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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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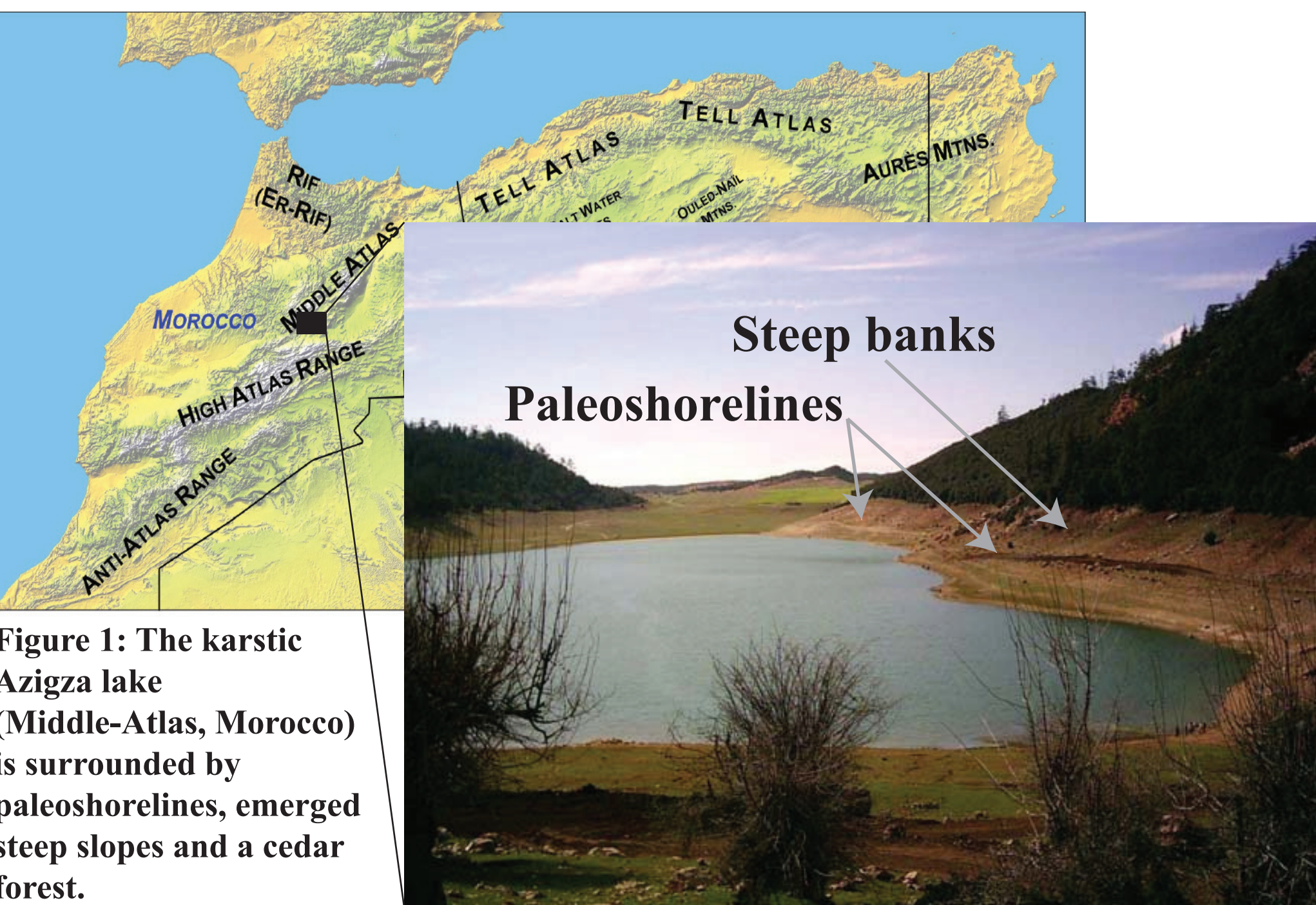


Figure 1: The karstic Azizga lake (Middle-Atlas, Morocco) is surrounded by paleoshorelines, emerged steep slopes and a cedar forest.

## 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 (Trambly 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 Azizga 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.

