolimnology of Walker Lake, Nevada

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Lake deposits are important archives for reconstructing past variations in regional and global climate, and these climate variations can be assessed through evaluating sediment depositional history, facies development, and the stratigraphic framework of a basin. Studying the evolution of temporal climate patterns by using sediment geochemical analyses is important for reconstructing regional environmental variations of the western Basin and Range. Walker Lake, Nevada has a maximum water depth of ~35 m and is situated in a half-graben basin that formed during late Cenozoic transtension, in the Walker Lane tectonic belt. Ten Kullenberg piston sediment cores (~2 to ~10 m in length), and ~300 km of CHIRP high-resolution seismic reflection data were collected in Walker Lake to assess late-Quaternary stratigraphic framework, seismic stratigraphy, and paleoclimate history. Based upon stratal relationships observed in the seismic reflection data, Walker Lake experience two extreme low-stand intervals, observed at ~4 m and ~12 m sub-bottom, in the middle of the lake.

Core 4A is one of the longest cores acquired (9.19 m) and contains the oldest recovered sediments (~8,000 kyr). Analyses of total inorganic carbon, total organic carbon, carbon and nitrogen abundances, and carbon stable isotopes from core 4A yield a valuable multi-proxy paleoclimate record. From 3.7 to 7.5 m depth, the carbon and nitrogen abundances and isotopes are surprisingly consistent down core and may be the result of protracted lake stability. Below 7.5 m depth the carbon and nitrogen abundances decrease, as do %$CaCO_3$ and $\delta^{13}C_{organic}$ values. These signatures represent drier events in the Walker Lake basin. The average C/N ratio of core 4A is 7.71, and the stable carbon isotope measurements range from -21.0 to -25.3‰, both indicate organic matter is dominantly composed of aquatic material. The environmental conditions of Walker Lake permitted the accumulation of high amounts of $CaCO_3$, ranging in abundance from 5 to 40% in discrete sediment samples. The Ca counts from the XRF data correlate with the Total Inorganic Carbon, showing that the calcium fraction in the sediments is from the $CaCO_3$. Results of analyses from a modern sediment transect indicate that regardless of water depth, calcium carbonate is currently being deposited across the entire basin.

A basin-wide angular unconformity is identified based upon stratal terminations in seismic data, and indicates a period of extreme low lake level or desiccation, and localized erosion. Paradoxically, there is no physical property or geochemical signal in the data reflecting this unconformity surface. An estimated age of this surface, 2000–2500 ka, is consistent with previous interpretations of partial diversion of the Walker River into the Carson sink. However, AMS radiocarbon analyses were completed at the Lawrence Livermore National Laboratory on macrofossils with correlative bulk organic mud sediment samples and there is an age disparity of up to 1900 kyr indicating contamination from older carbon. Accordingly, previous studies may have overestimated sediment ages and ages of major climatic events in the basin by using bulk organic mud and carbonate for constructing an age model.

# Historical Sediment Records From a Reservoir with Recurrent Cyanobacteria Blooms, Salto Grande, Argentina

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Many reservoirs around the world suffer the proliferation of cyanobacterial blooms, which pose potential risks to both human health and sustainability of ecosystems. Salto Grande Reservoir (Argentina-Uruguay border, 29°43´ to 31°12´ S and 57°06´ to 57°55´ W) filled in 1979, is an aquatic system (Uruguay River) affected by recurrent cyanobacterial blooms, mostly during the last decade. Sediments integrate the aquatic system and catchment environmental conditions into a continuous, high-resolution archive of local and regional, natural and human-induced changes, and hence can give information on algal population modifications.

The aim of this work is to analyze organic matter, nutrient and fossil pigments from short sediment cores to determine when (and why) Cyanobacteria species became dominant. We plan to relate these results with abiotic and biotic variables registered in the reservoir (from studies undergone just after the reservoir was filled and in subsequent years up to the present) in order to identify the forcing factors behind those changes. We also plan to study the impact of anthropogenic (agriculture, industries and urbanization) and natural (mainly climatic parameters such as temperature, precipitation) changes that took place in the Uruguay River basin. On February 2015, we sampled four sites in Salto Grande reservoir, three located in arms of the reservoir (3–9 m) and one in the main river channel (17 m). We will use the latter for paleolimnological purposes and use all sites for assessing the diversity of dormant phytoplankton and other bioproxies such as ostracods (Arthropoda, Crustacea) in the sediments. In the main river channel (Cerro Paloma, 17 m depth), we obtained a sediment core of 49 cm length. The core was open and macroscopically described considering grain size, sedimentary structures and color by using the Munsell table. The sediments display centimeter-scale laminations and had a predominantly silty-clay composition. We subsampled the core in slices of 1 cm, for running different analysis (organic matter, pigment, nutrients and quantification of dormant Cyanobacteria cells and ostracods). Model age will be performed by $^{210}$Pb dating. Preliminary results indicate that the sediments had high water content (61–66%) and were mostly (mean 88%) of clastic origin (silty clay). Interestingly, alternating dark-gray and light-brown levels have similar content of organic matter, and probably reflect *in situ* redox conditions. Xray images from cores taken from the arms of the reservoir display massive bedding as beds appear homogenous and lacking internal structure, probably as a consequence of intense bioturbation.

This study is supported by the CARU (Comisión Administradora del Río Uruguay) commission. Within the frame of this ongoing work, we are also planning to run germination experiments and to quantify akinetes (dormant stages of Nostocales, Cyanobacteria that play a key role in bloom dynamics) in the top core of each of the 4 cores. The data to be obtained will allow estimating the annual sedimentation rate in the reservoir, to link Cyanobacteria abundance with environmental data, and to assess the diversity of dormant cells (which can trigger blooms) in Salto Grande reservoir. None of these aspects have been investigated until today and will provide valuable information for the reservoir management.

# Marine to Lacustrine Evolution in an Evaporitic Environment: The Late Miocene Lorca Basin, Spain

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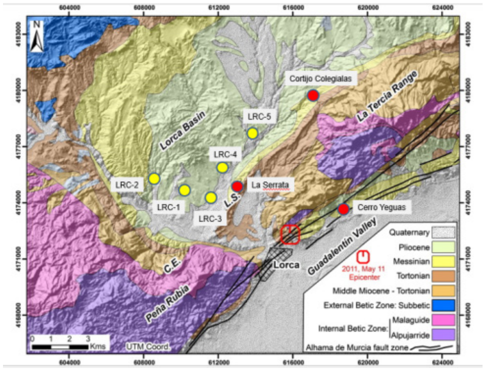
The Lorca Basin, in the eastern sector of the Betic Range (SE Spain), is an intramontane basin recording an evaporitic succession (La Serrata Formation), of up to 300 m thick, with a ~ 235 m thick saline unit within. Altogether, the evaporitic record was originally interpreted as Messinian (Geel, 1976) and later assigned to Tortonian (Krijgsman and others, 2000). The detailed geochemical study provides relevant paleogeographic information at local scale and highlights the importance of hydrochemical changes taking place in coastal evaporite basins changing between marine and non-marine conditions without lithological variations.

A stratigraphic framework is proposed correlating the outcropping gypsum beds (Gypsum Mb of La Serrata Fm) and the subsurface saline succession (Halite Mb) by means of strontium and sulfate isotopes (fig. 1).

In the lower part of the Gypsum Mb the isotopic trends suggest that gypsum formed from marine waters while in the upper part, with Triassic isotopic signals, gypsum formed in a coastal lake mainly fed by non-marine waters.

In the Halite Mb, the textures indicate precipitation in a very shallow, often dried, environment. Fluid inclusion compositions and bromine contents in salt show an evolution from normal marine brines, to brines resulting from the recycling of previously precipitated halite essentially by means of non-marine waters in a coastal lake setting.

The overlying Laminated Pelite Mb (Geel, 1976) consists in its lower part of a number of non-marine gypsum beds intercalated between marine marls suggesting post-evaporitic refilling events of the Lorca Basin by the Mediterranean Sea before its final continentalization during the Pliocene. Biostratigraphic studies in progress are expected to refine age allocation within the evaporitic unit and therefore improve our understanding of the relationship to the "Messinian Salinity Crisis".



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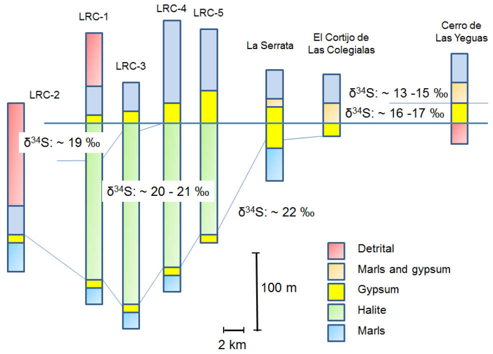

B

**Figure 1**: (A) Geological map for the Lorca Basin; (B) Stratigraphic correlation between the outcropping gypsum beds and the subsurface saline succession based on $\delta^{34}S$


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# Carbonate Lakes of the Eocene Bridger Formation, Unit B,Wyoming USA

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The Bridger Formation of Eocene age is the uppermost fluvial unit exposed in the lacustrine Greater Green River Basin (GGRB) of Wyoming (USA). Distribution of facies across the Bridger Formation in this southwestern portion of Wyoming into the lacustrine Green River Formation to the north has only recently been addressed in detail through chronology (dating of ash layers), sedimentology, and geochemistry (Smith and others, 2008). However, the connection of the fluvial sediments of the Bridger, interpreted as the floodplain deposits associated with the southern margin of Lake Gosiute, with the main lake sequence of Lake Gosiute in the GGRB is still unclear.

Unit B of the Bridger Formation has been correlated with the lacustrine, upper Laney Member of the Green River Formation to the north (Smith and others, 2008); the upper Laney Member represents the final, overfilled stage of lake deposits in the uppermost Green River Formation. The Bridger B unit is characterized by thick sequences of siliciclastic mudstones, sandstones, and thin limestones; the source of these thick mudstones is interpreted as eroded volcanic sediments carried into the GGRB from the south, originally sourced from volcanic episodes in the Absaroka and Challis volcanic fields to the north (Buchheim and others, 2000). Bridger limestones have been interpreted previously as transgressive lake deposits linked to the Laney Member (Brand, 2007). Field study in the central portion of the Devil's Playground Quadrangle (southwestern WY) supports a different conclusion. Limestones instead were deposited in the interchannel flood basins of an anastomosing river system receiving Ca-rich waters from Permian limestone provenance that fed into Lake Gosiute.

The stratigraphic interval studied in the Bridger B unit included the Golden Bench Limestone and five unnamed or undocumented limestone units immediately above and below it. These limestone bodies are not laterally continuous and vary in thickness from approximately 10 to 53 cm. Their textures suggest palustrine limestones containing massive micrite with rhizoliths and ostracodes. They abruptly appear and pinch out over distances of less than half a mile, and commonly are replaced by new limestone bodies within two meters above or below, giving the impression of lateral continuity from aerial photographs. Limestones of the Bridger B are clearly not laterally continuous to the north, indicating that these units were not deposited within Lake Gosiute as it transgressed. As an overfilled lake deposit, the upper Laney Member cannot transgress over such a large area—lake levels are stable with open basin drainage. The geometry of these Bridger B limestones is more consistent with carbonate lake deposits on an anastomosed perennial river floodplain (Gierlowski-Kordesch and others, 2013).

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# Early Pleistocene Climatic Record from Paleo-Lake Baza: Implications for Initial Human Dispersal into Europe

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With more than 4,000 km$^2$, the Baza Basin in SE Spain is the largest of the Betic continental basins. Lacustrine sedimentation commenced in the Late Miocene when the basin was isolated from the sea and continued until the Middle Pleistocene when the basin was captured by the Guadalquivir Basin. Paleo-Lake Baza (~800 km$^2$) can be divided in three concentric sub-environments where salinity increased from the marginal to the inner zone. The marginal deposits consist of an alternation of alluvial and palustrine carbonates. These deposits are rich in fossil vertebrate sites that also include early Pleistocene human remains and lithic tools at several stratigraphic levels. Evidences of subaerial exposure indicate that the sedimentary record is discontinuous at these sites. Furthermore, the absence of pollen in these facies owing to diagenetic processes hampers the reconstruction of the paleoenviromental history during the time of occupation by early humans. Information on the paleoenvironmental conditions is, however, preserved in the central part of the basin where the sediment record is continuous and pollen is preserved. In 2010, a 107.5 m long drill core was fully recovered from the Baza Basin depocentre. We investigated the core using a multiproxy approach, which includes detailed lithological core descriptions, continuous resolution MSCL and XRF measurements, palynological analyses, and detailed mineralogical and stable isotope analyses. Our results from the Paleo-Lake Baza core show that sediments are primarily composed of endogenic mineral phases (sulphates and carbonates) with little contribution from detrital components. The chemical stratigraphy shows significant and highly rhythmic changes where the Ti, Al, K composition varies in opposition to Ca. Ti, Al, K are related with detrital material arriving to the central part of the lake system during wetter periods, while peaks in Ca are related with endogenic evaporitic sedimentation during drier episodes. Current palynological data also indicate alternating periods of wetter and drier conditions. The chronological framework is based on magnetostratigraphy and on correlating climate proxy time series to the LR04 oxygen isotope stack. Our age-model suggests that the sediment record spans the period 1.5 – 1.1 Ma and captures periods of early Human occupation in the Baza Basin. Cyclicity in our record is dominated by the 41 kyr obliquity cycle and thus represents Early Pleistocene glacial-to-interglacial cycles. Our results suggest that early Humans migrated temporally into the intramountain Baza Basin during wet and warm (interglacial) phases, of the Early Pleistocene.

# Paleohydrology, Native Vegetation, and Fire Regime during Marine Isotope Stages 2-3 in the San Bernardino Mountains, California, USA

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Continuous paleoecological records are scarce from terrestrial sites in Southern California beyond the Last Glacial Period (i.e., Marine Isotope Stage 2, MIS 2). Baldwin Lake in the Big Bear Valley, San Bernardino Mountains (SBM), is a playa lake in the ecotone between desert and Mediterranean climate and vegetation. Thus it is well-situated for a high-resolution, long-term study of Southern California paleohydrology and vegetation change. Prior work on a 20 – 60 ka sequence established that lake productivity responds to globally-pervasive climatic forcing (Kirby and others, 2006). Here, we present a new record that dates to 100 – 10 ka. Rapid erosion and sedimentation into the lake basin during this time is due to the high relief, tectonic activity, and glaciation in this sector of the SBM. For the duration of MIS 3 (57 – 29 ka), a stratified perennial lake prevailed at the site, resulting in a high-resolution record with well-preserved fossil pollen and charcoal.

Compared to other lacustrine charcoal records in Southern California, counts of local charcoal (>125 µm) are relatively low throughout MIS 2-3. The onset of MIS 3 has the highest concentration (1 particle/year) and generally declines upsection. Extralocal charcoal (<125 µm), however, is present throughout most of the sequence. The fossil pollen assemblage at the site includes coniferous taxa, steppe vegetation, and desert groundcover. The latter group is comprised predominantly of Chenopodiaceae, *Ambrosia*, *Ephedra*, and *Sarcobatus*. *Pinus* spp. grains are ubiquitous throughout the sequence, and contributions from other arboreal taxa (e.g., *Salix*, *Quercus*, *Abies*) suggest wetter phases. *Artemisia* varies throughout MIS 2-3, and tends to grow either in open woodlands, or as dominant steppe groundcover. MIS 2 vegetation is characterized by lower pollen concentrations, and slight increases in herbaceous plant cover (e.g., Poaceae). We hypothesize that (1) similar to Owens Lake taxa, higher proportions of desert taxa reveal drier periods, and (2) compared to the present-day SBM, wildfire was a less important agent of landscape disturbance for the duration of MIS 2-3.

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# Reconstructing Prehistoric Land Use Through Time: The Río Verde Early Agricultural Landscape Project


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The Lower Río Verde Valley, Oaxaca, Mexico has been the focus of intensive archaeological exploration for the past thirty years. Through this ongoing research we have an excellent understanding of the valley's cultural history and, through a companion geomorphic and paleopedologic study, we have reconstructed the changing fluvial history of the valley and coastal region in great detail. Initial occupation of the valley appears to have occurred by the Archaic period (4700 cal yr. B.P.). Significant demographic expansion occurred by the Late Formative period (2350–2065 cal yr. B.P.) following floodplain aggradation and alluviation, and a change in stream morphology from a meandering to a braided form. During the Classic (1620–1060 cal yr. B.P.) and Postclassic periods (1060–505 cal yr. B.P.), major shifts in settlement and land use occurred, primarily from the productive floodplain to the piedmont (which today has limited productivity). These changes appear to have occurred as a result of political developments, rather than responses to climatic or landscape change. Paleoenvironmental reconstructions from two floodplain sites, approximately 5km apart, indicated periods of land use and abandonment by local farmers through time. However, these data provided insufficient spatial intensity for comparison with the archaeological data, thus precluding examination of human decision-making involving land use, subsistence, and labor allocation which occur at much finer spatial and temporal scales.

In order to rectify this knowledge gap we have developed and instigated Project RVEAL: The Río Verde Early Agricultural Landscape Project. To this end we collected cores from multiple sedimentary depositional sites (lacustrine, estuarine and archaeological) and undertook multi-proxy paleoecological analyses (e.g., pollen, phytoliths, charcoal, carbon isotopes). This regionally dense suite of sites, coupled with the archaeological record, has enhanced our spatial and temporal understanding of human land use dynamics over the past 3,000 years. We present here our preliminary synthesis of human/landuse change for this culturally important region. The paleoenvironmental record supports the archaeological record indicating a rise in human occupancy of the floodplain commencing in the Middle Formative (2755–2350 cal B.P.) in the southern floodplain region and by the Late Formative land use focusing to the south and west floodplain, and with a focus about the site of Río Viejo. However, during the Early Classic there was a shift in occupation away from Río Viejo with a focus on the western floodplain and piedmont region. During the Late Classic landuse activity refocused around Río Viejo as well as in the more northerly regions of the floodplain. During the Postclassic the western and southern regions were largely abandoned as was Río Viejo and land use was focused to the eastern side of the floodplain. This situation remained until the Colonial period when the full floodplain region was once again utilized.

# Evolution of a Clastic Margin along an Early Jurassic Freshwater Lake in an Indian Gondwana Rift Basin

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The Pranhita-Godavary valley of India is an intracratonic, Gondwana rift basin hosting ~4 km thick continental sediment fill (Early Permian to Early Cretaceous). The Upper Triassic to Early Jurassic succession has been sub-divided into the Maleri, Dharmaram, and Kota Formations. The Maleri-Dharmaram succession comprises an alternation of cross-bedded sandstone, pedogenically-modified mudrock, and cross-bedded intrabasinal calcirudites. Due to the presence of unidirectional-flow-generated sedimentary structures, numerous terrestrial vertebrate remains, a complete absence of marine fossils, and wave-generated features, this succession is considered to have been deposited in a variety of fluviatile environments. The Early Jurassic Kota Formation conformably overlies these fluvial deposits with a basal siliciclastic succession topped by a limestone bed a few meters thick. Earlier workers, on the basis of the presence of freshwater vertebrate and invertebrate fauna, have interpreted the limestone bed as a freshwater lacustrine deposit. The mode of transition from the fluvial systems to a carbonate-precipitating lacustrine environment in the Early Jurassic remains unclear. Based on field sedimentologic observations, the lower clastic succession of the Kota Formation is interpreted as a siliciclastic lake margin paleoenvironment associated with carbonate-dominated lacustrine conditions.

The siliciclastic shoreline succession comprises following facies associations: (A1) Alternation of multistoried coarse-grained sandstone bodies and pedogenically modified red mudstones of fluvial origin. (A2) Fines dominated basin-ward accreting inclined heterolithic strata, overlain by pedogenically modified red mudstones of deltaic origin. (A3) Composite foreset sequences accreting towards the basin and composed of imbricated foresets separated by reactivation surfaces representing delta front. (A4) Amalgamated lenticular sandy beds interspaced with greenish grey mudstones deposited in deeper basinal area. (A5) Very well laminated black carbonaceous shale deposited in the deepest part of the basin.

The lower part of the succession is characterized by the dominance of erosively based, fining upward, cross-bedded, fluvial, channel-fill deposits and subaerially exposed muddy, vegetated floodplains (A1). It is immediately overlain by thick deposit of a river mouth environment, characterized by the presence of small delta-like clinoforms and low-energy interdistributary bays (A2). This is followed upward by the dark mudstones of A4, enclosing lenticular convexo-planar sandstone bodies deposited in deeper part of a clastic lake. An abrupt shallowing of the basin is represented by the overlying thick sequence of heterolithic delta-front deposits (A3). They grade upward to a thick succession of carbonaceous shale (A5) deposited in open lacustrine condition and below the wave base. These shales grade transitionally up to an alternation of carbonate-mudstone laminites and bedded, massive, micritic limestone formed in a shallow ephemeral carbonate lake where the pulses of clastic input interrupted the carbonate precipitation. The main facies of the lacustrine carbonates are: (1) Laminated carbonates, composed of regular to irregular, continuous to discontinuous, laminations composed of varying percentage of siliciclastic and carbonate material. (2) Massive carbonate, composed of massive micritic limestone and marl. Algal mats are present at places. (3) Laminated to massive micritic limestone with features of subaerial exposers like profuse cracking, mottling, and brecciation.

**Figure 1.** Cosets of fines dominated basin-ward accreting inclined strata. Scale bar 1.5m.

**Figure 2.** Well laminated black carbonaceous shale grading upward to limestone. Person in upper left corner of the photograph for scale.

# Evidence of a Possible Tsunami in Lake Sediments on San Salvador Island, The Bahamas


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Triangle Pond and French Pond are two brackish to hypersaline interdunal lakes located on San Salvador Island, The Bahamas. San Salvador is a carbonate island located within the subtropical Caribbean. Lakes on the island are typically shallow and fed by groundwater, marine tidal inlets along with karst conduits, and/or precipitation delivered during the Atlantic hurricane season. This study was designed to compare the depositional history of two coastal lakes on the island that could record overtopping by hurricanes and other backbeach barrier events.

In 2013, a study was performed on ten soft sediment cores taken from Triangle Pond, which is located on the northwest coast of the island. Eight depositional units were determined using sediment composition and color, grain size, elemental analysis, and micro/macrofossil assemblages. Interpretation of the units indicates that Triangle Pond began as an open tidal creek approximately 3,500 years ago. The tidal creek was taken over by a mangrove swamp before Triangle Pond's tidal inlet closed approximately 450 years ago and the current hypersaline microbial mat conditions of the lake were established. The unit that represents the closing of the tidal inlet is a coarse-grained, bioclastic carbonate sand. Radiocarbon dating on the unit above and below the sand suggest that it was deposited almost instantaneously in one catastrophic event. Other features of this unit, such as bimodal deposition, erosional contact with the underlying unit, fining upward sequences of grain size, chaotic elemental input, and a mixture of offshore and mangrove macro/microfossil assemblages suggest that this unit might represent a tsunami deposit. In order to determine the validity of this hypothesis, three soft sediment cores were extracted from~~,~~ French Pond located along the southwest side of the island in March 2014.

Three sediment cores from French Pond were collected along a transect near the southern shoreline of the lake. Four layers were identified within the core, three of which were characterized as being of marine influence. The youngest layer is a microbial mat similar to the present day conditions. Below this layer is a sand layer. This layer shows a distinctive erosional boundary with the underlying peat suggesting rapid deposition. The unit shares the characteristics of a similar unit seen in the sediment cores from Triangle Pond. Radiocarbon dating of the underlying peat unit suggest that the sand layer in French Pond may have been deposited at the same time as the one deposited in Triangle Pond. The existence of similar catastrophic depositional units in two lakes suggests that the same event may have impacted both lakes. To further substantiate evidence of a tsunami deposit, microfossils will need to be extracted, quantified, and identified to determine if there is a causal relationship between depositional event and diversity of microfossil assemblage.

## Stunning "Lake-Like" World of an Active Rock Glacier in the Italian Alps

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A 40 m-long ice and debris core from the rock glacier Lazaun in the southern Oetztal Alps (South Tyrol, Italy) was studied in order to reconstruct its history. Radiocarbon dates on plant macrofossils embedded in the ice indicated the formation of the rock glacier to be around 10,300 cal. yr. BP. Two superimposed rock glacier lobes have been active since that time. In addition, the inferred age-depth model surprisingly implied stable sedimentation conditions for snow, ice, and rock debris throughout the Holocene. This allowed the paleoecologic study of the ice/debris core revealing a "lake-like" trap for pollen, cryptogam spores, non-pollen palynomorphs, and charcoal particles as well as plant and animal macrofossils. Core segments with laminated ice were of special interest as they revealed long-term organic deposition under limnic conditions. Finally, the Lazaun rock glacier core revealed a multi-centennial drought period around 4,000 cal. yr. BP related to reduced snow accumulation, prevailing warm climate, and a general Mediterranean/Central European climatic reorganization.

# Holocene Lake Level Fluctuations in Lacustrine Basins in the Great Plains of Western Canada

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Lake level fluctuations impact ecology, infrastructure, recreation, and water management across the northern Great Plains of western Canada. For example, well-publicized high water levels have plagued Lake Manitoba and Waldsea Lake during recent decades, whereas levels are decreasing in many other basins in the region. This review provides a context for understanding modern lake level change by summarizing recent research into water level fluctuations in the Canadian Great Plains lakes during the Holocene.

Today, this 800,000 $km^2$ Prairie region of western Canada contains literally millions of lakes and wetlands, which serve a critical role in waterfowl and wildlife habitat, recreation, and an array of economic and social pursuits. The vast majority of these lakes occupy small closed basins that respond dramatically to changes in climate, groundwater, drainage basin, and landscape modifications. Despite the large number of extant lakes, our understanding of Holocene water level fluctuations during the Holocene is based on fewer than thirty well-constrained stratigraphic sequences.

The stratigraphic records that extend back to at least the early Holocene suggest episodes of low lake levels between ~9,000 yr. BP and 5,000 yr. BP, interpreted to have resulted from a more arid climate at this time. Many of these records also show relatively high water levels and minor fluctuations for the past 4,000 years, as compared to the mid-Holocene. In addition, some of the more highly resolved records indicate lake level decrease during the Medieval Warm Period (MWP) and/or lake level rise during the Little Ice Age (LIA). Although these generalizations are reasonably synchronous over the vast geographic extent of the northern Great Plains, it is also clear that intrinsic processes can significantly obscure the overall lake level signals imparted by extrinsic mechanisms, such as climate and anthropogenic modifications.

Adjusting expectations of lake level change by considering fluctuations throughout the Holocene, rather than relying only on limited historical records, will help us make better choices for water management, property acquisition, and infrastructure development. However, it is critical to recognize that water level fluctuations much greater than those experienced during the past half century have occurred in these basins. Thus, the hydrologic variation and resulting ecologic changes witnessed during the past three to four decades are well within the range of natural variation observed during the past several millennia.

# Climate Change Patterns and Implications for Management Practices in the Truckee River Basin

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The Truckee River Basin in California and Nevada connects headwaters flowing from Lake Tahoe (496 $km^2$) to its terminus at Pyramid Lake (487 $km^2$) in the western Great Basin. Lake water levels and the ecologic health of such endorheic systems are particularly sensitive to changes in precipitation and runoff regimes as well as to consumptive water uses within the watershed. Pyramid Lake is an example of a terminal lake that has experienced several extremes in lake levels. It is a remnant of ancient Lake Lahontan, which during the Pleistocene extended over much of the western Great Basin. Several endemic species still exist, including the Lahontan cutthroat trout and the cui-ui, although their persistence is compromised by reduced flows into the lake. Derby Dam, for example, was constructed by the Bureau of Reclamation from 1903 to 1905 on the Truckee River between Reno and Pyramid Lake to divert water into the Carson River watershed for agricultural uses. In this presentation the current Truckee River Basin management practices are evaluated in context of anticipated climate regime changes and paleoclimate reconstructions derived from Lake Tahoe and other terminal lakes in the region.

# Paleolakes of the Miocene Horse Spring Formation: Extensive Microbially Mitigated Carbonate Deposition in a Complex Rift Setting

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Thick, laterally extensive carbonate units are *not* a hallmark of most ancient lacustrine sequences. Instead, siliciclastics and evaporites comprise significant portions of many of the carbonate intervals and are interbedded with them. This is particularly true for microbially-mediated carbonate units. In this poster we summarize the facies architecture of thick (100–200 m) and laterally extensive (up to 40 km) microbially-mediated lacustrine carbonates of the Miocene Horse Spring Formation of southern Nevada. These rocks formed in alkaline lakes in a complex transtensional rift setting, with Paleozoic marine carbonates dominating the paleogeography of the highlands that surrounded them. Furthermore, volcanism accompanied high rates of extension, leading to an evolving groundwater system marked by variable degrees of spring water input. During times of relative tectonic quiescence, shallow, laterally extensive, quasi-perennial lakes formed and may have persisted for as long as 0.8 Ma. When extension broke up the hanging wall of low angle faults, less laterally extensive, but thick, lacustrine carbonate sequences could form adjacent to basin margins. Although we cannot neglect the effects of paleoclimate on these lake systems—that formed at a time that bridges the peak of the mId-Miocene Climatic Optimum—we argue that tectonics governs the overall architecture of these carbonate units and that climate mainly manifests itself as facies changes within them.

Microbialite facies within these lakes include (1) monotonous sequences of stratiform stromatolites with clotted fabrics and thin, discontinuous laminae that suggest a microbial mat origin; (2) domal stromatolites ranging from 5–200 cm in diameter; (3) small thrombolitic shrubs; (4) dendrolites; (5) 20–50 cm high domal stromatolites with a delicate radial fabric; and (6) oncolites. In general, morphological diversity is greatest near interpreted spring centers or basin margins. Offshore carbonate facies become more stratiform, evolving into massive bioherms in deeper water facies. These facies cluster within three different architectural geometries (fig. 1). First are laterally extensive, thick tabular packages, exemplified by the Bitter Ridge Limestone. Second are thick, laterally restricted basin margin packages, found mainly with the Thumb and Lovell Wash Members. Third are thin, laterally extensive packages interbedded with siliciclastics and evaporites, mainly found within the upper Lovell Wash Member. Our work in the Horse Spring Formation significantly expands the knowledge base of lacustrine carbonates and sheds light on the depositional style and architecture of these carbonates in rift settings.

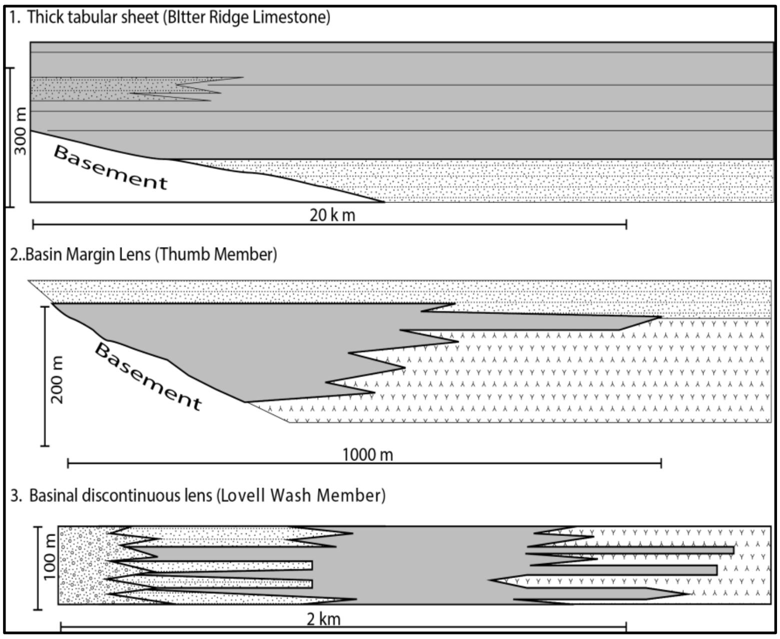


**Figure 1**. Architectural styles of Horse Spring Formation lacustrine carbonate packages (dark gray).

# Towards a Paleohydrological Record of the Holocene, Lower Pahranagat Lake, Central Nevada

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Closed-basin lakes in arid regions such as the Great Basin are rare, but valuable recorders of paleoclimatic and paleohydrologic change. The Lower Pahranagat Lake (LPL) is a very shallow (< 1 m), spring-fed, alkaline system in central Nevada that is thought to hold a sedimentary record spanning much of the Holocene. During January field seasons in 2012 and 2014 we collected sediment cores from three sites across LPL that span approximately 2,400 years based on $^{14}C$ age dating. The sedimentary and geochemical information in these cores includes the Medieval Climate Anomaly and Little Ice Age, both climatic episodes of broad interest.

LPL sediments are unusually carbonate-rich (typically >60% by weight with some intervals approaching 90%) and dominated by Mg- rich calcite. Thin (<2 mm), filamentous laminae within the cores suggests microbially-influenced carbonate precipitation. Based on sedimentary characteristics and geochemical analysis of the cores we have distinguished four lake stages in LPL. Sub-aerial/wetlands stages are characterized by a "spongy" carbonate mud (40–70% $CaCO_3$) facies with no laminations and relatively high clastic and biogenic content. Shallow lake stages like the modern lake condition are indicated by microbially-laminated carbonate mud (60–90% $CaCO_3$). A transitional stage between these first two is characterized by higher biogenic content and intermittent or no microbially-laminated carbonate mud (60–70% $CaCO_3$). A deeper water stage than currently exists today is characterized by massive-bedded carbonate mud (50–60% $CaCO_3$).

We also analyzed downcore samples of the <75 μm carbonate fraction for $\delta\,^{18}O$ and $\delta\,^{13}C$ from one of the sediment cores, along with surface samples from transects of the lake basin and margins. Both $\delta\,^{18}O$ and $\delta\,^{13}C$ values are sensitive proxies, with downcore values varying by up to 6 ‰ over the 2400 year record. Surface samples from the transects reveal a nearly similar level of isotopic variation spatially across LPL. We interpret the downcore $\delta\,^{18}O$ values to primarily reflect changes in basin hydrology and the regional climate. The $\delta\,^{18}O$ record suggests several multi-century dry/wet periods, consistent with other findings across the Great Basin during this period. Elevated $\delta\,^{18}O$ values in the uppermost part of the sediment record reflect human controls on the hydrology of the Pahranagat Valley that have largely reduced the amount of water reaching LPL over the last century.

Ongoing work is focused on using Sr and U isotopes in the carbonate fraction of LPL sediments to characterize past changes in the proportion of three notable sources of spring water that feed the Pahranagat Valley today. Additionally, an effort to collect a longer sedimentary archive, perhaps extending the current record by several thousand years will begin in the next year.

# Late Quaternary Variability from Saline Lake Characterization at Fuente de Piedra, Southern Spain

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The Iberian Peninsula is a key location for reconstructing the highly variable Late Quaternary climate in the western Mediterranean. Due to its position between the North Atlantic and the Mediterranean Sea, Iberia is very sensitive to climatic changes related to hemispheric and regional atmospheric patterns. Environmental reconstruction from lacustrine archives is challenging in Spain, due to the scarcity of large lakes in Iberia. But, complex environments like shallow saline lakes are widely distributed around the region. Such fluctuating environments have been used for paleoclimatic reconstructions as they provide multiple proxies of hydrologic variations due to changes in rainfall and evaporation.

In order to investigate information on Iberian environmental history, we studied a shallow saline lake, Laguna de Fuente de Piedra (southern Spain). Its watershed is composed of Triassic evaporites, Jurassic limestones, dolostones, and marls, and Neogene siliciclastic sediments. This basin was formed by karstic solution of Triassic evaporites and is now characterized by a mean depth of 0.7 m and a water surface, at maximum flooding stage, covering approximately 13 $km^2$.

A multi-proxy study was performed on several sediment cores (max. depth 14 m) recovered along the present-day lakeshore and from the center of the lake. Our study comprises detailed characterization of the drill cores through sedimentologic description, XRF-core-logging data, and XRD analyses. Additionally, mineralogy as well as crystal habits have been analyzed by SEM-imaging and EDAX to give insight into genetic processes. After dating 23 samples by $^{14}C$-AMS, a preliminary age model has determined that the sediment cores record events from the late Pleistocene to early Holocene.

The overall mineralogic composition of the central core is characterized by gypsum, celestine, dolomite, and minor siliciclastic components. Most of the dolomite formation is bio-induced (endogenic). Halite is present in all samples as cement. The marginal cores shows a similar composition but, in addition, layers are mostly composed of calcite and aragonite that are interbedded between more saline sediments.

Furthermore, sequences that indicate changes in paleoenvironmental conditions have been described through the entire sediment core. Each sequence comprises either two or three facies: (1) detrital gypsum, (2) endogenic dolomite, and (3) early diagenetic gypsum. The base is composed of detrital gypsum that grades into dolomitic mud. Interstitial gypsum of lensoidal and prismatic habits grew into the pores of both of these facies. This pattern records the flooding of the lake floor (eroding previous gypsum-bearing sequences) and later lowering of the water table by evaporation until pore water salinity increased to allow precipitation of early diagenetic interstitial salts (halite, gypsum, celestine). Variations in the sedimentologic features and geochemical compositions allow reconstruction of the changes in the rainfall/evaporation rates among the sequences. Thus, vertical arrangement of these sequences into higher-order parasequences can be interpreted as resulting from a varying climate (recorded in the variations of the hydrologic conditions), but this signal is modulated as well by tectonics through the infilling of the basin responsible for an overall shallowing trend.

