Title: The spring of Nadaouiyeh Aïn Askar – Paleoecology of a Paleolithic oasis in arid central Syria.

Authors:

Kalbe, Johannes^{1, 3}

¹University of Potsdam, Institute of Earth- and Environmental Science, Karl-Liebknecht-Straße 24-25, 14476 Potsdam-Golm, Germany; johanneskalbe@gmx.de

³ Institute of Applied Ecology, Carl-Hopp-Straße 4a, 18069 Rostock, Germany

Jagher, Reto²

² University of Basel, Integrative prähistorische und naturwissenschaftliche Archäologie (IPNA), Spalenring 145, CH-4055 Basel, Reto.Jagher@unibas.ch

Pümpin, Christine²

² University of Basel, Integrative prähistorische und naturwissenschaftliche Archäologie (IPNA), Spalenring 145, CH-4055 Basel, christine.puempin@unibas.ch

Abstract:

The site Nadaouiyeh Aïn Askar, an ancient artesian spring near the village of El Kowm, Central Syria, is an example of long lasting human occupation in a desert environment throughout the Middle and Late Pleistocene. The excavations expose a succession of sedimentary units, containing an artifact

assemblage assigned to the Acheulean techno-complex. Unit VI, attributed to the Marine Isotope Stage 13, is rich in ostracod valves and was chosen for the present environmental study. From these sediments *Heterocypris salina*, *H. incongruens*, *Cyprideis torosa*, *Ilyocypris* cf. *bradyi*, *I. inermis*, *I. cf. gibba*, *Darwinula stevensoni*, *Plesiocypridopsis newtoni*, *Pseudocandona compressa*, *Candona* cf. *neglecta*, *Pseudocandona* sp., *Trajanocypris* sp., *Physocypria* sp. and *Mixtacandona* sp. are documented for the first time in the Middle Pleistocene of the arid environment of central Syria. Data from these microfossils as well as geochemical proxies implicate three phases, turning the wetland from a palustrine setting into a spring supplied pond with increasing salinity. The high mineralization of the spring waters enables a discussion about early hominin adaptability to brackish waters as drinking water resources, common within the steppe and desert environments along the “out-of-Africa”-corridor in the eastern Mediterranean.

Keywords: Syria; Lower Paleolithic; Marine Isotope Stage 13; desert wetland ecosystems; Ostracoda; drinking water quality

1. INTRODUCTION:

1.1. General setting

The area of El Kowm with the Nadaouiye Aïn Askar site is located in the arid interior of Syria, about 90 km NE of Palmyra. The region occupies a wide orographic gap between the Balas-Abu Ruimain Block and the Bishri Anticline in the central Palmyrides mountain range that runs from the Anti-Lebanon Mountains to the Euphrates, separating the northern plains from the Arabian Desert in the south (Fig. 1A). At present, and also during most of the Pleistocene, arid conditions prevailed in the wider area of El Kowm, whose small oasis profits from a contiguous cluster of active artesian springs (Fig. 1B). Within a zone less than 12 km across, about 30 natural springs created a number of local

wetlands attracting game and humans from afar (Jagher and Le Tensorer, 2011; Jagher et al., 2015). Since the first documented arrival of hominins in the Middle East about 1.8 Ma ago, the wetland cluster of El Kowm oasis steadily has been frequented by people, leaving one of the richest Paleolithic legacies in the Levant in the length of history as well as in the intensity of human activities (Le Tensorer et al., 2001, Jagher et al., 2015).

The modern day springs in the El Kowm area present a particular hydrochemical setting with a high concentration of total dissolved solids (TDS), in average about 2300 mg/l, with a high percentage of sulphates and carbonates (Tab. 1) (Margueron, 1998). No freshwater springs from this basin are known nowadays. The wells discharge with temperatures between 24 and 32 °C, indicating aquifers about 350 – 500 m deep upwelling along faults of the Bishri fault system (Brew et al., 2001). Spring deposits occurred in two distinct settings, the first build substantial spring mounds, 200 m to 850 m across, rising up to 20 m over the original landscape (Le Tensorer et al., 2007; Jagher et al., 2015, Pümpin and Jagher, 2005). Other springs occur on karstic systems creating vast dolinas or depressions with extended water bodies or just discharge into the landscape (Jagher et al., 2015). With the diversity of spring types, the depending wetlands show different micro-ecological settings, with a limited extension according to the local topography and discharge intensity of each spring. The extent of these oases is difficult to estimate, but covered an area between a few to a few dozen hectares each, totalized to several square kilometers across the El Kowm Basin (Jagher et al., 2015).

1.2. Nadaouiyeh Aïn Askar

Excavations at the well-site of Nadaouiyeh Aïn Askar have been carried out between 1989 and 2003 by a joint Syro-Swiss team (Directorate General of Antiquities and University of Basel) (Fig. 2), revealing a almost complete section of the Acheulean techno-complex (covering the period of about 550 - 350 ka ago; Jagher et al., 2015; Jagher, 2000, 2011). In fact, Nadaouiyeh Aïn Askar is one of the

key-sites for the Middle East to understand the environmental conditions permitting early human dispersal “out-of-Africa” and comprehend the evolution of hand-axe traditions (Jagher, 2000, 2011). The vent of the spring at Nadaouiyeħ Aĭn Askar created a vertical karst-system (Turberg, 1999; Le Tensorer et al., 2007) that regularly collapsed, giving origin to a succession of at least seven cave-ins opening dolinas up to 30-40 m across and several meters deep, opening lowered sedimentation-spaces protected from erosion. Within a composite stratigraphic column of about 33 m, 32 distinct archeological levels can be grouped, on the basis of their geological context, into seven units, permitting to retrace the evolution of Acheulean hand-axe tradition in a unique resolution of this cultural period in the Middle East (Jagher, 2000, 2011).

The potential for a study of the ostracod fauna from this site was demonstrated by geoarcheological investigations with the detection of numerous ostracod shells visible in thin-sections (Fig. 3) and in sieved residues from granulometric analyses of unit VI (Pümpin, 2003).

According to the existing age models for Nadaouiyeħ Aĭn Askar (Jagher, 2011), unit VI can tentatively be dated to the second half of MIS 13. Within the excavated area of the archeological unit VI, no *in situ* preserved living floors were observed. The main settlement activity took place outside the excavated area, apparently in the dry area. Nevertheless rich archeological material of flint artefacts, including 168 hand axes, were discovered and copious paleontological material from hunted animals was excavated with occasionally bones still in anatomical connection. The remains of human presence were affected by post depositional effects, probably due to rising and falling water levels and the effect of oscillating waves, acting on the former banks of the pond aligning bones along to the original shorelines. The effects of rising and falling levels of water were clearly visible on different exposures of the layers adjacent to the studied profile, where these phenomena were only discernible in a more discrete manner. However, important human occupation occurred repeatedly during most of the deposition of unit VI.

The timing and regional significance of water availability and its influence on local wetland and spring systems in the central Syrian Desert environments during the Pleistocene are still poorly known, but

important for the general understanding of these ecosystems (Pigati et al., 2014), especially in sites documenting early hominin dispersals. Studies on Middle Pleistocene non-marine ostracod faunas, which can be used to infer past environmental settings, are scanty for the eastern Mediterranean region in general (Mischke et al., 2014a; Rosenfeld et al., 2002, 2004) and missing for Central Syria. Only one additional lacustrine record from Saudi Arabia, dated tentatively to MIS 13, is known from the Arabian-eastern Mediterranean Desert area in this interglacial period, without mentioning microfaunal data (Rosenberg et al., 2013).

Problems based on postdepositional diagenetic processes within Pleistocene sediments from interior desert environments originating from this region did not provide ostracod records older than 93 ka (Kalbe et al., 2014; Mischke et al., 2015), emphasizing the importance and particular interest of the El Kowm spring cluster within the Middle East.

