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Earliest cereal cultivation in Egypt recorded in the Faiyum Oasis lake deposits and its palaeoclimatic context

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We determine the beginning of the Neolithic farming in northern Egypt, based on analysis of core FA-1 of lake deposits in the Faiyum Oasis in northern Egypt. Regular lamination of the early Middle Holocene lake deposits, supported by radiocarbon dating and pollen analysis, indicates the earliest occurrence of domesticated cereals at ~7.8 cal ka BP in this region. The appearance of cereals in the Faiyum region was possible due to fundamental restructuring of regional climatic conditions caused by the changing atmospheric circulation in the eastern Mediterranean region. Stronger northwestern winds were accompanied by increased precipitation in winter and enabled 3 farming phases in the Faiyum Oasis at 7.8–7.6, 7.4–7.2 and 7.0–6.8 cal ka BP, separated by arid episodes with predominant southern winds. Most probably, cereal cultivation concentrated inside local wadis to the north of the lake and was rainfall-dependent. Therefore, early Egyptian farming did not develop based on irrigation systems as commonly thought, but was rain-fed, this being possible due to marked climate change at the beginning of the Middle Holocene.

Key words: Neolithic, Egypt, Qarun Lake, early cereal cultivation, climate change, Middle Holocene.

INTRODUCTION

Wheat and barley cultivation appeared in the Near East at the end of the 8th millennium BC and enabled expansion of Neolithic farming to Europe, western Asia and northern Africa, including the Nile Valley. Wheat played a crucial role in food production in these ancient times, being superior to most other cereals in nutritive value. Several, chromosomally differing, distinct species of the genus *Triticum* L. were brought into cultivation. Einkorn wheat (*Triticum monococcum*) was among the principal crops in Neolithic food production, however, it preferred a cool climate and was absent in hot regions such as Egypt. Durum-type wheat appeared probably in the Neolithic and gained prominence and constituted the main wheat crop in the dry-summer and warm Mediterranean region (Zohary et al., 2012).

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The Faiyum Oasis is located ~90 km to the south-west of Cairo in Egypt and occupies a depression covering ~1700 km^2, separated from the Nile Valley to the east and surrounded by escarpments of Eocene strata. In the Holocene, an extensive lake in the oasis was supplied with freshwater from the Nile via a channel that is occupied today by the Bahr Yusuf Canal (Said et al., 1972). The modern hyper-saline Qarun Lake, 40 km long from east to west and 5.7 km wide, with maximum depth to 8 m, is a relic of the extensive Middle Holocene palaeolake (Flower et al., 2006).

The Faiyum A culture represents the earliest fully developed agricultural (Neolithic) society in Egypt (Shirai, 2012, 2013; Holdaway and Wendrich, 2017). The first known Neolithic sites in the Faiyum region were excavated by Caton-Thompson and Gardner (1929, 1934) along the northern edge of the modern Lake Qarun (Fig. 1). Results of these investigations were then supplemented by the extensive fieldwork of Wendorf and Schild (1976), Wenke et al. (1983), Ginter and Kozlowski (1986) and many others (among them: Holdaway et al., 2016, 2018a, b; Koopman et al., 2016; Linseele et al., 2016; Phillipps and Holdaway, 2016; Phillipps et al., 2016; Holdaway and Wendrich, 2017). Numerous archaeological sites were discovered with thousands of flint tools, bone fragments, pottery shards, hearths, sandstone grinding stones and several grain

Fig. 1. Faiyum Oasis with location of the most important archaeological sites and of borehole FA-1 (drawing F. Welc)

storage pits (Wetterstrom, 1993; Wendrich and Cappers, 2005; Wendrich and Holdaway, 2017) A total of 67 storage pits were unearthed on Kom K (many of them lined with coiled basketry). In the area named as Lower K Pits, the remains of 109 pits were also located (Caton-Thompson and Gardner, 1934).

These represent the earliest traces of cereal cultivation in prehistoric Egypt linked with the Faiyum A culture (Caton-Thompson and Gardner, 1934). Some of the silos contained carbonized remains of emmer wheat (*Triticum turgidum* ssp. *dicoccon*), two-rowed barley (*Hordeum vulgare* ssp. *distichon*) and six-rowed barley (*Hordeum vulgare* ssp. *vulgare*) (Caton-Thompson and Gardner, 1934; Wenke et al., 1988; Schepers et al., 2006; Shirai, 2010; Wendrich et al., 2010). These discoveries indicate that the Faiyum A culture was based on farming, supplemented by hunting and fishing along with the use of domestic animals (see latest discussion in Holdaway et al., 2016; Linseele et al., 2016; Holdaway and Wendrich, 2017; Holdaway et al., 2018a, b).

Until recently, most data on the economy of the Faiyum A culture, particularly concerning the first signs of cereal cultivation, both in the Faiyum Oasis and northern Egypt, were collected exclusively during exploration of numerous archaeological sites scattered along the northern edge of Lake Qarun. Dating of the appearance of cultivated cereals is among the most important and still unresolved topics concerning the Faiyum Oasis. New geoarchaeological data concerning this issue were collected through examination of the Holocene deposits of Lake Qarun (Fig. 1). They were based on borehole FA-1, drilled in 2014 on the southern shore of the lake, that yielded a complete core 26 m long (Marks et al., 2016, 2018). The core was subjected to multi-proxy lithological, geochemical and palaeontological analyses, supported by a well-calibrated age-depth model based on radiocarbon determinations (Marks et al., 2018). It is the most complete and the longest sediment record of the lake that for a time filled the Faiyum Oasis. Part of the core, dated at 8.5–6.8 cal ka BP, was analysed to determine the occurrence of cultivated cereal pollen grains and to correlate this with environmental conditions in the Faiyum region.