## Did the Eocene Green River Lakes Change Earth's Climate?

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The early Eocene was a time of temperature maximum in Earth's history. Then, about 50 million years ago, something reversed the trend of increasing temperatures and the Earth began a long cooling trend that continued into the Pleistocene. The Green River lake system, covering parts of Colorado, Wyoming, and Utah, existed between about 53.5 to 45.2 Ma and the lake sediments contain one of the world's largest deposits of oil shale. Carbon dioxide content of the atmosphere at the time has been estimated from 1,125 ppm to as high as 2,250 ppm. Could the removal of carbon dioxide by photosynthetic organisms to form the kerogen in the oil shale have had an effect on Earth's climate and contributed to the cooling trend that started when the lakes were in existence?

The U. S. Geological Survey has calculated that the Green River Formation contains the equivalent of 4.285 trillion barrels of oil. This is less than the amount originally present because erosion has removed some of the formation. Using the conversion factor of 0.451 metric tons of carbon dioxide produced by completely oxidizing a barrel of Green River oil and multiplying by $4.285 * 10^{12}$ barrels gives 1.93 trillion metric tons of carbon dioxide that would be produced if all of the kerogen were oxidized. The kerogen was produced by the decomposition of algae and other photosynthetic organisms, which had previously grown by removing carbon dioxide from the atmosphere, so $1.93 * 10^{12}$ metric tons of carbon dioxide were removed from the atmosphere.

The mass of the atmosphere is approximately $5.14*10^{15}$ metric tons. Dividing the amount of carbon dioxide removed by algae in the Green River lakes (1.93 trillion tons) by the mass of the atmosphere gives $0.377 * 10^{-3}$ tons of carbon dioxide per ton of atmosphere, or 377 ppm by weight. Converting this to volume gives 248 ppmv. This is a substantial amount of carbon dioxide that would have been removed from the atmosphere. This would amount to between 11 to 22 percent of the $CO_2$, depending on which estimate of atmospheric $CO_2$ one uses. The present increase of carbon dioxide in the atmosphere of roughly 100 ppm is associated with a noticeable warming trend, so removal at two and a half times that amount ought to have contributed to a cooling of the Earth. Couple this with approximately the 55 to 470 ppm $CO_2$ removal attributed to the Eocene *Azolla* bloom in the Arctic Ocean, a total of 303 to 718 ppm $CO_2$ was removed from the atmosphere in the Eocene. These two $CO_2$ sinks could have reversed the warming trend and substantially changed Earth's climate.

# Investigating Limnologic and Biologic Characteristics of Sub-Alpine Lacustrine Systems in an Active Volcanogenic Landscape

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We summarize biologic and limnologic data collected in 2012–2014 from three lakes in Lassen Volcanic National Park (LAVO). The future objective was to use modern data to interpret variations in diatom and sediment composition from lake cores to determine responses to anthropogenic and natural disturbances. Manzanita Lake (1,790 m, 0.18 $km^2$ surface area) has a maximum depth of 9–10 m, and a ~30 $km^2$ catchment, and Butte Lake (1,850 m, ~1 $km^2$ surface area) has a maximum depth of 13–15 m. Manzanita and Butte lakes are accessible by road and subject to heavy recreational use. Widow Lake (2,084 m, ~0.10 $km^2$ surface area) is located in a high-elevation wilderness area accessible by hiking trail.

All three lakes are N-limited; Manzanita and Butte lakes are dimictic, mesotrophic systems. Widow Lake (polymictic) has a lower trophic status (sub-mesotrophic). Manzanita Lake had the highest concentration of silica (Si) in surface water inputs (18–34 mg/L), followed by in-lake Si concentrations of 3–7 mg/L for Butte Lake and 3–5 mg/L for Widow Lake. TP ranged from 10–44 ppb in Butte Lake, 15–31 ppb in Manzanita Lake, and 7–15 ppb in Widow Lake. $NO_3/NO_2$ ranged from 3–28 ppb in Butte Lake, 1–4 ppb in Manzanita Lake, and 1–3 ppb in Widow Lake. $NH_4$ ranged from 1–40 ppb in Butte Lake, 3–16 ppb in Widow Lake, and 2–13 ppb in Manzanita Lake. Phytoplankton are dominated by diatoms in Manzanita and Butte lakes. Diatoms are abundant in Widow Lake, but total biovolume in this system is lower.

All three lakes showed a seasonal diatom succession from spring, following ice-out, through the fall; however, they differed in the succession sequence. The succession was observed for two seasons and was consistent in each lake. Butte Lake exhibited a dominance of two N-sensitive species, *Asterionella formosa* and *Fragilaria crotonensis* in the spring, followed by *F. crotonensis* and araphid chains in the summer, and replaced by *F. tenera-nanana* group in the fall. Manzanita Lake showed a similar succession, except the fall species was *Aulacoseira granulata var. angustissima*. Widow Lake, the higher-elevation more-remote site, showed a slightly different succession, starting with *Tabellaria* and *F. tenera-nanana* group in spring, followed by *F. crotonensis* and *Tabelleria* in the summer, and *F. tenera-nanana* group in the fall.

Persistence of N-sensitive diatom species with moderate to high Si requirements throughout the summer in these lakes is atypical and may be related to Si, TP, and DIN supply and the resource ratio requirements of these diatom species. Major differences in the diatoms in these systems are expressed in the lack of *A. formosa* in Widow Lake and the presence of *A. granulata var. angustissima* in Manzanita Lake. A lack of *A. formosa* in Widow Lake may be the result of hydrology/catchment characteristics, or level of anthropogenic impact at this site. The seasonal bloom of *A. granulata var. angustissima* in Manzanita Lake may be connected with continuous stream inflow and fall lake structure. These data provide a modern baseline to help interpret down-core changes in diatom composition and diversity over the last century.

## Sediment Profile and Microfossil Assemblage of Shallow Lake Vrana near Biograd, Croatia


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Lake Vrana in Dalmatia is the largest natural lake in Croatia and is elongate in the NW to SE direction, parallel to the Adriatic Sea coastline. Lake Vrana is a shallow lake with a mean depth of 1.5 to 2 m, while its maximum depth is 4 m. It is a karstic lake within a cryptodepression. The lake is unique because of its position on the Adriatic coast in eastern Mediterranean; this location is ideal for understanding climatic records involving Mediterranean climate in this northern area. The lake is separated from the sea by a thin strip of karstified limestone (800–2,500 m wide), but it is connected to the sea through the 800 m long artificial channel "Prosika" (built in the 18th century) to the southeast. Lake Vrana is a freshwater to slightly brackish lake, salinity ranges between 0.7 and 1.2 ‰. An 11-meter-long sediment core was taken from the central part of the lake, covering the last 12000 cal yr. BP. The sedimentation rate was calculated using AMS radiocarbon dating ($^{14}C$). Analyses of total and organic carbon, sediment geochemistry, and mineralogy were performed to characterize the sediment and organic matter input. Microfossil analyses (ostracode and pollen) record changes in salinity and the vegetation history of the lake. Three lake phases can be characterized: (1) an initial, flooded karstic polje with clastic facies rich in carbonate, (2) an organic-rich low-energy wetland until 9150 cal yr BP, and (3) a permanent lake. The lower unit of the lake core comprising lake phases 1 and 2 (9150–6100 cal yr. BP) consists of carbonate-rich silts, without detectable marine influence. The upper unit of the lake core (6100 cal yr. BP to present) is characterized by carbonate sediments with an increasing siliciclastic component with time as well as by a gradual increase in marine influence and development of typical Mediterranean vegetation. The increased siliciclastic input is the result of increased soil erosion due to deforestation and human settlement. The present lake water conditions (alternating seasonal changes in the salinity from freshwater to brackish) were established at 3800 cal yr. BP.

## Late Pleistocene-Holocene Diatom Record of Lake Chapala (proy CHAPHOLO-2014)

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In order to study the climatic variability of Lake Chapala (México), we have obtained a 27 m core in the depocenter of the lake. This largest Mexican lake is associated with a continental triple junction inside the Chapala Acambay graben in the western sector of the Transmexican Volcanic Belt. Bulk organic sediments of the core were used to determine age through AMS $^{14}C$ dating, showing the sediments encompass the last part of the Pleistocene (12,320±60 cal yr. BP) to late Holocene (1,040±30 cal yr. BP). Sediment of lacustrine origin within the core consists of silty clay to sandy silt that is dark gray in color with brown to almost black organic layers. Burning episodes were significant at 2,570±30 and ca. 5,000 cal yr. BP. Volcaniclastic facies in the late Pleistocene and Holocene are associated with the emission of nearby volcanoes (Colima) with *Aulacoseira granulata* and *Stephanodiscus aff.niagarae* dominating the more turbid lakewaters of Lake Chapala until ca. 8,000 cal yr. BP. Then until present, *Stephanodiscus aff. medius*, *Cyclostephanus aff. Dubis, and Stephanodiscus aff. nemanensis* occurred in peaks along the record associated with epiphytic taxa and phytoliths. Detrital facies suggest a rare regression of the lake at this time.

Low percentages of *Surirella ovalis* and *S. aff. rhomboides* occur through the core, indicating a constant ionic concentration in the lake. Lamination occurs in some intervals of the core ca. 10,000 cal yr. BP and also some slumps as a result of sediment focusing could be responsible for the age inversions close to the bottom of the core. Diatoms as well as organic and inorganic carbon proxies evidence high lake levels associated with comparatively high runoff during the Early and Middle Holocene similar to other central Mexico lakes. Regressive episodes did not dry the lake since a nearly constant well- preserved diatom record is preserved in the core. Parallel studies (magnetic susceptibility, mineralogic and geochemical studies in progress) will aid in understanding the climatic variability of this tectonic lake and will provide a continental paleoclimatic record to compare with other key long records of eastern central Mexico, including Cuizeo, Acambay and Chalco Quaternary lakes and south Sayula paleolake.

# The YD Onset in Central and South Mexico and Markers of an Extraterrestrial Impact

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The Younger Dryas interval (YD) lasted 1,300 years and it is associated with a period of cooling in the environment between 12,900 and 11,500 cal yr. ka (10,900 and 9,800 $^{14}$C BP). During this time, there is a strong correlation with megafauna extinction and the disappearance of several Clovis PaleoIndian sites, mainly in the SW of the USA (Firestone and others, 2007). A major peak in impact-related platinum is observed in the GISP2 ice core, occurring at the onset of YD (Pataev and others, 2013). New age depth models based in more accurate dating of the strata confirm the age of the impact (Kinzie and others, 2014). Studies on bulk sediments based on other proxies, like high temperature melt glass major to 2,200 centigrade degrees (Bunch and others, 2012), osmium (Wu and others, 2013), and other isotopic analyses demonstrate that the impact material cannot have originated from the mantle as suggested by (Daulton, 2012). In the few-centimetre-thick strata associated with this recognized meteorite layer, characterized by a special suite of exotic minerals including highly ornamented magnetic microspherules, melted $SiO_2$ droplets with aerodynamic shapes (tektites), lonsdaleite, nanodiamonds and large numbers of charcoal fragments. This special layer has been reported so far in several countries at eighteen sites on four continents (Wittke and others, 2014). More recent investigations reveal that polyforms of carbon and cubic nanodiamonds formed under temperatures higher than volcanic episodes and pressures similar to conditions associated with cosmic impact. Research based on sedimentologic and stratigraphic evidence concluded that peaks in nannodiamonds accumulations are observed only in the YD strata. Particularly in México, a black mat was found in sediments from Lake Cuitzeo with twinned nanodiamonds (Israde and others, 2012) and in other YD dated sites, including the Tocuila mammoth site, the Acambay Mammoth, Chiapas, illustrating a wide geographic distribution for the meteorite layer in México across geologic settings and altitudes.

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# Quaternary Hydroclimatic and Ecologic Change at Lake Malawi, Southeast Africa

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African ecosystems are at great risk due to climate and land-use change. Despite the extraordinarily high biodiversity, long-standing hypotheses on ecology and biogeography of aquatic systems as well as terrestrial forest communities and their linkages have been unable to be tested until now due to lack of sufficiently long records. Long drill core records from continental rift lakes allow us to reconstruct dynamics in both aquatic and terrestrial ecology within the context of changing regional hydrology. Here, we present the first long, continuous record of integrated watershed ecology and hydroclimate from Lake Malawi, East Africa, which goes back to the Early Pleistocene (~1.2 Mya).

The presence of un-transported ostracodes within the core indicates times when the lake bottom was oxygenated, and thus significantly shallower than at present. A major change of state between river and non-river influenced environments occurred at the core site between ~850–740 ka, evidenced by a transition in dominant ostracode species assemblages. These conclusions are supported by other extremely shallow lake environment indicators, such as ooids, rounded and sorted quartz sand grains, framboidal pyrite, authigenic siderite (where co-occurring, indicative of anoxic marsh conditions), and the ostracode genera *Limnocythere* and *Ilyocypris*. The upper section of the core shows a strikingly different variability. For the last ~800 kyr, periodic transitions in lake level juxtapose deep water environments indicated by the absence of ostracodes with sustained regressions. The lowstands are characterized by extremely diverse assemblages of *Limnocythere*, *Cypridopsis*, and *Candonopsis*, which are not consistent with a marshy environment or proximal delta.

Changes in pollen assemblages in the non-river influenced strata suggest that alternating phases of forest expansion and collapse occurred. Although species diversity is much greater during forest phases, composition varies little from phase to phase. Very high abundances of afromontane taxa suggest frequent widespread colonization of the lowlands by high elevation trees. Each forest phase is interrupted by rapid decline of trees and expansion of semi-arid grasslands or bushland whose composition varies greatly from phase to phase. The expansion of arid vegetation is likely dynamically linked to thresholds in regional hydrology associated with lake level and moisture recycling within the watershed. This vegetation is unlike any found at Malawi today, with assemblages suggesting strong Somali-Masai affinities. Furthermore, nearly all semi-arid assemblages contain small abundances of forest taxa typically growing in areas with wetter edaphic conditions, suggesting that moist lowland gallery forests were present but restricted to riparian corridors during exceptionally arid times.

Alterations in the frequency of lake level fluctuations, as indicated by the ostracodes, occurred coeval with the mid-Pleistocene revolution (~900 ka), suggesting variability in tropical hydrology was linked to global boundary conditions. Furthermore, environmental change within the lake during the late Quaternary was strongly tied to the hinterland and resulted in dramatic reorganization of regional vegetation. These large-scale alterations of hydrology and ecology over the last 1.2 Myr in East Africa have important implications for early human biogeography across Africa as well as disturbance regimes that are crucial for the maintenance of modern East African landscapes.

# A Cyclical Middle Eocene East Asian Monsoon: Evidence from Lacustrine Longshore Bars

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The paleowind field is an important component of climate, but is less well documented because of the difficulty of identifying geologic information that can be used to quantify paleowind fields. We propose that the orientations and morphologies of lacustrine longshore bars, which are important products of wind-wave action and widely spread on the margins of both modern and ancient lakes, can be used as a proxy for quantifying paleowind direction and strength. We use cores and geophysical data to constrain bar geometries in an Eocene lake in East China and then to determine ancient wind direction and strength. We also use tempestite thicknesses to assess the intensity of paleo-typhoons. We find that the paleowind field involved cyclic variation of the relative intensities of northerly and southeasterly winds, presumed to be seasonal and monsoonal. A cycle period of about 400 thousand years (Ka) suggests forcing by the Earth's eccentricity orbital cycle. Each cycle generally began with mild northerly and southeasterly winds and relatively weak typhoons, followed by strengthening northerly winds and weakening southeasterly winds coupled with strengthening typhoons, and ended with mild northerly and southeasterly winds with relatively weak typhoons. The longevities of individual bars indicate that summer (southeasterly) and winter (northerly) wind fields were separately governed by cycles of ~40 Ka and ~31 Ka, respectively, possibly influenced by the Earth's obliquity cycle. These findings provide a new perspective on forecasts of future atmospheric flow fields and represent the oldest reported evidence for the East Asian monsoon (~45 million years).

# Anthropogenic and Climatic Influences on the Diatom Flora within the Fallen Leaf Lake Watershed, Lake Tahoe Basin, California

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Sediment cores and water quality data from the Fallen Leaf Lake (FLL) watershed were analyzed to gauge the effects of climate, land-use, and atmospheric nitrogen deposition (N-deposition) over the past 1,200 years. Diatom and geochemical analyses were conducted on a gravity core from FLL, a moderately impacted lake that is the lowest in the watershed. The FLL core delineated three zones of interest that correspond to the Little Ice Age (LIA), a transitional zone of warming and anthropogenic influence following the LIA, and an upper anthropogenic zone. The LIA is characterized by increased abundances of the diatoms *Stephanodiscus alpinus* and *Aulacoseira subarctica*, is calibrated with an age model derived from $^{14}$C and $^{210}$Pb dates to between 1385 and 1807 AD, and indicates a time of cooler, windier conditions. The transitional zone represents a ~140 year period of gradual warming following the LIA, and is characterized by increases in *Cyclotella rossii* and *Discostella stelligera,* and decreases in *Pseudostaurosira brevistriata*. This zone also shows increases in elemental cobalt, zinc, and tin that may be attributed to an increase in coal burning and smelting activities in California and Nevada. Beginning ~1910 AD, increased building, land-use, and recreation around FLL caused an increase in sediment accumulation. The increased sediment accumulation rate can be partly attributed to terrestrial organic input into FLL, as both total organic carbon and C:N ratios increase beginning ~1943 AD. Coincident with the sedimentologic shift is the appearance of mesotrophic diatoms responsive to nutrient enrichment, including the *Fragilaria tenera-nanana* group, *Tabellaria flocculosa* strain *IIIp*, and *Nitzschia gracilis*. These mesotrophic diatoms characterize the anthropogenic zone, increase rapidly in abundance ~1950 AD, and may be linked to the increased development around FLL. Down core proxies for atmospheric N-deposition in the FLL watershed are weakly expressed and appear to be overshadowed by stronger signals. Although the N-responsive diatom species *Asterionella formosa* is a dominant component in FLL today, it has been present in similar abundances for at least the last 1200 years. Nitrogen stimulation of *A. formosa* and other N-sensitive phytoplankton in FLL is attributed to the natural process of flushing N-rich water from the upper watershed during spring runoff. A negative shift in $\delta^{15}$N, another proxy of atmospheric N-deposition, is weakly expressed in the FLL core and is overprinted by additional down-core variation. Evidence supporting atmospheric N-deposition from Gilmore Lake (GL), a low impact site higher in the watershed, has also proved evasive. In GL, *A. formosa* was found in the water column, but not in surface sediments, indicating that its appearance is very recent, and not synchronous with the anthropogenic zone shift in FLL. N

concentrations in spring runoff into GL were <1 ppb, indicating that, for the sampling period, N inputs from wet deposition were negligible. The data show that the FLL record is sensitive to climatic cooling during the LIA and to anthropogenic activities commencing in the 1800s that increased throughout the latter half of the 20th century; however, there is no strong coherent signal of anthropogenic N-deposition.

# The Potential of Strontium Isotopes in Detecting Water Level Changes and Basin Connectivity of East African Paleo-Lakes Investigated Within the HSPDP Project

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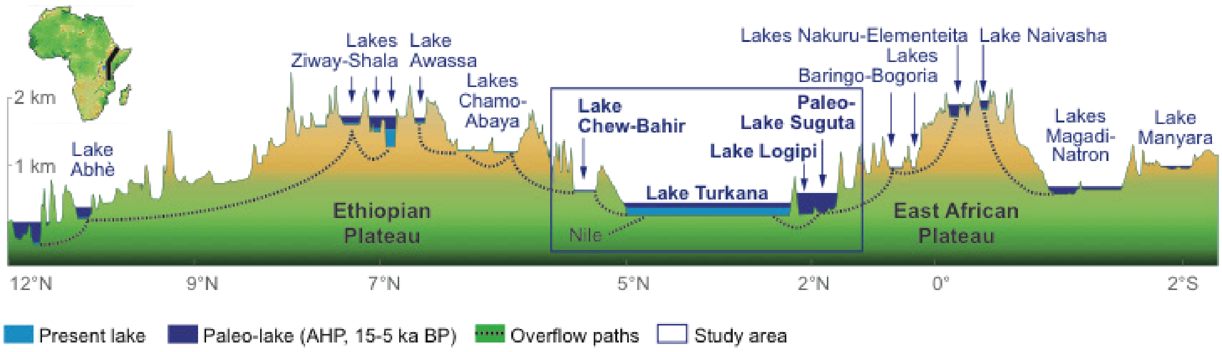
A major challenge in paleo-anthropology is to understand the influence of climatic changes on hominin evolution in Africa. The Hominin Sites and Paleo-lakes Drilling Project (HSPDP) is currently meeting that challenge by providing records covering the last ~3.7 Ma of paleoenvironmental change. Between 2013 and 2014, those records were cored at five sites closely located to key paleo-anthropologic findings in East Africa. One of the drilled sites is the Chew Bahir basin in southern Ethiopia, a deep tectonic basin, today covered by ~2,000 km$^2$ of saline mudflats, containing a several kilometer thick infill of fine lacustrine deposits. The site lies in close proximity to the Lower Omo, location of the oldest known fossils of anatomically modern humans. The duplicate sediment cores, each ~280 m long, are expected to provide valuable insights about East African environmental variability during the last >500 ka.

The lake basins in the eastern branch of the East African Rift System today contain mainly shallow and alkaline lakes. However, paleo-shorelines in the form of wave cut notches, shell beds, and beach ridges are common morphologic evidence for deep freshwater lakes that have filled the basins up to their overflow level during pronounced humid episodes, such as the African Humid Period (AHP, 15-5 ka). Combined with multi-proxy analyses from sediment cores of the same basin and time, these morphologic features help to quantify the paleo-water column above distinct sediment compositions. Unfortunately, further back in time, many of those morphologic features disappear due to erosion and the estimation of paleo-water depths depend merely on qualitative proxies from core analyses.

We here present a new method that shows a high potential to translate qualitative proxy signals from sediment core analyses to quantitative climate signals. The method aims at water level reconstruction of the multiple lake episodes (here: of paleo-lake Chew Bahir) using strontium isotopes in lacustrine fossils and microfossils. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) preserved in lacustrine fossils represent the averaged $^{87}Sr/^{86}Sr$ values of runoff from sub-drainages with varying lithology and age. The catchment of the Chew Bahir basin consists mainly of Precambrian basement that produced high $^{87}Sr/^{86}Sr$ ratios in the lake waters. During major humid periods, the drainage of the basin, enlarged when paleo-lakes Abaya, Chamo, and Awassa, located at higher elevations of the rift, were cascading down into the Chew Bahir basin. These basins drain mainly volcanic rocks that usually show very low $^{87}Sr/^{86}Sr$ ratios. The onset of this hydrologic connectivity should therefore be clearly visible in a reduction of $^{87}Sr/^{86}Sr$ ratios in the lacustrine fossils of Chew Bahir. First results from the Chew Bahir pilot study already confirm this assumption for the past 50 ka. Furthermore, the strontium isotopic signals of lacustrine fossils from Lake Turkana and paleo-lake Suguta and their potential in showing basin connection further down the plateau will also be presented. The new method may help to quantify paleo-lake levels beyond the past 50 ka and may also detect migrational barriers or routes due to the occurrence of synchronous large, connected and deep paleo-lakes.




North–south cross section of the eastern branch of the EARS, with both modern and paleo-water depths during the African Humid Period (AHP, 15-5 ka BP). Box indicates the study area presented at ILIC6.

# Lake Nam Co (Central Tibetan Plateau)— A High-Potential ICDP Drilling Site

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Lake Nam Co, located on the central Tibetan Plateau at the intersection of the Westerlies and the Indian Summer Monsoon, is well suited to study hydrologic and atmospheric changes over different time scales. Based on multi-proxy studies, the regional paleoclimatic and paleoenvironmental history of the past 24 ka cal yr. BP was reconstructed, demonstrating the potential of this lake as a geoarchive. However, the nature, thickness, and geologic time span of the sedimentary infill of the entire basin have not been determined yet. Nam Co was targeted by a joint (Sino-German) multichannel seismic survey using an airgun with a 64 m long seismic streamer (32 channels/2 m spacing). Although only a few lines could be acquired, data show promising results. Preliminary data processing and interpretation reveal well-layered sediments of ~800 m thickness in the center of the lake. Rapid sedimentation is confirmed for the flat lake bottom, although growth faults and doming are observed in the deeper sediments. Because no erosional unconformities were detected, continuous sedimentation throughout glacial/interglacial cycles is very likely. Seismic facies show cyclicity, probably linked to climatically driven changes in sedimentation processes. A comparison with the Holocene/Late Glacial seismic record reveals similar reflectivity units. Assuming sediment accumulation rates within the known range from the yet investigated sedimentary record of 0.4 to 1.7 mm $a^{-1}$, different seismostratigraphies can be developed assigning the units tentatively to marine isotope stages. Accordingly, geologic ages between ~400 and ~1,660 ka may potentially be reached by deep drilling, tackling paleoclimatic, paleomagnetic, tectonic, and biologic evolutionary questions.

# Microstratigraphic Zoning of Phosphorus and Trace Metals in Lacustrine Oil Shale of the Green River Formation, Uinta Basin, Utah, USA


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The Eocene upper part of the Green River Formation (GRF) of the Uinta Basin, eastern Utah, comprises variably fissile marlstone ('shale' *sensu lato*) with numerous beds of oil shale generally considered deposited in an offshore, stratified lake setting. At Gate Canyon, the entire upper GRF has been extensively sampled and analyzed using whole rock XRD, FEG-SEM, solution ICP-MS, and LA-ICP-MS. Relative to the marlstone, XRD indicates many of the oil shale beds are anomalously rich in calcium fluorapatite (CFA). SEM shows a diagenetic succession including rhombic dolomite, followed by microcrystalline CFA, and blocky low Mg-calcite. SEM-EDS has detected Na and S (as $SO_4$) at near expected values for balanced substitutions in the CFA lattice. Sulfate in the lattice would be indicative of suboxic conditions during diagenesis.

Consistently, solution ICP-MS indicates phosphatic intervals in the oil shale are also associated with Th, U, and Rare Earth Element (REE) anomalies. Light REEs may be slightly enriched with respect to background levels in the marlstone, but remain below Post-Archean Australian Average Shale (PAAS) values. There is a gradual increase in relative enrichment toward the Heavy REEs, and Lu values can reach three times PAAS values. Thorium and U are often enriched by more than an order of magnitude above background. LA-ICP-MS shows maximum values of all these trace metals typically occur within a centimetre of the margin of the phosphatic interval (fig. 1). Values of Light REEs peak closest to the margin of the phosphatic interval. Thorium always correlates most closely with Er to Tm, and these elements peak in a zone slightly inside of the Light REEs. Values for U and Lu are highly correlated and peak up to a centimeter in from the phosphate margin. Likely, REEs, Th, and U are also substituting into the CFA crystal lattice, particularly when conditions were more favorable toward the end of CFA diagenesis.

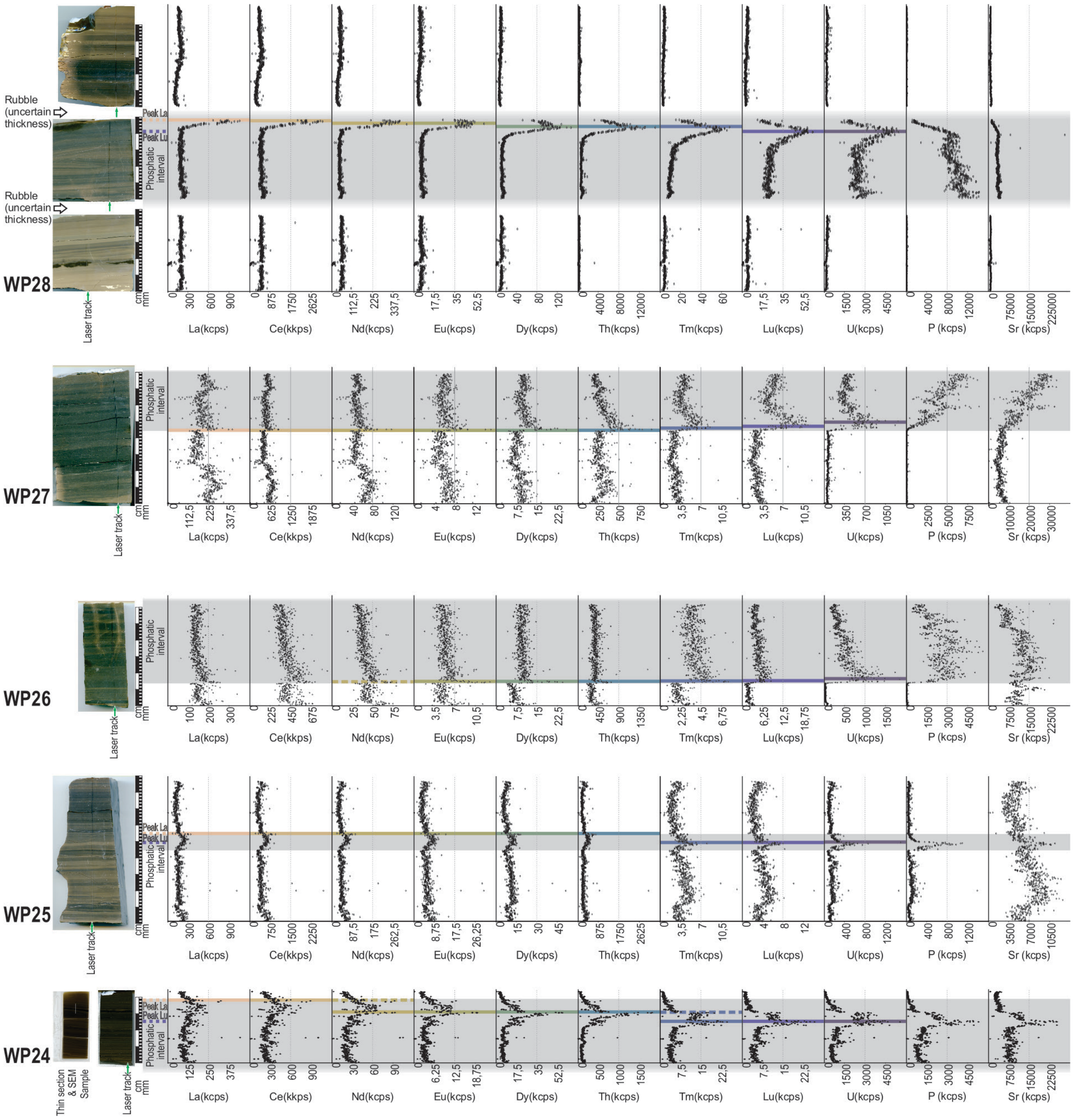

**Figure 1.** Microstratigraphy of five different oil shales from the upper Green River Fm. (~50 to ~100 m above the Mahogany Bed) at Gate Canyon, Utah, as illustrated by the raw data (kilo-counts per second) of selected REEs, Th, U, P, and Sr determined from LA-ICP-MS. Scales on the X-axis of individual plots vary to better distinguish peak abundance. Y-axis is limited by the tendency of the outcrop samples to grade from, or into, friable, papery shale.

# A Late-Holocene Sedimentary Record of Hurricane Landfalls, Climate Change, and Fire from Seasonally-Dry Tropical Forests in Southwestern Dominican Republic

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The body of literature on the ecological impacts of hurricanes is large, but nearly all studies have focused on relatively short-term (years) changes. A persistent question arising from many of these studies is whether hurricanes change forest composition over the long term (decades to centuries). In addition, increased post-hurricane fire hazards have been hypothesized for the subtropical maritime forests of the Southeastern United States, but whether this relationship holds for tropical forests is still unclear. This project examined the long-term impacts of hurricanes on tropical seasonally dry forests and the possible link between hurricanes and fire through paleoecological analysis of sediment records from a coastal lake, Laguna Alejandro, in the semi-arid southwestern Dominican Republic.

Our research methodology took a multi-proxy approach in analysis of lake sediment profiles to reconstruct the long-term environmental history of our site. We analyzed geological proxies (e.g., overwash deposits, sediment composition), chemical proxies (e.g., $\delta^{18}O$, organic carbon, magnetic susceptibility), and biological proxies (e.g., pollen, charcoal, ostracods) found in the sediments to document tropical storms and other climatic events and to examine how these events have influenced vegetation composition and fire activity over long time scales. AMS radiocarbon dates provided chronological control of our sediment profiles and indicate that sediments began accumulating at Laguna Alejandro at least by about 1300 cal yr BP.

We documented several hurricane landfalls at our site using traditional proxies, such as loss on ignition and the presence of sand or shell layers. We also demonstrated how $\delta^{18}O$ composition of ostracod valves in sediment archives can be used for identification of sediments generated by tropical storms, or for confirmation of suspected tropical storms (indicated by large influxes of $^{18}O$-depleted meteoric waters typical of tropical cyclones) in sediment cores from coastal lagoons like L. Alejandro. The $\delta^{18}O$ record may be a more sensitive record of storm activity versus traditional techniques, which are biased towards capturing major hurricane landfall events but may fail to capture weaker hurricanes and tropical storms. Our pollen data revealed that multiple tropical storms over the past millennium did not alter the vegetation composition of uplands around the lake over the long term. Following storm events, pollen of leguminous trees, an important tree in dry tropical forests, declined while shrub and herbaceous taxa increased. However, the legumes recovered with time after each event. Conversely, it appears that mangroves near the core site, indicated by peat in older sediments, were destroyed by a major hurricane ~1,000 years ago and never recovered. Increases in regional and local fire activity, as evidenced by small increases in the abundance of microscopic and macroscopic (>125 µm) charcoal fragments in sediments just above identified "storm layers" may be tied to hurricane events and regional changes in climate. Our data indicated increased aridity during the past four centuries, a finding in agreement with other records of Caribbean drought during the Little Ice Age.

## Paleolimnological Investigation of the Reclamation of Ashby Lake, Indiana, USA


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Ashby Lake is located in the Sugar Ridge Fish and Wildlife Area in Winslow, Indiana. The lake was formerly part of a region used as a coal strip mine and was donated to the Division of Fish and Wildlife in 1980. Since then, it has been reclaimed along with many other aquatic systems in the area. In the spring of 2014, a 33.5-cm sediment core was collected from the center of Ashby Lake to explore the potential impact of acidic drainage on this system, and to assess the effectiveness of the reclamation process on water quality over the past several decades. Lake sediments were sampled at a 0.5-cm sample resolution to analyze changes in fossil diatom assemblages, major and minor element concentrations, and phosphorus geochemistry. Diatoms are particularly sensitive biological indicators of acidity in aquatic systems and are commonly used to evaluate potential changes in water quality over time. Changes in the elemental concentrations will be evaluated by hand-held XRF and ICP-OES to determine heavy metal loads resulting from past mining activities and ongoing acidic drainage. A sequential extraction technique will be employed to elucidate sedimentary phosphorus associations to assess how the nutrient status of the lake has changed over time. Together these geochemical proxies will be used to explore landscape/watershed/lake interactions. Combining the geochemical and fossil diatom assemblage results will allow us to reconstruct the temporal variability in biogeochemical cycling of nutrients and metals within this aquatic system.

# Large Changes in Late Glacial and Holocene Climate States in the Mojave Desert, California: A Role For Insolation and Ocean-Atmosphere Forcings

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Silver Lake is the modern terminal playa of the Mojave River. As a result, it is well located to record both influences from the winter precipitation dominated San Bernardino Mountains – the source of the Mojave River – as well as the late-summer to early-fall North American monsoon. Here, we present various physical and geochemical data from a new 8.2 m sediment core taken from Silver Lake, California that spans modern through the 14.8 kcal yrs BP. Age control is based on six bulk organic carbon radiocarbon dates and one bulk >125 µm ostracod radiocarbon date processed with Bacon v 2.2 to generate an age model. Texturally, the core varies between sandy clay, clayey sand, and sand-silt-clay, often with abrupt sedimentological transitions. Our working hypothesis states that high percent clay values indicate persistent standing water wherein the deposition, accumulation, and preservation of fine grain sediment exceeds some undefined thickness that inhibits deflation during succeeding desiccation events or ephemeral lake environments. Based on this clay – lake status hypothesis, the sediment core is divided into five lake status intervals using percent clay for timing. Clay values are highest between 14,400 and 13,600 cal yr B.P., coeval to Lake Mojave II. Clay values decrease abruptly at 13,600 cal yr B.P. (encapsulating the Younger Dryas) indicating a return to an ephemeral lake. At 11,600 cal yr B.P., clay values increase abruptly indicating a return to a perennial lake; this early Holocene pluvial ended abruptly at 7,400 cal yr B.P. From 7,400 to 4,200 cal yr B.P., clay is low, but variable and mud cracks are common. This mid-Holocene interval is also characterized by sand dominanted by the 250–500 µm size fraction, the same size fraction most common in the nearby Kelso Dunes. From this, we interpret the period between 7,400 and 4,200 cal yr B.P. as the interval of peak Holocene aridity with enhanced dune activity. At 4,200 cal yr B.P., clay values increase but only moderately, indicating the return to more frequent but short-lived, perennial lakes. An analysis of forcings implicates changing winter – summer insolation patterns, tropical and northern Pacific sea surface temperatures, and the El Nino – Southern Oscillation as the primary drivers of Holocene climate. A comparison to winter dominated Leviathan Cave, Nevada (Lachniet and others, 2014) and the monsoon dominated Pink Panther

Cave, New Mexico (Asmerom and others, 2007) is used to examine the relative influences of winter vs. summer precipitation over the Holocene.