2. MATERIAL AND METHODS

For the present pilot study, a section of the stratigraphy with a nearly continuous sedimentological record and changing conditions within the depositional environment was selected (Fig. 4). A total of 14 sediment samples from a 0.95 m section with a dry weight of 200 g each were used for micropaleontological analyses. The material, comprising limestones, siltstones and mudstones, originally was sampled in 2001 for geoarcheological studies. Samples were dried in a drying oven at 50° C for 3 days. Subsequently they were treated with 3.5 % hydrogen peroxide (H₂O₂) until aggregates were dispersed. Samples were sieved in the laboratory with a 250 µm and a 125 µm mesh size sieve. In case of abundant coarse grained sediment particles an additional 1000 µm sieve was used. Residues were dried at 40° C. All ostracod valves were picked from the sieved residues of

samples P7/4.1 – P7/8.5 and counted with a low-power binocular microscope. Sample P7/8.6 was very rich in ostracod valves, so only 412 valves were picked. Ostracods were identified mainly with reference to Fuhrmann (2013), Janz et al., 2001; Karanovic (2012), Meisch (2000), and publications of Mischke et al. (2010, 2012), using a scanning electron microscope (SEM) Zeiss Supra 40 VP at the Freie Universität Berlin and a low power binocular microscope. Ostracods of the genus *Ilyocypris* were determined at the species level regarding the criteria mentioned by Mazzini et al. (2014) with particular attention on the marginal ripples of the postero-ventral margin of the left valves, according to Janz (1994) and Mazzini et al. (2014). All left valves of this genus were picked and examined under SEM.

The transfer function of Mischke et al. (2014b), based on ostracods from terrestrial aquatic ecosystems in the southern Levant, was applied to the ostracod associations of Nadaouiyeh Aïn Askar. Mischke et al. (2012, 2014b) determined *Ilyocypris* species with a low power binocular microscope for their surface sample dataset and mention only *Ilyocypris bradyi*. Valves of *I. gibba* and *I. bradyi* can not clearly distinguishable in this way, so all *Ilyocypris* ssp. from our samples were assigned to *I. bradyi* (for the calculation only) for a better application of the transfer function to our dataset.

Several authors (Curry, 1999; DeDeckker, 1981; Forester, 1986; Mezquita et al., 1999, 2005) suggest ionic composition as an equal or more significant variable than salinity in case of species assemblages in terrestrial aquatic environments. Therefore hydrochemical datasets of Magueron (1998) (Tab. 1) and Mischke et al. (2014b) were used to contribute to the discussion of ecological preferences of the single ostracod species from the Pleistocene sediments of Nadaouiyeh Aïn Askar in terms of today's TDS and sulphate ion enriched waters of the El Kowm spring cluster. The dataset of Magueron (1998) comprises temperature and hydrochemical data from natural and artificial springs and wells from the area of El Kowm. Due to the high variability in spring activity, even in the scale of years (Jagher et al., 2015), additional data were taken from three springs of Magueron's study to display the variability in hydrochemistry. Mischke et al.'s (2014b) dataset comprises hydrochemical details and ostracod

occurrences from 178 natural and artificial waterbodies of Israel and Jordan. For our study, ostracod species occurring in fifteen samples from Nadaouiyeh Aïn Askar were also displayed (Fig. 5). This dataset shows that only fifteen of the southern Levantine waterbodies, natural and artificial, have sulphate salinity above 20‰ of the TDS that fall in the range of today's values of the El Kowm spring cluster. Their qualitative and quantitative ostracod content is sufficient to be used for discussion of sulphate indication by Nadaouiyeh Aïn Askar Pleistocene ostracod fauna.

Numerical zonation was carried out by optimal partitioning using sum of squares criteria (ZONE software, Version 1.2; Juggins, 1991). For an objective measurement of faunal diversity the Shannon Diversity Index (H') was calculated (Spellerberg and Fedor, 2003; Zar, 1999).

Content of inorganic carbon (TC) and total organic carbon (TOC) was measured at University of Potsdam on powdered samples using a Vario EL Detector EA3000 (Elementar Analysensysteme GmbH, Hanau, Germany), with detection limit of 0.01 %. Total sulphur content (S) was measured on powdered samples at the GeoforschungsZentrum Potsdam (GFZ, Germany) by a CS 200 Detector (ELTRA GmbH, Haan, Germany) with a detection limit of 0.02 %.

3. RESULTS

The studied sediment column of site Nadaouiyeh Aïn Askar consists mostly of homogenous, consolidated, carbonate rich silts (Fig. 4). Some of the layers contain particularly high numbers of ostracod valves (Fig. 3, 6, 7). At least nineteen different species were recorded; total numbers of ostracods are presented in supplementary Tab.1. Charophyte gyrogonites of *Chara vulgaris* L. are relatively abundant in the samples of the upper part of the section (Fig. 8 and Pümpin, 2003). Shells of aquatic gastropods are absent in all of the sieving residues. Four significant ostracod zones were

calculated with the ZONE software (Juggins, 1991). The fourth zone consisted of only one sample, so it was combined with the third one. Total organic carbon (TOC) and total sulphur (S) contents are low and almost co-vary through the section (Fig. 9).

The sediments of the lowermost zone (Fig. 4: Zone P7/A, samples P7/4.1 to P7/6) differ by their darker brownish color. S is low (0.1 %), TOC is generally around 0.2 %, while the TC content decreases from 7.95 % to 4.45 % (Fig. 9). The samples contain a rather diverse ostracod fauna at the base of the section, comprising *Heterocypris salina* (Brady, 1868), *Heterocypris incongruens* (Ramdohr, 1808), Candoninae indet., *Cyprideis torosa* (Jones, 1850) (unnoded specimens) (Fig. 9), *Ilyocypris* sp. in smaller amounts, *Pseudocandona compressa* and juvenile *Pseudocandona* sp.. One single broken left valve of *Ilyocypris* shows a few distinct marginal ripplelets on the outer duplicature of the postero-ventral margin similar to patterns known from *Ilyocypris bradyi* G.O. Sars, 1890 (Janz, 1994; Mazzini et al., 2014: Fig. 11 1c). Additionally (juvenile) *Trajancypris* sp., *Candona* cf. *neglecta* and *Physocypris* sp. can be observed, but are rare in general. *Mixtacandona* sp., known from recent aquatic ecosystems in the eastern Mediterranean only from the Banyas stream on the foothills of the Hermon (Mischke et al., 2014b), was found in sample P7/4.2. The H' decreases from 1.82 at the deepest layers to 1.38 in upper part of this lowermost section (Fig. 9). Applying the transfer function of Mischke et al. (2014b) on the ostracods of Zone P7/A, conductivities between 0.93 and 1.39 mS/cm were calculated (Fig. 9).

The upper part of the sediment section (Zone P7/B and P7/C_{1/2}) has a light homogenous yellow-whitish color (Fig. 4) and TC is rising, up to 10.11 % (Fig. 9). This part shows significant variations in the composition and diversity of the ostracod associations.

In Zone P7/B (samples P7/7.1 to P7/8.2) the fauna is dominated by *H. salina*, and, in smaller numbers *H. incongruens*. Abundance of the genus *Ilyocypris* is slightly increasing with some occurrences of *Ilyocypris inermis* Kaufmann, 1900 (Fig. 7 b-c). Generally, the *Ilyocypris* specimens from this layer mostly assigned to the species *Ilyocypris* cf. *gibba* (Ramdohr, 1808), according to multiple marginal

ripplets on the inner duplicature of their postero-ventral margin (Fig. 7 d-f; Janz, 1994: Plate 1, Fig. 2a; Mazzini et al., 2014: Fig. 11, 5a). Some specimens of another *Ilyocypris* species were observed (Fig. 7 a), but could not be identified. *Darwinula stevensoni* (Brady and Robertson, 1870) starts to be common from sample P7/7.1 and is present in every sample of the upper zones, with slightly increasing numbers upwards. Some *Plesiocypridopsis newtoni* occur. Single shells of *C. torosa* and several Candoninae were found. The diversity is highest in the lower- and uppermost samples (H' : 1.30 – 1.44), and very low in between (H' : 0.84 – 1.16). TOC content is variable between 0.10 % and 0.33 %, S content changes between 0.12 % and 0.16 % (Fig. 9). Applying the transfer function of Mischke et al. (2014b) on the ostracods of Zone P7/B, conductivities varying between 1.46 and 2.87 mS/cm were calculated (Fig. 9).

