

Multi-proxy reconstruction of changes in water level and organic matter sources related to climate change over the Holocene (Lake Titicaca, Bolivia)

J. Tolu¹, S. Guédron^{2,3}, E. Brisset², R. Bindler¹, P.A. Baker⁴ and S.C. Fritz⁵.

¹ Department of Ecology and Environmental Science, Umeå University, Sweden

² Institut de Recherche pour le Développement (IRD), ISTERre, UGA – Grenoble, France.

³ Instituto de Investigaciones Químicas - Universidad Mayor de San Andrés, La Paz, Bolivia.

⁴ Division of Earth and Ocean Sciences, Duke University, Durham, USA and Yachay Tech, Urcuqui, Ecuador

⁵ Department of Earth and Atmospheric Sciences, University of Nebraska – Lincoln, NE, USA

Abstract:

Over the late Holocene, five periods of low lake Titicaca level have been identified resulting from negative moisture balance for the northern Andean Altiplano (Abbott et al., 1997; Mourguiart et al., 1998). The aim of our project is to refine these water level variations and decipher the influence of climate change on lake productivity and catchment input over the entire Holocene.

To reach these objectives, a sediment core from the Chua basin (Lago Huiñaimarca) was sub-sampled at high resolution and analyzed for multi-element geochemistry (36 major/trace elements), isotopic composition of sulfur as well as for the molecular composition of organic matter (OM). This latter was determined using a new method based on pyrolysis-gas chromatography-mass spectrometry (Tolu et al., 2015). Beyond its rapidity and requirement for small sample mass (<1 mg), which are criterions for multi-proxy and high-resolution paleo-reconstruction, this method yielded semi-quantitative data on 163 organic compounds. These compounds belong to different biochemical classes (e.g., carbohydrate, lipid, chlorophyll) and are of different origins (e.g., plant, algal) and degradation status (Tolu et al., 2015), making it possible to both use specific biomarkers and investigate changes in the overall OM molecular composition.

The sediments deposited between ~ 8000 and 6000 BP were strongly enriched in (poly)aromatics, which are indicative of OM polycondensation during degradation, i.e. 36 ± 10 vs 7 ± 3 % for the last ~ 5000 years. Moreover, only the degradation products of, and no, high molecular mass carbohydrates/polysaccharides, proteins and chlorophylls (e.g., (alkyl)furans, (alkyl)pyrroles) could be identified. This major change in the OM molecular composition coincided with a drastic change in sedimentation rate (~ 4000 year in the first 63 cm and ~ 2000 year over the last 100 cm) and suggests low lake/catchment productivity and/or highly degradative environment between ~6000 and 5000 BC (very dry event).

Based on both geochemical and OM proxies, the last ~ 5000 years could be split into 3 main units as deduced from diatom reconstruction of Weide et al. (2015). From ~ 5000 to ~ 3000 BP, the Chua basin was a wetland due to dry climatic conditions. From our data, this period appears to present (i) the highest algal production, probably from Characeae (high carbonates content); (ii) lower plant OM due to lower input from the catchment/lake shoreline (lower content of refractory elements); and (iii) higher proportion of degraded OM due to oxic conditions. This unit is surrounded by two shell layers which were characterized by biomarkers for plant growing in humid environments and lower proportion of degraded OM due to less oxic conditions (higher water level). The sediments of the last c. 3000 years were deposited under deep lake conditions, but our data, and especially $\delta^{34}\text{S}$, Mn and Mo contents and ratios for OM freshness, showed additional water level fluctuations which are coherent with recent reconstructions based on diatoms (Weide et al., 2015).