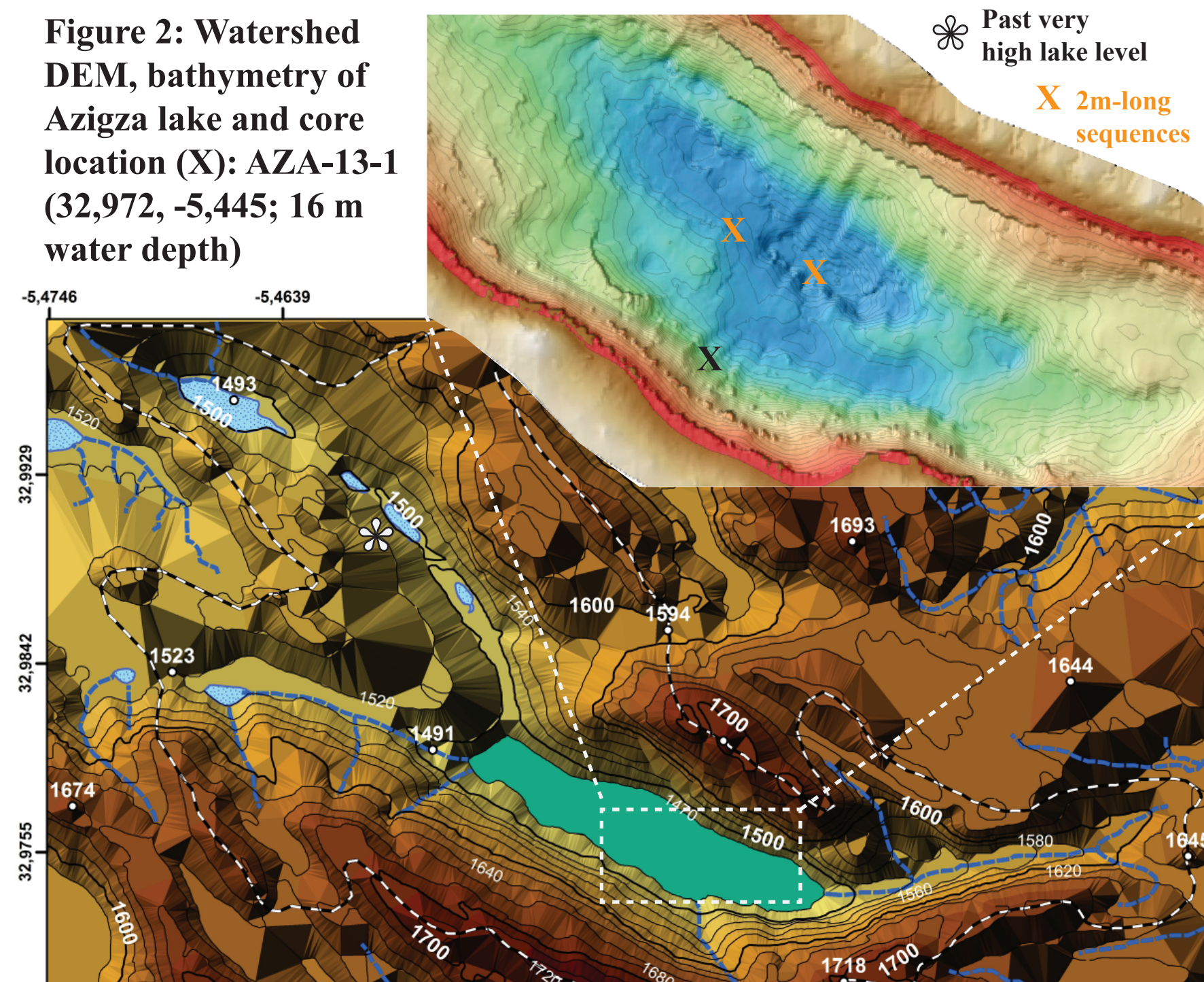


Figure 2: Watershed DEM, bathymetry of Azizga lake and core location (X): AZA-13-1 (32,972, -5,445; 16 m water depth)

