

Detection of a Probable Ancestral Delta of the Nile River

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ABSTRACT

Interpretation of a near-vertical Apollo-Soyuz color photograph of northern Egypt revealed a dark-colored and finely textured zone partially overlapped by the present Nile Delta. Extrapolation of the identified zone beyond the Apollo-Soyuz photographic coverage, using a false-color Landsat mosaic, indicated that this zone forms a part of a deltalike pattern. Review of the literature on the geology of the area indicated that its outcropping and subsurface rocks are of terrigenous types. In addition, all its deposits belong to fluvial, deltaic, prodeltaic, estuarine, and fluvio-marine facies.

Examination of the size, form, and extension of the identified pattern revealed that it is most probably the late Eocene to early Miocene ancestral delta of the Nile River. This supports the theory that the Nile originated in late Eocene time. From the southern borders of Egypt to the city of Asyût, the river followed a course similar to that of the present-day Nile. At the end of the early Miocene time, a sudden lengthening of its course occurred, and the river ceased depositing its sediments in the ancestral delta northwest of Asyût. Probably guided by faults, the river flowed northward to its present-day position. This change in the course of the Nile was probably associated with a regional uplift that affected Egypt during middle Miocene time.

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INTRODUCTION

Orbital photographs and images can furnish invaluable information on the geological attributes of the Earth's surface. In areas where knowledge is scant, examination of orbital photographs may emphasize regional patterns. Photointerpretation of such patterns may lead to the formulation of hypotheses regarding their nature and origin. The synoptic view of these photographs also provides a basis for extending geological information from well-studied areas to the surrounding less-known regions.

When studying exposed surface materials, it is noteworthy that true color photographs are superior to Landsat false-color images because of two reasons: (1) True colors can be interpreted on their merits (absolute scale) whereas false-color composites should be interpreted on the basis of assumptions or mentally translated true colors (relative scale). (2) Color photographs reveal, by virtue of color tone, considerable information on the textural characteristics of the sediments whereas Landsat images, which are made up of pixels,¹ are less reliable in studying textural characteristics.

Apollo-Soyuz Test Project (ASTP) photographs reveal true color zones in the Nile Delta region. West of the Nile Delta, three parallel color zones with sharp and straight-line boundaries have been identified (ref. 1). The boundaries of these zones are mainly oriented N85°E. The southernmost zone, which is the subject of detailed examination in this study is described by

¹ Pixels are spatially limited resolution elements.

El-Baz and El-Etr in another section of this volume (section entitled "Color Zoning in the Western Desert of Egypt").

ASTP PHOTOINTERPRETATION

Visual examination of the aforementioned southernmost color zone reveals the following:

1. The southernmost color zone can be traced west of the Nile Delta and possibly to the eastern side of the Suez Canal.

2. Differences between the southernmost zone and the intermediate zone are not only in color but are also in texture. The southernmost zone is characterized by very coarse to coarse texture as compared with the medium to fine texture of the intermediate zone. This textural variation is reflected in the field description by El-Baz and El-Etr of the southernmost zone as "a desert pavement composed of sand mixed with dark pebbles." The intermediate zone, however, was described as sand "which appears to be active, forming ripples and sand shadows behind desert brush."

3. Assuming that a qualitative scheme of color classification is applied to identify color zones, the total variation of color in the photograph can be divided into two categories: (a) color variance between zones and (b) color variance within zones. If category "a" is more predominant than category "b," the scheme of classification becomes valid. Qualitatively applying this concept to the southernmost and intermediate color zones reveals that the boundary between the two zones is defined by minimum variation within each zone and maximum differences between the zones. Figure 1 shows that the southernmost zone is characterized by abundant east-west-trending strips of different color and texture. This is in contrast to the intermediate zone, which appears to be homogeneous except for subtle and gradual color variations. The east-west-trending strips are examples of the "within zone variance," as described by El-Baz and El-Etr's field examination of that southernmost zone: "the topography of this zone is not flat but rather rolling or undulating. The amount of gravel increases on higher areas, and

the low areas are covered mostly with sand." (See section entitled "Color Zoning in the Western Desert of Egypt.") The east-west-trending strips (fig. 1) are interpreted as areas covered with Pliocene deposits or Quaternary sand. This interpretation is based partly on the geological map of Egypt (ref. 2) and partly on using photograph characteristics for areal extrapolation.