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# Halite Deposition in the Dead Sea as an Indicator of Water and Solute Budgets

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Recent deep drilling (2010–2011) in the Dead Sea obtained by the International Continental Scientific Drilling Program revealed thick sections of halite (total thickness of 54 meters), which precipitated during the last three interglacials. These intervals consist of alternating mud and halite layers (tens of centimeters), which represent changes between wet and very dry conditions in the lake's watershed. The compositions of the past lakes in the Dead Sea, obtained from fluid inclusions in halite, lie on an evaporation curve. They were produced by mixing between lake brines and inflow waters. Water and salt budgets show that the dissolved salts accumulated during wet intervals and precipitated when the lake level was dropping due to a decrease in the fresh water input into the lake. Considering the chemical composition of the lake obtained from fluid inclusions in halite and assuming an almost constant surface area in a tectonic basin, 10–14 cm of halite precipitate per meter of lake level drop. Thus, based on the salt and water budgets, roughly estimated lake level records and changes in the brine composition obtained from fluid inclusions and pore water, it is possible to reconstruct a high-resolution lake level record. Preliminary calculations show that the thickness of halite is greater than the calculated thickness based on the change in the lake chemistry. This suggests either marginal dissolution of halite and re-precipitation in the center of the lake, or the increase in brine discharge with higher Na/Cl ratios and lower Mg concentrations. The increase in Br in halite and Mg in halite fluid inclusions suggests a decrease by 60% of the lake volume as a the result of an averaged discharge of ~550 million $m^3$/yr (about a one-third of the present discharge). The different facies (fig. 1) of halite in the core can be ordered from wetter to drier conditions and may be an indicator of lake limnology and seasonality. Thus, the halite facies further refine the variability in water input during halite precipitation and imply lower discharge that the estimated average. The common facies is alternating large bottom-growth crystals of halite and small cumulate halite crystals (fig. 1g), which occur in different frequencies (fig. 1f, g, i, j). The bottom-growth crystals are associated with mud and are formed on the lake floor during wetter conditions while the small cumulates are formed on the lake surface due to high evaporation and very dry conditions.

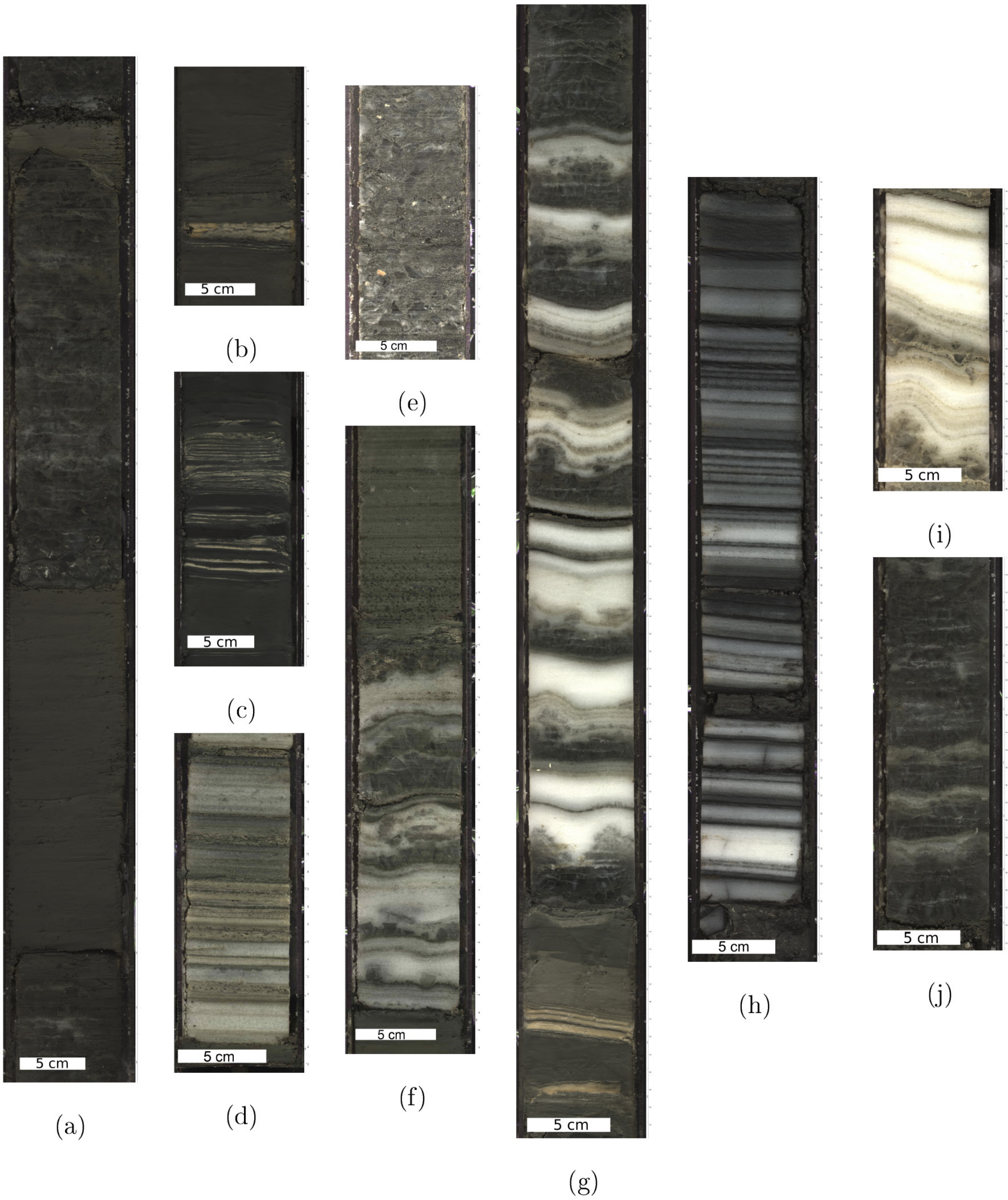


**Figure 1.**. Facies of evaporites from the Dead Sea. (a) Alternations between mud and bottom-growth halite crystals, (b) a gypsum layer, (c) alternating mud and aragonite, (d) alternating gypsum and halite, (e) large crystals of halite supported by mud, (f) graded bedded halite layer above alternating large bottom-growth and small cumulate crystals of halite, (g) alternating large bottom-growth and small cumulate crystals of halite above a mud layer with layers of gypsum, (h) alternating small cumulate halite crystals and mud (j) large bottom-growth halite crystals with thin layers of cumulates. (i) thick layers of cumulate halite crystals.

# The Role of Saline Lake Water Circulation in Aquifers: The Dead Sea Mass Balances

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This study presents the mechanism of saline lake water circulation in the aquifer and its significant impact on elemental budgets in the Dead Sea (TDS=340 g/L), which has wide implications for any salt lake. In any given coastal system where fresh water flows into a saline water body, a transition zone between the fresh and saline water is formed, and saline water circulates in the aquifer (fig. 1). While Dead Sea water flows into the aquifer (Kiro and others, 2013) and interacts with the sediments, gypsum, and barite (which are supersaturated in the lake water) precipitate and the water becomes reduced. These water—rock interaction processes remove, for example, Ba, Sr, $^{226}$Ra, and U, and contribute Fe and Mn to the lake (table 1). While $^{226}$Ra ($t_{1/2}$=1,600 yr) is enriched in the lake (~147 dpm/L) and removed by co-precipitation with barite, $^{228}$Ra (~1 dpm/L; $t_{1/2}$=5.75 yr) is contributed by recoil and desorption. This opposite behavior of the two radium isotopes was used in order to obtain a well-constrained radium mass balance in the Dead Sea and estimate the amount of lake water circulating in the aquifer. The calculated circulating lake water in the aquifer is 400 million m$^3$/yr, which is ~20% of the fresh water discharge (pre-1964, before the massive utilization of the fresh water resources and lake level drop). Although, this has no effect on the water budget, it has a major impact on trace element budgets in the lake. Circulation of saline lake water in the aquifer is the main sink of Ba and $^{226}$Ra, the main source of $^{228}$Ra, an important source for Fe and Mn and sink to U (table 2).

**Table 1.** Concentrations of trace elements in the Dead Sea and circulated water.

| | Sr | Br | Ba | Mn | Fe | U | Mo | Li | Rb | B | Si | $^{226}$Ra | $^{228}$Ra |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/L | | | μg/L | | | mg/L | | | dpm/L | |
| Dead Sea (2008) | 361 | 5.1 | 4.9 | 7 | 1 | 2.4 | 27 | 17.9 | 2 | 63.8 | 71.7 | 147 | 0.92 |
| Circulated Dead Sea | 340 | 5.9 | 1.5 | 8.2 | 7.5 | 0.07 | 6 | 26 | 1.5 | 72 | 3 | 60 | 20 |

**Table 2.** Inventory and circulation flux of selected elements in the Dead Sea.

| Element | Inventory (mol) | Circulation flux (mol/y) |
|---|---|---|
| Ba | $5\cdot10^{9}$ | $-10^{7}$ |
| U | $1.5\cdot10^{6}$ | $-3.8\cdot10^{3}$ |
| Fe | $2.7\cdot10^{9}$ | $8.9\cdot10^{7}$ |
| $^{226}Ra$ | $2\cdot10^{16}$ dpm | $-18\cdot10^{12}$ dpm/y |
| $^{228}Ra$ | $1.3\cdot10^{14}$ dpm | $13\cdot10^{12}$ dpm/y |

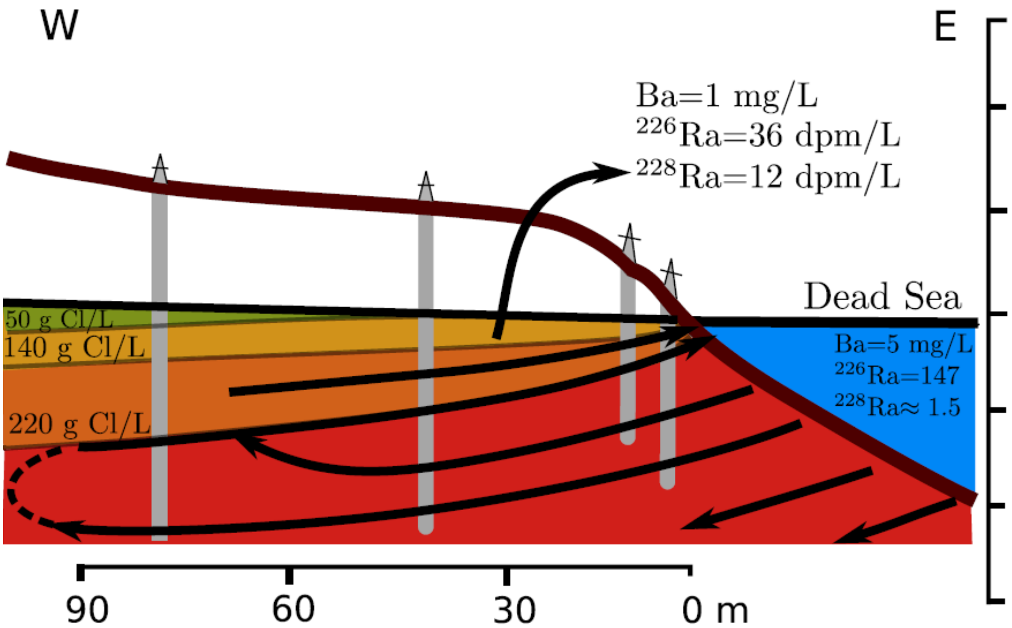


**Figure 2** The fresh-saline transition zone in the Dead Sea aquifer and demonstration of saline water circulation (Kiro and others, 2014)


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# Natural Disasters: The Forgotten Drivers of Lake Productivity

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Lacustrine sediments contain a great wealth of data on biogeochemical and limnological processes of historical importance which can be used to interpret natural ecosystem dynamics and climatic and anthropogenic impacts. In this study, we used this information to understand the impact of earthquakes, volcanic eruptions, and invasive mammalian terrestrial wildlife on the primary productivity of a deep lake, and to assist with understanding how these natural disasters can be factored into setting reference conditions for lakes in a changing global environment. A 49-cm sediment core was retrieved from Lake Okataina on the North Island, New Zealand, and its depositional history was dated using $^{210}$Pb and tephrochronology. Among New Zealand lakes, Okataina may be considered close to a "reference" lake, with 89% native forest and without a significant change in land use in the watershed over the past c. 800 years. However, perturbations to the lake during this time may be due to expanding populations of invasive terrestrial mammals, earthquakes, and volcanic eruptions which may influence catchment vegetation density and type. We hypothesised that these factors increased the flux of clastic materials into the lake which resulted in reducing conditions with concomitant increase in internal phosphorus release. The increased internal release of phosphorus drove increases in primary productivity. The results of the study showed that earthquakes and the activities of invasive terrestrial mammals led to increases in fluxes of clastic materials which resulted in increased productivity. Volcanic eruptions on the other hand created a stable environment. The results of this study show the importance of natural disasters in natural variability of primary productivity and the need to factor these events into the setting of reference conditions.

# Records of Lake Level Fluctuations, Faulting, and Volcanism from Summer Lake, Oregon, USA

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The Summer Lake sub-basin of pluvial Lake Chewaucan contains excellent Pleistocene (Pliocene?) and Holocene records of environmental change, paleomagnetism, fault movements, and volcanism (e.g., Cohen and others, 2000; Weldon and others, 2009; Kuehn and Negrini, 2010; Negrini and others, 2014). Numerous tephra layers present in the lake sediments preserve an exceptional long-term record of Cascade arc pyroclastic volcanism and also provide time-stratigraphic control for other studies in the basin and the region. Most of this prior work is based on outcrop sections and several cores on the west side of the basin. New work on stream gully outcrops in the southeastern portion of the basin from floor to margin is providing additional information. Some of these outcrops likely contain the oldest recognized sediments in the basin, sediments older than those reached even by the deepest existing cores. In a few places, sediments rich in fish bones or gastropod shells are present. Unconformities, gravel beds, and buried tufa mounds provide direct evidence of past lake levels. These records may be combined with information from cores to provide a more complete overall picture of lake level history. Multiple fault traces have been recognized with subdued scarps as much as 1–2 m high. Some fault traces have tephrochronologic evidence of much greater accumulated displacements in spite of the more limited surface expression.

We have been analyzing the tephra glasses in the electron microprobe lab at Concord University to facilitate site-to-site correlations, to provide age control via correlation to dated eruptions, and to help document the eruptive history that the tephra layers record. Thus far, we have had excellent success correlating tephra beds in the younger sediments to dated deposits elsewhere in the basin and region. This includes identification of Mazama ash in faulted dune sand which demonstrates that ground-rupturing earthquakes have occurred in the study area more recently than ~7,600 cal yr B.P. For the oldest sediments, we have had little success thus far in establishing convincing correlations to dated units, and therefore ages remain poorly constrained. To provide additional age control we are also pursuing $^{40}$Ar-$^{39}$Ar dating of tephras and U-Th dating of tufas.

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## Spatial Genetic Population Structure of *Brachionus* Rotifers in Kenyan Rift Valley Lakes: The Relative Impact of Geographic Proximity, Ecology, and Long-Distance Dispersal

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The Kenyan rift lakes exhibit a wide range of environmental conditions. Some are extremely saline and alkaline, whereas others are freshwater lakes. Although some of the lakes are subject to high anthropogenic impacts, others remain untouched by human influences. Previous research has been mainly concerned with temporal variations in the population structure in single lakes that were driven mainly by environmental changes. This new study investigated the spatial structuring of rotifer populations across a wide variety of environmental conditions and anthropogenic influences, and the mechanism causing differences in the population structure.

An analysis of 154 base pairs of the mitochondrial cytochrome c oxidase subunit I (COI) gene from surface samples of short cores collected at a total of nine locations in eight lakes, revealed two main rotifer species; *Brachionus dimidiatus* and *B. plicatilis*. *Brachionus dimidiatus* was the most abundant one with four haplotypes recovered, two of which were new. The analyses of the molecular variation in the rotifers showed a strong genetic population structure which was associated with specific ecological conditions indicating that local adaptation to environmental conditions may play a role in the development of new haplotypes. Phylogeographic analysis indicated association between genetics and geographic distribution of *B. dimiditus* haplotypes with evidence of restricted dispersal but with some long distance dispersal which is presumably influenced by the passive dispersal by flamingos. Overall, the results showed that the current spatial pattern of rotifers is a function of the intertwined interaction between local adaptation and dispersal. The outcomes of this study provide a good basis for further investigations of the temporal variations and history of rotifer colonization in the Rift Valley lakes.

# Combining Numerical Modeling of Pleistocene Glaciers and Lakes to Infer Climate Change During the Last Glaciation and Deglaciation in the Northern Great Basin, Utah and Nevada, USA

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The record of late Pleistocene mountain glaciation and paleolake highstands in the northern Great Basin (Utah and Nevada) is becoming increasingly well understood. Excellent preservation of shorelines in valleys occupied by paleolakes and of glacial features in mountains delimits the extents of lakes and glaciers, chiefly the last glaciation and deglaciation. In northeastern Nevada, a large number of small valley glaciers occupied the Ruby Mountains and East Humboldt Range, with glaciers on the east sides of these ranges occupying the headwaters of paleolakes Clover and Franklin (fig. 1). The timing of lake highstands and glacier maxima in these two valleys, based on radiocarbon dating of shoreline deposits and cosmogenic $^{10}$Be exposure dating of moraines, reveals intervals of overlapping glacier and lake maxima between 20,000-17,300 years ago (Laabs and others, 2013; Munroe and Laabs, 2013). Temporal correspondence between glacier and lake maxima presents an opportunity to resolve changes in temperature and precipitation during the last glaciation and deglaciation by combining numerical modeling of glaciers and paleolakes. Such an approach takes advantage of the different sensitivities of glaciers and lakes to temperature and precipitation and the availability of substantiated numerical methods of modeling mass balance and ice flow and lake hydrology.

The glacier modeling method is from Plummer and Phillips (2003), involving a 2-D, physically based approach to computing net annual mass balance and ice extent in a glacial valley. The method for modeling lake hydrology is modified from Condom and others (2004), which uses a locally calibrated evaporation scheme and soil-water capacity factor to solve for a range of temperature and precipitation changes accompanying a lake highstand. Both modeling approaches produce a distinct set of temperature and precipitation solutions for an interval of overlapping moraine deposition and lake highstand, which are combined to yield a unique solution of temperature and precipitation changes. Modeling of multiple valley glaciers in the Ruby Mountains and East Humboldt Range and highstands of Lakes Clover and Franklin yielded intersecting temperature depressions of 8-9° C with corresponding precipitation rates of 1.7–2.0 times modern. This range of temperature depression is consistent with other regional reconstructions of the last Pleistocene glaciation, but the magnitude of precipitation change is greater than predicted by many previous reconstructions. Spatial analysis of the modern and paleo-distribution of precipitation indicates that, due to the high pluvial indices of the lakes, the volumetric increase in precipitation required to sustain the lakes is small. A considerably larger volumetric increase in precipitation in the mountains was required to sustain glaciers at their maximum extent.

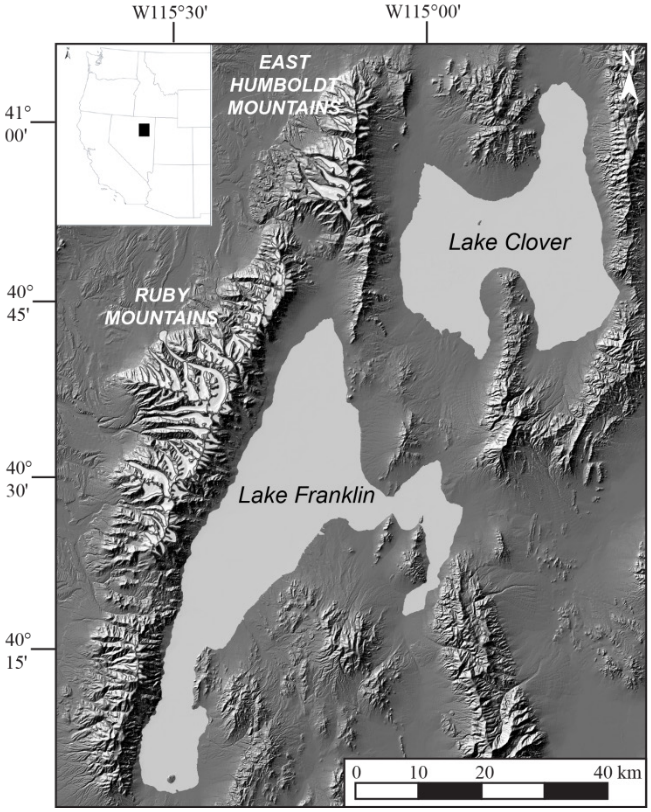


**Figure 1. Maximum Late-Pleistocene extents of mountain glaciers (white) in the Ruby and East Humboldt Mountains and of paleolakes Clover and Franklin (light gray) in northeastern Nevada, USA.**

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# Climate and Environmental Variability in the Mediterranean: A High-Resolution Stable Isotope and Geochemical Record from Lake Ohrid

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Lake Ohrid (Macedonia/Albania) is an ancient lake and is renowned for its high degree of biological diversity. It is the target site for the ICDP SCOPSCO (Scientific Collaboration on Past Speciation Conditions in Lake Ohrid) project, an international research initiative to study the links between geology, environment, and the evolution of endemic taxa. In 2011 a 10 m core was recovered from the western shore of Lake Ohrid adjacent to the Lini Peninsula. Here we present high-resolution (c. 30-year) stable isotope and geochemical data from this core through the late glacial and Holocene to reconstruct past climate and hydrology (TIC, $\delta^{18}O_{calcite}$, $\delta^{13}C_{calcite}$) as well as the terrestrial and aquatic vegetation response to climate (TOC, TOC/N, $\delta^{13}C_{organic}$, Rock-Eval pyrolysis). The data identify three main zones: (1) the late glacial-Holocene transition represented by low TIC, TOC, and higher isotope values, (2) the early and mid-Holocene characterised by higher TOC, TOC/N, and lower $\delta^{18}O_{calcite}$, and (3) the late Holocene which shows a decrease in TIC and TOC. In general there is an overall trend of increasing $\delta^{18}O_{calcite}$ from 9,000 yr B.P. to present, suggesting progressive aridification through the Holocene, which is consistent with previous records from Lake Ohrid and the wider Mediterranean region. Several proxies show commensurate excursions that imply the impact of short-term climate oscillations, such as the 8,200 yr B.P. event and the Little Ice Age. This is the best-dated and highest resolution archive of late glacial and Holocene climate from Lake Ohrid and confirms the overriding influence of the North Atlantic in the north-eastern Mediterranean. The data presented set the context for the SCOPSCO project cores recovered in spring–summer 2013 dating back to the early Pleistocene, and will act as a recent calibration to reconstruct climate and hydrology over the entire lake history.

# An Overview of Microbialite Genesis and Composition in Saline Lakes of Southern Australia

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Organic sedimentary structures in saline lakes are an excellent archive of changes in environmental conditions in a lake basin and catchment. By examining variations in mineralogy and composition, important deductions can be made about brine composition, climatic conditions in the drainage basin, and the nature of sedimentary processes. Shallow water microbialites in saline lakes can take a variety of forms and occur in response to many different physical, chemical and biological processes. There is still much discussion about the fundamental mechanisms by which the carbonate structures are forming.

In southern Australia, late Holocene and modern microbialites occur in a variety of saline lake types including maars, marginal-marine basins, and playas. Four lakes in Victoria (East Basin, West Basin, Bullenmerri, Gnotuk) and three lakes in South Australia (Sleaford, Pillie, Felmongery) have been selected to represent a spectrum of hydrologic and geolimnological regimes under which microbialites are forming. The structures in these lakes show variations in internal and external morphology as well as mineralogy. The range of conditions permits a detailed evaluation of the processes of carbonate microbialite formation. Petrography and geochemistry of the microbialites have potential to reveal a complex interaction of both primary and biologically induced precipitation of minerals. Some of the structures are monomineralic, whereas others show more complex mineralogical suites. Similarly there is a wide variation of sizes and shapes. Morphologies of these shoreline and nearshore sedimentological features include: wakestone pavements, phytoherm framestones, hardgrounds, beachrocks, crusts, boulder encrustations, tubular and branching microbialites, centimeter to meter scale pinnacles, and large bioherms.

# Geochemical Evolution of Saline and Hypersaline Lakes in Western Canada

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The composition of any closed-basin lacustrine brine is ultimately determined by two main factors: (1) the solutes acquired by dilute inflow waters through weathering processes and by atmospheric fallout, and (2) the subsequent evaporation and concentration of ions leads to precipitation of minerals, which further affects the final brine composition. This latter change in lake water composition is referred to as brine evolution and has been the subject of considerable scientific interest over the past 50 years.

Because of the wide spectrum of major ion water chemistry types exhibited by the lakes of the northern Great Plains of western Canada, combined with relatively uniform source material over this large 800,000 km$^2$ region, these lakes provide critical information to help better understand continental brine evolution. Because salt minerals are thermodynamically and kinetically responsive to even relatively minor changes in brine composition, the preserved endogenic mineral sequences can be interpreted in terms of the formative brine composition. Assuming post-depositional changes are minor, the mineralogical fluctuations in the Great Plains basins having relatively thick, continuous sequences of Holocene evaporites and evaporative carbonates provide insight to a complex series of evolutionary sequences. Markov chain analyses identified four generalized anion sequences and five cation sequences in the Holocene evaporites of several dozen Great Plains lakes. The most commonly occurring cyclicity among the anions (occurring in ~50% of the lakes) is: $CO_3^{-2} \rightarrow CO_3^{-2}$-$SO_4^{-2} \rightarrow SO_4^{-2}$. This anion sequence was best represented in Ceylon Lake in south-central Saskatchewan and was thus termed the Ceylon type. The three other anion sequences, which occur less frequently, are:

Alsak type: $CO_3^{-2} \rightarrow Cl^-$-$SO_4^{-2} \rightarrow SO_4^{-2}$
Metiskow type: $SO_4^{-2} \rightarrow CO_3^{-2}$-$SO_4^{-2} \rightarrow CO_3^{-2}$
Waldsea type: $SO_4^{-2} \rightarrow CO_3^{-2}$

The cation evolutionary sequences present in the study lakes were considerably more complex than the anion sequences and about 20% of the stratigraphic sections exhibited no statistically significant temporal compositional trends. The most common cation sequences present in about 60% of the lakes, are the Lydden type (33%): $Ca^{+2} \rightarrow Ca^{+2}$-$Mg^{+2} \rightarrow Na^+ \rightarrow Na^+$-$Mg^{+2}$-$Ca^{+2}$ and Ingebright type (28%): $Na^+$-$Mg^{+2} \rightarrow Ca^{+2}$-$Na^+$-$Mg^{+2} \rightarrow Na^+$-$Mg^{+2} \rightarrow Na^+$ followed by:

Metiskow type: $Ca^{+2} \rightarrow Na^+$-$Mg^{+2} \rightarrow Ca^{+2}$-$Mg^{+2}$-$Na^+ \rightarrow Na^+$
Little Manitou type: $Ca^{+2}$-$Mg^{+2} \rightarrow Mg^{+2}$-$Na^+ \rightarrow Mg^{+2}$
Freefight type: $Ca^{+2} \rightarrow Mg^{+2}$-$Ca^{+2} \rightarrow Mg^{+2}$-$Na^+$

Because of the complexity of the interplay between intrinsic processes (i.e., sedimentary, geochemical, hydrologic, and biological processes operating within the lake basin itself) and extrinsic processes (i.e., 'external' factors, such as climate change, drainage basin modification), identification of the causal mechanisms for these various evolutionary sequences is not straightforward. Clearly, much more quantitative data from the evaporites of these and other saline lakes in the region need to be collected in order to explain and properly model the observed composition trends.

# Diatom Indicators of Changes in Wetlands Associated with Lakes of Florida, USA: Important Information Provided by Numerically Rare Taxa

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Paleolimnological studies of human effects on landscape often address changes in lakes based on the remains of biological indicators, such as diatoms, in sediments. These studies are important for establishing reference conditions for lake management programs. The typical approach involves excluding rare species that contribute noise to statistical models that are designed to estimate the strongest determinants of limnetic water quality, particularly nutrients that are pertinent to lake-management concerns. Removal of rare species, however, contributes to the loss of ecological information about important secondary issues, such as human influence on lake hydrology. This study examines historic changes in wetlands that were associated with Florida lakes based on diatom evidence in sediment cores.

We examined diatoms in cores from five lakes and identified taxa that indicate the presence of wetlands on lake peripheries and in adjacent areas of watersheds. We chose open-water areas for our coring sites to ensure continuous deposition over time, but we selected smaller lakes (<100 ha.) so wetland influences would be documented and discernible in the sediment records. Wetland taxa were distinguished using literature-based descriptions of habitat preference, from environmental optima estimated by weighted averaging of diatoms in modern sediment samples from 75 lakes, and from ordination biplots of taxa with environmental variables. Wetland diatoms prior to significant watershed disturbance (c. 1900) were rare relative to limnetic diatoms, but they clearly indicated low pH and mineral conditions. In contrast, diatoms from open-water areas indicated alkaline waters with moderately high nutrient content.

Diatom assemblages showed that wetland influences declined during the 20th century as the lakes became more eutrophic. Wetland losses appear to have resulted from the infilling of wetland areas during residential and urban development, from the dredging and stabilization of shoreline areas, from inputs of stormwater runoff, and from the construction of weirs to stabilize lake stage at higher levels. In several cases, historic aerial photos and topographic maps document these changes. Although species richness appears to have declined in core samples, it is probable that wetland diatoms represent communities that were spatially distinct from open-water communities. Lake management and restoration programs can endeavor to restore reference conditions with respect to limnetic nutrient concentrations, but changes in hydrology that resulted from the destruction of wetlands associated with lakes indicate that the biology, chemistry, and water budgets of affected lakes will continue to differ significantly from conditions that existed during the past.

# Seismically Induced Erosion Above the Cascadia Subduction Zone—Insights from the Stratigraphy of Lake Quinault, Washington


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Along the Cascadia subduction zone, abundant paleoseismic evidence exists for both great subduction megathrust events (M>8.6) and large (M6–7.5), shallow crustal ruptures. Little is known, however, about the terrestrial upland response to large earthquakes in Cascadia. The increased volume of landsliding and hillslope transport following such events may have pronounced impacts on sediment delivery to the region's fluvial networks, lakes, and coastline. Over millennial time scales, mass wasting associated with large earthquakes may play an important role in the evolution of topography above Cascadia and other subduction margins.

Lake Quinault, located at the foot of the Olympic Mountains, is ideally situated to monitor the upland impacts of past earthquake events. The lake, with a maximum depth of 70 m, is impounded behind a late Pleistocene terminal glacial moraine. Lake-margin slopes are steep and the upper Quinault River has built a delta at the lake's eastern end. Radiocarbon results from a series of piston cores recovered in 2013 indicate mean sediment accumulation rates range from ~1 cm/yr near the delta toe to ~ 0.1 cm/yr at the lake's distal, western end.

The sedimentary infill of Lake Quinault is dominated by deposition from river floods. At the lake's proximal end, flood deposition over the past 600 years has been punctuated by a slump-turbidite recording delta-front failure ~300 years ago. This deposit, as well as a correlative fluvial event terrace upstream of the lake, appears to record the well-documented A.D. 1700 Cascadia megathrust event. At the distal, gently sloping, western end of the lake, where a ~5,000-year-long record was recovered, signals of seismicity are more muted, with the exception of an event 1,500-1,600 years ago. The event is recorded in seismic stratigraphic profiles by a series of gas chimneys that end abruptly ~2.5 m below the lake floor and are overlain by parallel, continuous reflectors. Piston cores show soft-sediment deformation at this level, and abrupt shifts in magnetic susceptibility, color, particle size, and flood layer thickness. We interpret these shifts to mark the contact between sediments that experienced shaking, lateral spreading, and degassing during a strong earthquake event and overlying sediments that have not experienced comparable seismicity. The earthquake apparently strongly impacted the Upper Quinault River catchment, causing increased sediment input to the lake and stepwise progradation of the delta.

The ~5,000-year-long record examined to date indicates that aside from the AD 1700 and 1,600–1,500 cal yr B.P. events, regionally documented earthquakes may have produced more subtle signatures in the Lake Quinault stratigraphy. There is evidence, for example, for two earlier episodes of soft sediment deformation, deposition of an unusual, eastward-thinning turbidite (ca. 2,800–2,700 cal yr B.P.), and grain size changes that suggest stepwise delta progradation ca. 800 years ago. It is unclear as yet whether the strong stratigraphic signals of the 1,600–1,500 cal yr B.P. event are stochastic, or whether they reflect aspects of that particular earthquake such as its timing relative to previous events or shaking intensity.

# The Lake Ohrid Drilling Project: Some Initial Interpretations of Stable Isotope Data Through the Last 15 Marine Isotope Stages

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The SCOPSCO (Scientific Collaboration on Past Speciation Conditions in Lake Ohrid) project is an international research initiative to study the influence of major geological/environmental events on the biologic evolution of taxa. The target site for this study is Lake Ohrid, which is considered to be the oldest lake with continuous existence in Europe and which has more than 200 endemic species. The recovery of long sediment successions from Lake Ohrid is the basis for obtaining more precise information about the age and origin of the lake, and about the climatic and environmental history of the region including the history of Italian volcanic eruptions. The main SCOPSCO drilling campaign was carried out in 2013, and here we describe data from a 569 m core taken from centre of the lake. Initial data from borehole logging, core logging and geochemistry indicate that the sediment succession from this site covers more than 1.2 million years of Earth's history. Total carbon (TC) and Total Inorganic Carbon (TIC) content show that the amount of TIC is a proxy for short-term and long-term climate change. TIC is high during interglacials and primarily originates from calcite precipitated in the spring-summer in the epilimnion, when photoautotropic organisms assimilate $CO_2$ utilizing the Ca and bicarbonate from the karstic springs. During the glacials, carbonate is almost absent except from discrete siderite layers. Total organic carbon is very low throughout both the glacial and interglacial periods and reflects the oligotrophic conditions in the lake. The oxygen and carbon isotope composition of the endogenic carbonate has been shown to be a function of the balance between freshwater input by rivers and springs and evaporation of the lake water. Variations both within and between interglacials show climate variability including periods of exceptional aridity and potentially very low lake levels. These early findings suggest that the record from Lake Ohrid will substantially improve the knowledge of long-term environmental change in the northern Mediterranean region, which forms the basis to better understand the influence of major environmental events on the evolution of organisms within the lake.

## A Multi-Proxy Lacustrine Record of Holocene Climate Change in SW Patagonia, Chile

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One of the largest uncertainties in the Holocene ocean-atmosphere carbon cycle is the role of the Southern Ocean (SO) and subpolar seas in controlling atmospheric $CO_2$ levels. The strength and position of the westerly winds is thought to control rates of $CO_2$ exchange as well as depth of ventilation. Secondarily, through their control on the large scale geostrophic circulation, the westerlies influence the position of major ocean frontal boundaries as well as stratification in the Southern Ocean—additional controls on SO carbon uptake. However, little is known about westerly wind variability over the Holocene. Southern Patagonia is an ideal locality for addressing this uncertainty, as it is the only major landmass that extends into the southern westerly wind field. In particular, lake environments hold potential for reconstructing precipitation, which is closely correlated with westerly wind strength in this region. Here we present a multi-proxy lacustrine sediment core record from Lago Sarmiento (51.06˚S, 72.91˚W), a large, closed-basin lake in southern Chilean Patagonia. We observe a decrease in C:N ratios between ~7,500 and ~5,500 $^{14}$C yr BP, indicating a transition from forest to grassland. We measured an increase in the C:N ratio at ~5,500 $^{14}$C yr BP to present, indicating a sustained shift from grassland to the modern *Nothofagus* forest and more humid conditions. We observe four distinct trends in bulk carbonate $\delta^{18}$O and weight percent carbonate. We interpret two negative trends, from ~3,000 to 2,000 and ~5,000 to 4,000 $^{14}$C yr BP, as progressive increases in westerly wind intensity and associated tendency towards positive water balance. Conversely, we interpret two positive trends in weight percent carbonate and bulk $\delta^{18}$O between ~7,500 and 5,000 and ~4,000 and 3,000 $^{14}$C yr BP as indicative of negative water balance. Comparison with other records from southern Patagonia and Antarctica is improving our understanding of the forcing mechanisms driving changes in the southern hemisphere westerlies.

