OUTLOOK 2015
10
WORLD ASSOCIATION FOR SUSTAINABLE DEVELOPMENT

PALEOECOLOGICAL STUDIES OF AN ARCHEOLOGICAL SITE IN SUDAN (MUSAWARAT ELSUFRA) EVIDENCE OF CLIMATIC CHANGE

AMEL HASSAN ABDALLAH*
AND
DAAFALLAH ALI IBRAHIM
Khartoum University, Sudan

Botany Department,
Faculty of Science,
University of Khartoum,
P.O. Box 321, Sudan
E-mail: amel762003@yahoo.com

ABSTRACT

Purpose: In this study we try to measure the environmental changes that took place in the study area Musawarat Elsufra. We try to find the causes of these changes and establish a comparison of the present and past vegetation of the area.

Methodology: Present vegetation was investigated using fresh plant materials for pollen analysis. Fossils were taken from the 'hafir' (basin) to study the fossil pollen grains at different soil depths. Soil surface samples were taken to analyse the chemical and physical properties of the soil.

Findings: The pollen analysis of the samples taken from the *hafir* (basin) of Musawarat reveals that there are 21 species belonging to 16 families. The dominant families were Cyperaceae, Commelinaceae, Mimosaceae and Amaranthaceae.

Value: Comparison of past and present vegetation maintains the causes of environmental change and ensures sustainable development in arid regions.

Keywords: paleoecology; climatic change; fossils pollen analysis.

*Corresponding author

INTRODUCTION AND LITERATURE REVIEW

Current fears concerning global climatic change are particularly focused on semi-arid zones, where increased aridity could have serious consequences. The study of past vegetation changes associated with climatic changes is, therefore, of importance and the technique of pollen analysis is proving valuable as a tool in this type of research. The Eastern Sahara has been the focus of various geological, paleontological, palaeoecolgical and archaeological research for more than 40 years (Nicoll, 2004). The primary palaeoenvironmental changes in Egypt and Northern Sudan have been inferred from various proxy records and cultural sites.

Covering lines of evidence from various geoarchaeological and interdisciplinary investigations conducted in Egypt and Northern Sudan suggests that significant environmental changes have influenced human activities throughout antiquity (Nicoll, 2004). In Northern Sudan it was aimed at discovering pluvial periods in the hyper-arid regions during the Holocene (Haynes et al., 1989; Mehringer, 1982; Ritchie, 1987; Ritchie and Haynes, 1987; Ritchie et al., 1985).

ECOLOGICAL AND CLIMATIC CONDITIONS IN MUSAWARAT

The Great Civilizations in the past are the best evidence for the effect of the environment on these civilizations, which appear in the warmest and cool places such as the Nile valley and between rivers, around the Mediterranean Sea and the civilizations of India and China. In all these places water was considered as an important factor that affected where people settled and constructed civilizations. The Great Meroetic Civilization was like Sudan's current climatic zones: the northern part is ecologically different from that of the south. There is clear evidence of this from the studies and conclusions of Meroe's kings during that period, and from the (Graffiti) of animals in the temple walls. This is in addition to fossils of fauna and flora distributed around ancient Meroe that reflect the climate. There were also foreign travellers who visited the area in the 18th and 19th century. All this evidence can be used to compare past and present climatic changes in the past 2000 years to the present day.

ECOLOGICAL AND CLIMATIC CONDITIONS BEFORE MEROE

Emery (1964) reported that all evidence indicates that people lived between the first waterfall and the second are livestock owner. Which insure that the campaign of King Sinefro around (2580–2613 years B.P.) who gained 2000 head of livestock. Trigger (1970) demonstrated that gifts for the King on any visit included ivory, Abanos wood and tiger skins, which are not found today. There is just graffiti on the Temple wall from around 2231–2272 years B.P.; in the Ibrim Palace further gifts appear in graffiti that include cows, tigers, dogs and monkeys, dating from 1436 to 1490 years B.P. In addition to that, Bit Alwally Temple refers to the period between 1224 and 1289 years B.P. where the same pictures appear. This shows that climatic conditions were totally different from today and the tiger has been hunted from its natural habitat not far from Egypt.

Mawson and Williams (1984) found some molluscs at the Hafir basin in Eastern Sudan: Carbon Fourteen (C14), for these snails indicated that they dated back to 1900–1700 years B.P.

