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Paleoecological studies of an archeological site in Sudan (Musawarat ElSufra)

Evidence of climatic change

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Abstract

Purpose – The purpose of this paper is to measure the environmental changes, which took place in the study area Musawarat ElSufra and the authors try to find the causes of these changes and establish a comparison of the present and past vegetation of the area.

Design/methodology/approach – 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 analyze 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.

Originality/value – Comparison of past and present vegetation reveal the causes of environmental change and insure sustainable development in arid region.

Keywords Climate change, Paleoecology, Fossils pollen analysis

Paper type Research paper

Introduction and literature review

Current fears concerning global climatic change are particularly focussed on the semi-arid zone, 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, paleoecological and archeological research for more than 40 years (Nicoll, 2004). The primary paleoenvironmental changes in Egypt and northern Sudan have been inferred from various proxy records and cultural sites.

Covering lines of evidence from various geoarcheological and interdisciplinary investigations conducted in Egypt and northern Sudan suggest that significant environmental changes have influenced human activities throughout antiquity (Nicoll, 2004). In the northern Sudan it was aimed at discovering pluvial periods in the

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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 is the best evidence for the effect of environment on theses civilization which appear in the warmest and cool places such as Nile valley and between rivers, around the Mediterranean sea and India and China civilizations. In all of these places, water is considered as an important factor affecting people, settlement and civilization constructions. Climatic zones in Great Meroitic civilization is like Sudan today climatic zones, the northern part is ecologically different from that at the south. Most evidence is clear from the studies and conclusion of Meroe's kings at that period and from the (Graffiti) of animals in the temple walls in addition to fossils of fauna and flora distributed around ancient Meroe which reflect the climate beside the foreign travelers who visited the area in the eighteenth and nineteenth century to compare past and present climatic changes in the past 2,000 years and till today.

Ecological and climatic conditions before Meroe

Emery (1964) reported that all witnesses indicate that people who live between the first waterfall and the second are livestock owners. This ensured that the campaign of Sinefro king around 2580-2613 BP gained 2,000 head of livestock. Trigger (1970) demonstrated that Kings used to bring ivory, abanos wood and cows monkeys tigers and tiger skins from their trips in the south and also their labour used to bring to them some gift from the south to north Sudan and Egypt. In addition to that Bit Alwally Temple refer to (1224-1289) the same pictures which referred that climatic conditions totally differed from today and it is natural habitat not far from Egypt and it has been hunted from the same area and send a life.

Mawson and Williams (1984) found some Mollusks at *Hafir* basin in eastern Sudan and carbon 14 (C14) for the snails indicated that it dated back to (1900-1700) before present.

Climatic condition during Merwatic period

Northern parts of Meroe are drier than the south. Taharga (664-690 BP) mentioned that Kawa temple was destroyed and sand closed its gate. There was a climatic change and drought at that time and there was fluctuated heavy rain and flood (Macadam, 1949). The southern parts of Meroe are more humid, that is why the capital transferred from Nabta to Meroe. This is clearer from the seed fossils of *Celtis integrfolia* which normally grow in an area covered with annual rainfall of 400 mm (Williams and Clarks, 1972). The presence of large Hafeir basin indicates that there was heavy rain in the past and the vegetation cover was more dense dominated by a lot of trees and long herbs, something which made the iron industry the main job of Meroe people (Shinnie, 1976). This area is similar to the Savanna region today.

Climatic condition during eighteenth and nineteenth century

The travelers saw a lot of trees and long herbs near Shendi and they heard lion voices and were advised to take care from lions in the area.

Climatic conditions at present

There is a climatic shift from Savanna to semi desert condition and the climate in the past was humid enough to allow the presence of these great civilizations and not like today's fluctuation in rainfall.

These studies were concentrated in Selima Oasis, Etrun Oasis and Oyo depression, between latitudes 18° and 22°. The studies suggest that savanna and grassland, occupied regions that today are hyper-arid regions, in a major pluvial episode between 9500 and 4500 BP. Wickens (1975) in his prehistoric study on the climatic and vegetational changes in Sudan 20000 years BP, showed that the orientation of the sand dunes indicates that, at the dry period 20000-15000 years BP the isohyets were 450 km to the south of their present position; at the wet period 6000-3000 years BP they were 250 km to the north. Also from the biological evidences he showed that there were northward shift of 400 km in the very wet period 12000-7000 years BP.

Ritchie *et al.* (1985) studied oyo sites and found that the pollen fossils belonging to vegetational zones from the mid Holocne and provide the first conclusive demonstration of vegetation and climate change in the early- to mid-Holocene of the eastern Sahara.

