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An exploratory Early and Middle Holocene sedimentary record with palynoforms and diatoms from Faiyum lake, Egypt

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ABSTRACT

We report on the sedimentology, pollen and diatom records in a 26 m long core of Holocene sediments from the Tersa area, near the centre of the Faiyum Depression (Egypt). Two radiocarbon and one OSL dates have been obtained for the core, dates range from 9545 ± 60 Cal. BP to c. 4040 BP. These correspond respectively with the Terminal Palaeolithic (Qarunian) and Neolithic Faiyum A (Faiyumian) cultures. The core is subdivided into 3 sedimentological units: unit 1 (21–26 m) is very thinly laminated, calcareous silt deposited in a deep water lake; unit 2 (9.5–21 m) is finely laminated sand, silt and carbonates formed as a lacustrine fan delta; unit 3 (9.5 m to the core top), is formed of massive silt, sandy silt and very fine grained flood plain sands. Planktonic diatom taxa, mainly *Cyclostephanos, Aulacoseira, Cyclotella* and *Stephanodiscus* spp. were abundant in units 1 & 2-a, indicating deep, open lake conditions. Magnetic minerals increased from the base of unit 2 indicating an increasing contribution of Nile alluvium. Benthic taxa such as *Fragilaria, Cocconeis*, *Amphora* and *Navicula* tended to increase towards the core top, from unit 2-b; 3-a to 3-b, indicative of lake shallowing and periods of low Nile floods. Unit 3-c is barren of diatoms and is compatible with terrestrial flood plain conditions. Vegetation was mainly represented by herbaceous pollen throughout most of the core and in the topmost sediment, pollen was scarce but pteridophyte (Osmundaceae) spores increased. Arboreal vegetation had low percentages in most of the record but increased in the middle section of the core (unit 2). A depositional deltaic environment was indicated throughout most of the core (sub-units 2-a & 3-a), where high abundances of Poaceae, Cyperaceae, Chenopodiaceae, Amaranthaceae, Polypodiaceae and Osmundaceae were recorded, indicating high Nile floods and fluctuating rainfall.

1. Introduction

Lacustrine sediments often provide outstanding natural archives of the Holocene paleoenvironmental changes. However, such Holocene records in Egypt are typically rather fragmentary and incomplete due to intensive erosional events during arid periods. For example, in the Nile Valley, and in the Delta, many Holocene records were eroded during low flood periods and the prevailing action of wind deflation. Early Holocene lacustrine sediments in the Western Desert were commonly formed in temporary playa lakes affected by climatic changes but these suffered complete desiccation, usually by the mid Holocene, and were then subjected to wind erosion processes (Hoelzmann et al., 2004; Hamdan and Lucarini, 2013). A notable exception is the Faiyum (also called Fayum) which has sustained a permanent lake through most of the Holocene and where continuous Holocene sediment records are preserved.

The value of microfossil, geochemical, sedimentological and chronological analyses in revealing the environmental histories of archaeologically important areas is well known (e.g. Flenley and King, 1984; Brown, 2002; Trampier, 2014). The continuity of Faiyum lake during the Holocene and the abundance of multi-proxy lake sediment archives (e.g. Wendorf and Schild, 1976), offers attractive possibilities for relating palaeolimnological records with the rich archaeology of the Faiyum basin. Successful application of palaeolimnological methods depends, however, largely on

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the quality and coherence of the sediment records available at a particular site. The Faiyum lake basin has an undoubted wealth of archaeological context combined with well-known and major environmental changes during the Holocene (Caton-Thompson and Gardner, 1929; Wendorf and Schild, 1976). Nevertheless, and despite the presence of potentially complete Holocene lake sediment sequences in the Faiyum, major challenges confront attempts to integrate multi-proxy, high-resolution palaeolimnological reconstructions of the lake and its near catchment with the archaeological record. The challenges mainly arise from difficulties concerned with variable preservation of micro- and macrofossils, sediment dating issues and spatial variations in the continuity of sediment accumulation within the basin (e.g. Hassan, 1986; Hassan and Hamdan, 2008; Flower et al., 2012). Discrepancies about former lake level records persist and exploitation of microfossils in continuous lake sediment cores offers one way to help refine the environmental history of Lake Faiyum. Progress must be made on all these problematic issues if the palaeolimnology and archaeology for this lake basin are to be integrated satisfactorily into a chronological framework for landscape change within the Faiyum. This paper reports upon the integrity of the microfossil and sedimentological archive available in a continuous sediment core from a terrestrial site near the centre of the Faiyum basin.

Modern Qarun Lake occupies only a small part of the Faiyum basin but it is the remnant of a much larger early Holocene lake, often referred to as Lake Moeris (Caton-Thompson and Gardner, 1929, 1934; Hassan, 1986). Today, this is evidenced most clearly by exposed diatomaceous lacustrine deposits, first described by Abdel-Aleem (1958), that occur in the vicinity of Lake Qarun. More recently, a total of 283 diatom species and varieties representing 57 genera has been identified by Zalat (2015) in exposed surface sections of the Holocene lacustrine sediment in the northern part of Faiyum Depression. The palynology of modern and sub-recent sediments of Faiyum basin has been studied by El-Fayoumi (1996) and Mehringer et al. (1979), respectively. These and other environmental indicators (raised beaches, mollusc shell debris and archaeological materials) of former high lake levels have been used to document the overall pattern of Holocene lake level changes in relation to human occupation sites and cultural development (Wendorf and Schild, 1976; Kozlowski, 1983; Hassan, 1986; Butzer, 1998; Hassan et al., 2006; Baioumy et al., 2010a,b; Hassan et al., 2012).

The vegetation history of the Faiyum is of major interest regarding the effects of climate change, landscape development and human activities. The area is well known as an early centre for Neolithic farming activities in Egypt (Caton-Thompson and Gardner, 1934) that began after about 7500 years BP (Shirai, 2010; Wendrich et al., 2010). As a preliminary study of pollen assemblages in a sediment core from a central location in the Faiyum, the gross composition of past vegetation are indicated in this study by identifying changes in the plant families represented. High resolution pollen analysis is however required to identify the introduction of plant domesticates and other plant species but this depends on establishing a detailed sediment chronology that is not yet available.

The specific objectives of the present study are to: (1) reveal paleoenvironments of Faiyum lake during Early-Mid Holocene by exploring lacustrine sediments and their microfossil content in the central region of the Faiyum basin, and (2) contribute to establishing a chronology for lake changes. The microfossil work focuses on palynological analysis and low resolution diatom analysis was done to indicate any major changes in water quality.

2. Methodology

This study utilizes sediment cores obtained from Tersa, a now terrestrial area (29° 24.820″ N, 30° 48.696″ E, ground level is −20.0 m below Sea Level) near the centre of the Faiyum Depression (Fig. 1). The core was drilled using a handle casing drilling machine. The core sediments were subjected to magnetic susceptibility measurements (0.10 m spacing) in the field using a Barrington MS2 meter and probe. The gross stratigraphy of the core was recorded using routine sediment logging description. Sediment colour was described using Munsell soil colour charts as the core was exposed.

For diatom analysis, a total of 18 sub-samples were selected from different core depths and prepared for preliminary analysis. Semi-quantitative diatom slides were prepared using equals weights and volumes of sediment and suspension. After acidification (to remove carbonates), samples were washed several times in

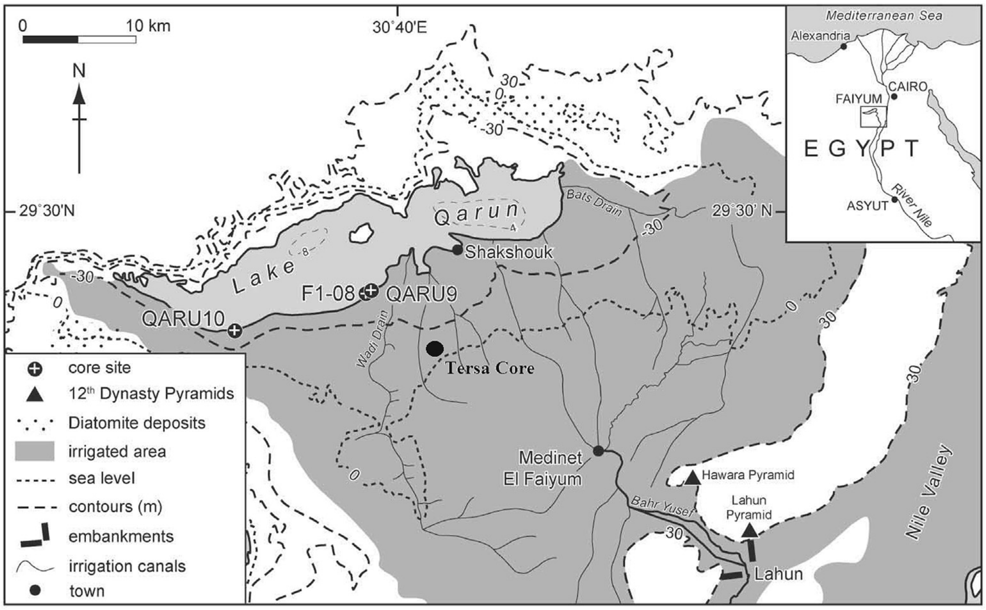

Fig. 1. Location map of Faiyum Depression and Tersa Core.

