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MOLLUSCS AND OSTRACODS OF THE QARUN LAKE: PRELIMINARY REPORT FROM FA-1 CORE IN FAIYUM OASIS, NORTHERN EGYPT

Marcin Szymanek

University of Warsaw, Faculty of Geology, Warsaw, Poland, e-mail: m.szymanek@uw.edu.pl

Abstract

A research was conducted on the Holocene lake sediments from the full-cored FA-1 drilling at the southern shore of the Qarun Lake in the Faiyum Oasis in northern Egypt. Altogether 10 taxa of molluscs and 8 taxa of ostracods were identified in the examined deposits, with total amounts of 768 and 2872 individuals, respectively. The fauna was investigated with palaeoecological purpose and allowed for preliminary reconstruction of sedimentary environment in the lake. The occurrence of *Valvata nilotica* Jickeli, 1874 and *Gomphocythere* sp. in the lower part of the core and a low proportion of carapaces (2.4–28%) indicated freshwater and higher-energy conditions, respectively. Rapid expansion of *Cyprideis torosa* (Jones, 1850) at a depth of 18 m could point to very short saline episode in the lake. The increase in salinity and drop of water level were evidenced in the uppermost part of the core (4–3.5 m), when the lake was dominated by *Hydrobia ventrosa* (Montagu, 1803), *Cerastoderma glaucum* (Poiret, 1789) and *C. torosa*. The steady sedimentation in a shallow lake was also supported by considerable amount of complete ostracod carapaces (45%). The faunal assemblage and smooth valves of *C. torosa* suggested salinity of 14–25‰.

Key words: Molluscs, ostracods, Holocene, Qarun Lake, Egypt

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INTRODUCTION

The Qarun Lake (29°26’36” – 29°31’15”N and 30°23’52” – 30°49’55”E) is located in the deepest part (43–44 m b.s.l.) of the vast Faiyum Oasis in northern Egypt, approximately 100 km south-west of Cairo (Fig. 1). Today, this shallow (mean and maximum depths of 4.2 and 8.5 m, respectively) and saline lake is approximately 40 km long and 5.7 km wide. It occupies an area of about 250 km^2 (Hughes and Hughes, 1992; El-Sayed and Guindy, 1999), which constitutes about 15% of the former lake basin occurring here since the early Holocene (cf. Caton-Thompson and Gardner, 1934; Wendorf and Schild, 1976). The lake formation was possible due to seasonal connections and distinct support of the Nile flood water, that occurred in the Faiyum Oasis since the early Holocene (e.g. Revel *et al*., 2014; Marks *et al*., 2016; Welc, 2016). The Nile floods inwashed fluvial deposits to the Faiyum Oasis, which together with diatomites, lacustrine silt and clay, and aeolian sand belong to the Quaternary main facies in the study area. They are underlain by Pliocene and Late Miocene rock formations, as well as limestones, marls and sandstones of Eocene and Oligocene age (Marks *et al*., 2016; Welc, 2016).

The 26-m long full-cored FA-1 borehole (10 cm in diameter) was drilled at the south-eastern shore of the Qarun Lake (Fig. 1). The lithological profile started with the early Holocene massive carbonate clay, covered by thin layer of sandy clayey silt and silty clay. Upwards, fine-laminated silt and clay occurred, with some mollusc remains noted at a depth of 18.9–18.7 m. These deposits were covered by thickly-laminated silt and clay with distinct shell-bearing horizon in the depth interval of 4–3.5 m. The sedimentation ended with 2-m thick modern sediments (Fig. 2).

