

Climate Change in the Nile Delta from Prehistoric to the Modern Era and Their Impact on Soil and Vegetation in Some Archaeological Sites

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Abstract: Since the time of the rainy Holocene, there have been periods of consecutive rain and drought on Egypt. Study of carbon 14 in the long-lived coniferous tree rings could see activity in the sun (spots and solar flares) during eleven years cycle, as well as knowledge of possible flooding of the Nile and the periods of increase and decrease of the extent necessary to meet the soil around Lake Qarun in Fayoum-Egypt. From historical records in ancient Egypt and Muslim countries, the possible link between periods of the disappearance of sunspots on the solar disc for several years and is known to inch lower level and role of the minimum level of Mandour creeping ice on Southern Europe to the Mediterranean Sea, and the offset of the drought in North Africa and the Sahel region of Africa during the last thousand years. Analyzed pollen fossils of the overlapped layers of soil in two areas of the Delta were Avaris in Sharkiya Province and Mendes in Dakahliya Province. The study pointed out that there are differences due to environmental conditions, demonstrated by the analysis of soil pH, increased electrical connectivity also, the evidence of sulfates and chlorides indicate high salinity of Mendes and Avaris. Also the analysis of fossil pollen of successive layers of soil for both regions resulted in findings of fossil pollen of the species *Chenopodiaceae* by 51.2%, in Mendes, while, 7% in the Avaris. This is strong evidence of the existence conditions of salt in Mendes than Avaris archaeological sites.

Key words: Climate change, wet habitat, palaeoecology, palynology, prehistory, predynasty, Avaris Sharkiya and Mendes Dakahliya Province.

1. Introduction

Climate change is often invoked as a trigger for the collapse of civilizations. The fall of the Akkadian Empire and the end of the Egyptian Old Kingdom around 4,200 years BP (before present) have both been attributed to climatic change resulting in regional desiccation [1-3]. However, there is widespread evidence that climatic and environmental stress played a major role in the emergence of early civilizations, and that acidification in particular acted as a trigger for increased social complexity associated with urbanization and state formation. Evidence that the

desert belt of the northern hemisphere experienced wetter conditions in the past is widespread, but is particularly rich in the Sahara [4-8]. Dating of archaeological sites, lake sediments and faunal remains indicates that wet conditions were established in the Sahara by around 10,000 BP after a long period of aridity associated with the last glacial period [9-11]. This humid phase was associated with an intensification of the African Monsoon caused by increased northern hemisphere summer insolation, resulting in its penetration far north of its current northernmost position [12-15]. The early Holocene humid phase was, however, punctuated by episodes of aridity that appear to have coincided with North Atlantic cooling events. Also evident from ice-rafted

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debris and Greenland ice-core records [16-21]. While summer insolation remained strong, the Saharan region recovered from these arid interruptions, and humid conditions were re-established. However, there is evidence that recovery was at best partial in the eastern Sahara after an arid event around 6,000 BP [19, 20] and the entire Sahara had entered a period of desiccation by around 5,000 BP [4, 7]. The process of environmental desiccation that followed the southward retreat of the monsoon was mediated by geography; while water persisted at or near the surface in some locations long after the significant rainfall, hyper-arid surface conditions were established rapidly in other Saharan regions. Malville and Shaltout [22, 23] suggest that “an exodus from the Nubian Desert at 4,800 (uncalibrated radiocarbon) years BP may have stimulated social differentiation and cultural complexity in pre-dynastic Upper Egypt.” It is plausible that the necessity to settle permanently in the Nile Valley, coupled with an increase in population due to immigration resulting from desiccation of the surrounding Saharan.

2. Aim of Study

The aim of this study is to provide information on the evolution of vegetation ecosystems and to document their response to climate change during prehistory, predynasty and recent period. We examine the response of dry and wet ecosystems to changes in regional climate, based on the fossil pollen data of the Nile Delta region.

3. About the Study Areas

Avaris (Egyptian: Hatwaret, Greek: Auaris), thought to be located at Tell el-Dab'a (some still argue for different locations), was the ancient capital of the Hyksos dynasties in Egypt. Located in the northeastern region of the Nile Delta, Avaris was the base of the Hyksos kings of Egypt's Second Intermediate Period. The city was built atop the ruins of a Middle Kingdom town that had been captured by the Hyksos. After their takeover, the Hyksos heavily

fortified the city and ruled the country using new technology, specifically the chariot which had never been witnessed before by the Ancient Egyptians. Tell El-Daba'a (Avaris), located in the northeastern Nile Delta (Fig. 1) has been known since 1885. This part of the Nile Delta is generally characterized by a low alluvial plain with southwest-northeast trending belts of higher ground known as Geziras (Arabic: sand-islands) and archaeological sites known as tells which are accumulations of ancient settlement debris. Excavations at the site have been conducted since 1966 [24].

Mendes is a city just north-west of Avaris in the Egyptian delta and the sacred goat (often called Khem, Chem or Ham) was the zodiacal goat of Capricorn. In accordance with the Dragon Court tradition, Mendes, the Greek name of Ancient Egyptian city of Djedet, also known in Ancient Egypt as Per-Banebdjedet (“The Domain of the Ram Lord of Djedet”) and Anpet, is known today as Tell El-Ruba. The city is located in the eastern Nile Delta (Fig. 1) and was the capital of the 16th Lower Egyptian named Kha, until it was replaced by Thmuis in Greco-Roman Egypt. The two cities are only several hundred meters apart. During the 29th dynasty, Mendes was also the capital of Ancient Egypt, which lies on the Mendesian branch of the Nile (now silted up), about 35 km east of al-Mansurah. Mendes was mentioned in the sarcophagi texts as the meeting place of Osiris and Ra. They unified and became the “united Ba”, the same texts state that Osir's ba was manifested through the ram's body consecutively Osir was represented as a ram and the worship of Osir went on to the Ptolemaic era. Mendes became the capital of Egypt during the 29th Dynasty. Civilization in the area goes back to the Old Kingdom as the most ancient discovered tombs, and there are mastabas referred to the first and second dynasties, but scholars proved their use during pre dynasties and archaic periods [25].

