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Influence of structures on drainage patterns in the Tushka region, SW Egypt

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ABSTRACT

Remote sensing (radar, thermal and topographic) and geophysical (Vertical Electrical Sounding and Ground Penetrating Radar) data are used to understand areas with enhanced groundwater potential in deeper aquifer settings between 22°0′–22°56′N and 30°21–31°20′E in the Tushka area of southwest Egypt. The premise is that areas with enhanced groundwater accumulations represent the best locations for agricultural development that is underway in this region and that deeper sources groundwater resources are the most sustainable. New fluvial and structural interpretations emphasize that the desert landscape was produced by fluvial action in the past. The correlation of high drainage and fault densities, coincident with gentle slope, guided sites for geophysical investigation that provides information about the aquifer depth and distribution, and the subsurface distribution of faults. Results confirm the presence of subsurface fault plains and fault zones and potential water aquifers at these locations. Surface environments further demonstrated an abundance of shrubs and cultivatable soils. The new approach therefore is a cost effective and noninvasive technique that can be applied throughout the eastern Sahara to assist in resource management decisions and support the planned agricultural expansion.

1. Background

95% of the population of Egypt lives on approximately 5% of the land, all in major cities that face water supply shortages. Pressure in the cities is even more acute today. One recommendation to help heal the country is to understand its physical geography and to think big; that is, to take people off of the limited amount of land in which they live and create space by establishing a 750-km-long corridor of development in the currently empty desert west of the Nile. This would stretch all the way from Sudan in the south to the Mediterranean coast in the north via an eight-lane superhighway. The water supply would come from the Nubian aquifers and Lake Nasser, Egypt's immense southern reservoir. Included in this idea is the Tushka Project, which exists to the west of the Aswan Dam and Lake Nasser, where the Tushka Depression is located (Fig. 1). The project involves diverting Nile water from the Tushka overflow basin, through a 360-kmlong canal, into the desert and four adjoining lakes (Fig. 1).

The Nubian aquifers underlie the region (e.g., El-Baz, 1988; Robinson et al., 2007). In these aquifers, groundwater resides in sandstone rocks (the Abu Ballas and Abu Simbel formations) that unconformably overlie basement rocks and are covered by alluvial and Aeolian Quaternary deposits. Structurally, the study area had been subjected to tensional forces especially East-West faults (extending up to 150 km in length) that have a strong influence and correspond with vertical or diagonal uplift of the basement rocks (Abdeen, 2001). Other fault sets are the E-W, NE-SW and NW-SE fault sets and have a less extensive influence on groundwater (Robinson et al., 2007).

Groundwater can exist in both a porous rock aquifer setting-where it is stored in the rock's primary porosity-or a fractured rock aquifer setting-where it is stored in the rock's secondary porosity (e.g., Bisson and El-Baz, 1991; El-Baz, 1995; National Research Council, 1996; Babiker and Gudmundsson, 2004). The two are likely to be hydraulically connected through fractures. The purpose of the current study is to understand both near-surface and deeper aquifer sources in the region. Deeper sources are favored as shallow near-surface reservoirs are relatively easy and inexpensive

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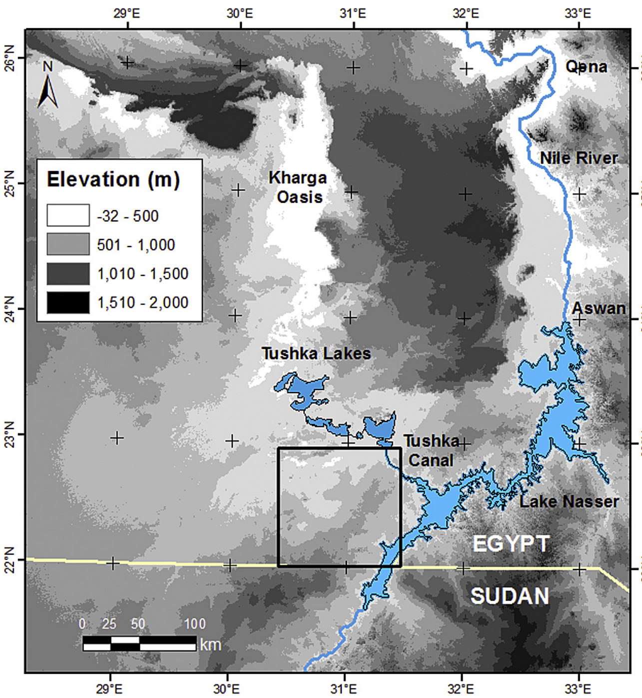

Fig. 1. Sketch map of the study area (delineated by the box) overlain on 90 m Shuttle Radar Topography Mission data. Place names mentioned in the text are labeled. In particular see the relative locations of Lake Nasser, the four Tushka Lakes and the Nile River.

to locate and tap, yet tend to be over-exploited, depleted and contaminated quickly. The deep aquifers, therefore, can provide an alternative, reliable and high quality groundwater resource for agricultural development. Deeper sources are likely to occur in a fractured-rock aquifer setting.

