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Recent hydrological variability and flood events in Moroccan Middle-Atlas mountains: micro-scale investigation of lacustrine sediments

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Scientific context and objectives

Since the 1990s, the Mediterranean basin undergoes an increase in extreme precipitation events and droughts likely to intensify in the XXI century (IPCC, 2013). Regional climate models indicate a strengthening of flood episodes at the end of the XXI century in Morocco (Tramblay et al, 2012). To understand the recent hydrological variability in North Africa, our study focuses on geochemical and microsedimentological analysis of a short sedimentary sequence from Azigza lake (Fig. 1; 2). This endoreic lake is located in the Middle Atlas karst system.

Limited data on past lake level changes during the last decades are provided by Gayral & Panouse (1954), Flower et al. (1989) and Flower & Foster (1992). To refine our knowledge of past hydrological changes in this region, the first objective is to reconstruct high and low lake levels throughout the last hundred years. The second objective is to detect and count flood events.

Methods

1- Geochemistry
- XRF and microscopy
- X-ray fluorescence
- X-ray diffraction (XRD)
- SEM and energy dispersive scanner
- Flatbed transparency exchange technique
- Thin sections (acetone

2- Microsedimentology
- Thin sections (acetone
- Optical microscopy
- XRF and clays
- SEM and energy dispersive spectroscopy
- 15 kV and 90 min acquisition time
- Molybdenum tube
- Flatbed transparency
- SEM and energy dispersive scanner
- Optical microscopy
- XRF and clays

3- Vegetation
- Vegetation line
- Steep banks
- Paleoshorelines

Results

Lake level changes during the past hundred years are recorded in the geochemistry and the microfacies of the sedimentary sequence. High lake level facies (Fig. 6a, Facies 1) is deposited when lake shorelines are closer to the vegetation line and steep slopes (Fig. 1). This facies is characterized by light brown sediments, less organo/more minerogenic (Fig. 5, 25 cm depth), with several erosive structures containing wood fragments and calcite shells of ostracods (Fig. 6a, Facies 1). Its geochemical signature is defined by higher Si, K, Fe and Ti that indicates more detrital input. Since (1) Si covary with K (Fig. 5, PCA), and since (2) sands are poorly present in the sediment (Fig. 4), we interpret the Si signal as indicator of the finest detrital fraction (clays and fine silts) brought by superficial runoff (SEM-EDS images of silty quartz are available in Figure 6b, Facies 2). Flood events are marked by Mn peaks, which is interpreted as manganese oxides precipitation under well-oxygenated deep water after flood events. Facies 1 is deposited during periods of lower precipitations (Fig. 5).

Figure 2: Watershed DEM, bathymetry of Azigza lake and core location (X): AZA-13-1 (43.57°, -5.49° in water depth)

Figure 1: The karstic Azigza lake (Middle-Atlas, Morocco) is surrounded by paleoshorelines, emerged steep slopes and a cedar forest.

Figure 3: Azigza lake photographs showing several water level changes since the 50s

Figure 4: Laser diffraction grain size

Figure 5: Geochemistry (XRF intensity) VS lake level changes

Figure 6: Microsedimentology

Figure 7: Mineralogy (XRD)

Discussion and perspectives

Lake level changes during the past hundred years are recorded in the geochemistry and the microfacies of the sedimentary sequence. High lake level facies (Fig. 6a, Facies 1) is deposited when lake shorelines are closer to the vegetation line and steep slopes (Fig. 1). This facies is characterized by light brown sediments, less organo/more minerogenic (Fig. 5, 25 cm depth), with several erosive structures containing wood fragments and calcite shells of ostracods (Fig. 6a, Facies 1). Its geochemical signature is defined by higher Si, K, Fe and Ti that indicates more detrital input. Since (1) Si covary with K (Fig. 5, PCA), and since (2) sands are poorly present in the sediment (Fig. 4), we interpret the Si signal as indicator of the finest detrital fraction (clays and fine silts) brought by superficial runoff (SEM-EDS images of silty quartz are available in Figure 6b, Facies 2). Flood events are marked by Mn peaks, which is interpreted as manganese oxides precipitation under well-oxygenated deep water after flood events. Facies 1 is deposited during periods of lower precipitations (Fig. 5).

These results demonstrate the high potential of Azigza lake to help understanding the past hydrological variability of the Middle-Atlas. Indeed, its water level and hydrosedimentary system is sensitive to rapid (floods), as well as long-term (dry and wet periods during several decades) changes in the precipitation regime. The two meters-long sedimentary sequence, recently retrieved from the deeper basin, would allow the reconstruction of the hydrological variability of Azigza lake for the past few hundred years.