References:

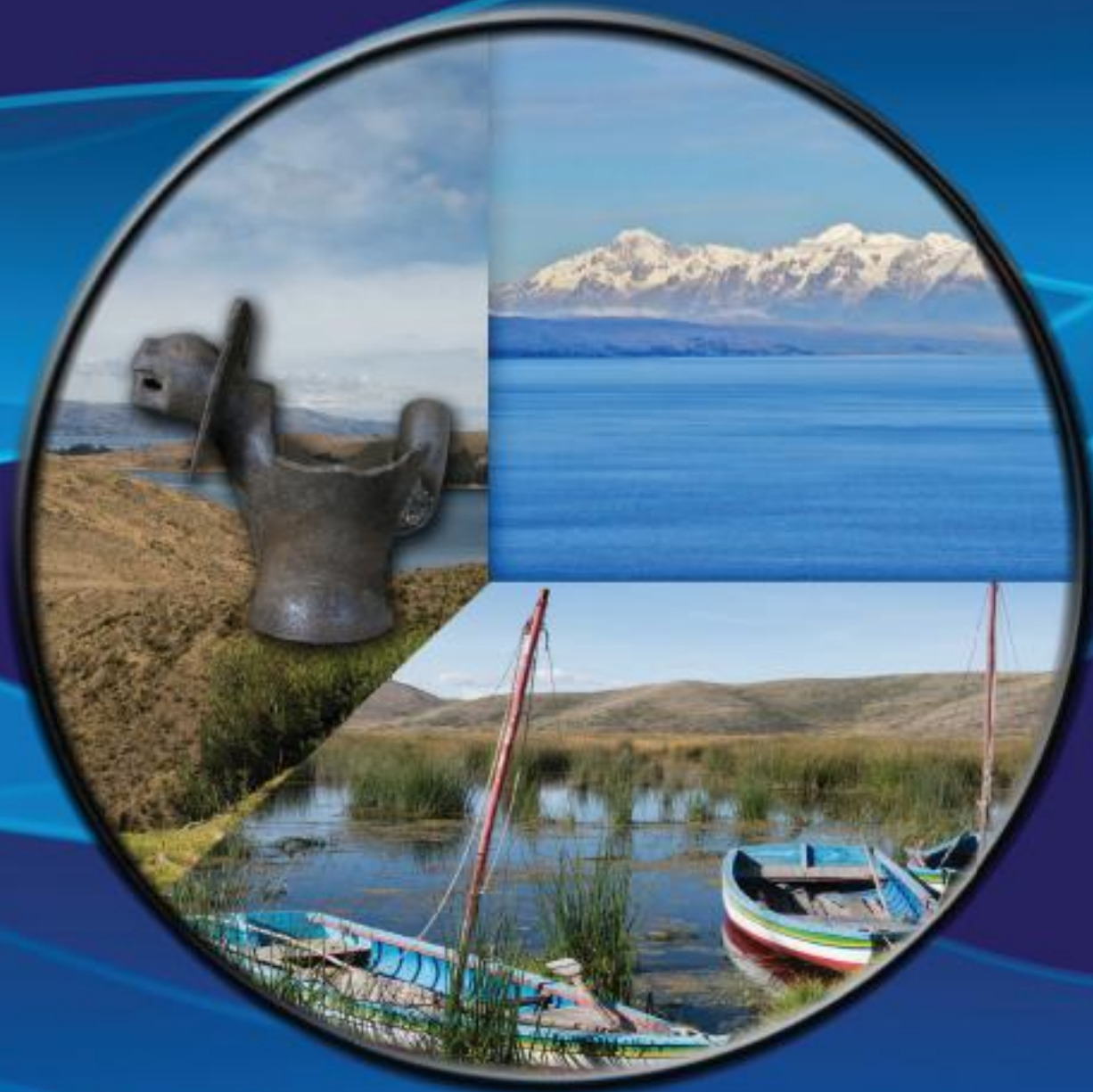
Abbott, M.B., Binford, M.W., Brenner, M. and Kelts, K.R., 1997. A 3500 ¹⁴C yr High-Resolution Record of Water-Level Changes in Lake Titicaca, Bolivia/Peru. *Quaternary Research*, 47(2): 169-180.

Mourguiart, P. et al., 1998. Holocene palaeohydrology of Lake Titicaca estimated from an ostracod-based transfer function. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 143: 51-72.

