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Evidence of drainage reversal in the NE Sahara revealed by space-borne remote sensing data

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ABSTRACT

Interpretation of Radarsat-1, Shuttle Radar Topography Mission (SRTM) and Landsat 7 Enhanced Thematic Mapper (ETM+) data provided an overview of the evolving course of Wadi Qena region in the northeastern Sahara of North Africa. This resulted in a reconstruction model explaining that Wadi Qena developed through time in stages, including tectonically-induced drainage reversal. This was evidenced by presence of two opposite courses, physical continuity of the main channel beyond the present watershed, and prominent asymmetry as the downstream drainage makes up 80% of the total indicating an opposite style of drainage. Uplift and Red Sea tectonics caused a blockage of the wadi course, segmented the surrounding rock masses, and upended the slope of the land. The river course reversed direction and followed a contorted pathway to become a tributary of the Nile. Vestiges of the earlier Wadi Qena are preserved in the form of paleoslopes, and diverted valleys. The results demonstrate that views from space provide powerful tools for better understanding of the paleohydrology in arid regions.

1. Introduction

The present Wadi Qena is a prominent geomorphic feature in the Eastern Desert of Egypt that covers approximately 16,000 km^2. It extends about 200 km from its south entrance at the Nile River to its end west of Ras Gharib town on the Gulf of Suez (Fig. 1a and b). It strikes north–south parallel to the Red Sea highlands. It has developed along unconformable contacts between Precambrian basement rocks to the east and a sedimentary sequence to the west, topped by massive limestone. The present Wadi Qena system runs southward opposite to the northern flow direction of the Nile River and joins it at the Qena Bend.

In fact, the present system of Wadi Qena has a complex setting that raised several questions as to: why its main trunk at Abu-Had prominence is divided into two opposite courses? Why the ancient pathway, about 20 km in width, east of Abu-Had extends northward for 50 km, then southward along a narrow loop, instead of heading southward? Where was the outlet of the Wadi Qena during its earlier stages? Why does the present Wadi Qena end at the junction between Qena Bend and the Nile Valley? All these questions encourage rethinking and raise a question: Did Egypt's Wadi Qena drain northward during an earlier stage? (Abdelkareem et al., 2010)

Several studies (e.g., Said, 1962, 1983, 1990; Issawi, 1983; Issawi and McCauley, 1993; Issawi and Osman, 2008; Abdelkareem et al., 2012a; Macgregor, 2012) explained the ancient drainage and its relation to other systems that drained earlier than the Nile River system. Issawi (1983) supposed that Wadi Qena was an ancient river that flowed from north to south and built its delta on both sides of the present Nile, and established its drainage course by the middle Miocene, which began in the early Miocene, in association with the Red Sea tectonics (Issawi, 1983; Issawi and McCauley, 1993). Based on radar data interpretation, McCauley et al. (1982, 1986) suggested that a Trans-African master stream system flowed from the headwater in the Red Sea highlands to the southwest across North Africa to the Atlantic at the paleo-Niger delta prior to the Neogene domal uplifts and the volcanic events across the paths of these ancient watercourses. That notion was contradicted by Burke and Wells (1989), Robinson et al. (2000); and Abdelkareem and El-Baz (2015a). Issawi and McCauley (1993) assumed that Egypt was drained by three major drainage systems during the Cenozoic Era: the Nile, Qena and Gilf Kebir river systems. They also stated that the present Nile began as surviving parts of these older drainage channels. The Qena river system was initiated after the northward uplift of the Red Sea hills, resulting in a southward gradient. Collecting water

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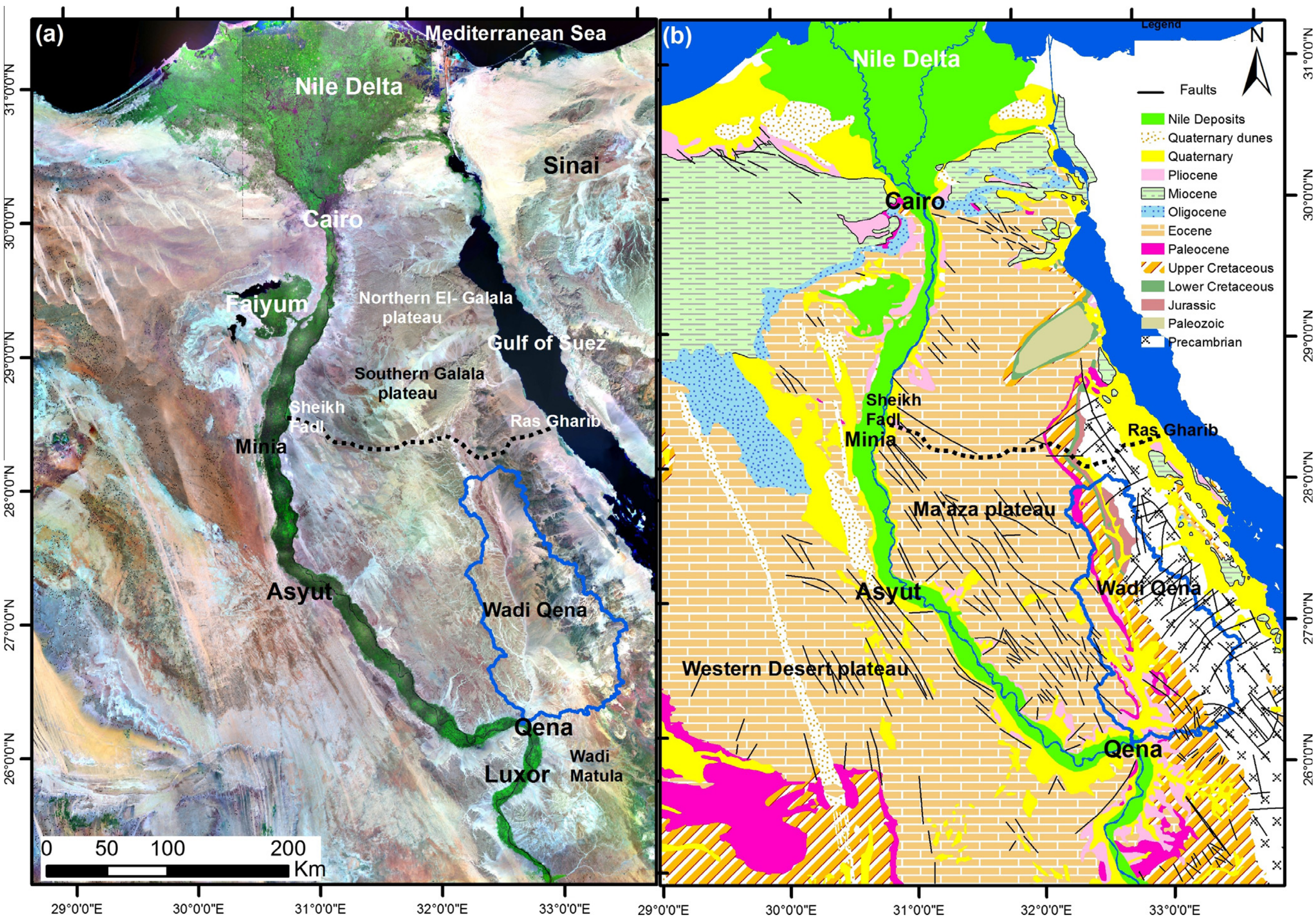

