
Short Contribution: Buried Canopic Channel Identified Near Egypt's Nile Delta Coast With Radar (SRTM) Imagery

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Shuttle Radar Topography Mission (SRTM) data, with ground-based geologic investigations, define the geographic position of the relict Canopic channel in Egypt's NW Nile delta. Two sinuous channel segments south of Abu Qir Bay are observed on a radar image: a more sinuous trace (36 km in length) west of Idku lagoon, and an eastern one (~20 km), reaching the lagoon's southeast corner. Sediment cores recovered along channel traces show sand-rich deposits (to > 4 m thick) beneath the surface, in contrast with silty muds in areas away from channels. Historic and archaeological findings indicate that the Ptolemaic Roman city of Schedia once lay directly along the Canopic that channeled water from the 3rd to 2nd centuries B.C. until ~5th century A.D., after which Nile water was displaced to the east via Bolbitic and, later, Rosetta branches. Identification of buried, but well-defined, Canopic channels provides baselines for renewed archaeological exploration in this delta sector. © 2006 Wiley Periodicals, Inc.

INTRODUCTION

The Canopic branch once flowed across the NW Nile delta, playing a significant role in Egyptian history. This now-extinct Nile distributary was long used as a major commercial waterway in the delta and also served as the major source of much-needed freshwater for Alexandria, Egypt's prime city located in a desert ~25 km to the west. Historic documents and recent geographic and geologic investigations indicate that the Canopic channeled flow to the Mediterranean for nearly 4500 years, a longer time span than any of the other Nile branches (Toussoun, 1926; De Cosson, 1935; Said, 1981). Largest of relict channels, the Canopic remained active in this delta sector from early Dynastic in the 4th millennium until late Roman-Byzantine time in the mid-1st millennium A.D. (Bernard, 1970; Chen et al., 1992; Stanley et al., 2004). It was primarily through the Canopic channel that vessels entered the Nile delta proper for trade and exchange at ports, such as Schedia, ~28 km east of Alexandria, and at Naucratis, about 55 km south of the coast (Coulson and Leonard, 1979). Although long occupied by ancient Egyptians, the NW delta region between the ancient towns of Damanhur (Hermopolis Parva), Abu Qir (Canopus), and Rosetta (Rachid) is one where relatively few ancient settlements have been discovered (Figures 1–3).

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Although inactive during most of the past 1500 years, a long but incomplete stretch of the relict Canopic (Figure 1) has been identified on the Nile delta plain by aerial photographs and Landsat images (El-Shazly et al., 1975; Abdel-Kader, 1982; Frihy, 1988; IWACO, 1989). Recently, three offshore Canopic channel traces have also been detected seaward of the coast in Abu Qir Bay (Figure 2) by means of detailed bathymetric and geophysical surveys (Stanley et al., 2004; Goddio, 2006). However, examination of these and other available documents reveals a gap of nearly 12 km where the relict Canopic channel has not been traced between the lower delta (Figure 1) and offshore margin (Figure 2).

The present investigation examines the sector in which the defunct branch is absent using Shuttle Radar Topography Mission (SRTM) data. This technique is applied here to identify the former Canopic channel that flowed on the historically active lower delta plain margin south of its former mouth in Abu Qir Bay.

GEOGRAPHIC AND GEOLOGIC CONSIDERATIONS

Most of the Nile delta plain in the study area, from 20 km south of the coast to the Abu Qir Bay shore, has an elevation ranging from -1 (in the area of the artificially drained former Abu Qir lagoon) to $+1$ masl. This flood plain slopes imperceptibly seaward at 5–10 cm/km. Higher relief terrain include a series of small mounds, or koms, distributed south of Idku lagoon. While several range to ~ 16 m in elevation, most koms have been modified and substantially lowered by human activity, mostly during the past century. Until the two dams were emplaced at Aswan, the plain was subject to annual floods of the Nile, and extensive low-lying surfaces and depressions remained submerged for several months of the year.

The present population density in the study area ranges from 200 to 800 persons/km² (Sestini, 1992). The Idku marshland and shallow (< 1 m) brackish lagoon system, one of four remaining in the northern delta (Figure 1), is rapidly being converted to agricultural land. Its present open-water area is now reduced to less than 30% of its size of a century ago (Loizeau and Stanley, 1993). Much of the surrounding low-lying land is subdivided into small fields that are entirely dissected by closely spaced irrigation canals and drains of small to large (> 10 m) width. Canal orientation and spacing are highly variable, with those of moderate to large width spaced only several hundreds of meters apart.

