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-Short Communication-

A 200,000-year record of the brine shrimp *Artemia* (Crustacea: Anostraca) remains in Lake Urmia, NW Iran

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1. Introduction

Carbonate fecal pellets and organic cysts of *Artemia* species constitute an important biogenic component of the sedimentary records in many saline and hypersaline lakes of the world. In some lakes they are the major contributor of biogenic carbonate sedimentation (e.g. Kelts & Shahrabi, 1986). However, little attention has so far been paid to their potential use in palaeoecology and palaeobiology. The geological record of *Artemia* remains extends back hundreds of thousands years in Great Salt Lake, Utah, USA (Eardley & Gvosdetsky, 1960). In Great Salt Lake, well-preserved *Artemia* cysts have been recovered from sediment cores as old as 27,000 years ago (last glacial maximum) (Clegg & Jackson, 1997). The later authors demonstrate that the chitinous shell surrounding the *Artemia* cysts would protects their DNA content from destructive environmental factors, including long periods of anoxic conditions, severe desiccation, temperature extremes and bacterial attack. They propose that the *Artemia* cysts present a unique opportunity for the scientific community to study the ancient DNA.

2. *Artemia* fecal pellets and cysts in Lake Urmia

Lake Urmia is the largest natural habitat of *Artemia urmiana* Günther, 1899 which is characterized by specific biometrical, morpho-metrical and genetic characteristics which distinguishes it from several other species of *Artemia* (Asem *et al.*, 2007). The oldest historical document that mentions the presence of *Artemia* dates to the Middle Ages more than 1,000 years

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ago (Asem, 2008). Recent findings of both fecal pellets and cysts extracted from a sedimentary profile show that the presence of *Artemia* in this lake is much older (Kelts & Shahrabi, 1986; Shah-Hosseini, 2003; Djamali *et al.*, 2008a). Figure 1 shows some Light microscopic and SEM pictures of *Artemia* fecal pellets and cysts.