# Initial Paleomagnetic and Environmental Results from an Approximate 150 Meter Drill Core from Clear Lake, Northern California, USA


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We have studied the paleomagnetic properties of a 150-meter drill core from Clear Lake in northern California to determine whether magnetic measurements can be used to establish chronostratigraphy for the core as well as provide information about regional paleoenvironmental conditions. U-channel samples from the core have been subjected to stepwise demagnetization of natural remanent magnetization (NRM), anhysteretic remanent magnetization (ARM), and saturation isothermal remanent magnetization (SIRM). The NRM directions are stable after the 20 mT demagnetization step and appear to record secular variations of the geomagnetic field. Several intervals of low NRM intensity values correlate with somewhat anomalous directions, and some may correspond to known geomagnetic excursions. One such interval occurs at about 48.5 meters below lake floor. This depth yielded a calibrated radiocarbon date of ~34,000 yr B.P., consistent with the Mono Lake excursion recorded between 35,000 and 32,000 yr B.P. Our analysis also suggests that the record of NRM/ARM reflects geomagnetic paleointensity variations. All of these factors imply that paleomagnetic data can make a substantial contribution toward the development of chronostratigraphy for the core.

The magnetic measurements are also capable of providing information about paleoenvironmental and paleoclimatic conditions in the vicinity of Clear Lake. Long-term patterns in the ARM intensity values suggest that there are four distinct paleoenvironmental regimes. The top 18 meters of the core represent a mostly low intensity interval with a very short high intensity zone in the top 2 m. From 18-32 meters depth, there is a transition from lower intensities to higher intensities. The high intensity interval extends from 32 to 90 meters depth. Then, from 90 meters to the bottom of the core (150 meters), ARM intensity oscillates between very high and low values. These long-term patterns demonstrate variations in the concentration of magnetic minerals over time. Normalized ARM intensity values show that high (low) magnetic mineral concentration intervals correspond to intervals of slightly higher (lower) magnetic coercivity. Changes in the magnetic mineralogy and concentration should be linked to regional climate variations that can be temporally constrained by the paleomagnetic data.

# Scanning X-ray Fluorescence Proxies Commonly Used with Lacustrine Sediments

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X-ray fluorescence (XRF) core scanning is a rapid, inexpensive, and non-destructive approach to determining the elemental composition of split sediment cores or u-channeled sediments. It has thus become an integral part of both marine and lacustrine sediment research. Here we discuss some of the commonly used XRF core scanning proxies with examples from lacustrine sediments. Many of these are useful even with uncalibrated XRF data, and can be used to evaluate downcore variability of major sediment constituents. K and Ti provide information lithogenic contents, Ca typically indicates carbonates (but when correlated with S can indicate gypsum), Si/Ti is related to biogenic silica content, and the ratio of incoherent to coherent scattering reflects organic carbon contents. Lighter elements tend to scatter photons inelastically, whereas heavier elements favor elastic scattering, so incoh/coh corresponds to organic content in many sediments. Elemental ratios can also reflect sediment composition and/or provenance. For example, Sr/Ca indicates aragonite in carbonate-rich sequences, Fe/Ti or Mn/Ti respond to redox processes, and K/Ti can be an indicator of chemical weathering. Variations in the response from any given element can be affected by water content, and to a lesser extent grain size.

# Flyover Country, A Mobile App for Limnogeological Research and Outreach

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Lake sediment science, education, and outreach are supported by Flyover Country (FC), an NSF-funded mobile app concept that exposes georeferenced content from a variety of databases and caches maps and data for offline use (fig. 1). Used in an airplane seat, FC communicates the excitement of scientific discovery through descriptions of the fascinating landforms below and their geologic contexts and histories. On the ground FC can be used for virtual field trips, or as an accompaniment to road trips, like an electronic version of *Roadside Geology*. The potential to include detailed data from state surveys, field trip guides, and extant databases (e.g., the NOAA National Geophysical Data Center's Index to Marine and Lacustrine Geological Samples, which holds LacCore's collection data) could support site selection for limnogeologists working in new field areas and synthesizing regional paleoenvironmental reconstructions. Collaborations with community tools such as Neotoma, Macrostrat, and the Paleobiology Database highlight FC's role as a part of NSF's EarthCube initiative—a community-driven cyberinfrastructure effort to connect, expose, and better utilize the wealth of geoscience data in disparate databases and lying "dark" in nondigital files.

A test case of FC will be Proyecto Lago Junin (PLJ), the NSF- and ICDP-funded drilling project in the Peruvian Andes taking place in July-August 2015. As an outreach component, we are collating and developing content for an offline field guide and project promotion targeted toward local community members, teachers, and schoolchildren; tourists and visitors to the site; and the numerous scientists involved. The PLJ module will be focused on three sections of road: from Lima to the lake, passing through one of the most mining contaminated sites on Earth and over the continental divide at 4,800 m; from the lake to Tarma, a valley village and the base of operations for the project; and the road around the lake itself, passing through agricultural villages and over mountain streams draining waning glaciers. The module, also available on the Web for additional accessibility, will serve as one platform for dissemination of outreach and educational materials co-developed with local teachers and nongovernmental organizations.

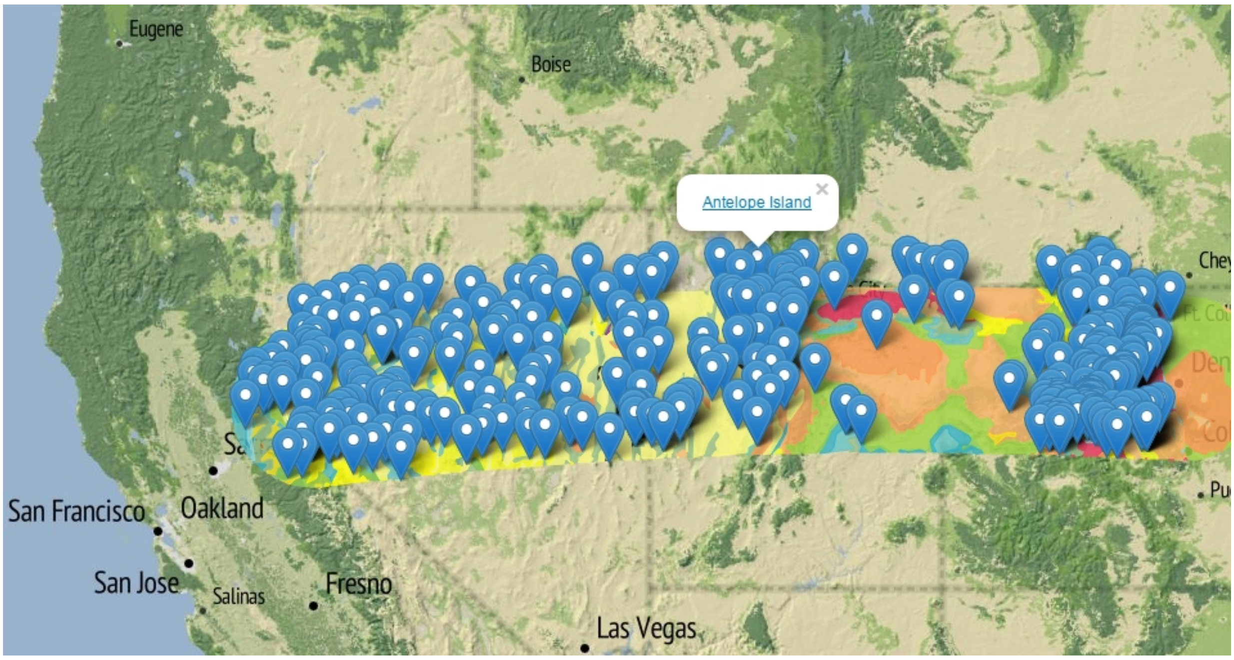


**Figure 1**. Example flightpath (Reno-Denver) from the Flyover Country demo. Colored map units are bedrock geology from the Geologic Map of North America, exposed through Macrostrat; points of interest (POI) are Wikipedia geology entries. Both map units and POI provide additional content when clicked. Basemap tiles are from Leaflet.

# 7,000 Years of Fire in Tropical Mexico

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Fire has been an important feature of the Earth system at least during the last 420 million years. Its importance derives from its action as a disturbance agent to ecological and human systems (Bowman and others, 2009). Studying fire at millennial time scales through the analysis of charcoal particles from sediments can provide important elements to understand its impact over natural systems and its patterns of natural variability. Furthermore, studies on modern relationships between fire and charcoal would offer tools to interpret the sedimentary charcoal in terms of the parental fires.

Here were report on the fire history of the Maya midlands through the analysis of charcoal from sedimentary sequences from lakes Metzabok (17°07'15 "N, 91°37'40"W, 50 m.a.s.l.) and Yalaluch (16°06'27"N, 91°41'06"W, 1450 m.a.s.l.) in Chiapas, tropical Mexico, both sequences spanning the last 7,000 years. The results were interpreted under the light of a modern study of charcoal particles from mud water interface from 51 water bodies of the region and their relationship with modern fires detected through satellite imagery.

Our results revealed two distinctive patterns in fire regimes: (1) a less intense presence of fire between 7,000 and 4,000 years BP, which showed some peaks probably associated with localized abrupt climate changes; (2) an increased presence of fire associated charcoal peaks from 4,000 years BP to present, consistent with evidence of human influence in the region, inferred from the presence of maize pollen grains in the sediments. Additionally, times that have been regionally identified as dry showed an increase in fire activity. This study allowed us to compare fire variability in the same system under contrasting human occupation conditions. Although natural climatic variability was associated with fire peaks throughout all the record, fire dominance was a pervasive characteristic of the human occupied section of the record.

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# The Influence of Distant Magmatic-Hydrothermal Activity on Brine Evolution in Closed Basins: Searles Lake, California

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Evaporites and associated sediments deposited in closed basins preserve information about the chemical composition of inflow waters and how they evolved through time. Searles Lake is a closed basin in eastern California with a modern ephemeral alkaline saline lake and thick deposits of evaporites, including trona and halite. During wet periods of the Pleistocene, Searles Lake was the third of five lakes fed by the Owens River. During dry intervals, inflow to Searles Lake from the Owens River via China Lake was reduced or eliminated and evaporites accumulated.

Core KM-3 from Searles Lake contains a 700 m thick succession of bedded evaporites and muds that preserve a 3.2 million year record of paleoenvironments and inflow water chemistry (Smith and others, 1983). Cryo-SEM-EDS analyses of fluid inclusions in halite and evaporite mineralogy show that the major ion composition of inflow waters to Searles Lake was changed by distant hydrothermal activity associated with magmatism approximately 1.27 million years ago (core depth of ~290 meters). Below depths of 290 m, the evaporites comprise calcium sulfate minerals (anhydrite, glauberite) and halite; fluid inclusions in the halite show the parent waters to be $Na^+$-$Cl^-$-$SO_4^{2-}$-rich with minor $K^+$. Above 290 m, the evaporites include sodium carbonates (pirssonite, gaylussite, trona) and halite and the fluid inclusion brines are $Na^+$-$K^+$-$HCO_3^-$-$CO_3^{2-}$-$Cl^-$-$SO_4^{2-}$-rich. These fluctuations in mineralogy and brine chemistry document an alkalinity spike beginning at ~1.27 Ma when inflow waters to Searles Lake crossed the $CaCO_3$ chemical divide and began to produce alkaline brines that precipitated trona upon evaporation.

The Owens River is a modern chemical analog for inflow water into Searles Lake for the last 1.27 Ma. Upon evaporation, Owens River water evolves into $Na^+$-$K^+$-$Cl^-$-$HCO_3^-$-$CO_3^{2-}$-$SO_4^{2-}$-rich brine capable of precipitating trona. A major contributor of solutes to the Owens River is Hot Creek, which is fed by hydrothermal springs in Long Valley Caldera. The Long Valley Caldera area today yields thermal surface waters with relatively high total dissolved solids, chloride, and especially high alkalinity from magmatically-derived $CO_2$. Significantly, Hot Creek is located ~300 km north of Searles Lake, which means that hydrothermal activity can profoundly influence inflow chemistry and brine evolution in distant closed basins. Earman and others (2005) were the first to suggest that magmatically-derived $CO_2$ is essential for the formation of sodium carbonate evaporite minerals such as trona.

The timing of volcanism at Glass Mountain and Big Pine Volcanic Field and the appearance of sodium carbonate minerals in core KM-3 suggests a causal relationship between magmatism in Owens Valley and inflow water chemistry at Searles Lake. Volcanism and associated hydrothermal activity at Glass Mountain and the Big Pine Volcanic Field, beginning at ~1.27 Ma, provided $CO_2$ and elevated alkalinity to Owens Valley surface waters. This magmatic-hydrothermal influence is significantly earlier than previous reports and began 0.5 My before the eruptions that formed the Bishop Tuff and Long Valley Caldera ~0.767 Ma.

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# The Sedimentary and Paleoenvironmental History of Lake Magadi, Southern Kenya Rift: New Evidence from Drill Cores in the Axial Graben

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Lake Magadi, a saline, alkaline lake in the southern Kenya Rift, was cored to bedrock in June 2014 as part of the Hominin Sites and Paleolakes Drilling Project (HSPDP), which aims to provide a high-resolution paleoenvironmental context for human evolution in East Africa. The cores (1A, B and C: total depth 137 m; 2A, total depth: 198 m), which are composed mainly of zeolitic mud, chert, trona, and carbonate, contain a Pleistocene and Holocene record of closed-basin paleoenvironments and paleoclimate in a tectonically active rift basin.

The trachyte basement, 0.8–1.4 Ma, is overlain sharply by carbonate grainstone with gastropods, ostracodes, and coated grains, indicating a period with freshwater lakes during the early stages of the Magadi Basin. The overlying sediments are thin bedded to laminated, greenish lacustrine muds and silts, with interlayered bedded and nodular cherts, and silicified mudstone. The diverse suite of chemical sediments (zeolites, chert, magadiite, and trona) indicates alkaline saline lake conditions for most of the history of the Magadi Basin. Frequent saline and anoxic conditions are implied by the lack of fossils and bioturbation, and black organic muds. Pyrite, which is common in the lower parts of the cores, shows that reducing conditions commonly developed in the lake and sediments. Although airfall and redeposited tephra are widespread in exposed Pleistocene sediments, few tuffs are distinctive in the lake cores, implying that most volcaniclastic grains have been altered to zeolites. Coarse siliciclastic sediments include thin matrix-supported conglomerates that appear to be subaqueous debris flow deposits, and rare sand and gravel intervals that indicate periods of subaerial exposure. Soft sediment deformation and microfaulting are common in the Magadi sediments. Evaporite layers, decimetres thick, alternate with interbedded organic-rich muds in the upper ~60 m of core 2A. They confirm that the most arid period at Lake Magadi was the Holocene and provide potential for obtaining a high-resolution Holocene paleoclimate record. Syndepositional dissolution surfaces in the uppermost trona beds indicate dilute floodwaters mixing into a shallow saline lake.

Future research will attempt to establish a chronology from bulk radiocarbon, Uranium-series dating of cherts, optically stimulated luminescence, paleomagnetism, and Ar-Ar dating of tephra. Comparison of the Lake Magadi lacustrine record with that from the nearby Koora Plain cores will help to resolve whether lake level and paleoenvironmental changes in southern Kenya were driven primarily by climate or by local or regional tectonic factors in the East African Rift.

# Integrating Biogeography, Ecology, Taxonomy and Molecular Analysis for the Improvement of Ostracode-based Environmental Reconstructions in the Northern Neotropics

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Environmental reconstructions based on neotropical biological proxies have provided important information for the understanding of past climatic changes. The freshwater ostracodes (bivalved microcrustaceans) are among the most important proxies in lacustrine environments, because of their high abundance and good preservation in sediments, especially in the karst lowlands of the northern Neotropics. The interpretation of fossil ostracode assemblages demands the analysis of their modern homologues. Modern species, however, usually exhibit intra and inter population morphological variations (particularly valve morphology) challenging an accurate identification and ecological characterization of the species. This represents a difficulty in the transfer of information from recent to fossil species, and is therefore one of the most important limitations of ostracode-based paleoenvironmental interpretations. In order to facilitate species identification, ecological characterization and fossil assemblage interpretation, we developed an integrative taxonomy on recent species by combining molecular analysis with morphological and geographical data of ostracode species collected from lakes located on a transect ranking from southern Mexico to Nicaragua. Preliminary results based on sequences of the gene Cytochrome oxidase I, and the morphological analysis (valve and appendages), suggest a total of 85 ostracode species, thus doubling the number of the previously known species in the region. Detailed analysis was conducted in the *Cypretta* group, since one single species was apparently widely distributed in the study region. Nevertheless, small morphological variations of shell and appendages among populations is notorious. The identification tree of the *Cypretta* group using neighbor joining and bootstrap values based on molecular data and morphological analysis suggest the existence of nine lineages, three already described (*Cypretta campechensis*, *Cypretta spinosa* and *Cypretta maya*) and six new species (fig 1.). These lineages are restricted to particular geographical regions such as southwestern and central part of Yucatan Peninsula, southern Salvador, northern and southern Guatemala and northern Honduras. The modern diversity and distribution of the Cypretta group across the region seems to result from a separate evolutionary history instead of environmental influences.

Species ostracode distribution was conducted using Parsimony analysis of Endemicity (PAE) and the data obtained from integrative taxonomy (molecular and morphological). This analysis revealed eight regions with higher faunistic affinities: Cenotes ring, Yucatan Peninsula-Caribbean coast, southern Yucatan-northern Guatemala, Guatemala highlands, central-southern Salvador, northern Honduras and Nicaraguan lakes, suggesting that most of the species have rather local and restricted distribution (fig. 2). Only some species are capable to be widely distributed in the region: *Cypridopsis vidua*, *Darwinula stevensoni*, *Alicenula serricaudata*, *Diaphanocypris meridana*, *Cytheridella ilosvayi*, among others. For all of these species, other factors play an important role in their distribution, their asexual reproduction type makes them highly tolerant and adaptable to wide range of environmental conditions. At the same time this property reduces their value as bioindicators. Our study highlights the importance of the integration of multiple disciplines in facilitating interpretations of fossil ostracode species assemblages and environmental reconstructions in the northern Neotropics.

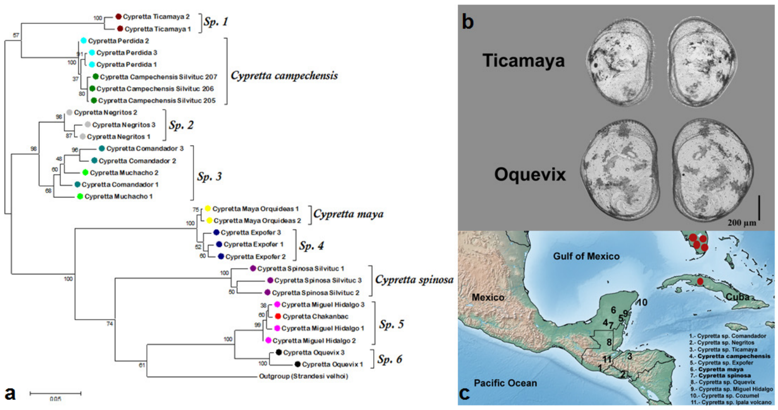


**Figure 1.** Analysis of the Cypretta genus diversity: (a) Identification tree of the Cypretta species based on COI gene, (b) Shell morphology size of two different populations of Cypretta, (c) Distribution of Cypretta genus in the study region. The colors indicate replicates of each species.

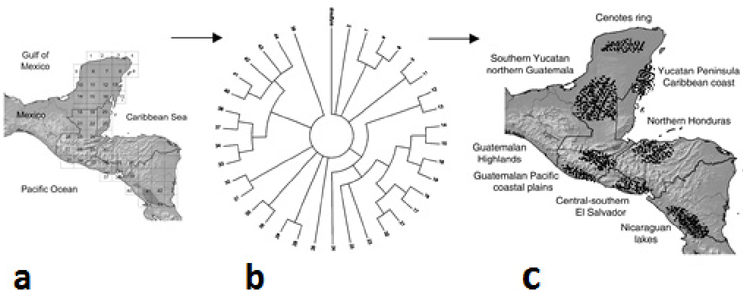


**Figure 2.** Biogeographic affinities of the ostracode fauna in the northern Neotropics: (a) Study area divided in arbitrary zones, (b) Area cladogram based in Parsimony (PAE), (c) Distribution map showing the endemic zones for the ostracode fauna in the study area.

# 350 Years of Chironomidae Assemblages in a Southern Patagonian Lake, Argentina: Trends and Sensitivity

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The Little Ice Age (LIA) usually refers to climatic anomalies over the northern hemisphere between the 13th and mid-19th century. For the mid-high-latitudes of South America, documentary evidence of this climatic event is not available due to the sparse settlement of the continental regions during this period. Additionally, the number of proxy-based reconstructions is still fragmentary. As such, *tempo* and *mode* of the LIA is still a matter of debate, especially in Southern Patagonian steppe. For example, the temporal range of the LIA, based on glacial maximum extent in the Southern Andes is generally agreed to have lasted between ~AD 1600 and ~AD 1900 (Masiokas and others, 2009), but high-resolution temperature reconstructions are still extremely scarce.

Our study focuses on the recent history of Laguna Azul (52°05'S, 69°35'W), a small closed-basin lake located in the southern Patagonian steppe. As chironomids are sensitive indicators of temperature conditions (Brooks, 2006), we set out to address whether the LIA climate cooling, as indicated by glacial Patagonian maximum extent, altered the ecological status of this lake using fossil and subfossil Chironomidae communities from an integrated sedimentary section composed by cores AZU03/5, AZU03/4-1, and AZU03/4-2.The lake was chosen for study because it is a remote lake located in the belt of the South Hemisphere Westerly Winds and is therefore theoretically closely coupled with atmospheric forcing factors. A further motivation for selecting this particular lake was that previous paleolimnological investigation (Mayr and others, 2005) suggested there had been long-term interactions between regional climate and lake status. These authors defined two lake status: between AD 1400 and AD 1700, period characterized by a decrease in lake level, and between AD 1700 and AD 1900, period characterized by rising lake level.

Chironomid assemblages were analyzed since AD 1450 until the late twentieth century. Surprisingly, communities did not exhibit species turnover during the last 350 years, being the Tanytarsini the dominant taxa throughout this period (fig. 1). This genus includes species generally associated with cold and/or oxygenated waters, specially *Tanytarsini* sp. 2, which is very similar and probably an ecological equivalent of *T. lugens*-type, a cold stenotypic species (Nevalainen and Luoto, 2012). The stability of the cold-associated chironomid communities suggests cold conditions similar to modern ones during the temporal range of the LIA. However, a small directional community shift was detected between AD 1650 and AD 1750. This shift suggests a slightly cooler period, which partially coincides with the Maunder Solar Minimum.

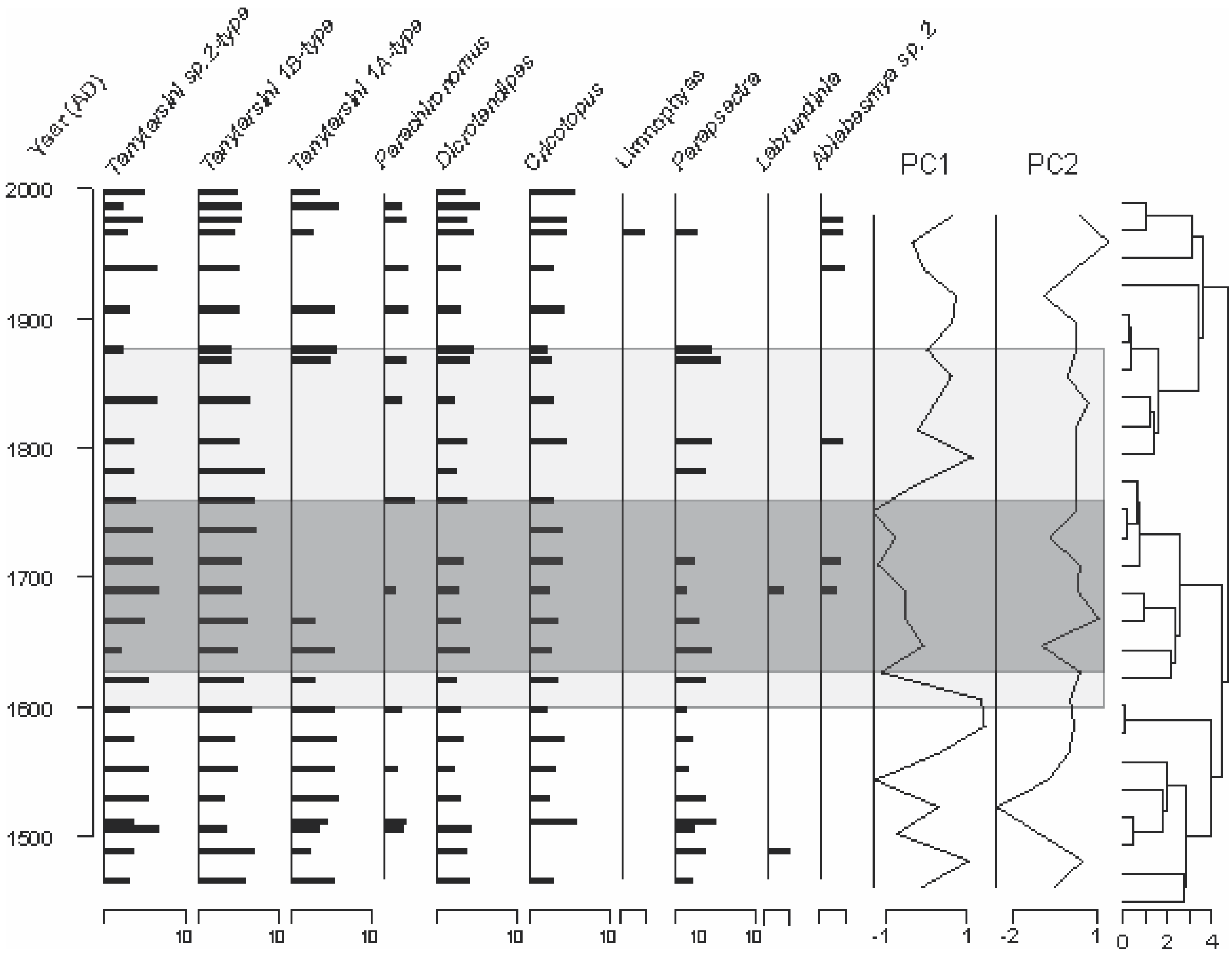


**Figure 1**. Abundance of the Chironomidae in the composed sedimentary section from Laguna Azul. The light gray band indicates the Little Ice Age in Patagonia sensu Masiokas and others (2009). The dark gray band indicates the Maunder Minimum.

Our results show that no faunal shifts occurred during the twentieth century climate warming, and there were no substantial changes in the ecological status of this remote Patagonian lake. This indicates that temperature-driven ecological thresholds have not been crossed out in the last 350 years in the Laguna Azul ecosystem. Species abundances have not substantially changed in the last 350 years, during the LIA or in response to post-LIA and late twentieth century climate warming. If the LIA represents a change in humidity, temperature anomalies or both in the southern Patagonian steppe is still an open question.

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# Chironomid Oxygen Isotope Ratios as a Proxy for Lake-Water Isotopic Reconstructions—Results of a Calibration Study from Patagonia

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Oxygen stable isotopes ($\delta^{18}O$) of biogenic sedimentary components from lake sediment archives are frequently used for palaeoclimatic reconstructions. However, the effects of host water isotope changes, temperature-dependent fractionations, and vital effects on the isotopic ratios of such biogenic proxies often cannot be disentangled.

Chironomids are non-biting midges whose lake-sediment dwelling larvae are extremely sensitive indicators of past temperatures. Quantitative palaeotemperature reconstructions based on chironomid assemblages show strong evidence of abrupt climate change. Recently, chironomids preserved in lake sediments have also been suggested as a source for obtaining $\delta^{18}O$ records. Wooller and others (2004) studied the relationship between $\delta^{18}O$ in chironomids and precipitation in four lakes from US, Canada and Greenland, showing that chironomid $\delta^{18}O$ is related to precipitation. More recently, Verbruggen and others (2010) demonstrated a strong relationship between $\delta^{18}O$ values of chironomids and lake water as well as precipitation in Europe from Italy to Sweden.

In this investigation we aimed to test the suitability of oxygen stable isotope analysis from chironomid head capsules of southern Patagonian lakes and streams (41 – 52°S) as a potential proxy to reconstruct past climatic conditions in the area. Lakes in semi-arid regions are sensitive to water-balance induced isotopic variations and their stable isotopic composition records meteorological extremes and climatic trends. Southern Patagoniais of particular interest for palaeoclimatic studies, because it is the only landmass meridionally extending over large parts of the Southern Westerlies core zone. The Westerlies' wind strength increases lake evaporation and decreases precipitation amount in the semi-arid part of Argentinean Patagonia, east of the Andes. Both effects have a negative influence on the lake water balance increasing heavy isotopic enrichment in endorheic lakes of eastern Patagonia. Stable isotope proxies of biogenic sedimentary constituents in lake sediments from this area could serve as recorders of palaeolake water isotopic composition allowing for reconstructions of past hydrological and west wind variations. However, so far, the application of these proxies in South America is limited to very few studies in which mainly biogenic carbonates of ostracods were investigated.

This study shows for the first time $\delta^{18}O$ results of Patagonian chironomid head capsules and demonstrates that chironomid $\delta^{18}O$ is closely coupled to their host water $\delta^{18}O$.The regression equation obtained from the Patagonian chironomids is very similar to the one obtained from a laboratory experiment in which chironomids were grown in two isotopically distinct waters under controlled conditions (Wang and others, 2009; Verbruggen and others, 2010) (fig 1). A temperature-dependence of the $\delta^{18}O$ values as stated in an earlier study (Wooller and others, 2004) was not confirmed by our data. Thus, for regions where $\delta^{18}O$ of precipitation is not a priori correlated with mean annual air temperature, as is the case for Patagonia (Mayr and others, 2007), $\delta^{18}O$ values may not be used for temperature reconstructions but can serve as a useful tool for evaporation-induced lake water isotope variations.

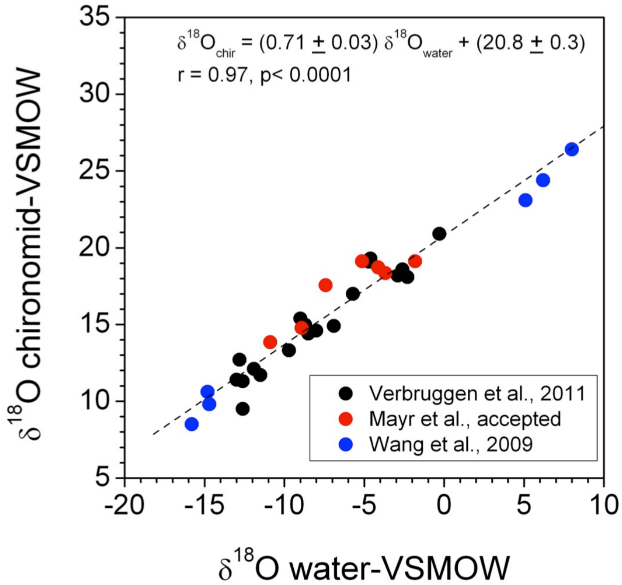


**Figure 1.** Chironomids chitin from different sites in showing correlations with host waters.


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# Ecosystem Processes from the Pleistocene-Holocene Transition to Present: A New Sedimentary Record from Devils Lake, Wisconsin, USA

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Processes and rates of ecosystem development can be reconstructed using lacustrine sedimentary sequences, but this approach requires records that contain the start of primary succession. Most lakes in the upper Midwestern U.S. were formed by glaciers at the end of the last Ice Age approximately 11,700 cal yr BP. Devils Lake, Wisconsin is a rare example of a lake from this region whose sediments extend into the Pleistocene and may include the Last Glacial Maximum (26,000 cal yr BP). Sediment magnetic, geochemical, pollen, and charcoal records were generated from a 10 meter core. Together with an earlier pollen record, these proxies combine to reveal a history of long-term climatic, vegetative and geologic change during the late Pleistocene to Holocene. We identify six sedimentary units that indicate a series of consecutive events rather than a predictable trajectory of ecosystem development at the site. Productivity in the lake was low during the late Pleistocene and increased during the Holocene, as reflected by the sediment lithology, which shows a sudden shift from glacial vivianite-rich and organic-poor clastic-dominated sediments to Holocene diatomaceous sapropels. Several important processes initiated around 17,000 cal yr BP, including the onset of organic matter accumulation and fire in the terrestrial ecosystem.

Aquatic ecosystem productivity lagged terrestrial ecosystem productivity throughout the record. Nutrient cycling (as recorded by sedimentary $\delta^{15}N$) was variable but not directional, and appeared to be correlated with climate conditions early in the record, and terrestrial ecosystem processes later in the record. Throughout the Holocene magnetic mineral concentration decreased as productivity increased, and the source of magnetic material shifted from almost exclusively lithogenic to approximately 50% derived from soil or biogenic sources. Two additional geochemical patterns were demonstrated with multivariate analysis of scanning X-Ray Fluorescence elemental counts, potentially corresponding to changes in weathering rates and nutrient availability.

# Development and Application of Infrared Spectroscopic Methods to Infer Past Lake-Water Quality Changes in Boreal and Subarctic Lakes

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Infrared (IR) spectroscopic methods are an emerging tool in studies of sediment geochemistry that provide a multitude of information from single measurements. These fast, non-destructive techniques can be used to directly quantify different sediment components and also indirectly infer more complex environmental variables. Here, we present further developments of IR spectroscopic applications and their applications in paleolimnological studies aiming at reconstructing past environmental changes in boreal and subarctic Sweden with a focus on changes in lake-water quality.

Sediment components such as total organic and inorganic carbon (TOC; TIC) and biogenic silica (bSi) can be quantified by IR spectroscopy due to their component-specific IR signatures. We developed a new independent PLSR calibration model for the determination of bSi by Fourier transformed infrared spectroscopy (FTIRS; 3750-450 $cm^{-1}$) based on synthetic sediment mixtures with known bSi content (Meyer-Jacob and others, 2014; fig. 1a). This model is independent from conventional wet-chemical techniques, which had so far been used as reference, and their associated measurement uncertainties. In one ongoing study, we have applied FTIRS (fig. 1b) and other analyses to the sediment of Torneträsk, which yields a large-scale regional record of climatic and environmental changes in northernmost Sweden during the Holocene.

IR spectroscopy can further be used to develop transfer functions for environmental variables because IR spectra provide information about the entire sediment composition including organic and inorganic components. Rosén (2005) originally developed a transfer function to infer past lake-water TOC levels based on visible near-infrared spectroscopy (VNIRS; 25000-4000 $cm^{-1}$) of sediment samples. This model is based on VNIR spectra of surface sediments and the corresponding measured lake-water TOC concentration, which assumes that quantitative and qualitative changes in lake-water organic matter leave their fingerprint in the sediment. We have continued to develop this model, which now includes 145 nemoral, boreal, and subarctic lakes across Sweden and a lake-water TOC gradient from 0.7 to 22 mg $L^{-1}$ (fig. 2a). We applied this model to sediment records from four lakes across central Sweden to assess observed lake-water TOC trends on a centennial to millennial time scale (fig. 2b). Our data show that the recent increase in lake-water carbon was preceded by a landscape-wide long-term decrease beginning already AD 1450–1600 in response to an extensive land use altering carbon cycling between terrestrial and aquatic ecosystems.

In these ongoing studies, we also use other inorganic and organic geochemical proxies (wavelength dispersive XRF and pyrolysis-GC/MS) as well as biological indicators (pollen, diatoms) to explore the key processes behind the observed changes. The incorporation of these additional techniques further allows us to better understand biogeochemical properties recorded in the IR spectra and driving transfer functions such as the one for LW-TOC.