Mean annual precipitation near the delta coast is 200 mm, with mean potential evapotranspiration rates ranging from 600 to 1100 mm/year. The Abu Qir Bay coast is affected by a low tidal range (20–40 cm), and strong wave-driven currents (20–50 cm/s, occasionally to > 100 cm/s) along the coast (UNDP/UNESCO, 1978). Winter storm wave surges (to 2 m in height) are driven landward by winds, primarily from N and NW quadrants (Sestini, 1989). Nile floods, along with storm surges, earthquake tremors, and tsunamis, have triggered episodic mass failures and lowering of water-saturated Nile sediment along the coast and in the bay (Guidoboni, 1994; Stanley et al., 2001, 2004).

The configuration of the study area changed markedly during the Holocene, as sea level rose and land subsided (Stanley and Warne, 1998). Sediment-core analyses indi-

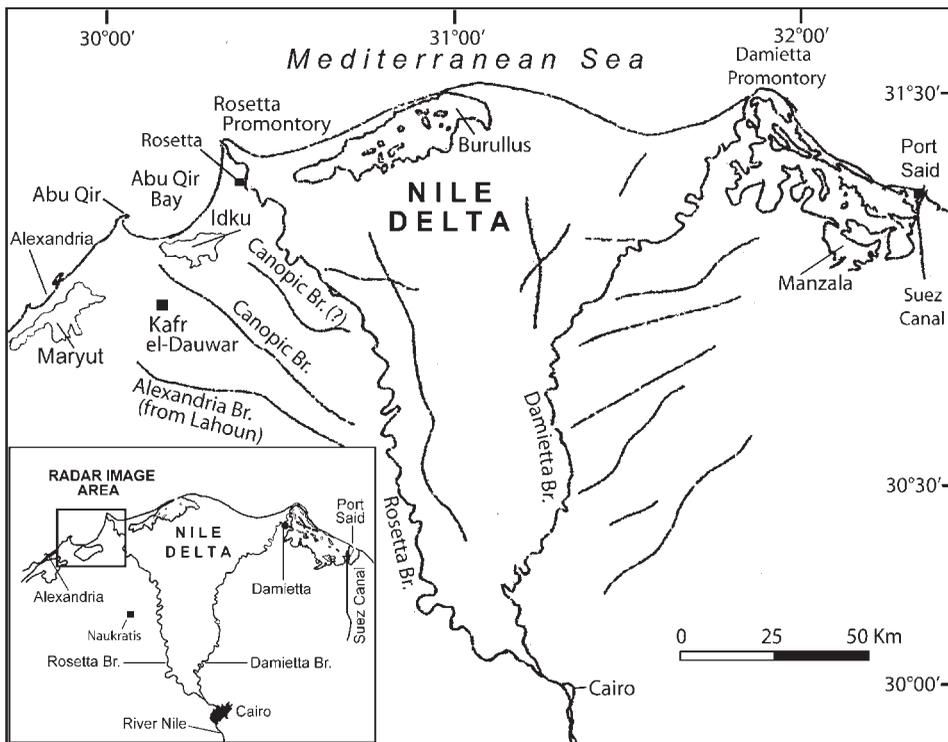


Figure 1. Map of the Nile delta based on Landsat images, showing the active Rosetta and Damietta branches of the Nile and traces of relict Nile distributaries, including those of Canopic channels that once flowed in the northwestern delta (after Abdel-Kader, 1982).

cate that thicknesses of the Holocene sequence south and west of Idku lagoon range to 30 m and include variable proportions of shallow marine, bay, coastal, lagoonal, marsh, river channel, and flood overbank facies (Chen et al., 1992). This Holocene cover is, in effect, only a thin veneer above the > 5000 m of underlying sedimentary sequences of Tertiary and Mesozoic age (Schlumberger, 1984). Much of the land area has subsided because of sediment compaction of Late Quaternary deposits and isostatic depression of thick underlying older strata. Core analyses of radiocarbon-dated Holocene sections indicate that the delta margin north of a coast-parallel flexure zone is still subsiding at rates to > 4 mm/year (Stanley and Warne, 1998). This lowering has provided substantial accommodation space for the rapid accumulation of sediment and consequent burial of archaeological sites (Stanley et al., 1992).