METHODS AND MATERIAL

LITHOLOGY OF THE CORE FA-1

The borehole was drilled using a self-propelled hydraulic rig and the core was collected in plastic pipes, each 1 m long and 10 cm in diameter. The lithology of the core FA-1 was described in detail and sampled at intervals of 5 cm in laboratory conditions to provide a high stratigraphic resolution (Marks et al., 2018).

DEPTH-AGE MODEL

Radiocarbon dating was based on 32 bulk samples of organic-rich mud or mud with dispersed organic matter (Marks et al., 2018). The hard water effect seems to have been very small, especially in the lower laminated part of the section where most samples were collected from the organic laminae. Radiocarbon measurements were performed in graphite targets in the Poznań Radiocarbon Laboratory in Poland (Goslar et al., 2004). A flexible age-depth Bacon routine was used to model the accumulation rate and its variability, and Student's t-distributions with wide tails were used to accommodate dating scatter. All default settings were used, except for the section thickness, which was set at 20 cm given the length of this core. Bacon used the *IntCal13* curve (Reimer et al., 2013) to calibrate the radiocarbon dates.

Based on the depth-age model obtained, a crucial step was to select the part of core FA-1 in which the chronology corresponds to the Neolithic in the Faiyum Oasis. Previous and recent radiocarbon chronological data sets enabled us to construct chronological frameworks of the Faiyum A culture (see e.g., Wendorf and Schild, 1976; Pazdur, 1983; Wenke et al., 1983; Hassan, 1985, 1986, 1988; Hendrickx, 1999; Shirai, 2010; Wendrich et al., 2010; Phillipps et al., 2012; Linseele et al., 2016). According to most of these authors the beginning of the Faiyum A culture can be established at ~7.6–7.5 cal ka BP. The latest available sets of radiocarbon calibration determinations published by Holdaway et al. (2017) changed the previous general view that inferred human activity in Faiyum in the first half of the Early Holocene (9.2 to 9.0 cal ka BP – Epipalaeolithic), followed by abandonment during the 8.2 ka event and Neolithic reoccupation during the Mid-Holocene 7.55 to 6.1 cal ka BP (Wendorf and Schild, 1976; Hassan, 1986; Wendorf et al., 2001). According to Holdaway et al. (2017), identification of this hiatus was based mainly on interpretation of the low numbers of determinations for this time, compared to the larger number of dates both before and after this period. However, this hiatus reflected a number of samples dated from particular sites rather than the actual absence of people. This means that the frequency of age determinations at any particular point in time is a product of a site-specific sampling and preservation fluctuations in such a plot (Fig. 2), that at first sight seem to show periods of more and less intensive occupation (Holdaway et al., 2017). These fluctuations in fact reflect different intensities of site-specific sampling and all these points need to be considered when considering the chronology of occupation in the Faiyum region. Past interpretations of the occupation chronology used the pre- to Mid-Holocene hiatus as a convenient time of departure from a socioeconomy based on hunting and gathering wild plants and animals to one based on domesticated plants and animals, as part of the introduction of the Neolithic package. Typological divisions also contributed to the dichotomy between the Epipaleolithic and the Neolithic (Holdaway et al., 2017).

What we can conclude based on these most recent data is that after a short decrease in the total data number in the so-called "chronological gap" (dated at 8.2–7.9 cal ka BP and separating the Epipalaeolithic from the Neolithic), the number of dates after 7.8 cal ka BP gradually increases again. This newest plot of dates indicates that the Faiyum Oasis was occupied throughout the entire Holocene, so a simple dichotomy between the Epipaleolithic and the Neolithic can no longer be maintained (Holdaway et al., 2017). For this reason, the core section from 14.8–18.0 m depth (6.8–8.5 cal ka BP) was designated for pollen analysis.

POLLEN ANALYSIS

1 cm^3 samples for pollen analysis were collected every 20 cm from 14.8–18.0 m depth of core FA-1. After the first results, additional sampling every 5 cm was done in the lower part of the core. Samples were prepared according to a standard procedure (Berglund and Ralska-Jasiewiczowa, 1986), using acetolysis for 3 minutes and before preparation of pollen slides the samples were stained with safranine. Pollen and non-pollen palynomorphs (NPPs) were counted using a reference collection and pollen determination keys (Moore et al., 1991; Beug, 2004) when needed. Uncertain determination of species of cereal pollen hinders palynological analysis (Behre, 1981). *Secale* is an exception, because it has an oval pollen grain as well as a specific shape and location of the porus (Beug, 2004). Unfortunately, *Secale* is a secondary cultivated species (Lityńska-Zając and Wasylikowa, 2005; Zohary and Hopf, 2012), so regarding the beginning of cultivation, one must look mainly for other cereals. Cereals belong to the family of grasses (Poaceae), but pollen grains of the cultivated species are larger than most other ones and possess a large porus (>2.7 μm in diameter) with a wide annulus (Moore et al., 1991; Beug, 2004). Some pollen of wild grasses such as *Bromus*, *Agropyron* and *Glyceria* are also large and could be mistakenly determined as cereals (Beug 2004; Demske et al., 2013). In this analysis the basic criterium for cereal pollen determination was the size exceeding 50 μm and an annulus of at least 12 μm (cf. Mercuri and Garcea, 2019). The nomenclature of pollen types follows Beug (2004) and >150 taxa were distinguished (Marks et al., 2019). Due to their very low frequency, the sum of grains of terrestrial plants (AP + NAP) in each single spectrum does not exceed a hundred (except for the deepest sample). It was significantly lower than the number of added spores of *Lycopodium*. The pollen diagram was prepared in the Tilia and Tilia Graph programs (Grimm, 1992). The pollen-analysed deposits are dated to 6.8 to 8.5 cal ka BP. The age-depth model assumes a systematic and regular linear accumulation of lake deposits, so the timing of phases of human activity was estimated according to this assumption.

