

Submergence and burial of ancient coastal sites on the subsiding Nile delta margin, Egypt

Submersion des sites littoraux le long de la marge deltaïque subsidente du Nil, Égypte

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Abstract – Ancient sites originally positioned along the Nile delta's coastal margin are used as gauges to measure effects of «eustatic» sea-level rise (~1 mm/year) and land lowering (= subsidence) of the sediment substrate beneath settlements during the late Holocene. The combined effect of these two factors, referred to as relative sea-level change, resulted in submergence and/or burial of the base of most sites along the delta at variable rates exceeding 1 mm/year. Based on these factors, submergence of sites to depths of 5-7 m is recorded in Abu Qir Bay off the NW delta; higher values (lowering to 5 mm/year) are recorded along the NE corner of the delta. Variations of substrate topography laterally along the delta margin are caused by differences of seismicity, isostatic depression, and sediment compaction and remobilization that affect underlying deposits. Geologically recent lowering of the northern Nile delta plain surface is comparable to that of many world delta margins.

Résumé - Les anciens sites archéologiques localisés le long du littoral du delta du Nil sont utilisés comme indicateurs des variations relatives du niveau de la mer. L'effet combiné d'une montée d'origine «eustatique», estimée à environ 1 mm/an, et de la subsidence aboutit à l'immersion et/ou à l'enfouissement de la majorité des sites archéologiques. Au nord-ouest du delta, nous avons retrouvé des vestiges archéologiques entre 5 et 7 mètres de profondeur dans la baie d'Abu Qir. La vitesse de mobilité relative dépasse donc 1 mm/an. Au nord-est du delta, cette vitesse peut aller jusqu'à 5 mm/an. Elle est liée à des variations structurales sous la marge deltaïque, qui sont à mettre en relation avec différents types de mobilité crustal isostatique, séismique, compaction différentielle des sédiments... L'affaissement de la marge deltaïque septentrionale du Nil est tout à fait comparable à celui de nombreux autres deltas dans le monde.

Introduction

This study compares the elevation of ancient coastal sites along Egypt's Nile delta with present mean sea level (MSL) of the Mediterranean to detect long-term nearshore changes during the late Holocene. The settlements considered here (Greek/Ptolemaic and Roman to Byzantine and early Arabic) were, for the most part, constructed at, or near, the delta's coast between ~2500 and 1300 years ago. A regional survey of these delta coastal sites could perhaps show the extent to which the

base of settlements (occupation horizon) has been stable through time or are now submerged beneath waves and/or buried by sediment.

Previous geological and archaeological investigations indicate that the Nile delta margin has experienced submergence during the mid- to late Holocene and, according to some, this phenomenon continues at present (SESTINI, 1989; STANLEY & WARNE, 1998). Coastal lowering has been attributed to the broad world (= eustatic) rise in sea level and concurrent, but more locally controlled, lowering of land (= subsidence) on the outer delta margin. Factors influencing the latter are

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seismicity, isostatic depression and sediment compaction and remobilization of underlying deposits. Geologists generally concur that, as in the case of many of the world's Holocene deltas, combined effects of sea-level rise proper and more-locally controlled land motion, referred to as relative sea-level change, have modified this margin.

However, an alternative hypothesis has also been proposed, one emphasizing stability of the Nile delta margin and questioning whether there has been any subsidence at all. This is based on the following propositions (SAID, 1993, p.77-78): (1) several early archaeological sites are still visible in the northern delta; and (2) the delta's underlying core comprises largely sand

and gravel not subject to compaction and consequent lowering. Of the two opposing postulates, the one favoring margin subsidence would have potentially more serious ramifications for projected archaeological exploration along the Nile coast and also for current municipal and industrial development and construction along this vulnerable low-lying delta margin. Thus, renewed focus on this topic is warranted to help better assess the contrasting subsiding versus fixed margin hypotheses. Where noted herein, changes relative to present msl are interpreted in light of geographic, sedimentological, and neotectonic considerations.

