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Migration of the Intertropical Convergence Zone in North Africa during the Holocene: Evidence from variations in quartz grain roundness in the lower Nile valley, Egypt

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ABSTRACT

This study reports the high-resolution (50–100 yr) temporal variations of quartz roundness used as a climate proxy in the sediment core FA-1 recovered in the Faiyum Basin of the lower Nile. A higher proportion of transparent angular quartz can be found in sediment transported from the upper to the lower Nile via runoff when the Intertropical Convergence Zone (ITCZ) migrated northwards during the Holocene. The stained rounded quartz in the core sediment can be linked to windblown input into the Faiyum Basin from the Sahara Desert when the ITCZ shifted southwards. Using this theory, we reconstructed the series of Holocene climate changes in relation to the ITCZ migration. Our quartz evidence revealed: 1) the African Humid Period (AHP) occurring in the basin at 9200–4200 cal. yrs BP; 2) a short-term (5800–5400 cal. yrs BP) aridification occurred during the AHP; and 3) the rapid onset of hyper-aridification at ca. 4200–4000 years ago, which then persisted. These ITCZ related climate pulses, have basin-wide implications supporting relevant paleoclimate studies in North Africa. In addition, our results suggested at least 3 times when hydro-geoengineering works were implemented to source water from the Nile for local farming during the hyper-aridification period.

1. Introduction

Continental rivers and mega-deltas are rich archives of Holocene climate records and associated human activities (Törnqvist, 1994; Macklin et al., 2015; Woodward et al., 2015). The lower Nile basin (Fig. 1A), including the delta coast, lakes and floodplain, located in the arid climate region where there has been a long period of cultural occupation, is an ideal recorder for studying the variations of hydrological balance and anthropogenic forcing in northeast Africa (Krom et al., 2002; Marriner et al., 2012). Although much is known from previous studies (Stanley, 1996; Beuning et al., 2002; Kuper and Kröpelin, 2006; Marriner et al., 2012; Blanchet et al., 2013), there are still gaps in understanding of the basin-wide climatic changes and human interferences that can be assessed using effective sediment proxies.

In the sub-equatorial and tropical regions of Africa, the shift of the Intertropical Convergence Zone (ITCZ), which migrates across the latitudes either seasonally or in over longer time periods is an important process to explain the hydrologic balance at the continental scale (Fig. 1B) (Marriner et al., 2012, 2013). Northward migration of the ITCZ can result in more precipitation in the Nile catchment, enabling the transport of more sediment downstream to the river mouth area on the Mediterranean coast. In contrast, the southward migration of the ITCZ causes a reduction in precipitation and consequently runoff. This reduces sediment transport downstream and windblown sediment becomes a more dominant source of sediment input into the lower Nile catchment (Woodward et al., 2015). Although much attention has been paid to attest this mechanism, there are limited effective sediment proxies to be able to explain the linkage between the ITCZ migration and hydrodynamic change, and the possible relation to human activities in the Late Holocene.