The FA-1 sequence is the longest, undisturbed and the most complete log in the region (e.g. Flower *et al*., 2012; Marks *et al*., 2016), providing valuable palaeoenvironmental and palaeoclimatic data indispensable for both the reconstruction of the Lake Qarun history and the Holocene climate change in northern Africa (Marks *et al*., 2016; Welc, 2016). This study briefly reports a composition of the molluscan and ostracod fauna of the FA-1 core. Its main goal was to recognise molluscs and ostracods from the studied sequence and apply them as an indicator of palaeolake conditions in the Qarun Lake, with the emphasis laid on the lake depth and changes in the water salinity. Those interpretations were predicted to indicate some crucial points

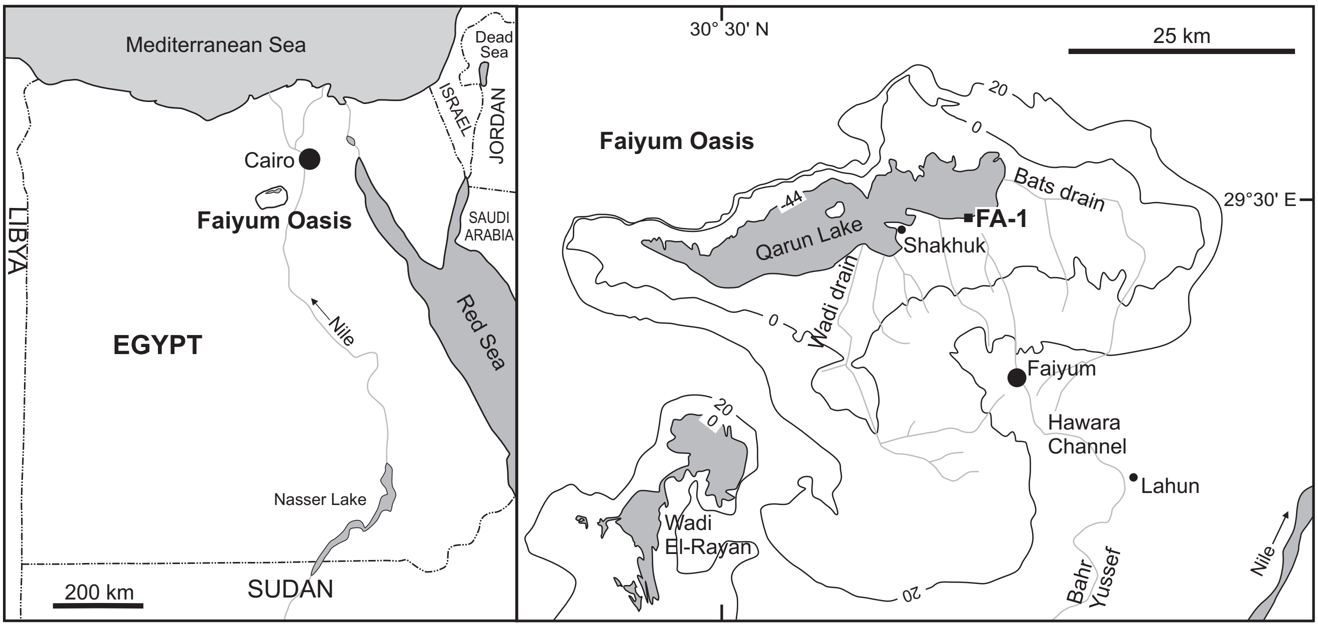

Fig. 1. Location sketch of the Lake Qarun and FA-1 core.

in the sequence and would be a base for further detailed reconstructions, supported by the high-resolution multidisciplinary studies comprising radiocarbon, geochemical and diatom analyses.