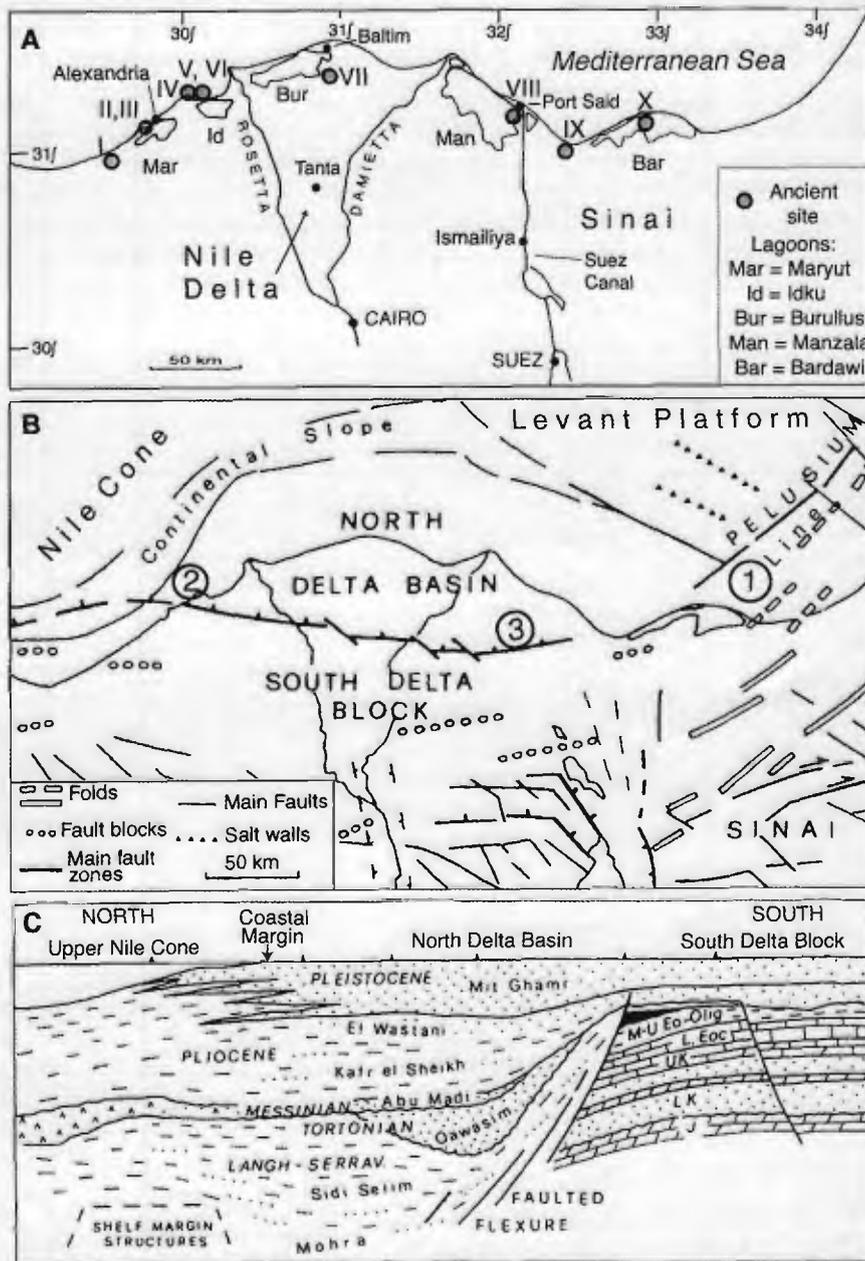


FIG. 1 - SITE LOCATIONS AND GEOLOGIC FRAMEWORK

A. Archaeological sites in (V-IX) and adjacent to (I-IV, X) the Nile delta shoreline and coastal lagoons discussed here.

B. Structural framework of NE Egypt (after SESTINI, 1989).

C. Cross-section from S-to-N showing Quaternary deposits above thick Tertiary and Mesozoic sequence (after SESTINI, 1989).

1. Background information

The Nile delta comprises a plain surface of ~22,000 km² and its northern margin is defined by an arcuate, largely wave-cut coast extending from east of Alexandria for 225 km to the sector east of Port Said and the Suez Canal (Fig. 1A). Tidal range is low (to ~30 cm). Moderate to strong coastal currents on the inner Nile shelf, with velocities ranging from ~20-100 cm/sec, are directed eastward. These currents, and winter storm waves with heights ranging from 1.5 to 3 m driven from the northern quadrant, result in a 2.5 to 7 km-wide zone of sediment erosion along the coast. Currents along the shoreline and inner shelf are responsible for displacement of silt and sand along the north Sinai and Levant margins (SESTINI, 1992).

Major tectonic constraints include the active Pelusium strike-slip fault system that trends NE to SW and clearly defines the eastern margin of the Nile delta (Fig. 1 B,1), and episodically active normal faults at Alexandria, the sector that abuts the NW delta margin (Fig. 1 B,2). Moreover, a major E-W trending fault system mapped at depth has divided the delta into southern and lower northern delta blocks (Fig. 1 B,3). South-to-North trending geological sections (SCHLUMBERGER, 1984; SESTINI, 1989) record a thin (<50 m) unit of Holocene deltaic strata (Bilqas formation, primarily silts and clays) that covers a wedge of sand- and silt-rich Quaternary deposits (Mit Ghamr formation). Beneath the delta shore,

these sediments overlie the thick sequence of Pliocene, Messinian (El Wastani, Kafr el Sheikh, Abu Madi), and older Tertiary and Cretaceous formations (Fig. 1C).

Nile distributaries that deposited the largely silt strata over the delta during the Holocene have been defined (TOUSSOUN, 1922; STANLEY & WARNE, 1998). Of specific interest here are detailed stratigraphic analyses that depict Holocene sections forming the low-lying northernmost 30 km of delta. Type sections of the Holocene and uppermost Pleistocene in the central, NW and NE delta, based on more than 100 borings drilled to depths of 20-60 m (STANLEY *et al.*, 1996), are shown (Fig. 2). Chronostratigraphy for these cores is determined by means of >300 radiocarbon dates (STANLEY *et al.*, 1996). These indicate that the delta began from 8500 to 7500 years before present, a time when the rate of rise of sea-level began to decelerate. The thickest Holocene sections (to ~50 m) accumulated in the NE delta sector, near Port Said, during the past ~7500 years. It is in this area that accommodation space (the depressed/lowered land surface upon which sediments accumulate) has been the greatest during the Holocene. Sediment accumulation rates due to both eustatic sea-level rise and lowering of land surface (relative sea level) along the delta margin ranges from minimal (<2 mm/yr) west of the delta margin proper (west of Canopus, ~20 km east of Alexandria), to a maximum (~5.0 mm/yr) in the vicinity of Port Said (STANLEY, 1990).