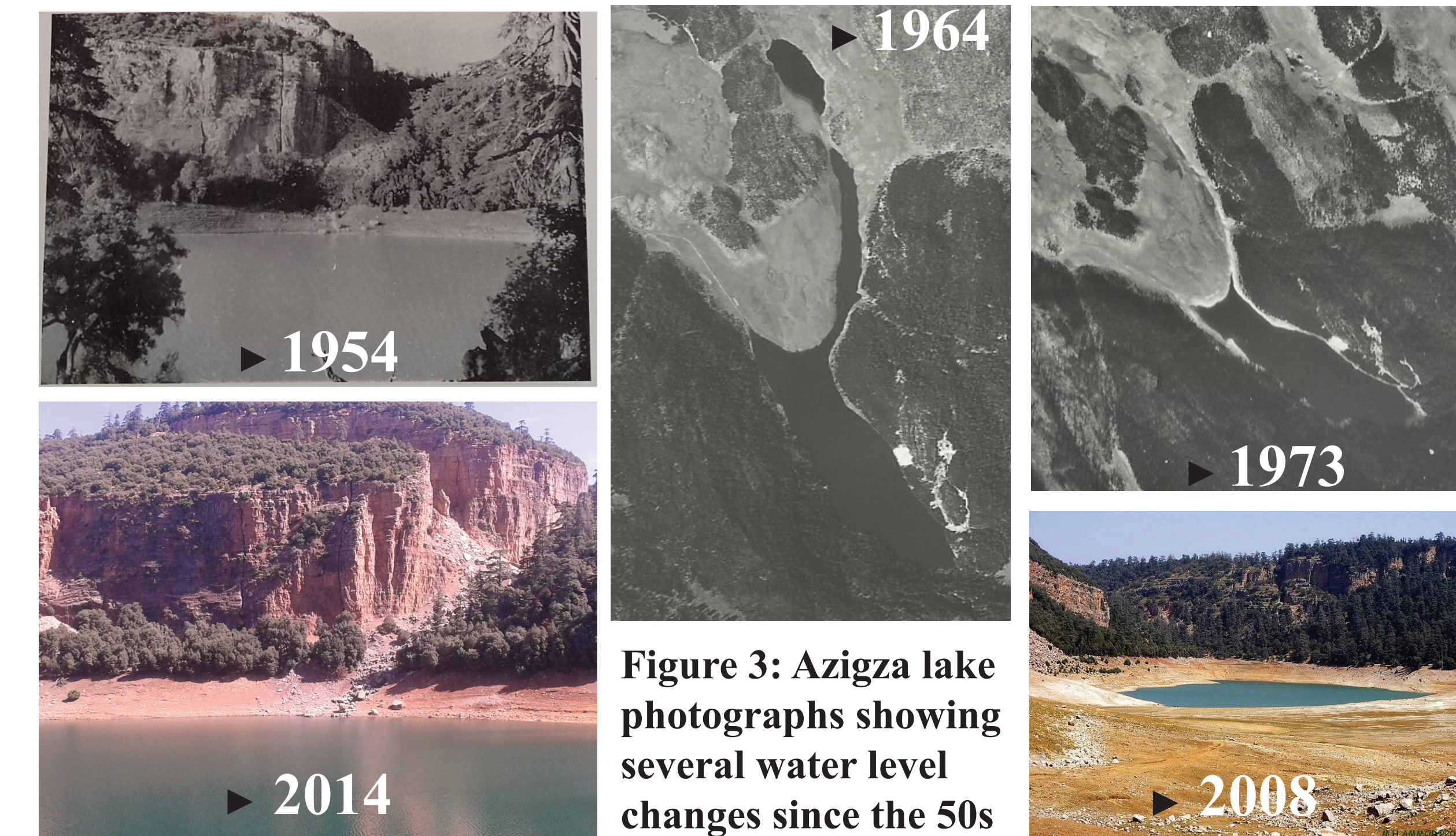