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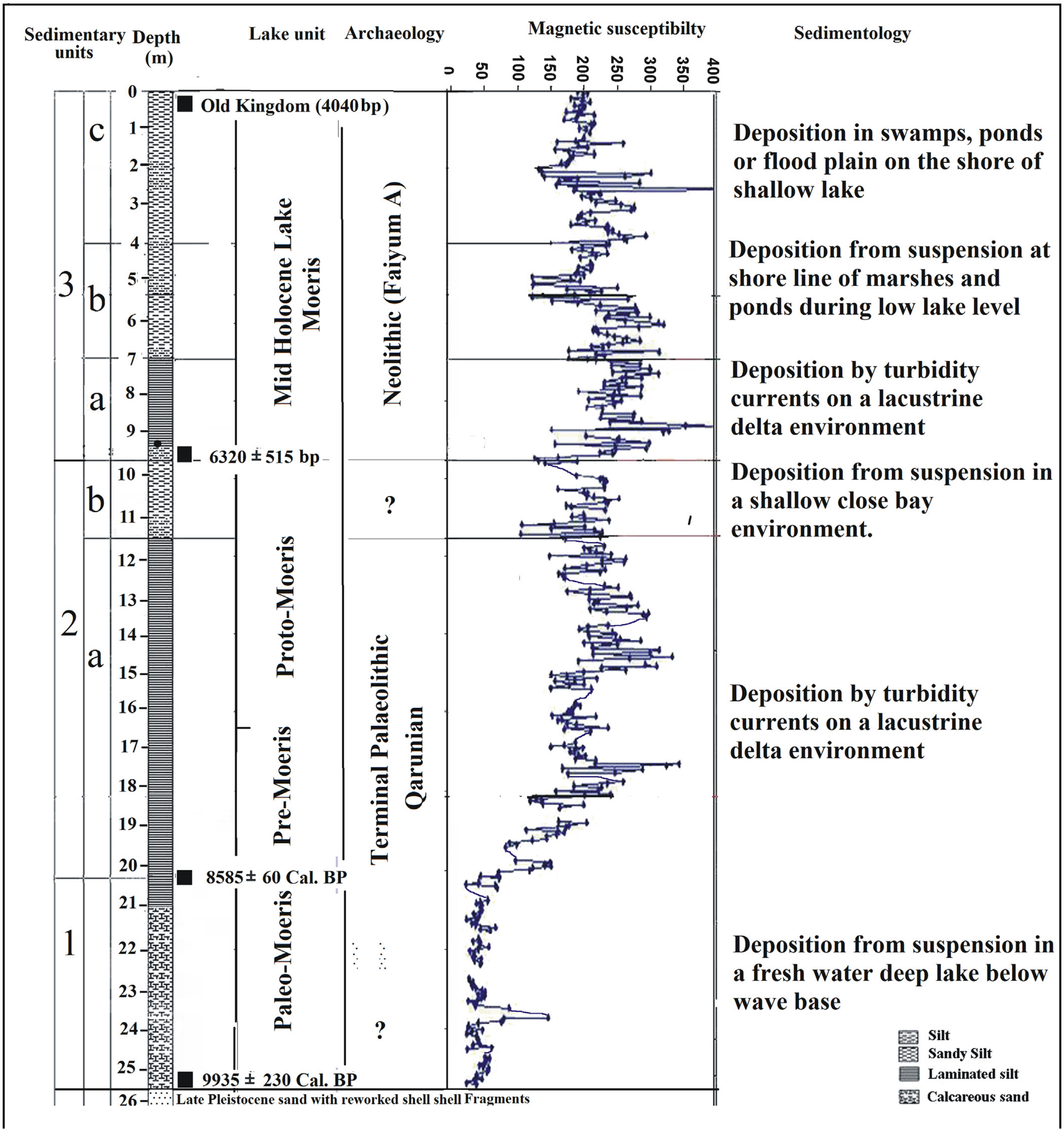

Fig. 2. Show the lithology of Tersa Core, their magnetic susceptibility and their sedimentological interpretation.

distilled water and used to prepare glass slides for microscopic examination at ×1000 magnification. Where present, diatom abundance was estimated and summary percentage frequencies of planktonic and benthic diatom taxa were assessed after counting c. 100 valves in each sample preparation.

For pollen analysis, a total of 67 samples, each consisting of one or two grams of the dry sediment were taken usually at intervals of 2.5 cm intervals in the core and treated using standard procedures (Faegri and Iversen, 1989), at the Palynology Laboratory, Department of Environmental Science, Alexandria University, Egypt. *Lycopodium* spore tablets were added to each sample in order to calculate total pollen and spore concentrations. Pollen residues were mounted in glycerin jelly and were analyzed under the light microscope at 400–1000 magnification. The identification of pollen grains and spores was performed using reference pollen collection material and regional pollen atlas (Reille, 1992). About three-hundred palynomorphs were microscopically scan counted and identified as far as possible for each sample. Counts were made

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along slide traverses and the position of notable specimens noted using an England Finder. Counts were arranged into plant families for graphical display.

3. Results

3.1. Lithology, magnetic susceptibility

The Tersa Core attained a depth of 26.5 m, and is subdivided into 3 sedimentary units, that unconformably overly late Pleistocene sand (Fig. 2). The boundaries between sedimentary units are defined by grain size, sediment composition, magnetic susceptibility and sedimentary structures (type of lamination, sedimentary sequences). The core base is represented by unit 1, 21.0 m–26.0 m) which consists of yellowish (10YR 7/4), thinly (c. 1 mm) laminated, stiff calcareous silt with very low magnetic susceptibility but increasing towards the section top. The laminations are characterized by changing colours ranging from light to dark yellowish grey. Unit 1 unconformably overlies a late Pleistocene quartzose sand unit with reworked marine shells and aeolian sand (Fig. 2). Unit 2 consists of two sub-units -a & -b. Sub-unit 2-a (12–21 m) is a dull orange (10YR6/3) colour, moderately soft, micro-laminated, with micro cycles (1–5 mm thick) of dark gray silt, very fine grained quartzose sand, diatomeous silt (cf. Flower et al., 2012) and increasing magnetic susceptibility. Sub-unit 2-b (9.5–12 m) is sandy silt, greyish brown (10YR6/2); soft to slightly stiff; massive to thin laminated; calcareous with carbonated concretions and nodules. Unit 3 consists of three sub-units; these are 3-a, -b, -c. Sub-unit 3-a (9.5–7.0 m) is lithologically similar to Sub-unit 2-a and represented by is greyish yellow brown (10YR6/2), slightly stiff, massive to thin laminated sandy silt, calcareous near the top and the bottom with carbonate concretions. The magnetic susceptibility pattern of this sub-unit shows a decline towards the top of the section. Sub-Unit 3-b (4.0–7.0 m) is dark brown (10YR 3/3), stiff, massive, silty clay, with abundant gypsum streaks filling fractures and with some carbonate concretions. Sub-unit 3-c (4.0–0.0 m) is greyish yellow brown (10YR6/2), massive to thin laminated sandy silt, calcareous with carbonate concretions. Magnetic susceptibility of sub-units 3-b &-c remained moderately high to the core top.

3.2. Chronology, lake levels and archaeological significance

A preliminary chronology for the Tersa Core was established partly by cross-correlation from previously published studies (e.g. Flower et al., 2012; Hassan et al., 2012). One new date was obtained using OSL techniques (Table 1) from a 12 cm section taken at 9.2 m depth in the core gave a date of 6302 ± 515 BP (A. Singhvi, pers. comm.). Two radiocarbon dates for core F1-08 (Table 2) were cross-correlated with units 1 and 2 in the Tersa Core using sedimentological changes. Lacustrine sediment in the Lake Qarun area of the Faiyum Depression is underlain by coarse sands (e. g. cores QUAR9 and F1-08 in Flower et al., 2012). In the Tersa Core, the base of unit 1 lies above the coarse sands (Fig. 2) and, by cross-correlation, the section interface is dated to 9935 ± 230 Cal. BP (see Yamada et al., 2011; Flower et al., 2013). Accumulation of thinly varved unit 1 lacustrine sediments begins at this point. A date of 8585 ± 60 Cal. BP in core F1-08 (Yamada et al., 2011; Flower et al., 2012) closely postdates the onset of thinly varved sedimentation. So, based on these dates and a field estimation of the time spanned by these varved sediments, unit 2 probably began around 8 k BP or 21 m core depth (Table 2). This depth marks the start of laminated deltaic sediment deposition in the Tersa Core. This ceases around 7 m depth, after the 9.2 m is OSL date to 6302 ± 515 BP for 9.2 m. The sandy silts of unit 3 begin around this time and persist until the Old Kingdom (c.4400 BP). The latter date is approximated according to Hassan et al. (2012) and reflects ground elevation at the Tersa Core site and associated pottery sherds similar to those found in cores from the Biyahmu and Ain Sellin sites (Hassan and Hamdan, 2008).