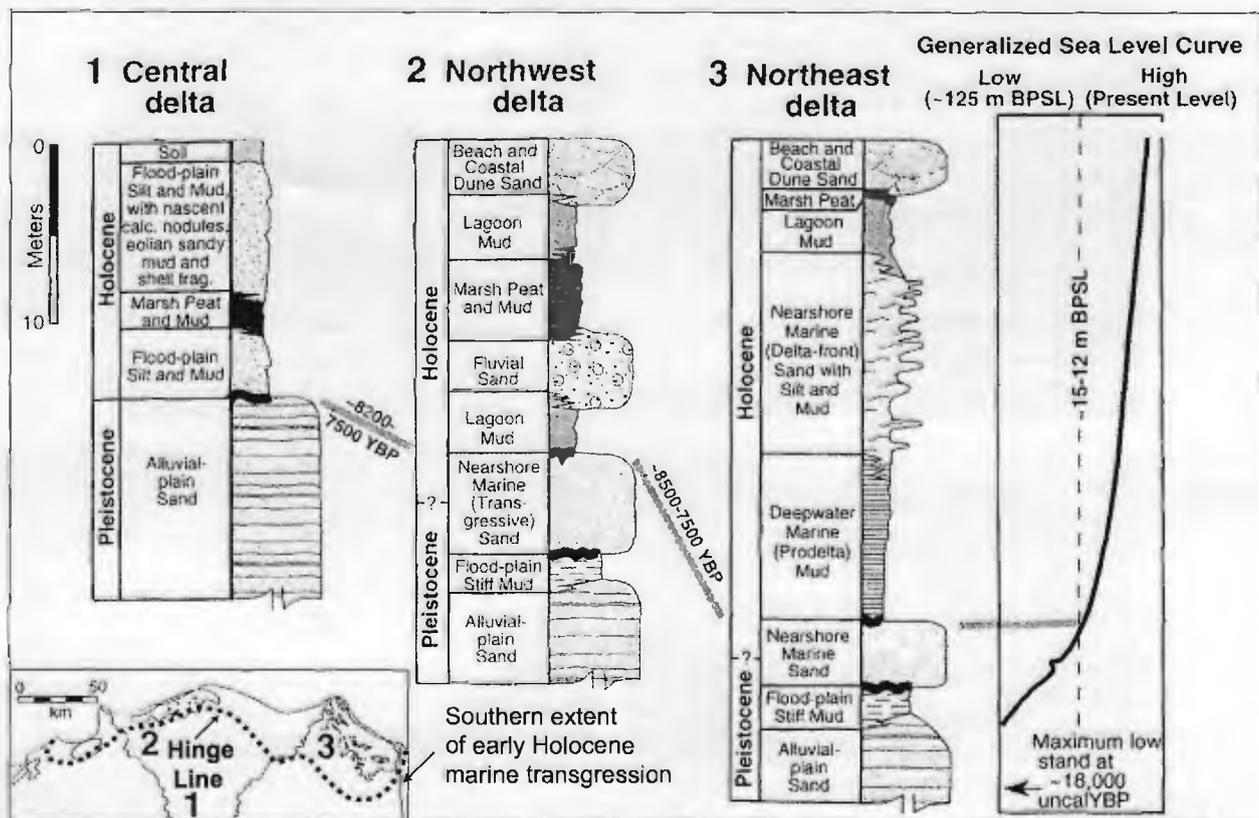


FIG. 2 - LATE QUATERNARY TYPE SECTIONS IN THE CENTRAL, NW AND NE NILE DELTA.

High rates of sediment accumulation in sectors of important subsidence are shown in the NE delta by thickened Holocene section at (3) and North of the hinge line in the northern delta (after STANLEY & WARNE, 1998).

Much information is available on Nile river history and hydrology (SAID, 1993; SUTCLIFFE & PARKS, 1999). Major control of Nile flow in the XIXth century (barrages, large irrigation canals), and emplacement of Lower and High Dams at Aswan in the XXth century, profoundly altered the depositional regime at the delta coast. Floodwaters that seriously impacted the lower Nile valley and delta once each year (late summer and fall) are now

contained in Lake Nasser at the Sudan-Egyptian border. Since closure of the High Dam, Nile water is released more regularly throughout the year to the lower valley, with much reduced loss of fresh water to the Mediterranean. Most Nile water flowing in the delta is now diverted to lagoons by way of artificial irrigation canals and sewage drains; only small amounts of fluvial and deltaic sediments (<10% of former Nile load) are