Zone P7/C₁ is characterized by a strong increase of *Ilyocypris* valves. Among these, most of the left valves can be assigned to *I. cf. gibba*, according to the occurrence and distribution of multiple marginal ripples on the inner duplicature of the postero-ventral margin (Janz, 1994: Plate 1, Fig. 2a; Mazzini et al., 2014: Fig. 11, 5a). A decrease of both *Heterocypris* species found in the samples can be observed. High numbers of *P. newtoni* were recognized in sample P7/8.3 from the base of the uppermost zone, decreasing upwards. *Darwinula stevensoni* and *Trajanocypris* sp. are common. Occasionally, valves of *Cypris* sp., *Candona* sp., and *Pseudocandona* sp. were found.

Sample P7/8.5 and the topmost Subzone P7/C₂ (sample P7/8.6) contain numerous gyrogonites of *Chara vulgaris* L. and the uppermost sample P7/8.6 is very rich in valves of juvenile and adult *C. torosa* as well as *I. cf. gibba*. Although the total number of ostracods increase, the diversity decrease strongly in the uppermost zone of the section, from an H' of 1.24 to 0.85. A decrease in S can be observed with a shift from 0.12 % to 0.31 % (Fig. 9). Applying the transfer function of Mischke et al. (2014b) on the ostracods of Zone P7/C, conductivities between 0.97 and 1.79 mS/cm were calculated (Fig. 9).

The top of the sediment column is cut by a much younger strong erosional event (layer Va.7.3 – archeological level c.7), destroying an important portion of the site, and overlain by the archeological layer c.7 (Fig. 4).

4. DISCUSSION

The bulk of the deposits consists of very fine grained carbonate precipitations. TC content increases from the middle of Zone P7/A to the top of the section and displays the increasing carbonate content to the top of the section. The wide co-variation of S and TOC (Fig. 9) suggests that most the sulphur seems to be related to organic compounds and displays rather the changing organic matter input than precipitated sulphates from the water column (Holmer and Storkholm, 2001; Gross et al., 2011). Pümpin (2003) assumed that, after a period of terrestrial conditions in the underlying stratum, the depression was intermittently flooded, creating palustrine to shallow lacustrine conditions (Fig. 4, layer c.8.1c).

4.1 Ostracod Zone P7/A

At the base of the ostracod Zone P7/A levels c.8.1c and c.8.1b (Fig. 4) show a relatively high ostracod diversity, but the abundance of valves within the sediment is very low, a fact which has to be considered for the reliability of the interpretation of the micropaleontological data. The occurrence of *I. bradyi* is often reported from springs (Meisch, 2000). This species tolerates slightly saline waters, up to 4400 mg/l (Jaekel, 1962; Klie, 1938; Sywula, 1966; Vesper, 1975; Wouters, 1983) as well as high sulphate contents (Fig. 4). *Mixtacandona* sp. is also often known from springs and wells (Meisch,

2000), with sulphate contents around 20 % (Fig. 5) and could be anticipated at such a site. *Pseudocandona* species usually occupy a wide range of habitats, such as springs, streams and ponds (Meisch, 2000), *P. compressa* is recorded from slightly salty waters (Meisch, 2000; Vesper, 1975). *Heterocypris salina* and *H. incongruens* occur in a wide range of habitats and are able to colonize water bodies with different physical and chemical properties. They are also able to tolerate seasonal desiccation. Together with *C. torosa*, they may indicate oligohaline to mesohaline conditions at the site (Frenzel et al., 2010; Meisch, 2000). In contrast, *Trajanocypris* sp., which occurs with few valves in this lowermost zone, suggests the presence of pure freshwater environments (Altınsağlı, 2004; Karanovic, 2012; Mischke et al., 2014b). The occurrence of this species could be explained by an allochthonous input, but the occurrence of ostracods with relatively thin-shelled carapaces in the samples may indicate that the recorded species composition and abundance is not significantly influenced by preservation or transportation effects. The conductivity values calculated with the ostracod transfer function of Mischke et al. (2014b) imply a salinity in the oligohaline range. The results of the calculations have to be interpreted carefully under consideration of the low total number of ostracod valves found in the samples of Zone P7/A.

The higher diversity within the ostracod association of Zone P7/A, together with the darker color of the sediments, points rather to a wetland setting than to a permanent larger spring pool directly at the site (Pigati et al., 2014). This issue confirms the micromorphologic analysis of ostracod Zone P7/A (Pümpin, 2003), which shows several discontinuities and erosional events indicating changes in the depth and permanence of the water body.

4.2 Ostracod Zone P7/B

Among the ostracod species from Zone P7/B, which coincides with the archeological layer c.8.1a (Fig. 4), the occurrence of *D. stvensoni* is significant because of its relatively long life cycle of two years (Meisch, 2000). *Plesiocypridopsis newtoni*, which also occurs in minor numbers, prefers small,

permanent water bodies, such as ponds and spring-pools, and is often found in the shallow littoral zone, as well as *D. stevensoni* (Meisch, 2000). Both *Ilyocypris* species identified from the sediments of this zone (*I. inermis* and *I. cf. gibba*) are frequently recorded from small, permanent water bodies and springs, often characterized by slightly salty waters (Karanovic, 2012; Klie, 1938; Meisch, 2000; Sywula, 1996). According to Mezquita et al. (2005), *I. gibba* has its optimum at higher sulphate contents (44.5 %) than *I. inermis* (24.5 %). *Heterocypris incongruens* strongly prefers clayey, shallow, permanent ponds and tolerates a distinct increase in salinity (Meisch, 2000). *Heterocypris salina*, a species repetitively collected from springs (Klie; 1939, Petkovski; 1966; Roca and Baltanas, 1993), occurs also in a wide range of salinity, including pure freshwater and low polyhaline habitats (Fig. 5), but prefers slightly salty environments with approximately ~6000mg/l (Ganning, 1967, 1971; Meisch, 2000). Eastern Mediterranean data from Mischke et al. (2014b) show a high compatibility with a broad range of sulphate contents as well as saline waters for *H. salina*, more than for *H. incongruens* (Fig. 5). *Heterocypris salina*, together with *I. cf. bradyi* are suggested to be reliable proxies for sulphate enriched waters at the site, while *C. torosa*, *D. stevensoni* and *H. incongruens* are not documented from recent aquatic eastern Mediterranean environments with hydrochemical characteristics similar to the springs of the El Kowm oasis cluster (Fig. 5; Mischke et al., 2014b). Calculated conductivity values, with a maximum of 2.87 mS/cm for sample P7/7.2 implicating oligohaline conditions at the site.

4.3 Ostracod Zone P7/C

Regarding the data from Pümpin (2003) environmental conditions within Nadaouiyeh Aïn Askar's aquatic system became more stable and deeper in the upper part (layer c.8.1 / Zone P7/C_{1/2}), corresponding to a considerable lateral extension of the local wetland. After an important erosional event at the interface of layers c.8.1a and c.8.1, which coincides with the boundary between the ostracod Zones P7/B and P7/C_{1/2} the watertable rose considerably, creating a stable limnic

environment with no indications of erosions and intermittance of the spring activity within the sedimentary record. The presence of airborne quartz sand and Cretaceous and Paleocene marine planctic foraminifers as indicators for dust entry to the sediments reflects the arid environment of this small wetland. Such dust deposits were intermittent and short lived events, as it is demonstrated by sporadically intercalated layers at micro scale. The input of eolian deposits overall to the local sedimentation is insignificant (Pümpin, 2003).