4. Materials and Methods

Two profile sectors were dug to 120 cm depth, at



Fig. 1 Satellite map of the of Ancient Nile Delta.

two locations both Avaris and Mendes archaeological sites (Figs. 2 and 3). Soil samples were taken every 10 cm for pollen analysis, and every 25 cm for physical and chemical analysis. Chronology of soil strata was obtained by Austrian Mission for archaeological excavations at Tell el Dabaa in Sharkiya Province and Canadian Mission for archaeological excavations at Tell el Robaa Dakahlia Province during March and April 2003. Radiocarbon dating of samples obtained from Canadian Mission archaeological excavations. The soil samples were extracted for their pollen content, sieved according to Faegri and Iversen [26]. 10 gm of soil were taken from the required sector level. 5 gm (sub-sample) were placed in boiling thermoplastic tube, mixed with 10 mL KOH (10%), placed in boiling water bath for 15 minutes. The samples were sieved through a 100 μ m aperture. The pollen grains were settled in monofilament sieve (7 μ m), then washed with dist water. The washings were made up with dist water and centrifuged at 3,000 rpm for 3 minutes. The liquid was decanted and 10 mL of HF (hydrofluoric acid) (40%) were added, which boiling

water bath overnight, centrifuged and decant. The pellet was resuspended in 10% HCl, to dissolve residual silicoflorides, centrifuged and decant. The pellet was resuspended in glacial acetic acid to dehydrate prior to acetolysis, and acetolysed (treated with glacial acetic acid) according to Moore *et al.* [27].



Fig. 2 Showing soil profile at Avaris archaeological site (Tell el Dabaa).



Fig. 3 Soil profile at Mendes (Tell el Robaa) archaeological site.

The purified samples mounted on glass slides and counted for their pollen grains up to 300 grains. Pollen identification routinely used $\times 400$ magnification with $\times 1,000$ magnification for small and difficult types with reference standard keys [28], and reference

herbarium collection specimens of ESRI (Environmental Studies and Research Institute) Sadat City University, while, pollen and spores nomenclature follows method in Ref. [29]. Pollen percentage, concentration, calculations were based on the sum of total land pollen, which included terrestrial Pteridophyte spores, Cyperaceae pollen, and unidentified pollen types. Concentrations of pollen-slide $> 12 \mu\text{m}$ were determined. Since particle fragmentation occurs during pollen processing, a sieving-based methodology modified from Ref. [30] was used.

5. Results

5.1 Soil Analysis

Avaris (Tell el Dabaa Archaeological Site), Table 1 revealed that: The type of the soil is mainly of medium and fine particles with values range between 38.8%-32.5% at depths 0-25 cm to 125-150 cm. The soil pH, ranged between 8.6-7.2 at depths 0-25 to 125-150 cm. Ca-carbonates content ranged between

Table 1 Physical and chemical properties of soil samples profile at Avaris archaeological site.

| Chronology | Depth/cm | Physical (particle size) (%) | | | | | |
|-----------------------------------------------------|----------|------------------------------|------|------|------|------|--|
| | | G | Sand | | | SC | |
| | | | C | M | F | | |
| Recent | 0-25 | 10.3 | 3.9 | 38.8 | 36 | 12.3 | |
| Early, Middle and New Kingdoms (about 2920-1070 BC) | 25-50 | 22.4 | 5.35 | 37.5 | 29.5 | 10.6 | |
| | 50-75 | 26.3 | 4.99 | 37.1 | 28.1 | 9.3 | |
| Predynasty 3500-3100 BC | 75-100 | 16 | 3.7 | 36.2 | 36 | 9.8 | |
| Prehistory | 100-125 | 10.8 | 4.2 | 32.7 | 27.2 | 15.3 | |
| About 8500BC | 125-150 | 8.3 | 2.8 | 32.5 | 30.1 | 15.6 | |

| Chronology | Depth/cm | Chemical | | | | | | | | | | | |
|-----------------------------------------------------|----------|----------|----------------------|-------|-----------|----------------|-----------------|-----------------|------------------|-----------------|------|------|------|
| | | PH | CaCO ₃ /% | N/ppm | E.C/MS/cm | Anions/M.meq/L | | | | Cations/M.meq/L | | | |
| | | | | | | Cl | SO ₄ | CO ₃ | HCO ₃ | Na | K | Ca | Mg |
| Recent | 0-25 | 8.6 | 7.6 | 40 | 0.4 | 1.2 | 1.48 | - | 1 | 1.24 | 0.44 | 1.4 | 0.8 |
| Early, Middle and New Kingdoms about (2920-1070 BC) | 25-50 | 8.4 | 5.9 | 22 | 0.2 | 1.6 | 0.5 | - | 1.2 | 1.21 | 0.29 | 0.8 | 0.65 |
| | 50-75 | 8.2 | 3 | 20 | 0.18 | 1.05 | 0.14 | - | 0.98 | 0.78 | 0.26 | 0.65 | 0.6 |
| Predynasty 3500-3100 BC | 75-100 | 8.1 | 2.5 | 17 | 0.58 | 1.5 | 0.4 | - | 0.8 | 0.78 | 0.11 | 0.61 | 1.6 |
| Prehistory | 100-125 | 7.9 | 2.2 | 9 | 0.36 | 1 | 1.02 | - | 1 | 1.06 | 0.43 | 0.8 | 1 |
| About 8500 BC | 125-150 | 7.2 | 2 | 6 | 0.35 | 1.75 | 0.82 | - | 1.5 | 1.14 | 0.53 | 0.63 | 0.24 |

M = moisture content; G = gravels; C = coarse sand; M = medium; F = fine sand; SC = finer sediments, E.C/MS = Electric Conductivity

2%-7.6%, total nitrogen 6-40 ppm, while electro-conductivity ranged between 0.4-0.35 mL. Mohs/cm at depths 0-25 cm and 125-150 cm, the amount of Na ranged between 1.24-0.78 M.meq/L, Cl (chlorides) ranged between 1.05-1.75 M.meq/L at depths 50-75 cm and 125-150 cm, and the amount of SO₄ (sulphates), ranged between 1.48-0.14 M.meq/L at depths 0-25 cm and 50-75 cm.

