CONFERENCE ON THE
ECOLOGICAL ASPECTS OF
INTERNATIONAL DEVELOPMENT
AIRLIE HOUSE, WARRENTON, VA. DEC. 9-11, 1968

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Shore-Line Phenomena and Their Impact on the Nile Delta

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CONTENTS

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1. Geomorphology of the Delta Shore

The Mediterranean coast line from Port Said (longitude 32° 19'E) to Alexandria (longitude 29° 53'E) is an undulating line that bears the features of an advancing delta , Fig. 1. Two promontories are associated with the mouths of Damietta and Rosetta branches of the Nile. The middle part between the two mouths extends into the sea to latitude 31° 36' which is 12 and 5 latitudinal seconds more than the tips of the Rosetta and Damietta promontories respectively. This middle part is the site of the mouth of an old branch of the Nile : the Sebennytic.

A series of shallow lakes occupy the northern part of the Delta: Lake Manzala (east), Lake Borollos (middle) and Lake Idku (west). These lakes receive the main bulk of the drainage water collecting from the Delta, they are separated from the sea by strips of land that are very narrow in several places and are connected with the sea through outlets. The Delta shore line is dotted with villages (fishing, date-palm and other crops cultivated in sand dune areas) and summer resorts (Ras-el-Bar, Gamasa, Baltim).

Along the shore there are bodies of sand dunes with distribution that seem to associate these dunes with the eastern banks of present and past Nile branches. Consider for instance the shore of the middle part of the Delta. The coastal land to the east of the Lake Borollos exit is covered by an extensive body of sand dunes that extend for about 15 kiloneters east of the outlet, further eastward they diminish. The strip of land to the west of this outlet has no dunes that are comparable to those of the east side. The Lake Borollos exit is the site of the mouth of the Sebennytic branch. This pattern is repeated at the sites of all the several branches of the Nile that debouched into the Mediterranean till the 9th century (according to maps produced by O. Tosson, Egyptian Geographical Society), see also maps of Egypt in classic times reproduced by Ball (1942) and map of the Delta in Predynastic times by Butzer (1959) and quoted here in Fig. 2. The sand was obviously brought to the shore line with the Nile sediments debouched at the mouth points. Softer silts and clays travelled further into the sea or transported along the shore line for long distances by littoral currents. Sand was deposited at the shore line and pushed to the eastern sides of the mouths by the eastward current that prevails throughout the main part of the year.

That the Nile sediments travel eastward is proved by studies of Shukri and his associates. Shukri and Phillip(1956) compare the mineralogy of recent shore-line sediments with that of the Nile sediments analysed by Shukri (1950 and 1951) and show that only little of the Nile sediments spread westward of Rosetta reaching Alexandria. Shukri and Phillip (1960) show that Nile sediments travel eastward reaching ~~to~~ the whole of the Sinai coast and further beyond.

Saïd (1958) notes that in the area from Gamasa (longitude 31° 30') to the Damietta mouth and further east the beach is made of fine sand with a depositional dip of no more than 2°. From Gamasa westward till Rosetta the beach is made of coarse sand with a depositional dip reaching 8°. He explains this difference in texture of beach sediments as due to difference between the Rosetta branch that carries a greater volume of water and hence coarser sediments and the sluggish stream of the Damietta branch.

2. Shore-line Retreat

2.1 Comparison of maps

Map in Fig. 3 shows the shore line at the western ~~side~~ side of the Rosetta mouth in 1898, 1918, 1926, 1944 and 1954. It is obvious that this promontory has lost about 1650 meters of its length in 65 years, average yearly retreat is about 29 meters. Wassing (1964) produces the following figures for the rates of shore line retreat :

Period	1898/1918	1918/1926	1926/1944	1944/1954
Retreat (m.)	300	620	375	350
Average per year	15	81	21	35

In 1898 the old lighthouse was 950 metres inland from the tip of the promontory, in 1926 it was a few meters from the tip, in 1942 the lighthouse became isolated from the mainland, and in 1954 a new lighthouse was built 2350 meters south of the site of the old lighthouse.

Comparing the 1919 map of the Lake Borollos exit with the 1949 map, we note that the width of the land strip separating the sea from the lake ranged from 850 to 1000 meters in 1919 and from 200 to 350 meters in 1949. At present it is much narrower.

The western side of the Damietta mouth is the site of the Ras-el-Bar summer resort. From Wassing's drawing (1964) reproduced here in Fig. 4, it is evident that during the 58 years (1902 - 1960) the length of the Ras-el-Bar peninsula has decreased by about 1800 meters, an average of 31 meters per year.