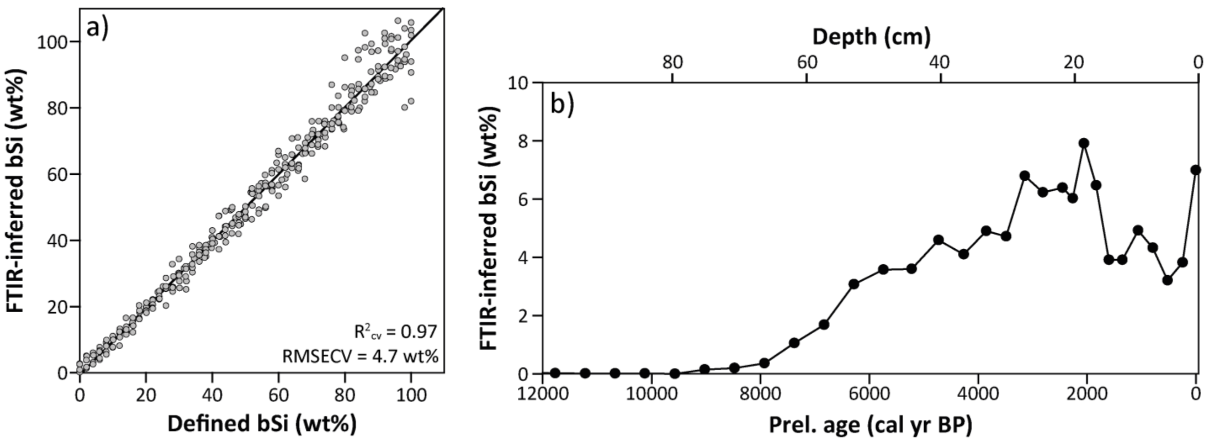


**Figure 1. (**a) Defined vs. FTIR-inferred bSi content. (**b)** FTIR-inferred bSi concentration in the sediment record from Torneträsk over the Holocene.

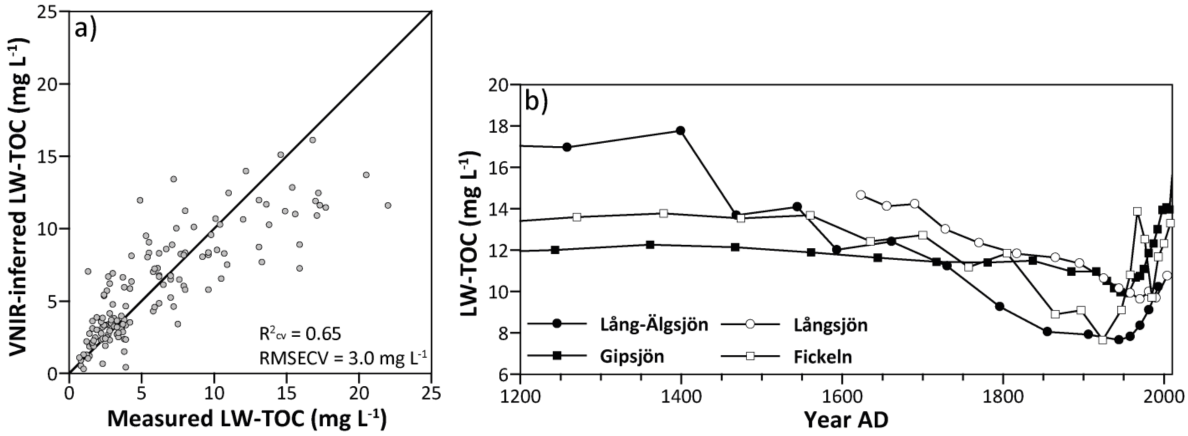


**Figure 2. (**a) Measured vs. VNIR-inferred LW-TOC. (**b)** LW-TOC reconstruction from four lake sediment records across central Sweden over the past 1,000 years.

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# Reconstructing Trophic Changes in Two Lakes Located in Nahuel Huapi National Park, Patagonia Argentina Using Non-Biting Midges (Diptera: Chironomidae)

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Lakes located in remote areas are the best reference ecosystems for the implementation of paleoenvironmental studies as they can provide baseline information about past climates and trophic history of the area. In protected areas, this kind of long term studies can help to early detection of impacts that may affect lake conditions, providing tools for management policies.

Subfossil chironomids (Diptera: Chironomidae) are useful lake paleoindicators due to their specific response to different environmental factors. The aim of this study was to study chironomids combined with fossil pigments (Chlorophyll Derivatives and Total Carotenoids) and organic matter (OM) to provide information about the trophic history of two high altitudinal lakes (Laguna Toncek and Laguna Verde) located both above 1,000 m in the protected area of Nahuel Huapi National Park (ca. 41°S- 71°W), Rio Negro, Argentina.

Results are shown in figures 1 and 2. A sharp variation in chironomid assemblages, organic matter content and CD/TC ratios are observed in the most recent sediments from both lakes. These variations took place during the last 70 years, according to 210 Pb dating. In Laguna Toncek, the presence of Podonominae and *Pseudosmittia*, in the oldest sediment until 1960 yr AC, could indicate cold and well oxygenated waters. By that time, OM and CD/TC ratio showed the lowest concentrations. Although Laguna Toncek was described as an ultraoligothopic lake (Diaz and others, 2007), our results indicated an increase of lake productivity towards more productive conditions after ca. 1960 yr AC. This change is mainly related to increasing touristic activity in the area during the last 50 years.

In Laguna Verde, an abrupt shift in the chironomid fauna is evident from ca 1947 yr AD towards recent times. However, none of the new chironomid assemblages are taxa related to productive conditions, moreover, the increase of *Rhietia* and *Parapsectrocladius* and the disappearance of *Chironomus plumosus* after 1947 AD are showing cold profundal conditions. In addition, the increase of OM and the decrease of CD/TC ratios, is showing allocthonous organic production by that time. Despite our results, previous investigations based in TP analysis characterized Laguna Verde as mesotrophic (Zagarese and others, 2000; Rogora and others, 2008).

This is the first attempt to reconstruct Laguna Toncek and Laguna Verde trophic history, based on analysis of paleoindicators. Both lakes show a change in the chironomid assemblages as well as in OM content and CD/TC ratios during the last 70 years. In Laguna Toncek, changes are definitely related to a change in the lake trophic status due to touristic impacts. In Laguna Verde, there is not a clear change in the chironomid fauna towards more productive assemblages. Thus , other environmental factors such as temperature and/or precipitation maybe coupled with lake productivity blurring the trophic signal. Further studies bringing neo and paleolimnological studies are needed to understand the chironomid record in terms of the interaction between climatic, trophic and lake processes dynamics.

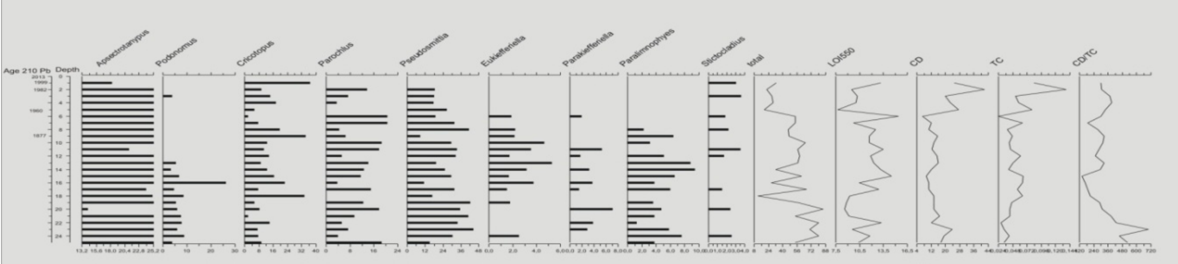

Fig. 1. Stratigraphic diagram distribution of chironomid assemblages, fossil pigment and organic matter of Toncek lake.

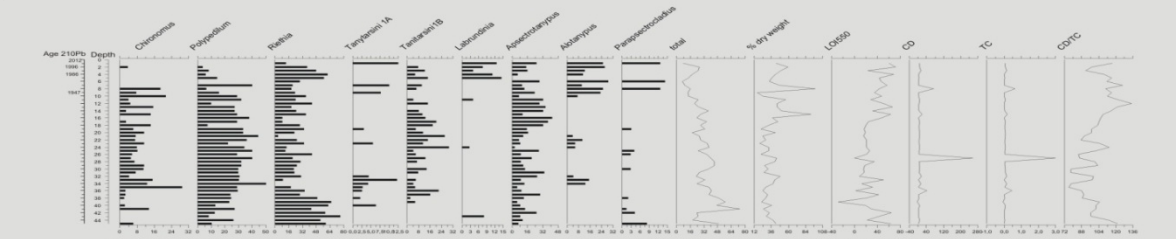

Fig. 2. Stratigraphic diagram distribution of chironomid assemblages, fossil pigment and organic matter of Verde lake.

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# Using Radar Stratigraphic Analysis to Identify Erosion and Deposition in the Duluth Bay Barrier, Lake Superior

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The Duluth Bay Barrier protects the major Great Lakes shipping ports of Duluth, Minnesota and Superior, Wisconsin from Lake Superior. The barrier is divided into Park Point and Wisconsin Point by a natural inlet. Over 2.5 km of shore parallel and shore perpendicular ground penetrating radar (GPR) transects were collected and analyzed on both points. GPR transmits electromagnetic (EM) energy into the subsurface. Waves reflect off changes in the dielectric properties of sediments. The amount of time it takes for the EM wave to return to the GPR system is measured and used to infer depth. Common midpoint surveys were collected, and a near surface velocity of .079 m/ns was calculated. By transmitting EM waves into the ground along a transect, an image of the subsurface is produced. This study utilized a pulseEKKO 100 GPR system for data collection with 100 MHz antennae. Data were processed and plotted through pulseEKKO software. Radar stratigraphic analysis divides reflection patterns into radar facies based on changes in geometric characteristics. Interpretation of radar facies allows the evolution of the Duluth Bay Barrier to be reconstructed. A major, continuous, undulating reflection is also imaged between 4 and 6 m depth and is interpreted as an erosional surface created during a lower lake levels. In shore parallel transects, facies are dominated by northward dipping reflections suggesting that littoral drift from the southeast feeds the Duluth Bay Barrier (fig. 1). A predominate radar facies in shore perpendicular transects are lakeward dipping inclined to sigmoidal reflections interspaced with subhorizontal reflections (fig. 2). The pattern is interpreted to be repeated erosional and depositional phases. Sigmoidal to inclined reflections are interpreted as erosional beach faces, subhorizontal reflections are believed to result from deposition in the surf zone. We believe the most likely source of the erosional beach faces to be storm activity. Radar stratigraphic analysis of the Duluth Barrier shows how erosion, littoral drift, human activity, storms and lake level change have affected the Duluth Bay Barrier.

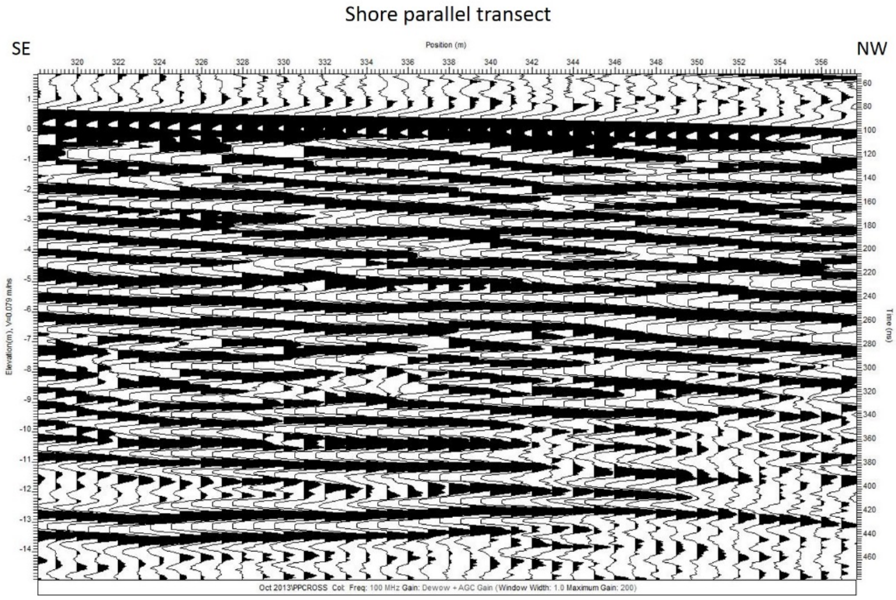


**Figure 1**: An example of topographically corrected shore parallel transect. Note the slight northwesterly dip of reflections to 5.5m depth. This suggests that in addition the barrier has been built from a southeast sediment source.

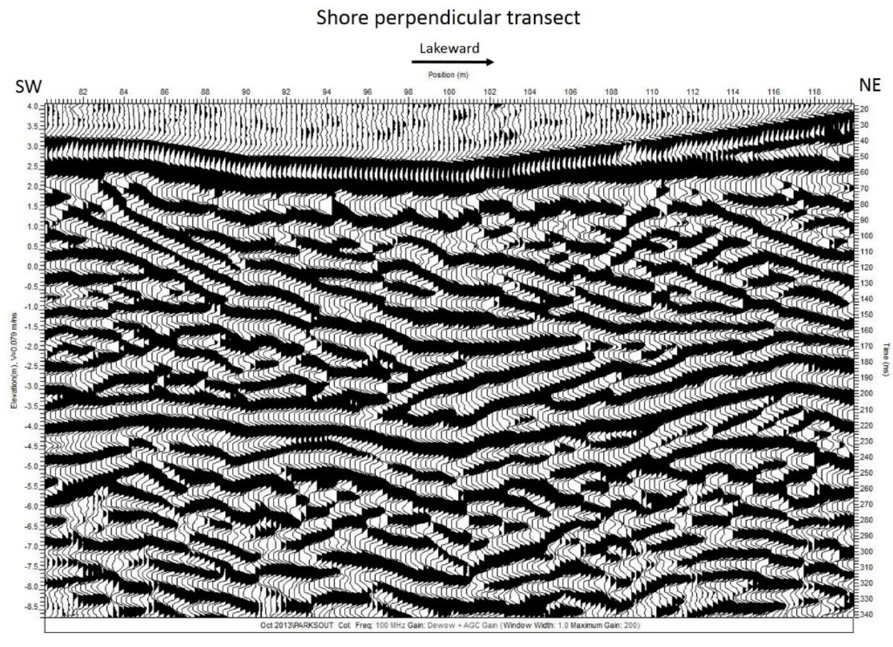


**Figure 2**: An topographically corrected example of a typical shore perpendicular transect. Note the lakeward dipping reflections in the upper 4m which suggests progradation of the barrier through time. Lakeward dipping reflections are above a continuous undulating reflection which is interpreted as an unconformity between a buried feature and the barrier.

# Mud Meets STEAM: Limnogeological Outreach, Diversity, and Education Supported by LacCore/CSDCO

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Lake sediments are ideal vehicles for place-based public outreach and science education for a diverse audience. Lakes are landscape features familiar to nearly everyone, and act as focal points for both rural and urban communities. Lake science integrates multiple scientific disciplines, geoscience subdisciplines, and the humanities, supporting STEAM education (science, technology, engineering, art, and math). Hands-on and inquiry-based activities can be readily done by nonexperts. Core-based science is also highly scalable, from a single core "pooped out" on the surface of a frozen lake and manually explored by students for texture and macroremains, to semester-long lab-based courses for undergraduate and graduate majors and nonmajors. Short records reflect human impacts to a lake ecosystem, while Holocene-scale cores teach about climate change on geological time scales.

LacCore provides several types of support for researchers and teachers wishing to include cores in their outreach/ed activities, and to bring the excitement of research and learning to all students and community members. LacCore provides field support and tools for core collection, site selection guidance, curricular content, free software tools that teach and streamline lithological description and sediment classification (TMI, CoreWall, PSICAT), an online library of lab and analytical methods, and consultation and advice from staff with years of experience in core collection and analysis in research and non-research settings.

Here we also present reflections on several outreach, diversity, and education (ODE) activities undertaken in collaboration with Minnesota institutions: (1) Using cores to study wild rice lakes on the Fond du Lac Band of Lake Superior Chippewa Reservation, with Tribal resource managers and students from grades K through college (supported by NSF-OEDG and -REU); (2) Core transects, sediments, and water from a meromictic lake in Minneapolis used for a semester of labs in a 20–30 student 2000-level majors' sequence University of Minnesota Earth Surface Processes course team-taught by a sedimentologist, a geochemist, and a geobiologist; (3) Holocene cores used to study vegetation and paleohydrology in an 18-student Carleton College climate change class targeted at underclassmen and open to nonmajors; and (4) Holocene cores used to study biogeochemical cycles over time in a 10-student Macalester College climate change class for Environmental Science majors. In each case students undertake real research and combine classroom and literature learning with hands-on laboratory activities. We also discuss undergraduate research using cores, in both cohort and individual modes, based on extensive experience over multiple instances of two REUs and a Keck Geology Consortium project. Core research has numerous advantages over other materials and disciplines for addressing NSF's Broader Impacts criterion.

# Environmental Effects of a Millennium of Mining, Metallurgy and Land Use in Central Sweden

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The rise of Sweden as a nation was founded on its natural resources, which have been heavily exploited since the Middle Ages. One of the key areas is the ore-rich Bergslagen region in central Sweden, where mining and metallurgy shaped both society and the environment. The close proximity of mines to lakes and watercourses and the use of waterpower in the blast furnace process intimately connected them to the water-rich landscape. These activities also required forest resources and entailed settlement and expansion of agricultural activities. Figure 1 shows the area around Moshyttan, one of the hundreds - if not thousands - of medieval smelters found all over Bergslagen. Using lake-sediment records, our research traces the earliest origin of these activities and explores their environmental significance, particularly as they relate to present-day conditions. Here, data are presented from eight lakes from two areas that represent a range of impact magnitude, from small-scale settlement at an isolated iron blast furnace at Moshyttan (Myrstener and others, written commun.) to large-scale mining and smelting surrounding the mines at Persberg. To encompass the whole spectra of activities at these sites, we have analyzed multiple proxies including geochemistry, biogenic silica modelled through FT-IRS, lake-water TOC modeled through VNIRS, pollen and diatoms.

Dated sediment records from both sites show an onset of metallurgical activities from the mid or late-1200's, which is consistent with new evidence from other sites showing this to be a period of rapid expansion of iron mining and metallurgy in many parts of the Bergslagen region (Bindler and others, 2011; Karlsson and others, in press). The early opening of the forested landscape led to decreases in lake-water TOC and an increase in trophic status of the lakes, as indicated by the diatom species composition. For lakes directly connected to mines and smelters, changes in geochemistry, charcoal particle counts and lead isotope ratios indicate sometimes drastic changes in sedimentation rates and a local metal pollution, mainly from mine drainage and leaching from slags. Despite the current remoteness of the studied areas, their environment has been and remains greatly altered by a millennium of human activities.

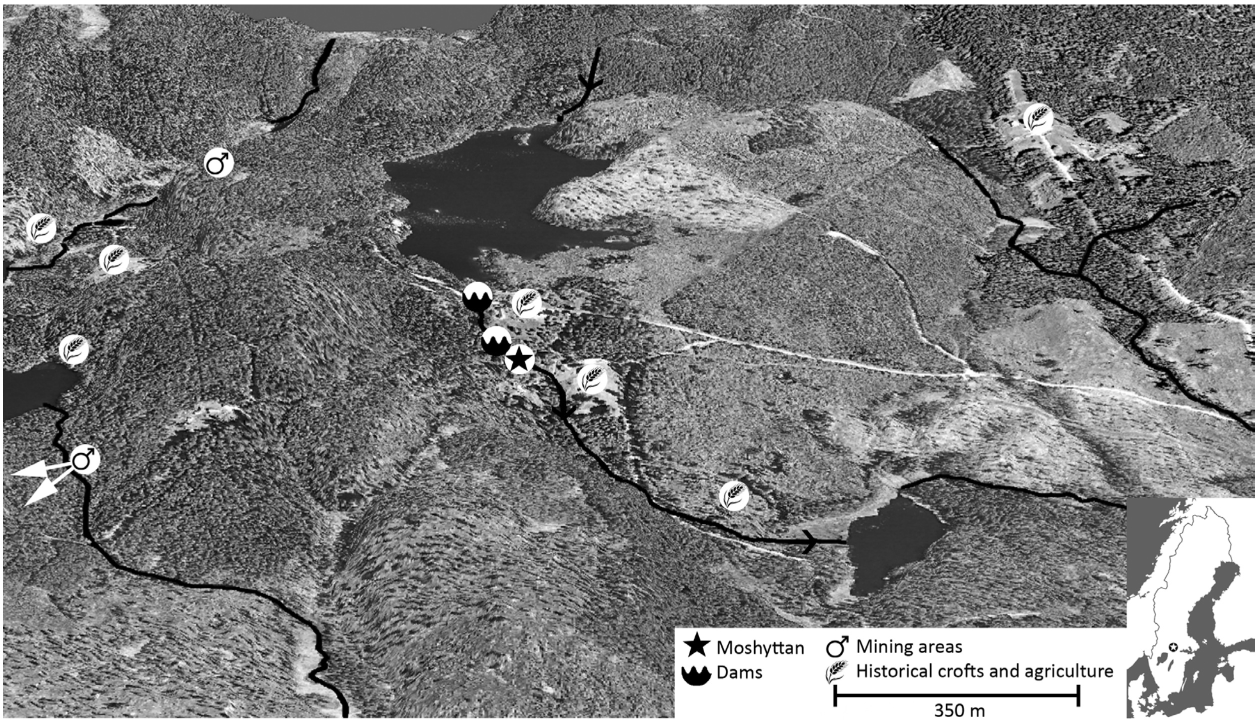


**Figure 1**. The landscape of Bergslagen in a nutshell. The area is only 2 km wide but it contains an iron blast furnace (Moshyttan), mines, dams and a several scattered crofts and fields.

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# Late Holocene (3.65 ka) Transition from Neopluvial Period to Increased Aridity in the Lake Tahoe—Pyramid Lake Watershed, California

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We present evidence for a millennial-scale interval of high winter precipitation (neopluvial) at the end of the mid Holocene in the Lake Tahoe-Pyramid Lake watershed that reached its peak ~3.7 kcal yr BP. A transect of 4 cores recovered from Fallen Leaf Lake in the Tahoe Basin were dated using AMS$^{14}$C on plant macrofossils, and analyzed using scanning XRF, C and N elemental and stable isotope measurements, and diatoms as paleoclimate proxies. Fallen Leaf Lake is a deep glacially-derived lake situated in the Glen Alpine Valley at an elevation of 1,942 m, ~45 m above the level of Lake Tahoe. In Fallen Leaf Lake, the end of the neopluvial is dated at 3.65 ± 0.09 kcal yr BP, and is the largest post-glacial signal in the cores. The neopluvial interval is interpreted to be a period of increased snowpack in the upper watershed, supported by depleted $\delta^{13}C_{org}$ (-27.5‰) values, negative baseline shifts in TOC and TN, lower C:N, and high abundances of *Aulacoseira subarctica*, a winter-early spring diatom. Collectively, these proxies indicate cooler temperatures, enhanced mixing, and/or shortened summer stratification resulting in increased algal productivity and/or suppressed terrestrial runoff. The neopluvial interval ends abruptly at 3.65 ka, with a change from mottled darker opaline clay to a homogeneous olive clay with decreased *A. subarctica* and opal, and followed by a 50% reduction in accumulation rates. After this transition $\delta^{13}C_{org}$ becomes enriched by 2‰ and TOC, TN, and C:N all show the start of positive trends that continue through the Holocene. Pyramid Lake is an endorheic basin situated at the terminal end of the watershed, and inflow arrives from the Lake Tahoe basin via the Truckee River. At Pyramid Lake, existing ages on paleo-shorelines indicate a significant lake-level rise beginning at some point after 5 kcal yr BP and reaching a highstand of about 1186 m between 3.8 – 4.1 kcal yr BP (Briggs and others, 2005), but new OSL ages on Holocene shorelines are pending. In the Walker, Mono, and Owens lake basins, the neopluvial shorelines represent the highest late Holocene shorelines (Stine, 1990; Adams and others, 2014). Collectively, these studies collectively indicate that the neopluvial and subsequent aridification intervals preserved in Fallen Leaf Lake sediments were at least regional in scale.

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# Early Quaternary Coastal Sedimentation in Lake Turkana, EARS, Kenya: Toward the Necessity to Incorporate Wave-Related Sedimentary Constructions in Rift Lake Depositional Models

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Coastal dynamics at the origin of large-scale sedimentary architectures are most of time overlooked in traditional depositional models for sedimentation in rift lake basin. Indeed, syn-rift strata are considered to mainly include fluvial deposits in the form of delta in axial system feeding a lacustrine water body. Subordinate deltas characterize the hinge transverse system in case of half-graben configuration while along faulted borders, coarse fan deltas are entering the water body, fed by erosion of the rift shoulder.

Nachukui Formation (western Turkana basin, northern Kenya) is one of the best exposed continuous syn-rift succession all over the world, spanning from Pliocene to Quaternary times (>4 Ma to ~0.5 Ma). It represents >700 m thick pile of fluvial-deltaic-lacustrine sediments deposited east of the border fault of the Turkana basin half-graben. In this contribution, we present two coastal successions, 48 and 45 m thick, documented from the Kaitio Member (1.87 Ma to 1.5 Ma). These two successions suggest long-term dominant coastal sedimentation during rift activity. Several transgressive-regressive cycles through shoreface and beach progradations and retrogradations are highlighted. Typical wave-related sedimentary facies are included in large-scale architectures. Endly, lake level evolution is presented and periodicities are discussed regarding astronomical forcings.

This contribution will be of interest for all geoscientists who deal with sedimentation in rift lake systems, suggesting that the impact of wave on lake sedimentation has to be more considered in the geological record.

# Sedimentation in Lake Saint-Jean (Québec, Canada): A Record of the Last Deglaciation

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Lake Saint-Jean (Québec, Canada) corresponds to an active sediment depocentre since the Late Pleistocene Laurentidian ice-front recession up to present-day. As a consequence, a comprehensive sedimentary archive is provided recording (1) the transition from glacial influenced to non-glacial influenced periods and (2) the transition from marine to lacustrine environment resulting from glacio-isostatic forced regression.

Stratigraphy of the last deglaciation in Lake Saint-Jean (Québec, Canada) is examined from 300 km of echo-sounder 2D seismic profiles, 22 short cores and onshore sedimentology. Ten seismic units have been identified reflecting evolution in depositional processes over more than 10 ka.

All along its evolution, the Saint-Jean basin is characterized by the evolution of high-energy coastal dynamics as evidenced by raised and active beach ridges, shoreface sediments as well as by the identification of a still active infralittoral prograding wedge. In opposition, during the same period, the offshore domain displays contrasted evolutions. The marine period was characterized by low-energy mud settling typical of glacimarine and prodeltaïc sedimentation, while the lacustrine period is characterized by the appearance of more energetic sedimentary processes mainly related to bottom currents and hyperpycnal flows. Erosive channel, deep erosional surfaces, sediment drifts, confined lobes and a lacustrine shelf correspond to the major sedimentary features identified on the lake bottom.

This sedimentary evolution is regarded considering the impact of the deglaciation through either the relaxation in sediment supply as well as the base-level fall from glacio-isostatic rebound.

# Wind-Driven Water Bodies: An Alternative Group of Lake Systems

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Continental paleo-environments are classically reconstructed based on archives taken from central deepest parts of lake systems, assuming that such records provide a comprehensive archive. This progressively convinced sedimentary geologists that lakes are dominated by low-energy depositional processes in opposition to open-marine domain characterized by higher-energy sedimentation. Nevertheless, some lake systems display intense bottom currents remobilizing sediment well below the wave base and resulting in erosion surfaces and sediment drifts. Moreover, these lake systems recurrently display wind-wave dominated nearshore through large-scale littoral morphostructures in the form of shoreface-connected ridges such as spits (flying and cuspate), down-wind barrier islands, wave-cut platforms. This suggests that wind controls the first-order dynamics as well as the sedimentary infill of numerous lakes.

In this contribution, based on three case-studies which are Mega-Lake Chad (Chad), Lake Saint-Jean (Québec, Canada) and Lake Turkana (Kenya), a new sedimentological paradigm is proposed, unifying some lakes with respect to their sedimentary evolution. Considering the wind as the primordial forcing on sedimentation, lakes from a wide range of geological and climate settings are included into a single set referred to as *Wind-driven Water Body* (*WWB*). They develop typical wind-wave related morphosedimentary features such as beaches and spits, associated at depth with sedimentary features such as sediment drifts, constructive sedimentary shelf and erosional surfaces together forming an original sedimentary system.

*WWB* concept has implications for paleo-environment reconstructions. Obviously, a major sedimentological issue concerns the distinction between sediments from *WWB* and open-seas in the geological record.

## High-Resolution Late Pleistocene to Mid-Holocene Climate Variability in Ireland: Evidence from Ostracod and Marl Isotope Values

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Stable isotope values of ostracode and marl calcite provide a record of variation in $\delta^{18}O_{(H_2O)}$ values and water temperature from the Late Glacial to Mid-Holocene period in western Ireland. Lough Monreagh, located in County Clare, contains marl sediment that includes pristine ostracode calcite whose $\delta^{18}O$ and $\delta^{13}C$ values when evaluated relative to modern thermal tolerance and ecological preferences are used to derive a paleoenvironmental record for Lough Monreagh that includes water temperature, eutrophication, and water depth, as well as terrestrial vegetation and weathering within the lake's watershed. Over 4,700 ostracodes representing all three freshwater superfamilies were identified to evaluate the trophic stage of the lake. $\delta^{13}C$ values of ostracode calcite suggest a significant increase in terrestrial vegetation beginning during the Allerød (13,600 cal yr B.P.), extending through to the Mid-Holocene (~7,000 cal yr B.P.). Marl and ostracode $\delta^{18}O$ values record variability in temperature and precipitation $\delta^{18}O_{(H_2O)}$ values that are in turn forced by variation in atmospheric and oceanic circulation. Water temperatures were calculated from $\delta^{18}O$ values of ostracode calcite and marl, constrained by temperature preference and tolerance ranges of ostracode species, yielding the highest resolution temperature record covering this period to date. Over 4,100 marl samples were analyzed to calculate temperature at a subdecadal to subannual resolution.

The lake progresses from a clear, cold-water (~8°C summer water temperature), low-nutrient environment during the Allerød, freezing abruptly during the Younger Dryas as evidenced by dark grey to black clay deposits aged 12,800 to 11,300 cal yr B.P. Following the Younger Dryas, transitional warming and increasing terrestrial vegetation are evidenced by decreasing $\delta^{13}C$ values of ostracoda and faunal transition to phytophyllic species. Summer water temperatures warm to >16°C, with ostracode species suggesting a shallow-water, fen- and macrophyte-rich environment with abundant plant life in and around the lake by ~8,000 cal yr B.P. Carbonate isotope and ostracode records end at ~7,000 cal yr B.P. at the sudden onset of peat accumulation that has been linked to early Neolithic activity in the Burren Region.

# Linking the Impacts of Land Use and Changing Climate on Water Quality in Northern New England Lakes

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With water quality becoming a key issue in managing water resources, the need to understand the impacts of land use and climate on freshwater systems has never been greater. Lakes are particularly responsive to watershed changes, many of which are ephemeral and only captured by continuous monitoring. Seasonal lake ice makes monitoring problematic for many reasons and so gaps exist in most long-term data records for fall, winter and spring months. Lake sediments, produced primarily within the lake or the terrestrial watershed, continuously record and archive lake conditions, potentially filling gaps in the monitoring datasets. Critical connections between these two dimensions are often overlooked, however, such that very few monitoring efforts include sedimentary datasets.

This study aims to identify transient, sub-annual changes in sedimentary archives, using integrated data from lake water chemistry, sediment traps and sediment cores in two northern New England lakes, Ossipee and Squam, NH. We compare our findings with documented records of local land use and climate change to determine how these manifest in our lake records. We seek especially to identify aspects of sub-annual change in water quality that leave trace records in the sedimentary archive.

We monitor physical and chemical water conditions at fixed moorings, and combine this with periodic sediment trap and sediment core collections at the mooring sites. The resulting time series include water column data for temperature, conductivity, dissolved oxygen, major ions and phosphorus in depth profiles in every season, and sedimentary data extending to pre-Colonial times. We use PCA analyses to identify sediment variables most closely associated with chemical and physical water quality, climate and land use indicators. The sediment time series include $^{210}Pb$ activity, particle size, mass magnetic susceptibility, organic carbon content, diatom community assemblages and mineral chemistry. We collaborate closely with local community stakeholders, including lake management associations and conservation groups, sharing findings on the combined potential implications of land use and changing climate on their respective lakes, to enable and encourage proactive responses that address future water quality management needs.

# Aquatic Bioindicators from the Northern Neotropics: Environmental Sensitivity and Ecological Interactions

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A training set based on multiple bioindicators (chironomids, cladocerans, ostracodes, copepods, and diatoms) from 63 aquatic ecosystems was established in the Yucatán Peninsula and surrounding areas (Guatemala, Mexico and Belize) with the goal of obtaining information on species ecological preferences for the improvement of paleoenvironmental inferences in sediments from Lake Petén Itzá and other lakes in the northern Neotropics. The training set was established along increasing N-S altitudinal (1–1,560 masl) and NW-S precipitation (~450 to >3,200 mm/yr) gradients, which interact to generate a highly complex study area. Furthermore, other factors such as closeness to the marine environment, geological origin (karst, volcanic, tectonic), among others, introduce additional sources of environmental variability. Pérez and others (2013) determined the main environmental variables that control species distribution in the study area for all bioindicators. However, there is still the need of a more detailed understanding of what determines the presence and abundance of a taxonomic group in the studied waterbodies, and their ecological interactions.

With this in mind, we calculated variance ratios (VR, covariance divided by variance) within and among taxonomic groups to elucidate the effects of environmental variability and ecological interactions at structuring aquatic communities. When VRs are equal to one, random drift is the most likely structuring factors, whereas VRs larger or smaller than one are probably associated with predominance of environmental or ecological interactions, respectively. Additionally, VRs were also calculated over the stratified dataset, a procedure designed to evaluate environmental and ecological sensitivity over finer environmental gradients defined by the stratifying variables (space, altitude, and chemical parameters). All VRs were statistically examined through randomization tests. All five taxonomic groups and 63 aquatic ecosystems were included in the analysis and indicated that within taxonomic groups, chironomids, cladocerans and diatoms were the most sensitive to environmental variability (VR > 1). The other groups displayed VRs that were not statistically different to 1, implying a predominance of random variables at structuring populations when the entire region was considered. When stratification was applied, it was possible to discern the roles of the environment, random processes and ecological interactions at finer scales. Our results clearly demonstrate that a multiproxy approach is much more informative when factors involved with the performance of each taxonomic group are taken into account. Thus, each bioindicator would be most useful within a determined range of the same environmental variable.

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# Neotropical Glacial/Interglacial Environmental Change Inferred from Ostracode Species Assemblages in an 85-ka Lacustrine Record from Lago Petén Itzá, Northern Guatemala

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Closed-basin Lake Petén Itzá, northern Guatemala, possesses the longest lacustrine sediment record from the northern lowland neotropics, spanning the last ~300 ka. The Yucatán Peninsula (Mexico, Guatemala, Belize) is one of the largest karst platforms in the world and is characterized by high numbers of aquatic bioindicators with carbonate shells. Ostracodes (*Crustacea: Ostracoda*) are abundant in long sediment cores retrieved from Lake Petén Itzá under the auspices of the Lake Petén Itzá Scientific Drilling Project (PISDP). Studies of cores collected at site PI-6 (70 m water depth) combined sedimentological, geochemical (elements, stable isotopes) and biological indicators (ostracodes), to infer climate and environmental changes from the last glacial maximum (LGM) through the deglacial-early Holocene transition (~23–10 ka BP). Neotropical aquatic communities were shown to be highly sensitive to environmental changes, especially changes in lake level and water-column conductivity and chemical composition.

Here, we extend the northern hemisphere neotropical paleoenvironmental record back to *ca.* 85 ka BP, using ostracode species assemblages. The long, continuous sediment record enabled study of aquatic community responses to glacial/interglacial climate changes. Dominant ostracode species were *Paralimnocythere opesta* and *Cypria petenensis*, indicators of shallow- and deep-water conditions, respectively. Their relative abundances during the past 85 ka provide insights into past lake level fluctuations. Greater relative abundances of *C. petenensis* during the glacial, along with lower proportions of *P. opesta*, indicate relatively high lake levels and moist climate conditions, which were interrupted by relatively drier Heinrich events and declines in lake stage. Abrupt climate changes, such as Heinrich events, are associated with modifications of the ostracode community. We applied transfer functions that were developed using a training set from 63 aquatic ecosystems on the Yucatán Peninsula, to the ostracode species assemblages in the Lake Petén Itzá core. We found higher number of adults and juveniles and inferred lower lake levels and higher conductivities for all Heinrich events. The highest rate of ecological change occurred during the LGM. The LGM assemblage, *Paralimnocythere-Typhlocypris-Darwinula-Cypria-Cypridopsis*, suggests cold and wet conditions. The dry and cold deglacial was characterized by the presence of nektobenthic species *H. punctata* and *C. okeechobei* associated with aquatic plants in shallow waters, indicating low lake levels. Dominance of *C. petenensis* in Holocene sediments is indicative of more humid conditions and higher lake levels. This study provides quantitative estimates for lake level and conductivity fluctuations over the past 85 ka, demonstrating the utility of ostracodes as paleoenvironmental indicators.

