Impact of environmental changes on lacustrine dynamics in the Lake Pavin over the last 7,000 years (French Massif Central)

Léo Chassiot, Emmanuel Chapron, Aude Beauger, Yannick Miras, Patrick Albéric, Grégoire Ledoux, Patrick Lajeunesse, Markus Schwab, Anne-Lise Develle, Fabien Arnaud, et al.

Impact of environmental changes on lacustrine dynamics in the Lake Pavin over the last 7,000 years (French Massif Central)

Léo Chassiot[1], Emmanuel Chapron[1,2], Aude Beauger[3], Yannick Miras[3], Patrick Albéric[1], Grégoire Ledoux[4], Patrick Lajeunesse[4], Markus Schwab[5], Anne-Lise Develle[6], Fabien Arnaud[6], Anne-Catherine Lehours[7], Christian Di Giovanni[1] and Didier Jézéquel[8]

[1] *ISTO, UMR 7327, CNRS, Université d'Orléans, BRGM, Orléans, France.* leo.chassiot@cnrs-orleans.fr
[2] *GEODE, UMR 5062, CNRS, Université Toulouse 2, Toulouse, France.*
[3] *GEOLAB, UMR 6042, CNRS, Université Blaise Pascal, Clermont-Ferrand, France.*
[4] *CEN, Université Laval, Québec, Canada.*
[5] *GFZ, Postdam, Germany.*
[6] *EDYTEM, UMR 5204, CNRS, Université de Savoie, Le Bourget du Lac, France.*
[7] *LMGE, UMR 6023, Université Blaise-Pascal, Aubière, France.*
[8] *LGE, UMR 7047, Université Paris Diderot, IPGP, Paris, France.*

Keywords: Maar, paleolimnology, hazards

Lake records provide insight into the interactions between human societies, past climate and the natural environment. Maar lake basin fills are key sites for paleoenvironmental studies covering the Holocene and periods beyond (Negendank and Zolitschka, 1993, Augustinus et al., 2012). They also could record sedimentary events linked to natural hazards specific to volcanic area such as crater outburst and limnic eruption (Anzidei et al., 2008, Chapron et al., 2010). Lake Pavin (French Massif Central, France) located in Western Europe is a meromictic maar formed ca. 7,000 years ago (Gewelt and Juvigné, 1988, Chapron et al., 2010). This lake is almost circular with an area of 44 ha and a maximum depth of 92 meters with anoxic waters below 60 meters depth. Recent studies on the water column confirm the presence of methane and carbon dioxide in these anoxic waters (Fig. 1, Busigny et al., 2014 and references therein).

Up to now, few paleoenvironmental studies have been made in this lake (Stebich et al., 2005, Schettler et al., 2007). Moreover, questions remain about the evolution of limnic and trophic status of this meromictic maar lake and natural hazards associated to it. For these reasons, this study focused on sedimentary deposits using geophysical mapping techniques (multibeam bathymetry and high-resolution seismic reflection) and sediment cores retrieved both in shallow water environments and within anoxic waters in the deep central basin (Fig. 1).

Multi-proxies analyses were carried out on sediments including X-Ray fluorescence, spectrophotometry and organic geochemistry by Rock-Eval pyrolysis. Radiocarbon dating has been performed both on leaves debris and bulk sediment in order to establish the chronology of sedimentary deposits (Blaauw, 2010).

Results report gas-rich sediments consisting primarily of diatoms, deposited in three sedimentary environments: a littoral area, a plateau clipped by a landslide scar in the northern part of the lake and a flat central basin surrounded by steep slopes (Chapron et al., 2010, 2012).

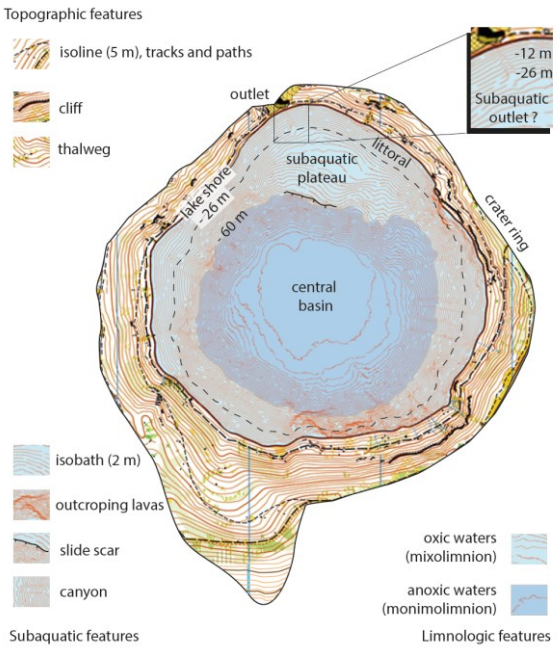

Fig. 1 – Geomorphological and bathymetric map of Lake Pavin and its catchment

In the central basin (Fig. 1), a 14 m long piston core was retrieved, covering the last 7,000 years. The sediment is composed of volcano-clastic materials covered by in-situ diatom-made sediment, interrupted by a massive unit resulting from a MWD. This event has been dated to ca. AD 1300 and corresponds to a fresh slide scar identified at the edge of the plateau (Chapron et al., 2010, 2012).