2.2 Coast at Lake Borollos exit

The land on the western side of the exit is a narrow strip of land that separates the lake from the sea. At present the eastern 10 km. part of this strip is about 100 meters wide, almost flat with mounds of sand that hardly reach one meter in height. The width of this strip increases gradually as one proceeds west towards the Rosetta mouth. The land on the east side of the exit is a triangle increasing from about 300 meters at its tip (exit) to about 8 kilometers at Baltim which is about 10 kilometers east of the outlet. The triangle area is covered with an immense body of sand dunes that average 10 meters above sea level, partly surveyed in Hume (1925) Villages, date-palm groves and small farms (melons, fruits, etc.) are scattered amongst the dunes. These dunes seem to impede the rate of shore-line retreat by contrast to the active retreat in the western side of the exit. The dunes move slowly inlandward exposing the sea shore at their windward side and overwhelming the lake shore at their leeward side. The inhabitants move their villages accordingly : they travel slowly on the back of sand dunes. On the sea shore one notes submerged relicts of destroyed villages and of dead date-palm groves. Stretches of clayey bottom of the littoral zone of the sea compare with the clayey bottom of the lake.

The village of Borg-el-Borollos, home village of the writer, was moved to its present site some eighty years ago. The old site is now about 2 kilometers in the sea, the present site on the eastern side of the Lake Borollos exit is protected by a concrete wall supported by a number of short groyens. These constructions require yearly maintenance and repair.

2.3 Coastal forts in the 19th century

A chain of coastal forts dotted the Delta coast in the late part of the 19th century. Archives in the Military Museum of Cairo contain inspection reports of these forts in 1880. The sites of many of these are at present under the sea. Inundated ruins of the two forts on the two sides of the Lake Borollos exit were still visible in 1930.

3. The Problem of Lake Exits

Each of the lakes of northern Delta is directly connected with the sea through one or more exit. At each of these exits the material-energy relationships are rather complex : waves and longshore currents with their loads of sediments (littoral processes), and tidal currents and seasonal currents with their loads of sediments (exit processes). The tidal current flows into the lake in flood, and out of the lake in ebb, of the tide. This is subject to variation in range from spring to neap and is modified by wave action. Seasonal currents in and out of the exit are due to variation in water level of the lake relative to sea level. Lake Manzala, for instance, receives an annual average of 4500 million cubic meters of water (drains and canals debouching into the lake). The monthly water discharge into the lake follows a seasonal rhythm : 100 million cubic meters in January-February and 700 million cubic meters in August-September. The water level in the lake varies accordingly due to the limited capacity of the exit.

The sum of the complex and varied processes is that the lake exits are subject to notable variation in size and position. We may quote the historical account of Lake Manzala exit as summarized in Report No. 18 (1964) of the Research Laboratory, Suez Canal Authority. In 1887 there was one exit 100 meters wide and more than 5 meters deep. In 1890 the exit was 50 meters east of the old fort, in 1921 it became 1000 meters east of the fort : it moved eastward 30 meters per year. In 1922 the exit was 75 meters wide with a 3 meter deep channel in its eastern side. In this year an artificial exit 20 meters wide and 3 meters deep was dug immediately west of the fort. In 1926 the newly dug exit had moved eastward causing the destruction of the fort. In 1942 this artificial exit was silted and a new exit was naturally formed further east of the original (first mentioned) exit. This new exit was deepened and a barrage was built across with the purpose of controlling the outflow of the lake water. In 1953 the orginal exit was silted, artificially cleared in 1955, silted again in 1956. This non-stability of the Lake Manzala exit is similarly noted in Lake Borollos exit.

The outflow current from the lake exit may be an effective factor in lowering the rate of beach erosion through its effect on the longshore current. The silting of these exits deprive the fish movement from lake to sea and *vice versa* from its natural passage and disturb the migratory movements associated with fish propagation. The maintenance of these exits is part of the general problem of beach protection.

4. Shore-line in Pleistocene and Later Times

The history of the Nile Delta is closely related to land/sea relative levels. This could be visualised by correlating and integrating information from studies on levels and histories of river terraces in parts south of Cairo (Sandford, 1934; Sandford and Arkell, 1929, 1933, 1939), deposit stratigraphy of the Delta (Judd, 1897; Fourtau, 1915; Attia, 1954 ; Yousri, 1962), geomorphological studies on the Pleistocene series of oolitic limestone bars parallel to the shore from Alexandria to the Libyan border (Shukri *et al*., 1956; Butzer,

Table 1. Approximate levels of Mediterranean relative to the present level (A) and distances of coast-line from Cairo (B), after Ball (1939).