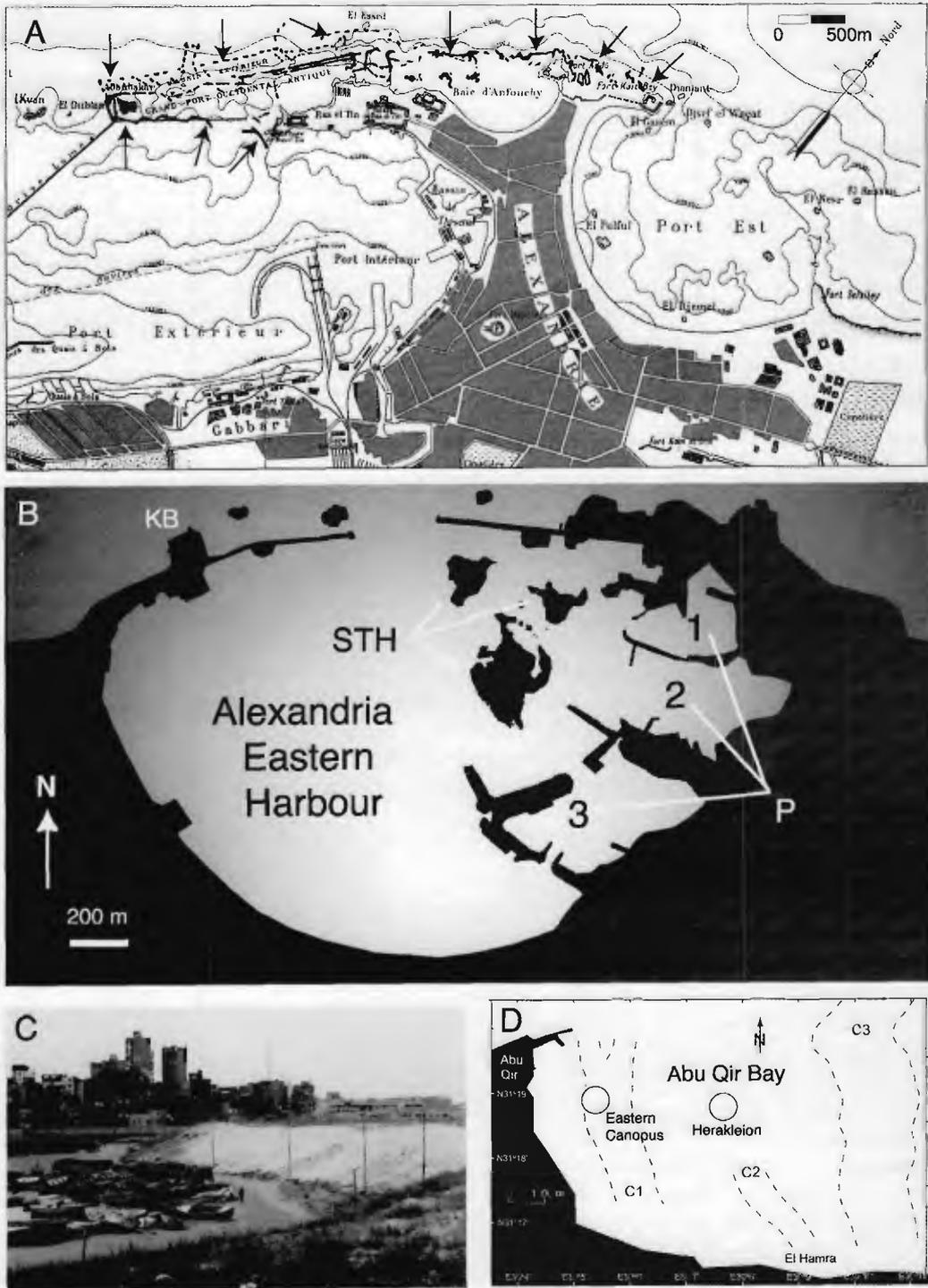


FIG. 3 – ALEXANDRIA AND ABU QIR SITES

- A. Site II, submerged structures (see arrows) in Anchoufy Bay and NE sector of Alexandria's Eastern Harbour (after JONDET, 1916).
- B. Site III, submerged royal quarters, 3 ports (P), and small topographic highs (STH) in Alexandria's Eastern Harbour (after GODDIO *et al.*, 1998).
- C. Canopus (modern Abu Qir) where some coastal features (site IV) on kurkar limestone base are now submerged.
- D. Sites V and VI, eastern Canopus and Herakleion, once along the Nile's Canopic channels and near the coast, now lie at depth (5 – 7 m) in Abu Qir Bay (after STANLEY *et al.*, 2004).

delivered to the coast. As a consequence of this artificial water diversion and reduction and associated phenomena (locally increased coastal erosion, pollution, salinization), the Nile delta has now entered its destruction phase, *i.e.* the former depocenter has been altered to the extent that it is no longer a functioning delta but, rather, a subsiding and eroding coastal plain. Background information on these topics is available in published syntheses (SESTINI, 1989; SAID, 1993; STANLEY & WARNE, 1998).

2. Sites on delta coastal margin proper

2.1. Abu Qir Bay

Abu Qir Bay lies ~20 km ENE of Alexandria, and its western margin is delineated by the carbonate peninsula on which the ancient Greek settlement of Canopus (modern Abu Qir) was built. Two cities built by the Greeks in Ptolemaic time (Fig. 1A, site V, Eastern Canopus; site VI, Herakleion) have recently been rediscovered at depths of 5 to 7 m in the bay off the NW Nile delta (GODDIO *et al.*, 2004). Each site was originally settled near channel mouths of the Nile's Canopic branch (Fig. 3D). They were established as trading and toll centers through which ships had to pass to enter the delta. Herakleion was partially submerged by the first century CE, while activity at Eastern Canopus continued, albeit in much reduced fashion, until about the mid-VIIIth century CE (following Arab occupation). Progressive relative sea-level rise, caused by depositional failure and sediment remobilization associated with Nile flooding and perhaps seismicity, was in large part responsible for lowering and submergence of the cities that had originally been positioned near the channel outlets (STANLEY *et al.*, 2004). The long-term rate of relative sea-level rise has been >3.0 mm/yr during the past 1300 years, since Eastern Canopus was submerged (STANLEY *et al.*, in GODDIO *et al.*, 2004). As the delta margin subsided during the past ~2500 years, the Abu Qir Bay shore migrated to its present position about 5 km south of the original coastline.