Mendes (Tell el Robaa Archaeological Site), Table 2 showed the main bulk of the soil is sand with values ranging between 26.2%-32.5% at depths 0-25 cm and 125-150 cm. The soil pH ranged between 8.9-7.5 cm at depths 0-25 cm and 125-150 cm. Ca-carbonates content ranged between 44.6%-29%, total nitrogen 98-20 ppm, while electro-conductivity ranged between 12.7-2.6 ml.Mohs/cm at depths 0-25 cm and 125-150 cm, the amount of Na ranged between 20.3-3.0 M.meq/L, Cl ranged between 150-27.3 M.meq/L at depths 0-25 cm and 125-150 cm. The amount of SO₄, ranged

between 36.93-0.12 M.meq/L at depths 0-25 cm and 125-150 cm.

5.2 Pollen Record at Avaris

- Period 1: Modern Soil Layers.

a total of 12 samples, (0-10 cm, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100, 100-110, 110-120 cm), were analyzed, where nine pollen types were recognized (Table 3). Records of the most important individual taxa are presented in Fig. 4.

The identified pollen, pteridophyte spores from Avaris profile Open Vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 17.5%, 17%, 21.7% and 19% respectively, and swampy vegetation recorded, *Typhaceae* 3.6%.

- Period 2: New Kingdom (about 1550-1070 BC)

open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 7.9%, 4.6%, 36.1% and 4.7% respectively.

Table 2 Physical and chemical properties of soil samples profile at Mendes archaeological site.

| Chronology | Depth/cm | Physical (particle size) (%) | | | | | |
|-----------------------------------------------------------|----------|------------------------------|------|------|------|------|----|
| | | G | Sand | | | | SC |
| | | | C | M | F | | |
| Recent | 0-25 | 3.5 | 16 | 26.2 | 22.3 | 32 | |
| Early, Middle and New Kingdoms (about 2920-1070 BC) | 25-50 | 4 | 18.1 | 26.9 | 20.5 | 30.1 | |
| Predynasty (3500-3100 BC) | 50-75 | 5.1 | 19.8 | 26.3 | 19.2 | 29 | |
| | 75-100 | 2.8 | 17 | 29 | 21 | 25.1 | |
| Prehistory (about 8500 BC) | 100-125 | 4.9 | 19 | 32.7 | 18.6 | 26.3 | |
| | 125-150 | 5 | 20 | 32.5 | 19.2 | 26.6 | |

| Chronology | Depth/cm | Chemical | | | | | | | | | | | |
|-----------------------------------------------------------|----------|----------|--------------------------|-------|--------------|----------------|-----------------|-----------------|------------------|-----------------|------|------|------|
| | | PH | CaCO ₃ (%) | N ppm | E.C Ms/cm | Anions/M.meq/L | | | | Cations/M.meq/L | | | |
| | | | | | | Cl | SO ₄ | CO ₃ | HCO ₃ | Na | K | Ca | Mg |
| Recent | 0-25 | 8.9 | 44.6 | 98.3 | 12.7 | 150 | 36.93 | - | 1.6 | 20.3 | 6.15 | 66.2 | 94.8 |
| Early, Middle and New Kingdoms about (2920-1070 BC) | 25-50 | 8.4 | 35.9 | 92.4 | 10.5 | 115 | 22.8 | - | 1.2 | 14.6 | 4.92 | 37.8 | 62.3 |
| Predynasty 3500-3100 BC | 50-75 | 8.2 | 37.2 | 80 | 7.6 | 89 | 21.6 | - | 1.3 | 10.4 | 3.2 | 17.5 | 48.1 |
| | 75-100 | 8.1 | 35.6 | 75.6 | 5.1 | 65 | 21.9 | - | 0.8 | 7.2 | 4.67 | 13.3 | 42.6 |
| Prehistory About 8500 BC | 100-125 | 7.9 | 28.1 | 60.5 | 3.8 | 42.5 | 0.82 | - | 1.7 | 8 | 2 | 14 | 16.5 |
| | 125-150 | 7.5 | 29 | 20.3 | 2.6 | 27.3 | 0.12 | - | 2 | 3 | 1.5 | 5.8 | 10.7 |

M = moisture content; G = gravels; C = coarse sand; M = medium; F = fine sand; SC = finer sediments; T.N = total nitrogen.

Table 3 The relative abundance (%) of different pollen types in of Avaris archaeological site.

| Chronology | Depth/cm | Pteridophyta | Gymn | | Monocot | | | Dicot | | |
|-------------------------------------|----------------|--------------|------|------|---------|------|------|-------|------|------|
| | | Lycopod | Pin | TY | PO | CY | CH | NY | AST | ON |
| Recent | 0-10 (surface) | - | - | 3.6 | 21.7 | 19.0 | 17.5 | - | 17.0 | - |
| | 10-20 | - | - | 1.9 | 24.5 | 15.7 | 12.6 | - | 15.3 | - |
| | 20-30 | - | - | 1.6 | 29.2 | 15.6 | 10.0 | 0.5 | 10.7 | - |
| New Kingdom about (1550-1070 BC) | 30-40 | - | - | 0.9 | 36.1 | 4.7 | 7.9 | 0.5 | 6.4 | 0.7 |
| Middle Kingdom about (2040-1700 BC) | 40-50 | - | 0.3 | 0.7 | 50.4 | 14.5 | 16.0 | 0.7 | 12.0 | 0.8 |
| | 50-60 | 0.2 | 0.9 | 1.5 | 55.0 | 16.2 | 9.0 | 1.0 | 35.0 | 1.4 |
| Early Dynasty about (2920-2575 BC) | 60-70 | 0.9 | 1.3 | 2.6 | 43.9 | 20.3 | 6.2 | 5.5 | 42.1 | 6.2 |
| | 70-80 | 2.0 | 3.6 | 3.5 | 61.4 | 26.1 | 5.0 | 10.3 | 34.5 | 12.0 |
| Predynasty about (3500-3100 BC) | 80-90 | 2.9 | 5.1 | 5.0 | 57.1 | 22.6 | 3.3 | 8.2 | 20.6 | 4.1 |
| | 90-100 | 3.5 | 8.5 | 10.5 | 33.8 | 17.0 | 2.4 | 6.4 | 9.3 | 5.2 |
| Prehistory About (8500 BC) | 100-110 | 5.6 | 6.4 | 7.0 | 37.4 | 12.1 | 3.4 | 3.9 | 11.2 | 6.0 |
| | 110-120 | 10.4 | 9.3 | 8.9 | 47.3 | 10.5 | 5.2 | 4.1 | 18.6 | 5.3 |