MOLLUSC AND OSTRACOD INVESTIGATIONS IN THE FAIYUM OASIS

The Holocene molluscs of the Faiyum Oasis were firstly described in the 19th century (Martens, 1879), whereas the first studies on their systematics conducted by Gardner (1932) provided data on 25 taxa collected from the lake beaches and lake deposits; however, without detailed locations of the sampling sites (Hassan *et al*., 2012). In general, the mollusc assemblages of the early Holocene were dominated by freshwater bivalves of the genera *Corbicula* and *Unio*. In the middle Holocene abundant gastropods *Melanoides* sp. and *Planorbis* sp. occurred, but since 19th century they have disappeared in the Lake Qarun, giving way to marine bivalve *Cerastoderma glaucum* (Hassan *et al*., 2012). Today, the latter constitutes even 70% of biomass of all molluscs in the lake, which are the main component of recent benthic fauna (Abdel Malek and Ishak, 1980; El-Shabrawy and Dumont, 2009). According to Naguib (1961) *C. glaucum* is accompanied by abundant *Pirenella* and *Mactra* snails, while the comprehensive studies of plankton and benthic organisms are represented (apart from *C. glaucum*) by five gastropod species, namely *Pirenella conica* Blainville, 1829, *Melanoides tuberculata* (O.F. Müller, 1774), *Hydrobia stagnalis* (Baster, 1765) = *Hydrobia ventrosa*, *Physa acuta* Draparanaud, 1805 and *Cleopatra bulimoides* (Olivier, 1804) (Abdel Malek and Ishak, 1980). Sattman and Kinzelbach (1988) reported only on three mollusc species from the Qarun Lake assigned to two ecological groups. *P. conica* and *Hinia costulata* (Brocchi, 1814) represented snails of Mediterranean origin, whereas *C. bulimoides* was a snail of the Nile River Valley characteristic of the coarse-grained sediments (Sattman and Kinzelbach, 1988; Alexandrowicz, 2001). Its occurrence in the Faiyum Oasis was treated as a clear evidence of penetration of this region by the Nile during the middle Holocene (Alexandrowicz, 2001). This was also supported by similar compositions of subfossil mollusc assemblages from the Faiyum Oasis (radiocarbon dated at 7–6.5 ka BP) and the modern fauna of the Nile Valley containing, among others, *C. bulimoides*, *Valvata nilotica*, *Theodoxus niloticus* (Reeve, 1856), *M. tuberculata*, *Gyraulus ehrenbergi* (Beck, 1837) and *Bulinus truncatus* (Audouin, 1827) (Alexandrowicz, 1986, 2001).

Finally, mollusc shells have been also applied in geochemical studies of the Qarun Lake. Hassan *et al*. (2012) used stable oxygen and carbon isotopes of the shells collected at geoarchaeologically dated sequences to reconstruct both the palaeoenvironmental changes in the lake and palaeoclimatic variations in northern Africa throughout the Holocene, including dynamics of water level changes and the Nile floods discharge, as well as evaporation and precipitation rates. Seven mollusc taxa were used in these studies including *Corbicula* sp., *Melanoides* sp., *Planorbis* sp., *Lymnaea* sp., *Cardium* sp. and *Coelatura* sp. (Hassan *et al*., 2012). Based on high concentrations of trace metals in their bodies, the modern molluscs of the Qarun Lake appeared to be a good bioindicator of the recent ecological status of the lake waters affected by the artificial pollution (Ali and Fishar, 2005).

Isotope and chemical composition was also studied for ostracod *Cyprideis torosa* from the Qarun Lake (Keatings *et al*., 2007). It is worth noting that being resistant to saline and chemical conditions unfavourable for other species, it was often the only ostracod that ocurred in the modern lake sediments (Abdel Malek and Ishak, 1980 – here described as *Cyprideis littoralis* (Brady, 1938); Perthuisot *et al*., 1990; Keatings *et al*., 2007). Both the characteristics of its population and geochemistry of its valves were used to determine the lake level variation, wave energy, degree of evaporation and water salinity affected by both the groundwater input as well as precipitation and dissolution of authigenic minerals (Keatings *et al*., 2007). Further ostracod studies in the Qarun Lake focused on the last 2000 years recorded in over 8-m long core collected in the deepest part of the lake (Keatings *et al*., 2010). At that time, nine taxa were recognised and described in detail, and then used for reconstruction of fluctuations in water depth, water salinity and its chemical composition. Changes in ion concentrations were based on variable relations of *C. torosa* and *Limnocythere inopinata* (Baird, 1843), as the former species preferred Na^+ and Cl^- rich waters and expansion of the latter was correlated with increased contents of Na^+, HCO_3^- and CO_3^{2-} and decreased of Ca^{2+}. These changes were caused by intensive human activity in the Faiyum Oasis connected with farming and irrigation and its influence on local hydrology and the Nile flood intensity (Keatings *et al*., 2010). It must be highlighted that ostracod assemblage described by Keatings *et al*. (2010) differed significantly from that reported earlier by Bassiouni *et al*. (1985, 1986). Among nine species *Cyprideis sohni* Bassiouni, 1979, *Cypridopsis vidua* (O. F. Müller, 1776) and several species of the genus *Leptocythere* should be mentioned (Bassiouni *et al*., 1985, 1986). According to Keatings *et al*. (2010) a diversity of fauna could be connected with its natural changes in the lake, species rarity and partly in some differences in taxonomy and nomenclature as *C. sohni* and *C. torosa* could be the synonyms.