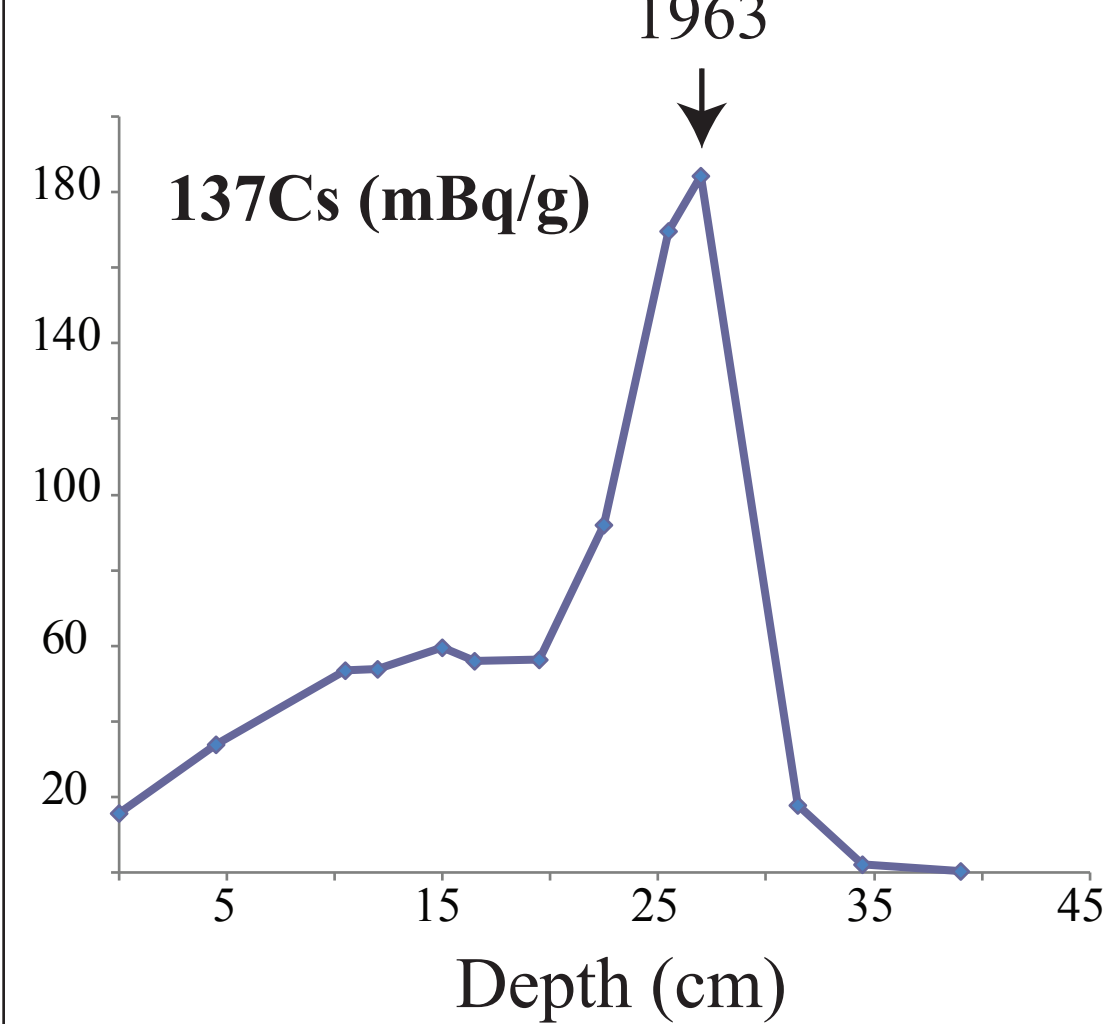