Within ostracod Zone P7/C, *Ilyocypris* is the dominating genus. Most of these shells seem to belong to *I. cf. gibba*, indicating, together with the frequent appearance of *D. stevensoni* and *P. newtoni*, a shallow and permanent water body at the site (Meisch, 2000). All of these species, including *H. salina* and *H. incongruens*, tolerating more or less mesohaline conditions and their very high abundances point to an elevated salinity (Fuhrmann, 2013; Pint et al., 2012; Meisch, 2000). Contrary to this, is the quite frequent occurrence of *Trajanocypris* in this zone, which has its optimum within freshwater conditions in recent times and is also less tolerant to SO₄ (Fig. 4; Altınışli, 2004; Karanovic, 2012; Mischke et al., 2014b). Due to the frequency of complete carapaces of adult ostracods visible in the micromorphologic thin sections (Fig. 3; Pümpin, 2003) and the occurrence of other thin shelled species and juvenile valves in this ostracod zone the influence of transportation on the composition of the ostracod association might be low. Ostracod assemblages characterized by occurrences of *H. incongruens*, *H. salina*, *I. gibba*, and *D. stevensoni* can be regarded as indicator of warm, carbonate waters enriched with sulphate and/or chloride and show often a high mineral content (Mezquita et al., 1999). The gyrogonites found in the upper layers can be ascribed to *Chara vulgaris* L., which is the most common species in the northern hemisphere (pers. comm. I. Soulié-Märsche). It is known from several recent water bodies and Holocene pond sediments in desert areas (Djamali et al., 2006; Soulié-Märsche, 1991; Soulié-Märsche and García, 2014). *Chara vulgaris* L. grows in shallow and mandatory clear, generally freshwater environments, but also tolerates slightly brackish conditions (Kirst et al., 1988; Winter and Kirst, 1990). To populate an aquatic ecosystem, they need submersion duration of at least three months (pers. comm. I. Soulié-Märsche).

The ostracod rich Zone P7/C₂ shows a clear shift into brackish/athalassic conditions with the abundant *C. torosa* (unnoded specimens), together with *I. cf. gibba*, *H. salina* and *D. stvensoni* (Pint et al., 2012). Based on the eastern Mediterranean dataset of Mischke et al. (2014b), *C. torosa* seems to avoid very high sulphate contents (Fig. 5) and colonizes preferentially permanent, large, shallow and warm water bodies (Pint et al., 2012), so the abrupt rise of *C. torosa* within this ecosystem may point to an enlargement of the water body, perhaps coherent with a depletion of SO₄. Contrary to this dataset, Mezquita et al. (1999) suggest, based on material from the Iberian Peninsula, a broader adaption of *C. torosa* to brackish sulphate-rich conditions, also visible in the dataset of Mischke et al. (2014b) (Fig. 5). Regarding the TOC/S ratio, considered as a rough proxy for paleosalinity (Berner, 1984; Gross et al., 2011; Holmer and Storkholm, 2001), the rise in S in the topmost part of the section can be seen as a hint for more saline waters as well as the low values of the diversity index H'. The calculated conductivity suggests oligohaline salinity (Fig. 9). Samples of this ostracod zone are dominated by *Ilyocypris* spp. with up to 76 % of the whole ostracod association. For their ostracod database, used for the transfer function, Mischke et al. (2012, 2014b) identify *Ilyocypris* species with a low power binocular microscope, mention only *Ilyocypris bradyi*. Valves of *I. gibba* and *I. bradyi* are not clearly distinguishable in this way, so all *Ilyocypris* ssp. from all samples were assigned to *I. bradyi* (for the calculation only) for a better application of the transfer function to our dataset. Generally, *Ilyocypris* tolerate only a low salinity (Meisch, 2000). *Ilyocypris bradyi* is documented for the southern Levant with a maximum of 4.4 mS/cm (dataset of Mischke et al., 2014b), accordingly. Contrary, Akdemir (2008) identified several specimens of *I. bradyi* in a Maar Lake in Turkey with a significant higher salinity (~62400 mg/l). Regarding those higher tolerances in salinity and the fact of *Ilyocypris* being the dominant ostracod in the samples P7/8.3-P7/8.6, calculated conductivity values might significantly underestimate the original salinity of the MIS 13 spring waters of Nadaouiye Aïn Askar. Nevertheless, this issue needs a larger database for a definite interpretation of this desert wetland ecosystem.

The high number of *Chara gyrogonites* within this sample documents still clear water conditions without turbidity. Turbidity in aquatic desert ecosystems is generally generated by wind induced dust, which was probably blocked by formation of a dense vegetation belt around the Nadaouiyeh Aïn Askar site.

4.4 Reconstruction of the prehistoric spring environment

The sedimentation of geological unit VI in Nadaouiyeh Aïn Askar took place in a protected environment of a natural depression, created by a cave-in of the karst-system. During the deposition of unit VI, the activity of the spring was considerable and limnic to marshy conditions prevailed (Pümpin, 2003), supporting the development of diverse ostracod populations. All ostracods found in the sediments of the section are meso- to polytitanophilic or titanoeuryplastic (Hartmann and Hiller, 1977; Hiller, 1971; Meisch, 2000; Tunoğlu and Ertekin, 2008; Vesper, 1975) and hence adapted to water rich in Ca. Similar conditions can be observed in today's water bodies in the site's surrounding area (Tab. 1).

The base of the profile (Zone P7/A) shows the development of a palustrine setting. It points to a phase with temporary puddles and small ponds of different salinity, indicating freshwater as well as slightly brackish conditions. The higher diversity, but small numbers of individuals is, in this composition, typical for wetlands in desert environments (Pigati et al., 2014).

The upper part of the sediment column (Zones P7/B and P7/C) displays the evolution of a wetland setting to a permanent shallow pond, with a distinctive decrease in ostracod diversity. Although an allochthonous input of ostracod valves cannot be excluded for such a small water body, we suggest a mostly autochthonous assemblage because most of the ostracods of these zones are preserved as complete carapaces (Fig. 3). The ostracod fauna at the base indicates oligohaline conditions changing to slightly mesohaline settings with the presence of smaller freshwater puddles near the site in the uppermost part of the profile. There is no modern ecosystem analogue from the southern Levant in

the dataset of Mischke et al. (2014b) in terms of water temperature, sulphate salinity and ostracod associations. Only a pond and a small stream with conductivity values of 3.8 mS/cm and sulphate content up to 10 % (site En Malqoah, N Israel) show an ostracod association similar to Zone P7/C (*Ilyocypris brady* (or *I. gibba*)i (dominant), *H. salina*, *H. incongruens*, *D. stevensoni* and *C. torosa*). Assuming the hydrologic system active today in the El Kowm oasis cluster was the same during the Pleistocene, we presume the values calculated with the transfer function of Mischke et al. (2014b) for Zone P7/C can be significantly underestimated. The lack of comparable terrestrial aquatic ecosystems in the eastern Mediterranean as well as the low ostracod valve numbers in Zone P7/A makes the application of ostracod transfer functions (Mischke et al., 2012, 2014b) on the fauna from this section of Nadaouiyeh Aïn Askar difficult.

The development of dense vegetation around the wetland can be derived from the occurrence of the characean populations, which are very sensitive to water turbidity. In this case, a dense vegetation belt of sedges may have been a protection against the omnipresent dust storms like the Khamaseen dust in spring, occurring in the eastern Mediterranean deserts (Abed et al., 2009). The presence of dense stands is demonstrated by fossilized stem fragments and rhizomes of Poaceae and Cyperaceae, discovered in the same sediment facies in the upper and lower layers. Their absence in unit VI is due to the position of the studied profile covering the center of the pond and not the margins of the local wetland.

The ostracod-record, and its paleoenvironmental reconstruction, is in full agreement with the stratigraphic and geoarcheological observations (Pümpin, 2003). Sedimentological results for layer c.8.1c and layer c.8.1b indicate a wetland setting for these two layers (Zone P7/A). For the subsequent layer c.8.1a (Zone P7/B), the geoarcheological results and ostracod analysis strongly agree on the general setting of the local wetland with a shallow permanent water body. The top of the studied section, layer c.8.1, is a uniform barely structured fine grained limnic carbonate, showing little evolution in the geoarcheological thin-sections (Pümpin, 2003). However, the ostracods in Zone P7/C clearly show an important salinity increase within this sedimentary unit.

The occurrence of freshwater puddles and oligohaline to slightly mesohaline environments in the uppermost part of the profile is difficult to explain. The water supply of today's, mostly epi-thermal springs of the El Kowm oasis cluster and their water chemistry rich in calcium, magnesium, and sulphates, is mainly driven by tectonics, a hydrological situation which probably can be expanded into the past. The existence of freshwater at the site, indicated by *Trajanocypris* sp., if not caused by tectonic-dependent fluctuations, might be attributed to higher local precipitation values during the deposition of Zones P7/A and P7/C sediments. A setting where higher precipitation also triggered more saline spring waters can be observed in the northern part of the Dead Sea Rift system, where fault related springs show an increase in the discharge as well as in the concentration of dissolved minerals in the water after the rainy season, when the groundwater table rises in the regional aquifers (Goldshmidt et al., 1967; Gvirzman et al., 1997; Kalbe et al., 2015; Mazor and Mero, 1969; Spiro et al., 2011). At the same time, due to higher precipitation, small freshwater puddles formed.