Wendorf and Schild (1976) described several successive lakes during the Early and Middle Holocene. They named them as Palaeo-Moeris (13 m asl), Pre-Moeris (19–24 m asl) and Proto-Moeris (19–24 m asl). Each of these lake stages were separated by episodes of low lake stands. The oldest early Holocene sediments (the Palaeo-Moeris stage) are dated to 10,090 ± 147 Cal. BP (Table 2). The

Table 1
Optically stimulated luminescence age for Tersa Core at depth of 9.5 m.

Sample No	Depth (m)	U (ppm)	Th (ppm)	K (%)	Cosmic Ray (micro Gy/a)	Water (%)	Dose rate (μGy/a):	Grain size(μ)	Age (using Mean ED)
Egypt_915-945	9.5	7.51 ± 0.75	6.12 ± 2.57	0.8	150	5	2920 ± 239	210–250	6302 ± 515 bp

Table 2
AMS ^{14}C ages of sediments of Lake Faiyum, Holocene lake stages and prehistoric cultures. Calibrated ages (calendar years) were calculated by applying calibration scheme (IntCal09) in Reimer et al. (2009), using the OxCal program.

Sample No		Sample location	Depth (m)	Lab. Code	Materials	^{14}C age (1σ error,BP)	Mean calibrated ^{14}C age (1σ error, Cal. BP	References
Faiyum cores								
1	Faiyum 08-1-23-39 cm	F1-08 (Faiyum08-1)	17.29	Poz-12059	sediment	7810 ± 30	8585 ± 60	Yamada et al., 2011
2	QARUN 08 19.90 m	F1-08 (Faiyum08-1)	19.90	Poz–37618	wood fragment	8840 ± 50	9935 ± 230	Yamada et al., 2011
Terminal Paleolithic Qarunian (In Hassan 1986)								
3	FS-2TS-8 level2	Western Faiyum	15 m asl	Beta-4871	charcoal	8220 ± 105	9210 ± 143	Wenke et al., 1983
4	FS-2TS-12 level4	Western Faiyum		Beta-4872	charcoal	7720 ± 70	8509 ± 63	Wenke et al., 1983
Early Holocene Lake								
5	Paleo-Moeris	E-29 G1	15 m asl		Shell	9000 ± 100	10091 ± 142	Wendorf and Schild, 1976
6	Pre-Moeris	E-29 H1	17-23 m asl	I -4128	charcoal	8100 ± 130	9011 ± 216	Wendorf and Schild, 1976
7	Pre-/Proto-Moeris	E-29 G3	15 m asl	I-4130	charcoal	7500 ± 125	8300 ± 111	Wendorf and Schild, 1976
8	Proto-Moeris	E-29 H2	24 m asl		charcoal	7140 ± 120	7976 ± 229	Wendorf and Schild, 1976
Neolithic Faiyumian								
9	Qasr el Sagha	VIIG/80		Gd-895	charcoal	5070 ± 110	5813 ± 116	Ginter et al., 1982
10		E29H2		I-4131	charcoal	5810 ± 110	6624 ± 131	Wendorf and Schild, 1976
11	Qasr el Sagha	X-81-5		Gd-979	charcoal	6290 ± 100	7190 ± 128	Ginter et al., 1982
12	Qasr el Sagha	XI-81		Gd-2021	charcoal	6480 ± 70	7390 ± 63	Ginter et al., 1982

Calibrated ages (calendar years) were calculated by applying the calibration scheme (IntCal09) in Reimer et al. (2009) using the OxCal program (Bronk Ramsey 1995, 2001).

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next Pre-Moeris stage is dated to 9011 ± 216 Cal. BP. Another date of 8300 ± 111 Cal. BP was obtained from deposits representing Pre-Moreis-Proto-Moeris transation stage (Table 2). Two dates of 8248 ± 122 and 7976 ± 229 Cal. BP were related to Proto-Moeris Lake. From the archaeological view point, Terminal Palaeolithic artifacts (Qarunian) were found in association with Pre-Moeris deposits (Hassan, 1986). Middle-Holocene sediments were considered to represent the lower part of the Moeris Lake stage and are represented mainly in the northern Faiyum by pale brown sands, unconformably overlying older lacustrine sediments (e.g., Neolithic site Kom "W"; Caton Thompson and Gardner, 1929, 1934; Wendorf and Schild, 1976). Published radiocarbon dates (Wendorf and Schild, 1976; Hassan, 1986) associated with Neolithic sites occupations are: 6624 ± 131 Cal. BP at 17 m asl and 6683 ± 143 Cal. BP at 15 m asl (Table 2).

In the Northern Faiyum, Caton-Thompson and Gardner (1929) identified two Neolithic cultures, named as Faiyum A and Faiyum B. The latter was thought to be a degenerated culture that followed Faiyum A. Wendorf and Schild (1976) subsequently identified Faiyum B as the Terminal Palaeolithic (Qarunian) culture, ca. 1000 years before the Neolithic Faiyum A. The Qarunian people were hunter gatherer-fishers who lived near the shore of the lake, evidently when the lake level was lower. The Qarunian, which lasted from approximately 9200 to 8500 Cal. BP (Table 2; Fig. 2), is referred to by different authors as either an Epipalaeolithic or Terminal Palaeolithic industry. The Qarunian culture corresponds to transgressions of the Pre- and Proto-Moeris lakes (Wendorf and Schild, 1976; Hassan, 1986; Kozlowski and Ginter, 1989). The Neolithic (Faiyum A or Faiyumian) culture is dated to between 5070 ± 116 to 7390 ± 63 Cal. BP (Table 2), and is important precisely because it represents the one of the earliest records known of a fully agricultural economy in Egypt (Hassan, 1986).

Correlation of the described units of the Tersa Core with the lake units of Wendorf and Schild (1976) and prehistoric cultures of Faiyum is given in Fig. 2. The upper part of unit 1 coincides with the Paleo-Moeris phase, while sub-unit 2-a, corresponds with both Pre-Moeris and Proto-Moeris phases. Sub-unit 2-b could be correlated with the recession phase at the end of Proto-Moeris lake while sub-units 3-a & -b correspond with Neolithic lake phases. From an archaeological point of view, the Terminal Palaeolithic (Qarunian) culture is represented by Upper part of unit 1 and unit 2-a. Sub-unit 2-b represents a hiatus period between the Qarunian and Neolithic Faiyumian cultures. The period between the Terminal Palaeolithic and the Neolithic in the Faiyum is separated by episode of low lake levels and greater aridification (Wendorf and Schild, 1976). Hassan (1986) has found evidence that the Faiyum Lake actually came close to drying up between around 7000 and 6000 BP. The Neolithic cultural period is represented in Tersa Core by units 3-a 3-&-b and where unit 3-c could be correlated with the Predynastic and the topmost part of the core considered as an Old Kingdom.

3.3. *Diatoms*

Diatom remains were abundant in the lower section of the studied core but many valves are poorly preserved and valve fragments are always common. Species diversity was low but planktonic taxa, such as *Cyclostephanos, Aulacoseira* and *Cyclotella* spp., dominated some units indicating past lacustrine phases (Fig. 3). Tychoplanktonic and benthic taxa including as *Staurosira, Cocconeis*, *Amphora* and *Navicula* were occasionally present and tended to increase up core with highest abundances between 18 m to around 7 m depth. The basal sediment (unit 1) is represented mainly by varved sediments (cf Flower et al., 2012) with high frequency abundances of the planktonic taxa *Aulacoseira granulata* and *Cyclostephanos dubius* with the latter increasing towards the top of this unit. Other planktonic taxa are represented by *Cyclotella ocellata*, *Stephanodiscus minutulus* and *Stephanodiscus galileensis* which reached highest frequency in the lowest sample (25.5 m depth). The planktonic diatoms in the micro-laminated sediment (unit 1) indicate deep open water possibly with water level fluctuations and nutrients accounting for the later rise in *C. dubius*. The non-planktonic (tychoplanktonic and benthic) diatoms in unit 2 comprise <10% of the assemblage. They are mainly fragilarioid taxa, with a few *Nitzschia* spp. and *Martyana martyi* valves. In the lower part of unit 2, ca. 20 m–11 m depth, diatoms remain abundant and are dominated by the same plankton species, mainly *Cyclostephanos dubius* and *Aulacoseira granulata*. Again the abundances of these taxa indicate the persistence of fairly deep water (see below) at the coring location at this time. *C. dubius* increases from the unit1/2-a transition point at 20 m and then fluctutes with in this section. However, the proportion of non-planktonic taxa generally increase in sub-unit 2-b, reaching 11–34% between 10 and 12.5 m depth and this possibly indicates a recessional phase of the Faiyum lake at this time. Planktonic *Aulacoseira granulata* fluctuate in sub-units 2-b and -3-a and *C. dubius* reaches highest abundances above 12 m sediment depth. Relatively high frequencies of non-planktonic taxa and dominance of *C. dubius* occur towards the top of sub-unit 3-a but total diatom abundance is very low. At the transition point to Unit 3 (c. 9.5 m) the diatom record was effectively lost (Fig. 3).