Figure 3: Azizga lake photographs showing several water level changes since the 50s

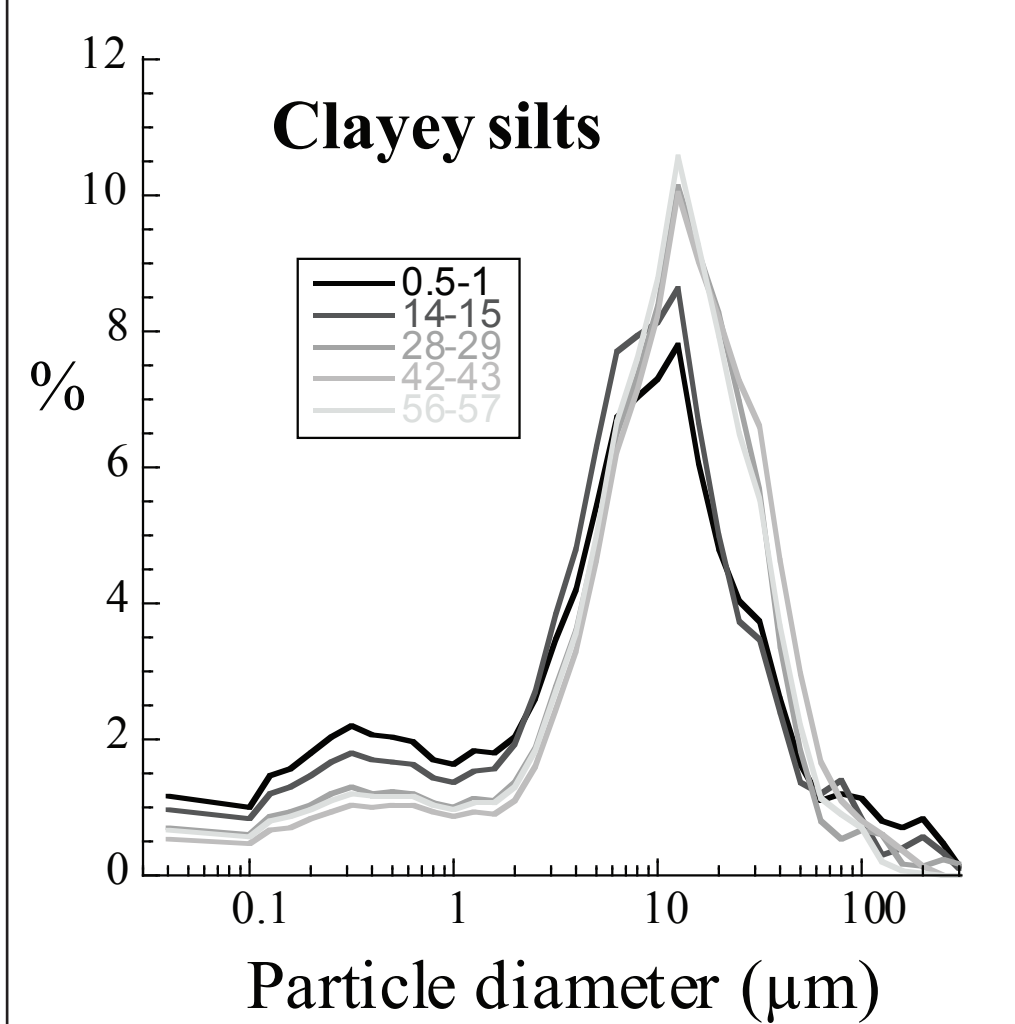
## Methods

- 1- Geochemistry (XRF) and mineralogy**
  - X-ray fluorescence
  - Itrax Core Scanner
  - Molybdenum tube
  - Resolution: 500 µm
  - 15 s time exposure
  - 30 kV and 25 mA
  - X-ray diffraction XRD (Fig. 7)
- 2- Microsedimentology**
  - Thin sections (acetone exchange technique)
  - Flatbed transparency scanner
  - Optical microscopy
  - SEM and energy dispersive spectroscopy (15 kV and 90 min acquisition time)