Period	Stage	A m.	B. km.
Late Pliocene	140-m. Nile-terrace	+154	25
"	150-m. " "	+129	28
Early Pleistocene	90-m. " "	+103	33
"	60-m. " "	+ 72	45
"	45-m. " "	+ 57	48
Early Palaeolithic	Chellean (30-m. Nile-terrace)	+ 41	53
" "	Acheulean(15-m. " ")	+ 25	64
Middle Palaeolithic	Early Mousterean(9-m.terrace)	+ 18	70
	Middle Mousterian	- 12	90
	Late Mousterian	+ 16	82
Late Palaeolithic	Early Sebilian	+ 13	85
	Middle Sebilian	+ 3	103
	Late Sebilian	- 43	181
Neolithic	Early Neolithic	- 10	173
Present day		0	170

1960), palynological studies on Delta deposits (Saad and Sami, 1967), radiocarbon dating of Nile sediments (Fairbridge, 1962, 1963), etc.

Ball (1939) produces the relative Mediterranean levels and distances of coast from Cairo that are quoted in Table 1. He infers that at the beginning of the Pleistocene (c. 5000,000 years ago) the sea level was about 100 meters higher than its present level. The Mediterranean and Red seas were connected by a wide strip (see maps in Fig. 5). The sea level dropped by successive stages until the Middle Mousterian (c. 30-40 thousand years ago) when the sea level reached about 12 meters below its present level and the Delta extended to about 90 kilometers north of the latitude of Cairo. The sea level rose reaching about 16 meters above present level in the Late Mousterian. This was followed by level drop reaching to about 43 meters below present level in the Late Sebilian (c. 10000 years ago), at that time the coast line advanced to about 11 kilometers beyond the present position. Though different in detail yet comparable in general theme are relationships concluded by Sandford and Arkell (1939) and Zeuner (1952).

Maps in Fig. 5 show the shore line during successive periods of the Pleistocene as given by Shukri et al. (1956). The Sicilian (early Pleistocene in Ball's figures of Table 1) map shows the direct connection between the Red Sea and the Mediterranean. Which continued through the Milazzian. The Tyrrhenian (Chellean to Acheulean) map shows the subsidence of the Mediterranean. The Monasterian (Acheulean to Sebilian) map shows further subsidence of the sea with concomitant expansion of the Delta.

Butzer (1959) examined the boreprofiles from the Delta (e.g. Fourtou, 1915; Attia, 1954) and produced the map quoted in Fig. 2 for the "Delta in Predynastic and early historical times". There is every reason to believe that brackish swamps and lakes extended southward to the limits shown in this map . Archeological evidence such as the sites of ancient towns and river branches in the Delta given by Daressy (1928-1934) show that human settlements advanced gradually in a northward direction from the Predynastic to the Hellenic times.

Swampy conditions prevailed in a substantial part of the northern Delta during the Pharaonic times. This was the habitat of <u>Cyperus papyrus</u> growth which abounded in ancient Egypt and was used for papyrus-paper industry. This species has disappeared from the Delta obviously under the influence of the silting of the swamps; the only locality in Egypt where this plant is at present recorded is one of the lakes of Wadi Natrun

(Dr. M.N. El-Hadidi, personal communication). These swamps must have been brackish or fresh, and not sea lagoons, for the reed swamp vegetation to grow.

The Delta, at least in its northern reaches, was apparently built stepwise : formation of lagoons bounded by off-shore bars, Saïd (1958). These lagoons were gradually changed into brackish swamps by accumulation of river water and were later silted by accumulation of river sediments. The swampy deposits remain as subsurface layers or lens-shaped bodies of organic mud rich in plant remains and invariably described in boreprofiles. Palynological analysis of these organic deposits (Saad and Sami, 1967) show the preponderance of reed-swamp growth. These layers of organic mud are in many sites at depths of 7-10 meters below ground level which is rather deep for the reed growth. But it is very likely that they are pushed downward under the weight of later sediments.

The positions of the several branches of the Nile shown in Butzer's map are comparable to those shown by the description of the Nile Delta given by classic geographers : Herodotus, Strabo and Ptolemy; Ball (1942). The sites of the mouths of these branches are associated with the distribution of bodies of sand dunes along the shores of the Delta.

5. Causes of Recent Retreat

The recent retreat of the Delta shore line may be due to rise in relative sea level and/or marine erosion.