CLIMATIC CONDITION DURING THE MERWATIC PERIOD

The Northern part of Meroe is drier than the south. Taharga (664–690 years B.P.) mentioned that Kawa Temple was destroyed and the site covered with sand. There was a climatic change and drought at that time, fluctuating with heavy rain and floods (Macadam, 1949). The Southern part of Meroe is more humid; that is why the capital transferred from Nabta to Meroe. This is clear from the seed fossils of *Celtis integrfolia*, which normally grows in an area with an annual rainfall of 400 mm (Williams and Clark, 1972). The presence of a large Hafir basin indicates that there has been heavy rain in the past, also the vegetation cover was denser and dominated by a lot of trees and long herbs. This made the iron industry the main job of the Meroe people (Shinnie, 1976). This area is similar to the Savannah region today.

CLIMATIC CONDITION DURING THE 18TH AND 19TH CENTURY

The travellers saw a lot of trees and long herbs near Shendi, and they heard lions roaring; they were advised to take care because lions were in the area.

CLIMATIC CONDITIONS TODAY

There is a climatic shift from Savannah to semi-desert conditions. The climate in the past was humid enough to allow the presence of these great civilizations, not like today's large fluctuations in rainfall.

These studies were concentrated in Selima Oasis, Etrun Oasis and Oyo depression, between latitudes 18° and 22°. The studies suggest that Savannah and grassland occupied regions that today are hyper-arid regions, in a major pluvial episode between 9500 and 4500 years B.P. Wickens (1975), in his prehistoric study on the climatic and vegetational changes in Sudan 20,000 years B.P., showed that the orientation of the sand dunes indicates that, during the dry period 20,000–15,000 years B.P., the isohyets were 450 km to the south of their present position; during the wet period 6000–3000 years B.P. they were 250 km to the north. Also from the biological evidence he showed that there was a northward shift of 400 km during the very wet period 12,000–7000 years B.P.

Ritchie et al. (1985) found that the sediment from the Oyo sites belong to the following phytogeographical groupings:

1. Sudano-Sahelian taxa found today in the tropical Savannah of north-central Sudan and adjacent territories of Africa.
2. Sahelo-Suharan taxa with modern distribution in the thorn scrub and herbaceous desert belt of North Africa.
3. Saharan taxa today confined to the Sahara and adjacent Arabian desert.
4. Tibesti-Montane elements, so designated because the nearest pollen source is the Tibesti Massif.
5. Mediterranean taxa.
6. A group of taxa of uncertain geographical affinity.

Their results provide the first conclusive demonstration of vegetation and climate change in the early to mid-Holocene of the Eastern Sahara.

These findings agree with Maley's (1977, 1981) tentative conclusions for the distant Lake Chad record, with the general Holocene lake level trends for north-east Africa and with changes in the position of the African monsoon predicted on the basis of Milankovitch orbital forcing factors.

Most of these studies include the analysis of pollen stratified in alluvial and other sediments, pollen associated with archaeological sites, and studies of the relationship between current vegetation and pollen rain; these provide a key for the interpretation of fossil pollen assemblages. Our main objective here is to compare the past and present vegetation of the study area, Musawarat ElSufra, and to investigate the causes of climatic change being climatic or otherwise. This is to establish if the causes are due to natural (climatic) or anthropogenic (man-made) reasons. This work was *9-concentrated on an archaeological site in the semi-arid zones in Northern Sudan.

METHODOLOGY

Fresh materials treatment

Flowers of the plant species of the area were used to prepare pollen grain slides. These are considered as reference slides to be used in identifying the fossil pollen grains. The methods used for preparing these slides are those described by Faegri et al. (1989). The flower taken from the field was chemically treated with KOH and the acetoloysis mixture.

Fossil pollen analysis

The hafir of Musawarat El Sufra is considered as an open section, and samples were collected at points along the walls of this section from two different directions in the hafir (north and south), at depths of 50, 100, 150, 200, 250 and 550 cm from the top, so as to reconstruct past vegetation. The area covered in this study is located east of the Sufra wadi and 65 km from ancient Merwe Town, at a latitude 16° 22` North and longitude 33° 22` East. Muswarat Elsufra (Great Enclosure) is located some 15 km east of Nagaa and 30 km from the Nile. It is one of the sites of the great Meroitic civilization, which refers to the 4th century before present.