2.2. MEDIBA site

The MEDIBA site (Fig. 1, VII), located on the eastern shore of Burullus lagoon and ~16 km south of the town of Baltim on the north-central margin, was discovered as a result of the Smithsonian coring program (WARNE & STANLEY *et al.*, 1993). Abundant archaeological materials in core S-44, mostly pottery fragments, were found in original stratigraphic position (Fig. 4, A). Lithostratigraphic analysis indicates that the site was originally settled during the late Holocene along a protected brackish-water lagoon similar to those now formed in the northern delta. Archaeological dating showed that material ranged from New Kingdom (1600-1500 BCE) at core depth of ~9 m, to Ptolemaic (300-0 BCE) at ~2m beneath ground surface. This site was seasonally flooded by the north-flowing Sebennitic branch

of the Nile, and its subsequent burial by sediment is attributed to long-term subsidence rates of 1.0 to >2.0 mm/yr on the northern delta plain surface.

2.3. Tel Tennis

Tel Tennis (or Tinnis or Thenessus) is a former commercial town and seaport located on a low-lying sand island ~6 km due west of the Suez Canal and 5 km south of Port Said (Fig. 1A, site VIII). Its present surface elevation is little more than 1 m above present water level in the northeastern sector of Manzala lagoon (Fig. 4, B). The few remaining archaeological vestiges, including tombs and cisterns, lie between the present sand surface and depths below the lagoon surface. Excavations undertaken thus far posed challenges due to the shallow water table. Some archaeological materials collected at this locality and in the adjacent region over the past century, now in Cairo and other museum collections, are interpreted as dynastic in age. However, some of this old material is now interpreted as having been displaced and reused to adorn sites in the Thenessus/Tennis sector and elsewhere in post-Dynastic time. While there are partially buried ruins and tombs of the Roman era, most material recovered in the upper several meters of strata is of Coptic and Islamic age. Ongoing archaeological surveys indicate that there is little autochthonous material that can be dated earlier than the VIth century CE (Dr. A. L. GASCOIGNE, Cambridge University, 2003, personal communication). The present island in the shallow (<2 m) lagoon is the eastern extension of a former NW-SE trending coastal sand ridge of late Holocene age. The ridge on which Tennis was built once sealed an earlier lagoon setting from the sea (COUTELLIER & STANLEY, 1987); it is similar in make-up to the modern ridge (~5 km to the north) on which the city of Port Said has recently been built. Engineer borings indicate that the upper sand layer is a 3-4 m-thick cushion lying upon a thick sequence (>40 m) of soft compressible mud (STANLEY *et al.*, 1996; Mr. D. WELCH, 2003, personal communication). All that remains of this relict coastal sand ridge is a series of islands that have been subject to erosional effects due to relative sea-level rise (to >5.0 mm/year). At this rate, if any older (Dynastic, Greek, early Roman) materials had once accumulated here, they would now be buried at depths 6 m below msl in soft, water-saturated mud-rich deposits beneath the sands.

2.4. Pelusium

The fortified port city of Pelusium (or Tel Farama), located at the delta's NE corner near the mouth of the Nile's former Pelusiatic branch (Fig. 1, site IX), was in existence during Egypt's Late Dynastic Kingdom. It is known for the battle during which Egypt's army was defeated by the Persians in 526 B.C.E. (MANLEY, 1996). Pelusium, and several other sites to the west of it (Tel Luli, Tel el-Fadda), are now partially buried by sediment and lie 3 km south of the present coast. Pelusium is land-locked