5.1 Recent rise in sea level

Butzer (1960) concludes that there has been a temporary marine regression of the Mediterranean from -2 to -4 meters in classical times, followed by a new rise to the present level. Submerged Greco-Roman ruins are recorded in Cyrenaica, Maryut, etc. and seem to indicate this recent sea-level rise. Ball (1939) refers to the islets in Lake Borollos and Lake Manzala that are covered with ruins of ancient villages whose lands have disappeared beneath the shallow waters of the lakes. Audebau (1919) studied the levels of water that had accumulated in lower chambers of rock-cut catacombs of Alexandria, dated from the 2nd century. He concludes that the Mediterranean has risen relative to land about 2.6 meters in the course of the last 18 centuries, an average of 14 cm. per century. Ball argues that this change in sea-land levels since the second century is due to local sinking of land that forms the northern Delta and not due to regional subsidence. He provides in support of his view evidence from a subterranean Roman aqueduct near Marsa Matrush , c. 200 km. west of Alexandria. When cleared of the sand that choked it, fresh water collected in it just as it did when first excavated. It taps water from the fresh-water layer that does not exceed one meter of thickness and that overlies, in the coastal dunes and ridges, salt water, Had the sea level at the time when the aqueduct was excavated been 2-3 meters lower it would have been impossible for it to tap fresh water. Yet it is interesting to note that Audebau's figure of 14 cm. per century is not very different from Fairbridge's (1962, a) figure, "Sea-level is currently rising 1.2 mm. each year".

5.2 Marine erosion

We are here concerned with changes that have taken place during the last 100 years and coastal retreat that is actively taking place now at the alarming rate of several meters per year, Figs 3 and 4. These are obviously due to erosive action of littoral processes : waves and currents. The eroded materials are carried eastward by the prevalent littoral current and are partly trapped by the groyens built at Port-Said to protect the entrance of the Suez canal. The area of the Port-Said township has expanded on the land formed by these deposits.

The question that poses itself is : why is this recent retreat ? The erosion processes must have been operative all the time : the eastward littoral current has throughout centuries moved Nile sediments east of the river mouths, wave action is universal; yet the shore line morphology-even in its present form-bears features indicative of building, Fig. 1. The answer may be sought in the material-energy balance concerned in the two processes : building by sediments brought to the shore line by the river especially in flood season and erosion agencies. The net outcome of these two opposed processes, was until recently, slow building and the delta was gaining ground at least at the mouths of the river where promontories were formed. Change of balance has caused the present retreat.

Quantities of sediments carried in suspension by the Nile water are calculated by Ball (1939). He gives these in millions of tons past Wadi Halfa (Sudano-Egyptian border) and Cairo during flood seasons of three years as follows :

	Wadi Halfa	Cairo
1929	136.13	73.81
1930	75.69	41.62
1931	118.27	57.30

The suspended material diminishes in the journey from Wadi Halfa to Cairo by about half of its quantity. Part of the load is further lost through the journey from Cairo to the sea. This loss is due, in part at least, to interception through irrigation canals, at the Aswan Reservoir, the various barrage, etc.

Earlier this century W. Willcocks in his account of the Nile (1904) calculates that of the mean discharge of 3040 cubic meters per second which passes Aswan, 400 cubic meters per second are utilized in Upper Egypt (south of Cairo) and 540 cubic meters per second are utilized in Lower Egypt (Delta), and 2100 cubic meters per second reach the sea. This means that until 1904 two thirds of the Nile water entering Egypt was poured into the sea with their load of sediments. But by the end of the 19th century the Delta Barrages were completed(1861), an extensive network of canals were established, the Aswan Reservoir and a series of barrages in Upper Egypt were in the process of planning. The purpose was to change the basin-irrigation system that was preponderant in Egypt to perennial irrigation. ~~Dam~~ Reservoirs were established in the Sudan : Sennar dam on the Blue Nile (1925), Jebel Awlia dam on the White Nile (1937), Er-roseiris dam on the Blue Nile (1964), Khash;-el-Girba dam on the Atbara River (1962), etc. The establishment of the High Dam at Aswan (completed 1968) will bring the Nile in Egypt under full control, and will reduce the water discharged into the sea and its load of sediments to almost nil.

Before the elaboration of these irrigation and Nile-control constructions that started on a large scale by the end of the 19th century, the load of sediments reaching the shore from the sea, especially the parts west of the exits, are likely to collapse. If this is allowed to happen the two lakes will be transformed to sea bays extending into the northern Delta. Land reclamation endeavours during the last 50 years, and recent reclamation schemes to bear fruit during the next five years, will have gained for Egyptian agriculture about one million acres of land. But these large stretches of land are at, or only little above, sea level. The reclamation of these areas was made possible through pump-drainage into the lakes. The transformation of these lakes to marine bays will endanger the hydrological set-up of the northern Delta drainage systems. The southern shores of the present lakes will become marine beaches, and in case of storms the high waves are likely to cause marine inundation and salt-water sprays.