4. The southernmost zone discussed in this paper shows a clear east-west grain (fig. 1), which is reflected in the alinement and orientation of the northern and southern boundaries of the zone; the east-west-trending strips of Pliocene deposits and Quaternary sands; and the basaltic extrusions.

5. The Abu Rawâsh dome, of white Cretaceous limestone and chalk, crops out in this southernmost zone (fig. 1). Outcrops of this Cretaceous rock contribute to the within-zone color and textural variance. In addition, the outcropping of these Cretaceous rocks within predominantly lower Miocene rocks indicates a structural high (ref. 3) and supports the prevalence of structural control.

6. East of the Nile Delta and west of the Suez Canal, east-west extension faults are known to exist widely and to predominate the structural grain of that area (refs. 3 and 4). Faults of similar trend are also known to cut across the present Nile Delta (ref. 5).

These observations clearly indicate that the structural pattern of the eastern part of this zone can be extrapolated through the present Nile Delta and to the west of it. Therefore, structural control by faults and/or megafractures (undifferentiated and labeled lineaments in fig. 1) should explain the development of the east-west-trending depressions in which Pliocene and Quaternary deposits are accumulated. The predominance of extension faults should also explain the widespread occurrence of basaltic extrusions in this zone. The northern boundary of the zone (fig. 1) with its straight-line appearance and its persistence for more than 400 km may reflect a fault line. The southern boundary of the zone that lies east of the Nile Delta coincides with a group of east-west-trending faults mapped by Abdel-Rahman and El-Etr. (See section entitled "Structural Pattern of the Northern Part of the Eastern

Desert of Egypt.”) In addition, most parts of the southern boundary of the western part of the zone coincide with faults on the geological map of Egypt (ref. 2).

COLOR ZONE EXTRAPOLATION

To amplify their understanding of the nature of the study zone, the authors extrapolated beyond ASTP photographic coverage and compared these data with all available geological information.

A false-color mosaic of Landsat images of Egypt was used for the extrapolation. Zone extrapolation resulted in the recognition that the study zone forms part of a much larger pattern. The pattern is delta-shaped and lies mostly in the Western Desert of Egypt (fig. 2). The identified pattern is darker in color than the surrounding mass and is well defined by easily mappable boundaries. This deltalike pattern occupies approximately 55 000 km², which is much larger than the area occupied by the present Nile Delta, which is 18 000 km². Approximately 5000 km² of the identified pattern lie to the east of the present Nile Delta, whereas 5000 km² lie below the present delta in the Western Desert of Egypt.

The V-shaped tip of the identified pattern lies to the northwest of Asyût and widens gradually to form the base of a triangle at the northern edge. The western boundary of the pattern truncates the present-day Qattara Depression and suddenly terminates on a straight line oriented N85°E that follows the northern slope of the Qattara Depression. This N85°E line delimits the northern boundary of the identified pattern and can be traced eastward until it passes the Suez Canal near Ismailia where it suddenly terminates. The eastern edge of the deltalike pattern curves around the Faiyûm Depression where the middle Eocene limestone rocks are exposed. This boundary crosses the Nile Valley south of Cairo and extends eastward terminating just east of the Suez Canal (fig. 2).

Examination of color variations over this deltalike pattern indicates the following: (1) Colors are generally deeper in the southern part of the pattern than in the northern part (eastward,

however, color intensity decreases remarkably). (2) Longitudinal chains of lighter-colored sand dunes are superposed on this pattern.

The shape, position, and size of the identified deltalike pattern suggest the possibility that the detected pattern may reflect an ancient (fossil) delta of the Nile River.

GEOLOGIC DISCUSSION

The hypothesis that the identified deltalike pattern represents an old Nile Delta is tested on the basis of the available literature on this area including the works of Beadnell (refs. 5 to 16). Figure 3 shows the time-rock units of the area as presented on the geological map of Egypt (ref. 2). The area is composed of Eocene, Oligocene, and lower Miocene rocks. The Eocene rocks probably belong to the late Eocene time except for a few isolated outcrops that formed topographic highs during the deposition of the upper Eocene, Oligocene, and lower Miocene.

The upper Eocene rocks have relatively limited exposures in the area. These are composed of brown sandy limestone, sand, and shale beds (ref. 3). The upper Eocene rocks in the subsurface consist of clay, shale, siltstone, and marl (ref. 15). However, upper Eocene rocks elsewhere in the Western Desert constitute the Qasr el Sagha Formation, which is characterized by numerous vertebrate remains with few marine shells.