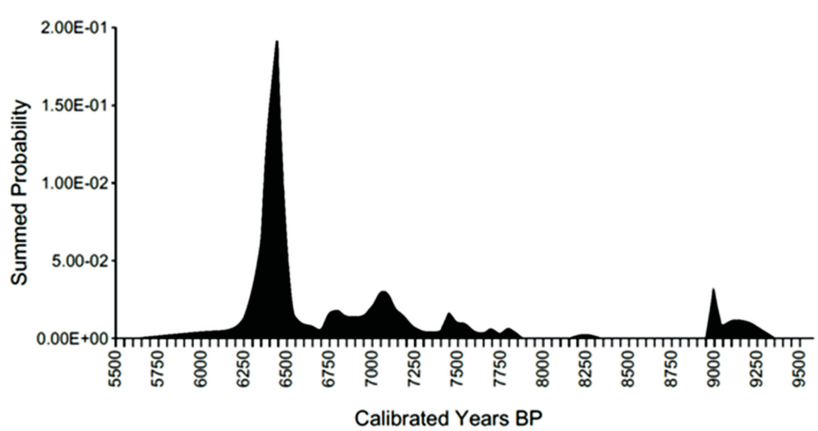

Fig. 2. Plot of radiocarbon determinations (summed probability) from the Faiyum northern shore sites, after Holdaway et al. (2017) (slightly modified by F. Welc)

RESULTS

LITHOLOGY OF THE CORE FA-1

The basal part of the core FA-1 (<20.85 m depth) is composed of massive yellow-brown carbonate clay (Fig. 3) that comprises weathered waste material of Eocene marls washed into the basin in a dry climate (Marks et al., 2018). This is overlain by lake silt, cut by desiccation cracks and covered by sand with mollusc shell debris (19.75–20.75 m depth). These deposits are overlain by thinly laminated clayey silt of a deep lake (13.05–19.75 m depth). Stable sedimentation is interrupted by deformation structures (17.7–18.05 m depth), a sandy layer (15.43–15.45 m depth) and intercalations of redeposited plant detritus. Higher, there is clayey silt with thick irregular diatomite and ferruginous laminae and with sandy layers, though the silt is more massive upwards (4.0–13.05 m depth). Semi-modern beach sediments and soil form the top.

POLLEN ANALYSIS

General results of the pollen analysis (excluding cereals) of the lower part of the core FA-1 were published by Marks et al. (2019).

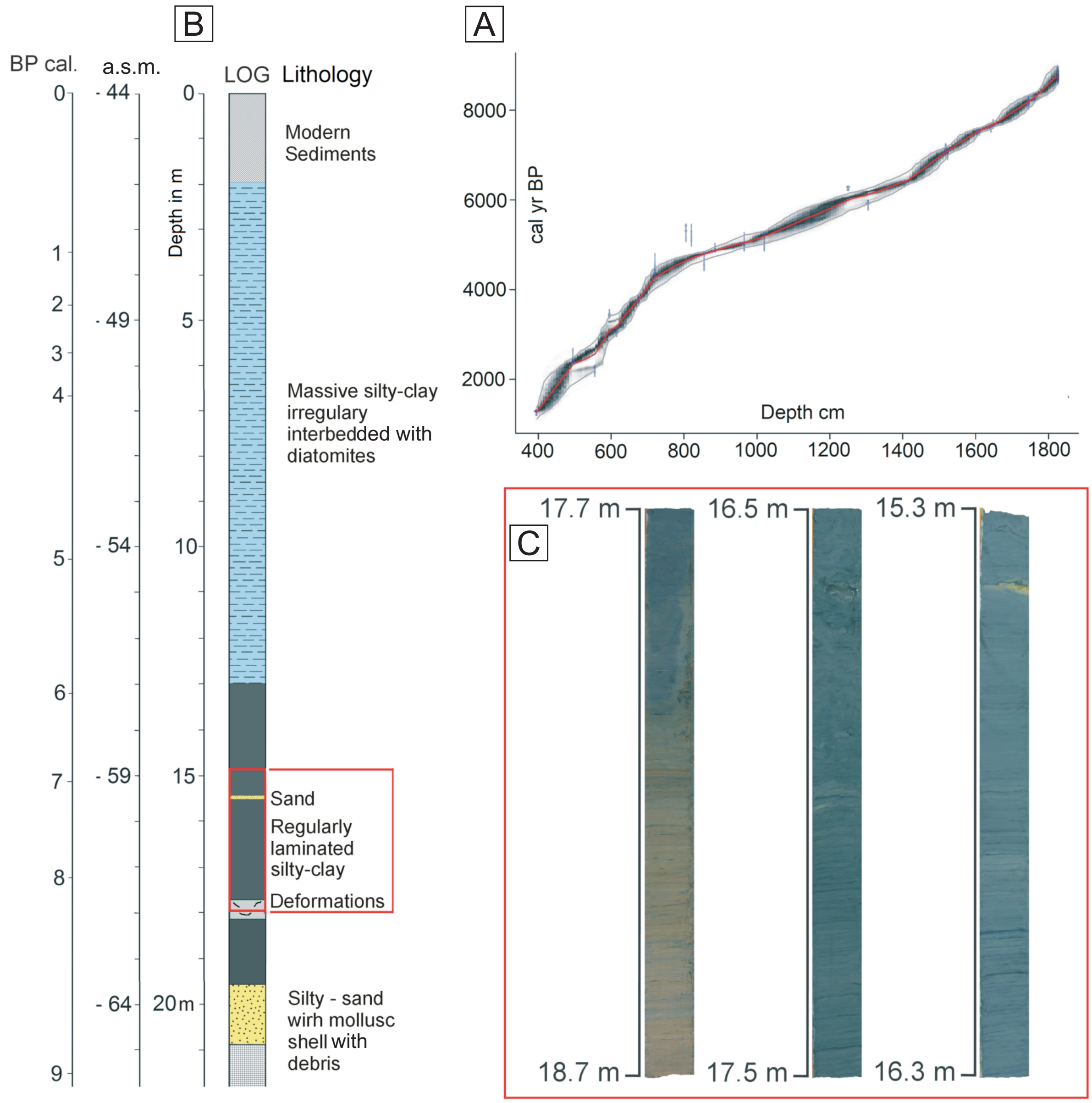

Fig. 3. Dating and lithology of core FA-1 (lithological log drawn by F. Welc)