The lakes are at present bodies of brackish water separating the northern Delta from the sea. The change of these bodies, of brackish water (salinity 0.8-1% in Lake Manzala; Montasir, 1937) at present in contact with the Delta lands to salt water (salinity 3.5-3.9% in the Mediterranean) will influence the salinity of the underground water with obvious repercussion on the fertility of these lands.

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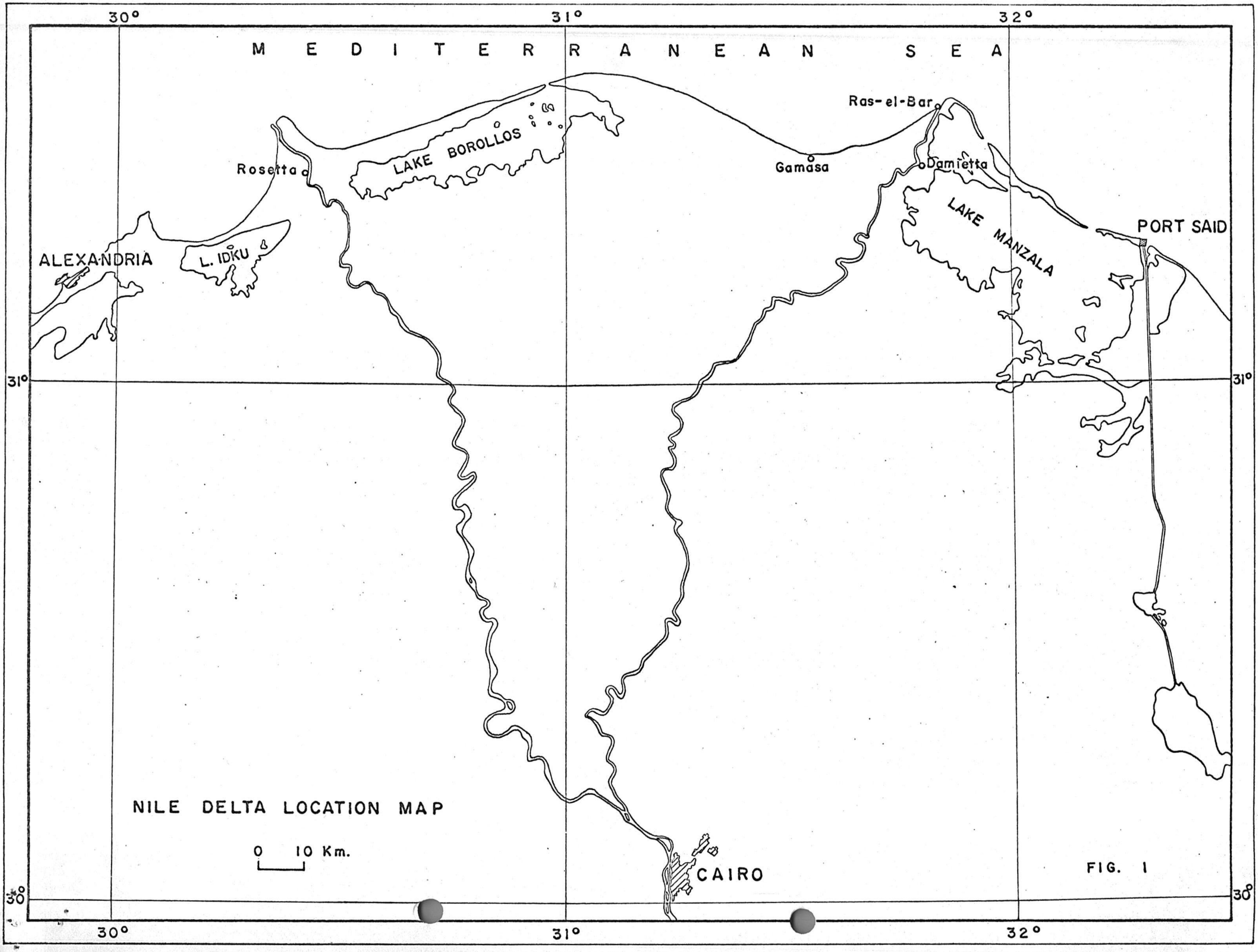
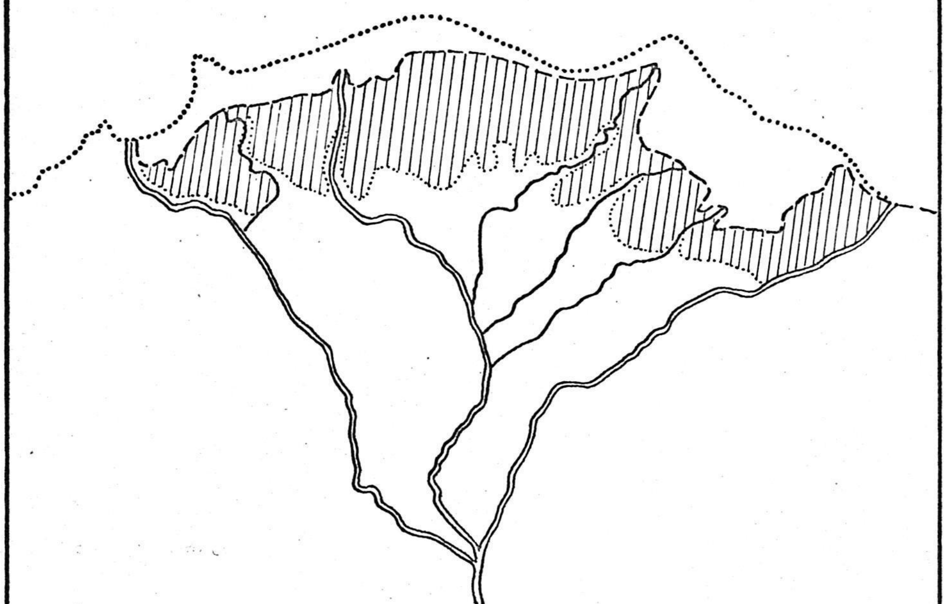