Tolu, J., Gerber, L., Boily, J.-F. and Bindler, R., 2015. High-throughput characterization of sediment organic matter by pyrolysis gas chromatography/mass spectrometry and multivariate curve resolution: A promising analytical tool in (paleo) limnology. *Analytica chimica acta*, 880: 93-102.

Weide, M. et al., 2015. A Late Holocene Lake Level Reconstruction of Lago Huiñaimarca, Southern Lake Titicaca, Peru/Bolivia. In: USGS (Editor), Sixth International Limnogeology Congress. International Association of Limnology & USGS, Reno, Nevada, USA, pp. 225-226.

COLOQUIO INTERNACIONAL SOBRE LA CONTAMINACIÓN ACTUAL E HISTÓRICA EN LOS ECOSISTEMAS ACUÁTICOS ANDINOS



La Paz, 3 al 5 de mayo de 2016
Universidad Mayor de San Andrés, Cota Cota, La Paz





Proceedings

**International colloquium on current and ancient contamination in
Andes aquatic ecosystems**

**Coloquio internacional sobre la contaminación actual y histórica
en los ecosistemas acuáticos Andinos**

**Colloque international sur la contamination actuelle et historique
des écosystèmes aquatiques andins**

La Paz – May 3rd – 5th 2016

Universidad Mayor de San Andrés – Campus de Cota-cota, La Paz

Organization direction:

Stéphane Guédron (ISTerre-IRD/UMSA): stephane.guedron@ird.fr

Dario Acha Cordero (LCA/UMSA): darioacha@yahoo.ca

Marc-Antoine Vella (IFEA): mav.vella@gmail.com

Oswaldo Eduardo Ramos Ramos (IIQ/UMSA) : rroe@kth.se

Organization committee:

Stéphane Guédron (ISTerre-IRD/UMSA): stephane.guedron@ird.fr

Dario Acha Cordero (LCA/UMSA): darioacha@yahoo.ca

David Amouroux (LCABIE-IPREM/CNRS): david.amouroux@univ-pau.fr

Marc-Antoine Vella (IFEA): mav.vella@gmail.com

Christophe Delaere (ULB): Christophe.Delaere@ulb.ac.be

Oswaldo Eduardo Ramos Ramos (IIQ/UMSA) : rroe@kth.se

Mauricio. R. Ormachea Muñoz (IIQ/UMSA) : maurormache@gmail.com

Jorge Quintanilla (IIQ/UMSA): ceedi77@gmail.com

David Point (GET-IRD/UMSA): david.point@ird.fr

Céline Duwig (LTHE-IRD/UMSA): celine.duwig@ird.fr

General Planning

- **May 3rd 2016: Contamination and eutrophication of Lake Titicaca**

AM session: Mercury biogeochemistry and contamination of aquatic ecosystems of the Andes region

Keynote Lecture: Hg contamination in Latin America: the past is not what we think, nor the future (J.-R. Davee Guimarães).

PM session: Chemical contamination, eutrophication and monitoring of Lake Titicaca and its watershed

Keynote Lecture: Eutrophication of the Cohana Bay (D. Acha).

- **May 4th 2016: Arsenic issues in the Andes**

AM session: Arsenic biogeochemistry and contamination of aquatic ecosystems of the Andes region

Keynote Lecture: Arsenic contamination of groundwater (Chile) (G. Lobos).

PM session:

Workshop 1: Arsenic and mercury speciation.

Workshop 2: Paleoenvironmental studies in the Andean altiplano.

- **May 5th 2016: Historical reconstructions of the human-climate interactions in the altiplano: implication of archeological purposes**

AM session: Paleo-environmental reconstruction of Altiplano's archives

Keynote Lecture: Holocene Paleoclimatic and Paleoenvironmental History of the Lake Titicaca Basin (S. Fritz & P. Baker).

PM session: Archeology: historical human – environment interactions

Keynote Lecture: Recent contribution of terrestrial and subaquatic archeological investigation in Lake Titicaca (C. Delaere & M-A. Vella).