A – age-depth model with probability distribution of the calibrated radiocarbon dates (OxCal), *Bacon* software; **B** – log of core FA-1 with fragment examined shown by a rectangle; **C** – close-up photos of the pollen-analysed core (by F. Welc)

The identified terrestrial but non-cereal pollen grains were divided into three geographic groups depending on their possible wind-blown directions. In this paper we focus on cereals and other pollen types indicating the possibility of early cultivation in the Faiyum Oasis. Domestication of plants was not an abrupt and simultaneous process (Clark, 1984; Wendorf et al., 1992), because at first, selected grass grains having large pollen grains were collected and their differentiation from cultivated species was not possible in this research.

Both the frequency and preservation of pollen grains were very poor (Fig. 4). In some cases detailed measurements were not possible, because pollen grains were crumpled and only their general sizes were obtained. Many pollen grains had destroyed or unclear sculpture, probably due to subaerial decomposition. Most samples contained only a few cereal pollen grains, probably due to self-pollination and highly dispersed occurrence at these very early cultivation stages.

In core FA-1 cereal pollen grains included *Triticum* type, *Hordeum* type, *Secale* and cereals undiff. (Fig. 4). The oldest pollen grain of cereals undiff. was found at 17.6 m depth (8.3 cal ka BP). The first pollen grain of *Triticum* type appeared at 17.4 m depth (8.2 cal ka BP). *Secale* and *Hordeum* type occur at 17.35 m depth (8.175 cal ka BP), accompanied by a culminated Poaceae (nearly 50%). Based on the occurrences of cereals, the upper part of the core examined was subdivided into 3 phases:

1. 16.2–16.7 m depth (7.6–7.8 cal ka BP): *Hordeum* type and *Secale* together with increased content of Poaceae, abundant *Pediastrum boryanum* and *P. simplex*.

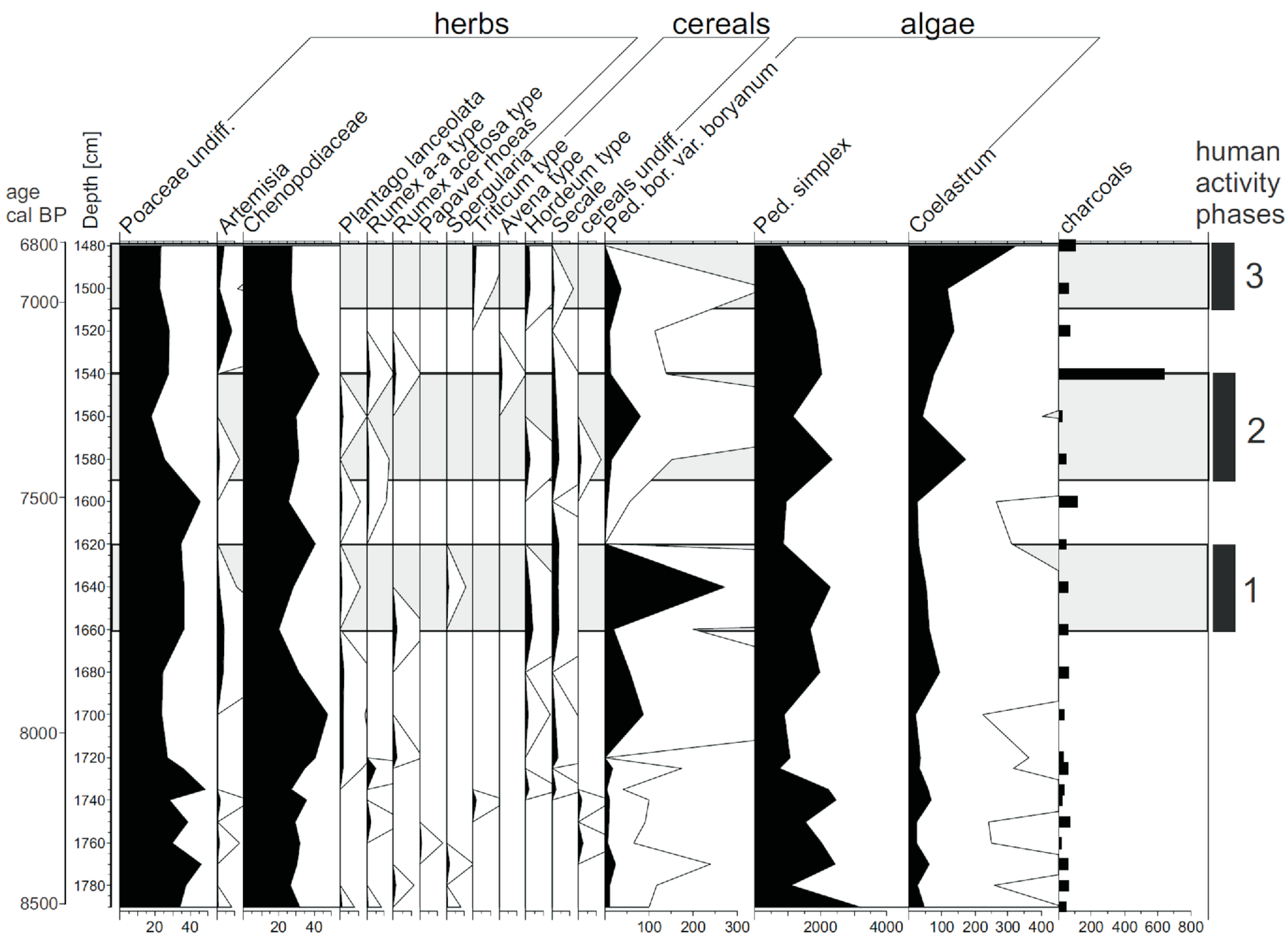

Fig. 4. Pollen spectrum of herbs, cereals and algae in the lower part of core FA-1; indicated are occurrences of charcoals and phases of cereal grain occurrence