Lycopod = *Lycopodium*; Gymn = gymnosperm; Pin = *Pinus*; Monocot = monocotyledon; TY = Typhaceae; PO = Poaceae (Graminae); CY = Cyperaceae; Dicot = Dicotyledon; CH = Chenopodiaceae; NY = Nymphaeaceae; AST = Asteraceae (Compositae); ON = Onagraceae.

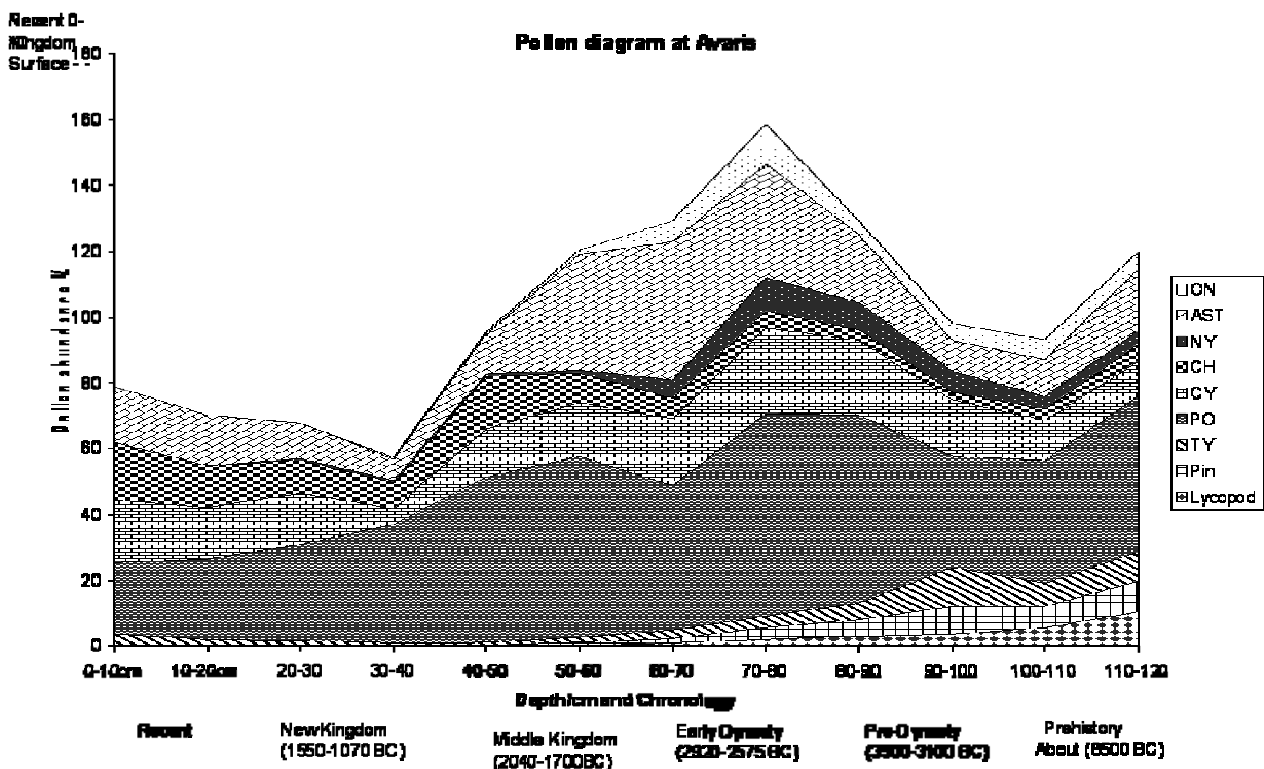


Fig. 4 Pollen diagram showing the relative abundance of pollen at Avaris profile.

Nile water plants, *Nymphaeaceae* and *Onagraceae* with abundances 0.5% and 0.7%, and swamp vegetation, *Typhaceae* was 0.9%.

• Period 3: Middle Kingdom (about 2040-1700 BC)

Open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 16%, 12%, 50.4% and 14.5% respectively, and Nile water plants, *Nymphaeaceae* and *Onagraceae* with abundances 0.7% and 0.8%, while swampy vegetation, *Typhaceae*

0.7% and *Pinus* type 0.9%.

- Period 4: Early Dynasty (about 2920-2575 BC)

Open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 6.2%, 34.5%, 61.4% and 26.1% respectively, while, Nile water plants, *Nymphaeaceae* and *Onagraceae* with abundances 10.3% and 12%, swamp vegetation, *Typhaceae* 3.5%, *Pinus* type 3.6%.

- Period 5: Predynasty (about 3500-3100 BC)

Open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 2.4%, 9.3%, 33.8% and 17%, respectively. Lycopodium spores 3.5%, *Pinus* type 8.5%, swamp vegetation, *Typha* type 11.8%.