The Oligocene rocks of the area constitute the Qatrani Formation. They are composed of cross-bedded sandstone and gravel with interbeds of shale and limestone. Most of these sediments contain mixed fluvio-marine mollusks whereas others contain huge tree trunks some of which are silicified, forming “petrified forests.” In addition, numerous beds of the Qatrani Formation contain remains of various land animals, crocodiles, tortoises, and turtles. Said’s description (ref. 3) of the Oligocene deposits leaves no doubt that they were formed by “rivers of considerable size.” The Oligocene rocks attain their maximum thickness (250 m) in the Widan el Faras hills almost half-way between the Baharîya Oasis and the Faiyûm Depression (fig. 3). East and west of that location,

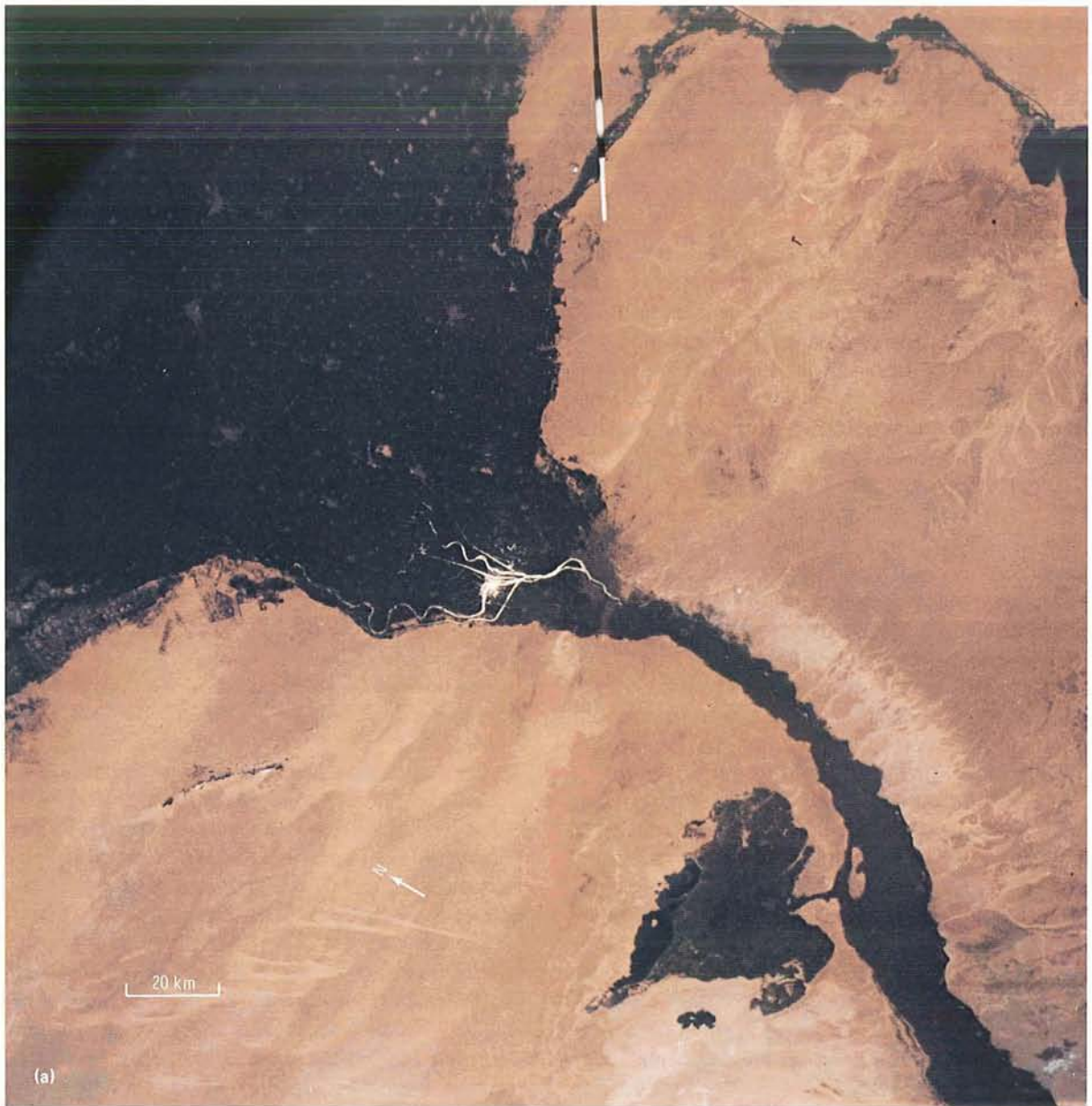


FIGURE 1.—ASTP photograph and sketch map of the zone east and west of the present Nile Delta. (a) Photograph AST-9-556 showing the color and textural photograph characteristics. (b) Sketch map of same area showing structural characteristics of the zone.