They agree with tentative conclusion of Maley (1977, 1981) 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 archeological sites, and also studies of the relationship between current vegetation and pollen rain, which 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. To establish if the causes are due to natural (climatic) or anthropogenic (man-made). This work was concentrated on an archeological site in semi-arid zone 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 Elsufra 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 cm and 550 cm from the top, so as to reconstruct past vegetation. The area covered in this study is located east to the Sufra Wadi and 65 km from ancient Merwe Town, 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 refereed to the fourth century before present.

Results

Fossils pollen analyzed 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 which pollen grain is belonging to was carried out using the available relevant African floras with a special attention to scientific publication of Sudan and the neighboring countries and the distribution was carried out according to Andrews (1950/1952/1956) and that was shown in Table I (Plates 1-4).

Discussion and conclusion

Past vegetation was examined by analyzing fossils pollen grain found in the samples taken from *Hafair* of Musawarat ElSufra.

In total, 22 types of plant species were recorded in the slide examined. These were described and fully identified, it was noticed that the number of plant species is 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 paleoenvironments of the arid and wind-deflated Sahara is 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 such plant pollen as *Commelina bengalensis* and *Cyperus* sp. Indicate 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 *Hafair* of Musawarat ElSufra indicates that the rainfall of the area was more than enough to allow for its growths the plants grows best in marches and swamps along streams, lakes, ponds ditches where water level fluctuates from 15 cm below soil surface to 15 cm above.

At the family level, the Mimosaceae is a large and well represented family throughout Africa but when identified to species level (e.g. *Parkia bicolar* and *Mimosa pigra*). As for *Parkia bicolar* Andrews (1950/1952/1956) 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 one humid area. As Andrewes and Bamford (2007) whose studied the Loetoli, Tanzania reported that higher rainfall increase 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 with the above mentioned low number of plant species. The reason probably is 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 type of diatoms support our suggestion that habitat in the past is not like the present.

The past vegetation of the area contained some species which 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 a savanna to a semi-desert condition in this area.

Table I.
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* Schweinf. 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.	Cyperaceae	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. BahrelGazal 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.