- Period 6: Prehistory (about 8500 BC)

Open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 5%, 2%, 18.6%, 47.3% and 10.5%, respectively. Nile water plants, *Nymphaeaceae* and *Onagraceae* with abundances 4.1% and 5.3%, but, swamp vegetation were, *Typhaceae* 8.9%, and *Pinus* type 9.3%.

5.3 Pollen Record at Mendes

- Period 1: Modern Soil Layers.

A total of 12 samples, (0-10 cm, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100, 100-110, 110-120 cm), were analyzed, where nine pollen types were recognized (Table 4). Records of the most important individual taxa are presented in Fig. 5. While, the identified pollen, pteridophyte spores from Mendes profile open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 51.2%, 0.6%, 24.6% and 1%, respectively.

- Period 2: New Kingdom about (1550-1070 BC)

Open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 40.5%, 2.3%, 16.3% and 4.9%, respectively.

- Period 3: Middle Kingdom about (2040-1700 BC)

Open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* with abundances 28.8%, 10%, 9.6% and 5%, respectively.

Nile water plants, *Nymphaeaceae* and *Onagraceae* with abundances 10 and 6.5%. Swamp vegetation, *Typhaceae* 1.5%, *Pinus* type 0.9%.

- Period 4: Early Dynasty about (2920-2575 BC)

Open vegetation, *Chenopodiaceae*, *Asteraceae*,

Table 4 The relative abundance(%) of different pollen types of Mendes archaeological site.

| Chronology | Depth/cm | Pterid Gymn | | | Monocot | | | Dicot | | |
|-------------------------------------|------------------|-------------|-----|------|---------|------|------|-------|------|------|
| | | Lycop | Pin | TY | PO | CY | CH | NY | AST | ON |
| Recent | 0-10cm (surface) | - | - | - | 24.6 | 1.0 | 51.2 | 1.8 | 0.6 | 0.9 |
| | 10-20 | - | - | - | 25.0 | 2.0 | 49.8 | 2.0 | 2.7 | 0.6 |
| | 20-30 | - | - | - | 16.8 | 4.0 | 36.9 | 3.0 | 13.4 | 0.8 |
| New Kingdom about(1550-1070 BC) | 30-40 | 0.3 | - | - | 16.3 | 4.9 | 40.5 | 4.7 | 2.3 | 19.5 |
| Middle Kingdom about (2040-1700 BC) | 40-50 | 0.7 | 0.3 | - | 7.3 | - | 31.8 | 10.7 | 2.7 | 31.8 |
| | 50-60 | 1.8 | 0.9 | 1.5 | 9.6 | 5.0 | 28.8 | 10.0 | 10.0 | 6.5 |
| Early Dynasty about (2920-2575 BC) | 60-70 | 2.6 | 1.3 | 2.6 | 53.6 | 7.1 | 20.0 | 6.5 | 8.5 | 5.2 |
| | 70-80 | 3.1 | 3.6 | 3.5 | 74.0 | 8.2 | 5.0 | 6.0 | 7.4 | 11.1 |
| Predynasty about (3500-3100 BC) | 80-90 | 3.4 | 5.1 | 5.0 | 83.3 | 10.5 | 3.3 | 4.2 | 3.3 | 3.3 |
| | 90-100 | 5.5 | 8.5 | 11.8 | 48.2 | 15.0 | 2.4 | 4.6 | 3.0 | 4.5 |
| Prehistory about (8500 BC) | 100-110 | 10.6 | 6.4 | 7.0 | 45.5 | 14.8 | 3.4 | 5.3 | 5.0 | 4.1 |
| | 110-120 | 15.5 | 9.8 | 9.8 | 48.5 | 11.6 | 5.2 | 3.0 | 3.0 | 6.2 |

Pterid = pteridophyta; Lycopod = *Lycopodium*; Gymn = gymnospermae; Pin = *Pinus*; Monocot = monocotyledon; TY = *Typhaceae*; PO = *Poaceae* (Graminae); CY = *Cyperaceae*; Dicot = Dicotyledon; CH = *Chenopodiaceae*; NY = *Nymphaeaceae*; AST = *Asteraceae* (Compositae); ON = *Onagraceae*.