Data on somewhat older ostracod assemblages in the Faiyum Oasis are scarce. Only Boukhari and Guernet (1985) described the early Holocene ostracods represented by up to ten species with *C. torosa*, *Darwinula* cf. *stevensoni* (Brady et Robertson, 1870), *Ilyocypris bradyi* Sars, 1890, *L. inopinata*, *Gomphocythere* cf. *obtusa* (Sars, 1910) and the others (Boukhari and Guernet, 1985; Keatings *et al*., 2010).

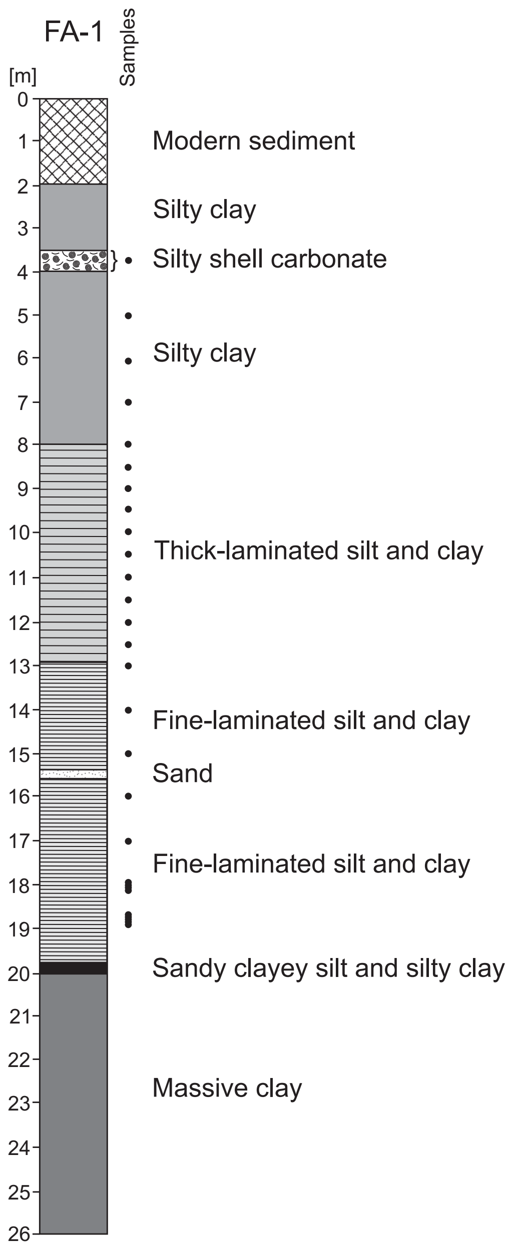

Fig. 2. Simplified lithological profile of FA-1 core (after Marks *et al*., 2016, modified).

MATERIALS AND METHODS

According to the abundance of fossils in the sediments, 6 and 29 samples were analysed for molluscs and ostracods in the FA-1 core, respectively. Malacological samples, 50 cm^3 each, were collected at 5 cm intervals at depth 18.9–18.7 m, whereas a single bulk sample (volume of 370 cm^3) was examined from the depth 4.0–3.5 m. Samples were macerated and washed through a 0.5 mm mesh, according to procedures described by Ložek (1964, 1986, 2000) and Alexandrowicz and Alexandrowicz (2011). All shells, their identifiable apical fragments and fragments with characteristic sculpture were picked from the dried residue. Then, they were taxonomically determined under a stereoscopic microscope at magnifications up to 64x with reference to taxonomical keys (Brown, 1994; Götting, 2008; Welter-Schultes, 2012) and counted following Ložek's (1964) method for broken individuals, which takes five shell fragments as a single complete individual (with proper corrections above 25 fragments). For bivalves the number of valves was given and some damaged specimens were determined only to the genus level (Fig. 3). Ecological preferences of mollusc species were based on Taraschewski and Paperna (1981), Brown (1994), Götting (2008), Welter-Schultes (2012) and Ghamizi *et al*. (2010, 2012).