RESULTS

Fossils pollen analysed from the basin's (*hafir's*) soil showed different types of pollen flora, which include 22 species belonging to 14 families. The most dominant families were Commelinaceae, Cyperaceae and Mimosaceae. Pollen grain identification was carried out according to El Ghazali (1989) and Bonnefille and Riollet (1980). The identification of species to which a pollen grain belongs was carried out using the available relevant African floras. Special attention was paid to scientific publications of Sudan and the neighbouring countries, and the distribution was carried out according to Andrews (1950, 1952, 1956). The results are shown in Table 1.

Plate 1 Present Vegetation Pollen analysis: Aizoaceae Capparidaceae

(a) *Zaleya pentandra × 5000*

(b) *Zaleya pentandra × 5000*

(c) *Cadaba farinosa × 5000*

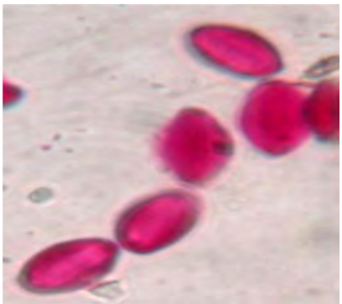
Table 1 Fossil pollen grains found in the *Hafir* of Musawarat Elsufra and present vegetation

No	*Past vegetation species*	*Family*	*Life form*	*Distribution in Sudan*	No	*Depth*	*Present vegetation*
1	*Justicia odora* (Forsk) Lam.	Acanthaceae	Under shrub	Red Sea Hills	1	100	*Acacia tortilis subsp. tortilis* (Hochest)
2	*Blepharis linariifolia* Pers	Acanthaceae	Under shrub	Central Sudan	2	100	*Cadaba farinosa*. Forsk
3	*Sansevieria ehrebergiis* Sch-weinf.ex Bak	Agavaceae	Under shrub	Red Sea district, Wadi Ossair South of Suakin	6	NA	*Panicum turgidum*. Forsk
4	*Celosia polystachia* (Forsk)	Amaranthaceae	Herb	Widespread	4	100, 250	*Cynodon dactylon*.L. (pers.)
5	*Achyranthus aspera* L	Amaranthaceae	Herb	Widespread	1	100	*Fagonia cretica*. Sensu ASchweiber
6	*Commelina benghalensis* L	Commelinaceae	Herb	Red Sea District, Central and Southern Sudan	1	NA	*Tribulus teresteris*. L.
7	*Commelina africana* L.	Commelinaceae	Herb	Red Sea Hills, Erkawit. Southern Sudan	11	NA	*Capparis deciduas*. Forsk
8	*Cyperus articulatus* L.	Cpperaceae	Herb	Blue Nile Province. Southern Sudan	6	100	*Boerhavia repens*. L.
9	*Cyperus rupicundus* L	Cyperaceae	Herb	Widespread, River bank	1	NA	*Citrullus colocynthis*. Schrad
10	*Cyperus laevigatus* L	Cyperaceae	Herb	Red Sea District, Darfur, Jubel Marra. Equatoria	1	NA	*Euphporbia aegyptiaca*. Boiss
11	*Delonix elata* (L.) Gamble	Caesalpinaceae	Tree	Red Sea Hills	1	NA	*Zaleya pentandra*. (L.) Jeffer
12	*Asparagus abyssincaus* Hochst ex A Rich	Liliaceae	Shrub	Central and Southern Sudan	10	NA	*Indogifera hochstettri*.Bak
13	*Acacia senegal* (L.)	Mimosaceae	Tree	Central Sudan	1	100	*Setaria vertisilata*. L. (Beav.)
14	*Mimosa pigra* L	Mimosaceae	Shrub	Swamps and river banks	19	NA	*Corchorus tridens*.L.
15	*Pakia bicolar* A.Chev	Mimosaceae	Tree	Equatoria	1	100	*Corchorus depressus*. (L.) Christens
16	*Commicarpus africanus* (Lour) Dandy, comb. nov	Nyctaginaceae	Herb	Northern and Central Sudan	8	200	*Aristida adscensionis* L.
17	*Vossia cuspidata* (Roxb.) W.Griff	Poaceae	Herb	Central and Southern Sudan	8	100	*Oldenlandia herbacea*. (L.) Roxb
18	*Phragmites australis* (Cav.) Trin. Steud.	Poaceae	Grass	Fung.prov. North white Nile prov. Bah-relGazal prov. Bahr eljubel	2	200	*Maerua crassifolia*. Forsk
19	*Phoenix dactylifera* L.	Palmae	Tree	Northern Sudan, cultivated	4	100	*Sorghum purpureoseiceum*.(Hochst)
20	*Protea gaguedi* J.F Gmel	Protaceae	Shrub or tree	Central and Southern Sudan	1	100	*Balanites aegyptiaca*. (Del.)
21	*Grewia bicolar* Juss.	Tiliaceae	Shrub or Tree	Central Sudan	6	100	*Pallenis Cyrenaica*
22	*Cassia* sp.	Fabaceae	Herb	Widespread	1	100	*Zephyranthus* sp.
							Boerhavia erecta.L.