The view is that areas with enhanced groundwater accumulations represent the best locations for agricultural development, and deeper sources are the most sustainable. As such, the goal of the present study is to analyze the influence of structures on drainage; identify those structures recharged by groundwater, and in which groundwater resides or is transmitted; identify those structures and areas requiring field investigation and geophysical surveys. Ultimately, locations with enhanced groundwater accumulation can be determined.

Since most drainage and fractures are sand-covered and exist in the near surface in the area of interest (Fig. 1), innovative data sources are required for their detection. Radar and thermal imagery are used to determine those locations for field and geophysical surveys. The latter provides additional information about the subsurface distribution and relative water content of the faults, as well as aquifer depth. Working within a GIS allows the scale transformation between satellite and field data to be easily resolvable. Further, the techniques are guided, low-cost, nondestructive and noninvasive compared with exclusive drilling.

2. Data used

Radar data are principally used for the detection of near-surface features. Their role for this purpose is well documented (e.g., McCauley et al., 1982, 1986a, b; Robinson et al., 2000; Robinson, 2002). For instance, these data show that broad areas of the southwestern desert of Egypt are dissected by a dense fluvial network of palaeochannels, which are now dry (e.g., El-Baz and Robinson, 1997; Robinson et al., 2000; Robinson, 2002; Robinson et al., 2007). Much of the drainage is structurally controlled and this is considered to be a principle expression of fracture rock aquifers e.g., Bisson and El-Baz, 1991; National Research Council, 1996; Robinson, 2002; Robinson et al., 2007; Gaber et al., 2011, 2015). Surface water is once expected to have recharged the Nubian aquifers along these structures (e.g., Robinson et al., 1999, 2000, 2007). The depth of near-surface imaging varies according to the moisture content of the sand at the time of imaging and the wavelength used for imaging. Calculations by Schaber et al. (1997) favor penetration depths of 0.5 m for C-band Radarsat, with an increase at longer wavelengths and a decrease at shorter ones. Further, palaeodrainage can be discriminated preferentially at large incidence angles (e.g., Elachi and Granger, 1982) and scenes are selected according to this criterion.

The role of thermal imagery in providing information relevant to hydrogeology has also been studied (e.g., Pratt and Ellyett, 1979; Schmugge et al., 2002a,b; Wukelic et al., 1989). Thermal responses relate to physical properties of the surface in a similar manner to radar (Jensen, 2000 p.249); thus, it is conceivable that some near-surface imaging may be achieved at thermal wavelengths. This is also indicated by drainage observed in the thermal browse images of the AOI – that is not apparent in the visible bands (Fig. 2). On this basis, thermal data are also checked for mapping

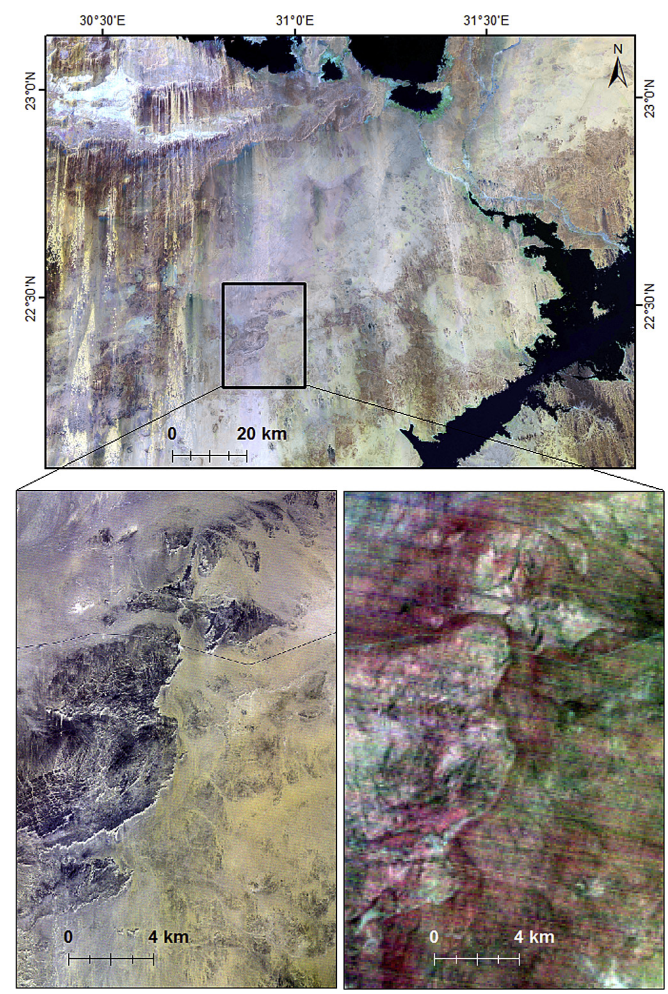

Fig. 2. ASTER browse images in the study area. On the left is the visible image and on the right is the thermal image. Drainage patterns are obvious as dark tones in the thermal image but are not clear in the visible bands. This may imply that thermal wavelengths image near-surface palaeochannels.

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