3.4. *Pollen analysis*

The palynological examination of sixty seven samples from the Tersa Core revealed the presence of sixty four plant families comprising three main groups: Angiospermae, Gymnospermae and Cryptogams. The pollen and spores were further categorized as arboreal or herbaceous and floristic diagrams of the Tersa Core are shown in Fig. 4.

Arboreal pollen comprises two main types, non–native pollen and native types (Fig. 4): A- Non-native pollen types are represented by three families; Pinaceae, Fagaceae and Betulaceae (Fig. 4-A). Pinaceae and Fagaceae families are known as Mediterranean pollen (Cheddadi and Rossignol-Strick, 1995). The former is the most abundant family in this group and attains its maximum pollen concentration (281.56 sp/gr sediment) at 12.40 m depth (sub-unit 2-a). The most common genera of this family are *Picea* sp and *Pinus* sp. Fagaceae is the second most abundant pollen type and attains peakconcentration of about 88.49 sp/gr at a depth of 20.2 m (sub-unit 2-a). This family is represented mainly by the genus *Quercus* sp. Pollen of Betulaceae (or Corylaceae) attains highest concentration (61.94 sp/g, sediments) at depth of 21 m (sub-unit 2-a). The Bombacaceae (most abundant in unit 2) represents pan-tropical trees and together with preceding taxa represent long-distance pollen in the Tersa record.

B-Native shrub and herbaceous pollen types include 22 familes and the most abundant are Aracaceae, Bignoniaceae. Fabaceae and Rubiaceae. Arecaceae (Palmae); pollen reaches highest concentration (177 sp/g sediment) at 24.4 m depth (unit 1). Six generarelated to the Arecaceae family were recognized (Fig. 4-A); these are *Astrocaryum, Bactris, Chamaedorea, Cryosophila, Elaeis,* and *Oenocarpus.* The Bignoniaceae family reaches highest concentration (294.96 sp/g sediment) at depth of 24.4 m (unit 1). Five genera belonging to Bignoniaceae were recorded, these are: *Adenocalymma* (wild garlic), *Arrabidaea, Spathodea, Stizophyllum,* and *Tabebuia*. Fabaceae pollen is also recorded with high concentration (247.77 sp/g sediment) at depth of 24.77 m (unit 1). Six genera were recorded as belonging to this family; these are: *Acacia (=Vachellia)* sp; *Desmodium, Phaseolus, Pithecelllobium* and *Prosopis*. Next in abundance are Rosaceae, Bombacaceae, Ephedraceae,

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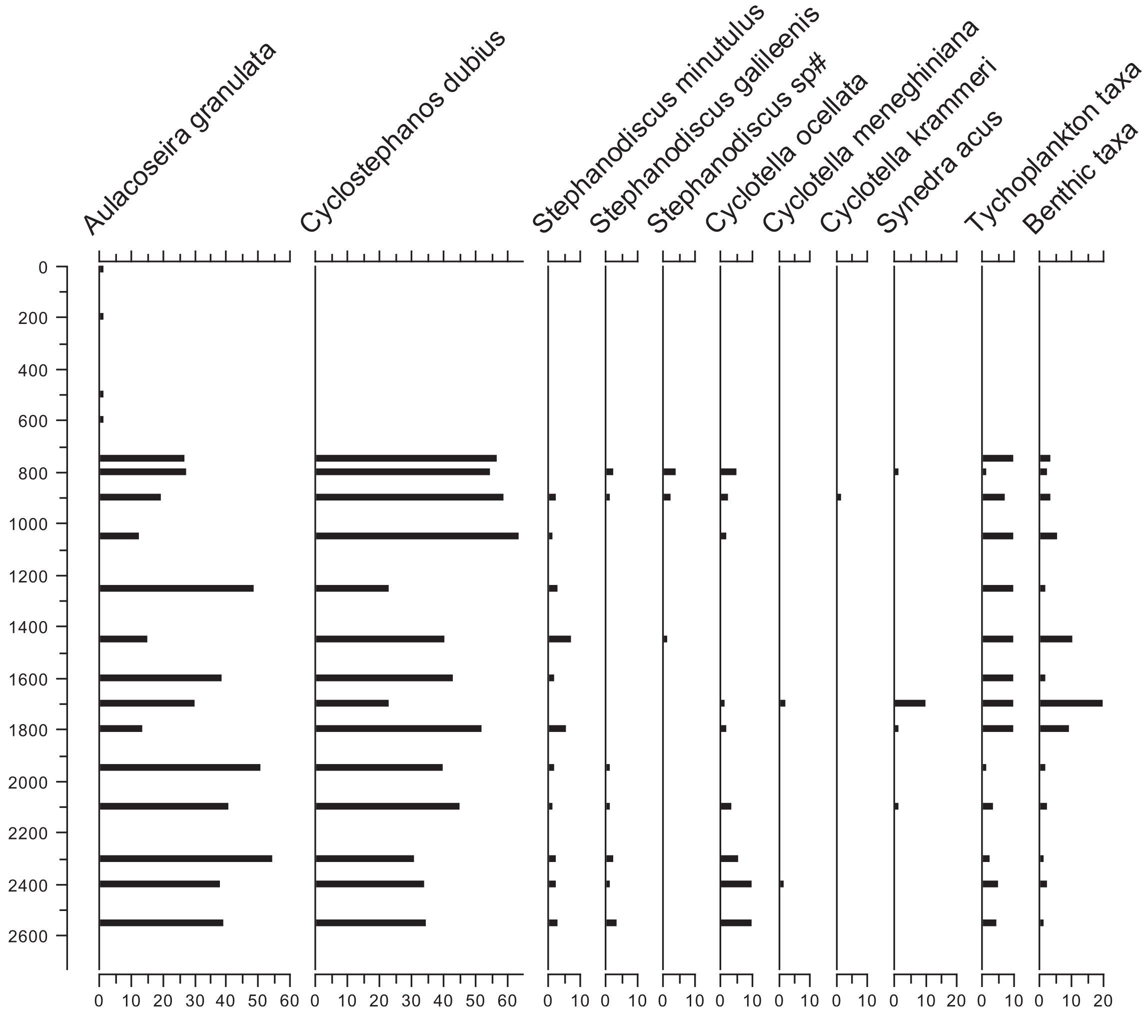

Fig. 3. Preliminary percentage frequency summary diatom diagram for the Tersa sediment core. The non-planktonic taxa are combined into tychoplanktonic and benthic components. Above 700 cm depth diatoms were absent except for a very few valve fragments (mainly of *A. granulata*).

Zygophyllaceae, Meliaceae, Tiliaceae, Cyatheaceae, Acanthaceae and Apocynaceae (Fig. 4-B). Pollen types of Ephedraceae release small amounts of pollen to the atmosphere and signal an arid climate (Cheddadi and Rossignol-Strick, 1995); they reached a peak value (117.98 sp/g sediment) at depth 23.50 m (unit 1). Zygophyllaceae family (mostly xerophytic shrubs; Täckholm, 1974), reached the highest concentration (117.98 sp/g sediment) at depth 20.80 m (sub-unit2-b). The families with rare or very rare occurrences in the core sediments are: Sterculiaceae, Annonaceae, Loranthaceae, Proteaceae, Anacardiaceae, Flacourtiaceae, Salicaceae. Myrtaceae, and Buxaceae. Some of these families were recorded in the sediments only once (Fig. 4-B). El-Fayoumi (1996) recorded Rubiaceae, Rosaceae, Ephedraceae, Zygophyllaceae, Tiliaceae, Salicaceae and Myrtaceae in the modern vegetation in Faiyum Depression.

Herbaceous pollen includes three pollen types; Xero-halophytic, Helophytic (aquatic) and Mesophytic (Fig. 5). Xero-halophytes are desert species of halophytes, plants that are able to grow in habitats excessively rich in salts or under saline conditions. They are well represented in the core sediments by the Chenopodiaceae and Amaranthaceae families; they are typical vegetation for evaporation pans in and around the Faiyum Depression (Figs. 4-C & 5). Chenopodiaceae pollen types are recorded in nearly all core samples and reached the highest concentration (1720.65 sp/g sediment) at depth 22.00 m (unit 1). This family is represented mainly by three genera; *Atriplex, Bassia* and *Chenopodium*. Elsewhere, seeds belonging to Chenopodiaceae have been recorded in the Hidden Valley Neolithic site, Farafra Depression, Western Desert of Egypt (Fahmy, 2001). Amaranthaceae reached a maximum concentration (671.05 sp/g sediment) at depth 25.00 m (unit 1). El-Fayoumi (1996) recorded both families by high percentage values in the current vegetation of Faiyum Depression. Ritchie (1985) found abundant Amaranthus-Chenopodiaceae pollen types (up to 24%) in the Holocene sediments from Dakhla Oasis, Egypt.

Helophyte plants are plants adapted to growing in or near water in water-logged soil. They include 11-families of which Poaceae and Cyperaceae are the most abundant in the Tersa Core sediments (Fig. 4-C). Poaceae reached peak value (1069.93 sp/g sediment) at depth 23.20 m (unit 1). Cyperaceae reached the highest value (1887.80 sp/g sediment) at depth 23.50 m (unit 1). Four genera belong to this family; these are *Cladium, Cyperus, Hynchospora,* and *Schoenoplectus*. Malvaceae, Typhaceae, Parkeriaceae, Nymphaeaceae and of the bryophytes Ricciaceae is also well represented in the sediment core. Ricciaceae spores also have been recorded in Nile silt from Holocene sediments of the Nile Delta (Saad and Sami, 1967) and from the Nile cone (Rossignol-Strick, 1972). Both Poaceae and Ricciaceae (common nilotic pollen and spores) reached high value in the core basal section (unit 1).

