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Research article

Pollen analysis of animal coprolites recovered from vegetation mounds in El-Ga'ab paleolake: evidence for vegetation history of the desert of northern Sudan

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Abstract: In arid zones vegetation mounds are natural indicators for land degradation. Studying plants and animals remains in different strata of these mounds provide information about the past land use in which parts of the natural environment were modified into arable fields and pastures. They are suitable sites for preserving animal coprolites. In this study, two samples of different animal coprolites were collected from vertical trenches in vegetation mounds of Um Hilal and El-Hamra areas of El-Ga'ab depression in northern Sudan. Pollen grain analysis was conducted and eleven species that belong to eight families were identified. Five species recorded for El Hamra area and nine species were identified for Um Hilal area. Most of the pollen grains were identified as *Suaeda monoica* and *Salsola imbricata* which are halophytes indicates habitats of high soil salinity in El-Ga'ab depression. These species are still dominant in other law elevated areas of less dry sand dunes. *Polygonum* sp. Pollens were recorded in Um Hilal area indicating a moist habitat. Record of the comparatively large number of tree pollen grain of *Acacia ehrenbergiana* indicates no change in the dominant tree species. Presence of the pollen grains of *Triticum* sp. (wheat) and *Heliotropium parciflorum* is an evidence for past agricultural activities. This study recommended further intensive investigations of the old dry vegetation mounds distributed in the desert of northern Sudan to reconstruct its palaeoenvironment.

Keywords: Archaeobotany, Pollen grains, Coprolite, Northern Sudan, Vegetation history.

INTRODUCTION

Many researchers have suggested that the deserted areas had faced a great transformation concerning the vegetation cover due to the aridity factors, as a result of that transformation the tropical plant communities had replaced by herbaceous-dominated dessert ecosystems; which was proven by pollen taxa from archaeological sites (Mercuri *et al*., 2011; Lezine *et al*., 2011; Florenzano *et al*., 2016). Tropical plant taxa such as *Celtis*-type, *Alchornea*, *Syzygium*-type and *Piliostigma* which were discovered as a pollen grains in the Sahelian and Saharan climates, started to appears around 8500 BC (Watrin *et al*., 2009). Meanwhile, some Sahelian plant species such as *Acacia* had begun to appear in the Saharan regions around 6300-5800 BC (Mercuri, 2008; Watrin *et al*., 2009).

In Sudan, Lopez Saez & Garcia (2003) studied some pollen samples, which were collected from three prehistoric sites along the Blue Nile, el- Mahalab and Sheikh Mustafa, and Sheikh el-Amin. These three archaeological sites were dated to the Early Holocene and to the Middle Holocene, and they are situated within the present semi-arid zone in Sudan. According to the identified pollen grains; such as *Acacia* and Herbaceous sp. (*Gramineae*) it has noted that the area was open Savannah grassland. These pollen results are very similar to the pollen grains results from the Neolithic site of Kadero (Barakat, 1995). Florenzano *et al*. (2016) presented fragmentary records of pollen and non-pollen palynomorphs from archaeological sites in Northern Upper Nubia, particularly from Sai Island. Their study concluded that the dry environments and deserts could not provide a good state of preservation for pollens as the wet environments. A recent study by Florenzano *et al*. (2018) has shown some botanical results based on pollen analysis from Holocene archaeological sites on Sai Island in Northern Sudan. Their results provided a valuable contribution to the understanding of past human-environment interactions and land transformations in the region. This paper aims to report on the results of pollen analysis of animal coprolites obtained from two vegetation mounds (*Tarabeel*) in El-Ga'ab Depression; particularly from Um Hilal and El Hamra areas in the desert of northern Sudan.

MATERIALS AND METHODS

Study area

The study area is located in El-Ga'ab palaeolake which is situated on the western bank of the Nile River south of the

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Third Cataract figure 1. The total area of the palaeolake is about 700 km^2 extends for 123 km across the Western desert. It was connected to the Nile during the early Holocene and separated but remains flooded by the Nile during the Mid-Holocene (Tahir, 2012). According to Madani *et al*. (2015) the larger part of the area is an absolute desert with an average annual precipitation less than 0.1 mm. Wickens (1982) considered this area as part of the most arid areas of the world. Madani *et al*. (2015) documented the presence of old vegetation mounds formed mainly by *Tamarix aphylla* (L.) Karst. near the old settlement relics, such as graves, churches and other buildings assigned to the Christian period. Materials collection sites inside El-Ga'ab are located in Um Hilal, and El-Hamra areas, about 33 km and 36 km from the Nile respectively.