Following this scenario, three cycles can be reconstructed within the analyzed section of the Nadaouiye Aïn Askar stratigraphy, as it is shown by the microfossil data and confirmed by the micromorphological analysis. The first one is characterized by palustrine oligohaline conditions at the site when most likely higher freshwater supply, perhaps triggered by higher precipitation, occurred. Then a small and permanent pond emerged, mainly fed by oligohaline and probably sulphate enriched spring water in times with assumed less precipitation. Finally, precipitation increased, triggering higher oligohaline to mesohaline water supply by the spring and re-established smaller freshwater pools nearby, together with a dense vegetation belt. The hydrochemistry perhaps shifted to lower sulphate content in the uppermost part of the section.

4.5 Early hominin adaption to highly mineralized water resources at the spring of Nadaouiye Aïn Askar

Drinking water quality in terms of TDS content is a heavily discussed issue, because salt content has influence on human behavior and can be a health risk or even a lethal factor (Gleibermann, 1973; Meadow, 1993; Stevenson et al., 2010). Natural selection for electrolyte conservation has also been an important issue throughout human evolutionary history (Jackson, 1991). While international recommendations concerning the maximum TDS value exists (<1000 mg/l TDS: USEPA 2012; WHO 1996, 2010, 2011), studies and reliable data about the maximum of dissolved solids in drinking water modern human inhabitants of arid environments can really sustain are very rare. Observations during field work in the El Kowm basin show, that local people of the arid El Kowm area in Syria use the heavily mineralized waters of the spring cluster as drinking water (1900 – 5100 mg/l TDS, Tab. 1), even when freshwater alternatives, provided by the government, exist. Gastrointestinal problems and other health issues are ubiquitous among the modern population of El Kowm due to the high content of sulphate but also the presence of radioactive elements in the drinking water. Paque (1963, 1980) documented the same observations for Moroccan Bedouins, who drink water with a maximum sodium concentration up to 1704 mg/l and sulphate up to 848 mg/l (Agadir-Tissint, 4300 mg/l TDS in total). The Moroccan springs (Paque, 1980) show sulphate values that are comparable to the lowermost range in sulphates at the El Kowm springs (Tab. 1). The sodium concentrations in the active springs of El Kowm are lower and correlate to the general values of the Moroccan spring waters monitored by Paque (1980).

For the adaptability of early hominins to drinking water resources with high salinity values no data are available. A Mousterian site in the northern part of the Jordan Rift Valley might show a preference to open air localities with saline springs, even if a large freshwater resource exists directly at the site (Kalbe et al., 2015). The ostracod fauna of the Nadaouiyeh Aïn Askar section shows significant variations in the salinity of the ancient spring wetland, whereas early hominins were present at the site over the whole time, documented by the artifact record in the sediment column. We can expect, at least for ostracod Zone P7/B, where no indication for available freshwater at the site occur in the microfauna, the capability of these Lower Paleolithic hominins to cope with higher

salinity, especially to higher sulphate concentrations in drinking water resources, was at least comparable to local communities of modern humans adapted to desert environments. If this assumption is valid, the biogeographical range of early humans, restricted by salinization of water resources, is enlarged into regions with wetland ecosystems showing clearly brackish conditions.

5. CONCLUSIONS

By their geographical location in the “middle of the road” of the dispersal route “out of Africa”, desert wetlands attracted animals and early humans to these water resources, even when they supply ecologically less optimal oligohaline or mesohaline waters. The adaption of aquatic organisms to fossil and recent desert wetland environments is poorly known for the northern Levant and the Arabian Peninsula. This study provides the first detailed ostracod data for the Middle Pleistocene of Central Syria, clearly demonstrating the potential of the Nadaouiyeh Aïn Askar site as unique archive for the reconstruction of wetland ecosystems in arid areas of the eastern Mediterranean and the Arabian Peninsula, past and present. This can be assumed also for the other El Kowm sites, which can complete our understanding of formation and timing of this specific hydrological system. The particular hydrochemical setting of the Nadaouiyeh Aïn Askar site and of the modern springs in the El Kowm area, even if they were highly variable in the past, lead to the conclusion that early hominins in the eastern Mediterranean deserts were able to adapt to brackish drinking water resources.

The micropaleontological and sedimentological record of the Nadaouiyeh Aïn Askar sites allows us to reconstruct a development of the aquatic environment within a Middle Pleistocene desert wetland and spring ecosystem evolving from a paludine setting into a spring supplied pond with the occurring of a brackish/athalassic water body during the late MIS 13. Confirming the results from

micromorphological studies, ostracod analysis of sediment samples complemented hydrochemical assumptions about the fossil spring in terms of SO₄ content and salinity based on datasets from Israel, Jordan and Syria.

Future studies on the Early and Middle Pleistocene deposits of the spring cluster of the El Kowm oasis will hopefully provide a more complete ostracod record of the site as well as hydrological and environmental reconstructions of this important Syrian prehistoric landscape and unique place within the biogeographic corridor between Africa and Eurasia.

ACKNOWLEDGEMENTS: The ostracod research on the sediments of Nadaouiyeh Aïn Askar was funded by the Deutsche Forschungsgemeinschaft (DFG, grant Mi 730/18-1). The Authors like to thank explicitly S. Mischke for supporting this study with the dataset from Mischke et al. (2014b) and application of the transfer function to the ostracod associations of Nadaouiyeh Aïn Askar. They are also grateful to him and I. Soulié-Märsche for discussions about the fauna and flora of aquatic desert environments. We thank A. Musiol and S. Schuman, who have provided the work at the geochemistry laboratories at Potsdam University and the GFZ Potsdam. A first assessment of the ostracod record from Nadaouiyeh Aïn Askar was done by H. Janz (Tübingen). Valuable comments and suggestions by Peter Frenzel and two anonymous reviewers greatly improved the manuscript. We would also like to thank the Directorate General of Antiquities and Museums in Damascus for the kind permission to export the samples. Excavations and geoarcheological investigations at Nadaouiyeh Aïn Askar were funded by the Swiss National Science Foundation, Freiwillige Akademische Gesellschaft and the Tell Arida Foundation. Finally, we are thankful to J.C.D. Kosch for hints regarding references concerning the content of TDS in drinking water sources and to S. Olen for English proofreading.

495

496 REFERENCES:

497

498 Abed, A.M., Al Kuisi, M., Khair, H.A., 2009. Characterization of the Khamaseen (spring) dust in Jordan.
499 Atmos. Environ. 43, 2868–2876.

500 Altınsaçlı, S., 2004. Investigation on Ostracoda (Crustacea) Fauna of some important wetlands of
501 Turkey. Pak. J. Biol. Sci. 7, 2130–2134.

502 Akdemir, D., 2008. Differences in Ostracoda (Crustacea) assemblages between two Maar Lakes and
503 one Sinkhole Lake in the Konya region of Turkey. Turk. J. Zool. 32, 107-113.

504 Berner, R.A., 1984. Sedimentary pyrite formation: an update. Geochim. Cosmochim. Ac. 48, 605–615.

505 Brew, G., Barazangi, M., Al-Maleh, A.K., Sawaf, T., 2001. Tectonic and geologic evolution of Syria.
506 Georabia 6, 573–616.

507 Curry, B.B., 1999. An environmental tolerance index for ostracodes as indicators of physical and
508 chemical factors in aquatic habitats. Palaeogeogr. Palaeocl. 148, 51–63.

509 DeDeckker, P., 1981. Ostracods of athalassic saline lakes. Hydrobiologia 81, 131–144.

510 Djamali, M., Soulié-Märsche, I., Esu, D., Gliozzi, E., Okhravi, R., 2006. Palaeoenvironment of a Late
511 Quaternary lacustrine-palustrine carbonate complex: Zarand Basin, Saveh, central Iran. Palaeogeogr.
512 Palaeocl. 237, 315–334.