# What's Up with the Paleo-High in Lake Gosiute?

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Recent detailed stratigraphic correlations of the Tipton Shale and correlative Farson Sandstone members of the Eocene Green River Formation have identified the extent of a paleo-high on the basin floor that influenced lacustrine deposition. For example, at least two intervals of littoral carbonates characterized by stromatolite beds or exposure surfaces found on the paleo-high in the lower Tipton Shale grade into deeper water mudstone facies both proximally and distally to the basin margin. The width of this feature (7–10 km) along a depositional dip transect can be established based on isopach trends. Stratigraphic thicknesses in the overlying underfilled Wilkins Peak Member show that this area was a paleo-high during middle Wilkins Peak time. However, the high does not appear in the lower and upper Wilkins Peak Member isopachs. In addition to changes is lithofacies related to water depth, a cluster of enigmatic mounded facies documented in this study and in previous reports (Roehler, 1981; Mayry, 2007; Walker, 2008) are located on this paleo-high. All of these carbonate mounds have siliceous zones and are commonly brecciated. Some contain stromatolites and others contain gastropod and bivalve shells found in littoral carbonates deposited laterally. Some of these mounds continue into the overlying Wilkins Peak Member. These features have been interpreted as spring mounds formed near the surface of Lake Gosiute and likely lead to intensified microbial activity locally. Their presence on the paleo-high suggests a possible fracture network which provided a conduit for spring discharge.

The paleo-high recognized in this study corresponds to the intersection of the east-west trending Sandy Bend Arch and the north-west trending outcrop belt. The Sandy Bend Arch can be defined on the present-day structure map of the top of the Cretaceous Mesaverde Group. Thus, it had a post late Cretaceous growth phase. The arch also trends along to a Bouguer gravity high, implying the involvement of crystalline basement. Flexural modelling suggests that the Sandy Bend Arch may be located at the point of minimum convolved basin subsidence related to loading of the surrounding Laramide uplifts (Uinta Mountains to the south and Wind River Mountains to the north).

Detailed stratigraphic correlations presented in this study suggest that the Sandy Bend Arch had episodes of growth during the Eocene. By inference, these episodes correspond to phases of uplift of the surrounding mountains. Thus, the temporally well-resolved lacustrine strata of the Green River Formation may have provided yet another record of Laramide deformation.

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# Zeolitic Alteration in Saline, Alkaline Paleolake Basins in the Southern Kenya Rift Based on Analysis of Minerals from Koora Plain (ODP) and Lake Magadi (HSPDP) Core Samples

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To understand environmental and climate change in East Africa over the past several hundred thousand years and the possible impact of that change on human evolution and stone technology, we analyzed lacustrine sediments from two adjacent basins in the southern Kenya Rift. X-ray diffraction analysis of core samples obtained during the Olorgesailie Drilling Project (ODP) in the Koora Plain and the Hominin Sites and Paleolakes Drilling Project (HSPDP) at Lake Magadi have revealed distinct zeolite assemblages in each basin. Zeolites form from the alteration of volcaniclastic material (e.g., tephra, tuff) in saline, alkaline waters, such as those found in lakes of the southern Kenya Rift. Given the proximity of the Koora Plain to Lake Magadi (~15 km), one could argue that their climatic and tectonic histories should be closely linked. The mineralogy and geochemistry of each basin, however, appear to be distinctly different. Abundant authigenic zeolites throughout the core at Lake Magadi suggest it was a closed basin lake for most of its history, perhaps recharged primarily by hot springs at the lake margin as in the modern environment. In contrast, the Koora Plain paleolake experienced fresh phases suggestive of an open basin, when diatomaceous silts and diatomites accumulated, and saline periods indicated by saline diatoms and zeolitic facies in closed basin settings. The dominant zeolites in the ODP core from the Koora Plain are analcime and phillipsite, with pronounced zeolitic zones alternating with zones of other authigenic minerals such as low Mg-calcite. The most common zeolite in the Lake Magadi cores is erionite, although other zeolites such as analcime, chabazite, clinoptilolite, and phillipsite are also present. Erionite found in the Magadi cores is formed mainly by the reaction of trachytic glass + $H_2O$, with subsequent zeolite phases forming by erionite reacting with additional cations (e.g., erionite + $Na^+$ $\rightarrow$ analcime) or tuffs reacting with the saline, alkaline waters. The Lake Magadi core contains virtually no recognizable volcaniclastics, implying that the tuffs were all altered to zeolites, whereas the ODP core has relatively abundant volcanic material. The preservation of tuffs in the ODP core indicates periods of freshwater paleolake conditions, while the lack of preservation of volcaniclastics in the Magadi core suggests persistent saline, alkaline conditions, with the exception of a freshwater phase during the initial basin formation. These data provide insight into paleoclimate and tectonic history in the southern Kenya Rift during the late Pleistocene and Holocene, which will aid our understanding of the relationship between environmental and climate change and hominin evolution.

# Revised History of Tecopa Basin, Southeastern California, USA

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The Tecopa basin served as the terminus of the Amargosa River during much of the Quaternary. Its stratigraphy, sedimentology, chronology, and diagenesis have long been studied to investigate paleoclimate and the integration history of the river (Sheppard and Gude, 1968; Hillhouse, 1987; Sarna-Wojcicki, 1987; Morrison, 1999; Forester and others, 2005; Larson, 2008; Menges, 2008; Caskey and others, 2014). We use shoreline deposits and strandlines to reconstruct lake level and ostracodes as indicators of depositional and hydrochemical environment.

We can document only five lakes that had enough fetch to construct distinct shorelines. The oldest shallow lake coincided with deposition of the 2.1-Ma Huckleberry Ridge ash. The next lake was associated with a 1.25-Ma tephra, but no beach deposits have been identified. Ostracodes in these two deposits are mostly incompatible with Amargosa River water. A shallow lake just predates the 0.76-Ma Bishop ash, recording the first river incursion; ostracodes in younger lakes tolerate its water chemistry. The first large lake coincided with deposition of the 0.64-Ma Lava Creek ash. A second set of lake deposits with abundant beach gravel lies ~15 m stratigraphically higher. This lake may have an age of ~600-500 ka based on deposition rates and U-series analysis by J.B. Paces (U.S. Geological Survey, written commun., 2013). Shoreline altitudes suggest northward basin uplift. We infer a long hiatus between this lake and a younger, slightly lower lake, hypothesized as early OIS 6 in age based on geomorphic relations; overflow and draining of this lake created the Amargosa River canyon and fed Lake Manly in Death Valley. A yet younger lake may represent a stillstand during basin incision.

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# A 1,600 Year Record of Climate Change from Big Soda Lake, Nevada, USA

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Sediments from >30 m deep lake basins that are dominated by groundwater inputs are likely to produce laminated, continuous records that can be used for high-resolution paleoclimate records. A 1,600-year record of hydrologic and climate variability for the Carson Sink area of northwestern Nevada was developed from multiproxy analyses of the upper 2 m of laminated sediment recovered from Big Soda Lake, a 63 m deep groundwater-fed volcanic crater lake near Fallon, Nevada (fig. 1). High resolution $\delta^{18}O$ analysis of calcite and X-Ray Fluorescence data from lake sediments indicate several centennial, decadal and sub-decadal changes in lake levels during the past 1,600 years. The high resolution data and lake level reconstructions are supported by an independent chronology provided by Pb-210, radiocarbon, and two dated tephras. The stable isotope, geochemistry, and brine shrimp cyst results all indicate significant shifts in climate during the time period covered. From A.D. 400–850 the climate alternated between wet and dry conditions; from A.D. 850–1060 it was relatively dry; wet conditions prevailed between A.D. 1050–1260; drier conditions returned between A.D. 1260–1400. From A.D. 1400 to A.D. 1700 the climate was dry overall, but after A.D. 1700 the climate became relatively wet again. The period since A.D. 1850 has been complicated by human activity in and around the lake. The observed 18 m increase in lake level during the early decades of the twentieth century was caused by an increase in surface-water irrigation of the surrounding farmland, which resulted in a rise of the regional groundwater table. These changes resulted in a major shift in the isotopic, geochemical and brine shrimp cysts in the lake record. The Big Soda Lake record indicates that climate oscillations on both the decadal and centennial scales have occurred during the past 1,600 years and that these changes are in broad agreement with several other paleoclimatic records that have been developed in the western Great Basin, suggesting that these fluctuations in climate were at least regional in scale.

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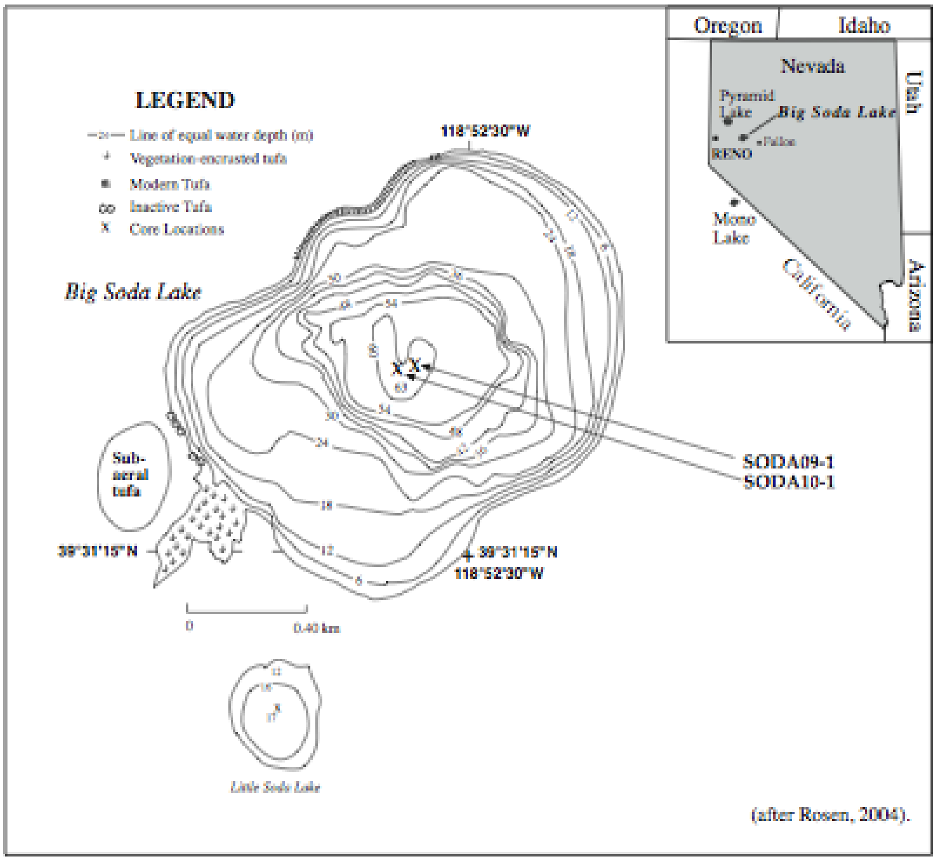


**Figure 1.** Location of Big Soda Lake, Churchill County, Nevada. Core recovery locations for SODA09-1 and SODA10-1 are also indicated.

# Nutrient and Metals Contamination in Little Lake Bonnet (USA): An Example of Human Impact on Sensitive Lakes of Florida's Central Ridge

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Florida's Central Ridge is a topographically higher portion of the state that formed as remnants of beaches and barrier-islands during the Miocene to early Pleistocene. Ridge lakes are perched in sand deposits and are naturally low in productivity, pH, and cation content. As a result, they are particularly sensitive to landscape disturbances. Ridge lakes have been subject to citrus agriculture, and more recently to excessive residential and recreational developments resulting from rapid population influx.

We examined water-quality impacts and metals contamination in Little Lake Bonnet, Highlands County that arose from golf courses and citrus agriculture. Little Bonnet currently is mesotrophic (mean TP = 26 µg/L, TN = 1,970 µg/L, Secchi depth = 0.46 m, pH=7.6). The lake lies between two oligotrophic lakes that have half its nutrient concentrations, with Lake Letta (TP = 14 µg/L, TN = 420 µg/L, Secchi = 1.83 m) only 300 m to the east, and Lake Lotela (TP = 12 µg/L, TN = 730, Secchi = 1.77 m) 500 m to the north. Approximately one-third of Little Bonnet's shoreline consists of golf-course fairways that were established in the late 1920s, and approximately 50% of the shoreline is citrus groves planted by the early 1950s. A channel to the lake was cut through golf fairways by the 1950s. Our previous studies showed increases in stable lead deposition from atmospheric alkyl lead fallout, and potentially from lead-arsenate pesticide use on citrus and turfgrass. This study adds analysis of arsenic to the metals evaluation, and assesses eutrophication with sedimented diatoms, algal and cyanobacterial pigments, nutrient accumulation rates, and $\delta^{13}C$ and $\delta^{15}N$ stable isotopes.

Three sediment cores were retrieved, analyzed for metals content, and $^{210}Pb$ dated. The central core was analyzed for diatoms, pigments, and stable isotopes. Arsenic and lead concentrations increased abruptly in the 1930s, likely from the application of lead-arsenate pesticides. Arsenic deposition after c. 1960 probably resulted from monosodium methylarsenate application on golf courses. Algal-pigment profiles showed increases in chlorophyll derivatives, oscillaxanthin, and myxoxanthophyll since the early 1960s. Trophic state, as assessed by autecology and WA estimates of limnetic total P based on a transfer function derived from 69 P-limited lakes, increased concurrently. Total C, N, and P accumulation rates peaked during the 1950–1960s with the establishment of citrus agriculture. $\delta^{13}C$ values showed slight increase in primary productivity, but $\delta^{15}N$ values showed substantial enrichment after the mid 1950s from nitrogen-rich fertililzers.

Dilute lakes on Florida's Central Ridge are highly sensitive to land use disturbances, including fertilizer and pesticide applications on golf courses, residential developments, and agriculture. The Central Ridge is considered fragile because of its limited range, its ancient origins and endemic flora and fauna, but it is underprotected from rapid development.Ridge lakes are still regarded as scenic water features for residential and recreational developments, as convenient sources for agricultural water supply, and as endpoints for stormwater discharge, but this study illustrates their exceptional vulnerability to landscape alteration, and need for protection as imperiled ecosystems.

# Sedimentary Response and Correlation of an Ephemeral Pond and Soils during Deglacial and Holocene Climate Evolution, Swan Lake, Southeastern Idaho

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Bioclimatic systems that have developed around perennial lakes are important ecological resources in the arid western US and provide many benefits to the ecosystem. Lake sediments can record fluctuations in climate (such as temperature and effective moisture) and can offer insight into regional variations in climate patterns. Additionally, soils represent regional climate over long period of time (many $10^3$ years), but lack the ability to represent changes over hundreds or even thousands of years depending on the landscape and climate. We studied a 7.65-m core from Swan Lake, which is a small lake and wetland complex that seasonally overflows, to examine small scale climate changes in its continuous sedimentary record. Six soil pits were dug in the surrounding vicinity to study the soil profiles to be correlated afterwards with the Swan Lake sediment deposits. The depth of the pits varied and were between 40 and 65 CMS, presenting four easily recognizable horizons, an organic horizon, a high clayey-sand horizon, fine to medium size sand horizon, and the lowest horizon was formed by gravel and sand. Our core is similar to that studied by Bright (1966) in exhibiting two primary sedimentary facies, mud and peat, which spanned 13.5 cal ka. We used radiocarbon dates (15), particle size analyses, sediment mineralogy, stable isotopes on calcium carbonate sediments, and clumped isotopes on calcium carbonate as a proxy for paleo-temperature to supplement other measures such as density, LOI, and fossil studies. Mud in the lower half of the core is primarily clay plus silt-size quartz and feldspar, but it transitions to calcium carbonate mud at ~5.8 ka. Clays also change, from 660 to 585 cm and 350 to 220 cm in the lower section of the core to increased kaolinite and illite in the upper section. Ostracodes in the carbonate muds are fairly uniform, indicating a mixture of wetland and pond environments from the modern to 5.8 ka. Similarly, summer temperatures obtained using $\Delta_{47}$ measurements show fluctuations in the range of 18.1 to 23.4 $^{o}$C with the lower temperatures generally corresponding with carbonate muds and higher temperatures with peats. We tentatively have interpreted muds as open water, shallow lake conditions and peats as wetlands. The shift from clay to carbonate muds may represent warming as well as increasing carbonate in surrounding soils. Particle size and x-ray diffraction analyses are still in the process of being compared with the grain size distribution of the lake as well as the clay mineralogy from the surrounding soils. As a groundwater-fed lake, soil composition as well as climatic conditions can affect water composition. If our interpretations are correct, the time from

onset of the Younger Dryas to the end of the early Holocene was effectively dry, with low groundwater discharge. Similar events occurred from 4.7 to 1.0 ka and briefly at ~400 cal yr BP. Colder climate may have led to drier conditions in this part of the eastern Great Basin.

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# The Origin of Shallow Lakes in Khorezm, Uzbekistan

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The economy of the Khorezm province in northwestern Uzbekistan relies on agricultural production. To sustain their staple crop, cotton, water from the Amu Darya is diverted for irrigation, reducing river flow to the Aral Sea. The province has more than 450 small shallow (<3 m deep) lakes that may have developed as a result of irrigation. Sediment cores were collected from 13 lakes (fig. 1) as part of this study to elucidate the origin of these small lakes and how they have changed over time. Under Soviet governance from 1924 to 1991, much of Uzbekistan was transformed from a relatively arid landscape to irrigated farmland. Hydrologic changes during this time period appear to be reflected in these lakes (Shanafield and others, 2010; Oberkircher and others, 2011; Scott and others, 2011). Lead-210 and Cesium-137 dating of the cores indicate that the lakes are less than 100 years old, which supports a modern history of the lakes. The thickness of lacustrine sediments in the cores analyzed ranged from 20 to 60 cm, indicating a relatively slow sedimentation rate and a relatively short-term history for the lakes. Pollen and loss on ignition analysis of a subset of the lake cores indicate that these water bodies have transitioned from a dry saline arid landscape during pre-lake conditions that had carbon-poor and pollen-poor basal sediments to carbon-rich near-surface sediments dominated by abundant freshwater pollen taxa. Sediments at the base of the cores contain pollen taxa dominated by the halophytes *Amaranthaceae/Chenopodiaceae* (Amaranth/Goosefoot families) and *Tamarix* (salt-cedar) indicating that in general, vegetation growing nearby was adapted to arid saline conditions. Near the top of the cores, the first appearance of weedy pollen and plant crops are encountered, as well as large increases in the glycophytes *Typha/Sparganium* (Bulrush/Bur-reed) and *Populus* (aspen) indicating freshwater conditions.

Lead-210 and Cesium-137 profiles in some of the cores are not consistent with continuous deposition. This could have been caused by sediment mixing by farm animals or because of non-deposition periods caused by periodic lake desiccation. Loss on ignition percentages in some lakes increase from the bottom of the core to within 10 cm of the surface where percentages stabilize or decline. The stabilization of LOI percentages in the lakes may be caused by the maturation of the system as it reaches equilibrium with the surrounding landscape, or by possible human influences in the watershed such as the use of herbicides.

Pesticide profiles of DDT (dichlorodiphenyltrichloroethane) and its degradates and ϒ-HCH (gamma-hexachlorocyclohexane) show peak concentrations in the top 10 cm of some of the cores, where estimated ages of the sediments are associated with peak pesticide use during the Soviet era.

All of the above data indicate a relatively young age of the lakes and indicate that without irrigation and canal inputs, the lakes would not exist as freshwater lakes, but would likely be saline playas or ephemeral wetland depressions.

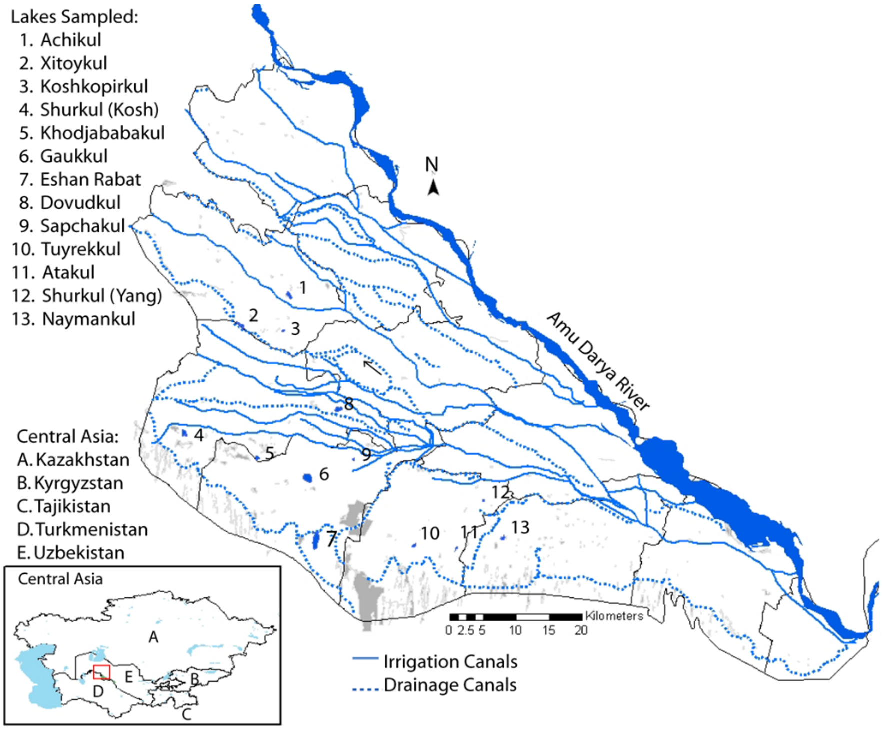


**Figure 1.** Location of the lakes studied (in blue) in Khorezm, Uzbekistan, and the distribution of the more than 400 other lakes in the region (in grey).


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# Linking Neo- and Paleolimnology to Understand the Incorporation of Environmental Signals in a Varved Sediment Record: The Nylandssjön Project


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Lake sediments provide an excellent opportunity to study how our environment has changed with time. But in order to extract and "read" the hidden information in sediment records, we need to understand how environmental signals are incorporated into sediments. Hence, it is imperative that we know how they are formed, what processes affect their formation, and how *in situ* processes – i.e., diagenesis – affect them.

Since 2001 the Environmental Change Assessment-group at Umeå University has an ongoing project linking neo- and paleolimnology in Nylandssjön, a small lake with varved sediments in boreal Sweden. By combining sediment cores (collected almost yearly since 1979), sediment traps (an almost continuous record with 6-30 day periods since 2002), lake-water monitoring (10–30 day intervals since 2001) and catchment soil samples, our aims are to understand: (1) temporal and spatial variations in the primary sources of the sediment material; (2) how the sedimenting material is affected in the water column; (3) how the sediment is affected by diagenesis; and finally iv) how the preserved signals relate to variations in relevant external factors, e.g., weather, land use, atmospheric deposition. Below follows a short summary of our findings so far.

Lake-water monitoring shows both seasonal and year-to-year variation in, e.g., oxygen saturation and iron concentrations (Gälman and others, 2009a). There are also large variations in the timing, magnitude and species composition of algal blooms between years.

The sediment trap material and sediment cores also show substantial seasonal and year-to-year variation Gälman and others, 2006). Sediment accumulation is larger in spring and summer than in winter; and summer samples are enriched in fresh organic material whereas winter samples consist of more degraded organic material. There are also differences in the iron speciation between seasons; with iron sulfides present in winter samples, while only iron oxyhydroxides are found in samples from spring and early summer. Interestingly, oxidized iron species are stable in these anoxic sediments, at least for several decades.

By comparing sediment cores from different years, we could conclude that with time in the sediment that: (1) carbon, nitrogen, $\delta^{15}N$, chlorophyll-a, bromine, varve-thickness and methylmercury decrease; (2) $\delta^{13}C$ and phosphorus increase; and (3) lithogenic elements, as well as, sulfur, mercury and iron are stable (Boës and others, 2011; Gälman and others, 2008; 2009b; Maier and others, 2013; Rydberg and others, 2008).

A comparison of the geochemical record to weather data suggests that (1) colder and wetter winters resulted in more coarse-grained mineral material in the sediment, and (2) seasonal weather data can only explain 30–40 % of the geochemical variability observed in the sediment. The remaining variation can likely be attributed to internal processes, precipitation events and land-use practices (Rydberg and Martinez-Cortizas, 2014).

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# Reconstruction of Windstorm Events from Saline Lake Sediments

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Playa Lake sediments are used as proxies for past climate properties because they respond sensitively to slight changes in the hydrologic regime of the lake. However, little research has been conducted into paleoweather conditions and in particular, the reconstruction of windstorm events from saline lakes, whether permanent or ephemeral (playa) lakes. Many of these shallow lakes are formed by deflation processes. Hence, since wind is an effective erosional and depositional agent, this makes them excellent sites for reconstructing paleo-storm events in inland environments where there are no windstorm proxies available.

The flat, shallow water ponds located in a hydrologically closed wetland in La Mancha (a semi-arid region in Central Spain) are saline and contain evaporite minerals, mainly sulfates. These ponds are usually dry in the summer and fill with water during the rainy seasons. In the winter, the rea is subject to episodic storms accompanied by gusty winds. Prevailing winds from the southwest have led to a preferential expansion and orientation of the lakes toward the northeast. Numerous, long traces left behind by rocks have been recorded in the basins (fig. 1). Systematic monitoring provides evidence that at least seven trace formation events occurred between winter 2012 and January 2015. Stones often moved several times during each event before reaching their final resting place, which indicates that the movement of stones is frequent in these settings.

eal time observation, sedimentary structures and meteorological data indicate that the traces are formed by wind-induced water currents. Thus, the paths of the stones perfectly match the changes in wind direction recorded during specific windstorm events. The general orientation of the traces broadly coincides with the prevailing wind direction in the area and therefore the traces are more common on shore of the lake towards which the predominant winds blow. In addition, wind-induced water currents, on the order of 1.5 m/s, are seen to be responsible for the formation of other unexpected bedforms and deposition features that commonly occur alongside the traces made by the stones (groove marks).

The associated basal erosional surfaces include mud runnels, longitudinal scour, obstacle scour often associated with V-shaped erosional remnants and pockets, as well as a variety of continuous and discontinuous tool marks. The distinctive deposition features are, among others, one or more successive linear strandline accumulations of stones, contorted microbial mats (mat deformation structures), spilling mud, algae, herbs, tumbleweed, etc. at the edge of the retreating water (fig. 2); trains of ripples at the shores; carbonaceous drapes, imbricated pebbles; inverse grading bedding; stone scattering; as well as anomalous detrital layers, which mainly consists of authigenically-produced minerals (gypsum), organic remains and clastic particles.



**Figure 1.** Trace left by a stone.

**Figure 2.-** Strandline accumulations of tools.

Accordingly, episodic winter storm events of brief duration have a greater impact on playa lake deposits than previously suspected. The resulting sedimentary structures are remarkably similar to storm deposits in tidal environments and record the hydraulic and climatological conditions within ancient deposits. A plausible ancient analogue is found in Miocene successions from the central and southern parts of the continental Madrid Basin in central Spain. In these cases, chemical and detrital gypsum facies alternate several times as a result of changing weather conditions.

**Acknowledgments**

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# Gypsum Microbialites and Mat-Related Structures in Shallow Evaporitic Lakes

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The saline Lillo wetland, located in the Spanish La Mancha region, is comprised of both permanent and ephemeral (playa) lakes. The lakes mainly consist of thin muddy-evaporite deposits, dominantly silt-sized lenticular gypsum that precipitates from sulphates brines. The lakes support extensive growth of phototrophic microbial mats that induce changes in the mechanical and chemical behavior of the evaporite sediment leading to the formation of distinctive microbialite and microbial mat-related structures. The latter consist of a variety of construction, deformation and destruction forms, which change spatially and seasonally according to hydrodynamic conditions. The microbial structures are known from siliciclastic and carbonate coastal deposits, but little is known about the occurrence of such structures in modern and ancient lacustrine evaporites.

El Longar, a permanent lake, is covered in microbialites with flat to pustular morphologies, which due to desiccation can develop polygonal cracks, commonly with convolute margins at the shoreline (fig. 1). Densely arranged lenticular gypsum crystals together with calcite, celestite and sulphur grains are embedded in the microbialite mats. In summer, the surface of the microbialites is coated with hexahydrite. Throughout all the seasons, the most dominant structures found in these settings are those related with the gas production from the decay of buried microbial mats. Gas accumulation below the mats and subsequent release mainly generates: large gas domes delimited by cracks; mud volcanoes; petees often arranged into a polygonal network and mud holes. Pockets of photosynthetic gas bubbles are also common.

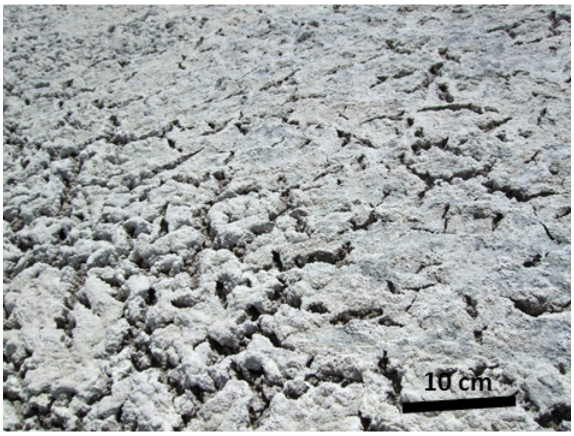


**Figure. 1**. Polygonal gypsum microbialites.

**Figure. 2**. Wrinkle structures.

The playa lakes desiccate in the summer whilst during the winter they are affected by storms that lead to erosion and reworking in the shallow ponded water. Under the effect of strong water currents the mat is partially eroded and broken into pieces, creating a suite of structures, namely: flip-over, folding, mat flakes and accumulations, ripples, and V-shaped erosional remnants (flat-topped rises) and erosional pockets (deeper lying sediment surface parts). Stones and other objects are involved in the formation of the erosional remnants and pockets as they act as obstacles to the water currents that erode the mats on which they rest. The eroded pieces of the mat become folded and accumulate at the water's edge, whilst the obstacle often slides over the surface creating a groove. Destruction marks formed in the summer include desiccation, erosion by wind and production of ripple patches and mat fragments (mat chips). Worthy of note is the relative abundance of wrinkle structures (fig. 2) in the study lakes, as these structures are rare in modern environments. The wrinkle structures consist of linear to honeycomb-like ripples and intervening pits. They develop in the upper littoral zone after being flooded by multidirectional water currents.

The above-described combination of sedimentary structures can help to identify microbial mat structures in the evaporite rocks that may have accumulated under their influence in saline lakes. Microbial structures provide an important tool for understanding evaporite paleoenvironments largely devoid of fossils. The occurrence of comparable microbial evaporites in Miocene lacustrine successions from Central Spain suggests that microbial structures are more common than previously thought in sulfate rocks.

**Acknowledgments**

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# First Observation of Hummocky Cross-Stratifications (HCS) from the Megalake Chad Deposits: Description and Implication for Possible Tropical Storms during the African Humid Period

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Megalake Chad is a very large (>350,000 km$^2$) and relatively shallow (max depth: ~150 m) paleolake that corresponds to the highstand reached by Lake Chad during the African Humid Period (Holocene). Both field observations and remote sensing reveal that most of the offshore domain of this paleolake is dominated by the deposition of finely laminated diatomites still preserved over several tens of thousands square kilometers, whereas its nearshore zone is fringed over >3000 km by conspicuous littoral landforms that are the result of the reworking of fluvial- and eolian-derived clastics by wind-waves and alongshore drift (e.g., spits, beach ridges, wave-ravinement surface, wave-dominanted deltas).

Considering (1) the remarkable dimension of this water body, (2) the evidence of wind-driven paleohydrodynamics, and (3) the regional climate controlled by the seasonal shift of the Intertropical Convergence Zone, one could reasonably expect that tropical storms could have developed over Megalake Chad. However, at time, no evidence of paleo-storms has been described in this basin.

Hummocky cross-stratification (HCS) is a major primary sedimentary structure that became popular after its comprehensive description by Harms and others (1975). This characteristic sedimentary structure is considered as a prime criterion for the recognition of storm deposits in marine and lacustrine environments.

Here we report the first observation of HCS associated to the sedimentary record of Megalake Chad. The presence of this structure suggested that the paleo-monsoon was able to generate intense storms that in turn represent another source of clastics redistribution in the Megalake Chad. This localized observation of HCS motivates new field investigations for the identification of other storm deposit successions elsewhere in this large lake basin in order to characterize storm-waves and the recurrence of stormy episodes.

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## Lessons from a Fossil Spit Along the Eastern Shore of Megalake Chad

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Megalake Chad is a very large paleolake extending between 10°N – 18°N, and 12°E – 19°E, over more than 350,000 km$^2$, with a maximum water-depth of ~150 m. This paleolake corresponds to the most recent highstand of Lake Chad that developed during the climatic optimum of the African Humid Period (AHP).

Considering its dimension, Megalake Chad is well expressed on remote sensing images where offshore deposits dominated by widespread diatomites fringed by prominent nearshore clastic morphosedimentary features are clearly identified. Using recent satellite imagery (SRTM, ASTER-GDEM, Landsat, Pleiades), relict littoral landforms appear coherently distributed and organized all around the lake basin. Along the ~3,000 km long paleoshoreline of Megalake Chad, some of the most remarkable features correspond to isolated ridges, spits, beach ridges, wave-ravinement surface, tombolos and wave-dominated deltas. Altogether, these features are the key (1) to firmly delineate paleoshorelines of Megalake Chad, (2) to define its maximal size and follow its evolution, and (3) to reconstruct the alongshore drift and hydrodynamics driven by prevailing paleowinds (Harmattan-like).

One of the most informative and representative littoral landform of Megalake Chad, the fossil spit of the Goz Kerki, has been studied from very high resolution satellite imagery (Pleiades-CNES). This fossil spit, comparable in size and shape to the modern Belosarayskaya spit (Azov Sea), is preserved along the eastern paleoshoreline of Megalake Chad. This area shows a well developed strandplain, composed of numerous narrow prograding beach ridges at a nearly constant elevation, then followed by detached beach ridges situated at successively lower elevations. The upper beach ridges record the highstand of the paleolake and its normal regression (climatic optimum of the AHP, maximum water-level regulated by the Benue Trough spillover), and then the lower ones record the onset of its climate-driven forced regression (end of the AHP). Post-lake erosional processes (water and wind) have not yet significantly affected the preservation of this paleo-spit, but they provide evidence of subsequent short-lived pluvial episodes within a long-lasting arid phase.

As a consequence, the paleo-spit of the Goz Kerki highlights the importance of wind-driven hydrodynamics in large lakes and represents a comprehensive record of the African Humid Period, allowing to follow its evolution from its rise to its demise.

# The Lake CHAd Deep DRILLing Project (CHADRILL) - A Rosetta Stone for the Last 10 million years of Environmental and Climatic Changes in North-Central Africa

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A recent climate modelling study (Zhang and others, 2014) has identified the pivotal role of the shrinkage of the Tethys Sea for north African aridification during the Tortonian stage, showing arid–humid oscillations at orbital time-scales. This marked change to modern-like climatic conditions occurred at a crucial time interval for the evolution of African fauna (notably hominins) and flora. Indirectly, this study highlights the paucity of our understanding of the paleoclimate and paleoenvironment of north Africa, that is at time based on marine cores off Africa (continuous record, but averaged conditions) and on continental exposures and cores (local conditions, but discontinuous). With the CHADRILL project, we propose to tackle this lack of adequate archives by drilling in Lake Chad (13°N, 14.5°E), the unique location to recover a continuous record of the climate and environment of continental Africa over the last 10 million years (Sylvestre and others, 2014).

The Chad Basin is an intracratonic sag-basin that has accumulated a thick (~600 m) and extensive pile of continental Neogene to Quaternary sediments, with a depocentre close to the position of the modern Lake Chad. Lake Chad is a large, shallow, permanent, freshwater lake that fringes the southern edge of the Sahara desert (Sahel). Lake Chad is almost exclusively fed by the Chari-Logone river system that originates from the wet tropics, where precipitation is directly controlled by the West African Monsoon and the seasonal migration of the ITCZ. This particular configuration makes this terminal lake a very sensitive indicator of climate and the environment evolution of north-central Africa at various time-scales.

The seasonal variation in size-depth of Lake Chad follows the pattern of the monsoon rains. In the recent past Lake Chad was considered as the fourth largest permanent freshwater lake of Africa. As a consequence of the severe droughts over the last few decades, its size has decreased drastically from ~25,000 $km^2$ in the 1960's to ~2,000 $km^2$ in the 1980's. Comparable changes during recent historical times have also been reported, along with geological, archeological and paleontological evidence for much earlier lake fluctuations. For example widespread lake deposits, prominent littoral landforms, and archeological artefacts suggests that during the climatic optimum of the *African Humid Period* a giant paleolake known as Megalake Chad (>350,000 $km^2$) developed. Deeper in the geological times, from the late Miocene, several paleolake episodes have been deduced both from a geotechnical borehole drilled close to the shore of Lake Chad, and from exposures in the northern part of the Chad basin where a rich an diverse vertebrate fauna that includes two new hominid species has been found.