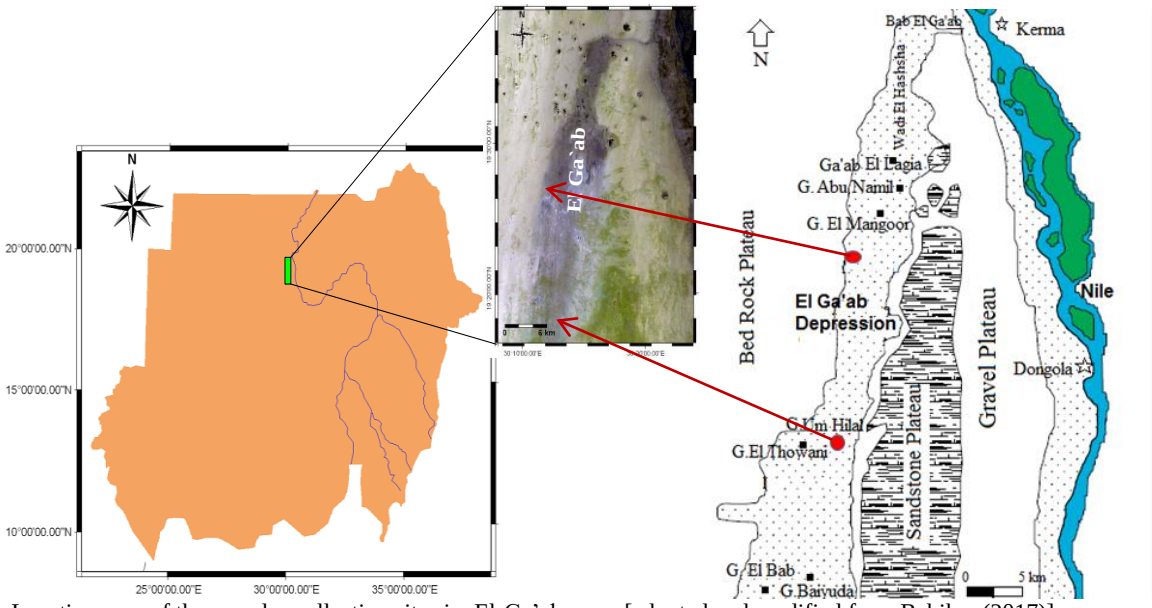

Figure 1. Location map of the samples collection sites in El-Ga'ab *area*. [adopted and modified from Babiker (2017)]

Collection and analysis of animal coprolites

Two samples of different animal coprolites were collected from vertical trenches in vegetation mounds of Um Hilal and El-Hamra areas during in 2015 (Figs. 2 & 3). Samples were treated for pollen analysis following the standard acetolysis method (Erdtman, 1934, 1960; Faegri & Iversen, 1975). Standard taxonomic features such as general shape class, shape from different views, Apertures, exine feature, were used for the identification of pollen grains under the light microscope (A. KRÜSS. OPTRONIC GERMANY D-22297) with the help of magnification powers: 1000x and 400x. Different views of pollens were photographed under the microscope using digital camera and light microscope at the laboratories of Faculty of Science, Department of Botany, University of Khartoum. Authentication of the identification was done consulting relevant atlases, publications and electronic photographic galleries (El Ghazali, 1993; Gosling *et al.*, 2003; Azzazy 2011; online global pollen project accessed at https://globalpollenproject.org/Taxon?rank=Species and online photographic gallery of pollen grains accessed at https://pollenatlas.net/). Results were documented for the identified species and their corresponding families. Updating of plant names was taken into account according to the recent literature of the world plant list http://www.theplantlist.org/). The number of pollen grains identified for species was counted for each location.