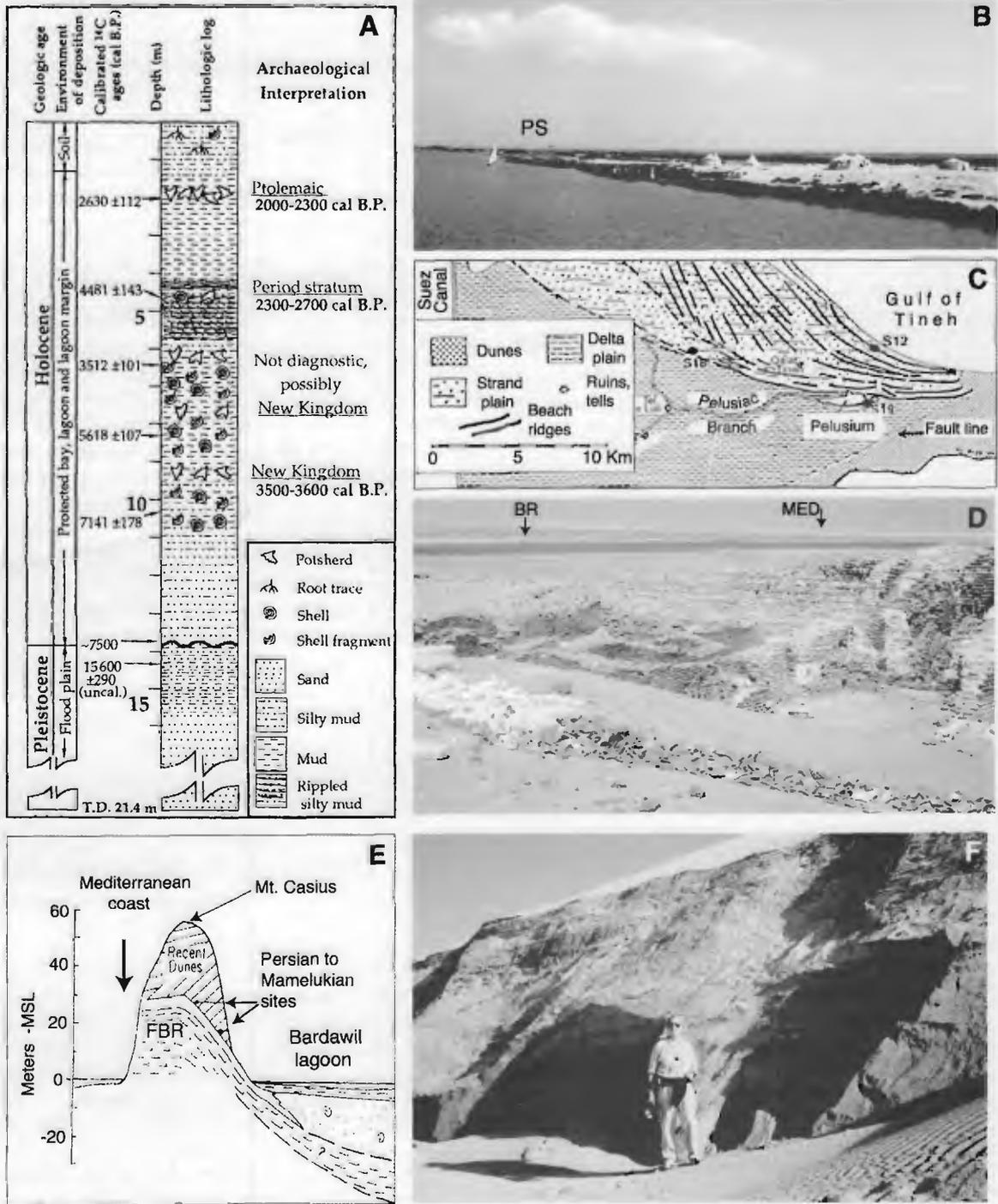


FIG. 4 – CENTRAL AND EASTERN DELTA SITES

- A. Core log at MEDIBA site (VII) shows section buried by Sebennitic Nile branch and wetland sediment (after STANLEY *et al.*, 1992; WARNE & STANLEY, 1993).
- B. Site VIII, Tel Tennis on low-lying sand island in NE Manzala lagoon, south of Port Said (PS).
- C. Site IX, Pelusium (Tel Farama), once at mouth of the Nile's Pelusiac branch, now land-locked 3 km south of coast; note active Pelusium fault line south of site (after SNEH & WEISSBROD, 1973).
- D. Ruins of Pelusium (bones and pottery fragments in foreground) surrounded by beach ridges (BR) and salt flats; Mediterranean shore (MED) lies to the north.
- E. Site IX cross-section showing Mt. Cassius on linear uplifted Pleistocene ridge (FBR) (after NEEV *et al.*, 1987).
- F. North-facing cliff of semiconsolidated Pleistocene deposits at the coast below Mt. Cassius, displaced along the Pelusium fault line.

and separated from the shore by extensive beach ridges and salt flats (Fig. 4, C, D). The history of this site, interpreted by dated sediment borings and historical records (GOODFRIEND & STANLEY, 1999), indicates that it was suddenly cut off from both the Nile branch and Mediterranean coast as a result of floods (perhaps in 813,

816 and/or 820 CE). These floods are believed to have induced rapid blockage of the Pelusiac, and break-through to the coast of a new branch west of Port Said, most likely the Damietta branch. As a result, a large influx of sediment (~1 km³) was suddenly released and carried eastward by coastal currents to the Gulf of Tineh where it

accumulated in an area of marked subsidence. This high-deposition sector is directly associated with the active Pelusium line fault system, the surface expression of which lies just to the south of the site (Fig. 4, C). The occupation horizons beneath some late Roman and Byzantine structures are at least 2 m below msl, recording rates of relative sea-level rise to at least 2 mm/yr.

3. Coastal margins west and east of delta

The NW limit of the delta margin proper lies at the carbonate-fluviomarine terrigenous sediment boundary near Canopus (Fig. 1, site IV). Few early vestiges at Canopus (Fig. 4, C), including those of possible Greco-Roman period, indicate minimal submergence (< 2 m below msl). The coast, extending >100 km to the SW to Arabs Gulf, is bound by high-relief ridges and low small islands offshore formed of moderately to well consolidated Pleistocene limestone known as kurkar (HASSOUBA, 1980).