THE MISSING CANOPIC TRACE

Among the major physical and historically significant characteristics of the Nile delta are the vein-like leaf patterns and seaward-trending distributary channels (Coleman,

1982). These Nile channels migrated laterally across the broad delta floodplain, distributing their sediment load widely between the main feeder fluvial channel and the coast, and giving rise to the characteristic Δ -fan shape and three-dimensional architecture of this delta system (Toussoun, 1926; Said, 1981; Sestini, 1989). Each branch periodically altered its geographic position by avulsion, deserting its older channel and assuming a new course at a lower elevation on the floodplain (Törnqvist, 1994). This phenomenon resulted from the interplay of sediment depositional processes modified by a diverse set of controlling factors, including climatic, hydrologic, geographic, coastal marine, and tectonic elements. Another factor of major importance in recent time is human activity, which has completely altered the delta-plain surface (Stanley and Warne, 1998). Of significant note have been the (a) building of dams, barrages, and very closely spaced irrigation canals, (b) intensification of agricultural activity, and (c) marked reduction of the flow of Nile water distributed across the delta plain.

Nile channels once extended much farther northward, to and across the Egyptian shelf as recently as the latest Pleistocene, at the time when world (eustatic) sea level was much lower. In the NW delta, these channels were then linked with the Rosetta submarine channel and canyon system on the Nile Cone (Ross and Uchupi, 1977; Bellaiche and Mart, 1995). Bathymetric and geophysical exploration just seaward of the coast in Abu Qir Bay revealed several Canopic channel traces that trend north to now-submerged settlements (Herakleion, Eastern Canopus) on the Canopic promontory (Figure 2; Stanley et al., 2004; Goddio, 2006). Seismic surveys have shown that these recently discovered channels once extended at least 6 km north of the present bay shoreline (Figure 2). Evidence for this seaward prolongation of channels is also indicated by sediment cores recovered landward of the coast and in the bay (Chen et al., 1992; Stanley et al., 2004).

In the Nile delta plain proper, however, the now-defunct Late Holocene Canopic channel can be traced northward only as far as Idku lagoon. Various studies have suggested that the missing Canopic channel segment extended across several possible areas between the northwestern delta plain and offshore Abu Qir Bay. Some propose flow to the west of the Idku wetland (De Cosson, 1935; El-Bouseily and Frihy, 1984; El Fattah and Frihy, 1988; Frihy, 1988; Chen et al., 1992); others suggest flow across the sector now occupied by the Idku lagoon (Frihy et al., 1995). The course of the Canopic in this sector was abandoned as Nile waters shifted eastward and were channeled by the Bolbitic (Bolbitine) branch (Toussoun, 1926) and then almost entirely by the Rosetta branch in the 4th–7th centuries A.D. The latter was artificially modified and, in recent time, has received as much as 70% of Nile water flowing north of Cairo (Said, 1981).

SRTM BACKGROUND AND METHODOLOGY

The Shuttle Radar Topography Mission (SRTM) was designed to acquire high-resolution digital topography data of the earth. Launched on February 11, 2000, this mission (STS-99) was a collaborative project between National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA), along with the German Space Agency (2000) and the Italian Space Agency (2001).