Throughout this core, changes in mineral and organic content reflects evolution in the trophic status of the lake from its origin to the present day, with a gradual transition from a young lacustrine system fed by clastic material toward an organic-rich maar with strong algal supplies. Results also show major differences in organic and inorganic content once the MWD occurred, highlighting its impact on the limnological evolution.

On the plateau (Fig. 1), acoustic mapping and sedimentary analyses indicates a MWD deposit surrounded by diatomites. This MWD is dated around AD 600 and may have been caused by a crater outburst that was followed by a water-level drop in the lake and a catastrophic flood in the valley downstream.

On the littoral environment, which consist of brownish sediments (Fig. 1), two erosive layers made of sand and/or leaves have been correlated to previously mentioned events (AD 600 and AD 1300) and have been deposited after wave-induced erosion of the lake shores. The major lake-level drop is also confirmed by (1) sedimentological evidences for a crater outburst flood downstream in the valley and (2) shifts in sedimentary organic matter composition after AD 600 within the entire lake.

Finally, this study underlines the impact of MWD on limnology. Even if the triggers of these major events remain unclear at this date, this work underlines their key-role on the trophic status evolution of maar Lake Pavin during the late Holocene. It also illustrates the instability of such gas-rich sediments, which can be easily reworked under climatic and tectonic trigger. Because catastrophic phenomena such as limnic eruption can occur into meromictic maar lakes, further evaluations have to be made to define the role of gravitational processes on natural hazards linked to these peculiar environments.

Acknowledgements

Authors would like to thank contributors to projects MEEDDAT and DICENTIM for fruitful discussions as well as field and laboratory assistance.

References

Anzidei, M., Carapezza, M.L., Esposito, A., Giordano, G., Lelli, M., Tarchini, L., 2008. The Albano maar lake high resolution bathymetry and disolved CO_2 budget (Colli Albani volcano, Italy): constrains to hazard evaluation, Journal of Volcanic and Geothermal Research, 171, 258-268.

Augustinus, P., Cochran, U., Kattel, G., D'Costa, D., Shane, P., 2012. Late Quaternary palolimnology of Onepoto maar, Auckland, New Zealand: implications for the drivers of regional paleoclimate. Quaternary International 253, 18-31.

Blaauw, M., 2010. Methods and code for 'classical' age-modelling of radiocarbon sequences. Quaternary Geology 5, 512-518.

Busigny, V., Planavsky, N.J., Jézéquel, D., Crowe, S., Louvat, P., Moureau, J., Viollier, E., Lyons, T.W., 2014. Iron isotopes in a Archean ocean analogue. Geochimica et Cosmochimica Acta 133, 443-462.

Chapron, E., Albéric, P., Jézéquel, D., Versteeg W., Bourdier, J.-L., Sitbon, J., 2010. Multidisciplinary characterisation of sedimentary processes in a recent maar lake (Lake Pavin, french Massif Central) and implication for natural hazards. Natural Hazards and Earth System Sciences 10, 1-13.

Chapron, E., Ledoux, G., Simonneau, A., Albéric P., St-Onge, G., Lajeunesse, P., Boivin, P., Desmet, M., 2012. New evidence of Holocene Mass Wasting Events in recent volcanic lakes from the French Massif Central (Lakes Pavin, Montcineyre and Chauvet) and implications for natural hazards. In: Yamada et al. (eds.) Submarine Mass movements and their consequences. Advances in natural and technological hazards research 31.

Gewelt, M., Juvigné, E., 1988. Téphrochronologie du Tardiglaciaire et de l'Holocène dans le Cantal, le Cézallier et les Mont Dore (Massif central, France) : résultats nouveaux et synthèse. In: Bulletin de l'Association française pour l'étude du quaternaire 25 : 25-34.

Negendank, J.F.W., Zolitschka, B., 1993. Paleolimnology of European Maar Lakes. Lectures Notes in Earth Sciences 49, 509 pp.

Schettler, G., Schwab, M.J., Stebich, M., 2007. A 700-year record of climate change based on geochemical and palynological data from varved sediments (Lac Pavin, France). Chemical Geology 240, 11-35.

Stebich, M., Brüchmann, C., Kulbe, T., Negendank, J.F.W., 2005. Vegetation history, human impact and climate change during the last 700 years recorded in annually laminated sediments of Lac Pavin, France. Review of Palaeobotany and Palynology 133, 115-133.