## Age model



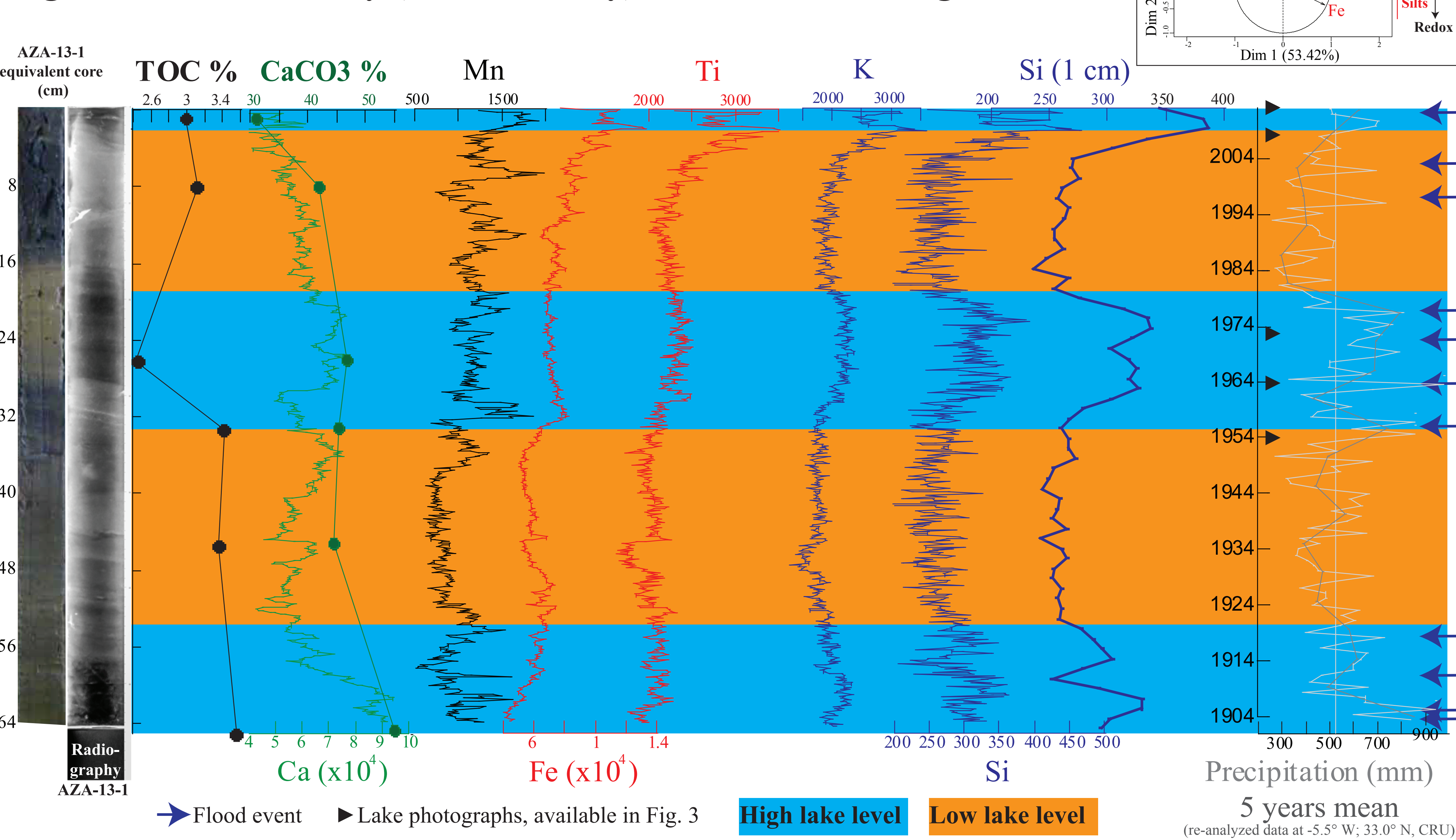
## Figure 4: Laser diffraction grain size