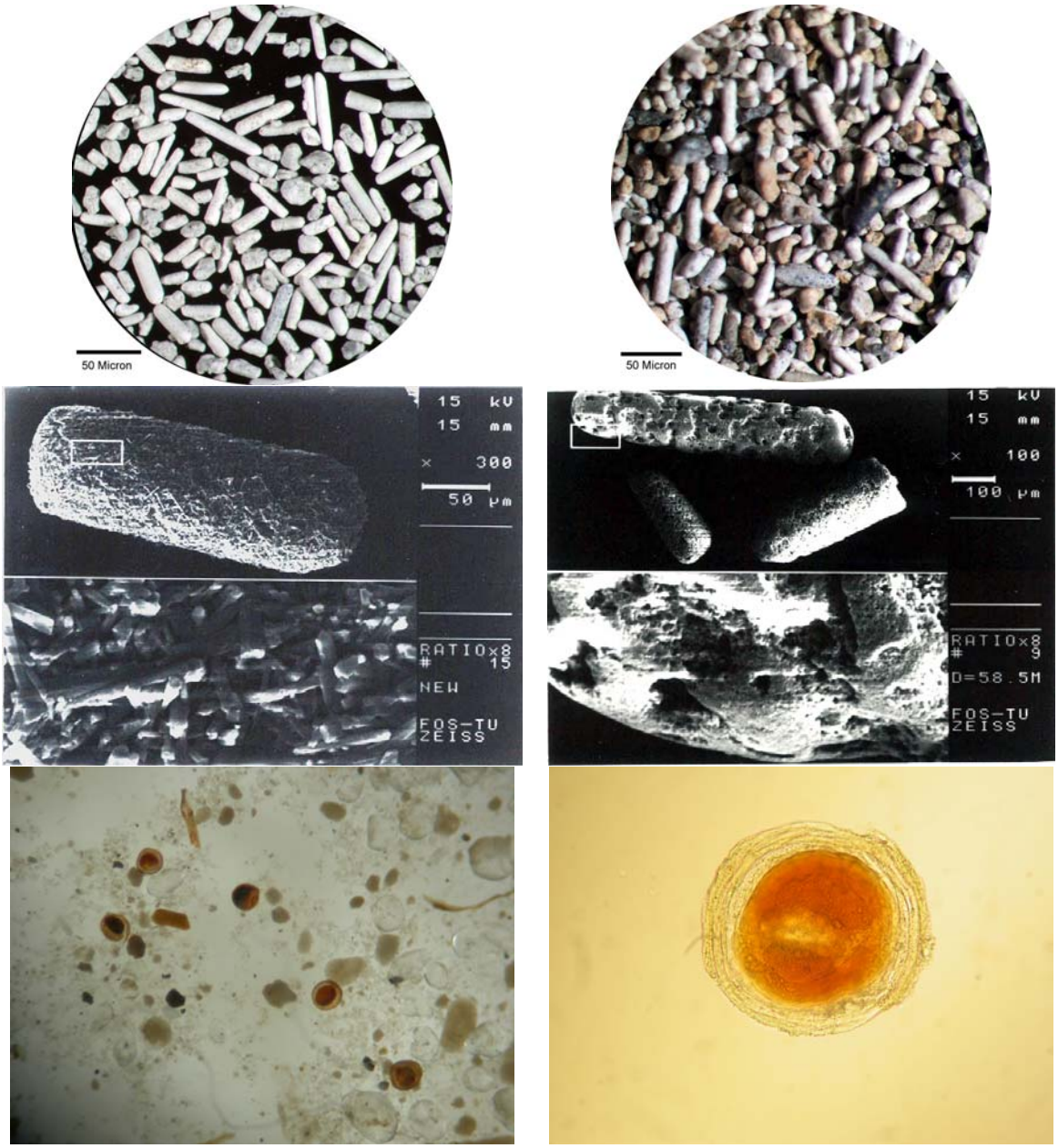

Figure 1: a and b: Photomicrographs of recent aragonitic fecal pellets from early-middle Holocene (a) and from the last glacial period (b). c and d: SEM images from a modern fecal pellet with very fine aragonitic needles (c) and a Last Interglacial fecal pellet with traces of bacterial erosion (d). e: *Artemia* cysts from core interval corresponding with the last glacial period (35.5 m depth) photographed under reflex microscope. f: An *Artemia* cyst from the interval corresponding the last interglacial period photographed under light microscope. The cysts measure approximately 235 µm. Note the preservation of the inner cell content which is detached from the external shell. Images a-d are derived from Shah-Hosseini (2003).

2.1. Fecal pellets

Kelts and Shahrabi (1986) found *Artemia* fecal pellets as old as early Holocene, showing that this Crustacean lived in the lake since at least the beginning of the Holocene. They also show that the organic content of fecal pellets gradually diminishes down the cores. Later, Shah-Hosseini (2003) documented the presence of *Artemia* fecal pellets in a long lacustrine core from the middle part of Lake Urmia. This core was more recently the subject of a palynological investigation, which provided a pollen sequence covering the two last glacial cycles, i.e. the last 200,000 years (Djamali *et al.*, 2008a). This investigation was also an opportunity to take several samples throughout the sequence in order to estimate their content in fecal pellets. The frequency and concentration of fecal pellets in Lake Urmia vary considerably within the Holocene and late Pleistocene cores of Lake Urmia (Kelts & Shahrabi, 1986; Sharifi, 2002; Shah-Hosseini, 2003), implying significant fluctuations in the lake productivity in terms of abundance of *Artemia*. This could have partly been due to a complex hydrological history of the lake, which has undergone substantial lake level changes during the Quaternary and probably the Pliocene (Djamali *et al.,* 2008a,b). Even at present-day, Urmia displays substantial fluctuations in lake level due to high interannual variability of the total precipitation and the seasonal regime. Hence, the Urmia lake level fluctuations can be a major factor in controlling the high temporal variations in the abundance of *Artemia* fecal pellets even in very recent top sediments (e.g. see Sharifi, 2002).

