



A 2000-year lacustrine record of environmental change in the Middle-Atlas: the Lake Afourgagh (Morocco)

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Karstic lakes of the Middle-Atlas mountains in Morocco are of great interest in social, economic and ecological fields. Recurrent droughts and the evolution of agriculture since the early 1970s has led to a rapid worsening of these environments (falls in lake levels, sometimes with complete drainage, and soil erosion in lake catchments). The severe drop in the level of Lake Afourgagh during the last two decades (maximum depth of 15 m in 1984, 6m in 2005) has caused the exundation of the most recent deposits. These deposits have recorded the environmental fluctuations and thus the climatic and/or human factors responsible for their variations. The lake catchment, mainly composed of Liassic dolomites (about 63% of the surface) and limestones, is highly karstified. Karstification, coupled with local tectonics and triassic saliferous pocket dissolution resulted in the development of a range of karstic sinks where groundwater comes to the surface. Lake Afourgah is one of these groundwater fed lake, closed today, but showing marks of a past lake stabilisation level (palæoshore-line) corresponding to an outflow through a wadi. A multi-proxy study allowed the reconstitution of the lacustrine system successive environmental changes. The geometry and facies of Lake Afourgagh deposits provide evidence for successive major lake level fluctuations during the last 2,300 years. Sedimentation is mainly biogenic with the laying down of thick Charophyte-rich tufas interbedded with silty layers in

distal areas and palaeosols in proximal areas (lateral facies evolution). These alternations point to four major deposit sequences with lowstand phases dated at 2090, 1380, *ca.* 1200 and 660 cal BP. The successive environments (highly linked to the development of large charophyte meadows) and level fluctuations of the lake are constrained by the study of the biogenic phase, particularly charophytes (3 species), ostracods (15 species), diatoms (more than 35 species) and malacofauna (4 species). The mineralogical data display high carbonate contents, with aragonite that can account for up to 87 % of the total composition of the charophyte rich tufas. These observations are linked to the high Mg/Ca ratio of the water, to its variable salinity and to the capacity of some charophyte species to bioinduce aragonite along their stems. The ongoing study concerning organic matter (origin and composition), $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ will provide further informations about the environmental changes. The different climatic events are viewed in relation to those observed in the Middle-Atlas, and also to those of North Africa and the Mediterranean region. However, human activities considerably modulate the climatic impact today and have possibly done so over the last two millennias.