Pollen Diagram of Mendes

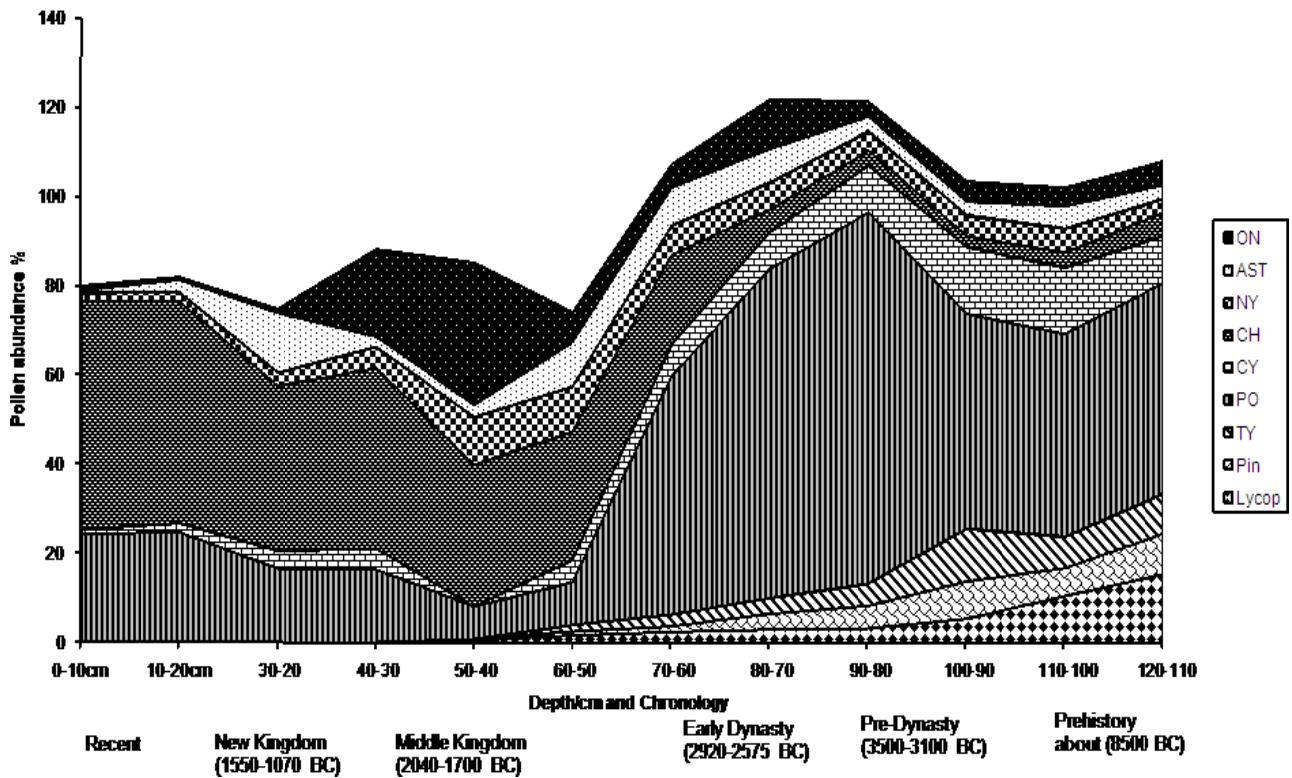


Fig. 5 Pollen diagram showing the relative abundance of pollen at Mendes profile.

plate 1.

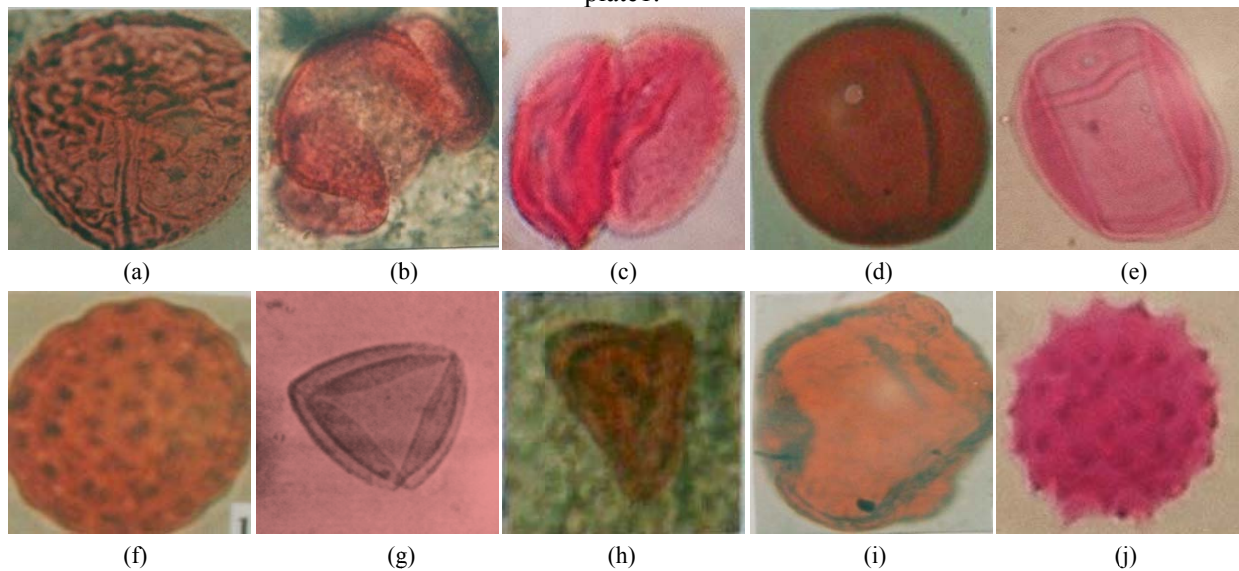


Fig. 6 Legends to plate 1. (a) *Lycopodium* spore 50 μm , (b) *Pinus* type 48 μm , (c) *Typha* pollen type 39 μm , (d) cereals type 74 μm , (e) wild grasses 43 μm , (f) *Cyperus* type 43 μm , (g) *Chenopodium* type 30 μm , (h) *Nymphaea* type 48 μm , (i) *Eclipta* type 30 μm (j) *Jussiaea* pollen type 80 μm .

Poaceae and *Cyperaceae* recorded abundances 5%, 7.4%, 74% and 8.2%, respectively, while, Nile water plants, *Nymphaeaceae* and *Onagraceae* recorded abundances 6% and 11.1%, but, swamp vegetation, *Typhaceae* 3.5% and *Pinus* type 3.6%.

- Period 5: Predynasty Period, about (3,500-3,100 BC)

Open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* recorded abundances 2.4%, 3%, 48.2% and 15% respectively, while *Lycopodium* spores 5.5%, *Pinus* type 8.5% and swamp vegetation, *Typha* type 10.5%.

- Period 6: Prehistoric period, about (8,500 BC):

Open vegetation, *Chenopodiaceae*, *Asteraceae*, *Poaceae* and *Cyperaceae* recorded abundances 5.2%, 3%, 48.5% and 11.6% respectively, while, Nile water plants, *Nymphaeaceae* and *Onagraceae* with abundances, 3% and 6.2%, but the swampy vegetation recorded, *Typhaceae* 9.8%, *Pinus* type 9.5%.

6. Discussion

Climate change is often invoked as a trigger for the collapse of civilizations. The fall of the Akkadian Empire and the end of the Egyptian Old Kingdom around 4,200 years BP have both been attributed to climatic change resulting in regional desiccation [1, 2, 3]. However, climatic and environmental stress played a major role in the emergence of early civilizations. Dating of archaeological sites, lake sediments and faunal remains indicates that wet conditions were established in the Sahara by around 10,000 BP after a long period of aridity associated with the last glacial period [9, 37, 11]. This humid phase was associated with intensification of the African Monsoon caused by increasing the Northern Hemisphere summer insolation [12-15]. It has been noted that the rise of dynastic civilization in Egypt coincided with the onset of widespread Saharan desiccation, and a number of authors have suggested that increased social complexity in the Nile Valley may have been precipitated by desertification in the eastern Sahara.