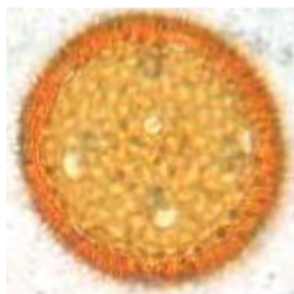
(d) *Capparis decidua* × 5000 **(e)** *Capparis decidua* × 5000 **(f)** *Capparis decidua* × 5000

Cucurbitaceae Euphorbiaceae

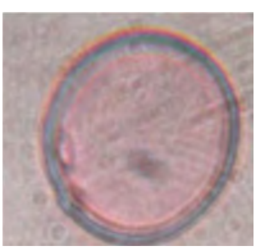
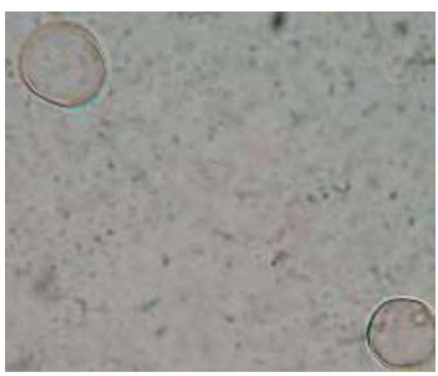
(g) *Maerua crassifolia* × 2000 **(h)** *Citrullus colocynthis* × 3000 **(i)** *Euphorbia aegyptiaca* × 5000

Mimosaceae Nyctaginaceae

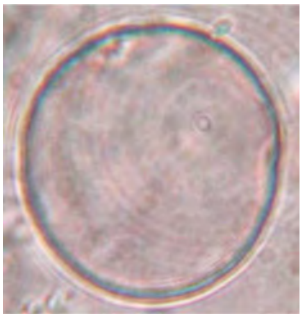
 

(j) *Acacia tortilis subsp.tortilis* × 3000 **(k)** *Borehavia repens* × 3000

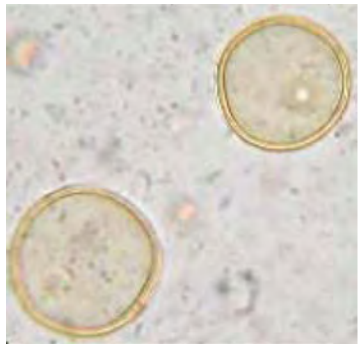
Poaceae

(l) *Setaria vertisilata* × 2000 **(m)** *Cynodon dactylon* × 3000 **(n)** *Pannicum turgidum* × 3000