Fig. 1. Wadi Qena area in the Eastern Desert of Egypt (a) Landsat ETM+ mosaic covering the study area; the Wadi Qena region is marked by the dashed blue line (b) geological map (part of geological map of Egypt by EGSMA, 1981) showing the study area; the watershed basin of Wadi Qena (marked by a blue line) lies east of the middle section of the Nile Valley. The Nile divides the Eocene plateau into Ma'aza plateau in the east and Western Desert plateau in the west. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

from the Red Sea upland and drained southwestward along the earlier pathway of Wadi Qena crossing the present Nile joining tributaries from Kharga and drained southwestward (see sketches in Issawi and McCauley, 1993, p. 374; Goudie, 2005). Issawi and Osman (2008) summarized that the older rivers in Egypt drained from the Red Sea highlands in the east to the west and fanned over the present western limestone plateau. Furthermore, they mentioned that the uplift pulses were greater in the north than in the south. Thus, the Wadi Qena River ran from north to south.

The presence of exposed Oligocene sediments in the northern region of Egypt over the limestone plateau that extend from the city of Suez to the western tip of the Qattara Depression (including the Faiyum area) caught the attention of several authors (e.g., Abdel-Rahman and El-Baz, 1979; Said, 1983, 1990). These Oligocene sediments are well-sorted and well-rounded orthoquartzitic sands. They most likely have been derived from the Nubian Sandstone that covers the basement rocks to the south (El-Baz, 1982), and are of Oligocene in age (Said, 1983, 1990). It is suggested that the sediments were eroded from the Nubian Sandstone by a major paleoriver that existed during humid phases and transported northward along the river course, where they were deposited on the plateau. Issawi et al. (1999) proposed a paleoriver system, called the Bowen and Kraus River, that originated from the Red Sea highlands, near the Galala region, and flowed northwestward fanning in the northern side of the Faiyum Depression, and forming a vast terminal delta. This delta was first proposed, based on Apollo-Soyuz photographs by Abdel-Rahman and El-Baz (1979) who indicated that most of its deposits are fluvio-marine. Based on the aforementioned discussion, it is evident that the Oligocene sediments where is the former Nile delta is located in Egypt were carried north via large rivers from south. Since there was no connection between the present Nile River in its geomorphology and the former delta during the Oligocene epoch, we propose the Wadi Qena Paleoriver was one of the most probable waterway that connected the south Egypt and Sudan with north Egypt (e.g., Faiyum) during the Oligocene. Along this wadi Qena, that attained external drainage to the ancestral Mediterranean Sea (Tethys Sea), Oligocene sediments were transported northward to form the deltaic deposition where is the former delta was located (Abdelkareem et al., 2012a).

Several structural features have clearly affected Wadi Qena, one of them is the Qena-Safaga shear zone (QSSZ) that trends NE–SW or ENE–WSW and has a significant effect on the Nile course near Qena town (El-Gaby et al., 1988). Akawy (2002) describes the NE–SW Qena-Safaga shear zone as a westward continuation of the NE–SW Aqaba fault trend. Akawy and Kamal El-Din (2006) interpreted the main channel of Wadi Qena as having originated along the N–S fault that was later impacted by the NE–SW shear zone. The Aqaba fault trends facilitated the northeast–southwest drainages along the Red Sea, particularly, at Qena and south Qena town during the late Miocene to the early Pliocene period. Yousef (1968) determined the age of the Aqaba to be of the late Pliocene or early Pleistocene period. Furthermore, the trend is reflected by joints and fractures along the path of the Nile in Qena area (Abd El-Razik and Razvaliaev, 1972).