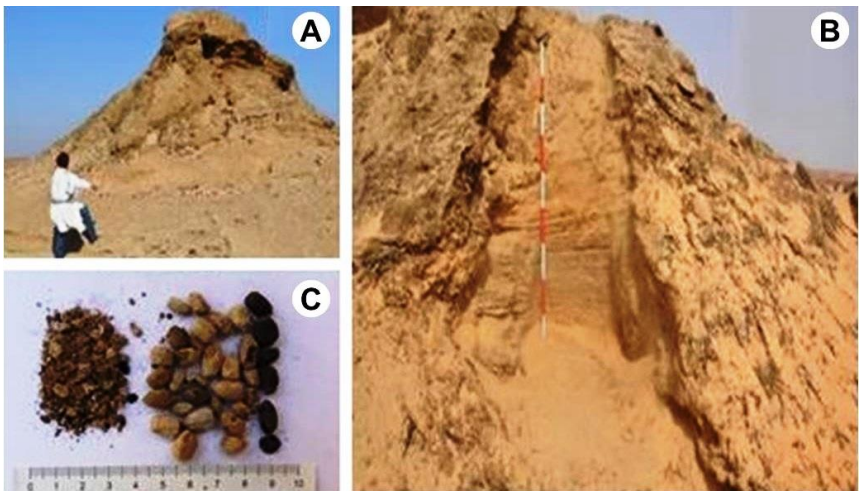

Figure 2. Coprolites samples from Um Hilal area: **A**, Vegetation mound; **B**, Vertical trench on the vegetation mound; **C**, Animal coprolites.

Figure 3. Coprolites samples from El-Hamra area: **A**, Vegetation mound; **B**, Trench on the vegetation mound; **C**, Animal coprolites.

RESULTS

In this study eleven species that belong to eight families have been identified from the pollen grains samples. Five species were recorded for El Hamra area and nine species were identified for Um Hilal area. Figures 4 and 5 Shows pollen grains under magnification power x1000 from Um Hilal area and al Hamra respectively. Table 1 shows the identified plants from Um Hilal and El Hamra areas with their corresponding density recorded for the studied samples. Pollen sample from Um Hilal shows the highest density record for *Suaeda monoica* Forssk. ex J.F.Gmel. followed by *Salsola imbricata* Forssk. which is also reported to be of the highest records in El Hamra pollen sample. Figures 6 and 7 shows the proportions of different plant species identified form pollen samples of Um Hilal and El-Hamra.

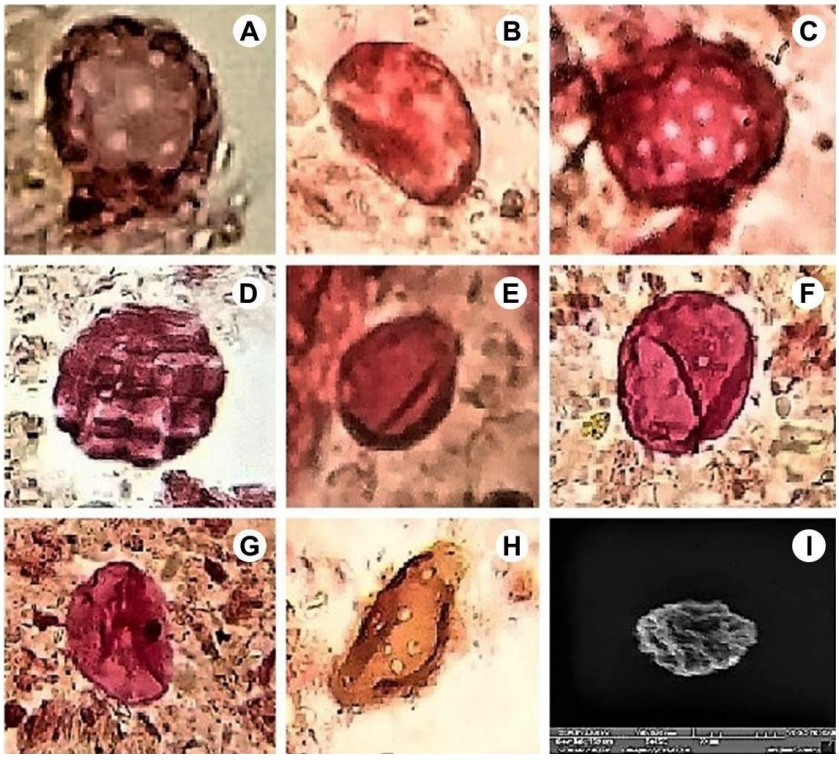

Figure 4. Pollen grains from Um Hilal area: **A**, *Salsola imbricata* Forssk.; **B**, *Phoenix dactylifera* L.; **C**, *Suaeda monoica* Forssk. ex J.F. Gmel.; **D**, *Acacia ehrenbergiana* Hayne; **E**, *Heliotropium parciflorum* (Mart.) Gürke; **F**, *Triticum* sp.; **G**, *Cassia* sp.; **H**, *Hyphaene thebaica* (L.) Mart; **I**, *Polygonum* sp.

Table 1. Identified species and their corresponding density in pollen samples.