Ostracods were collected at every 5 cm at depth intervals of 18.9–18.7 m and 18.1–17.9 m, at every 1 m at the depths 17–13 m and 8–5 m, and at every 0.5 m between 13 and 8 m (Fig. 3). A volume of 10 cm^3 of the sediment per sample was wet-sieved with 0.1 mm mesh (Löffler, 1986). Ostracods were recognised under a stereoscopic microscope (magnification up to 64x) according to Sywula (1974) and Keatings *et al*. (2010); however, some juvenile

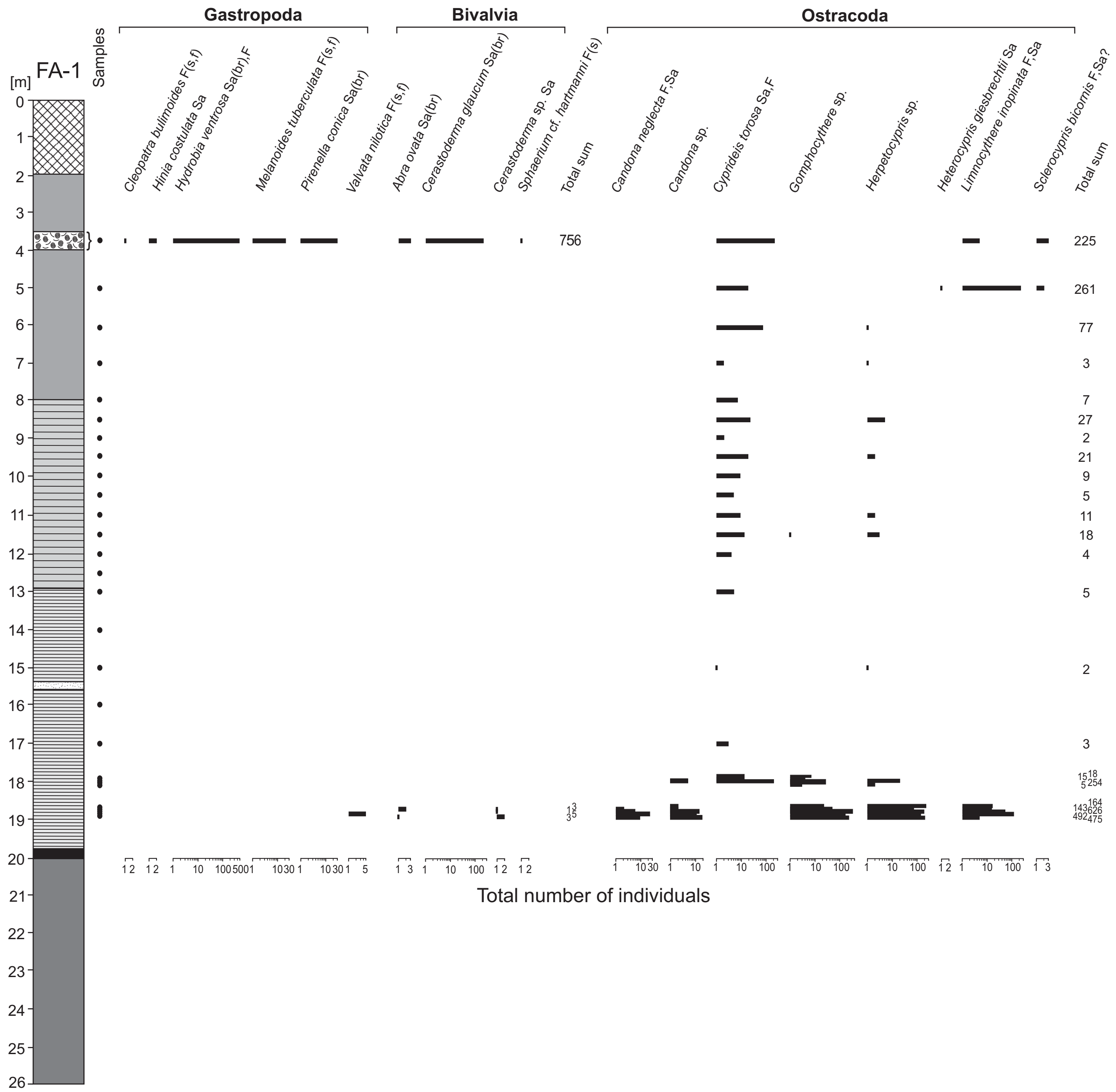

Fig. 3. Logarithmic diagram of faunal abundance in FA-1 core. Ecological preferences are given after the species name: F – freshwater: s – stagnant water, f – flowing water; Sa – saltwater: br – brackish. For bivalves and ostracods a number of valves is given.

and incomplete individuals were classified only to the genus level. A number of valves was counted in each sample (Fig. 3), whereas in samples with the most abundant fossils a proportion of both the complete carapaces and the valves was used to indicate the energy regime of the lake (cf. Keatings *et al.*, 2007, 2010).