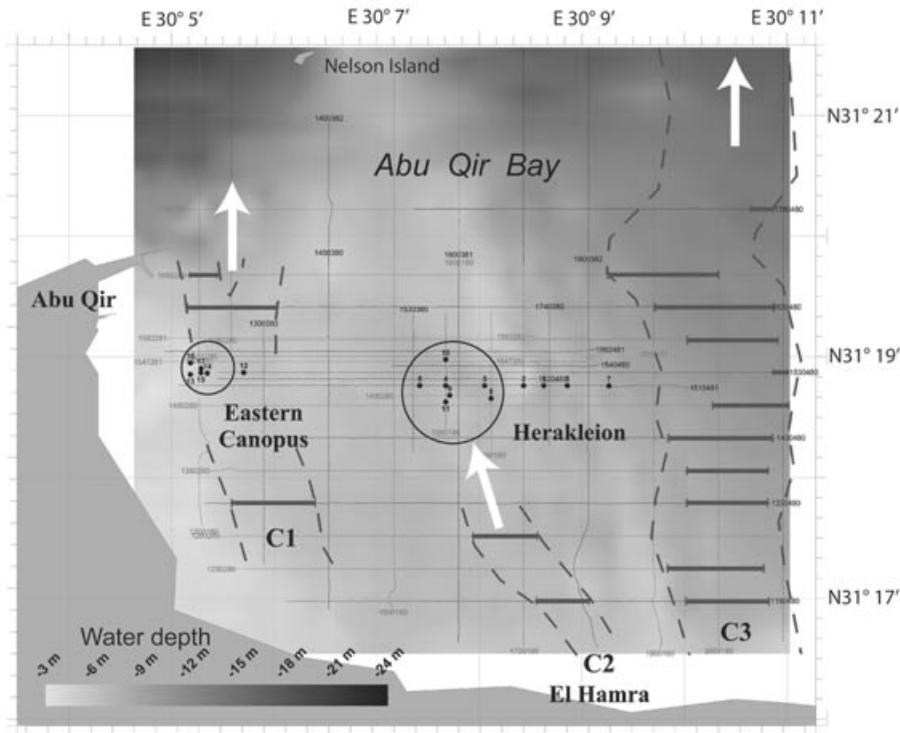


Figure 2. Closely spaced high-resolution seismic survey lines and sediment cores (dots) reveal three former north-directed Canopic channels (see arrows) in western Abu Qir Bay (after Stanley et al., 2004).

Mapping was carried out using the Shuttle Imaging Radar-C and X-Band Synthetic Aperture Radar (SIR-C/X-SAR) at an orbital altitude of 225 km (Johnson Space Center, 2000). SRTM used a technology called imaging radar, also known as radar interferometry (Farr and Kobrick, 2000; Rosen et al., 2000). This method compares two radar images taken at slightly different positions to obtain elevation or topographic information. The two radar images are taken at the same time (called single-pass interferometry), with one image taken from a radar antenna in the shuttle's payload bay and the other from a radar antenna at the end of a 60-m (197 foot) mast extending from the shuttle. Each antenna transmits and receives radar signals using the SIR-C Band (5.6-cm wavelength) and X-SAR Band (3.1-cm wavelength). The synthetic aperture radar is a side-looking instrument that obtains data along a continuous swath of land. The C-Band radar mapped a 225 km (139 mile) wide swath per orbit, and the X-Band radar mapped a narrower 50 km (31 mile) wide swath per orbit (Jet Propulsion Laboratory, 2005). The synthetic aperture radar sends out pulses of microwave energy towards the earth and measures the strength and amount of time it takes for the antenna to read or acquire the

energy scattered back to the antenna. Calculations based on the differences between these images derive the surface elevation information (Smith and Sandwell, 2003). SRTM data uses the WGS84 EGM96 geoid as the geodetic reference (National Geospatial-Intelligence Agency, 2004).

Because radar wavelengths are much longer than visible or infrared light wavelengths, this form of synthetic aperture radar can be used to map the earth's surface in cloudy or hazy conditions at any time of the day or night (GeoCommunity Spatial News, 2005). The SRTM image in Figure 3 is a cropped subset of larger, rectified, terrain-corrected images (N31E029.hgt and N31E030.hgt) and has a nominal resolution of 1 Arc Second (30 m). This data was collected in 1 degree by 1 degree latitude and longitude "cells" and processed at the Jet Propulsion Laboratory (JPL) in Pasadena, California.

OBSERVATIONS

The radar image, incorporating the area between 31° 01' and 31° 31' N latitude and 29° 46' and 30° 33' E longitude, reveals two sinuous channel-like traces of interest in the study area (Figure 3a). The more distinct one to the west extends sinuously from south of the small town of Abu Hummus toward the NW, along the western margin of Idku lagoon to El Hamra on the western Abu Qir Bay coast (Figure 3b). The straight-line distance from SE to NW points of the Canopic channel on the SRTM image in Figure 3a is 27 km; the total distance along the meandering trace is 36 km. The elevation of the SE point observed on the image lies at +1 masl.

At least 6 bends (or the equivalent of three full meanders as normally defined; cf. Leopold et al., 1964) are observed along the trace, with an average meander amplitude of 1.0–2.5 km and meander length of ~5 km. The channel trace follows paths of currently existing canals and is locally controlled by higher-relief kom features. Only one short (5.5 km) E–W segment parallels the large el-Mahmudiya Canal built to channel Nile water to Alexandria. However, most stretches of the sinuous trace on the radar image follow smaller canals (Defense Mapping Agency, 1977). At its northern end, the channel fans out indistinctly near the Abu Qir Bay coast. From SE to NW, the channel on the image traces the following features (see arrows and numerical codes on Figures 3, 4): (1) el-Rizga Canal, (2) el-Mahmudiya Canal, (3) el-Nasiri Canal, (4) el-Karyun Canal, (5) el-Kanubiye Canal, and (6) el-Wasla el-Raislya Canal.