Mesophytes are terrestrial plants adapted to moderate moisture conditions for growth. They include 26-families, dominated

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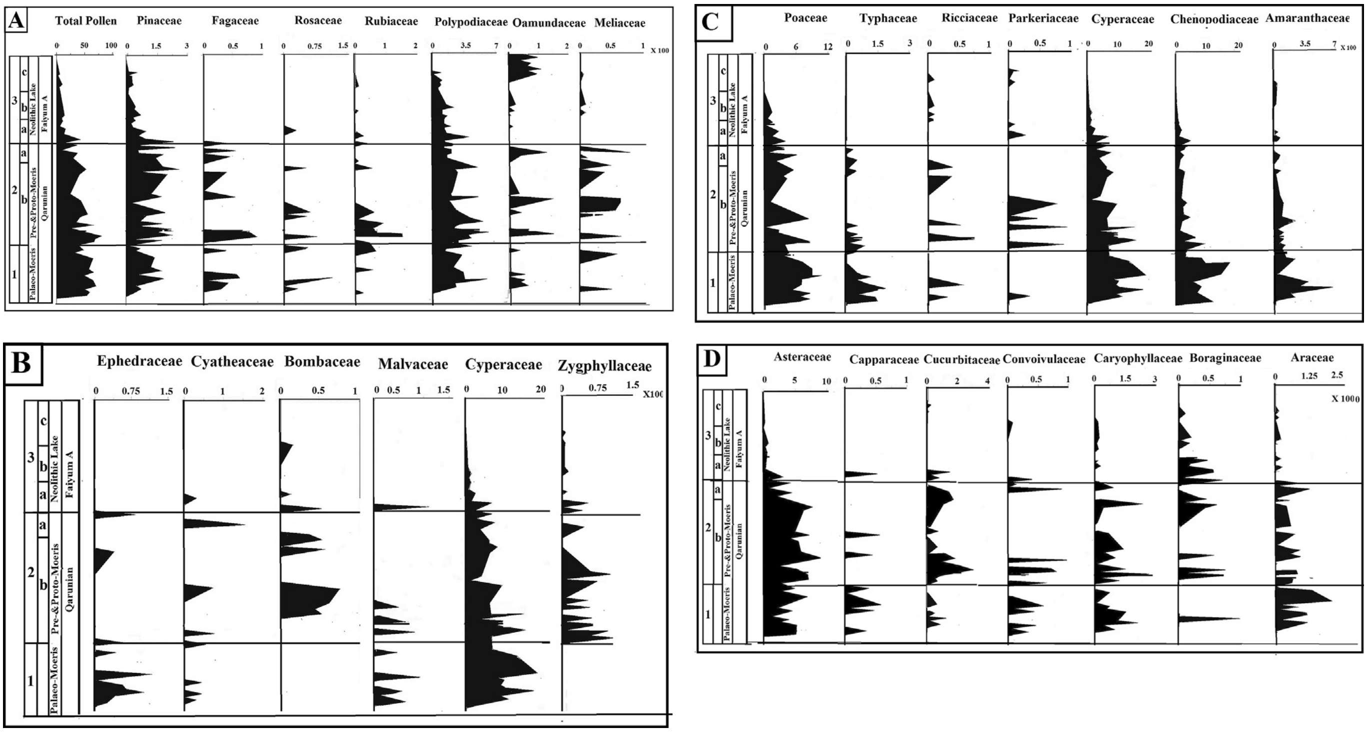

Fig. 4. A. Pollen diagrams represent the most abundant families of Native and Non-Native trees in Tersa Core. B. Pollen diagrams represent the most abundant families of Native Tree in Tersa Core. C. Pollen diagrams represent the most abundant families of Herbaceous plants (Xero-halophyte and Helophtic pollens) in Tersa Core. D. Pollen diagrams of the most abundant families of Mesophytic plants in Tersa Core.

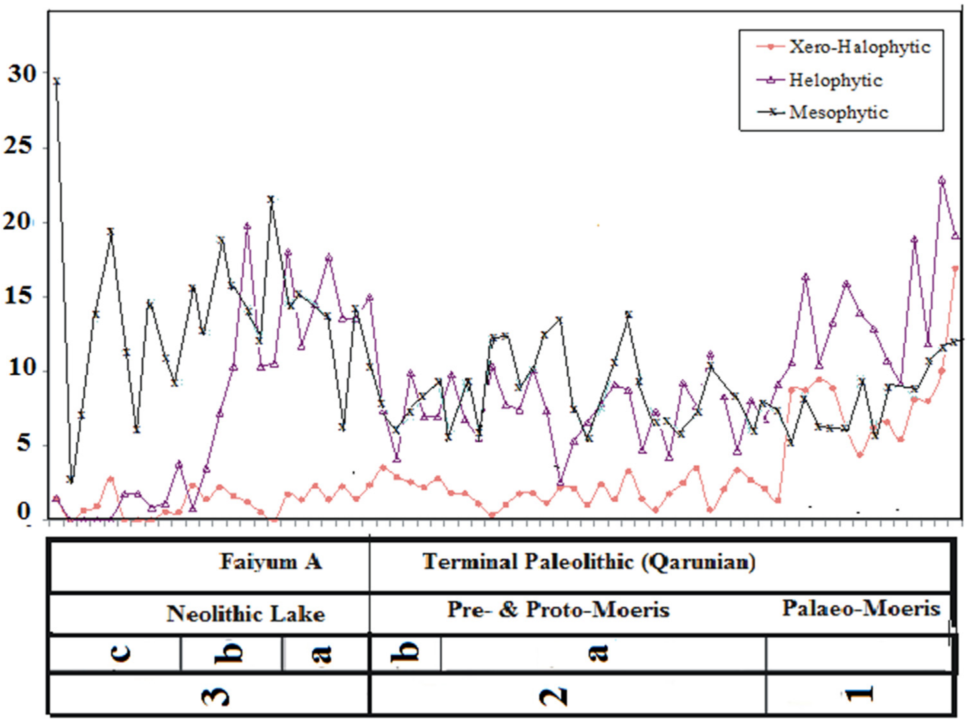

Fig. 5. Percentage diagram of the herbaceous pollen groups.

by Asteraceae, Caryophyllaceae, Brassicaceae, Convolvulaceae, Euphorbiaceae, Boraginaceae, Urticaceae and Laminaceae (Fig. 4-D). They are also recorded in the current vegetation in Faiyum Depression by El-Fayoumi (1996). Asteraceae pollen types occur in nearly all samples and reach a peak value (908.50 sp/g sediment) at 17.80 m (unit 2-a) depth. This family is worldwide in distribution and is particularly represented in semi-arid regions of the tropics and subtropics, centered in the Mediterranean

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region (El-Ghazaly, 1991). Fabaceae is cosmopolitan in distribution and reached a highest concentration (247.77 sp/g, sediments) at 24.77 m depth (unit1). Brassicaceae are also found worldwide and are centered in the Mediterranean region, southwest and central Asia (Heywood, 1987). Caryophyllaceae is also centered in the Mediterranean region (El-Ghazaly, 1991). Araceae, Cucurbitaceae, Amaryllidaceae and Selaginellaceae pollen types were also abundant and well represented in core sediments, Araceae reached peak concentration (225.24 sp/g sediment) at depth 23.20 m (unit 1). Cucurbitaceae reached the highest value (309.71 sp/g sediment) at 19.60 m depth (unit 2-a). Selaginellaceae reached the maximum value (260.81 sp/g sediment) at 17.20 m depth (unit 2-a). Pollen types of Apiaceae, Aristolochiaceae, Capparaceae, Phytolaccaceae, Geraniaceae, Liliaceae, Marantaceae, Blechnaceae and Marattiaceae are rare and sporadically represented in core samples (Fig. 4-D). Musaceae, Polygonaceae and Polygalaceae are very sparse in core sediments, their pollen are recorded once or twice in core sediments.

Freshwater algae of Tersa Core are represented by two families; Dictyosphaeriaceae and Volvocaceae. The former is represented by genus *Botryococcus*, which grow in freshwater to slightly brackish water environments (Rull, 1997). Family Volvocaceae is represented by genus *Pediastrum*, which often live within zones of freshwater aquatic vegetation (Rull, 2001). Both genera are abundant in all studied core sections of lacustrine sediments. The sediments of Tersa Core show a high concentration and wide varieties of fungal spores (Fig. 6). Fungal remains are valuable anthropogenic indicators of deforestation, soil erosion, grazing and crop cultivation (Van Geel et al., 2003). The concentration of fungal spore decreased up core (except for 20.2 m, Fig. 6), that may reflect water level changes and increased anthropogenic impacts (unit 3).