the Qatrani Formation thins out gradually (ref. 3). The lenticular shape displayed by the thickness of the Oligocene sediments adds more support to their fluvio-marine origin. The southernmost extension of the Oligocene deposits is represented by an extensive sand and gravel plain (fig. 3). Ac-

cording to Said (ref. 3), these deposits include pebbles of quartz, chert, flint, quartzite, and jasper derived mainly from the Nubia Sandstone and Eocene rocks to the south.

East of Cairo, the Oligocene rocks (also described by Said, ref. 3, as fluvatile) have a very

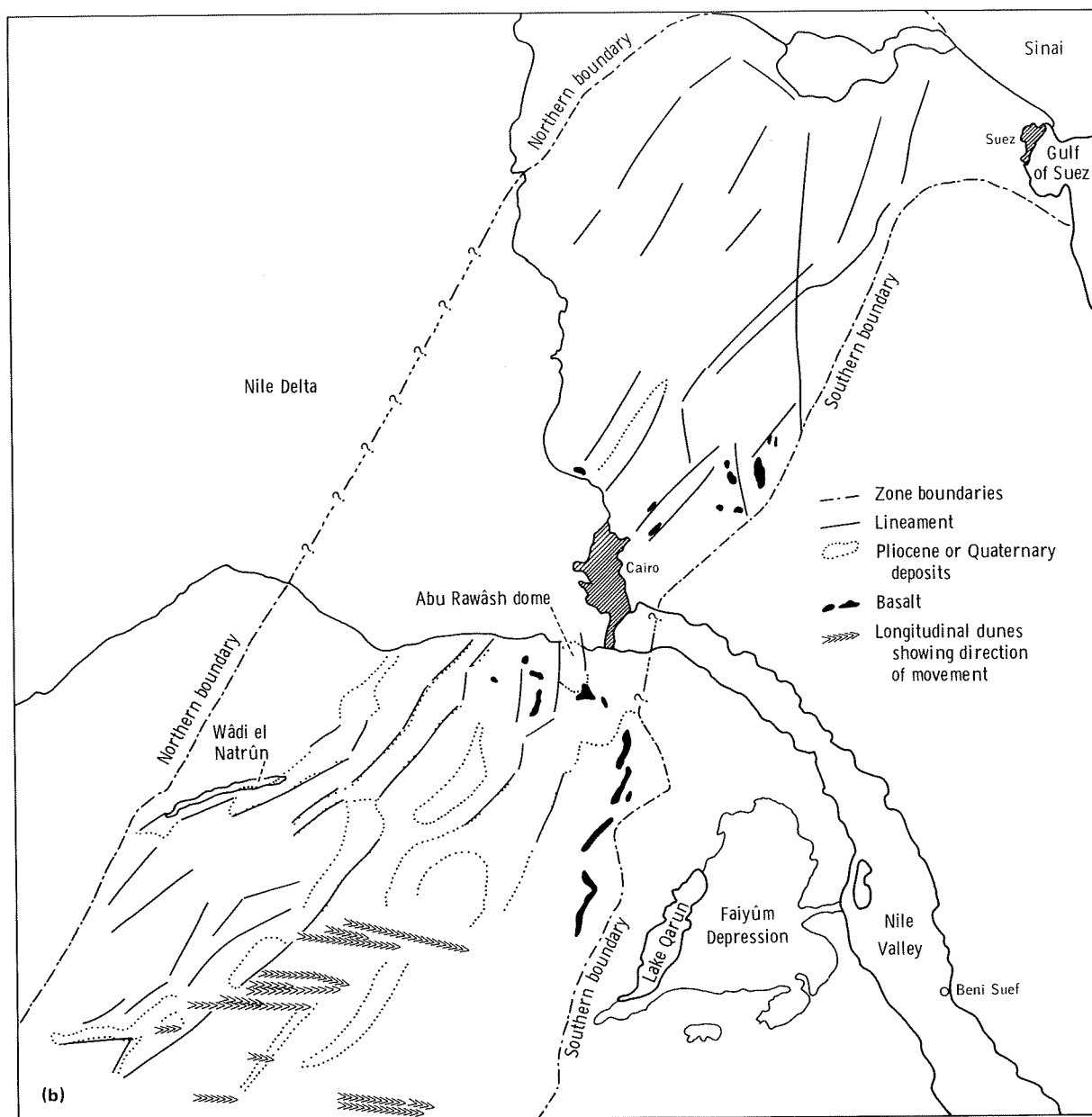


FIGURE 1.—Concluded.