Adams and Cialowicz [30] state that the formation of the pharaonic state was the result of the expansion of the Naqada culture of Upper Egypt and was “encouraged by the pressure of a greater population in the south, where climatic change in the late Predynastic had reduced winter rainfall and husbandry in the deserts and brought about a reliance of agriculture in natural basins.” This view is supported by Wilkinson [31], who argues that populations that had previously practiced seasonal migration between the Nile Valley and the summer savannah in what is now Egypt’s Eastern Desert were forced to settle permanently in the Nile Valley as a result of the cessation of summer rainfall.

Soil analysis of the present study reflects decrease salinity with depth; this can be explained with continuous leaching of salts at two studied sites according to Abd El-Fattah et al. [32].

Palynological studies: one of the aims of pollen studies is the reconstruction of palaeoenvironmental changes. The relative abundance of certain pollen and spores reflects conditions in which they survive also their habitats. During Period 1 (recent period) local swampy vegetation dwindled and, at the end of the period, dry forest decreased to reach a minimum representation. This marked decrease in forest species, together with abundant open vegetation reflects a progressive decrease in humidity, strongly suggesting decrease in precipitation. *Chenopodiaceae* was recorded the highest abundances 51.2% at Period 1 recent layer at Mendes, while, Period 2 New Kingdom (about 1550-1070 BC) characterized with increase of open vegetation, also the Nile flooding is good. During Period 3 (Middle Kingdom, about 2040-1700 BC), the data of pollen abundances revealed that dominance of Nile water plants, e.g., *Nymphaea* and *Jussiaea* pollen types 10.7% and 31.8% at Mendes, the presence of these plants suggest Nile water and tributaries, also reflects Nile flooding at this period, (Patel et al, 1984 and El Ghazali, 1989) [33, 34]. *Asteraceae* and *Poaceae* reached the maximum

representation during Period 4 Early Dynasty about (2920-2575 BC) at Avaris, where 74% for *Poaceae* at the same period at Mendes and 26.1% for *Cyperaceae* at the same period at Avaris, *Cyperaceae* pollen reflects a significant degree in herbaceous vegetation on the valley floor, and therefore should be included in the pollen and sum is best supported, in this connection [35] which stated that *Cyperaceae* species were growing in wet or dry places, and it is salty or un-salty, while, during Predynastic Period 5 about (3100 BC) *Typha* pollen type was high (10.5 and 11.8), this high abundance may indicates reed swamps conditions at the two sites during this period [10], and the palynological assemblage indicates humid climatic conditions for this period, and an increase of precipitation, but during Prehistoric Period 6, *Lycopodium* spores (Fig. 6), recorded 10.4% and 15.5% at Avaris and Mendes, this may indicates a humid climate and habitats. On the other hand, *Pinus* type was recorded abundance 9.3% and 9.8% at the same depth and period of Avaris and Mendes. This high representation reflects higher precipitation, also suggests the down slope migration of the lower forest and we conclude that climatic conditions became moist to relatively wet, Schulz [36].

7. Conclusion

We can conclude that there is a succession of climatic changes leading to vegetation successions during the six studied periods, the ecosystems respond sensitively to changes in plant available moisture (precipitation) where the wet habitats and forest vegetation were dominant during Period 6 (Prehistory), followed by reed swamps during the Predynastic, Period 5 (about 3100 BC), and habitats changed to herbaceous vegetation during Period 4 (Early Dynasty about 2920-2575 BC), and Nile water flooding and dominance of Nile water plants during Period 3 (Middle Kingdom, about 2040-1700 BC), while dominance of open vegetation cover during Period 2 New Kingdom about (1550-1070 BC), then decrease

in humidity, and strongly suggesting decrease in precipitation. *Chenopodiaceae* was recorded the highest abundances 51.2% in Period 1 recent layer at Mendes indicating that habitat changed to halophytic vegetation, while changed to mesophytic habitats at Avaris in recent time. So, Palynology serves reconstruction of the past vegetation and climate changes.

References

- [1] Cullen, H. M., DeMenocal, P. B., Hemming, S., Hemming, G., Brown, F. H., Guilderson, T., and Sirocko, F. 2000. "Climate Change and the Collapse of the Akkadian Empire." *Geology* 28: 379-82.
- [2] Hassan, F. A. 1997. "Nile Floods and Political Disorder in Early Egypt." In *Third Millennium BC Climate Change and Old World Collapse*, edited by Dalfes, H. N., Kukla, G., and Weiss, H. Berlin Heidelberg: Springer-Verlag.
- [3] Weiss, H. 1997. "Late Third Millennium Abrupt Climate Change and Social Collapse in West Asia and Egypt." In *Third Millennium BC Climate Change and Old World Collapse*, edited by Dalfes, H. N., Kukla, G., and Weiss, H. Berlin Heidelberg: Springer-Verlag.
- [4] Jolly, D., Harrison, S. P., Damnati, B., and Bonnefille, R. 1998. "Simulated Climate and Biomes of Africa during the Late Quaternary: Comparison with Pollen and Lake Status Data." *Quaternary Science Reviews* 17: 629-57.
- [5] Kutzbach, J. E., and Liu, Z. 1997. "Response of the African Monsoon to Orbital Forcing and Ocean Feedbacks in the Middle Holocene." *Science* 278: 440-3.
- [6] Lezine, A-M. 1989. "Late Quaternary Vegetation and Climate of the Sahel." *Quaternary Research* 32: 317-34.
- [7] Lioubimsteva, E. U. 1995. "Landscape Changes in the Saharo-Arabian Area during the Last Glacial Cycle." *Journal of Arid Environments* 30: 1-17.
- [8] Maley, J. 1977. "Palaeoclimates of the Central Sahara during the Early Holocene." *Nature* 269: 573-7.
- [9] Goudie, A. 1992. *Environmental Change*, 3rd ed., Oxford: Oxford University Press.
- [10] Ritchie, J. C. 1985. *Modern Pollen Spectra from Dakhlah Oasis*. Western Egyptian Desert: Grana.
- [11] Roberts, N. 1998. *The Holocene: An Environmental History*, 2nd ed., Oxford: Blackwell Publishers Ltd..
- [12] Claussen, M., Kubatzki, C., Brovkin, V., Ganopolski, A., Hoelzmann, P., and Pachur, H. J. 1999. "Simulation of an Abrupt Change in Saharan Vegetation in the Mid-holocene." *Geophysical Research Letters* 26: 2037-40.
- [13] Claussen, M., Brovkin, V., Ganopolski, A., Kutzbaki, C.,