4. Discussion

4.1. Sedimentology of Tersa Core

The early-mid Holocene sediments of Tersa Core are subdivided into three sedimentological units according to lithological and textural characteristics. The thinly laminated calcareous sediment of unit 1 is indicative of a deep lake. These laminae show a typical varve structure with annual sequence of sediment comprises three parts, a layer of clay/silt size mineral grains, a diatom rich layer (see below) followed by a calcite (micrite) layer (cf. Flower et al., 2013). The silt and clay laminae are interpreted as in-washed allochthonous sediment accumulated following settling of particles from the water column to the lake floor in a low turbulence environment below the wave base (cf. Kliem et al., 2013). This component was probably derived from river interflow and includes some windblown dust. The existence of fine calcite layers are derived from summer pulses of micrite precipitation in the lake, and then they provide a sedimentary signal of annual seasonality. Moreover, low magnetic susceptibility (see Fig. 2), combined with high carbonate and diatom content, in unit 1 sediment indicates few magnetic minerals and relatively low flux of detrital sediment. Hence, Nile sediments, with high magnetic susceptibility, appear to be less important in unit 1 than in those of unit 2, which may indicate that the source of sediments of unit1 are mainly of local origin (i.e. reworked carbonates and aeolian sediments. The varved sediment indicates strong seasonality in the Faiyum climate during the early Holocene and corresponding in part to active winter rains at this time (Shirai, 2010; Hamdan and Lucarini, 2013).

Unit 2 (9.5–21 m), is represented by lacustrine delta sands and mud (sub-unit 2-a) and shallow near shore massive silt and sand (sub-unit 2-b). The former facies are represented by couplets of fine siliciclastic sediments (up to 1 cm in thickness). Each couplet is made up of a light, relatively fine grained sand and a darker coloured relatively finer grained sandy silt. The lighter coarser grained layer begins at a rather sharp boundary that gradually becomes finer grained and more silty, grading at least into the darker silty layer. On the other hand, contact between light and darker coloured layers is gradational. The light colour probably indicates late summer layers deposited when the Nile floods deliver abundant detrital materials and thefiner dark layers are mostly deposited during winter, when little terrigenous material is available and suspended fine grained materials settle out. In the middle part of sub-unit 2-a, seasonal rhythmites were recorded which coarsen upward changing from dark grey silt to very fine quartzose sand above. Such laminae are usually intercalated with and thick carbonate layers (up to 2 cm thick). The carbonate layers are nearly always rich in planktonic diatom remains indicating a standing lake water origin. The fine sands are probably deposited by turbidity currents formed in a sub-aquatic lake delta environment. The coarsening upward of the mud sand layers could be formed by subaqueous mass flow processes. These are attributed to dispersive pressure involving the upward dispersion of coarse grains (Lowe, 1982).

Sub-unit 2-b consists of yellowish grey, massive silt and sandy silt with a few interbedded sand layers. The silt is slightly coarser than that in Sub-unit 2-a, diatoms are common and occasional calcified root casts. The interbedded sands are characterized mainly by parallel and incipient wave ripple cross-laminations. The predominance of finer laminated sediments, the presence of incipient wave-generated structures, and presence of diatomsall suggest that deposition occurred in a shallow interdistributary bay environment. The existence of sand lenses might have been deposited from short-lived high-energy currents, representing crevasse-spray or crevasse-delta deposits (Reading and Collinson, 1996). The deposits of sub-unit 2-b, suggest a declining lake likely caused by diminishing Nile floods during the Terminal Palaeolithic–Neolithic transition phase.

Sediment of unit 2 is further characterized by high magnetic susceptibility indicative of sediment with abundant magnetic minerals most likely derived or re-worked mainly from Blue Nile sources (Foster et al., 2008). The early Holocene was a period of substantially wetter conditions in Northern Africa coinciding with a sharp increase in moist conditions as inferred from many sites in the Eastern Sahara/Sahel and Arabian Peninsula for the Holocene/Pleistocene transition (Hoelzmann et al., 2004). Also at this time, increased humidity was causing step-wise increases in lake levels in northern Africa. Consequently, a picture for the Faiyum emerges whereby this large basin was dry prior to the onset of this early Holocene wet period. Local rainfall began to accumulate forming a freshwater lake that was gradually augmented by entry of Nile water into the basin and river levels rose. Direct impacts of Nile water must have been a gradual process because the Tersa Core and both lake marginal cores QARU9 and F1-08 (Flower et al., 2013) are without evidence of massive flood deposits until after the phase of thinly laminated deep water sediments. Also the Tersa Core shows that magnetic minerals did not markedly increase until the beginning of unit 2. Nile water gained direct access to the lake area gradually, possibly through an extensive wetland developed around distributaries emanating from the Hawara gap. Irrespective of the precise Nile inflow mechanisms, the preliminary descriptions of the sediments of the Tersa units 1 and 2 provide clear evidence concerning the development of an early Holocene large freshwater lake within the Faiyum. During periods when Nile floods entered the Faiyum, in the early Holocene, water highly charged with sediments, contributed to a delta fan at the edge of the mega-lake, and unit 2 corresponds to this second phase of this lake.

Unit 3 (0–9.5 m), is represented mainly by fine siliciclastic sediments (silt, sandy silt and silty sand). Sediments of this unit are

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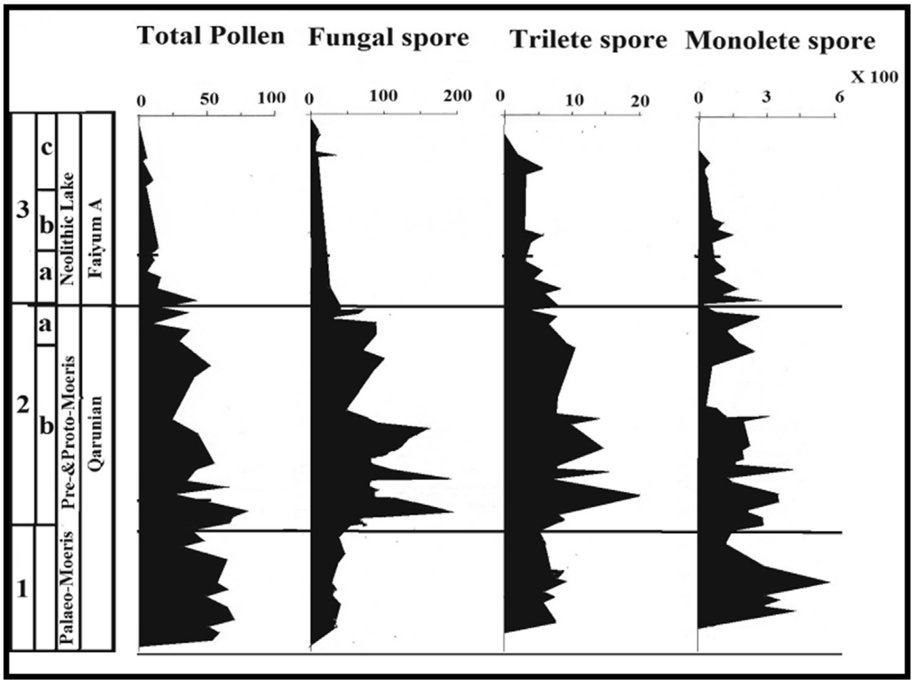

Fig. 6. Spore concentration diagram of Tersa Core.

dull yellowish brown (10YR5/3) and slightly stiff. The sedimentological parameters of this unit indicate that it was principally deposited during periods of retreating lake and river floods. Sub-unit 3-a represents the last stage of the active Faiyum lake delta, while the almost complete lack of diatoms in sub-units 3-b&-c provides additional support for a flood plain origin of these sediments.

4.2. Diatom biostratigraphy

Unit 1 shows a typical varve structure with annual sequence of sediment comprises three parts, a layer of clay and silt size mineral grains at the base and a diatom rich layer (mainly of *Cyclostephanos* and *Aulacoseira)* and a calcite (micrite) layer (deposited during the warmest season and often with organic matter (see Flower et al., 2013). These varves are restricted to unit 1 and according to critical depth relationships for the formation of varved sediments (e.g. Larsen et al., 1998), water depth at the coring location would need to have exceeded at least 28 m depth using the current lake morphometry and possibly nearer 90 m depth for the lake when at a maximum size in the early Holocene (see Hassan et al., 2006). The source of Faiyum lake water was mostly derived from the annual influx of Nile floodwater with minor contributions from local rainfall during Early and Middle Holocene (Wendorf and Schild, 1976; Hassan, 1986). The beach of the early Holocene Lake stood at 10 m asl, the lake then covered about 1300 km^2 and contained about 37 km^3 water (Hassan, 1986). The Neolithic Lake with shorelines at about 20 m as1 was about 2100 km^2 in area, with a capacity of about 53 km^3 water (Ball, 1939; Hassan, 1986). It is noteworthy that the unusual *Stephanodiscus galileensis* flora which occurred (c. 9000 BP) at the base of core QARU9 (Flower et al., 2013) was not detected in high abundance the Tersa Core (Fig. 3). The small increase of this species in the deepest Tersa sample (25.5 m) suggests the possibility it may be common below 25 m depth and high resolution diatom analysis is required in the future.