similar composition to those west of Cairo. Shukri and Ayouty (ref. 13), however, have noted that sillimanite is abundant in these deposits in contrast to those of the Western Desert. A likely source rock for this mineral is the metamorphic terrain west of the Gulf of Suez.

Based on field study, relationships of the basaltic extrusions in Bahariya Oasis indicate that two phases of volcanic eruptions may have occurred during the Oligocene time (authors' observations). The age of the earliest phase is not well established, whereas the later phase marks the late



FIGURE 2.—False-color Landsat mosaic of Egypt showing the boundaries, shape, size, and location of the probable ancestral delta of the Nile River.

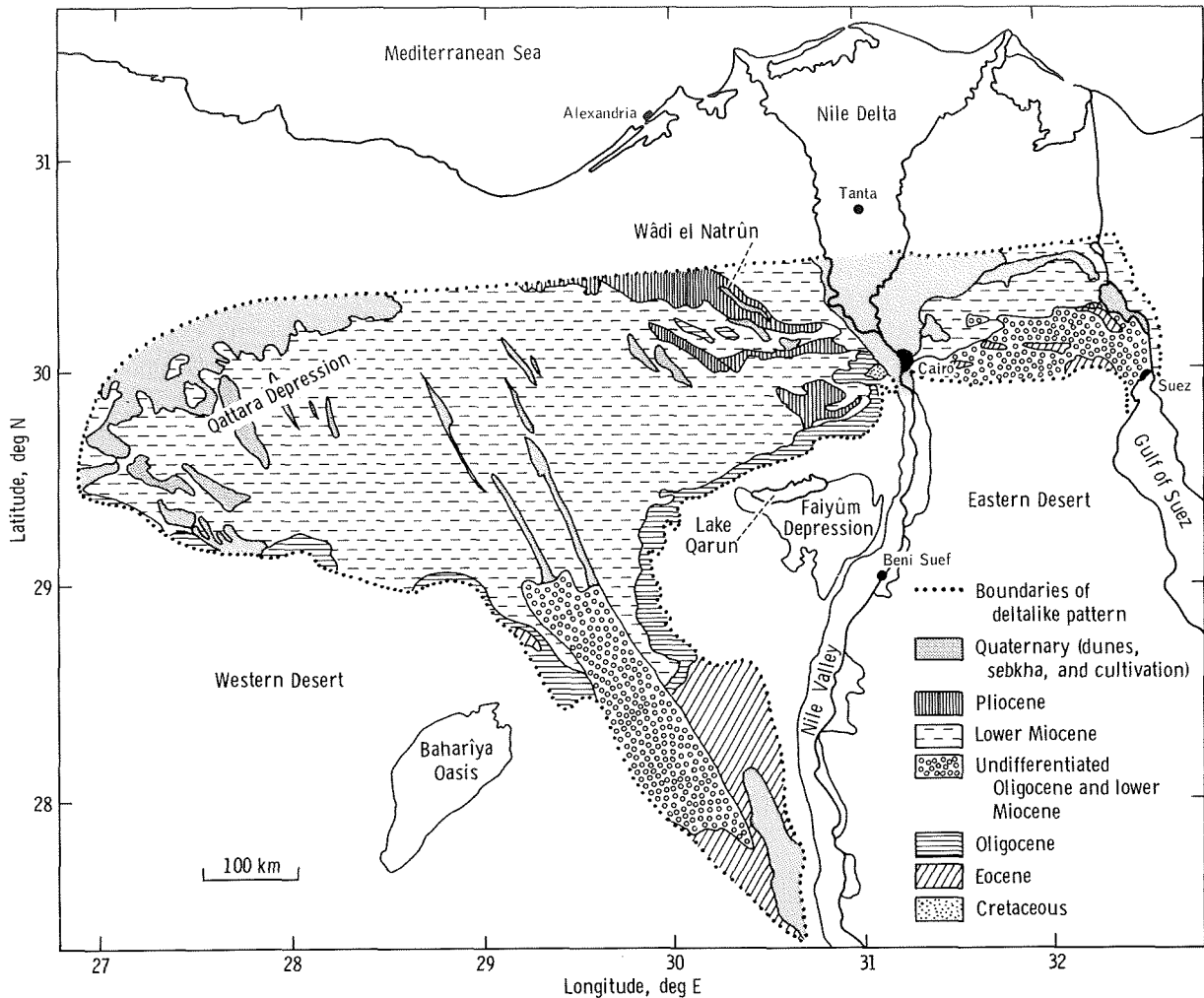


FIGURE 3.—Geological sketch map of the probable ancestral delta of the Nile. This map is based on the geological map of Egypt (ref. 2) and is modified east of Wâdi el Natrûn (based on Said, ref. 3) and simplified east of Cairo. Fault lines are not shown for simplicity; some are shown in figure 1(b).

Oligocene time and forms the unconformity surface between the Oligocene and the overlying lower Miocene rocks.

The lower Miocene deposits in the deltalike pattern occupy extensive areas in both the Western and Eastern Deserts. The type locality of these deposits is near Moghra Oasis where the section is exposed along the northern slope of the Qattara Depression. The sediments of the lower Miocene (Moghra Formation) are very similar to

the previously described Oligocene strata except for their much lighter colors. They are composed of sand and gravel containing silicified wood, vertebrate remains, and freshwater fossils. Locally, these clastics may be found interbedded with their marine marl beds, indicating limited sea-level fluctuations during deposition.

Similar to the Oligocene deposits, the lower Miocene deposits attain their maximum thickness along the axis of the deltalike pattern. They attain

a thickness of 615 m approximately 100 km southwest of Wâdi el Natrûn. The northern boundary of the deltalike pattern (fig. 3) corresponds to the boundary of facies change of the lower Miocene deposits; west, northwest, and north of the Qattara Depression, marine deposits of lower Miocene age predominate. It is also noteworthy that the northern boundaries of the deltalike pattern correspond to the northern boundary of the Qattara Depression. This may indicate that the northern boundary of the Qattara Depression is, in fact, a fault