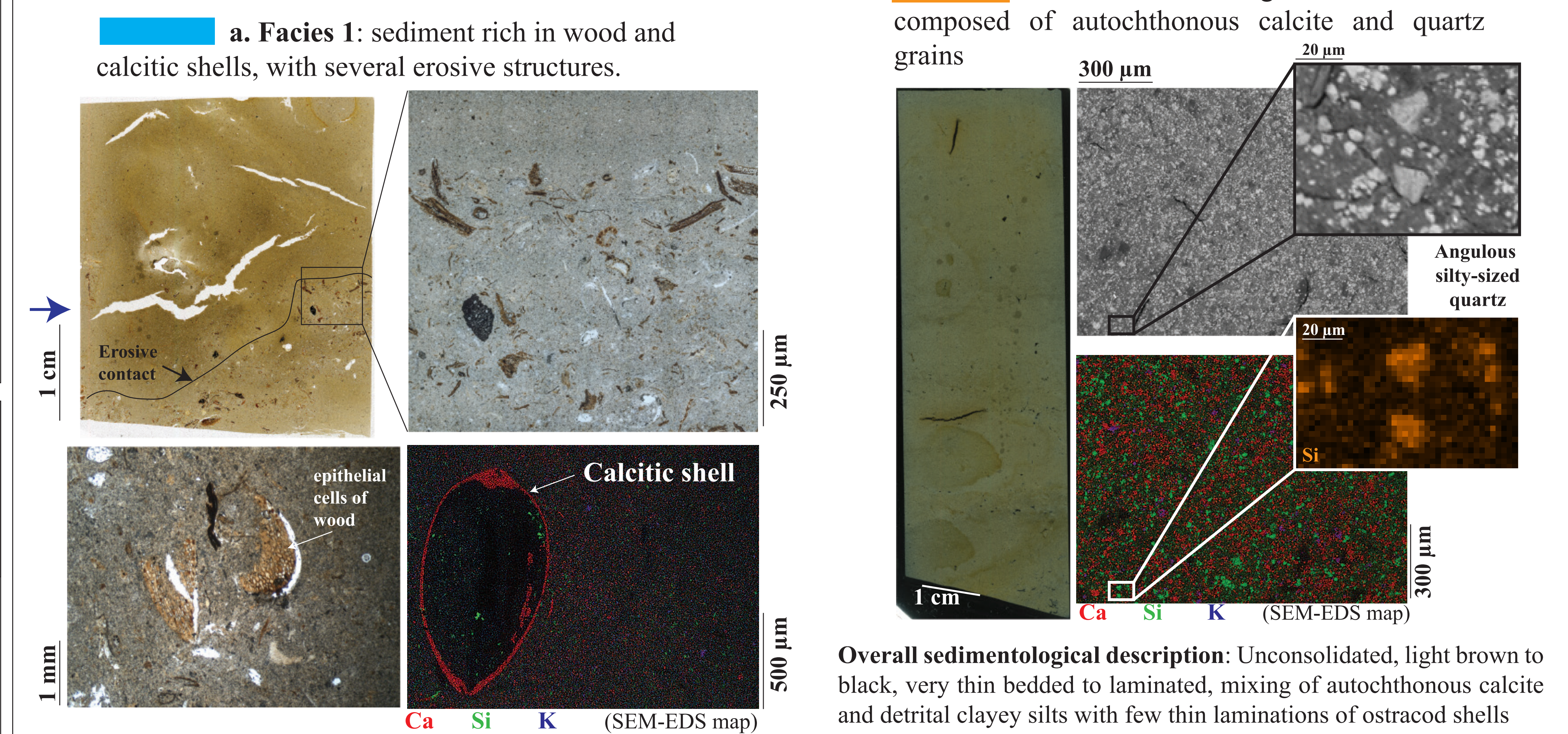
**137Cs peak at depth 27 cm + Homogenous grain size of detrital particles (=limited changes in the sedimentation rate)**  
=> Age at the base (64 cm depth) ~ year 1900