**Climate Change in the Nile Delta from Prehistoric to the Modern Era and their Impact
on Soil and Vegetation in Some Archaeological Sites**

- and Petoukhov, V. 2003. "Climate Change in Northern Africa: The Past Is not the Future." *Climatic Change* 57: 99-118.
- [14] Ganopolski, A., Kutzbaki, C., Claussen, M., Brovkin, V., and Petoukhov, V. 1998. "The Influence of Vegetation-Atmosphere-Ocean Interaction on Climate during the Mid-Holocene." *Science* 280: 1916-9.
- [15] Tuentner, E., Weber, S. L., Hilgen, F. J., and Lourens, L. J. 2003. "The Response of the African Summer Monsoon to Remote and Local Forcing Due to Precession and Obliquity." *Global and Planetary Change* 36: 219-35.
- [16] Alley, R. B., Mayewski, P. A., Sowers, T., Stuiver, M., Taylor, K. C., and Clark, P. U. 1997. "Holocene Climatic Instability: A Prominent, Widespread Event 8,200 Years Ago." *Geology* 25: 483-6.
- [17] Bond, G., Showers, W., Cheseby, M., Lotti, R., Almasi, P., deMenocal, P., Priore, P., Cullen, H., Hajdas, I., and Bonani, G. 1997. "A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Cycles." *Science* 278: 1257-66.
- [18] Cremaschi, M., Pelfini, M., Arzuffi, L., Di Mauro, V., Santilli, M., and Zerboni, A. 2001. "A Palaeoclimatic Record for the Late Holocene in the Central Sahara: Tree Rings of *Cyperus Dupretiana* from the Wadi Tanezzuft Area SW Fezzan, Libya." In *Abstracts of the International Conference "Tree Rings and People"*,
- [19] Di Lernia, S., and Palombini, A. 2002. "Desertification, Sustainability, and Archaeology: Indications from the Past for an African Future." *Origini* XXIV: 303-34.
- [20] Goodfriend, G. A. 1991. "Holocene in Land Snail Shells from the Negev Desert and Their Implications for Changes in Rainfall Source Areas." *Quaternary Research* 35: 417-26.
- [21] Guo, Z., Petit-Maire, N., and Kröpelin, S. 2000. "Holocene Non-orbital Climatic Events in Present-Day Arid Areas of Northern Africa and China." *Global and Planetary Change* 26: 97-103.
- [22] Malville, J. M., Wendorf, F., Mazar, A. A., and Schild, R. 1998. "Megaliths and Neolithic Astronomy in Southern Egypt." *Nature* 392: 488-91.
- [23] Shaltout, M. A. M., 2006. "Solar Activity and the Nile Flooding in Egypt from Pre-history to 20th Century" *Journal of History of Geophysics and Cosmical Physics* VII (1): 181-94.
- [24] Bietak, M. 1996. *Avaris. The Capital of Hyksos. Recent Excavations at Tell El Dabaa*. London: British Museum Press.
- [25] Donald, B. Redford, 2001. "Mendes." In *The Oxford Encyclopedia of Ancient Egypt*, edited by Redford, D. Cairo: Oxford University Press and the American University in Cairo Press.
- [26] Faegri, K., and Iversen, J. 1989. *Text Book of Pollen Analysis*. Chichester: John Wiley.
- [27] Moore, P. D., Webb, J. A., and Collinson, M. E. 1991. *Pollen Analysis*. Oxford: Blackwell Science Publications.
- [28] Andrew, R. 1984. "Practical Pollen Guide to the British Flora". *Quaternary Research Association Technical Guide* 1. Bassett, I. J., C. W. Crompton, 139.
- [29] Bennett, K. D., Whittington, G., and Edwards, K. J. 1994. "Plant Nomenclatural Changes and Pollen Morphology in the British Isles." *Quaternary Newsletter* 73: 1-6.
- [30] Adams, B., and Cialowicz, K. M. 1997. "Protodynastic Egypt, Shire Publications Ltd.," Buckinghamshire, UK.
- [31] Wilkinson, T. 2003. *Genesis of the Pharaohs*, Thames and Hudson Ltd., London.
- [32] Abd El- Fattah, R. I., Baraka, D. M., and El-Hady, A. F. 1993. *Anions and Cations Accumulation in Some Plants from South Sini under Different Habitat* Egypt: Desert Inst. Bull." (in Press).
- [33] Patel, V. C., Skvarla, J. J., and Raven, P. H., 1984. "Pollen Characters in to the Delimitation of Myrtales." *Ann. Mo. Bot. Gard.* 71: 858-965.
- [34] El Ghazali, G. 1989. "A Study on the Pollen Flora of Sudan." Ph.D. thesis, Univ. Bergen. Botanical Institute.
- [35] Ayyad, S. M., 1988. "Pollen Grain Ecology of the Mediterranean Sea Coast Egypt." Ph.D. thesis, Mansura University, Egypt.
- [36] Schulz, E. 1974. "Pollen Analytische Untersuchungen Quarter Sediment." *Pressdienst Wissenschaft* 5: 59-69.