Phases of increased human activity are marked by numbers 1–3 (drawing K. Milecka); explanation of abbreviations: Ped. – Pediastrum

2. 15.4–15.9 m depth (7.2–7.4 cal ka BP): pollen grains of *Secale*, *Hordeum* type and cereals undiff., curve of Poaceae decreases, high content of *Pediastrum* and *Coelastrum*.

3. Above 15.1 m depth (7.0 cal ka BP): a few pollen grains of *Triticum* type, *Avena* type and *Secale*, increased content of Poaceae, culmination of Chenopodiaceae.

The above phases should not be unambiguously referred to settlement and cultivation. They are phases of slightly higher concentrations of cereal-group pollen grains.

DISCUSSION

The cultivation of cereals began in the Near East and at first, wild plants were collected. This was followed by cultivation of cereals that spread in the neighbouring areas (Lityńska-Zając and Wasylikowa, 2005: Zohary et al., 2012). However, it is still unknown in detail when cereal cultivation appeared in particular areas. The best way to confirm cereal cultivation is to identify plant fossils at archaeological sites or in laminated deposits. Plant fossils (pollen, seeds, *etc.*) are conserved in anaerobic conditions, and so lake deposits and wetlands (mires) are excellent preservational environments (Berglund, 1986; Tobolski, 2000), though are located mostly in temperate and cold areas in the world. Areas with warm and dry climate, where cereal cultivation was initiated, do not favour conservation of pollen and macrofossils, and mires are scarce there.

Sites with cultivated barley have been found since 9.5 cal ka BP in the Near East. Then, barley spread into Greece (8.0 cal ka BP) as well as central and western Europe. Cultivation of barley reached Lower Egypt as early as in the 7th millennium BC and since that time, it has been a significant crop in the region (Lityńska-Zając and Wasylikowa, 2005). Zohary et al., (2012) named barley as *one of the main cereals in the belt of the Mediterranean agriculture and a founder crop of the Old-World Neolithic food production*. For Harlan and Zohary (1966), it is the most important early cereal. *Avena* occurred quite late as a cultivated plant and at first, it was a weed during cultivation of wheat and barley. There are no oat remains at archaeological sites in the Near East and Mediterranean regions in the Neolithic and the Bronze Age. Some grains found there came from wild plants (Lityńska-Zając and Wasylikowa, 2005; Zohary et al., 2012) and grew together with wild wheat and barley.

Rye (*Secale*) was domesticated in the early Neolithic (Behre, 1992) and is indigenous to Anatolia in Turkey. Then, it migrated as a weed with other cereals and the number of its finds increased. When agriculture moved into areas where climate was less favourable for wheat and barley, the amount of rye increased and it gradually became a crop in itself (Behre, 1992). The acculturation of *Secale* in Europe (and possibly in other regions too) was independent of the earlier one in Anatolia (Behre, 1992).

The Faiyum site has some limitations resulting both from the pollen analysis methodology and the location of the site, namely a low frequency of pollen in the deposits resulting from aridity and scarce vegetation in northeastern Africa. The percentage content of particular taxa is statistically unreliable and cannot be interpreted in the standard way as a representation of vegetation communities. The absence of pollen grains in this case is not definite evidence of the real absence of a plant in the past vegetation cover.

All the spectra have only few arboreal pollens that reflect the climate and vegetation of the research area (Marks et al., 2019). Some pollen grains came from central Europe, some from the Mediterranean region and others from tropical or subtropical areas. These were all wind-blown from various directions during as atmospheric circulation changed (Marks et al., 2019). Investigations at the FS-2 site, located to the north-west of Lake Qarun, suggest that in the 8th millennium BC the Faiyum Oasis was occupied by perennial and seasonal Mediterranean-like vegetation that expanded mostly in winter (Wetterstrom, 1993). Such vegetation was noted also at the El Omari and Maadi sites near Cairo where wild grasses and other plant species were identified, characteristic of conditions drying at the beginning of summer (Barakat, 1990).

Another problem of pollen analysis of cereals is their quantitative interpretation. This is related to their production, potential to disperse, real migration distance and conservation in organic deposits. Different cereals produce different amounts of pollen. *Secale* is an allogamous (wind-pollinated) plant, which produces a lot of pollen, up to 19,000 in each flower (Subba Reddi and Reddi, 1986; Tobolski, 1990; Okuniewska-Nowaczyk et al., 2004). Other cereals, namely *Triticum*, *Avena* and *Hordeum* belong to self-pollinating plants and, due to the high efficiency of this process, have low productivity and dispersal of pollen. They are usually underrepresented in pollen diagrams (Milecka et al., 2004). At the same time, the low content of pollen grains indicates near shore cereal cultivation. Regarding the Faiyum Oasis, its lake was much larger in the 8th millennium BP (Marks et al., 2016) and the cultivated area must have been located several kilometres away from the borehole FA-1 (Fig. 1). This large distance (Aaby, 1994) as well as the weak pollination and dispersal of cereal pollen grains (except for *Secale*) strongly influenced the scarce representation of cereals in the spectrum (Fig. 4). The first pollen grain of *Triticum* type was identified at 17.4 m depth (Fig. 5), i.e.,~8.1 cal ka BP. Without any doubt, the grain did not come from the field nearby the lake, because cultivation of *Triticum* in Egypt is shown to have started in the 8th millennium BP (Wendrich et al., 2010; Madella et al., 2014; Holdaway et al., 2017). Long-distance transport is unlikely, and thus the pollen grain found at 17.4 m depth, despite its features (sizes) being of *Triticum* type, came most probably from wild Poaceae. Pollen grains of *Hordeum* type and *Secale* were identified in younger deposits.