All together, these data suggest that numerous paleolake highstands, most probably controlled by orbital parameters, developed in this basin over the past ten million years or so. It is now up to an international scientific drilling project to reveal the richness of the sedimentary archives preserved by Lake Chad.

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# Wave-Dominated Clastic Shorelines in Lakes: Modern and Ancient Examples from the Lake Turkana Basin, East African Rift System, Kenya

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Wave-dominated shorelines almost exclusively refers to coastal marine environment. However, numerous modern lakes exhibit typical wave-dominated littoral landforms, and associated sedimentary deposits are known from several paleolakes successions. Wave-related processes are often minored in lake depositional models that mainly emphasize on clastics transported by axial and lateral rivers, then distributed by fan-deltas and/or deltas into a standing water body where reworking of clastics is limited/episodic. However, if one considers both the modern Lake Turkana and the paleolake deposits exposed in the Turkana Basin, this vision is clearly incomplete.

There, wave-dominated shorelines can be evidenced (1) for the modern Lake Turkana from active littoral landforms (e.g., beach ridges, sand spits, washover fans, or arcuate-cuspate deltas), (2) for the Holocene (African Humid Period) climate-driven highstand of Lake Turkana and its subsequent forced regression from conspicuous perched beach ridges and spits, and (3) for the Pliocene-Pleistocene (Omo Group/Nachukui Formation) from typical nearshore sedimentary facies and stratigraphic architectures associated to several paleolake highstand episodes.

This preliminary overview from the Lake Turkana Basin observed at three different time intervals, suggests that wave-dominated shorelines can represent significant portions of lake coasts and of paleolake successions.

# Linking Plio-Pleistocene Climate Variation within the Mojave Saline Basins using Polarity Boundaries and Ar-Ar Dating

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The northern Mojave Desert of eastern California and western Nevada, including Death Valley National Park, has excellent exposures of thick sedimentary sections, as well as proximity to the Long Valley magma system, a source of dozens of sanidine-bearing ashes erupted throughout the Late Pliocene and Pleistocene. Active tectonics, especially the mid-Pleistocene stress rearrangement, has uplifted outcrops of these sedimentary sections in an otherwise continuing process of basin infilling. Many of these Basins have episodes (including during the Holocene) of lacustrine sedimentation typically with features indicating high salinity. Seasonally wet playas and mudflats are another typical facies in the central part of many Mojave Basins.

Paleomagnetic polarity boundaries are worldwide event horizons (<2 kyr) that have the potential for correlation between the deposits in each of the Mojave Basins. By tracking the lithology (and other proxies) from basin to basin at or near the same polarity boundary, one would be able to get a 'snap-shot' of the climate in the region. Variations between basins could then be ascribed to more proximal effects, such as local tectonics or increasing rain shadow from the uplifting Sierra Nevada. But currently, even the more recent polarity boundaries are not sufficiently well dated to confidently place them within a specific precessional cycle of the astronomically calibrated time scale. Now we compare data across too wide an age window, so that measured climate proxies are only loosely connected to the orbital forcing agents that drive the Earth's climate.

Ar-Ar dating of single crystals of sanidine can now be analyzed using multi-collector mass spectrometers that have the precision for assignment to a specific precessional cycle (~20 kyr) within the Pliocene. And during the younger parts of the Pleistocene, sub-precessional precision is possible. We have initiated a research program in the Mojave Basins to link lithological/mineralogical climate indicators to precisely dated ash beds that occur close to polarity boundaries. Specific research targets are the Matuyama/Brunhes (0.78 Ma, the Early/Mid Pleistocene boundary); Jaramillo (1.07–0.99 Ma); Reunion (2.13 Ma); Gauss/Matuyama (2.58, the Plio/Pleistocene boundary); and the Mammoth (3.33 Ma). Once these dates have been refined, the magnetozone boundaries can then be used in any area to generate a much wider and more precise view of climate at those times.

# Trace Fossils of the Eocene Green River Lake System in the Bridger Subbasin, Wyoming

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Trace fossils of the Eocene Green River Formation in the Bridger subbasin, Wyoming, exemplify the idealized model for traces and lake-type basins. The Wilkins Peak Member, in particular, provides an example of an underfilled lake-type basin that records different assemblages in basin center and basin margin environments. This study investigated ten localities in the Bridger subbasin of Wyoming to develop a model for trace fossils in underfilled basins, and to test the integrated lake-type trace fossil model in balanced fill and overfilled lake-type basins. Results from detailed stratigraphic, sedimentologic, and ichnologic analyses at these localities were placed into the generalized stratigraphic context and interpreted lake history.

The basin center contains a thick sedimentary package due to continued subsidence throughout deposition of the Wilkins Peak Member, which represents an underfilled lake-type. The basin center trace fossil assemblages are infrequently overprinted on palimpsest substrates towards the tops of progradational units deposited during low lake levels. Two distinct trace fossil assemblages in the basin center correspond to two distinct facies macro-associations representing (1) lacustrine and (2) deltaic and alluvial depositional systems. Trace fossil suites associated with lacustrine modes are low diversity, high density and are dominated by horizontally oriented simple invertebrate trails (e.g., *Helminthoidichnites*) and poorly preserved mammal footprints. Trace fossil suites associated with deltaic and alluvial deposits of the alluvial mode are moderately diverse. The suites comprise high-density simple burrows (e.g., *Planolites*), low density simple vertical burrows (*Skolithos*), bird footprints, mammal footprints, insect trails, meniscate backfilled burrows (e.g., *Taenidium*), and other probable insect traces. The packaging of the basin center successions and the vertical distribution of trace fossil suites shows that sedimentation was nearly continuous. Lacustrine deposits representing balanced fill and overfilled lake-types in the basin center generally lack trace fossils.

Trace fossils in basin margin areas more commonly have cross-cutting relationships and represent hiatuses when lake level was low, and possibly sediment bypass through deposits representing the previous high lake level. Basin margin trace fossil assemblages vary depending on whether the sedimentary package represents overfilled, balanced fill, or underfilled lake-types. Shoreline and lacustrine deposits from times of expanded lake levels, backshore, mudflat, and alluvial facies associations at the basin margins are also characterized by distinct trace fossil suites. They include high-density simple horizontal burrows, meniscate backfilled burrows in vertical and horizontal orientations, mammal footprints, and crayfish burrows.

Trace fossils are helpful for recognizing surfaces representing hiatuses in subaerial environments at the southern and western basin margins of the Bridger subbasin. The stratigraphic evidence demonstrates that these hiatuses may be due to low lake levels related to climate cycles ~100 ky in length, and also due to tectonic activity and uplift of the basin margin. The degree of variability in trace fossil assemblages and their associated depositional environments and stratigraphic packaging from the studied underfilled lake-type basin localities is not observed in the successions representing balanced fill and overfilled lake-type basins.

# Radar Stratigraphy and Architecture of a Detached Barrier Island from Huangqihai Lake, North China: Implications for Coastal Washover Barrier Boundary Hierarchy and Barrier Evolution

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Ground Penetrating Radar (GPR) data collected with a 400 MHz antenna are used together with sedimentologic observations from trenches to research the radar facies and sedimentary architecture of a detached barrier island system on the north shore of Huangqihai Lake. Six types of radar surface, both depositional and erosional, were identified. Radar facies bordered by radar surfaces were interpreted based on the reflection characteristics and termination patterns. Eight different radar facies were identified in the profiles, and these fall into three groups (inclined, horizontal and irregular). The whole barrier system comprises barrier bar and salt marsh units—distinguished using GPR profiles. Linking radar and sedimentologic data allows us to develop a model of barrier bar evolution, indicating that this was formed during a cycle of lake-level change. The characteristics of the different building blocks (washover lobes, sheets and swash laminated sands) within the barrier bar unit and their depositional regimes were studied. Based on the known lake evolution in the Holocene, a relative chronological framework was assessed. Two storms in the 1880s and 1960s may have played an important role in building the barrier bar.

Ground-penetrating radar and trenching studies of a detached barrier island on the north shore of Huangqihai Lake also provide information on the bounding surfaces of the barrier, with important implications for the coastal washover barrier boundary hierarchy and interpretations of such depositional record. A four-fold hierarchy bounding surface model, representing different level of impact and genesis, are defined. Each level of the hierarchy is being enclosed by a distinct kind of surfaces characterized by different GPR characteristics, shape, coverage and origin. It is suggested that this hierarchy model can be applied to the deposits of coastal washover barriers.

# Varved Sediments in Landslide-Formed lakes: Slope Failures and Natural Eutrophication Promote Formation of High-Resolution Sediment-Delivery Records in Central Idaho, USA

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Landslide-formed lakes in central Idaho occur preferentially in watersheds underlain by erodible rocks of the Challis Volcanic Group, which host numerous large drainage-impounding slope failures in tributary drainages of the upper Salmon River. Three extant and persistent (>2,500 years old) lakes formed by these impoundments exhibit histories of high modern primary production (algal blooms) and notably high organic carbon high burial rates relative to other lakes in the Salmon River basin. We attribute this naturally eutrophied state to relatively high total phosphorous concentrations of the Challis rocks and to hydrologic settings promoting high internal P loadings. Resulting Holocene sediment sequences comprise repetitive 1–2 cm winter-summer couplets, with summer/fall lamellae consisting of near-pure diatom frustules. Near-annual frequency of these couplets is supported by coherence between radiometric ($^{210}$Pb and $^{14}$C) dating and varve counts (performed visually on high-resolution line scans of the Herd Lake core sequence).

Embedded within these rapidly accumulating, annually-resolved sequences of diatomaceous ooze, episodic clastic pulses (primarily silt and clayey silt) record erosional events in the contributing watershed. We attribute these pulses to periods of high precipitation and slope instability in areas underlain by Challis Group rocks, well known locally for producing debris flows and other mass wasting features in response to extreme precipitation events. Scanning X-ray fluorescence (XRF) provides a highly resolved record of runoff intensity through the elemental signatures recorded by these clastic pulses. Log-ratio transformations of xrf intensity data allow spectral analysis of these time series and comparison to low-resolution sediment-mobility records and to high-resolution records of the climatic forcing responsible for sediment transport. The distinctive primary production status, resulting high organic-matter fluxes, and excellent sediment preservation within these lake systems provide embedded runoff signals with a degree of temporal resolution unique among Holocene lakes of the region.

# Quantification of Centennial-Scale Sedimentation Rates in Lake Geneva, Switzerland/France

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In Alpine mountain ranges erosion, sedimentation and transport processes are mainly driven by climate and impact on sediment transfer processes. Additionally, in the last ca. 200 years, anthropogenic activities have also significantly changed the sediment balance in these watersheds. In the Alpine basins these impacts are hydrological and geomorphic (e.g., flow abstraction, dam construction, sediment flushing, etc.). When such changes occur in a lake watershed its sediments will record these past changes.

The *Sedfate* research program aims to quantify the impact of anthropogenic activities in the last ca.100 years on the erosion and sediment transfer in the Rhone River catchment down to Lake Geneva (Switzerland/France). To achieve this, the direct effects of human activities on this system needs to be differentiated from the effects of climate variability and from long term 'background' erosion rates. The project is designed based on four closely related sub-projects, in which is our specific sub-project A. Sub-project A aims at reconstructing the total sediment input to Lake Geneva brought by the Rhone River during the ca. last 100 years. For this we need to refine our understanding of the clastic sedimentary processes in the Rhone delta as well as our current knowledge of the distribution of sediment rates in space and time.

Comparison between historical bathymetry and recent multibeam data from Lake Geneva was performed in a GIS environment. The resulting thickness map shows up to 18 m of sediment accumulated in the proximal delta during the last 128 years. This map revealed previously unknown sedimentation patterns. A proximal, 1,800 m wide and 3,400 m long, tongue prograding from the present Rhone River mouth was interpreted as resulting from interflows and overflows from the inflowing waters. Another sedimentation area follows the levees with two 200 m wide stretches on each side of the Rhone sublacustrine canyon. This deposition area is certainly due to overspill of large flows occurring in the canyon. At the end of the canyon, at ca. 290 m depth, a large fan-shaped depositional area with ca. 11 km$^2$ shows a large sediment volume accumulated during the past century.

Mean sedimentation rates (SR) have been calculated to range from +0.1 to +22 cm/year, with erosion restricted to the canyon bed.

The various lithologies of the recent Rhone delta sequences will be defined in space and time for each depositional environment using bulk density, magnetic susceptibility, granulometry, water content, mineralogy and XRF analysis in long/short cores retrieved in the eastern lake basin. Radiodating techniques ($^{137}Cs$, $^{210}Pb$, $^{14}C$) will be applied to determine mean SR which will verify our calculated SR map and help understanding sediment fluxes changes over time. Core correlation will be achieved through XRF and MSCL data, allowing comparison with data from previous studies. Sediment mineralogy will be analyzed in order to correlate SR variations with changes in sediment sources in the watershed.

Preliminary SR results inferred from bathymetry data seem to be in agreement with data from previous authors as well as with our first SR inferred from sediment dating ($^{137}CS$).

# Late Silurian-Early Devonian Lacustrine Limestone in Alaska's Alexander Terrane Fortifies Paleogeographic Links to the Old Red Sandstone Continent

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The Karheen Formation of southeastern Alaska (Alexander terrane) is an 1,800 m-thick redbed molasse sequence that formed during the Late Silurian-Early Devonian in the wake of the Klakas orogeny. In the Karheen's type section, polymictic conglomerate, cross-bedded sandstone, and alternating red and green mudstone display complex facies relationships with thin, platy limestone. Previous research interpreted the Karheen's platy limestone as marine in origin. New evidence, including a lack of marine fossils, indicates that the platy limestone formed in a deep, permanently stratified lake in cyclic association with siliciclastic, lake-margin facies. Five transgressive-regressive cycles record the sudden expansion of a lake, rapid deepening, and the accumulation of varved sediment comprising bipartite, calcareous- and organic-rich laminae. In each cycle, the platy limestone exhibits abrupt transition with underlying siliciclastic facies (alluvial-fluvial conglomerate and sandstone interbedded with muddy overbank deposits). Progressive lake shallowing and the progradation of alluvial plain facies during regressive phases are recorded in the upward transition from platy limestone to marl, which is rhythmically interbedded with paper-thin lime shale and then abruptly overlain by coarse siliciclastics.

Comparative analysis with coeval Lake Orcadie deposits in Scotland shows that the Karheen Formation is strikingly similar in age, thickness, lithology, paleontologic characteristics, and tectonic setting to the Old Red Sandstone. Thus, the Karheen's platy limestone and interbedded facies, together with other published geologic data from southeastern Alaska, anchor the Alexander terrane to a specific part of the Uralian Seaway—the N. Atlantic-Caledonide region and the Old Red Sandstone continent—during the mid-Paleozoic.

# Mercury and Methylmercury at Lake Nacimiento, California


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Mercury ore was mined from the Klau and Buena Vista underground mines (central Coast Range, California) from 1868 to 1971; an estimated total of 8 million pounds of mercury was produced. The Klau/Buena Vista Mines Superfund Site was placed on the Superfund List in 2007. Documented releases of mercury from the site have migrated downstream along the floodplain of Las Tablas Creek, to Lake Nacimiento about 6 miles north. Gilbane was tasked by EPA to perform a Remedial Investigation (under CERCLA guidelines) to assess the nature and extent of mercury and methylmercury contamination in water and sediment at Lake Nacimiento. Sampling of surface sediments and sediment depth-profiling were completed using Van Veen and vibracore samplers. The water column was monitored monthly for one year, continuing seasonally in the second year, at five locations. Recent mercury sampling in Lake Nacimiento showed largemouth bass with 1.8 ppm, smallmouth bass with 1.0 ppm, and carp with approximately 0.5 ppm.

The investigation of Lake Nacimiento revealed the following notable findings:

- Total mercury in near-surface sediments is most abundant in deep-channel portions of the reservoir, where clays and organic matter have accumulated;
- Recent, relatively clean sediments (low in mercury) appear to have buried sediments with higher mercury in the main stem of Lake Nacimiento, possibly reflecting the influence of the small, upstream Las Tablas Creek Reservoir acting as a contaminant catch-basin since its construction in 1970.
- One locale of mercury methylation is in the upper portion of the lake-bottom sediment column, during part of the mid summer-early fall period of stratification. Because of declining summer water levels, localities that had a thermocline early in the dry summer season can lose it, thereby opening a route for sediment-generated methylmercury to migrate more freely to shallow waters, even during stratification. This could be one of at least two possible routes of exposure of methylmercury to biota in the lake.
- Lake Nacimiento is a large monomictic lake that does not stratify or de-stratify simultaneously across the entire lake, but otherwise behaves normally. The lake’s significant depth means that a thick anoxic zone can develop once stratification sets in. The normal step-wise sequence of metabolic processes dominates the hypolimnetic ecosystem after stratification occurs. Potentially troublesome levels of methylmercury start to appear

in the hypolimnion relatively early during stratification, after iron reduction and some amount of sulfate reduction have begun to occur. Methylmercury concentrations appear to increase into the early fall. Methylmercury concentrations for the past two years have ranged from ND ($<0.05$ ng/L) to 6.6 ng/L in Year 1 and 10.8 ng/L in Year 2, both in October near the end of the stratified period.

- During full water-column destratification and mixing in late fall, methylmercury migrating upward from the hypolimnion tends to remain stable at least for a few weeks before breaking down, presumably allowing for uptake of mercury within the cells of plankton and algae, and subsequent tropic migration up the food chain. Biota sampling will be performed in two events in the current year.

## Diatom-Inferred Holocene Record of Moisture Variability in Lower Bear Lake, San Bernardino Mountains, California, USA

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Holocene diatoms present in Lower Bear Lake sediments, provide a 9,200-year hydroclimatological record for the San Bernardino Mountains in southern California. Based on several physical and chemical properties as well as gastropod and ostracod assemblages, Kirby and others (2012) inferred nine (five major (PE-V to PE-I), four minor (PE-IIIa-c, PE-IIa) decadal to multi-centennial pluvial episodes, associated with atmospheric rivers, in sediment core BBLVC05-1 (34°15’20” N, 116°55’20” W; 4.5 m length). The new diatom data allows evaluation of these pluvial events, as well as detailing changes in lake surface water properties. The diatom record shows a gradual increase in salinity during the Holocene, corroborating the inference of decreasing lake size made by Kirby and others (2012). The longest pluvial episode (PE-V; 9,170?-8,250 cal yr BP), is dominated by fragilaroid taxa, indicating fresh, slightly alkaline waters. An increase in halophilic taxa at ~8,700 cal yr BP suggests a several-decades-long drier interval within the pluvial. PE-IV (7,000-6,400 cal yr BP) is dominated by benthic taxa, including relatively high numbers of epiphytic taxa, indicating an increase in aquatic macrophytes. The abundance of *Aulacoseira* in PE-IV and PE-III (3,350-3,000 cal yr BP) suggests increased turbulence due to increased storminess. PE-III and PE-II (850-700 cal yr BP) contain greater abundances of benthic (epiphytic) and halophilic species, although the latter never dominate the assemblage, suggesting that the lake was smaller than during the previous pluvial episode and that the abundance of aquatic macrophytes was higher. PE-I (500-476 cal yr BP) was not sampled. Aerophilic taxa comprise up to 3% of the assemblage during pluvial events suggesting increased erosion during those periods, and the presence of symbiotic species throughout the record indicates nitrogen-depleted waters. Greater abundance of assemblages dominated by freshwater diatoms generally corresponds to pluvial events identified by other proxies. Furthermore, the diatom data suggest Lower Bear Lake likely diminished in size through the Holocene becoming more saline in the late Holocene. This decrease in size may have been a response to an insolation-forced decrease in winter season precipitation with a negligible contribution from the North American Monsoon.

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## Millennial-Scale Temperature and Hydroclimate Variability over the Past 150 ka in Turkey Using a Biomarker-Multiproxy Approach of Lake Van Sediments

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Decadally-resolved lacustrine paleoclimate records from deep closed lakes can provide detailed insights into the mechanisms of past environmental changes in the continental interior. We retrieved a 220-m long sedimentary sequence from Lake Van (Turkey) covering 600,000 years of decadal to orbital-scale climate variability. Application of a suite of proxies (e.g., sediment color, TOC, pollen, elemental concentrations, and stable isotopes) has already revealed past variations in lake productivity, lake level, water mixing, chemistry and shoreline distance as well as vegetation changes in correspondence to millennial-scale hydroclimate variability in the Near East during the glacials and terminations.

More recently, several studies using lipid biomarkers stored in Lake Van sediments for paleoenvironmental reconstructions provided first insights into modern processes as well as long-term paleoenvironmental changes in and around the lake. However, a high-resolution biomarker-based study, sufficient to resolve changes on a centennial-scale, is still lacking.

Here we focus on present temperature and hydroclimate changes during several D-O events from MIS 3 and over the last two terminations at centennial resolution. Mean air temperatures (MAT) were reconstructed based on down-core distributional changes in soil bacterial derived membrane lipids, the so-called branched glycerol dialkyl glycerol tetraethers (brGDGTs). Since recent studies have reported that additional aquatic production may influence the paleo-record, we also analyzed sediment trap and surface sediment samples to disentangle the soil and aquatic contributions to the record. Simultaneous analysis of the leaf wax hydrogen isotopic composition ($\delta^2H_{wax}$) as well as those of long-chain ketones ($C_{37}$ alkenones), synthesized by haptophyte algae, result in a reconstruction of changes in the source water due to variable precipitation/evaporation ratio.

The CBT/MBT-based mean annual temperatures (MAT) show variability in correspondence to the interstadial/interglacials and stadial/glacials and follow our expectations in amplitude in the shifts between warm/wet interstadials (high MAT and BIT) and cold/dry stadials (low MAT and BIT). Isotopically lighter dD-values of leaf-wax n-alkane C29 argue for increased humidity during the interstadials and interglacials.

The excellent quality, age control and sensitivity of this sedimentary archive together with the wide range of classical proxy records available furthermore makes this site ideal to cross-validate records of continental climate variability.

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# Scanning X-ray Fluorescence Results from a ~1 Ma Paleoenvironmental Record Adjacent to the Olorgesailie Archeological Sites, Kenya

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The influence of high-latitude glacial cycles and precessional or half precessional forcing on Plio-Pleistocene African climate remains an area of continuing controversy (Herbertand others, 2010; Trauth and others, 2010; deMenocal, 2011; Potts, 2013). Regional climate records—sea surface temperatures or dust fluxes from Gulf of Aden sediments—have been linked to major shifts in human evolution. Outcrops in the Kenyan and Ethiopian rift valleys document repeated occurrences of freshwater lake-systems and wooded landscapes from the past 4 million years at locations that are presently seasonally-dry savanna. However, limited insight into continental climate dynamics at finer temporal and spatial scales restricts our ability to infer how environmental change may have affected adaptive change and lineage turnover in hominins or broader-scale mammalian evolution during the Plio/Pleistocene.

A 2012 drilling campaign recovered a total of 216 m long sedimentary sequences at two drill sites on the Koora Plain, a depositional basin adjacent to Olorgesailie, a major Early-Late Pleistocene archeological locality (Potts and Behrensmeyer, 2004; Pennisi, 2013). Together with the Hominin Sites and Paleolakes Drilling Project (HSPDP), these research initiatives aim to characterize East African paleoclimate with sufficient precision to enable correlation with hominin evolution and to identify evolutionary causal factors at specific time slices since ~4 Ma.

$^{40}Ar/^{39}Ar$ dating of tephra present in the cores and a detailed lithostratigraphy—including smear-slide microscopic analyses, and X-radiographic and optical images—provide the framework for high-resolution paleoenvironmental and paleoclimatic reconstructions. Here we present high-resolution XRF scanning data from these sedimentary sequences. Patterns in these data reflect depositional changes with time (e.g., diatom productivity, weathering processes) driven by environmental variability and can potentially be linked to climate parameters such as precipitation. In particular, we have focused on the details of a well-preserved laminated section of the core record, which we anticipate may harbor information about seasonal lake dynamics relevant to evaluating East African orbital and millennial-scale climate variability patterns.

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# Carbon Isotope Variability in Marl and Organic Matter from a Subarctic Lake: Environmental and Lacustrine Productivity Changes from the Late Pleistocene through Holocene in Northwestern North America

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High resolution long-term climate records are exceptionally important for providing a better understanding of mechanisms that force climate variability, as well as the duration and intra-variability of significant climatic perturbations. Lacustrine carbon cycling has long been a vital tool in limnological and environmental studies because carbon budgets are sensitive to climate and environmental change. Lakes situated in carbonate bedrock are especially valuable for paleoclimate and environmental research because they may contain annual deposits of carbonate precipitate (marl) deposited with organic matter, thus allowing for high-resolution, multi-proxy reconstruction of environmental change. Here, we provide a high-resolution record of lacustrine carbon budgets, including a sub-decadal carbonate isotope ($\delta^{13}C_{carb}$) record complemented by a lower-resolution carbon and nitrogen isotope ($\delta^{13}C_{org}$ and $\delta^{15}N_{org}$) record of organic matter, as well as other sedimentological and chemical proxies (e.g., grain size, carbonate content, carbon and nitrogen content, carbon/nitrogen ratios, total organic carbon, and total organic matter). An 11 m core was retrieved from Spirit Lake, a subarctic marl lake located in the climate-sensitive and rain-shadow region of the St. Elias Mountains in the southern Yukon Territory, Canada. Authigenic sediment recorded variation in local aquatic productivity and lake evolution, as well as regional climate variability during the Late Pleistocene and Holocene. We observe substantial variability, extremely high carbon isotope values, and one of the largest shifts in $\delta^{13}C_{CaCO_3}$ values observed in lake sediment. A positive shift of ~25‰ in $\delta^{13}C_{CaCO_3}$ values occurred during the last glacial/interglacial transition, marking the onset of a significantly higher rate of carbonate production. Significant shifts in the other proxy values are also observed during this time, including a 6-10‰ decrease in $\delta^{13}C_{org}$ values. The rest of the record exhibits decreased variability in $\delta^{13}C_{CaCO_3}$ and $\delta^{13}C_{org}$ values, quantifying fluctuations in the sources of carbon input into the lake from isotopically discrete sources, thus directly and/or indirectly characterizing the lake's productivity, regional climate variability, terrestrial changes and the plant types/abundances around the lake. Moreover, this sediment record extends beyond the last glacial/interglacial transition, providing the longest regional lacustrine carbon record to date, with important implications for regional environmental interpretations.

# Volcanic Controls of Holocene Depositional Evolution of Laguna del Maule (LdM), Southern Andean Volcanic Zone, Chile

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Laguna del Maule (LdM) is a volcanic lake (36º04'S, 70º30'N, 2200 m asl, 54 km$^2$ surface area, 50 m maximum depth) located in a caldera in the Andean Transitional Southern Volcanic Zone in central Chile. The LdM volcanic field is one of the most seismically and volcanically active in the Andes, with several caldera-forming eruptions during the last 1.5 Ma, intense postglacial (< 25 ka) and Holocene activity with rhyolite and rhyodacite coulees and domes. Recent surveys show renewed activity with up to 25 cm/yr uplift since 2007 (Singer and others, 2014).

In 2013, we recovered over 40 m of sediment cores at four sites in LdM and collected > 20 km of seismic lines. The cores were imaged and sampled for TOC, TIC, TS, TN, BioSi, and bulk mineralogy. Physical properties and geochemical composition were analyzed with a Geotek MSCL and XRF scanner respectively. Dating the LdM sequence is challenging because of the large $^{14}C$ reservoir effect. Using a Bayesian age-depth model including $^{210}Pb$ and $^{137}Cs$ profiles, the Quizapú volcanic ash (1932 AD) and 17 AMS $^{14}C$ dates we constructed an age model for the 4.8 m long composite sequence, which spans the entire Holocene. Core sediments are massive to banded, quartz and plagioclase-rich silts with variable diatom (BioSi, 15-30 %) and organic matter (TOC, 1–5 %) contents. Six lithostratigraphic units were defined based on sedimentological and geochemical composition (fig. 1). The onset of the Holocene is marked by a large shift from massive Unit 6 to laminated Unit 5. Unit 4 is composed of graded to homogeneous sediments that may have formed by mass wasting processes associated to some of the volcanic eruptions during the mid Holocene (Singer and others, 2014). Deposition of increased organic matter and diatom-rich facies occurred after 4 ka BP (Units 3 to 1).

Volcanic activity in the LdM basin has been intense throughout the Holocene, with up to 17 ash and lapilli layers intercalated in the sediment sequence. Strong volcanic influence in lacustrine deposition occurred both in biogeochemical ($CO_2$ fluxes responsible for large reservoir $^{14}C$ effects) and surface processes (changes in basin morphology and surface drainage). Comparison of LdM with other records shows strong similarities in timing and direction with main regional Holocene environmental and climate phases. Increased bioproductivity from early to mid-Holocene correlates with increasing SSTs and relatively higher available moisture throughout central Chile. The change in lake dynamics at *ca*. 4 ka also occurs in other lake records from South America and suggests the onset of ”modern” climate dynamics. The Little Ice Age stands out as a significant period of climate change with a complex hydrological signature in Central Chile (Carrevedo and others, 2015).

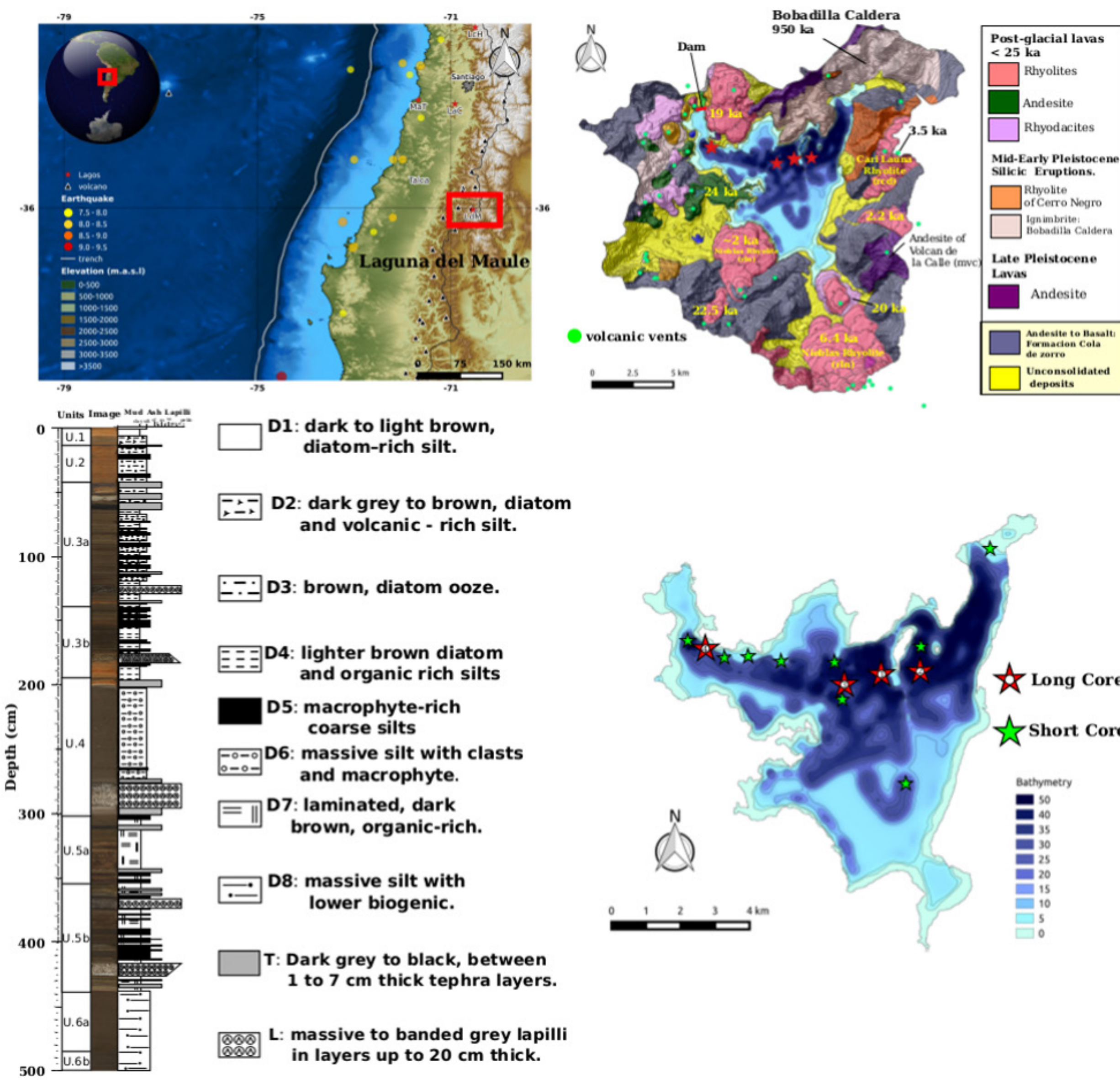


**Figure 1.** Top-left: Location of Laguna del Maule Basin (red frame). Top-right: Geological map with main volcanic units and ages and the bathymetric map with long cores locations (red stars). Bottom-left: Composite sequence of Laguna del Maule showing main units, core image and facies stratigraphy. Bottom-right: Detail of the LdM bathymetry with color scale in meters and the location of the recovered cores (long: red stars and short: green stars).

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# Characterization of Microbialites in Bridger Bay, Antelope Island, Great Salt Lake, Utah

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The shallow waters of Bridger Bay (fig. 1), on the northwestern tip of Antelope Island in the southern arm of hypersaline Great Salt Lake, support extensive microbial carbonate formation, especially in the north-northeast portion of the bay near Egg Island. Lake levels in the fall of 2014 were near 60-year lows (as low as 1,278.1 m [4,193.3 ft] AMSL, compared to the near-term historic average of about 1,280 m [4,200 ft]), giving unprecedented access to the microbial structures. Characterizing the microbialites of Bridger Bay, including facies delineation and aerial extent, can inform interpretations of similar deposits in the ancient rock record (e.g., Eocene Green River Formation), including potential petroleum reservoirs.

The goals of this project were to (1) characterize, in detail, the different types of microbial carbonates found in the bay, including thin, circular, domical microbialites; ring structures resulting from exposed collapsed domes; carbonate grains such as ooids and eroded pustular microbial growths; and large, thickly layered stromatolites; (2) delineate facies transitions from onshore to offshore, including exposed carbonate mud flats, remnants of older microbialite communities, ooid shoals, and offshore organic-rich mud; and (3) document the differences in the microbial communities from the sheltered waters of the bay (smaller, flat, superficial domal structures) and the windward side of the bay's northern spit (much larger, thickly layered stromatolites). The aforementioned characteristics where documented through routine field observations, petrographic analyses, and aerial photo documentation using a quadcopter mounted with a high-resolution video camera.

The dominant carbonate structures in Bridger Bay are domical microbialites, ranging in size from less than 0.5 m up to 2 m in diameter. The low-profile domical structures are composed of a partially lithified, mostly featureless (faintly laminated near the surface) outer crust about 10 to 20 cm thick, which covers unconsolidated ooids and mud (fig. 2). When submerged in the water, the outer surface of the structures is covered with brown-green microbial pustules. As the water level drops and wave energy increases, these growths are eroded off the top of the microbial domes and redeposited between the domes as thin, shallow shoals on or near the beach. When the structures are exposed for extended periods of time (as little as a few days to weeks), the microbial domes begin to bleach white.

As the lake level and water table decrease further, the inner structure of the dome collapses, leaving behind only a raised outer ring.

Several remnants of what are thought to be an older population of microbialites are also present near Bridger Bay at slightly higher elevations (1,280–1,283 m [4,200–4,210 ft]). Typically only the "roots" of these structures are preserved, but a few large, well-lithified, thickly layered stromatolites, up to 3 to 4 m in diameter, were found on the windward side of the spit of land connecting Antelope Island and Egg Island (fig. 3). These stromatolites are highly eroded but could have once been up to 4 m tall, possibly making them some of the largest stromatolites found in Great Salt Lake.

**Figure 1.** Panoramic photograph of Bridger Bay featuring low-profile domical microbialites. Notice the exposed, bleached top of the dome in the lower center of the photo (geologic hammer for scale).