Identified Plants species		Numbers of specimens	
Family name	**Species name**	**Um Hilal**	**El Hamra**
Amaranthaceae	*Salsola imbricata* Forssk.	13	8
Arecaceae	*Phoenix dactylifera* L.	3	5
Amaranthaceae	*Suaeda monoica* Forssk. ex J.F. Gmel.	20	-
Leguminosae	*Acacia ehrenbergiana* Hayne	5	-
Boraginaceae	*Heliotropium parciflorum* (Mart.) Gürke	7	-

Poaceae	*Triticum* sp.	6	-
Leguminosae	*Cassia* sp.	5	4
Arecaceae	*Hyphaene thebaica* (L.) Mart	2	-
Tamaricaceae	*Tamarix aphylla* (L.) H.Karst	-	6
Cappariaceae	*Capparis* sp.	-	3
Polygonaceae	*Polygonum* sp.	1	-

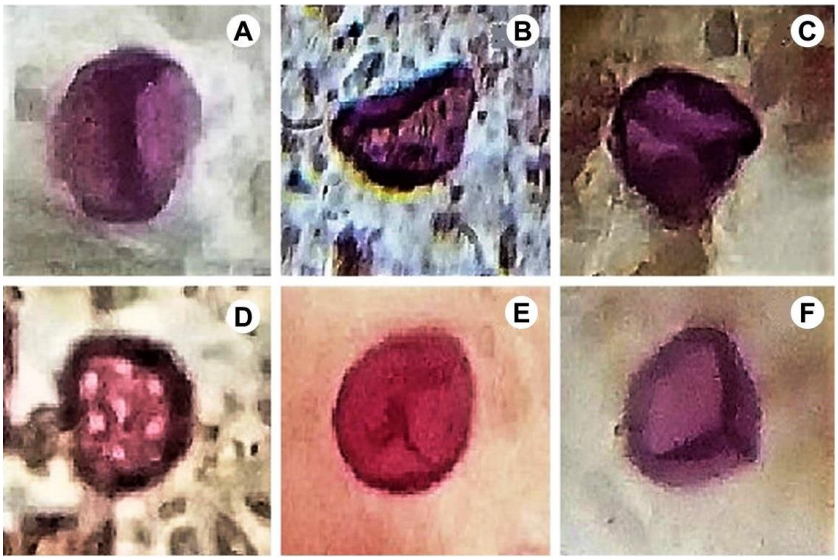

Figure 5. Pollen grains from El Hamra area: **A**, *Tamarix aphylla* (L.) H.Karst; **B & C**, *Phoenix dactylifera* L.; **D**, *Salsola imbricata* Forssk. ex J.F. Gmel.; **E**, *Cassia* sp.; **F**, *Capparis* sp.

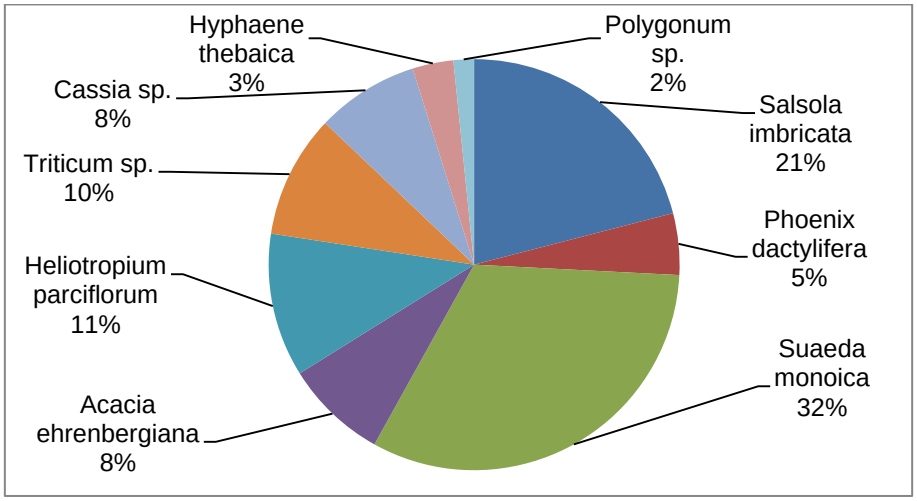

Figure 6. Proportions of different plant species identified form Um Hilal pollen sample.