NILE DELTA LOCATION MAP

FIG. 1

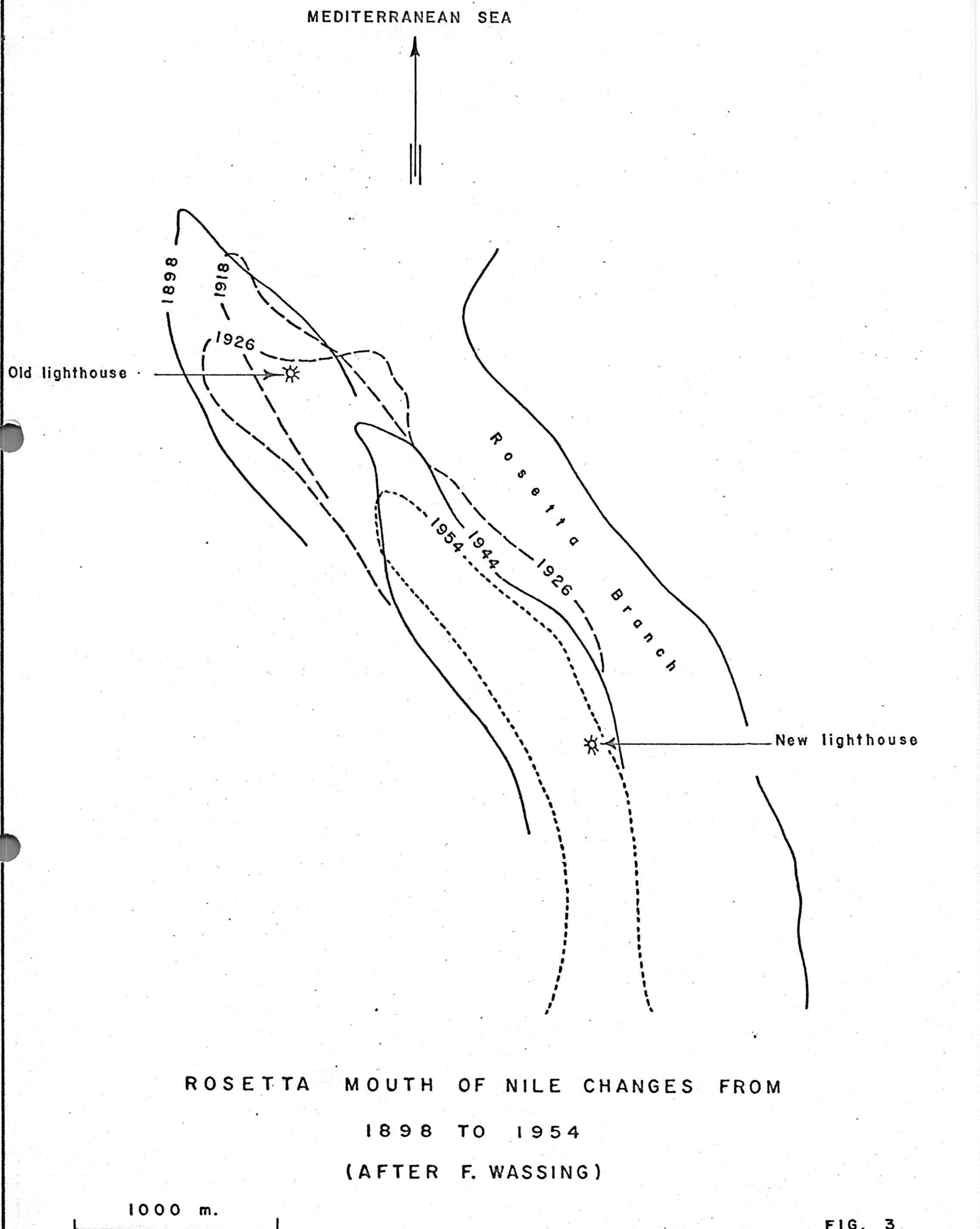


THE DELTA IN PREDYNASTIC AND EARLY HISTORICAL TIMES, AFTER BUTZER (1959)

