1st CONFERENCE OF THE ARABIAN JOURNAL OF GEOSCIENCES (CAJG)
12–15 NOVEMBER 2018, HAMMAMET, TUNISIA

Springer
SPRINGER NATURE

Paleoclimate evolution of the Kordofan region, Sudan, during the last 13 ka

Dawelbeit Ahmed[1], Jaillard Etienne[2], Eisawi Ali[3]

[1] Department of geology, Faculty of Science, Kordofan University, El Obeid, Sudan.
[2] Grenoble Alpes University, ISTerre, IRD-CNRS-IFSTTAR-USMB, France.
[3] Faculty of Petroleum and minerals, Al-Neelain University, Khartoum, Sudan.
Ahmeddawelbeit69@gmail.com

Abstract. The Kordofan region is located at the southern end of the present-day Sahara in Sudan. ^{14}C dating and archeological findings allowed to date the latest Pleistocene-Holocene deposits in Kordofan. Several proxies (gastropods, pollens, stable isotopes, major element chemistry, and clay mineralogy) have been used to reconstruct the climatic evolution for the past 13 ky. The region was submitted to arid conditions prior 10 ky BP. Between 10 and 6 ky BP, the region experienced a wet climate marked by lacustrine/palustrine and fluviatile deposits. After ≈ 6 ky BP, the climate evolved to dry conditions, although the southern part remained more humid. Sometime between 3 and 1 ky BP, a strong aeolian activity is recorded by a sedimentary hiatus and erosion features. From 1000 yr BP to Present, the region became arid. This evolution can be correlated to the well-known evolution of Eastern Sahara during this interval.

Keywords: Stable isotopes, palynology, sedimentology, climate, Kordofan region.

1 Introduction

The period between 20 and 12 ka BP is well documented as a period of dune building in the central Sahara, the Nile basin and East Africa [1]. This hyper arid period is followed by a humid phase between ≈ 12 and 6 ky BP, known as the African Humid Period (AHP) [2], since it is marked by the occurrence of numerous lakes [2]. Some lake basins in North Africa were exceptionally large in Libya, Chad, Algeria and Kenya [3]. The subsequent development of the Sahara desert is recorded by the migration of prehistoric populations toward the present day Sahelian zone or the Nile valley in the last 10 ky [4].

Although the Kordofan region (Sudan) is located at the southern limit of the Eastern Sahara, its latest Quaternary climate evolution has never been studied. This paper is focused on the understanding of the climate evolution of central Kordofan during the latest Quaternary, through several climatic proxies.

2 Methodology

Two field campaigns were carried out in Kordofan, which were complemented with some short field works. They allowed the sedimentological study and sampling for laboratory analysis. The latter included ^{14}C dating, paleontology of gastropods, palynology, C and O stable isotopes, XRF major elements measurements and clay mineralogy analysis.

3 Results

3.1 Sedimentology

^{14}C dating allowed to distinguish four main chronological units, corresponding to five main climatic periods (Fig. 1B).

- The lower unit (U1) is made of fine to coarse sands, subsequently pedogenetized (mottling, calcareous nodules), which yielded ages varying from ≈ 13 to 10 ka cal BP.
- The second unit (U2) consists of palustrine limestones in the northern and central part, and of fluviatile deposits in the southern part. ^{14}C ages vary from ≈ 10 to 6 ky BP in the North and from ≈ 8 to 6 ky cal BP in the South.
- The third unit (U3) is restricted to the southern part. It formed of mottled sandstone and sandy shales. ^{14}C ages vary from ≈ 5 to 3 ky BP.
- A sedimentary hiatus, detected between ≈ 6 and 1 ky cal BP in the North and between ≈ 3 and 1 ky cal BP in the South, is interpreted as an arid period dominated by strong wind erosion, which occurred between ≈ 3 and 1 ky cal BP (Fig. 1B).
- The upper or forth unit (U4) is formed of red sandstone in the North, replaced gradually by flood plain sediments to the South. Its maximum age is ≈ 1100 y BP.

The South-North evolution of these units indicates that the southern area was more submitted to fluviatile influences than the northern ones during Holocene times.

3.2 Paleontology of gastropods

The vertical distribution of gastropod sub-fossil shells shows that aquatic and semi-aquatic gastropod species dominated in the palustrine limestone (U2), while land snails dominated in U4. This indicates that U2 was formed under wetter condition than U4.

3.3 Palynology

Twenty-two samples from three sections from the southern area were analyzed for palynological investigation. 1213 counted pollens and spores have been classified into four groups, representing aquatic, tropical, savanna and arid environments. Pollen assemblages from the U3 are dominated by the aquatic, tropical and savanna groups indicating wet conditions, while those from the U4 are from arid environment, reflecting dry conditions.

3.4 Stable Isotopes

Forty-nine samples of gastropod shells (3 sites) and calcareous nodules (2 sites) were analyzed for oxygen and carbon isotopes. Gastropod shells of the U2 are depleted in ^{18}O, while those from the U4 show a rapid ^{18}O enrichment upward. Coeval depletion in $\delta^{18}O$ values recorded in the Nile valley has been interpreted as evidencing high rainfall episodes [5]. The enrichment in ^{18}O in the U4 can be interpreted as the result of a strong evaporation [6], reflecting drier conditions [5]. The calcareous nodules are generally depleted in ^{18}O, with little variability through time.

3.5 Major elements geochemistry

Twenty-three samples from the U1 and U4 of two sections were analyzed for major elements (XRF) analysis. The calculated Chemical Index of Alteration (CIA) [7] is high for both the U1 and U4. High CIA values (76 to 100) in sedimentary rocks suggest intense chemical weathering in the source region [8].