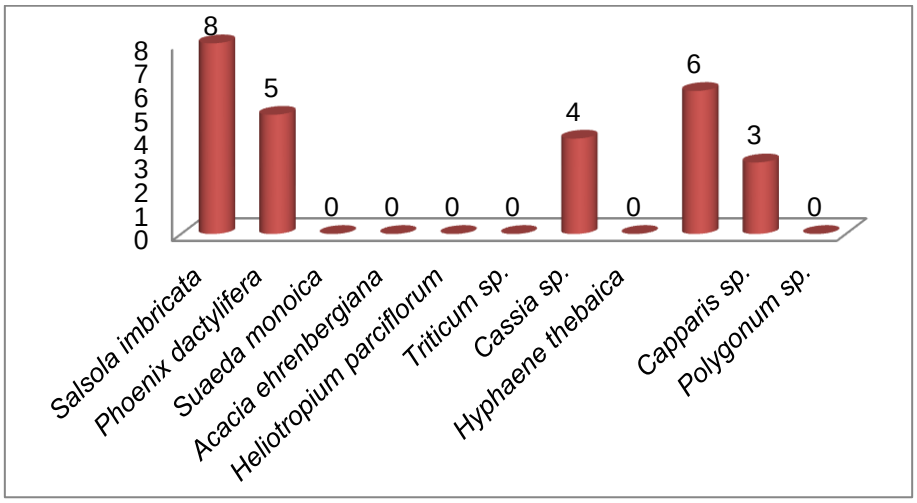

Figure 7. Proportions of different plant species identified form El Hamra pollen sample.

DISCUSSION

The pollen grains analysis of the samples collected from the vegetation mounds of Um Hilal and El-Hamra sites provided direct and good evidence about some of the composition of the flora of this areas during the late Christian and early Islamic periods in El-Ga'ab depression. Diversity in the species identified from the pollen grains samples in the studied areas also indicates suitable habitats for vegetation growth in the past. Different colors and size of the collected coprolites samples indicate the potentiality of the vegetation mounds to preserve them in good conditions for a long time. The moist environment inside the vegetation mounds in Um Hilal and El-Hamra is probably the main reason behind the good preservation of both coprolites, pollens and other archaeological materials. This observation conforms with the results obtained by Madani *et al.* (2018). Concerning pollen preservation, This result is in agreement with the observations of Florenzano *et al.* (2018) who reported about the good quantity and quality of pollen obtained in their study on Sai Island compared to poor pollen samples obtained by Florenzano *et al.* (2016) in the desert in northern Sudan . Most of the pollen grains were identified as a *Suaeda monoica* (Suaeda) and *Salsola imbricata* (Ikhreet). According to Woldewahid *et al.* (2007) the *Suaeda monoica* plant community is identifiable in the coastal plain of Sudan and along the Arabian Red Sea coast, which gives clear evidence that the El-Ga'ab area provided the same conditions for those plant communities to grow. Both plant species are still dominant in other law elevated areas of less dry sand dunes grow in Um Hilal and El-Hamra. *Polygonum* sp. (Timsahya) in northern Sudan is distributed mainly on the Nile banks. The record of this pollen grain in Um Hilal area is an indication of moist habitat. A comparatively large number of tree pollen grain sample is recorded for *Acacia ehrenbergiana* Hayne which is still considered as a dominant plant species. The presence of the pollen grains of wheat (*Triticum* sp.) and of the commont weed in the northern Sudan agricultural schemes (*Heliotropium parciflorum* (Mart.) Gürke) is an evidence for the presence of agricultural activities in the past.

CONCLUSION

This research concluded that the vegetation mounds are suitable sites for preserving plant remains and animal coprolites. Studying plants and animals remains in different strata of these mounds will provide information about the past land use in which parts of the natural environment were modified into arable fields and pastures. Vegetation mounds could also explain the rate of sand erosion and land degradation processes in the desert. Most of the pollen grains were identified as a *Suaeda monoica* (Suaeda) and *Salsola imbricata* (Ikhreet). Which are salt-tolerant plants indicates the presence of saline habitats in El-Ga'ab depression. Up to date, both species are forming the dominant species of other law elevated areas of less dry sand dunes. the areas. The record of Polygonum sp. (Timsahya) in Um Hilal area is an indication of moist habitat. Record of a comparatively large number of tree pollen grain of *Acacia ehrenbergiana* indicates no change in the dominant tree species. The presence of the pollen grains of wheat (*Triticum* sp.) and (*Heliotropium parciflorum*) is an evidence for past agricultural activities. For reconstruction of the palaeoenvironment, further intensive investigations of the vegetation mounds formed in the desert of northern Sudan were recommended.

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