Based on the age-depth model of core FA-1, cultivation seems to have begun ~7.8 cal ka BP and barley was the first or the main cereal used (Figs. 4 and 5). Possibly, no *Triticum* was cultivated in the Faiyum Oasis in the oldest cultivation phase. However, taking into consideration both the uncertain determination of its pollen grains and the ecological factors described above, it is difficult to say if *Triticum* was cultivated after 7.8 cal ka BP, when the *Triticum* type pollen was found (Figs. 4 and 5). *Secale* appeared concurrently with barley, though it was not a crop but a weed (Behre, 1992; Zohary and Hopf, 2012).

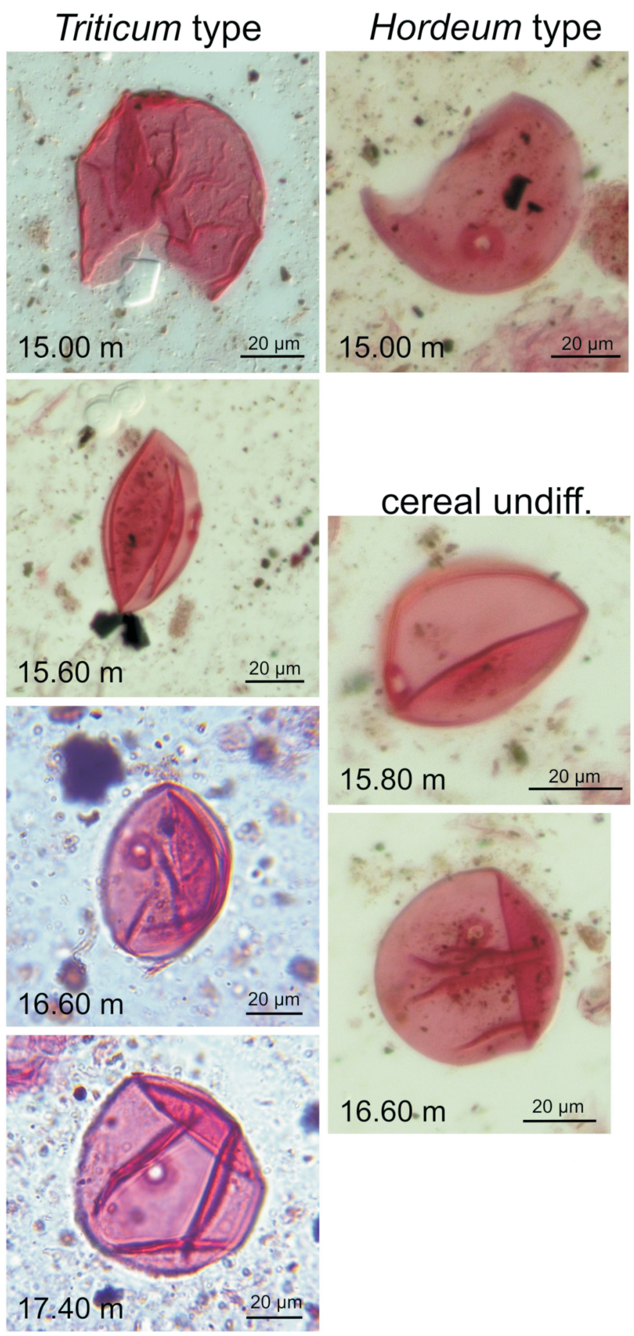

Fig. 5. Examples of cereal pollen grains from the FA-1 core: 17.4, 16.6, 15.8, 15.6 and 15.0 m depth (photos by M. Lutyńska and M. Karpińska-Kołaczek)

The charcoal content does not allow distinction of any clear phases of human activity (Fig. 4). It is almost stable, except for the sample at 15.4 m depth (~7.1 cal ka BP). At the Neolithic archaeological sites along the northern shore of Qarun Lake, traces of fireplaces were identified (cf. Holdaway and Wendrich, 2017), but the charcoal in core FA-1 presumably reflects extensive wildfires among shore vegetation in extremely dry periods.

The presence and peaks of algae comprise an additional indication of possible settlement phases. The biodiversity and quantity of planktonic organisms, *Pediastrum* and *Coelastrum*, increase together with growing nutrient supply, which usually happens with settlement and human influences (Fig. 4). *Pediastrum boryanum* and *P. simplex* found in the Lake Qarun deposits are cosmopolitan species, characteristic of α-mesosaprobic waters (Komarek and Jankovska, 2001). The pollen samples contain abundant coenobia of *P. simplex*, a species that avoids cold zones and is most common in tropical lakes, and prefers neutral to alkaline and oligohalobic water (Jankovska and Komarek, 2000; Komarek and Jankovska, 2001). Such ecological demands are in agreement with the freshwater stage of a deep lake (13.0–17.8 m core depth) in the 8th millennium BP (Marks et al., 2016). *P. boryanum* var. *boryanum* is a less frequent species in core FA-1, however, it occurs in eutrophic, but not polluted waters and is believed to be adapted to increasing eutrophication. Therefore, changes in the content of this species, better expressed than that of *P. simplex*, seem to reflect periodic human influence indicated in the lake by nutrient input. Species of *Coelastrum* are also found in meso- or eutrophic lakes (Starmach, 1989; Krupa et al., 2014) and increase of its content during the phases of cereal cultivation are clearly seen (Fig. 4).