**Figure 2.** An exposed and collapsed microbial dome.

**Figure 3.** A large eroded stromatolite, about 4 m in diameter.

# The Twin Crater Lakes of Newberry Volcano, Oregon

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Newberry Volcano near Bend Oregon contains two small crater lakes, East Lake and Paulina Lake (fig 1.). Both lakes are carbonate-rich, with a $CO_2$ input in East Lake and a hot fluid input in Paulina Lake. These lakes are both thermally stratified in summer and frozen over in winter, and are presumably dimictic. The lake waters are to large degree oxygenated, although a few vertical profiles show some oxygen depletion in the hypolimnion. East Lake shows increasing bicarbonate and decreasing pH with depth, whereas Paulina Lake has a more complex compositional profile. East Lake is a terminal lake, whereas Paulina Lake has an outlet, Paulina Creek. The chemical composition of these two lakes has not varied much over the last few decades, suggesting a compositional (and isotopic) steady state. The DIC is isotopically heavy in East Lake surface waters ($\delta^{13}C$=+4 ‰), slightly less so in Paulina Lake (0 ‰). The strong $\delta^{13}C$ gradient with depth in East Lake is presumably caused by photosynthesis in the surface waters and diffusional escape of isotopically light $CO_2$. The $\delta^{13}C$ of the $CO_2$ input at the lake bottom is ~-6 ‰. The water residence time of East Lake is 2-3 decades, whereas Paulina Lake has a residence time of less than a decade. Both lakes show very modest amounts of dissolved methane in the hypolimnion, but ten times as much in the waters above the thermocline (15m). The surface water methane has an isotopic fingerprint in $\delta^{13}C$ and $\delta D$ of the fermentation type, whereas the deeper waters appear to carry thermogenic or geothermal methane. The occurrence of aerobic methanogenesis in the surface waters of these lakes is quite unusual. The volcanic input in East Lake carries besides $CO_2$ also $H_2S$ (oxidized to sulfate in the water column) and Hg, which ends up largely in the sediments (up to 4 ppm Hg) and in the fish (up to 3.5 ppm Hg). The Paulina Lake sediments have background concentrations of Hg, but are strongly enriched in As, Fe, and P. Both lakes have diatoms as important primary producers, and the sediments are extremely rich in silica (up to 90%) and locally produced organic carbon (4-8 % $C_{org}$). The Paulina Lake sediment has up to 14 % $Fe_2O_3$, presumably of hydrothermal origin, and the lake waters are rich in dissolved silica (20 ppm Si). Stable isotope water budget models predict a substantial hot water influx into Paulina Lake, which makes for very thin spots in the winter ice cover and a short water residence time. The primary production in the ecosystem in both lakes is largely driven by geothermal components such as $CO_2$, P, and Si, with fixed nitrogen provided by cyanobacteria (*Nostoc* sp.), and sunlight being added from outside the system. These volcanically fed lakes may represent remote analogs of systems that deposited BIFs in the Proterozoic, which together with the copious amounts of cyanobacterial gelatinous spheres on the shallow sections of the lake bottoms creates a ‘Proterozoic Park’ setting.


**Figure 1.** Paulina Lake (PL) and East Lake (EL), separated by a volcanic ridge of about 6 kyr.

# Lake Caviahue, Neuquen, Argentina: A Volcanically Acidified Lake

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Lake Caviahue (37°52'S 71°05'W) is situated in the Province of Neuquen, Argentina near the Chile border at about 1,300 m amsl (fig. 1). It has a horseshoe shape, ~ 10 $km^2$ surface area, 0.5 $km^3$ of water, and a maximum depth of 100 m. The lake is thermally stratified during the austral summer and homogenized during the cold and snowy winters. The lake has a highly acid volcanic river (Upper Rio Agrio) as one of its inlets (pH=1-2) that drains the eastern slopes of the active Copahue Volcano. Lake water pH has varied from 2.2 to ~3 since 1997, and pH changes occur in response to the volcanic fluxes of the Copahue hot springs. The volcano erupted in 2000 and 2012 and the lake acidified prior to and during these events and then became more dilute afterwards. The dilution led in 2008-2009 to the saturation of part of the lake water body with Schwertmannite, a ferric-hydroxy-sulfate that strongly adsorbs the oxyanions of As, V and P. The residence time of water in the lake is ~ 42-45 months. Stable isotope data indicate that evaporation is only a small factor in its water balance. Despite its low pH, the lake has a thriving ecosystem. The dissolved components in the lake waters vary over time and the total quantities represent substantial amounts of dissolved volcanic rock that were brought into the lake through the Upper Rio Agrio. The latter imported in March 2013 resp 70, 85 and 98 tonnes of Al, Mg and Ca into the lake. A P flux of 0.7 tonnes for March 2013 led to 150–190 ppb dissolved P in the lake, which in earlier years reached > 400 ppb P. This P abundance makes the ecosystem in the lake N-limited. The 2008–2009 Schwertmannite saturation led to the sequestration of most dissolved P, which would have led to P limitation of the ecosystem. The lake turned rapidly more acid again past 2009, losing Schwertmannite saturation, and possibly re-dissolving the earlier mineral precipitates.

**Figure 1.** Lake Caviahue, Argentina

# Depositional Setting and Quality of the Deep-buried Reservoirs from Bindong Area, Eocene Lijin Sag of Bohai Bay Basin, East China

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Deep-buried thin bedded sandstone and siltstone reservoirs of the upper fourth member of the Shahejie Formation ($Es4^1$) are important oil exploration targets in Bindong Area, Lijin Sag of Dongying Depression, Bohai Bay Basin in East China. Detailed sedimentological analysis of core data indicates that there are 17 different lithofacies representing different styles and processes of sediment transport, ranging from sandstone to mudstone. Petrological analysis shows these reservoirs mainly consist of fine sand- to silt- lithic arkose. Four types of well developed sedimentary structures are recognized, which formed by gravity flow, unidirectional flow, oscillatory flow and combined flow, respectively. The beds are normal graded and contain Bouma-like sequences. The typical sedimentary cycle consists of fining upwards successions, from an erosive base, followed by gravity flow induced massive or faint laminated bed or soft sediment deformation and successively to unidirectional-combined-oscillatory flow induced beddings, attributed to storm deposits (tempestite). The reservoirs have undergone significant diagenetic processes which can be divided into negative and positive types. Negative ones include compaction and authigenic minerals cementation such as carbonates, clay minerals and overgrowths of quartz and feldspar. Positive ones include dissolution, carbonate cementation, overpressures and fractures. Carbonate exhibits both positive and negative functions to reservoir quality. Cutoff values of several parameters of the reservoirs were calculated. The lower limit of porosity and permeability are 9.46~5.57% and 2.2257~0.2277 $\times 10^{-3} \mu m^2$ respectively, depending on the depth. The upper limit of carbonate content and mud content are about 20 and 9%, respectively.

## Flume Tank Study of Surface Morphology and Stratigraphy of a Fan Delta

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The potential of fan-delta strata to produce hydrocarbons has intensified interest in researching these materials. However, little attention has been paid to the developmental patterns of fan-delta associated sand bodies, i.e., channel, mouth bar, and slide-slump deposit, which are favorable for the development of high quality reservoirs. Therefore, we conducted a flume experiment to simulate a fan-delta under controlled boundary conditions and hope to explain the genesis of these associated sand bodies. The experiment revealed that deposition was dominant in flood periods when the channels were highly loaded with sediments, and the fan-delta aggraded and prograde uniformly. In contrast, erosion was dominant in periods of low flow and the fan-delta prograded nonuniformly. The experiment showed developmental relationships between different facies. Subaqueous channels are the underwater extension of subaerial braided channels. As water and sediment were fed into the flume, the subaqueous channel was eventually replaced by a mouth bar. During this evolution process, the mouth bar first prograded, followed by accretion, backstepping and widening, with an increasing to decreasing depositional rate. After the mouth bar emerged, it caused the flow to bifurcate. The two branches would be bifurcated again by subsidiary mouth bars. Nevertheless, several bars might almost simultaneously develop basinward of the outlet if the channel was wide and shallow. Progressive deposition around the bar increased the angle of bifurcation and the original mouth environment evolved into fan-delta plain. It is worth mentioning that sediment failures would form in front of torrential and highly loaded channels.

# Using Thermal Infrared Imaging as a Tool for Understanding Groundwater-Surface Water Interactions in Microbialites

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Microbialite growth is driven by sedimentary and biogeochemical processes that occur at the interface between microbialite surfaces and interactions between the overlying water column and groundwater inputs from below. Solutes transported across the microbialite-water interface provide microbial communities with the chemical and physical requirements needed for growth. Understanding the dynamics of fluid exchange across the microbialite-water interface is therefore necessary for understanding how microbial communities mediate microbialite growth. However, measurements of fluid exchange in microbialite-producing environments are largely relegated to field observations of groundwater input through underlying sediments, rather than through the microbialite features themselves.

In this study, we use thermal infrared imaging as an unobtrusive and simple method for making field observations of fluid exchange through microbialites. We compare field measurements made at two modern, lacustrine microbialite-producing environments; Lake Clifton, Western Australia and Big Soda Lake (BSL), Western Nevada, USA. Lake Clifton is a shallow (<4 m depth) saline lake with a salinity approximately 3-times that of seawater. Microbialites grow on the eastern gently sloping foreshore and are located broadly in an area where groundwater discharges into the lake. The Lake Clifton microbialites have a clotted internal fabric consisting of aragonite mesoclots that are relatively porous. External morphology ranges from classic domal shapes to a broad reef of coalesced structures (fig. 1). Big Soda Lake (BSL) is a deep (63 m) meromictic maar lake with salinity approximately two-thirds that of seawater in the mixolimnion where the microbialites are growing. Microbialite mounds form mostly on the north and south side of the lake where groundwater springs discharge to the lake. Due to the steep slope of the lake bed, the microbialites are more than 3 m high and mostly form tall conical structures (fig. 2). The microbialites are composed of internal clotted fabrics composed of highly porous monohydrocalcite and calcite.

Thermal infrared imagery at Lake Clifton and BSL indicated groundwater springs discharging through microbialites. At both Lake Clifton and BSL, groundwater flowing through the springs was clearly delineated in thermal infrared by a temperature difference between groundwater and lake water of 5°C or higher. The springs were generally isolated to small conduit openings near the center of the microbialites. Thermal imaging also shows that even though some microbialites at both lakes have holes in the center where groundwater preferentially discharges, groundwater is also discharged throughout the microbialites through their porous fabrics.

Although similar in internal fabric, the slope of the lake foreshores and surrounding catchments are different. The difference in catchment slopes indicates that the groundwater head at BSL is greater than at Lake Clifton, thus allowing tall conical microbialites to form in BSL and smaller more broad microbialites to form at Clifton. The gentle slope and shallow lake level of Lake Clifton also limits the vertical growth of the microbialites, because vertical growth is limited by the lake level.

Thermal imaging is a useful tool for visualizing how groundwater moves through microbialites and provides some insight into how ions derived from groundwater are distributed to the growing microbialite.

**Figure 1**. Lake Clifton microbialites during summer low water. Note the low relief and domal structures.

**Figure 2**. Big Soda Lake microbialites during low water and drought conditions in October 2014. Note high relief of the crater wall and tall conical structures.

# A Late Holocene Lake Level Reconstruction of Lago Huiñaimarca, Southern Lake Titicaca, Peru/Bolivia

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The Late Holocene was a period of significant cultural development in the Lake Titicaca Basin, including changes in lake resource use (e.g., fish, totoro reeds). It has been hypothesized that when lake level was high, use of aquatic resources likely was high, because aquatic habitat was greatly expanded. Conversely, when lake level was lower, aquatic resource use was decreased and was supplemented by land resources (e.g., crops, camelids). However, archaeological data (plant and animal remains) from the southern shores of Lake Titicaca do not co-vary with existing lake-level reconstructions. It is unclear whether this is because there is no correlation between the two, or if it is because the limnologic record is incomplete. Existing lake-level data for the period of human occupation is based on hiatuses in the sedimentary record. These data are limited in that the resolution is at century to millennial scale, the reconstruction is non-continuous, and the data record only extreme fluctuations. In the 20th century, lake-level has been highly variable on a decadal and sub-decadal scale. As such, it is not unreasonable to assume that in the past it has been as variable.

We are reconstructing lake level at multi-decadal scale, comparable to the archaeological record, for the past ~6,000 years using diatom species abundance as a proxy for past lake level. We used continuous samples from a gravity core taken from Lago Huiñaimarca, the southern basin of Lake Titicaca, and determined relative species abundance in order to reconstruct the history of lake-level.

Our results suggest a hiatus in accumulation immediately prior to ~4,800 yrs BP that extends to ~6,800 yr BP. Beginning at ~4,800 cal yr. BP shallow epiphytic species dominated the community. At ~3,300 cal yr. BP, oligosaline planktic and epipelic benthic species dominated the diatom flora, followed by an increase at ~1,500 cal yr. BP of freshwater planktic species, which become dominant after ~900 cal yr. BP. These data suggest that beginning at ~4,800 cal yr. BP, the small basin of Lake Titicaca began to fill, but it was initially shallow and still somewhat saline, most likely a wetland area with abundant aquatic plants. From ~3,300 cal yr. BP onward, lake level began to increase and the lake became gradually fresher allowing the expansion of freshwater species from ~1,500 cal yr. BP onward.

Within these general trends in diatom species abundance, smaller changes are observed on multi-decadal scales. This includes a peak in freshwater planktic species ~3,100 cal yr. BP and a peak in shallow water benthic species at ~350 cal yr. BP. These results provide a better understanding of lake level during human occupation in the Lake Titicaca Basin.

# Groundwater Augmentation Alters the Chemistry and Biology of Dilute Lakes in Karst Regions: A Comparative Study

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Florida's basement geology in coastal lowland regions consists largely of phosphate-bearing Tertiary limestone deposits covered by a thick mantle of Plio-Pleistocene sands and clays. Lakes perched in surface deposits tend to be acidic, and low in mineral content and productivity. Hydrologic changes in recent decades caused by alterations in watershed drainage, groundwater withdrawal for irrigation, and climate variation have led to declines in lake levels in some areas. To maintain lake stage for residential concerns, lake-management agencies issued permits for the pumping of groundwater directly from the karst Floridan aquifer for water augmentation of the lakes. The chemistry of groundwaters, however, is significantly higher in pH, ionic content, and dissolved phosphorus than that of surface waters. A few studies reported recent changes in ionic composition and algal diversity in some augmented lakes, and one of our previous studies documented long-term changes in diatom communities in four augmented lakes. The present study is a systematic comparison of long-term changes in diatom communities from augmented and non-augmented lakes to determine whether groundwater augmentation exerts effects on the chemistry and biology of lakes apart from other anthropogenic influences.

Sediment cores were obtained from 27 lakes from a four-county region in south central Florida. Thirteen lakes were identified by Southwest Florida Water Management District as having received groundwater inputs, and 14 lakes were chosen as non-augmented controls. All lakes were generally similar in other respects. Detailed diatom analyses were performed on $^{210}$Pb-dated cores from 5 augmented lakes and from 2 non-augmented lakes. Cores from the remaining lakes were sampled at broader intervals to depths that would precede the augmentation period. Diatom assemblages were evaluated two ways, first by comparing summary autecological percentages of taxa based on salinity (ionic), pH, and trophic preferences as defined by the literature, and second using a weighted-averaging transfer function that yields pH inferences for sedimented diatoms based on a calibration set of 74 lakes ($r^2$ = 0.82, RMSE = 0.52).

Eleven of the 13 augmented lakes showed evidence of recent alkalization as suggested by diatom pH autecological preferences, whereas only 3 of the 14 non-augmented lakes showed shifts towards alkaline conditions. Similarly, the WA pH model suggested pH increases in 11 of the augmented lakes, but in only 5 of the non-augmented lakes. Sedimented diatoms in 11 augmented lakes showed preferences for higher trophic state conditions in recent times whereas increased trophic state was indicated in only 6 non-augmented lakes. Diatom salinity preferences were only slightly higher in augmented (6) than in non-augmented (4) lakes. Determining specific causes for water-quality change is complex because lakes in this region are potentially affected by many anthropogenic factors, including stormwater and agricultural runoffs or septic sources, but assuming that these factors affected both sets of study lakes about equally, our results suggest that direct augmentation of dilute surface waters from the deep aquifer in karst regions is likely to cause discernible changes in the chemistry and biology of lakes.

## Impacts of Climate Change and Oils Sands on Phytoplankton Production of Boreal Lakes


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As development of the Athabasca Oil Sands continues, there is increasing potential for perturbation of the structure and function of adjacent aquatic systems in Saskatchewan's boreal region. Atmospheric pollutants emitted in a plume from the Alberta Oil Sands development extend into northwestern Saskatchewan (SK) and may be a source of nitrogen (N) and other contaminants to downwind lakes. Nitrogen deposition can potentially result in lake acidification, but can also increase nutrient loading and lake production, particularly in lakes where algal populations are limited by N supply. However, to date, it has not been possible to isolate the potential effects of industrial development from those of regional climate change.

The design of this study attempts to separate industrial and climatic stressors of lake production using multiple paleolimnological proxies. If industrial sources impact SK lakes, we hypothesize that only N-limited lakes within the plume will exhibit a response (e.g., increased primary production, acidification). Whereas, if climate variation is significant, a coherent change will occur within and outside the plume. Sediment cores were taken from 16 N- or phosphorus (P)-limited lakes located inside the Oil Sands plume and in un-impacted reference regions. Sedimentary stable isotopes of N and carbon (C) deposited over the past 100 years were analyzed to estimate changes in nutrient sources and C cycling. Isotope data will be compared to other proxies included in this study, such as fossil pigments, cladocera, diatoms, and scaled chrysophytes.

Historical $\delta^{15}N$ sedimentary profiles indicate that $N_2$-fixation may be an important source of dissolved N in N-limited lakes. Initial C data suggest that the $\delta^{13}C$ of SK boreal lake sediment have decreased over the last 100 years. In N-limited lakes, this decrease begins post-1950s and is approximately twice the trend in reference lakes, suggesting possible acidification or change in internal C cycling is occurring. After the 1940s, impacted, N-limited lakes show a decline in the C:N of sediment organic matter and reaches a minimum of 10. This decline suggests an increase in phytoplankton biomass in recent years and may indicate a more productive state. Overall, initial results indicate that N deposition from the Oil Sands may be causing increased production and alteration of C cycling in N-limited boreal lakes in SK.

# Stratigraphic Evolution of the Lake Tanganyika Rift

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New commercial seismic reflection data collected from the southeastern part of Lake Tanganyika provide an opportunity to make new substantially new observations and interpretations of the evolution of Lake Tanganyika. These new data, acquired by Beach Energy Ltd., provide the best new deep subsurface images of the Lake Tanganyika rift since the Project PROBE data collection in the early 1980's. New observations and interpretations build upon previous work, and integrate the new and legacy multichannel seismic (MCS) reflection data sets.

A critical new observation in these data is the confirmation of a sequence of reflections beneath the "Nyanja Event", a widespread set of high-amplitude reflections visible at or near the base of the section across the entire survey area. Previously this was considered to be the base of the syn-rift section, but here we interpret the Nyanja Event as representing the onset of the current extension stage. New MCS data clearly show that there were earlier episodes of sedimentation and perhaps extension that predate the modern lake. These deep reflections are locally absent in many places, possibly on account of attenuation of the acoustic signal by the Nyanja Event surface. One area of sub-Nyanja Event strata extends axially for a ~70 km long stretch of the Manda Half Graben. These likely represent deposits from a discrete paleolake.

The late-Cenozoic section above the Nyanja Event is separated into six depositional sequences, identified as S1- S6. The earliest, post-Nyanja Event sequences (S1) contain reflection packages with low to moderate amplitudes, low frequencies, and poor continuity. This sequence is generally uniform in thickness and internal character over broad reaches of the study area, and is likely indicative of shallow lacustrine and fluvial intervals that dominated during early phases of rifting. Overall relief in the system during S1time was considerably less than at present. Following the stratigraphic transition to Sequence S2, there is a sharp transition to a reflection package with very high-amplitude, high frequency reflections with excellent continuity (S2). This is interpreted as a change to deeper lacustrine conditions, and is likely an interval of source rock accumulation. In late S2 time, and accelerating during S3 time, we observe increased rates of gravity-induced sediment flows, and enhanced stratal truncations along many key surfaces, indicative of increasing variability in lake level, sediment dynamics and transport, and also relief in the lake and greater rift valley.

Recent sedimentation in the southern part of the basin is considerably faster than in the northern areas, likely on account of the three axial drainages that enter at the lake's southern tip. The northern reaches of the study area have been profoundly influenced by a recent connection with the Lake Rukwa Rift, when that lake overflowed via the Ifume River. Extensive deltaic deposits and corresponding deep-water, coarse grained materials are observed emanating from this area, and which provide ample stratigraphic targets and opportunities for hosting hydrocarbon reservoir facies.

# Precipitation of Calcium Carbonate in a Shallow Lake: Assessing the Role of Primary Production, Organic Matter Degradation and Sediment Mixing

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In this presentation the genesis of carbonates in a shallow eutrophic lake (Lake Sarbsko, Poland) is deciphered. The lake is located on the southern Baltic coast in Poland and its specificity lies in its high productivity, seasonal changes in salinity, and intense vertical mixing of water column and bottom sediments. Therefore, hydrochemical processes in the lake water column are strongly affected by microbial processes in the sediments. Emphasis is placed upon the relationship between carbonate sedimentation and microbial degradation of organic matter, as well as on vertical mixing of sediments. The cycling of carbonates in the lake was investigated by an analysis of lake water chemistry (pH, $Ca^{2+}$, $Mg^{2+}$, alkalinity, $SI_{calc}$) and the stable carbon isotope composition ($\delta^{13}C$) of dissolved inorganic carbon and sedimentary calcite.

It was established that:

1. The precipitation of $CaCO_3$ in Lake Sarbsko occurs in surface and bottom water (and not within the pore waters) owing to intense photosynthesis.
2. The $CaCO_3$ is not formed in the pore waters despite the fact that in some periods the $SI_{calc}$ values are reasonably high. It is hypothesized that the strong oversaturation is caused by higher salinity of pore waters and the inhibiting effect of $Mg^{2+}$ on calcite crystallization.
3. $\delta^{13}C_{calc}$ in sedimentary calcite argue for a major role of organic matter-derived carbon in precipitated calcite. This is presumably due to coincidence between the maximum phytoplankton activity in the lake water column and the enhanced intensity of microbial decomposition of organic matter in summer. $^{12}C$-enriched carbon is released from the decomposing organic matter and incorporated into precipitating $CaCO_3$.
4. During the precipitation of calcite, Lake Sarbsko water displays undersaturation of $CO_2$ and the invasion of atmospheric $CO_2$ is favoured. Consequently, atmospherically derived carbon can contribute to $\delta^{13}C_{calc}$ signatures.
5. The precipitation of calcite in Lake Sarbsko occurs within a relatively short time during the mid-summer. In late summer it is suppressed by the vertical mixing of lake waters and sediments, which leads to an increase in $pCO_2$ and a lowering in pH in the surface and bottom waters. A similar effect might be caused by the very intense precipitation of calcite in mid-summer. Consequently, both turbulent mixing of the lake and decalcification of lake water can decrease $CaCO_3$ saturation in the lake.
6. The very negative values of $SI_{calc}$ in pore waters indicate that during summer dissolution of $CaCO_3$ is favoured within the sediments.

## Production of $CH_4$ and $CO_2$ in Coastal Lakes on the Polish Baltic Coast: Driving Factors, Intensity and Temporal Variability

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Coastal lakes along the Polish Baltic coast are very productive freshwater/brackishwater ecosystems and potential sources of $CH_4$ and $CO_2$. Among many factors controlling production of microbial gases salinity seems to be of great importance and it is known to affect the mechanism of methanogenesis.

Salinity becomes more and more an important ecological factor in coastal ecosystems due to increasing frequency of saltwater ingressions to coastal lakes. Nevertheless, it is not established whether in these environments the effect of salinity on microbial processes can be distinguished from the changes governed by temperature and bioproductivity.

To verify this we selected 7 coastal lakes located on the Polish Baltic coast: Resko, Jamno, Bukowo, Kopan, Wicko, Gardno and Lebsko which display changes in salinity between 0.1 and 6.57‰. In these lakes we sampled sediment gas and water to analyze concentrations of $CH_4$, molecular composition of gas as well as stable C and H isotope signatures of $CH_4$ and $CO_2$.

It was found that: (1i) the concentrations of $CH_4$ in lake waters are rather low, (2) the lakes display different pathways of methanogenesis and that (3) there is no clear relationship between salinity and the composition of gas.

## Stable C Isotope Record of Short-Term Changes of Water Level in the Lakes of Different Morphometry: Lake Anastazewo and Lake Skulskie, Central Poland

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We present the stable C isotope record of the changes in water level of the two morphologically different lakes in central Poland within the past 20 years. The goal of the research was to explain the relationship between lake water level and δ13C signatures in bulk sedimentary organic matter (δ13CTOC) and to assess the potential of δ13CTOC as a paleolimnological proxy of lake level changes. This was done by the comparison of the fossil δ13CTOC record with instrumental data on lake level changes in a shallow and small lake as well as in a large and deep basin. In both lakes the elevation of the water table varied greatly between 1980 and 2000 AD. The δ13CTOC data have been supplemented with δ15N, bulk geochemistry as well as paleoecological data. We showed that the δ13CTOC react to short-term and low-amplitude fluctuations in the water level however the response is highly dependent on the morphometry of the lake. In shallow and small basin δ13CTOC decreased along with lake level drop due to oxidation and greater input of terrestrial organic matter. On the contrary, in deep/large lake δ13CTOC decreased with increasing water level due to enhanced delivery of terrestrial organic matter to the lake during highstands. Our results have broad paleolimnological implications as they show that the δ13CTOC cannot act as a universal paleohydrological proxy. Its interpretation can be ambiguous and must be supported with additional geochemical and paleocological information from the studied lake.

# Using Phytoliths to Reconstruct Paleolimnological and Terrestrial Vegetation History at Orbital Time Scales from the Early Pleistocene West Turkana, Kenya, Drill Core of the Hominin Sites and Paleolakes Drilling Project (HSPDP)

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Phytoliths are microscopic opal silica plant remains that are deposited in soils and lake sediments after the plant-parts that produce them decay. Pollen and phytoliths share some similarities in how they are extracted and quantified; however, there are significant differences in taphonomy, preservation and taxonomic resolution. One difference is that phytolith records tend to represent a more localized vegetation signal than that derived from pollen. A major strength of phytolith analysis is its ability to taxonomically resolve grasses (Poaceae) to subfamily, tribe and even lower levels of identification. In East Africa, the overwhelming majority of grasses can be categorized into four plant functional types (PFTs): $C_3$ cool climate/shade tolerant (Pooideae), $C_3$ wet/shade tolerant (Bambusoideae), $C_4$ mesophytic (Panicoideae), and $C_4$ xerophytic (Chloridoideae). Other important phytolith producing taxa in the region include sedges (Cyperaceae), palms (Arecaceae) and woody dicotyledonous trees and shrubs.

During the summer of 2013, researchers from the Hominin Sites and Paleolakes Drilling Project (HSPDP) recovered a 216 meter long drill core (~2.0–1.4 Ma) from the west side of Lake Turkana, in northern Kenya, which targeted deposits of paleolake Lorenyang, a predecessor of the modern Lake Turkana. Initial core descriptions and multi-sensor core logging was completed in the fall of 2013 at LacCore (U of MN). For phytolith extraction, organics and carbonates were removed from 1-$cm^3$ samples using strong acid and base. Clays were removed using gravity settling and siliciclastics were removed using density separation. Phytolith counts at 96 cm (~2,400 yr) resolution have recently been completed, and phytolith preservation ranged from excellent to poor.

Intervals of pristine phytolith preservation and high phytolith concentrations appear to be correlated with periods of insolation maxima, and may reflect freshwater conditions associated with marsh discharge into paleolake Lorenyang. Smear slide analysis of these samples suggest they were formed under low energy settings. Intervals with poor phytolith preservation or a total loss of biogenic silica due alkaline porewater conditions appear to be correlated with periods of insolation minima and sequences of dampened insolation maxima. Terrestrial vegetation appears to have responded to insolation forcing as well, with mesic and arboreal taxa increasing in abundance towards insolation maxima. Within the very localized phytolith source area, transitions from fresh to alkaline porewater, mesic to xeric soil moisture, wooded to more open habitats, and vise versa, appear to have been rapid. These rapid transitions may have had implications on hominin mobility and resource utilization. These results demonstrate that phytoliths are useful indicators of both paleolimnological and local vegetation history, and provide data that is complimentary to well established terrestrial vegetation proxies such as pollen and stable isotope analysis.

# Tephrochronology and Paleoenvironmental Change During the Past 15,000 years from Whitshed Lakes, South-Central Alaska

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Sediment cores from Upper and Lower Whitshed Lakes located near Cordova, Alaska were used to create a tephrochronology and to reconstruct environmental and climatic change during the past 15,000 years. Independent age models were developed for both lakes using radiocarbon dates, and profiles of short-lived radioisotopes for the surface of the cores. The geochemistry of seven unique tephras was analyzed for major oxides and used along with the stratigraphy of magnetic susceptibility (MS) to correlate four visible and disseminated tephra layers between the two lakes. The correlated tephra were used to synchronize the age models, which reduced the uncertainty in both the age models and the age estimates of the tephras.

Several proxies for productivity were analyzed in the cores: organic matter, biogenic silica (BSi), and spectrally inferred chlorophyll-*a*. Following deglaciation by 14.6 ka, these proxies indicate a return to colder, unproductive conditions during the Younger Dryas (12.5–11.6 ka). From 10.9 to 2.7 ka, BSi in both lakes is generally high and stable. From 2.7 to 1.7 ka Upper Whitshed Lake BSi declined from 30 to 10%, coupled with a decrease in the relative concentration of chlorophyll-a (650–700 nm trough area), most likely due to a reduction in nitrogen input as alder (*Alnus*) was replaced by conifers (*Picea* and *Tsuga*) (Tingley and others, 2013). In Lower Whitshed Lake a much smaller shift in BSi occurs at the same time (from 30 to 22%). Upper Whitshed BSi is negatively correlated with summer precipitable water as represented by the local grid point in NCEP climate reanalysis product, suggesting that the reduction in BSi after 2.7 ka could also be driven by increased summer cloudiness (reduced photosynthesis), or increased summer precipitation (increased sedimentation, diluting BSi).

From 1663 ± 52 until 1964 CE, Lower Whitshed Lake was connected with the Gulf of Alaska due to a rise in RSL (Garret and others, 2015). The sill rose above sea level during the 1964 Great Alaska Earthquake.

The paired-lake comparison allows for an investigation of the replicability and uncertainty of proxies analyzed in both lakes. Spikes in MS associated with visible and disseminated tephra are found in both lakes. Millennial-scale patterns within BSi and OM are similar between the two lakes, and these proxies correlate significantly between the two lakes ($R^2 = 0.18$, $p = 0.020$; $R^2 = 0.44$, $p = 0.001$, respectively). However, the BSi records contain substantially more variability between the records compared to the signal that is common to the records and the signal-to-noise ratio is less than 1, suggesting that a large portion of the variability in these records is not climatically driven. Discrepancies in the BSi record are likely driven by different environmental conditions within the lakes, potentially caused by a marine influence on Lower Whitshed Lake.

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# Sedimentary Model of Modern Beach Bar in Qinghai Lake, China

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The beach bar, as a new important oil and gas reservoir in China, is now an important target for exploration. However, its depositional mechanism has not yet been fully modeled. Qinghai Lake, the largest modern lake in China, is the focus of our study.

Modern beach bars are analyzed and general sedimentary models are established based on modern coastal dynamic theory, which includes the analysis of theoretical and mathematical models and the modern sedimentary investigation. The key factors controlling the development of beach bars in Qinghai Lake are the wave length and height, the lakeshore terrain, material supply, and lake level changes. Breaker bar and surf bar I are both developed in a gentle gradient slope (less than 1/20). Breaker bars develop near the breaker zone whose water depth is the function of wave height and wave length produced in the deep lake. The maximum thickness of breaker bar is the depth of water at the breaker point of the waves minus the breaker wave height. Surf bar I develops in the surf zone where the surf water depth is equal to the breaker wave height. The maximum thickness of surf bar I is the same as the breaker wave height. Both kinds of beach bars incline towards the lake center in the surf zone and breaker zone. In addition, the breaker zone and surf zone merge together in high gradients (more than 1/20), so both kinds of bars are indistinguishable from each other. These types of bars in high gradient settings are here called surf bar II with a maximum thickness equal to the water depth of the breaker wave.

Clearly, the use of marine coastal dynamic theory can be applied to lake shorelines. Wind waves and slope play important roles in the location and construction of Qinghai Lake beach bars. The thickness of these beach bars is determined by the height of the wind waves and the angle of the shore slope.

# Prospects for a Million-Year History of the Mono Lake Basin from a Long Drill Core

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The Mono Lake basin is an extensional basin on the eastern flank of the Sierra Nevada, and has long been occupied by a lake of variable size, depth, chemistry, and hydrology. It has provided a catchment for pyroclastic products of Plio-Pleistocene volcanic activity from surrounding volcanic centers of Long Valley, Mono-Inyo Craters and the Bodie Hills. Dramatic glacial canyons, many containing multiple sets of moraines, terminate in the lake basin, making the lake a proximal archive of glacial sediment and run-off from the Sierra Nevada. The combination of large fluctuations in lake level with volcanic and hydrothermal activity makes Mono Lake a geochemically intriguing water body in which to explore biological and mineralogical interactions.

The last glacial period at Mono Lake is preserved in one of the classic Quaternary lake sequences in the western US, the Wilson Creek Formation (WCF). The rock flour- and tephra-rich sediments of the WCF are exposed in multiple creek beds around the basin, and preserve rich, high-quality records of paleoclimatic and paleomagnetic change, as well as an exceptional record of regional volcanism. The post-glacial record remains elusive, in deep water buried beneath disrupted deposits resulting from the uplift of Paoha Island ~300 years ago, and in shallower water interrupted by dramatic lowstands during intervals of arid climate. The great potential for a record of older glacial-interglacial climate variability and volcanic activity is indicated by deformed and incomplete exposures on Paoha Island, which contain interbedded glacial sediment, diatomites, and multiple tephras.

We propose that a long drill core in Mono Lake could connect these disparate archives and produce a unique record of past changes in the magnetic field, the climate system, regional volcanic and tectonic activity, and extreme biogeochemistry. Seismic data and the stratigraphy of multiple gravity and piston cores, along with other geophysical data, provide a framework for selecting coring sites that optimize the paleoclimatic, paleomagnetic, volcanologic, and biogeochemical records that can be recovered from the Mono Lake basin.

# Holocene Climate History of the Central Eastern Sierra from High-Resolution Geochemistry of the BINGO Sediment Core, Mono Lake, California, USA


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Mono Lake, California is a closed-basin lake on the east side of the Sierra Nevada, and inflow from snowmelt dominates the modern hydrology. Lake-level changes have been extensively described for the last glacial period (>12,000 years ago; Zimmerman and others, 2011) and the late Holocene (Stine, 1990), but are poorly known for the intervening period. We recovered a 6.25 m-long core from ~3 m of water in the western embayment of Mono Lake, which records at least the last 10,000 years. The sediments of the core are variable, ranging from black and gray silt near the base, laminated olive-green silt through the middle, to layers of peach-colored carbonate nodules interbedded with gray and olive silt and pea-green organic ooze in the mid-late Holocene. Volcanic tephras from <1 to 8 cm thick occur throughout the core.

Results of 0.5 cm-resolution scanning-X-ray fluoresence (XRF) analysis indicate changes in lithology due to volcanism, erosion, and changing lake level and chemistry. Titanium (Ti) records the dominant detrital input, from weathering of Sierra Nevada granite to the west and Miocene and Pliocene volcanic rocks to the north, east, and south. The locations of potassium (K)-rich rhyolitic tephras of the Mono-Inyo Craters are indicated by dramatic peaks in the K/Ti ratio. Calcium (Ca) and strontium (Sr) correspond with occurrence of carbonate-rich layers, due to high concentrations of coarse biogenic carbonate, such as was mapped by Newton (1994) in very shallow waters in the modern lake.

The lowermost 1.5 m of the BINGO core is finely bedded silt with significant disruption of the bedding, terminating in an unconformity. This interval likely indicates a period of highly dynamic lake level during the deglaciation. The early Holocene period, from ~10,300 to ~7,500 cal yr BP, is characterized by finely laminated olive-green silt with very homogenous chemistry, probably indicating a stable, stratified lake and a relatively wet climate, consistent with many regional records (e.g., Antinao and MacDonald, 2013). This section merits mm-scale scanning and petrographic examination in the future. The end of the wet early Holocene is marked by increasing frequency of authigenic carbonate layers after ~8,000 cal yr BP, indicating the shoreline periodically regressing toward the core site. After ~7,500 cal yr BP, the sediment in BINGO becomes highly variable with increased occurrence of carbonate layers, suggesting a lower and more variable lake level. A short interval of olive-green, laminated silt just above a radiocarbon date of 3,870 ± 360 cal yr BP may record the Dechambeau Ranch highstand of Stine (1990), although low Ca/Ti levels and well-bedded silt appear as early as ~4,300 cal yr BP. The highstand terminates at ~3,350 cal yr BP in a dramatic rise to some of the highest Ca/Ti levels in the core, suggesting a period of >1,000 years of extremely dry climate, regionally identified as the late Holocene dry period, lasting until ~2,070 cal yr BP.

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