A separate second, somewhat less distinct, channel-like segment is observed > 7 km to the east (Figure 3a). This less sinuous feature extends to the NW for a straight-line distance of ~20 km from the town of Damanhur (ancient Hermopolis Parva) toward the SE corner of Idku lagoon (Figure 3b). The trace separates into two segments, both of which follow canals farther to the NW that now extend toward the southeastern margin of the once much larger Idku wetland. The channel path is traced NW of Damanhur along the Bisintawai Canal (7); an eastern segment then follows the el-Dakhia Canal (8), while the western one extends to the vicinity of the Sabah el-Kheir Drain and el-Hammami Canal (9). The traces become indistinct in the Idku wetland, about ~12 km south of the bay.

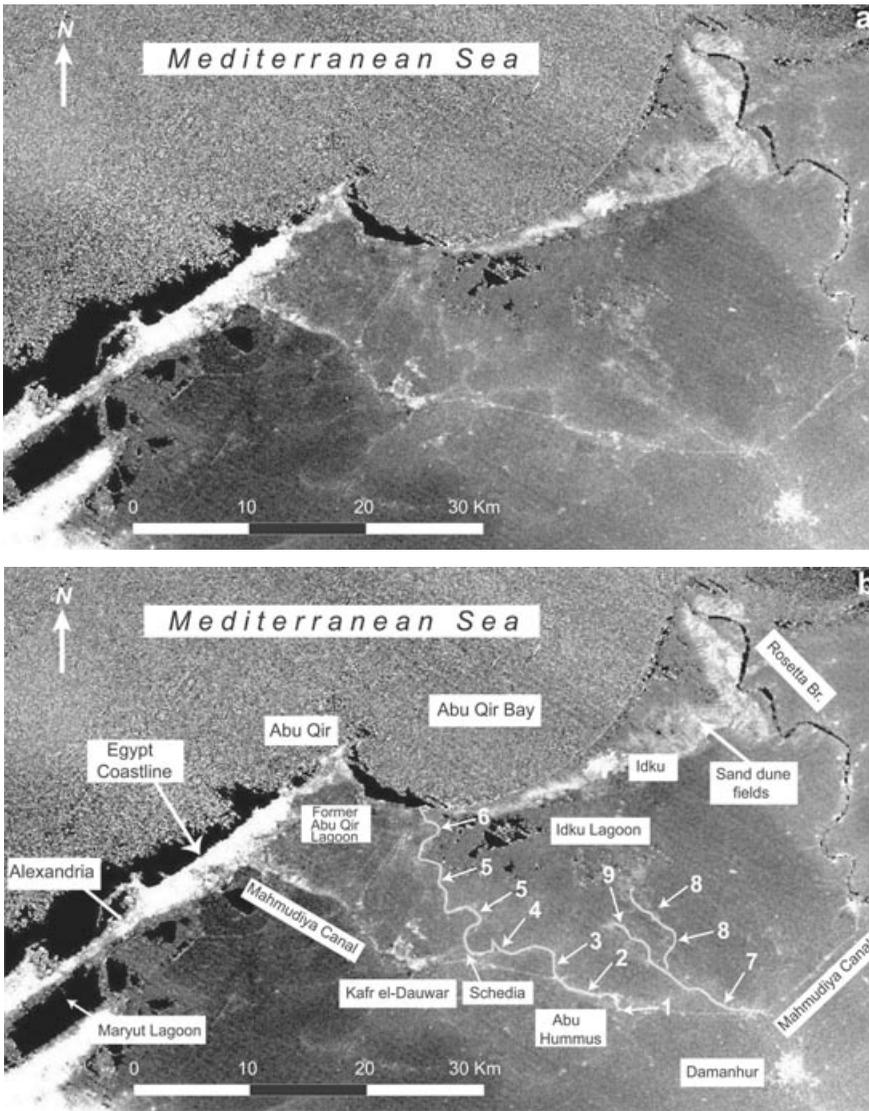


Figure 3. (a) Radar (SRTM) image showing northwest Nile delta area between Alexandria and the Rosetta branch. (b) Same image on which geographic features are indicated, including two channel segments of the relict Canopic branch described in the study. The region around Alexandria has been processed to distinguish the coastline from the sea, visible on images as speckled 'rough texture.'