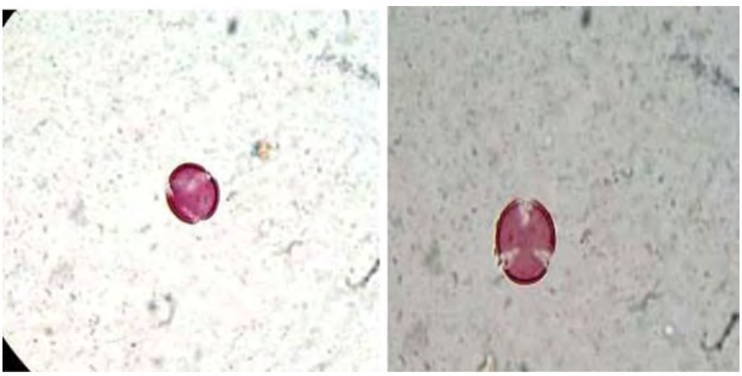


(o) *Sorghum purpueosericeum* × 2000



(p) *Aristida adscensionis* × 3000

Rubiaceae



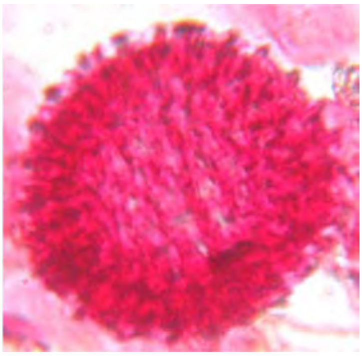
(q) *Oldenlandia herbacea* × 2000

Tiliaceae

(r) *Corchorus depresus* × 5000

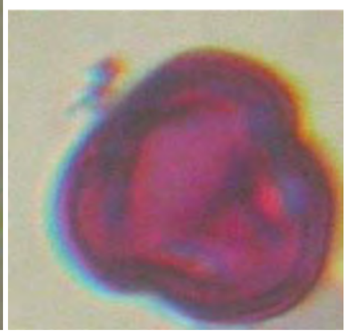
(s) *Corchorus triedens* × 2000

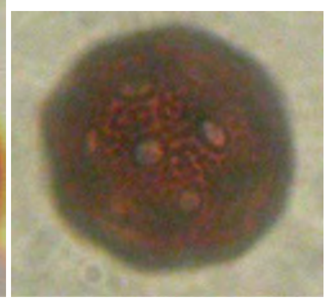
Zygophyllaceae



(t) *Fagonia cretica × 2000* **(u)** *Tribulus terestris × 3000*

Amaryllidaceae Balanitaceae: Nyctaginaceae





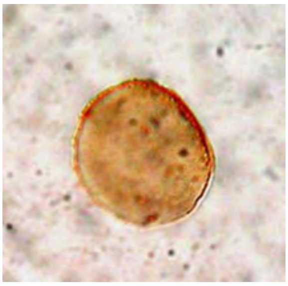
Zephyranthes grandiflora Balanites aegyptiaca Del Boerhavia erecta

Plate 2 Fossil Pollen grains

Acanthaceae

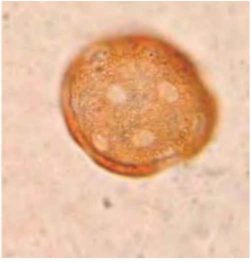
(a) *Justicia odora × 3000* **(b)** *Belpharis linarifolia × 1000*

Agavaceae Amaranthaceae



(**c**) *Sansevieria ehrenbergii* × 1000

(**e**) *Achyranthus aspera* × 1000



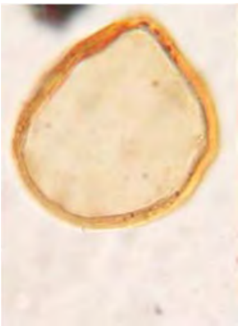
(**d**) *Celosia polystachia* × 2000

Commelinaceae

(**f**) *Commelina bengalensis* **Commelinaceae** 2000 (**g**) *Commelina Africana* × 1000

Cyperaceae

(**h**) *Cyperus articulatus* × 3000



(**i**) *Cyperus rubicundus* × 2000

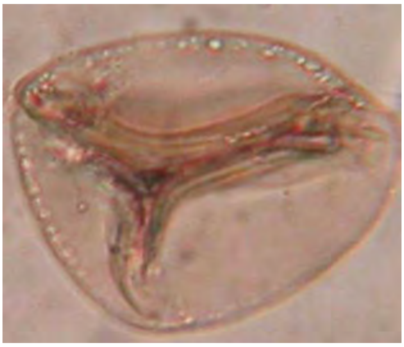
(**j**) *Cyperus laevigatus* × 1000

Caesalpinaceae Liliaceae

(**k**) *Delonix elata* × 3000

(**l**) *Asparugus aethiopicus* × 2000

Fabaceae

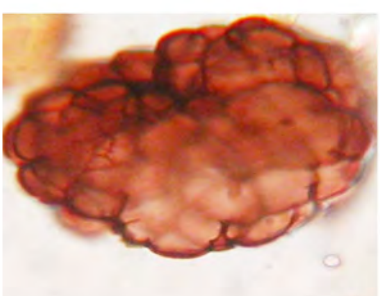
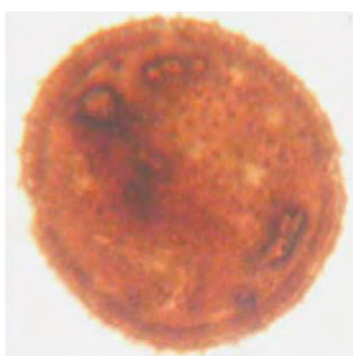