The spectacular Ptolemaic and Roman ruins in the eastern sector of Alexandria's Eastern Harbour (Fig. 1, site III), including submerged structures of the so-called Royal Quarters and 3 ports in this area (Fig. 3, B), lie at much greater depths than those at Canopus. For example, a series of cross-sectional profiles of one of the main piers in this sector show its base at -8 to -9 m MSL, while the top of the structure is locally at -5 to -6 m below harbor waters (GODDIO *et al.*, 1998), indicating considerable post-construction submergence. Ongoing geoarchaeological research reveals that lowering of such magnitude is a likely function of tectonically-associated catastrophic events, along with more progressive relative sea-level rise. This large amount of rapid subsidence can in part be attributed to effects of the large tsunami in 365 CE and to those of subsequent seismic events that seriously affected the Alexandria region (KEBEASY, 1990; GUIDOBONI, 1994).

Archeological material from Middle to Late Kingdom Dynastic, Ptolemaic, and Roman times has also been recorded, some at considerable depth, in the NW sector of the Eastern Harbour near the base of the famous lighthouse (EMPEREUR, 2000). Moreover, structures (breakwaters, quays) were mapped in detail somewhat further to the west, in Anchoufy Bay and the NE part of Alexandria's Western Harbour (Fig. 1, site II; Fig. 3, A). These features, many built directly on the consolidated kurkar and presently submerged, were defined almost a century ago by JONDET (1916) and still require more accurate dating (MORCOS, 2000). It remains to be proved whether they are of Dynastic age and among the world's oldest harbour features, as suggested by JONDET (1916), or younger (Ptolemaic to Byzantine) as claimed by others. It is noted that the depths of the top of breakwaters varies markedly (1.5 to 4 m or more) below MSL. This is not altogether surprising since these structures were built in an area of limestone ridges that are locally offset and dislocated. There are several likely causes for

submergence of structures along the Western Harbour's Northern coastline and the area just seaward of it: subsidence induced by faulting and sediment failure and remobilization underlying structures as indicated by JONDET (1916), along with progressive rise in eustatic sea level.

Only a few sites positioned directly along the shoreline are sufficiently detailed and dated further west of the Nile delta and Alexandria. Most obvious along this coastal margin are a series of well-exposed and high-relief kurkar ridges that are located several hundred of meters inland from the shoreline (HASSOUBA, 1980). These display jointing and minor fault offsets, perhaps the result of tilt and uplift (NEEV *et al.*, 1987). The most pronounced site in this sector is the Ptolemaic temple site of Taposiris Magna (Abusir), positioned about 45 km west of Alexandria and 1 km landward of the oolite carbonate sand shore (Fig. 1, site I). It was built on one of the ridges at an elevation of >30 m and is readily visible from an offshore distance.

East of the Nile delta proper (~50 km ENE of Pelusium) lies a site at Mount Cassius along the central Sinai margin and northern edge of Bardawil lagoon (Fig. 1, site X). Here, archaeological remains (Persian, Mamelukian) were discovered on the marked topographic high. These materials occur at between 20 to 30 m elevation, above partially consolidated Flandrian beach rock (FBR) and partially buried by overlying modern sand dunes (Fig. 4, E, F). Uplift of this remarkable linear belt of Quaternary sediment is associated with NE-SW strike-slip motion along the Pelusium line fault trend (Fig. 1, B) as discussed by NEEV *et al.* (1987). It would not be surprising to discover submerged ancient settlements offshore, parallel to the raised ridge, in the vicinity of the Via Maris, major coastal road of antiquity, (STANLEY, 2002).

4. Discussion and conclusions

This overview indicates that ancient settlements at and close to the present northern Nile delta coast serve as gauges to measure long-term interactive effects of land motion and sea-level change. Even relatively young archaeological sites (late Greco-Roman to Byzantine and early Arabic) have been subject to various amounts of subsidence relative to Mediterranean level (Fig. 5). Findings summarized herein, emphasizing recent submergence of the northern delta, are supported by independent investigations conducted during this past century by numerous workers, including geographers, geologists and archaeologists. This phenomenon, recording variable rates of relative sea-level rise, is particularly pronounced on the delta plain north of a hinge line boundary (Fig. 2, inset) that generally conforms to the present + 1 m elevation contour on the low-lying delta margin (WARNE & STANLEY, 1993).