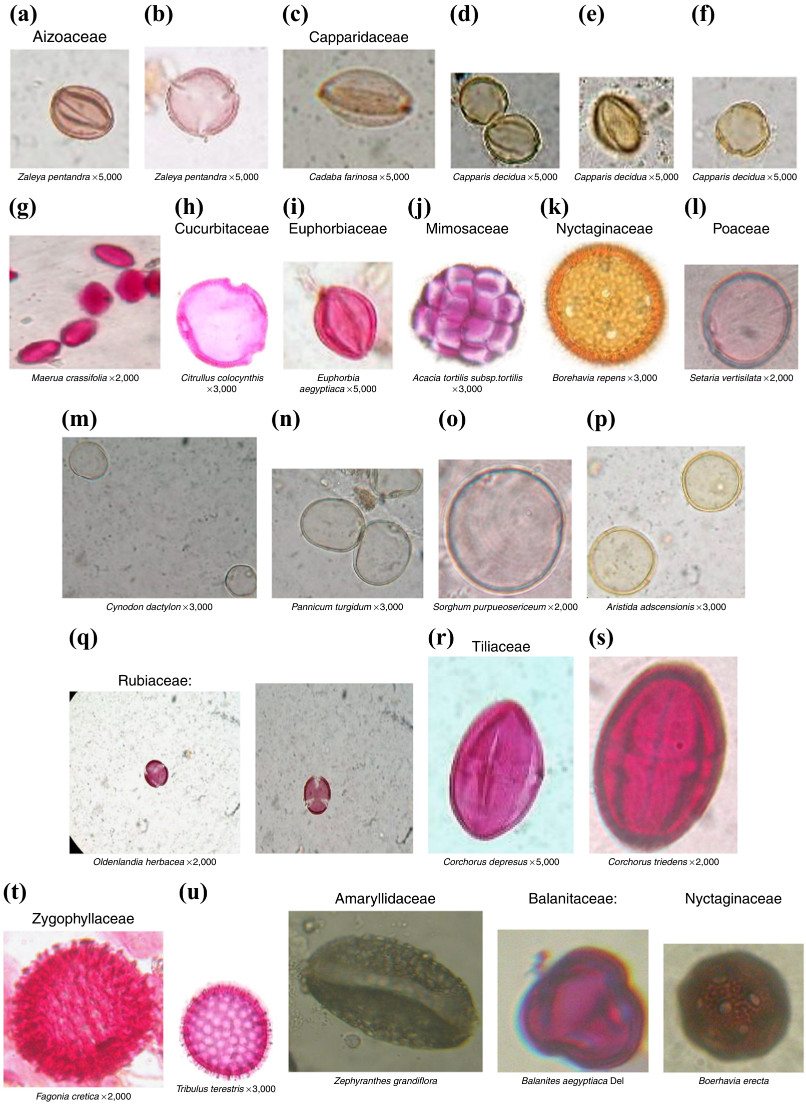


Plate 1.
Present vegetation pollen analysis

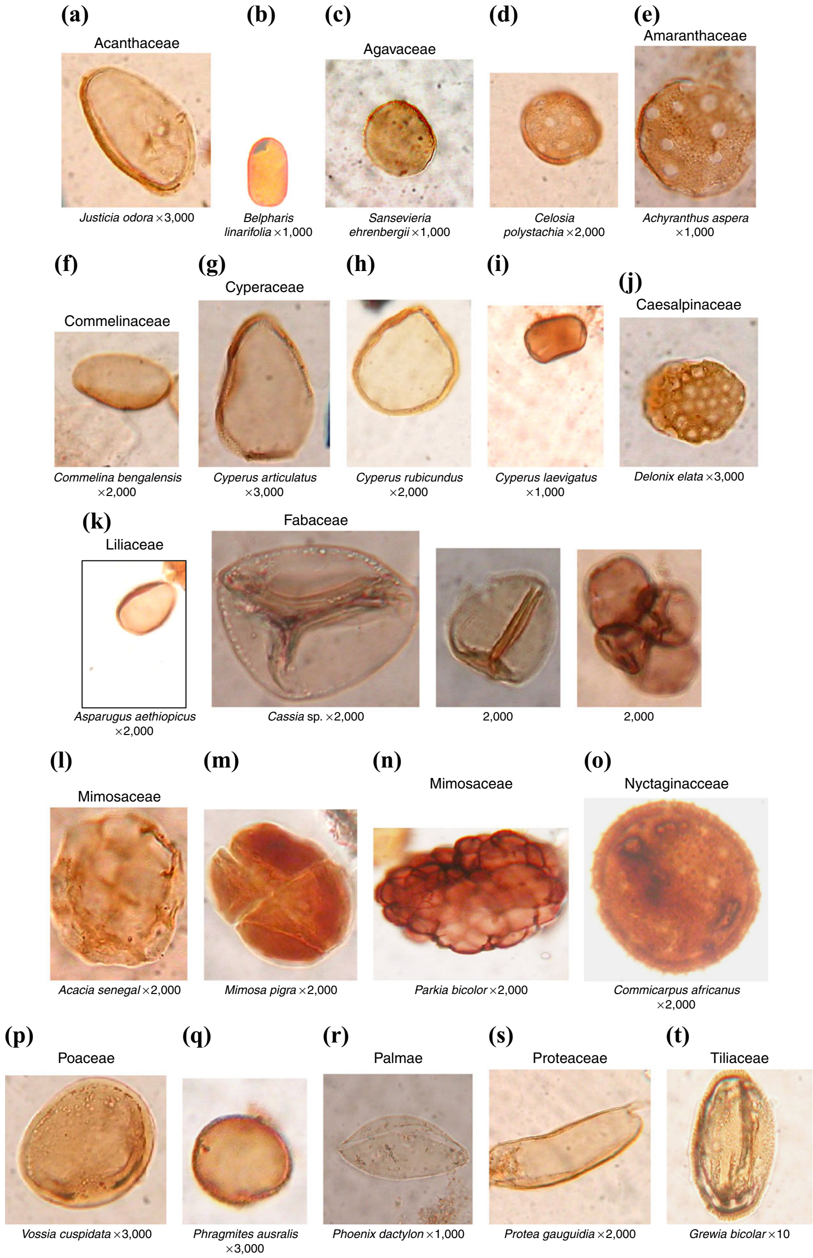
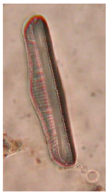


Plate 2.
Fossil pollen grains

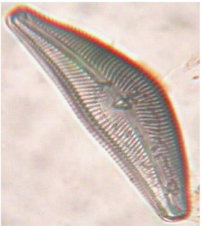
Frustulia rhomboids (Her.) De Toni *Rhopalodia gibba* (Ehr.)



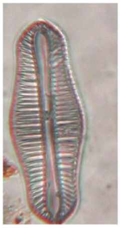
O.Muller (Valve view).