.... Modern Coastline
---- Coastline about 4000–3000 B.C.
|||||||||||| Extent of brackish lagoons about 4000–3000 B.C.

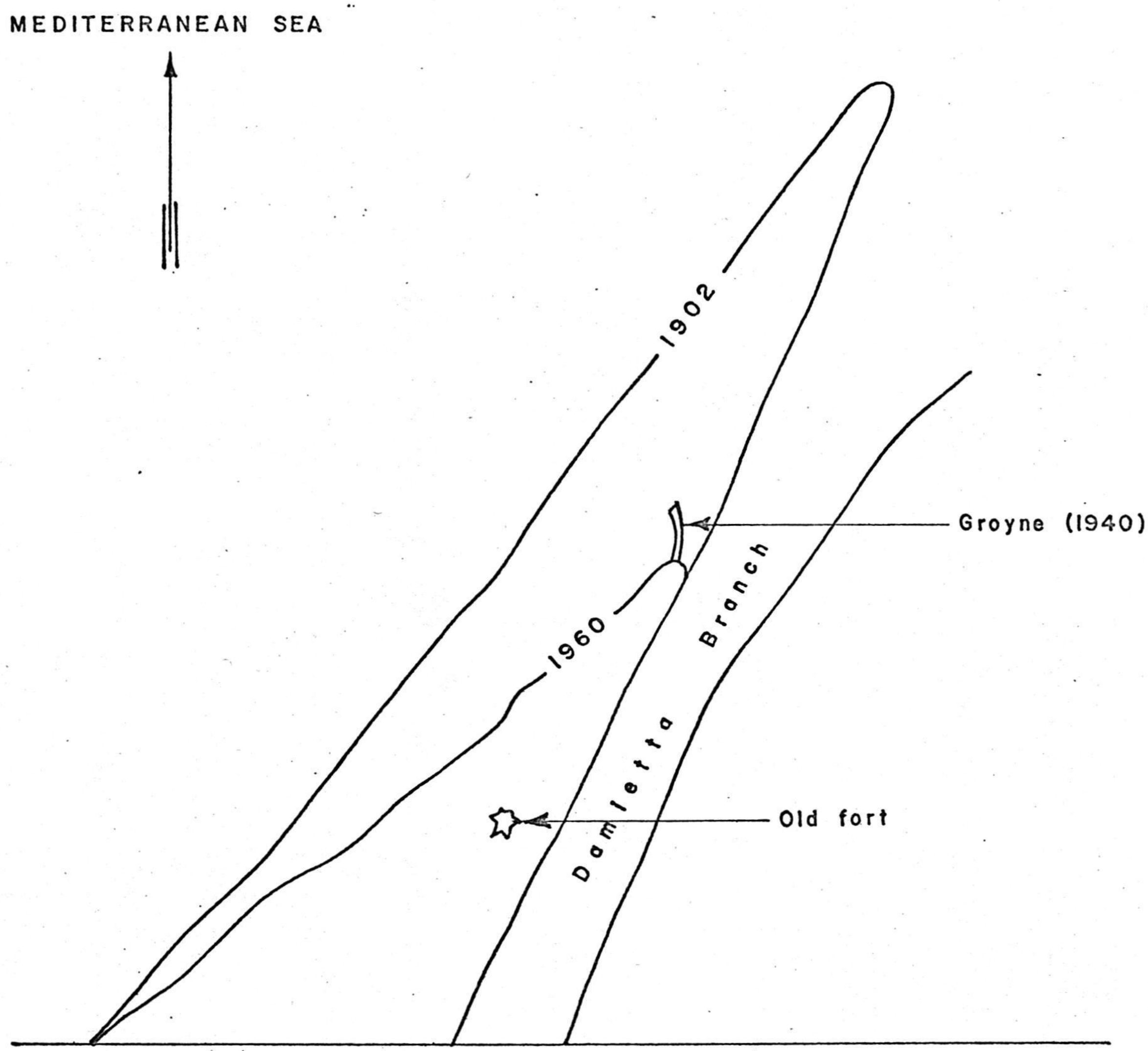
0 20 Km.