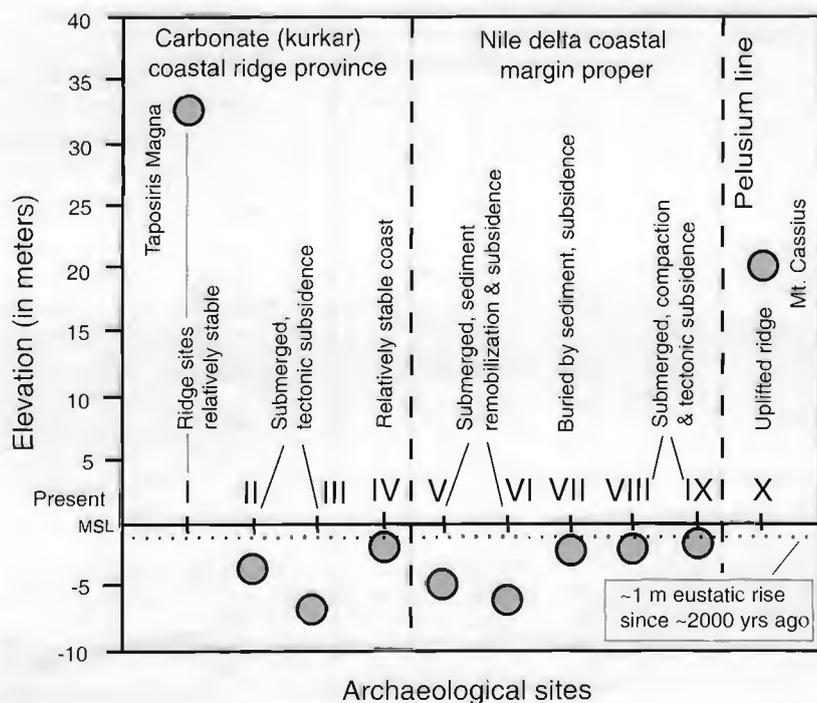


FIG. 5 - DIAGRAM SHOWING ELEVATION OF ARCHAEOLOGICAL HORIZONS AT BASE OF SITES (FROM GREEK TO EARLY ARABIC; ~600 B.C.E. TO ~750 C.E.) RELATIVE TO PRESENT MEDITERRANEAN MSL.

Note those below MSL on the Nile delta margin proper (V-IX) and some on adjacent sectors (II-IV). Eustatic sea-level rise proper accounts for ~1 m of submergence (dotted line) since early Roman time. However, most sites record occupation layers >1 m below MSL, thus indicating additional component of submergence by subsidence, *i.e.* lowering of the sediment substrate beneath settlements.

There is a general consensus that eustatic rise in sea-level during the late Holocene has been fairly constant (FAIRBANKS, 1989); this would account for at least 2 m of submergence since early Greek/Ptolemaic (~600 BCE) time, and ~1 since Roman time (Fig. 5). The present study, however, records (1) a greater and (2) uneven submergence of land by water and/or burial by sediment from W to E along this coastal sector (Fig. 5). This indicates that much of the northern part of the Nile delta has been affected, at least to some extent, by an additional and variable amount of vertical land motion (subsidence) from site-to-site during the late Holocene. Subsidence rates measured on the basis of dated cores and elevation of archaeological horizons appear to have been highest (2 mm/yr or more) north (seaward) of the hinge line; along the coast, strata bearing *in situ* material of Ptolemaic to early Arabic age (600 BCE-700 CE) lie at considerable depth (to -7 m) in Abu Qir Bay on the NW delta margin. The survey indicates that lateral variation in elevation is primarily a response to differences of seismicity, vertical land motion, and effects of sediment compaction and remobilization, including liquifaction, affecting the substrate underlying human-built structures.

The postulate that the Nile delta has not subsided since Predynastic time as proposed by SAID (1993) is based in large part on his observations of sites located on what he terms the northern reaches of the delta. His list includes Buto, Diospolis inferior and at least 92 mounds

around Faqus, settlements that he attributes to early Dynastic and even Predynastic time. He indicates that their presence at or near sea-level can be used as a major line of evidence for non-subsidence of the delta since Predynastic time. However, it turns out that all the above sites lie well south (by 25 km or more) of the coast (BAINES & MALEK, 1985; MANLEY, 1996) and are positioned south of the hinge line discussed above. Only Tel Tennis, to which SAID (1993) attributes an early dynastic or Predynastic age, lies north of this subsidence boundary. However, as discussed in a previous section here, this settlement is actually several thousands of years younger than he indicates. Moreover, SAID's suggestion that the Nile delta is composed of a sand and gravel core that is not compressible warrants critical attention. It is much more important to emphasize that the Pleistocene deposits lie upon considerable thicknesses of Tertiary and Mesozoic sediment; these formations alone, for example, account for >5000 m of section beneath Abu Qir Bay. Of note, then,

is that the sequence of Pliocene and Miocene formations comprising primarily fine clastic components, and older underlying formations that include more rigid deposits such as limestones, together, have been subject to long-term isostatic lowering (SCHLUMBERGER, 1984). It is this, and associated deformation at depth, that would account for some changes affecting upper sediment layers at the surface. The northern Nile delta and its margin, at least with respect to these aspects, are comparable to many of the world's large deltas (STANLEY & WARNE, 1998).

Findings in this investigation suggest it would be useful to extend the geoarchaeological survey of ancient sites well inland of the coast, to the south of the hinge line, so as to detect possible subsidence of the delta plain proper. Measurement of elevations and ages of living floors of archaeological excavations positioned along S-N profiles, between the Nile delta's apex near Cairo and the coast, would serve to record the extent and variation of regional subsidence that may have occurred since Dynastic time. Such a survey, involving cores and seismic profiling, could perhaps lead to discovery of still unknown settlements beneath the Nile silts.

Long-term averaged measurements of accurately dated sites along the coast would serve to guide archaeologists needing to excavate in zones of high water table, and provide information for engineers planning construction along the delta's vulnerable low-lying shore.

This effort is clearly as practical as it is scholarly, especially when taking into account ongoing land loss and damage of modern population centers such as those north of Rosetta on the NW delta coast, Baltim on the north-central coast, and Port Said on the NE delta coast. In sum, study of relative sea-level rise and effects of subsidence by examination of ancient sites along the Nile delta coast is a useful 'reverse-Lyellian' approach, one that emphasizes evaluation of the past as a valuable key to understanding the present and preparing for the future.

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