513 Forester, R.M., 1986. Determination of the dissolved anion composition of ancient lakes from fossil
514 ostracodes. Geology 14, 796–799.

515 Frenzel, P., Keyser, D., Viehberg, F.A., 2010. An illustrated key and (palaeo)ecological primer for
516 Postglacial to Recent Ostracoda (Crustacea) of the Baltic Sea. Boreas 39, 567-575.

- 517 Fuhrmann, R., 2013. Atlas quartärer und rezenter Ostrakoden Mitteldeutschlands. Naturkundliches
518 Museum Mauritianum, Altenburg.
- 519 Ganning, B., 1967. Laboratory experiments in the ecological work on rockpool animals with special
520 notes on the ostracod *Heterocypris salinus*. Helgoland. Wiss. Meer. 15, 27–40.
- 521 Ganning, B., 1971. On the ecology of *Heterocypris salinus*, *H. incongruens* and *Cypridopsis aculeata*
522 (Crustacea, Ostracoda) from Baltic brackish-water rockpools. Mar. Biol. 8, 271–279.
- 523 Gleibermann, L., 1973. Blood pressure and dietary salt in human populations. Ec. Food Nutr. 2, 143–
524 156.
- 525 Goldshmidt, M.J., Arad, A., Neev, D., 1967. The mechanism of the saline springs in the Lake Tiberias
526 depression. Geol. Surv. Isr. Bull. 45, 1–19.
- 527 Gross, M., Piller, W.E., Scholger, R., Gitter, F., 2011. Biotic and abiotic response to
528 palaeoenvironmental changes at Lake Pannons' western margin (Central Europe, Late Miocene).
529 Palaeogeogr. Palaeocl. 312, 181–193.
- 530 Gvirzman, H., Garven, G., Gvirzman, G., 1997. Hydrogeological modeling of the saline hot springs at
531 the Sea of Galilee, Israel. Water Res. 33, 913–926.
- 532 Hartmann, G. Hiller, D., 1977. Beiträge zur Kenntnis der Ostracodenfauna des Harzes und seines
533 nördlichen Vorlandes (unter besonderer Berücksichtigung des Männchens von *Candona candida*).
534 125 Jahre Naturwissenschaftlicher Verein Goslar, pp. 99–116.
- 535 Hiller, D., 1971. Untersuchungen zur Biologie und zur Ökologie limnischer Ostracoden aus der
536 Umgebung von Hamburg. Arch. Hydrobiol., Suppl. Vol. 40, 400–497.
- 537 Holmer, M., Storkholm, P., 2001. Sulphate reduction and sulphur cycling in lake sediments: a review.
538 Freshwater Biol. 46, 431–451.

539 Jackson, F.L.C., 1991. An evolutionary perspective on salt, hypertension, and human genetic
540 variability. *Hypertension* 17, I-129–I-132.

541 Jaeckel, S.G.A., 1962. Die Tierwelt der Schlei. Übersicht einer Brackwasserfauna. *Schr. Naturwiss. Ver.*
542 *Schleswig-Holstein* 33, 11–32.

543 Jagher, R., 2000. Nadaouiyeh Aïn Askar. Entwicklung der Faustkeiltraditionen und der Stratigraphie
544 an einer Quelle in der syrischen Wüstensteppe. Dissertation, Universität Basel.

545 Jagher, R., 2011. Nadaouiyeh Aïn Askar – Acheulean variability in the Central Syrian Desert, in: Le
546 Tensorer, J.-M., Otte, M. (Eds.), *The Lower and Middle Palaeolithic in the Middle East and*
547 *neighbouring regions. Basel Symposium (May 8.-10. 2008), Liège, ERAUL 126*, pp. 209-224.

548 Jagher, R., Le Tensorer, J.-M., 2011. El Kowm, a key area for the Palaeolithic of the Levant in Central
549 Syria, in: Le Tensorer, J.-M., Otte, M. (Eds.), *The Lower and Middle Palaeolithic in the Middle East and*
550 *neighbouring regions. Basel Symposium (May 8.-10. 2008), Liège, ERAUL 126*, pp. 197–208.

551 Jagher, R., Elsuede, H., Le Tensorer, J.-M., 2015. El Kowm Oasis, Human Settlement in the Syrian
552 Desert during the Pleistocene. *L'Anthropologie* 119: 542-580.

553 Janz, H., 1994. Zur Bedeutung des Schalenmerkmals 'Marginalrippen' der Gattung *Ilyocypris*
554 (Ostracoda, Crustacea). *Stuttgarter Beitr. Naturk. Ser. B* 206, 1–19.

555 Janz, H., Jellinek, T., Hamedani, A., 2001. Holozäne Süßwasser-Ostracoden aus dem Iran.
556 *Senckenbergiana lethaea* 81, 183-205.

557 Juggins, S., 1991. ZONE software, version 1.2. Newcastle University, Newcastle.

558 Kalbe, J., Ames, C., Nowell, A., Cordova, C., Pokines, J.T., 2014. Pleistocene wetlands in the eastern
559 desert of Jordan: Environmental reconstructions by ostracod and gastropod analysis. Abstracts of the
560 "Middle Palaeolithic in the Desert II" conference, 11. – 13.12.2014, Bordeaux, France, p. 30.

561 Kalbe, J., Mischke, S., Dulski, P., Sharon, G., 2015. The Middle Palaeolithic Nahal Mahanayem Outlet
 562 site, Israel: reconstructing the environment of Late Pleistocene wetlands in the eastern
 563 Mediterranean from ostracods. *J. Arch. Sci.* 54, 385–395.

564 Karanovic, I., 2012. Recent freshwater ostracods of the world. Springer, Heidelberg.

565 Kirst, G.O., Janssen, I.B., Winter, U., 1988. Ecophysiological investigations of *Chara vulgaris* L. grown
 566 in a brackish water lake: Ionic changes and accumulation of sucrose in the Vacuolar sap during sexual
 567 reproduction. *Plant Cell Environ.* 11, 55–61.

568 Klie, W., 1938. Ostracoda, Muschelkrebse. – Die Tierwelt Deutschlands und der angrenzenden
 569 Meeresteile nach ihren Merkmalen und nach ihrer Lebensweise, 34. Teil: Krebstiere oder Crustacea.
 570 Jena.

571 Klie, W., 1939. Beiträge zur Kenntnis der Ostracodenfauna Ungarns. – *Allatani Közlemenyek* 36, 168–
 572 174.

573 Le Tensorer, J.-M., Jagher, R., Muhesen, S., 2001. Paleolithic Settlement Dynamics in the El Kowm
 574 Area (Central Syria), in: Conard, N.J. (Ed.), *Settlement Dynamics of the Middle Paleolithic and Middle*
 575 *Stone Age*. Tübingen, Kerns Verlag, pp. 101–122.

576 Le Tensorer, J.-M., Jagher, R., Rentzel, P., Hauck, T., Ismail-Meyer, K., Pümpin, C. & Wojtczak, D.,
 577 2007. Long-term site formation processes at the natural springs Nadaouiyeh and Hummal in the El
 578 Kowm Oasis, Central Syria. *Geoarchaeology* 22, pp. 621–639.

579 Magueron, T., 1998. Fonctionnement hydrologique de la depression d’El Kowm (Syrie), données
 580 préliminaires pour une interprétation paléohydrologique. Diplôme d’études approfondies « Science
 581 de l’eau dans l’environnement continental ». Université d’Avignon et des Pays de la Vaucluse.

582 Mazor, E., Mero, F., 1969. The origin of the Tiberias-No’it mineral water association in the Tiberias-
 583 Dead Sea Rift Valley. *Isr. J. Hydrol.* 7, 318–333.

584 Mazzini, I., Gliozzi, E., Rossetti, G., Pieri, V., 2014. The *Ilyocypris* puzzle: A multidisciplinary approach
585 to the study of phenotypic variability. *Int. Rev. Hydrobiol.* 99, 1–14.