FIG. 2



ROSETTA MOUTH OF NILE CHANGES FROM
1898 TO 1954
(AFTER F. WASSING)

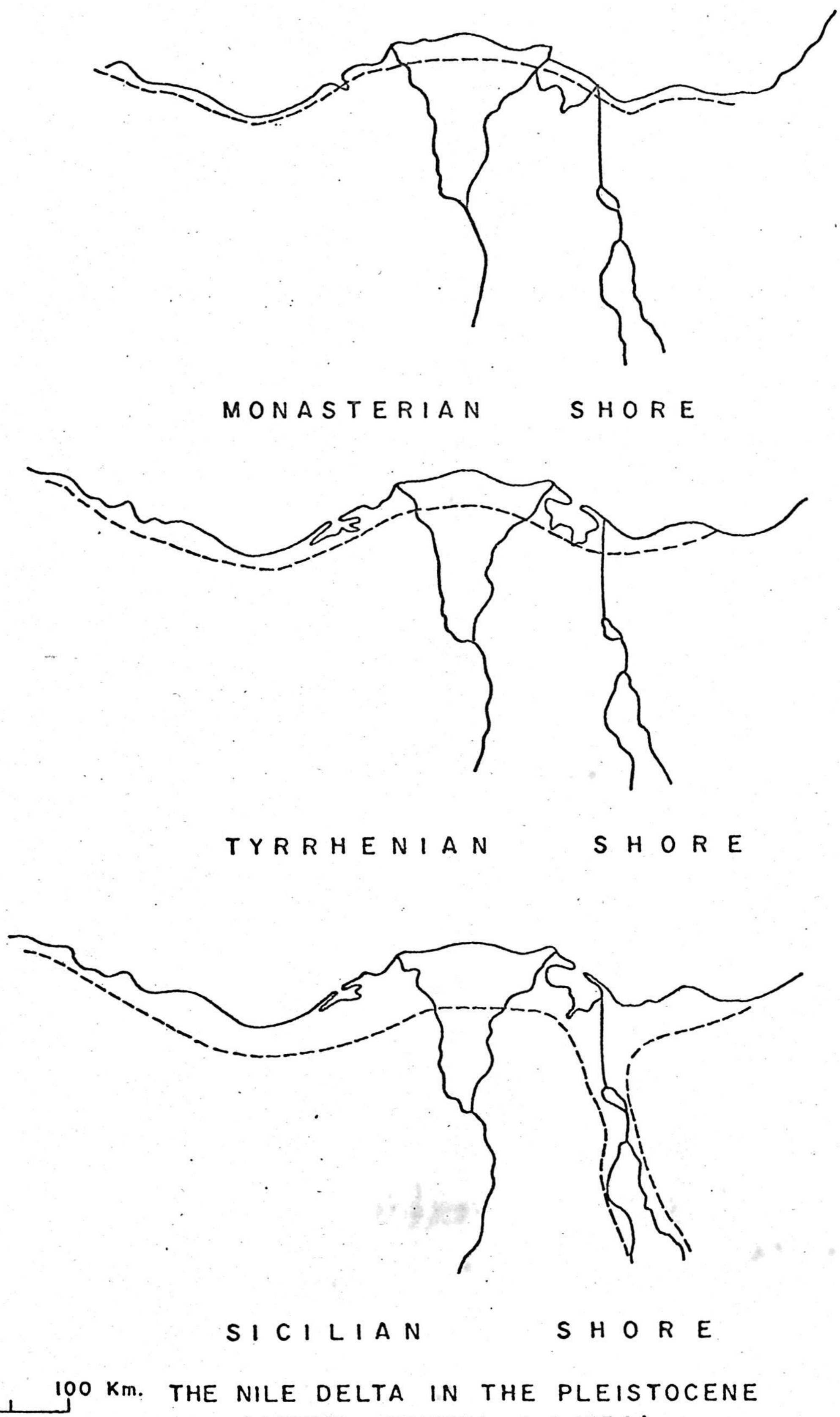
FIG. 3



RAS-EL-BAR ON THE WEST SIDE OF THE MOUTH OF DAMIETTA BRANCH SHORE LINE IN 1902 AND 1960 (AFTER F. WASSING)

1000 m.

FIG. 4



THE NILE DELTA IN THE PLEISTOCENE
(AFTER SHUKRI et al. 1956)

FIG. 5