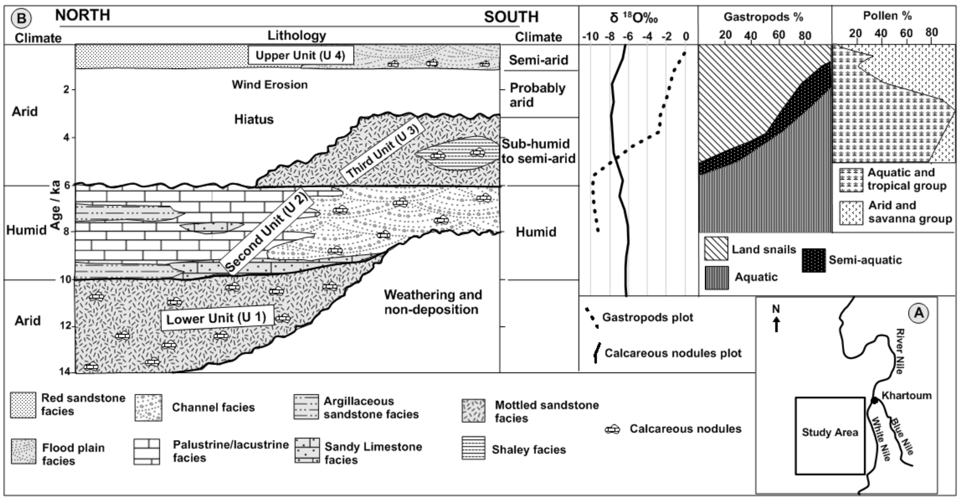

Fig. 1. (A) Location map (B) summary of paleoclimate results.

3.6 Clay mineralogy

Eight samples from the U1, U3 and U4 of one section show a remarkable domination of smectite and kaolinite, while illite is less dominant. Smectite decreases upward, while kaolinite shows an opposite trend. These results suggest that the source areas were more submitted to chemical weathering than physical weathering, especially during deposition of U4.

4 Discussion

Our sedimentological and paleoclimatic study in the Kordofan region enabled us to reconstruct the following evolution. Aeolian deposition took place prior to ≈ 10 ka BP and covered most of the studied area. We correlate this arid period with the 20-12 ka BP interval, which is known as an arid period of dune building in northeastern Africa. In Kordofan, palustrine-lacustrine limestone, pollens of humid vegetation, aquatic gastropods and depletion in $\delta^{18}O$ values in the latter are recorded between 10 and 6 ky BP, and evidence a wet climate during the early to middle Holocene. This wet event is correlated with the AHP [3; 2], during which the present-day hyperarid Sahara desert was vegetated and covered by numerous lakes [10]. The exact start and termination dates of this wet phase are not accurately determined in this study, since part of the corresponding sediments may have been removed by the subsequent aeolian erosion.

According to previous works, this wet phase occurred between 11 to 9 and 6 to 4.5 ky BP in Northeast Africa [3; 9; 11].
The late Holocene period (≈ 6 ka to Present) recorded drier conditions in the northern part of the study area, while the southern part remained wetter. This aridification is well documented in Eastern Sahara [12]. As examples, northern Chad experienced a progressive drying out due to an abrupt hydrological change [13], palynological evidences from Lake Yoa (Chad) indicate a gradual shift from moist to arid condition during the last 6000 yr [14], and desertification and aeolian deflation occurred during the Middle and Late Holocene in Egypt and northern Sudan [15].

5 Conclusions

The study of the sediment record of the Kordofan region allowed the reconstructions of the climate variability since 13 ka, based on sedimentological, geochemical, and paleontological analysis. The climate evolution can be summarized as follows: dry conditions prior to ≈ 10 ky BP, wet conditions between ≈ 10 and 6 ky BP, wet to dry conditions from ≈ 6 to 3 ky BP, dry from ≈ 3 to 1 ky BP associated with strong aeolian erosion, and dry after 1000 y BP, although wetter in the south. These climate changes can be correlated to the well-known climatic evolution of Eastern Sahara during this interval. These results highlight the climate changes along the still poorly known southern limit of Eastern Sahara.

References

1. Williams, M.A.J., 2009. Global and Planetary Change 69, 1–15.
2. deMenocal, P.B., et al., 2000. Quaternary Science Reviews 19, 347-361.
3. deMenocal, P.B., Tierney J.E., 2012. Nature Education, Knowledge 3.
4. Kuper, R., Kröpelin, S., 2006. Science 313, 803-807.
5. Apell, P., Williams, M., 1989. Palaeogeog, Palaeoclimat, Palaeoecol 74, 265-278.
6. Leng, M.J., Marshall, J.D. 2004. Quaternary Science Reviews 23, 811–831.
7. Nesbitt, H.W., Young, G.M., 1982. Nature 299, 715-717.
8. Madhavaraju, J., et al., 2016. Revista Mejicana de Ciencias Geológicas 33, 34-48.
9. Pachur, H.J., Kröpelin, S., 1987. Science 237, 298-300.
10. Cole, J.M., et al., 2009. Earth and Planetary Science Letters 278, 257–266.
11. Tierney J.E., et al., 2011. Earth and Planetary Science Letters 307, 103–112.
12. Tierney, J.E., deMenocal, P.B., 2013. Science 342, 843-846.
13. Kröpelin, S., et al., 2008. Science 320, 765-768.
14. Lézine, A.-M., et al., 2011. Climate of the Past 7, 2413–2444.
15. Nicoll, K., 2004. Quaternary Science Reviews 23, 561–580.