Diplonis elliptica kutz (Cleve)

Caloneis silicula (Her.) Cleve. (Ehr.) O.Muller (girdle view)



Cymbella laneolata (Her.) Brun.

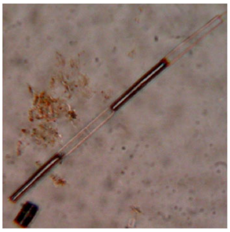


Rhopalodia gibba

Navicula rhyncocephala Kutz.

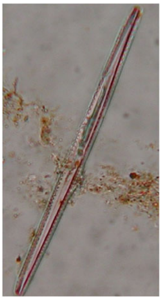
Pleurosigma delicatulum W.Smith

Melosira sp.

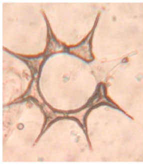


Melosira sp.

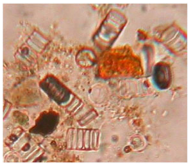
Brebissonia boeckii (Her.) Grun



Amphipleura pellucida Kutz.



Pediastrum sp. Green algae



Melosira sp

Plate 3.
Different types of diatoms

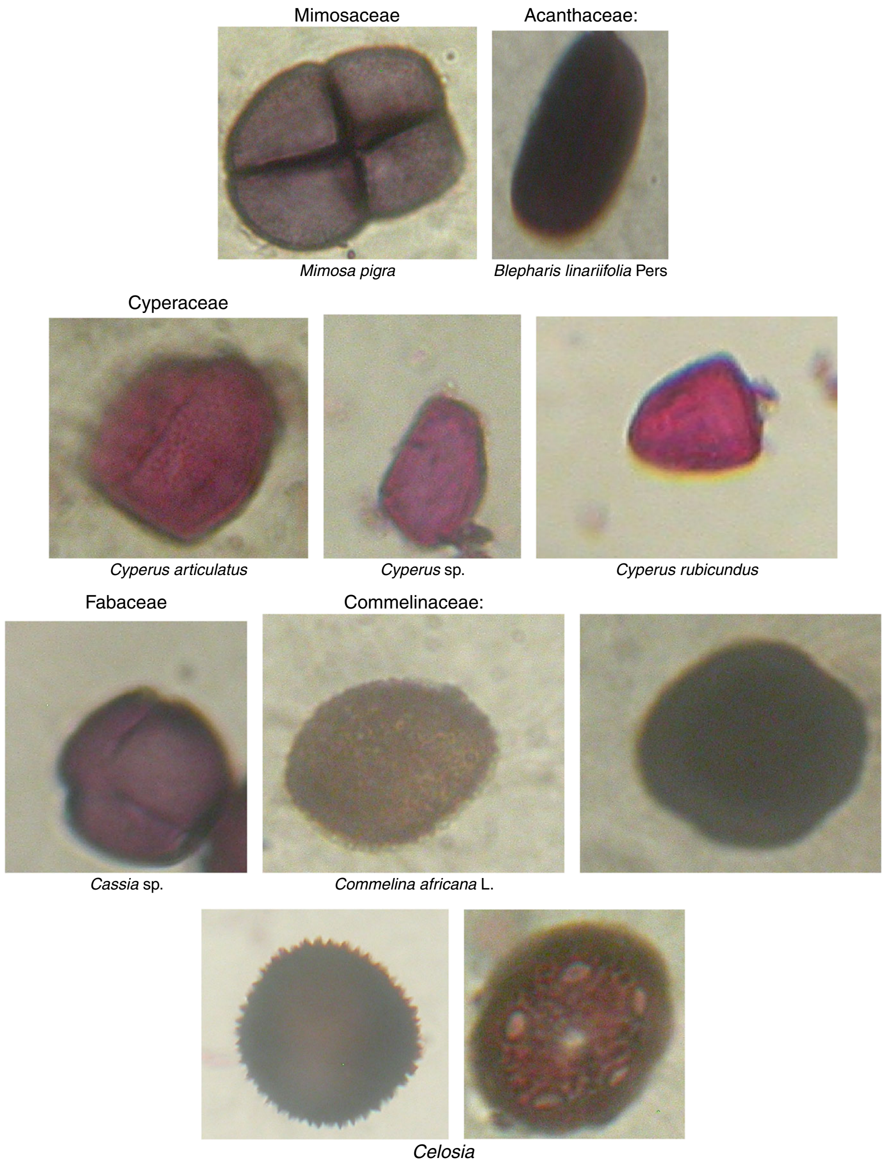


Plate 4.
Confirmation to some fossil pollen grains

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