Cassia sp. × 2000 × 2000 × 2000

Mimosaceae

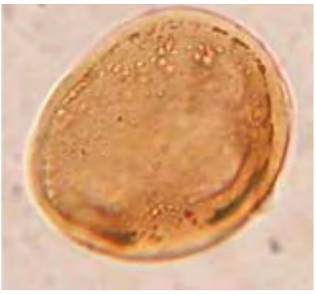

(m) *Acacia senegal* × 2000 **(n)** *Mimosa pigra* × 2000

Mimosaceae Nyctaginacceae

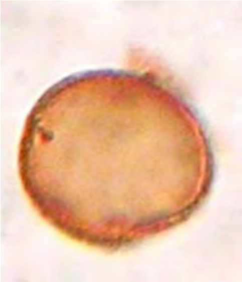



(o) *Parkia bicolor* × 2000 **(p)** *Commicarpus africanus* × 2000

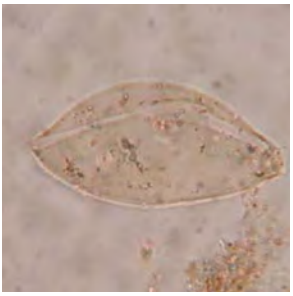
Poaceae Palmae



(q) *Vossia cuspidata* × 3000



(r) *Phragmites ausralis* × 3000



(s) *Phoenix dactylon* × 1000

Proteaceae Tiliaceae

(t) *Protea gauguidia* × 2000

(u) *Grewia bicolar* × 10

Plate 3 Different Types of Diatoms

Frustulia rhomboids *(Her.) De Toni Rhopalodia gibba (Ehr.)O.Muller (Valve view).*

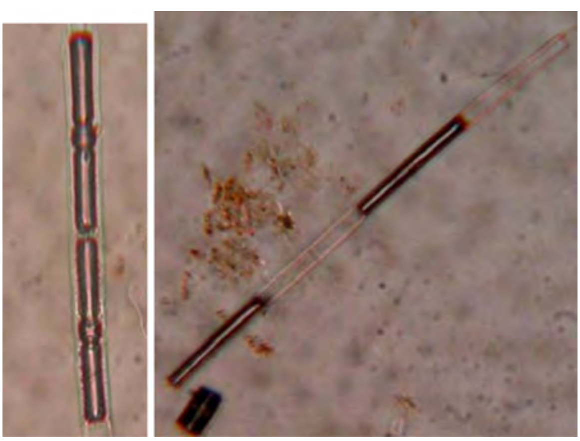
Diplonis elliptica kutz(Cleve)

Caloneis silicula (Her.) Cleve. Cymbella laneolata (Her.) Brun. Rhopalodia gibba (Ehr.)

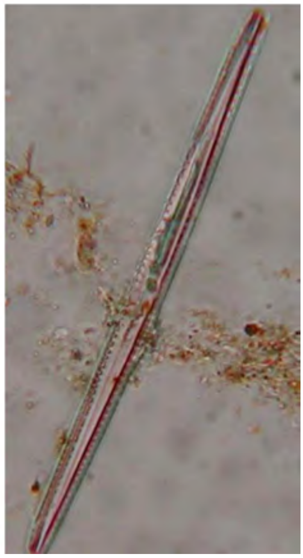
O.Muller (girdle view)

Navicula rhyncocephala Kutz. Pleurosigma delicatulum W.Smith

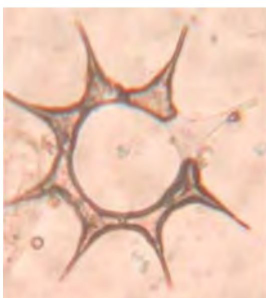
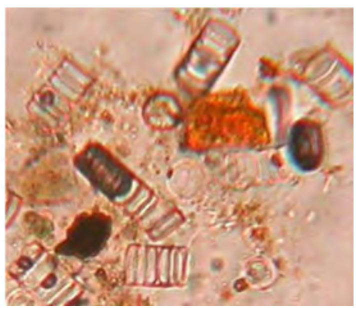
Continue (Plate 3)



Melosira sp. Melosira sp.

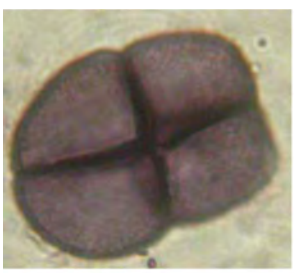
Brebissonia boeckii (Her.)Grun Amphipleura pellucida Kutz.