CHARACTERISTCS OF MOLLUSCS AND OSTRACODS IN FA-1 CORE

In total, the analysed material comprises 10 taxa of molluscs (6 snails and 4 bivalves) and 8 taxa of ostracods represented by 768 and 2872 individuals, respectively (Fig. 3). The lowermost samples contained very scarce mollusc remains. No shells have been found at a depth of 18.7 m, whereas below (at a depth of 18.9–18.75 m) only 1–2 species and 1–5 individuals were noted in a single sample, with the freshwater snail *Valvata nilotica* endemic to the Ethiopian Highlands and the Lower Nile and some single fragments of saline bivalves *Abra ovata* (Philippi, 1836) and *Cerastoderma* sp. (Fig. 3). Abundant shells belonging to 756 individuals of 8 taxa occured in the upper part of the sequence, at a depth of 4.0–3.5 m. The mollusc assemblage was dominated by brackish species, namely *Hydrobia ventrosa* and *Cerastoderma glaucum*, accompanied by euryhaline snails *Pirenella con-*

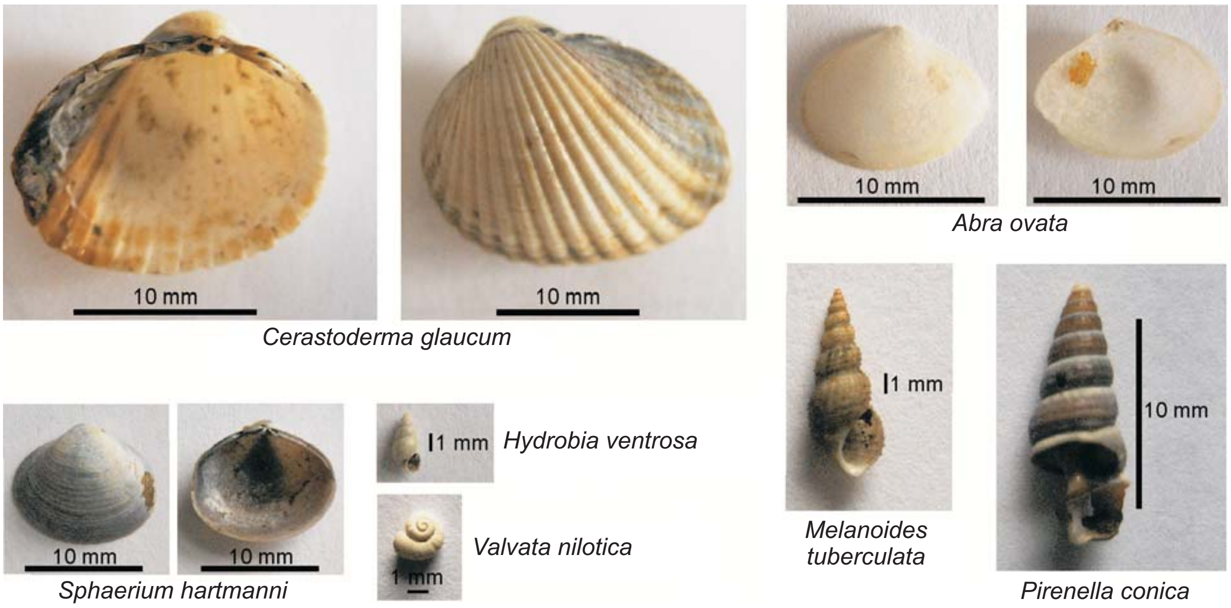

Fig. 4. Selected mollusc species in the Lake Qarun from the FA-1 core.