Aulacoseira granulata remains common in unit 1 and in the lower part of sub-unit 2-a, and this species is indicative of moderately eutrophic conditions. Today it proliferates in the upper Nile river basin during flood conditions (late summer) and is prevalent in deep flowing waters (Talling and Rózska, 1967). In African lakes it is associated with high dissolved silica and turbulent well mixed water and it limited by changing nutrient ratios, low nitrate and possibly low light conditions (Talling and Rzóska, 1967; Kilham et al., 1986). In the Tersa Core it tends to be less frequent in the unit 2 section and unit 3-a in sympathy to changes in *Cyclostephanos dubius*. Sediment magnetic susceptibility increases in unit 2 and this points to an increasing contribution of allogenic sediment to the lake and increased nutrient supply would favour increasing proportions of *C. dubius*. This diatom is an indicator of high nutrient status in shallow lakes (e.g. Bennion, 1995) and its presence signals increasing lake eutrophy at this time. Similarly, in a Danish lake this species responded to catchment disturbance beginning in the Pre-Roman Iron Age (Bradshaw et al., 2005). While the planktonic diatom abundances give little evidence for any marked changes in lake water pH or conductivity, the higher proportions of benthic and tychoplankton planktonic taxa in unit 2 do support a shallowing lake scenario at this time. The loss of diatom records in unit 3 is compatible with permanent lake water having receded from the Tersa Core location by around 6000 years BP.

4.3. Palynostratigraphy and vegetation history of Faiyum Depression

4.3.1. Early Holocene (9935 ± 230 to 8585 ± 60 Cal. BP)

This interval (21.0–26.0 m), is characterized by high pollen productivity (3233–6466 sp/g, sediments), and reflects a wetter climate. It contains relatively low percentages of non-native tree pollen (Fig. 4). Ritchie (1985) similarly recorded low frequency of non-native tree pollen in the Holocene pollen spectral analysis of Dakhla Oasis, Western Desert, Egypt. Native tree pollen was present with moderate percentages; however, Xerophytic tree pollen; Ephedraceae and Zygophyllaceae are recorded in high concentrations (Fig. 5). Arecaceae (Palms) are well represented in this interval

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where they reached highest concentrations (Fig. 5). The presence of Palms (together with Ephedraceae and Zygophyllaceae) indicates a semi-arid to arid warm local climate (Al-Ameri and Jassim, 2011). Polypodiaceae also well represented and recorded its highest concentration in this interval (c. 619.43 sp/g, sediments)and the herbaceous pollen also had highest percentages in this interval. Aquatic-wetland herbaceous pollen were in highest abundance (represented by 4.68–22.86% of total palynomorphs) and dominated by Poaceae, Cyperaceae, Typhaceae and Ricciaceae. Kholeif (2004) observed an abundance of Poaceae (Nilotic pollen) and Ricciaceae spores corresponding to periods of high Nile flood and low sea level of late Pleistocene-Early Holocene. Xerophytic herbaceous pollen is second in abundance (1.35–16.91% of total palynomorphs) dominated by Chenopodiaceae over Amaranthaceae. The latter is characteristic of salt marshes and arid environments (El-Ghazaly, 1991). Burjachs et al. (1997) also found maxima of xerophilous arboreal taxa in the first half of the Holocene at south Mediterranean sites. Poaceae and Chenopodiaceae pollen types were very common in this interval and are typical of marshlands and saline soils around salty lagoons (El Ghazaly, 1991; Bottema, 1992; Cheddadi and Rossignol-Strick, 1995). Mesophytic herbaceous pollen are the third in abundance (3.68–11.40% of total palynomorphs), dominated by Asteraceae, Fabaceae and Araceae. Freshwater green algal remains were widely presented in this interval (6–58% of total palynomorphs). Fungal spores (Fig. 6) showed its highest concentration (18229.0 sp/g, sediments) at 20.20 m depth and may indicate less environmental disturbance. This interval is generally characterized by high spore concentration, monolete and trilete (Fig. 6), and represented by Blechnaceae, Cyatheaceae, Marattiaceae, Osmundaceae, Parkeriaceae, Ricciaceae and Selaginellaceae. These families suggest active fluvio-deltaic sources (Mudie, 1982; Tyson, 1993). Groot and Groot (1966) consider fern spores to be indicators of humid climate. Accordingly, unit 1 sediments offer evidence of a local landscape dominated by a deep freshwater lake seasonally inundated by freshwater supplied by both rainfall and gradual ingress of Nile water. Hassan et al. (2012) concluded that Early Holocene is characterized by high 1ake levels in Faiyum and rising Nile discharge.

4.3.2. Early-Mid Holocene, Qarunian, (8585 ± 60 Cal. BP – 6302± 515 BP)

This interval (9.5.0–21.0 m) comprises 2 sub-units; 2-a & -b, and corresponds to the Qarunian culture. Sub-unit 2-a (12.0–21.0 m), with high pollen productivity (66140-7175 sp/g sediments), but shows lower percentages of helophytic herbaceous pollen (7.69–11.15% of total palynomorphs) than in unit 1. This may reflect frequent higher lake level and in turn, high Nile floods. The freshwater green algae are also reduced (5.92–20.28% of total palynomorphs)Xerophytic herbaceous pollens (i.e. Chenopodiaceae and Amaranthaceae) were also recorded in lower percentages than unit 1. Xerophytic tree pollen and Zygophyllaceae were also reduced and Ephedraceae was not recorded in this section. Sub-unit 2-b (11.5–9.50 m) shows drop in the pollen productivity (992–3362 sp/g sediments), which, together with decreasing Poaceae and Fabaceae (including *Acacia*) indicate increasing aridity. Sub-units 2-b is also distinguished by gradual increase in the native-tree pollen from base to top Helophytic herbaceous pollen decreased but Xerophytic herbaceous pollen and xerophytic tree pollen were similar to the underlying sub-unit 2-a. This may be indicate a decline in local rainfall and increasing importance of Nile water in sustaining the lake (as indicated by the initial increase in magnetic minerals). Nevertheless, overall Nile discharge probably declines in unit 2 and seasonality changes are diminishing together with reductions in chenopods and Zygophyllaceae plants associated with seasonal wetlands. Finally, the studied pollen assemblage of sub-unit 2-a, indicate that during Terminal Palaeolithic (Qarunian) culture, wet meadow wetland thrived surrounding freshwater mega-lake.

4.3.3. Middle Holocene, Neolithic Faiyumian (6302 ± 515 BP-4040 BP)

This interval (9.50 m to the top sediment of the core), is characterized by a clear decrease in pollen productivity reflecting an increasingly arid climate (see Fig. 4 Non-native tree pollen is recorded at depth 1.90 m. The concentration of fungal spores were highly reduced (Fig. 6), possibly reflecting increased sediment dynamics, which led to loss of plant material and/or more anthropogenic landscape disturbance. Herbaceous pollen decreased during this period, especially helophytic pollen which reached its lowest percentages. These changes indicate low Nile floods as well as low lake level during most of Neolithic and proto-dynastic, in comparison with Terminal Palaeolithic (see Hassan, 1986). Dry climate during the Neolithic Faiyum A culture is also confirmed by the increase of Xerophytic taxa and decrease in the concentration of spores and freshwater green algal remains. As a result of climate change and hydrologic manipulations for land reclamation begun during the Old Kingdom, the lake level fell, producing a larger marginal marshy zone. This probably accounts for the persistence of Polypodiaceae and increase in Osmundaceae spores in the top sediment. The Faiyumian landscape beyond the shrunken lake margins was probably semi-arid desert environment as indicated by low concentration of Poaceae together with intervals of moderate existence of Fabaceae (*Acacia*) sustained by winter rainfall (El-Muslimani, 1987). The high concentrations of Chenopodiaceae and other Xerophytic taxa all probably evidence seasonal desiccation, most likely in depressions and wetland areas surrounding the lake and linked to seasonal variations in lake level.

4.4. Summary history of Faiyum lake

The Tersa Core spans approximately 6000 years of lake or near lake conditions in the now terrestrial area near the centre of the Faiyum Depression. It provides a sedimentary record of lake level and other environmental changes during the early to mid Holocene (Fig. 7). High lake levels are well known for the early Holocene from former beach ridges and other lacustrine exposures (e.g. Hassan, 1986). The period occurs within the African humid period (e.g. Street-Perrott and Perrott, 1990; deMenocal et al., 2000; Kiage and Liu, 2006) which ended around 5.500 to 4500 years BP. However, the Faiyum is well north of the Holocene variations in the ITCZ that affected the East African lakes (Wang et al., 2005). The initial very early Holocene phase of the Faiyum (Moeris) Lake basin is characterized by an absence of lacustrine sediment containing freshwater diatoms, ostracods or freshwater bivalves and is represented mainly by aeolian sand deposits pre-dating 9938 years BP (Flower et al., 2013). Although the existence of Pleistocene lake sediments below these sands cannot be excluded, the latter date indicates that lacustrine deposition (unit 1) marked the beginning of the Holocene lake. Analysis of the subsequent varved sediments show that the lake rapidly developed a freshwater community of planktonic diatoms (*Aulacoseira* and *Cyclostephanos* spp) (Fig. 7A). The lake at this time was deep, at around 100 m in depth form beach ridge evidence (see Hassan et al., 2006; Flower et al., 2013). The vegetation in and around the lake was sustained by freshwater and open savanna conditions existed in the surrounding landscape. The sediments of unit 1 are characterized by an abundance of planktonic diatoms (Fig. 7A) and high percentages of aquatic plants (Fig. 7B). This clearly supports a deep lake condition at this time and in turn higher Nile floods. Bernhardt et al. (2012), used the abundance of Cyperaceae pollen as an indicator of freshwater input into the Nile Valley and variations in their abundance can provide a valuable clue to fluctuation in the Nile floods. Correspondingly, Cyperaceae pollen in Tersa Core shows higher abundance in the samples of unit 1.