586 Meadow, R., 1993. Non-accidental salt poisoning. *Arch. Dis. Child.* 68, 448–452.

587 Meisch, C., 2000. Freshwater ostracods of western and central Europe. Spektrum, Heidelberg.

588 Mezquita, F., Tapia, G., Roca, J.R., 1999. Ostracoda from springs on the eastern Iberian Peninsula:
589 ecology, biogeography and palaeolimnological implications. *Palaeogeogr. Palaeocl.* 148, 65–85.

590 Mezquita, F., Roca, J.R., Reed, J.M., Wansard, G., 2005. Quantifying species-environment
591 relationships in non-marine Ostracoda for ecological and palaeoecological studies: Examples using
592 the Iberian data. *Palaeogeogr. Palaeocl.* 225, 93–117.

593 Mischke, S., Almogi-Labin, A., Reuven, O., Rosenfeld, A., Schwab, M.J., Boomer, I., 2010. Quantitative
594 reconstruction of lake conductivity in the Quaternary of Near East (Israel) using Ostracods. *J.*
595 *Paleolimnol.* 43, 667–688.

596 Mischke, S., Ginat, H., Al-Saqarat, B., Almogi-Labin, A., 2012. Ostracods from water bodies in
597 hyperarid Israel and Jordan as habitat and water chemistry indicators. *Ecol. Indicators* 14, 87–99.

598 Mischke, S., Ashkenazi, S., Almogi-Labin, A., Goren-Inbar, N., 2014a. Ostracod evidence for the
599 Acheulian environment of the ancient Hula Lake (Levant) during the early-mid Pleistocene transition.
600 *Palaeogeogr. Palaeocl.* 412, 148–159.

601 Mischke, S., Almogi-Labin, A., Al-Saqarat, B., Rosenfeld, A., Elyashiv, H., Boomer, I., Stein, M., Lev, L.,
602 Ito, E., 2014b. An expanded ostracod-based conductivity transfer function for climate reconstruction
603 in the Levant. *Quat. Sci. Rev.* 93, 91–105.

604 Mischke, S., Opitz, S., Kalbe, J., Ginat, H., Al-Saqarat, B., 2015. Palaeoenvironmental inferences from
605 late Quaternary sediments of the Al Jafr Basin, Jordan. *Quatern. Int.*
606 <http://dx.doi.org/10.1016/j.quaint.2014.12.041>.

607 Paque, C., 1963. Alimentation sans sel dans une population nomade saharienne utilisant des eaux
 608 exclusivement salées; approche de L'excrétion urinaire (Na, K). C.R. Hebd. Seances Acad. Sci. 256,
 609 331–332.

610 Paque, C., 1980. Saharan bedouins and the salt water of the Sahara: A model for salt intake, in: Kare,
 611 M.R., Fregly, M.J., Bernard, R.A. (Eds.), Biological and behavioural aspects of salt intake. Academic
 612 Press, New York London Toronto Sydney San Francisco, pp. 31–47.

613 Petkovski, T., 1966. Ostracoden aus einigen Quellen der Slowakei. Acta Mus. Maced. Sci. Nat. 10, 91–
 614 107.

615 Pigati, J. S., Rech, J.A., Quade, J., Bright, J., 2014. Desert wetlands in the geological record. Earth-Sci.
 616 Rev. 132, 67–81.

617 Pint, A., Frenzel, P., Fuhrmann, R., Scharf, B., Wennrich, V., 2012. Distribution of *Cyprideis torosa*
 618 (Ostracoda) in Quaternary Atlalassic Sediments in Germany and its application for Palaeoecological
 619 Reconstructions. Internat. Rev. Hydrobiol. 97, 330–355.

620 Pümpin, C., 2003. Geoarchäologische Untersuchungen an der pleistozänen Fundstelle von
 621 Nadaouiyeh Aïn Askar (Syrien). Diplomarbeit, Universität Basel.

622 Pümpin, C., Jagher, R., 2005. Révisions géologiques. Travaux de la Mission Archéologiques Syro-Suisse
 623 d'El Kowm 10, 46–59.

624 Roca, J.R., Baltanás, A., 1993. Ecology and distribution of Ostracoda in Pyrenean springs. J.
 625 Crustacean Biol. 13, 165–174.

626 Rosenberg, T.M., Preusser, F., Risberg, J., Pliik, A., Kadi, K.A., Matter, A., Fleitmann, D., 2013. Middle
 627 and Late Pleistocene humid periods recorded in palaeolake deposits of the Nafud desert, Saudi
 628 Arabia. Quat. Sci. Rev. 70, 109–123.

629 Rosenfeld, A., Honigstein, A., Scarpa, D., 2002. Pliocene – Pleistocene lakes in southern Israel –
 630 Ostracods and hominids. GSI Curr. Res. 13, 86–93.

631 Rosenfeld, A., Nathan, Y., Feibel, C.S., Schilman, B., Halicz, L., Goren-Inbar, N., Siman-Tov, R., 2004.
 632 Palaeoenvironment of the Acheulian Gesher Benot Ya'aqov Pleistocene lacustrine strata, Northern
 633 Israel – lithology, ostracod assemblages and ostracod shell geochemistry. J. Afr. Earth Sci. 38, 169–
 634 181.

635 Soulié-Märsche, I., 1991. Charophytes as lacustrine biomarkers during the Quaternary in North
 636 Africa. J. Afr. Earth Sci. 12, 341–351.

637 Soulié-Märsche, I., García, A., 2014. Gyrogonites and oospores, complementary viewpoints to
 638 improve the study of the Charophytes. Aquat. Bot. 120, 7–17.

639 Spellerberg, I.F., Fedor, P.J., 2003. A tribute to Claude Shannon (1916-2001) and a plea for more
 640 rigorous use of species richness, species diversity and the „Shannon-Wiener“ Index. Global Ecol.
 641 Biogeogr. 12, 177–179.

642 Spiro, B., Ashkenazi, S., Starinsky, A., Katz, A., 2011. Strontium isotopes in *Melanopsis* sp. as
 643 indicators of variation in hydrology and climate in the Upper Jordan Valley during the Early-Middle
 644 Pleistocene, and wider implications. J. Hum. Evol. 60, 407–416.

645 Stevenson, R.J., Case, T.I., Oaten, M.J., 2010. Salt-induced thirst results in increased finickiness in
 646 humans. Physiol. Rec. 60, 385–398.

647 Sywula, T., 1966. Investigations into saline areas of Poland, faunistic studies: Ostracoda and
 648 Copepoda. Physiogr. Res. West. Pol. 18, 35–65.

649 Turberg, P., 1999. Cartographie électromagnétique du site de Nadaouiyeh Aïn Askar. Trav. Mission
 650 Archéol. Syro-Suisse d'El Kowm 4, 16–25.

651 Tunoğlu, C., Ertekin, İ.K., 2008. Subrecent ostracoda associations and the environmental conditions
 652 of karstic travertine bridges on the Zamantı River, southern Turkey. Türkiye Jeoloji Bülteni 51, 151–
 653 171.

654 USEPA, 2012. 2012 Edition of the drinking water standards and health advisories, U.S. Environmental
 655 Protection Agency, Washington, DC.

656 Vesper, B., 1975. Ein Beitrag zur Ostracodenfauna Schleswig-Holsteins. Mitt. Hambg. Zool. Mus. Inst.
 657 72, 97–108.

658 WHO, 1996. Guidelines for drinking-water quality, 2nd ed., Vol. 2. Health criteria and other supporting
 659 information. World Health Organization, Geneva.

660 WHO, 2010. Water for health. WHO guidelines for drinking-water quality, World Health Organisation,
 661 Geneva.

662 WHO, 2011. Guidelines for drinking-water quality, 4th ed., World Health Organisation, Geneva.

663 Winter, U., Kirst, G.O., 1990. Salinity response of a freshwater charophyte, *Chara vulgaris*. Plant Cell
 664 Environ. 13, 123–134.

665 Wouters, K., 1983. Contributions to the study of Belgian Ostracoda, 1. The Ostracoda from the
 666 environs of Buzenol (Gaume District, Belgium). Bull. Inst. R. Sci. N. B. Biol. 55, 1–9.