DISCUSSION

The western, more sinuous trace appears to have extended into what is now the western part of Abu Qir Bay and is interpreted here as one of the most recent channeled segments of the Canopic. It has been determined that the Canopic extended

northward to the town of Herakleion (Figure 2) as recently as the 1st century A.D. (Goddio, 2006) and to Eastern Canopus until the 7th century A.D. (Bernand, 1970; Stanley et al., 2004); at those times, the settlements were still above sea level on the delta margin north of the present bay shoreline. Following several important phases of submergence during the past 2000 years, the bay's coastline retreated southward by ~5 km to its present location. This landward shoreline shift, at an average rate of ~2.5 m per year, resulted largely from combined effects of sea-level rise and lowering of land by compaction, isostatic depression, and sediment failure.

It is postulated that the channel-like segments observed on the radar image are visible due to sediment textural changes coupled with variation in soil moisture content. Sediment cores as well as the time when the radar image was acquired (February 2000, during the winter rainy season) provide ground truth in support of this interpretation. Although the two channel-like features follow existing canals, core analysis in the immediate vicinity suggests that the sinuous features are likely visible because they trace partially sand-filled segments of the Nile's once-active lower Canopic branch. These natural channels used preexisting natural floodplain surfaces of low elevation; the modern canals currently flow above the relict Canopic traces. Evidence for this interpretation is found in Smithsonian cores S-70 (length 19.8 m) and S-72 (length 19.8 m) recovered directly on the western channel trace, along the el-Kanubiya Canal and located, respectively, ~4 and 10.5 km north of Schedia, core S-71 (length 44.2 m) ~2 km east of El-Hamra (Figure 4), and core S-67 (length 19.8 m) recovered close to the eastern channel (Figure 4).

Samples collected from the upper sections of these 4 borings, radiocarbon-dated at less than 3000 years before present and lying a few meters below the present surface (Stanley et al., 1996), comprise a large proportion of silty sand (sand fraction to > 70%). In contrast, the upper sediment layers recovered away from the channel traces (e.g., core S-69 between the two channel segments) comprise higher proportions of finer-grained silty mud and a lower sand content (< 10%); such sections may perhaps be characterized by a lower moisture content than sandy ones at shallow depths beneath the delta plain surface.

Additional field data also suggest that the observed channel-like traces once were those of the Canopic in the sector west of Idku lagoon. It has been noted that heavy mineral content in sands and coarser-grain sizes of samples collected north of Idku lagoon and just off the coast in Abu Qir Bay indicate the position of the former branch mouth (El-Bouseily and Frihy, 1984; El Fattah and Frihy, 1988).

Also pertinent with respect to interpreting the Canopic traces observed here are results from recent exploration efforts (1980–1992, 2003–2004) at the site of the Ptolemaic Roman city of Schedia that once directly bordered the western channel segment identified in this study (Figure 3c). Schedia, a commercial center, was strategically placed at this locality where freshwater from the Canopic could be readily transferred to Alexandria via a canal. Here also, goods transported in large vessels sailing on the Canopic were transferred onto shallow draft boats for transport to the city via the canal (Strabo, 1932; Bergmann and Heinzelmann, 2003). Neither Schedia, its ancient canal, nor the Canopic channel is visible at ground surface today, and what remains is a result of intense rural activity and human modification.