Pediastrum sp. Green algae Melosira sp

Plate 4 Confirmation to some fossil Pollen grains

Mimosaceae Acanthaceae

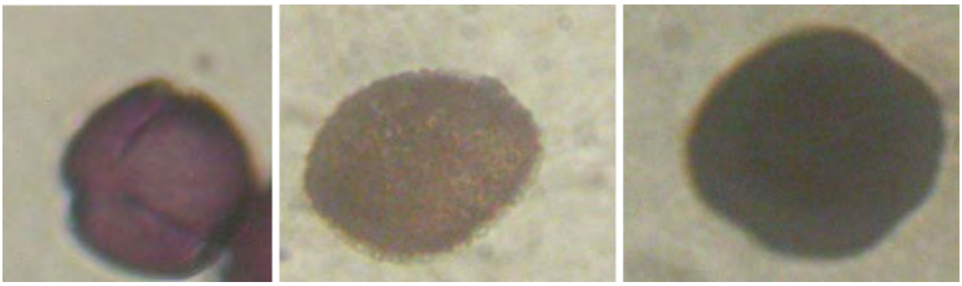



Mimosa pigra Blepharis linariifolia Pers

Cyperaceae

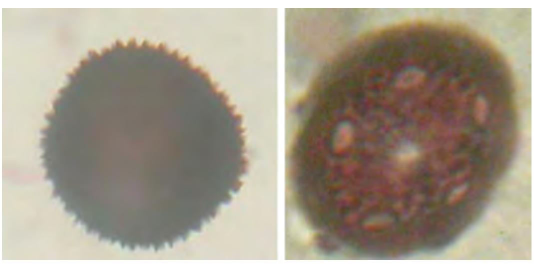
Cyperus articulatus Cyperus sp. Cyperus rubicundus

Fabaceae Commelinaceae



Cassia sp. Commelina africana L.

Celosia



DISCUSSION AND CONCLUSIONS

Past vegetation was examined by analysing fossil pollen grain found in the samples taken from Hafir of Musawarat Elsufra.

A 22 types of plant species were recorded in the slide examined. These were described and fully identified and it was noticed that the number of plant species was low in the past vegetation. This is in line with Ritchie et al. (1985) who reported that a major problem in the study of Holocene Palaeoenvironments of the arid and wind-deflated Sahara was the low preservation potential of sediments from which a record of past climatic change can be established.

From the plant records it is clear that the presence of plant pollen such as *Commelina bengalensis* and *Cyperus* sp. indicates that there is a lot of water in the area. Andrews (1950, 1952, 1956) described the natural habitat of these families in central and Southern Sudan, an indication of the wet climate required by these species.

The presence of *Phragmites Australis* in the flora from the *Hafir* of Musawarat Elsufra indicates that the rainfall of the area was more than enough to allow for its growth: the plants grows best in marshes and swamps along streams, lakes, ponds or ditches where the water level fluctuates from 15 cm below the soil's surface to 15 cm above.

At the family level, the Mimosaceae is a large and well represented family throughout Africa when identified to species level (e.g. *Parkia bicolar* and *Mimosa pigra*). As for *Parkia bicolar*, Andrews (1952) identified this plant as a forest tree adapted to the environmental variables. *Mimosa pigra* is distributed in the swamps and on riverbanks. This also indicates that the area was once a humid area. As Andrews and Bamford (2007), who studied the Loetoli, Tanzania, reported, higher rainfall increases the diversity, height and density of plants species while reduced rainfall would lead to decreasing species richness and greater domination by *Acacia* species. This seems to contradict the above mentioned low number of plant species. The reason is probably due to the fact that most plants are zoophilous plants that leave no pollen in the deposits (Faegri et al., 1989).

It was concluded that the occurrence of different types of diatoms support our suggestion that the habitat in the past was not like the present.

The past vegetation of the area contained some species that are not found today, and that their natural environment was like that of central and Southern Sudan rather than the study area in the north. Moreover, the dominance of Cyperaceae and commelinaceae in the past shows that the climate was wet enough in this area to allow for the presence of these plants. This was made clearer by the presence of diatoms.

This study showed that there was a climatic shift from Savannah to semi-desert conditions in this area.

REFERENCES

Andrews, F.W. (1950, 1952, 1956) *The Flowering Plants of the (Anglo-Egyptian) Sudan*, Vols. 1–3, Arbroath, Scotland: T. Buncle and Co. Ltd.