667 Zar, J.H., 1999. Biostatistical Analysis, 4th ed., Prentice-Hall, New Jersey.

Figure 1

Figure 2 color

Figure 2 bw

Figure 3 color

Figure 3 bw

Figure 4 color

Figure 4 bw

Figure 5 color

Figure 5 bw

Figure 6

Figure 7

Figure 8

Figure 9

Table 1

Locality	T	pH	HCO ₃	SO ₄	Ca	Mg	Na	K	TDS
	[°C]		[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]
Beit Franslin	26.5	7.5	246.0	1024.5	408.0	132.5	79.0	7.0	2096.6
Aïn Beni Ali	23.8	7.5	256.0	966.7	339.0	116.0	49.0	8.0	1821.0
Bir Qdeïr (E)	28.8	7.4	226.0	1423.4	451.0	172.0	52.0	11.0	2410.6
Umm El Tlel	32.9	7.4	220.0	1441.0	414.0	159.0	59.0	17.0	2406.8
Umm El Tlel ¹	32.2	-	-	-	157.5	144.6	60.4	7.6	2444.0
Beït Maana	23.8	7.3	235.0	1406.7	413.5	159.0	63.0	9.0	2379.8
Sin Al Aïd	30.1	7.3	220.0	1547.1	500.0	169.0	57.0	9.0	2596.0
Jurat al Hummal	26.8	7.4	244.0	1149.0	363.0	124.0	54.0	7.0	2033.0
At Safar	22.7	7.4	278.0	942.0	326.0	114.0	63.0	7.0	1869.6
Umm Qbeiba(SE) ²	19.2	7.5	156.0	2963.0	631.0	365.2	304.0	26.0	5093.1
Umm Qbeïba	31.0	7.5	237.0	1251.1	368.0	131.0	47.0	7.0	2129.1
Umm Qbeïba (S) ¹	-	-	-	-	301.2	188.8	46.6	5.2	2060.0
Aïn Sbeïcha	29.3	7.3	253.0	1672.2	498.0	175.0	53.0	8.0	2777.6
Aïn Sbeïcha ¹	28.9	-	-	-	423.9	153.9	51.0	6.2	2368.0
Bir Keiri (Bakhri)	28.3	7.4	232.0	1456.0	428.0	155.0	52.0	8.0	2413.6
Sheikh Ali	26.5	7.4	244.0	1347.0	404.5	158.0	77.0	12.0	2380.3
El Kowm	29.0	7.6	256.0	935.0	304.0	109.0	46.0	9.0	1734.6
Hadj Hassar Anouzi	26.5	7.3	220.0	1686.7	482.0	177.0	52.0	9.0	2704.9
Bir Tooth	28.7	7.3	220.0	1657.8	481.0	174.0	56.0	9.0	2674.3
Aïn Rasil	29.4	7.5	248.0	1004.8	323.0	114.0	44.0	10.0	1813.2
Taibe ³	22.3	7.6	332.0	321.0	155.0	61.5	73.0	6.0	-
Aïn Salileh ¹	-	-	-	-	433.1	175.1	110.0	8.7	3820.0
Hummal ¹	28.1	-	-	-	247.2	104.1	47.2	4.7	1900.0

Figure Captions:

Fig. 1: A: Digital elevation map of Syria; B: hydrological setup of the area of El Kowm (Central Syria) with distribution of active springs and wells, El Kowm village is located at the main cluster of spring mounds.

Fig. 2: Panoramic view at the excavation in the Quaternary spring deposits of Nadaouiyeh Aïn Askar (Central Syria) in 1999, looking south (depth of dig about 6 m), black bar in the center of the figure indicates the upper part of unit VI (archeological layers C.8.1c – C.8.1; Fig. 4).

Fig. 3: Microphotography of a thin section of c.8.1 (unit VI) with cross sections of ostracods (a) and charophyta (b: calcified gyrogonite, c: less calcified gyrogonite).

Fig. 4: Profile P.7 in the Nadaouiyeh Aïn Askar excavation. The blue squares in the left column show the location of thin section samples of Pümpin (2003), c.8b to c.7 are the archeo-stratigraphic layers according to Pümpin (2003), P7/4.1 to P7/8.6 in the right column show the location of samples for this study. Different grey shades indicate the three ostracod zones in this section. The complex of layers c.8.1b, c.8.1c and c.8a show at the bottom of the right side the kind of deformation due to the cave-ins of younger dolinas. Nevertheless, the archeological record is perfectly preserved in its geological context. Scale = 0.4 m.

Fig. 5: Sulphate vs. salinity-plot, showing tolerances of *C. torosa* (unnoded valves), *D. stevensoni*, *H. salina*, *H. incongruens*, *I. bradyi*, *P. newtoni*, *Trajancypris* sp. and *Mixtacandona* sp. from recent aquatic continental ecosystems of the southeastern Mediterranean, based on a dataset from Mischke et al. (2014b); Dataset 1 = hydrochemical dataset from Mischke et al. (2014b); Dataset 2 = hydrochemical dataset of springs and wells of the El Kowm area, based on data from Magueron (1998) and this study (Tab. 1).

Fig. 6: Ostracods of Middle Pleistocene spring deposits of Nadaouiyeh Aïn Askar (El Kowm oasis cluster, Central Syria). (a) *Cypris* sp. right valve (RV) internal view (iv) P7/8.3; (b-d) *Trajancypris* sp.: (b) left valve (LV) external view (ev) P7/8.5, (c) LV iv juvenile (juv.) P7/8.3, (d) RV ev juv. P7/8.3; (e-f) *Heterocypris incongruens*: (e) RV iv P7/8.2, (f) LV ev P7/8.2; (g-h) *Heterocypris salina*: (g) LV iv P7/8.4, (h) RV ev P7/8.1; (i-j) *Plesiocypridopsis newtoni*: (i) LV iv P7/8.3, (j) RV ev P7/8.3; (k-n) *Cyprideis torosa*: (k) LV iv P7/8.6, (l) RV ev P7/8.6, (m) RV iv juv. P7/8.6, (n) LV ev juv. P7/8.6; (o) *Physocypris* sp. LV iv P7/4.1; (p) *Pseudocandona* cf. *compressa* RV ev P7/4.1; (q) *Mixtacandona* sp. RV ev P7/4.2; (r-s) *Darwinula stevensoni*: (r) RV iv P7/7.1, (s) RV ev P7/8.6; (t) juvenile Candoninae indet. RV ev P7/6; (u) *Candona* cf. *neglecta* RV iv P7/5.1 (fragment); scale bar 400 µm.

Fig. 7: Ostracods of Middle Pleistocene spring deposits of Nadaouiyeh Aïn Askar (El Kowm oasis cluster, Central Syria). (a) *Ilyocypris* sp. 1 LV iv P7-8.3; (b-c) *Ilyocypris inermis*, b: LV iv P7-8.2, c: RV ev P7-7.3; (d-f) *Ilyocypris* cf. *gibba*, d: detail from (e) enlargement of postero-ventral margin of *I. cf. gibba* to highlight marginal ripples, e: LV iv P7-8.5 with gypsum crystals, f: RV ev P7-8.6; scale bar 200 µm for a – c and e – f, scale bar for d 100 µm.

Fig. 8: Gyrogonites of *Chara vulgaris* L. from samples P7/8.5 and P7/8.6; a) lateral view (lv), b) apical view (av), c) lv, d) basal view (bv), e) lv, f) bv ; scale bar: 500 μm .

Fig. 9: Absolute abundances of selected ostracod species per 200 g sediment, Shannon diversity index (H' (without unit): continuous line), conductivity (con [mS/cm]: circles, calculated with the transfer function and the dataset of Mischke et al. (2014b)), TOC, TC and S of the archeological unit IV, sample numbers are displayed on the left y-axis, ostracod zones are displayed on the right y-axis.

Tab captions

Tab. 1: Hydrochemical data from springs and wetlands within the of El Kowm oasis cluster, Syria. T = temperature, TDS = Total dissolved solids, data from Magueron (1998) except: ¹ sampled by R. Jagher in 1993; ² sampled from groundwater near the surface, ³ springs sampled out of the range of the El Kowm oasis.

Supplementary Tab. 1: Absolute abundances of ostracod valves and characean gyrogonites per 200 g sediment and Shannon Diversity Index (H') of late MIS 13 sediments from Nadaouiyeh Aïn Askar spring deposits.