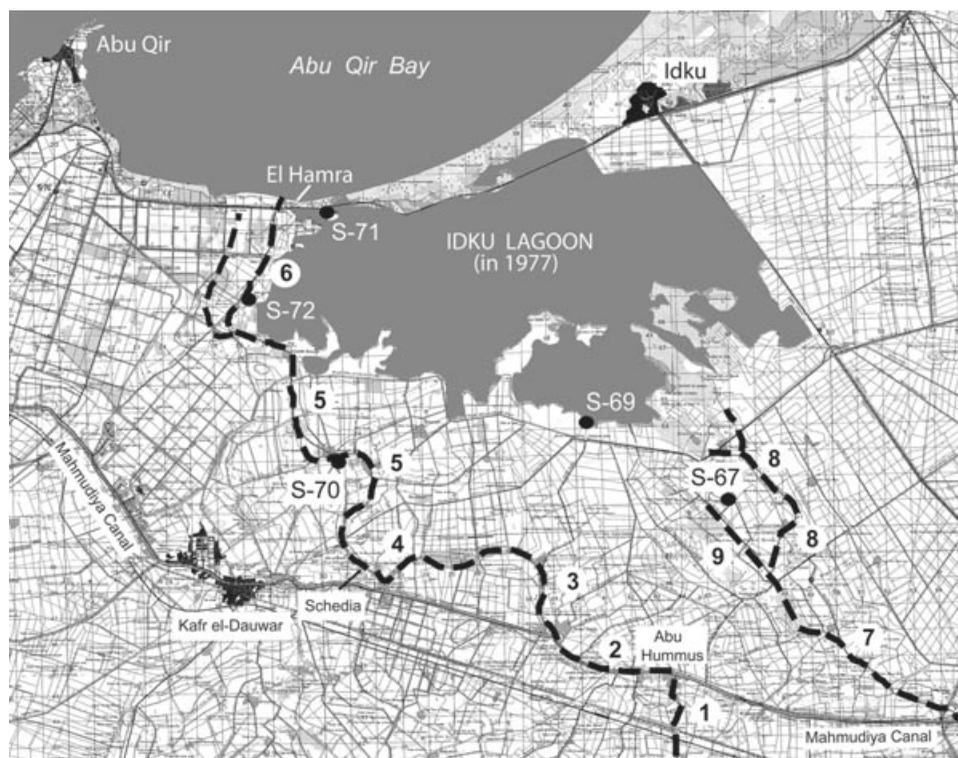


Figure 4. Map, based on Defense Mapping Agency (1977) topographic sheets, showing position of two segments of the Canopic observed on the radar image in Figure 3. The relict channels follow canals coded (1) to (9) and identified in text. Also depicted are four cores (S-67, 70–72) positioned along the two silty sand traces discussed in text, and one core (S-69) collected in a silty mud area in between.

Moreover, the shallow groundwater level in this region makes excavation difficult. Nevertheless, a recent geophysical (geomagnetic) survey indicates the course of the Canopic Nile branch was positioned immediately adjacent to dwellings discovered at the site (Bergmann and Heinzlmann, 2004).

The approximate age of the Canopic channel at this locality can be determined based on archaeological finds at Schedia. The town's early history is dated to the 3rd and 2nd centuries B.C., with later municipal expansion during the Roman imperial period. Schedia appears to have decreased in importance by late Roman and Byzantine times, further declining in status until it was partially abandoned during the 4th or 5th century A.D. It is estimated that during this period, spanning nearly six centuries, the Canopic along this channel sector remained an active to partially flowing Nile distributary. Based on their field survey, Bergmann and Heinzlmann (2003, 2004) indicate that the channel, with a possible width of ~250 m, became completely filled with sand-rich sediment. Their geomagnetic surveys and shallow excavations in this agricultural area reveal the presence of habitations and the course of the Canopic Nile now

buried beneath one to several meters of reworked sediment. Sithsonian core S-70 north of the site (Figure 4) indicates that the Holocene cover and sandy channel body is 4 m in thickness (log of boring in Stanley et al., 1996). Channel segments near Damanhur, farther to the east, may also represent traces of subsequent channeled Nile water, perhaps in a younger east-displaced Canopic (Figure 1) or Bolbitic branch.

CONCLUSIONS

The Canopic channel segments identified south and west of Idku lagoon functioned for nearly six centuries, from the 3rd to 2nd century B.C. to perhaps as late as the 5th century A.D. During much of this period, this distributary was the prominent navigational and trade route in the delta and a major freshwater source for Alexandria. Given the cultural history of the region, it would be expected that such an important waterway would have been bordered, at least locally, by habitations. However, records of documented archaeological sites in this northwest delta study area (Fraser, 1972; Egypt Exploration Society, 2005) indicate few finds and no substantial settlements prior to the Islamic period, other than Schedia, positioned along the channel traces identified on the STRM image.

It is likely that the archaeological record located along these stretches has now been, for the most part, dismantled, modified, concealed, and/or rapidly buried by accumulating sediments and centuries of intense reworking by agricultural activity and village development. The information on the buried, but well-defined, positions of Canopic channel segments will now provide a novel baseline with which to renew archaeological efforts in this sector of the northern delta.

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