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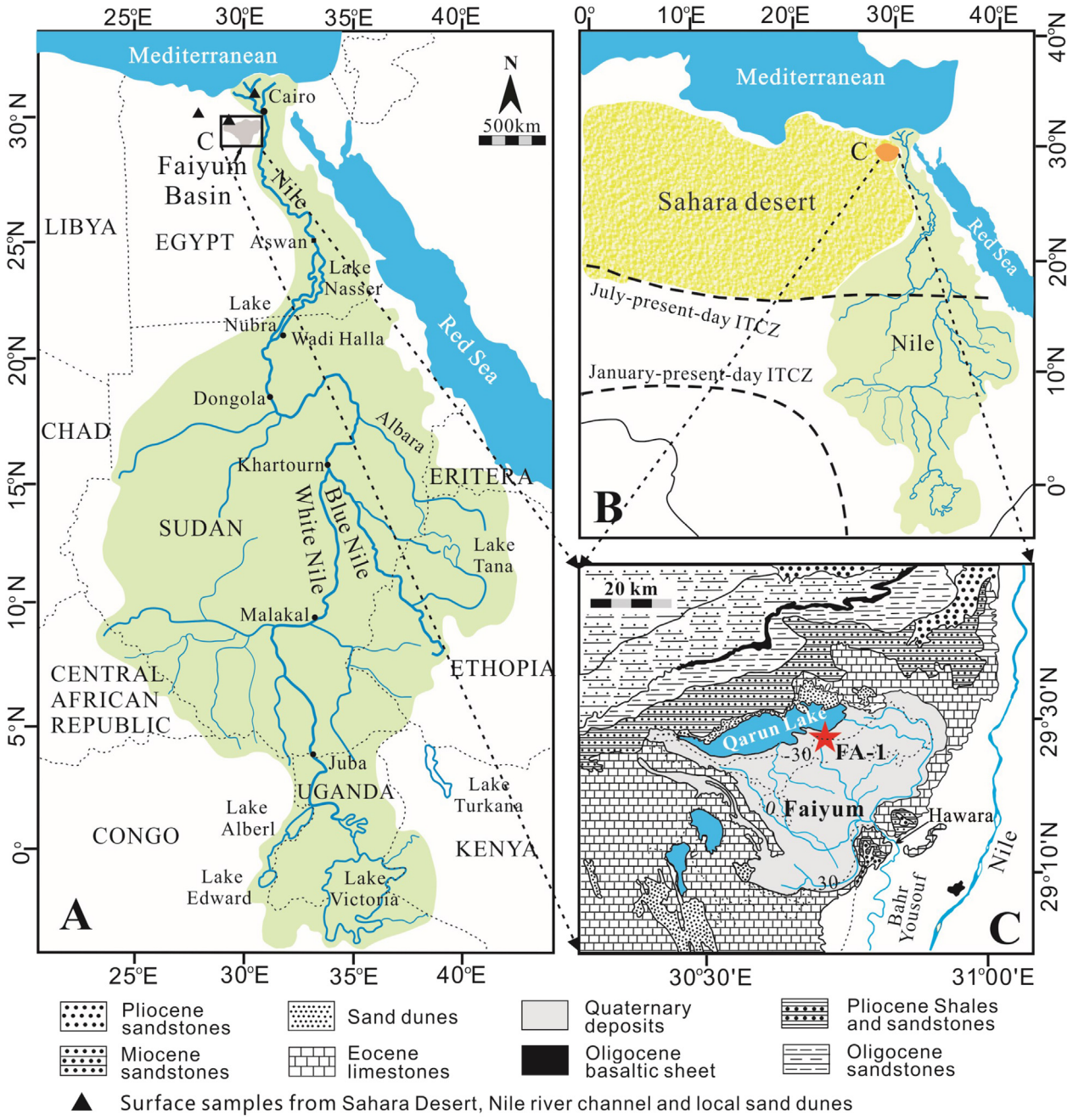

Fig. 1. (A) Map showing the Nile Basin and the study area; (B) ITCZ position in summer and winter over North Africa (modified after Marriner et al., 2012); (C) the Faiyum Basin with sediment core site FA-1 and rock exposures (modified after Wanas, 2008).

Quartz in the lower Nile and its delta coast is one of the most sensitive environmental proxies (Stanley and Chen, 1991), due to its unique morphological variation across the distinctive wet and arid climate settings in North Africa. There are two distinctive quartz morphologies that can be identified in the lower Nile sediments, transparent angular quartz and stained rounded quartz. The former is believed transported from the upper Nile to the delta coast via runoff when the climate was wet, whereas the latter signals windblown processes dominating when the climate was dry. Undoubtedly, the rounded quartz was mostly derived from the Sahara Desert, where quartz grains had experienced a long period of windblown abrasion (Goudie and Middleton, 2001; Giraudi, 2005).

2. Study area and study objectives

The Faiyum Basin (ca. 1700 km^2) is a fault-controlled depression, ca. 30 km west of the lower Nile River, and ca. 250 km to the delta coast (Fig. 1A,C). The basin is connected with the Nile mainstream through an artificial waterway on the southeast (the Hawara Canal, Fig. 1C), which supplies the Faiyum Basin with freshwater for farming. Qarun Lake (29.28°N; 30.29°E) in the northern Faiyum Basin is shallow and saline with a water surface area of ca. 235 km^2 (Fig. 1C). The lake water level is presently 44 m below the mean sea level (msl), and the precipitation is <10 mm per year (Marks et al., 2017). The Holocene sediment thickness in the Faiyum Basin ranges generally from 5 to 25 m (Flower et al., 2012; Marks et al., 2017). A

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