Summing up, the earliest concentration of the pollen grains of cereals found in the core FA-1 is dated at ~7.8 cal ka BP and this is also reflected by radiocarbon data from the archaeological sites in the Faiyum Oasis.This age seems to fit well with beginning of the Neolithic in the Faiyum Oasis that is between ~7.5–7.8 ka (Hassan et al., 2006; Shirai, 2010; Phillipps et al., 2012; Holdaway et al., 2017; see also Fig. 2).

It is important in this context that cereal pollen is concentrated in three segments of core FA-1 at 16.2–16.7 m (7.6–7.8 cal ka BP), 15.4–15.9 m (7.2–7.4 cal ka BP) and14.8–15.1 m depth (6.8–7.0 cal ka BP). Therefore, three possible phases of increased human activity were distinguished, based on increased content of cereal pollen accompanied by a rise in the green algae *Pediastrum and Coelastrum* (Fig. 4). We can infer that this was a transitional time of collecting wild plants together with the beginning of cultivation after 8.0 cal ka BP. The significance of wild grasses is stressed by the high content of Poaceae in the deposits and its growth concurrent with the presence of cereals. The date 8.2 cal ka PB is an important time horizon related to a distinct climatic cooling (Wright and Thorpe, 2003). Examination of core FA-1 showed that at this time the lake level in the Faiyum Oasis was presumably the lowest during the Holocene (Marks et al., 2016; Welc, 2016). Investigations into the monsoon area of Africa indicate unequivocally that after 8.4 cal ka BP, a considerable reduction in precipitation occurred due to a limited northwards migration of the Intertropical Convergence Zone, resulting in a weaker monsoon (Barber et al., 1999; Haug et al., 2001; Rohling and Palike, 2005; Wanner et al., 2011). According to Kindermann and Riemer (2015), cooling and lower precipitation after 8.2 cal ka BP forced people to migrate from the interior of Sahara and to settle in the Nile Valley. A source of water was the key element in this migration, so the attractiveness of the area adjacent to the Lake Qarun was considerable. This factor, together with animal domestication before 8.0 cal ka BP, was crucial for the beginning of the Neolithic in this area (Kindermann and Riemer, 2015). Wendrich et al. (2010) and Madella et al. (2014) showed that domestic cultivation has occurred since at least 7.0 cal ka BP. On the other hand, there is little doubt that the domesticated wheat and barley found in the Faiyum Oasis originated from the southern Levant (Shirai, 2010). The appearance of flax (*Linum usitatissimum*), seeds of which were found in a granary pit of the Upper K Pits (Caton-Thompson and Gardner, 1934), can also be considered in the same context of appearance of domesticated wheat and barley. Since no wild ancestors of flax have been known in northeastern Africa, there is little doubt that the flax of the Faiyum Neolithic came from the southern Levant as part of the Levantine domesticated package or in weed form (Shirai, 2010).

It is also important that domesticated wheat and barley found in the Faiyum Oasis required for their growth low temperatures and an adequate supply of water, especially in winter and spring, and without any doubt these critical demands were needed for introduction of domesticated wheat from the Levant into Egypt (Shirai, 2010). In the Middle Holocene, the Faiyum Oasis was outside the northern limit of the summer monsoon, and thus rainfall could only be brought with the northern atmospheric circulation in winter (Welc and Marks, 2014; Welc, 2016). The regional air circulation system in the Middle Holocene was presumably connected with a clockwise eastern Mediterranean Sea current (cf. Shirai, 2010) and winter rain minima were coincident with cooling events (cf. Zielhofer et al., 2017). Based on palynological and diatom research of core FA-1, two main phases of atmospheric circulation have been distinguished in the early Middle Holocene (Marks et al., 2019). In the first phase (7.83-8.50 cal ka BP) there were three intervals (240–260 years each), starting with northwestern and followed by southern winds. The second phase (6.70–7.83 cal ka BP) was composed of three intervals (360–420 years each) initiated with northern winds, passing through north-western to southern ones. The southern winds coincided with regional aridification (Marks et al., 2019). Northwestern and northern winds induced turbulence of the Qarun Lake waters and brought rainfall in winter (Brookes, 2003). Their timing perfectly corresponds with three presumed human activity phases reflected by concentrations of cereal pollen in core FA-1 at 7.6–7.8, 7.2–7.4 and 6.8–7.0 6.8 cal BP and these were separated by more arid episodes (cf. Marks et al., 2019). These data clearly show that winter rainfall in the Faiyum Oasis were much more intense in the early Middle Holocene than today (Welc, 2016). Inflow of humid and cold air masses into this area at this time could have been steered by eastern Mediterranean circulation, driven mainly by the Arctic Oscillation and this resulted in increased winter rainfall (Goodfriend, 1991; Arz et al., 2003; Phillipps et al., 2012). The mechanism of intensified rainfall in the early Middle Holocene of the eastern Mediterranean region, including Egypt, has not yet been explained (Arz et al., 2003) but winter rains in the Neolithic Faiyum seem to have been influenced by circulation dependent either on the North Atlantic Oscillation or baric systems in the eastern Mediterranean region such as the Cyprus Cyclone (Cyprus) Low (Welc, 2016; Marks et al., 2019).