Very high lake levels can reduce the lake salinity and create unfavourable environmental conditions for the reproduction and proliferation of *Artemia*. On the other hand, very low lake levels are also harmful for the life cycle of *Artemia* because they may lead to extremely high concentrations in salt content. One of the other reasons for the reduction of *Artemia* abundance during high lake stands may be the appearance of predators, such as fishes (for example some halophile species of *Aphanius*), although no evidence of the presence of sub-fossil fishes has so far been reported for these periods. Increased population size and/or the number of visits by birds, e.g. greater flamingo (*Phoenicopterus roseus* Pallas 1811) and shelduck (*Tadorna tadorna* L. 1758), must also be included. In Lake Urmia region, these two water birds have stomach content strictly composed of *Artemia* biomass and cysts (Shoa Hasani & Emamifar, 2008). It has been shown that flamingos could have a strong impact on the populations of macro-invertebrates (Hurlbert & Chang, 1983; Glassom & Branch, 1997). The explosion of planktonic algae during a short interval before the beginning of the last interglacial period correlates with the disappear-rance of *Artemia* remains from the lake sediment, suggesting that the higher-trophic predators such as fishes might have been abundant during this interval. The temporal change in the concentration of *Artemia* fecal pellets may thus be used as an indicator of lake level changes and therefore regional hydrological changes. However, caution should be taken in the interpretations as other environmental factors, such as temperature changes, water circulation, taphonomic history, etc. can also be important in the production, deposition and preservation of fecal pellets in the lake bottom sediments.

2.2. Cysts

Artemia cysts are present throughout the length of the long cores of Lake Urmia, although with varying concentration and preservation. It seems

that variations in the abundance of *Artemia* cysts depend on a combination of environmental conditions and not only salinity and temperature changes. Table 1 indicates the high concentrations of *Artemia* cysts observed during both glacial and interglacial periods. A sample from 35.5 m corresponds to high water levels in Lake Urmia during the last glacial period (Djamali *et al.*, 2008a,b) and is characterized by relatively high concentration of *Artemia* cysts. A sample from 66.5 m (last interglacial interval, ~130,000 to 110,000 years ago) is marked by very high *Artemia* concentration values. In contrast, during the same climatic episode (Last Interglacial) but slightly earlier, the sample from 69.5 shows low concentrations. The lake levels would have been similar to the present ones, as inferred from the values of aquatic plant pollen. The lowest *Artemia* cyst concentration values are related to the penultimate glacial period at 79.5 m depth.

These data show that the variations of *Artemia* cyst concentrations are controlled by complex interactions of different environmental factors. Higher resolution records of the variations of cyst concentrations compared to the variations of other palaeoecological and palaeohydrological proxies should help elucidate the role of these factors in the future.

Table 1: Some characteristics of the *Artemia* cysts in different intervals of the long core sample from Lake Urmia. The amounts of *Artemia* cysts are reported as number per gram of the dry sediment.

Depth (m)	Climate stage	Lake level inferred from aquatic pollen	Weight (gr)	Number of *Artemia* cysts (n)	Concentration (n/gr)	Cyst diameter (µm)
35.5	Last Glacial	High	7.9	231	29.2	235.8
66.5	Last Interglacial	Like present	3.2	289	90.3	-----
69.5	Last Interglacial	Like present	2.7	30	11.1	242.4
79.5	Penultimate Glacial	Very low	4.1	17	4.1	-----

One of the most important discoveries in the Lake Urmia long cores is the presence of many *Artemia* cysts in which the organic rest of the original egg is still distinguishable detached from the chitinous capsule (Fig. 1e and f). It is not still clear to what extent the molecular structure of DNA has been preserved in the older cysts. However, in accordance with the publication of Clegg and Jackson (1997), our discovery also highlights that the potential of these cysts should be examined in future molecular phylogenetic studies.

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