Andrews, P. and Bamford, M. (2007) 'Past and present vegetation ecology of Laetoli, Tanzania', *Journal of Human Evolution*, pp.1–21.

Bonnefille, R. and Riollet, G. (1980) *Pollen des Savane'afrique,Center National dela Recherche Scientifique*, Paris, SBN2-222.024978-Edition du CNRS.

El Ghazali, G.E.B. (1989) *Study on the Pollen Flora of Sudan with Special References to Pollen Identification*, Unpublished PhD Thesis, Botanical Institute, University of Bergen.

Emery, W.B. (1964) *Egypt in Nubia*, London: Hutchinson, pp.136–139.

Faegri, K., Kaland, P.E. and Krzywinski, K. (1989) *Textbook of pollen Analysis*, London: Wiley, J. and Sons. Alden Press, p.328.

Haynes, C.V., Eyles, C.H., Pavlish, L.A., Richie, J.C. and Ryback, H. (1989) 'Holocene palaeoecology of Eastern Sahara, Selima Oasis', *Quaternary Science Review*, Vol. 8, pp.109–136.

Macadam, M.F.L.I. (1949) *The Temple of Kawa*, Vol. 1, Inscr Oxford University Press London, No. IV, p.14.

Maley, J. (1977) 'Palaeoclimates of Central Sahara during the early Holocene', *Nature*, Vol. 269, pp.573–578.

Maley, J. (1981) *Etudes palynoloiques dans le bassin du Tchad et paleoclimatologie de l'Afrique nord-tropicale de 30 000 ans a l époque actuelle*, Travaux et Documents de L ORSTOM 129 Paris.

Mawson, R. and Williams, M.A.J. (1984) 'A wetter climate in eastern Sudan 2000 years Age', *Nature*, Vol. 308, London, p.51.

Mehringer, P.J. (1982) 'Early Holocene climate and vegetation in the eastern Sahara; the evidence from Selima Oasis Sudan', *Geological Society of America, Abstracts with Programs*, Vol. 14, p.564.

Nicoll, K. (2004) 'Recent environmental change and prehistoric human activity in Egypt and Northern Sudan', *Quaternary Science Reviews*, Vol. 23, pp.561–580.

Ritchie, J.C. (1987) 'A Holocene pollen record from Bir Atrun Northwest Sudan', *Pollen and Spores*, Vol. 29, pp.391–410.

Ritchie, J.C. and Haynes, C.V. (1987) 'Holocene zonation vegetation in Eastern Sahara', *Nature*, Vol. 330, pp.645–647.

Ritchie, J.C., Eyles, C.H. and Haynes, C.V. (1985) 'Sediment and pollen evidence for an early to mid-Holocene humid period in the eastern Sahara', *Nature*, Vol. 5, pp.314–352.

Shinnie, P.L. (1976) *Meroe, A Civilization of the Sudan*, London: Thumes and Hudson, pp.33–34.

Trigger, B. (1970) 'Nubian Nergo Black Nilotic', *African Antiquity*, Vol. 1, Brooklyn Museum, Fig 12, p.31.

Wickens, G.E. (1975) 'Changes in the climate and vegetation of the Sudan since 20,000 B.P.', *Boissiera*, Vol. 24, pp.43–95.

Williams, M.A.S. and Clark, J.D. (1972) 'Prehistory and quaternary environment in central Sudan', *Paleoecology of Africa*, Vol. 9, 1972–1974, pp.52–53.

BIOGRAPHICAL NOTES

Amel Hassan Abdallah is a Lecturer at the University of Khartoum, Faculty of Sciences, Department of Botany, Sudanese. She has published a number of papers. She is a Member of the Sudanese Natural Heritage Society and a Member of Young Women's Conservation Biologist (YWCB) in Africa. She won the Minister of Higher Education Prize for academic excellence awarded by the Sudan Natural Science Institute in 2001, and won the El Zubair Prize for scientific innovation and excellence awarded by the Association of the Promotion of Scientific Innovation in 2007. Her main interests are plant ecology and environmental microbiology.

Dafaalla Ali Ibrahim is Associate Professor, University of Khartoum, Faculty of Sciences, Department of Botany, Sudanese. He received candidatus scientarium from the University of Bergen, Norway. He was a general director of Taaseel directorate, Ministry of Higher Education and Scientific Research 2001–2009. He is a Co-author of the Integrated Dictionary of Biological Terms. His main interests are plant ecology and conservation biology.