ica, *Hinia costulata* and three freshwater species: *Cleopatra bulimoides, Sphaerium* cf. *hartmanni* Jickeli, 1874 and the most abundant *Melanoides tuberculata* (Figs 3, 4).

The ostracod fauna of the FA-1 core outnumbered the molluscs with 8 taxa represented by 2872 individuals. A number of taxa and individuals varied from 1 to 6 and from 2 to 626 per sample, respectively. The poorest assemblages were noted at 18.05 m, 17.95–17.9 m and at the depth interval of 17–6 m (Fig. 3). Samples from the depth of 18.9–18.7 m were dominated by freshwater *Gomphocythere* sp. and juvenile and/or damage valves of *Herpetocypris* sp. accompanied by *Limnocythere inopinata* and *Candona neglecta* Sars, 1887, occurring both in fresh and saltwaters and in various depth conditions (common from littoral to deep profundal; Sywula, 1974). Worth noting is a lack of *Cyprideis torosa*, characteristic of calm, near-shore zones of brackish water bodies (Sywula, 1974; Neale, 1988; Keatings *et al*., 2010), which in the FA-1 core predominated at the depths of 18 and 4–3.5 m (Fig. 3), with valves all without nodes. In the highest part of the core, this species was accompanied by only single valves of *L. inopinata* and *Sclerocypris bicornis* (G.W. Müller, 1900) (Fig. 3).

In the FA-1 core distinct changes in the valve/carapace ratio were observed. Altogether carapaces constituted about 21% of the assemblage, changing from 22–28% in the lowermost samples, through 2.4% at a depth of 18.7 m to 45% in the depth interval of 4–3.5 m.

INTERPRETATION OF THE FAUNAL RECORD OF FA-1 CORE

Relatively low volume of the examined material accompanied by a low frequency of molluscs shells in the lowermost part of the sequence made a detailed quantitative analysis impossible; however, the fauna of the FA-1 core provided some significant palaeoenvironmental data for the Qarun Lake. In general, the recognised molluscs and ostracods exhibited wide ecological tolerance occurring in both salt and freshwater bodies (Sywula, 1974; Brown, 1994; Park and Martens, 2001; Keatings *et al*., 2010), but various relations between characteristic species noted in several samples pointed to changes of palaeohydrological and depth conditions during deposition of lake deposits.

The fauna of the depth interval of 18.9–18.7 m appears to indicate freshwater environment evidenced by occurrence of *Valvata nilotica* and *Gomphocythere* sp. Single shell fragments of saltwater bivalves *Abra ovata* and *Cerastoderma* sp. might have been redeposited during drilling from the uppermost part of the core. The identification of *Gomphocythere* ostracods only in the rank of genus hinder further interpretations at this level, but it must be highlighted, that the *Gomphocythere* species were mostly reported from a soft sublittoral substrate of freshwater bodies (Park and Martens, 2001; Boomer and Gearey, 2010; Cohen *et al*., 2013). In Lake Qarun *Gomphocythere* cf. *obtusa* (Sars, 1910) was described by Boukhari and Guernet (1985), but due to lack of comparative material the verification of valves from FA-1 core appears impossible. In contrast, they contain distinct ventral ridge and lateral crests, which may refer to individuals from the Tanganyika Lake described as *Gomphocythere* n. spec. and sharing the morphological traits with *Gomphocythere downingi* Park and Martens, 2001 (Cohen *et al*., 2013). Thus, a taxonomy of the *Gomphocythere* sp. in the Lake Qarun requires further studies and comparisons with other African lakes and should stay open at this moment.