## Results

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

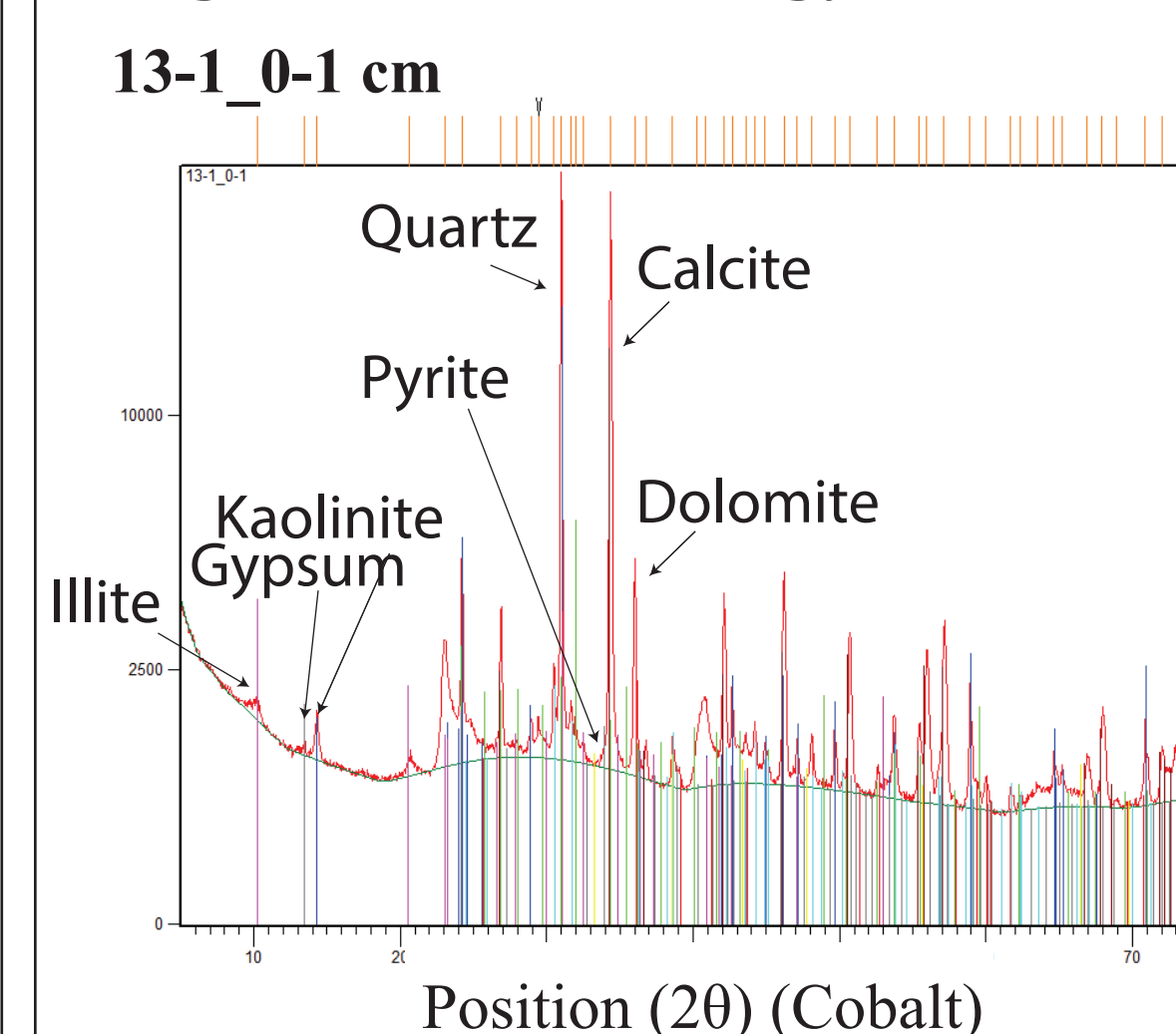


## Results Figure 6: Microsedimentology



## Results

### Figure 7: Mineralogy (XRD)



**Major peak calculations:** Calcite: 45%, Quartz: 38%, Dolomite: 10%, Aragonite: 3%, Kaolinite: 2%, Pyrite: 2%, Illite: 1%, Gypse: 0.5%

## 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 organic/more minerogenic (Fig. 5, 25 cm depth), with several erosive structures containing wood fragments and calcitic 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 precipitations under well-oxygenated deep water after flood events. **Facies 1 is deposited during periods of higher precipitations (Fig. 5).** - **Low lake level facies (Fig. 6b, Facies 2)** is deposited when shorelines are close to smoother bank slopes, (Fig. 1). This facies is represented by homogeneous sediments composed of autochthonous calcite and quartz grains, with substantial decreases in the XRF detrital proxies (Si, K, Ti and Fe, Fig. 5). Autochthonous calcite is not revealed in the CaCO3% and Ca-XRF signal because calcitic shells of ostracods are highly presents in Facies 1. **Facies 2 is deposited during periods of lower precipitations (Fig. 5).** These results demonstrate the high potential of Azizga lake to help understanding the past hydrological variability of the Middle-Atlas. Indeed, its water level and hydrosedimentary system are 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 Azizga lake for the past few hundred years.