After 8585 ± 62 Cal. BP and up to 6302 ± 515 BP, the water depth of the Faiyum lake, at the location of Tersa Core, was reduced by the progradation of a new lacustrine delta (unit 2), as Nile floods became a more important direct influence within the Faiyum and rainfall reduced. Nile water inflowed through the Howara channel and was discharged through at least two distributary channels with the Faiyum before debouching into the lake. The progradation of the intra-Faiyum delta ceased some 6000 years ago (end of unit 2) probably coinciding with sudden drop in the lake level due to periods of low Nile floods. The progradation of the Faiyum delta probably resumed again as a result of rise in lake level as Nile floods increased (sub-unit 3-a). The archeological excavations at Khartoum Northern Sudan indicate that the Nile flood levels were very much higher than today, during Middle Holocene (Williams and Nottage, 2006). The deltaic depositional environment of unit 2 (Terminal Palaeolithic, Qarunian culture), is supported by an abundance of pollen grains of the following: Poaceae, Cyperaceae, Chenopodiaceae, Amaranthaceae, Polypodiaceae and Osmundaceae (Fig. 5). The existence of more planktonic diatom taxa over benthic species (Fig. 7-A), during Qarunian culture, and in addition to frequent abundance of both aquatic and terrestrial pollen (Fig. 7-B), probably indicate optimum Nile flooding as local rainfall diminished (cf deMenocal et al., 2000). During the Faiyum A (Neolithic) culture, which is represented by unit 3, the level of the lake was low as indicated by the absence of diatoms (Fig. 7-A), diminished total aquatic pollen over the terrestrial pollen (Fig. 7-B), and an abundance of herbaceous pollen over arboreal pollens (Fig. 7-C). Refining the current model of climate and lake level changes in the Faiyum now depends on higher resolution studies of sedimentary changes and their chronology.

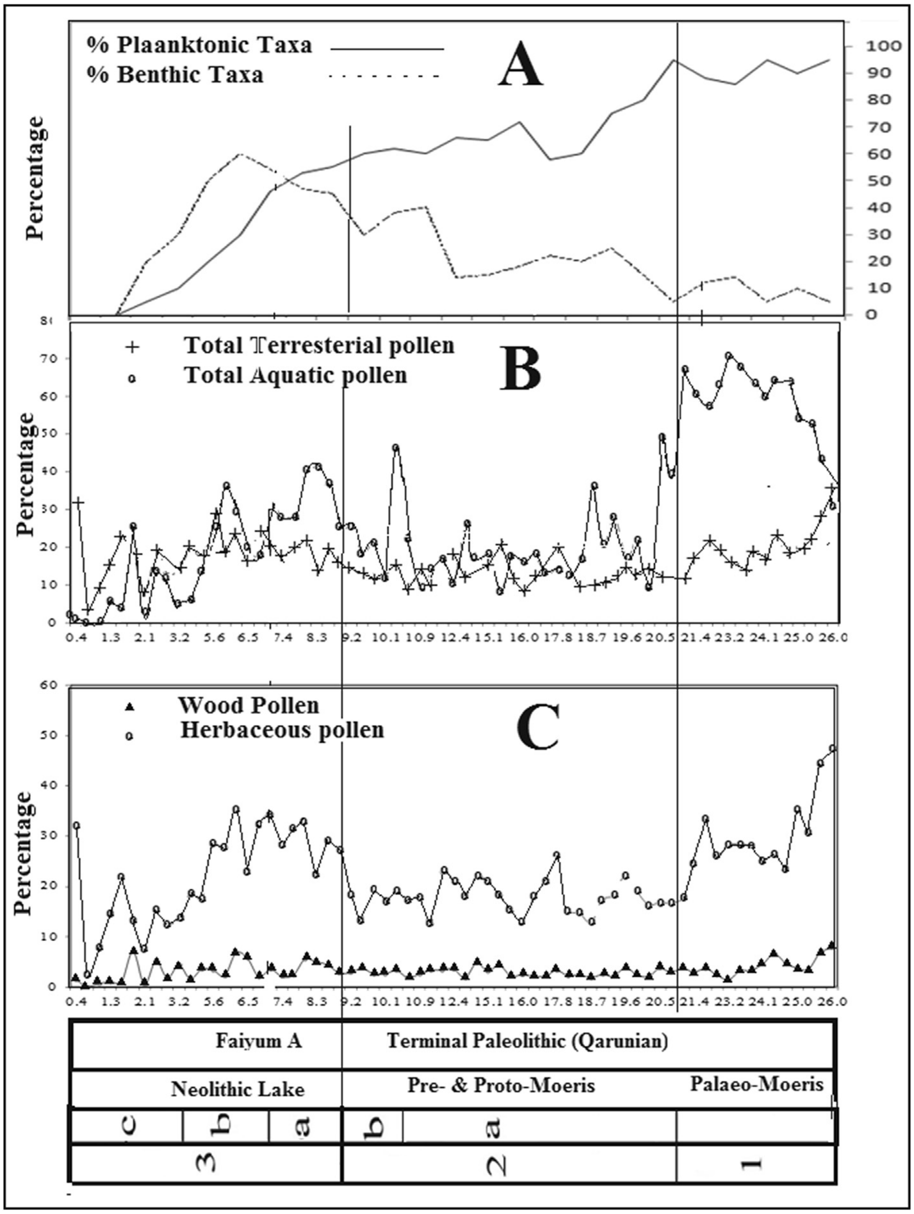

Fig. 7. A-distribution of tree and herbaceous pollens; B- distribution of aquatic and terrestrial pollen of the sediments of Tersa Core; C- the distribution of plantonic and benthic diatom of the sediments of Tersa Core.

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5. Conclusions

1 The present study uses sedimentology, diatom analysis and paleonology of a 26-m long core from Tersa in the central area of the Faiyum Depression to infer past environmental changes. Two radiocarbon and one OSL dates establish that the sediment sections span the early to mid-Holocene.

2 The core sediments are subdivided into three sedimentological units, these are; unit 1 (21–26 m; 9935 ± 230–8585 ± 62 Cal. BP), composed of thinly laminated stiff calcareous silt deposited as pelagic sediment in deep open lake. Unit 2 (9.5–21, and dated to 8585 ± 62–6302 ± 515 bp), is subdivided into two sub-units; sub-units 2-a & -b. These are represented by thicker laminae coarsening up from silt to fine sand layers that are intercalated with thick carbonate layers usually with diatoms. Sub-unit 2-b, consists of massive silt with thin medium sand layers and were deposited in shallow bay near the shore line indicate decling lake level. Unit 3 (0–9.5 m; −6302 ± 515 bp-4400 Cal. BP) consists of three sub-units 3-a-b, -c. Sub-unit 3-a, is similar to sub-unit 2-b, while as sub-units 3-b&-c represent a terrestrial flood plain environment.

3 Summary diatom analysis shows that planktonic taxa, such as *Cyclostephanos, Aulacoseira* and *Cyclotella* spp. were abundant in units 1, with 1a indicating deep, open lake conditions at the Tersa Core location. Frequency abundance of *Cyclostephanos dubius* tended to increase up-core indicating higher nutrients and possibly shallower water. Non-planktonic diatom taxa such as *Fragilaria, Cocconeis*, *Amphora* and *Navicula* showed increased abundances in sub-units 2-a-b;-c and reflect shallowing of the lake level and periods of low Nile floods. Unit3 was essentially barren of diatoms and indicative of terrestrial flood plain conditions.

4 The vegetation recorded in the core was mainly herbaceous and the arboreal vegetation was recorded with low percentages during most of the sediment units. The depositional environment was mainly deltaic reflected from the abundance of Poaceae, Cyperaceae, Chenopodiaceae, Amaranthaceae, Polypodi aceae and Osmundaceae.

5 Sediment records of helophytic pollen (Chenopodiaceae and Amaranthaceae) indicated periods of high flood plain salinity. Their distribution in the middle part of the core, correspond to the Qarunian culture when short dry and arid episodes interrupted the early-mid Holocene wetter events. The helophytic pollen are dominant in the upper part of the core and correspond to the Faiyumian and Proto-dynastic periods, reflecting a prevailing dry climate trend.

6 Holocene sedimentology of the Faiyum basin is complex, both spatially and temporally, and a full chronological record of past environmental changes is still required. The precise timing of water level variations still critically depends on high resolution sediment dating. Nevertheless, the environmental changes demonstrated in the Tersa Core contribute to understanding of the prevailing early and mid-Holocene environ ments.

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