The faunal assemblage of the lowermost samples with scarce molluscs and abundant ostracods with *Gomphocythere* sp., *Candona neglecta* and *Limnocythere inopinata* could record somewhat a deeper part of the lake compared to the uppermost part of the sequence, and presumably with higher-energy conditions, suggested by a low frequency of carapaces (2.4–28%) and considerable amounts of broken valves (cf. Keatings *et al*., 2010), especially at the depths of 18.75 and 18.7 m. Increased content of *Cyprideis torosa* at the depths of 18 m and 4–3.5 m, and expansion of molluscs typical of saline waters in the latter (namely *Hydrobia ventrosa*, *Cerastoderma glaucum*, *Cyprideis torosa*), may record episodes of increased salinity in the lake. The isolated peak of *C. torosa* at the depth of 18 m (Fig. 3) is especially worth noting, as it suggests presence of a very short episode with higher salinity. It appears that after this episode some unfavourable conditions for ostracods and/or valve preservation could occur, as indicated by very scarce fauna noted between 17 and 5 m (Fig. 3).

Changes in the uppermost part of the core are connected with both the higher salinity and the lake shallowing, evidenced by high contents of *H. ventrosa* and *C. torosa* typical of shallow and calm habitats (Sywula, 1974; Götting, 2008; Welter-Schultes, 2012). The steady sedimentation in a shallow lake was also supported by considerable content of complete ostracod carapaces (45%) and the occurrence of *Pirenella conica*, which avoids a wave action (Taraschewski and Paperna, 1981; Whatley, 1988; Boomer *et al*., 2003; Keatings *et al*., 2010). An admixture of freshwater species in this relatively thick sample (4–3.5 m) could suggest some shell mixing, but most of them co-occur with brackish taxa in other Egyptian lakes, whereas *Melanoides tuberculata* and *Cleopatra bulimoides* were even listed amongst the brackish snails (e.g. Sattmann and Kinzelbach, 1988).

Taking into consideration an increased salinity of the Qarun Lake, there rises a question of its salinity range. *P. conica* has the highest salinity tolerance reaching up to 90‰ (Taraschewski and Paperna, 1981). *C. glaucum* and *A. ovata* occur at 3–61‰ and 3–41‰ (Gontikaki *et al*., 2003), respectively, whereas *H. ventrosa* reveals the most narrow tolerance between 6 and 25‰ (Götting, 2008; Welter-Schultes, 2012). Based on the latter and the smooth valves of *C. torosa*, which occur in the salt concentrations usually higher than 14‰ (Vesper, 1975; Neale, 1988; Keyser and Aladin, 2004; Keyser, 2005), the salinity range recorded in the uppermost part of FA-1 core (4–3.5 m) can be estimated at 14–25‰. Moreover, at that time the lake waters appeared to be rich in Na^+ and Cl^-, preferred by *C. torosa*, in contrast to former phase of Na^+, HCO_3^- and CO_3^{2-} predominance and low contents of Ca^{2+} recorded by expansion of *Limnocythere inopinata* at the depth of 5 m (cf. Keatings *et al*., 2010; Marks *et al*., 2017). Variable relations of *C. torosa* and *L. inopinata* were also noted in other sections of the Qarun Lake being connected with farming in the region and/or changes in the Nile supply (Keatings *et al*., 2010), but in the light of the faunal data presented in this paper this problem should remain open.

CONCLUSIONS

Both the composition and the structure of faunal assemblage in FA-1 core allowed for a palaeoenvironmental reconstruction of the Qarun Lake. Three phases of fauna development were distinguished. The oldest was represented by a lower part of the sequence (18.9–18.7 m depth) with scarce molluscs and numerous ostracods, when the freshwater lake was relatively deep and affected by higher wave/currents energy. Then, at the depth of 18 m the first, short saline event was recorded by rapid expansion of *Cyprideis torosa*, followed by the phase with poor faunal assemblage. Another expansion of *C. torosa* correlated with the increase in the water salinity and the lake shallowing was documented in the upper part of FA-1 core (4–3.5 m depth). The fauna was dominated by brackish species (*Hydrobia ventrosa*, *Cerastoderma glaucum*, *Pirenella conica*) typical of calm, near shore zone. Smooth valves of *C. torosa* and abundance of *H. ventrosa* pointed at that time to the salinity range between 14 and 25‰.

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