Based on this data, it seems obvious that the beginning of cultivation of winter cereals in the Faiyum region at ~7.8 cal ka BP should be associated with intensification of the northwestern Mediterranean atmospheric circulation. It intensified winter rainfall making cultivation of the Levantine cereals possible (Shirai, 2010) but the occurrence of wheat and barley farming in the Faiyum area should be connected with sowing seasons and the location of farmlands. According to Krzyżaniak (1977), the Neolithic farmers sowed grain on narrow strips of land along the lake shore during times of inundation. Stemler (1980) promoted a similar opinion claiming that grains were sown at the end of summer (dry season) on narrow strips of land along the lake. However, Hassan (1988) pointed out that the Neolithic settlement in the Faiyum area occurred in autumn and winter but not in summer and that the crops were collected at the same time. According to Kozłowski (1983), the Faiyum people lived in winter mainly in large encampments whereas in the dry season (summer) moved to small settlements along the lake shore where they were occupied mostly with fishing and hunting aquatic animals such as hippopotamus, crocodiles and turtles (Gautier, 1976). Among the cultivated cereals, barley predominated, reaching 72.3% (Hassan, 1984). Cereal farming was introduced to Egypt from the southern Levant via the Negev and Sinai (Wendorf and Schild, 1976; Shirai, 2010). We fully agree with the thesis that the Neolithic people may have learnt the idea of rain-fed farming in the southern Levant, and then managed to adapt the farming to the unique environment of Egypt. Cultivation of winter cereals as barley and wheat required sufficient moisture. As we see, regular winter precipitation was established at the beginning of the 8th millennium BP and enabled cultivation of both cereals in the Faiyum region at the same time. If the first farming experiment in the Faiyum region was rain-fed, then the cultivated area could not be necessarily located on the lakeshore, and so sowing could be attempted also in desert wadis, when winter rain started to fall and the wadi bed became wet enough due to surface runoff (Shirai, 2010; Welc, 2016). This assumption seems to be supported by the fact that in the period discussed the lake in the Faiyum Oasis was relatively deep and extensive (Marks et al., 2016; Welc, 2016). Inflowing fluvial waters were slightly charged with sediment as indicated not only by the lithology of the core FA-1, but also by the low mean sedimentation rate, generally the lowest in the Holocene (Welc, 2016; Marks et al., 2018). This again suggests that this early farming was not based on cultivation of small, artificially irrigated fields located directly at the lake shore but in numerous wadis that, after winter precipitation, stored moisture for sufficiently long to make growing of plants possible (Fig. 6). It should be emphasized that this hypothesis must be tested by future geoarchaeological research, because so far no traces of intensive human activity have been found in the wadi system north of this former Middle Holocene lake.

CONCLUSIONS

Core FA-1 is a unique archive of palaeoclimatic and palaeoenvironmental data, not only representative of the Qarun Lake and the Faiyum Oasis but also of a much more extensive region. A low and regular sedimentation rate expressed by regular lamination of the lake deposits and supported by several radiocarbon dates was used to construct a detailed and reliable age model for the early Middle Holocene. The phenomenon of appearance of cereals in the Faiyum region in the 8th millennium BP corresponds with climatic events in northeastern Africa and the eastern Mediterranean at the beginning of the Middle Holocene.

The pollen analysis of core FA-1 indicated the earliest occurrence of cereals at 7.8 cal ka BP, i.e. This was a time when regional climate conditions were fundamentally transformed from ~7.8 cal ka BP due to changing atmospheric circulation in the eastern Mediterranean region. Stronger northwestern winds resulted in intensified winter precipitation and corresponded with three increased farming phases in the Faiyum Oasis at 7.8–7.6, 7.4–7.2 and 1.0–6.8 cal ka BP. These phases were separated by arid episodes when southern winds prevailed. The data collected here suggests that cereal cultivation was rainfall-dependent and most probably concentrated inside local wadis to the north of the lake. This means that the ancient Egyptian farming in the Faiyum Oasis was not developed based on the irrigation system as commonly thought, but was rain-fed, this possibility being due to climate change in the eastern Mediterranean at the beginning of the Middle Holocene.

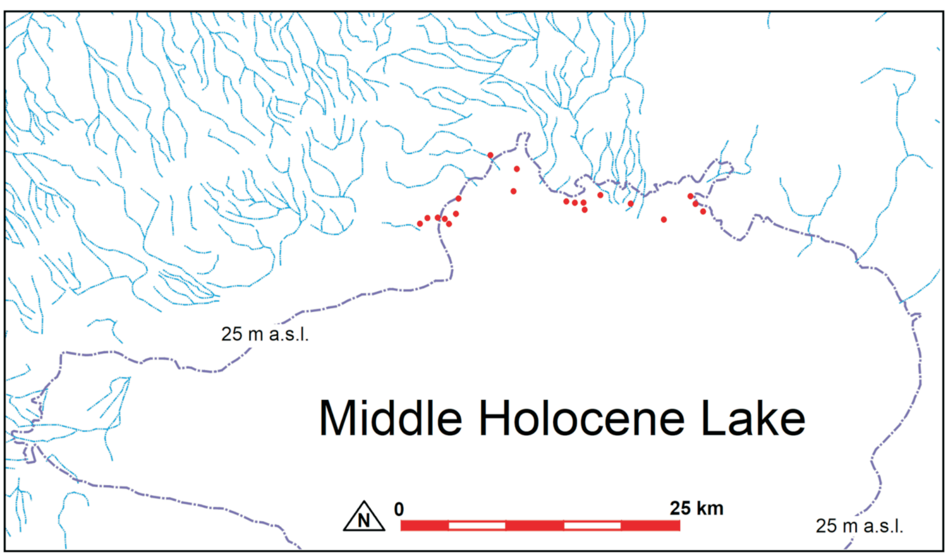

Fig. 6. Faiyum Oasis with the present wadis and location of the most important Neolithic sites with the maximum extent of the Neolithic lake at 25 m a.s.l. (drawn by F. Welc)

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