line and a boundary of marked facies change. The lower Miocene rocks to the north of that boundary are predominantly marine and those to the south are predominantly sandy. The distribution of sand dunes in the Qattara Depression (fig. 2) indicates that all the dunes originate south of the northern Qattara boundary; i.e., all the dunes are derived from the lower Miocene Moghra Formation.

The Miocene rocks that crop out east of Cairo are not fully understood. However, according to Said (ref. 3, p. 223) "it seems possible to correlate the lower sandy beds of the Miocene of the Cairo-Suez district with the lower Miocene Moghra Formation described from the Western Desert. There is no conclusive paleontological proof that the former beds are of lower Miocene age."

CONCLUDING REMARKS

From the previous discussion, it is clear that the upper Eocene, Oligocene, and lower Miocene deposits present in the area indicate very similar facies. The large area covered by the deltalike pattern, the huge thickness of sediments that belong to similar facies, and the continuity of the facies indicate that these deposits were laid down by a single continuous event and not by intermittent events. The unanimous agreement, in the literature, on describing these sediments as fluvial, estuarine, prodeltaic, deltaic, and fluvio-marine leaves no doubt as to their origin. The position of the identified deltalike pattern (fig. 3), the position of its V-shaped tip in the proximity of the Nile Valley northwest of Asyût, and the similarity of the northwest orientation of the axis of this pattern to the orientation of the Nile Valley

south of Asyût, lead the authors to believe that the identified deltalike pattern is in fact an ancestral delta of the Nile.

The pear-shaped pattern that is interpreted here as an ancestral Nile Delta appeared with less clarity on a visible image (0.5 to 0.7 μm) taken by the NOAA 2 VHRR (National Oceanic and Atmospheric Administration 2 very-high-resolution radiometer) of the Nile Valley on October 23, 1974. The pattern was tentatively interpreted as an "old Nile Delta" (ref. 17), based on the hypothesis of Hantar (ref. 14). However, the present study of ASTP photographs and Landsat images provides new evidence and makes the interpretation more valid.

The ancestral Nile appears to have followed a similar course to that of the present Nile from Asyût and southward. It must have originated in late Eocene and lasted until the deposition of lower Miocene sediments (approximately 28 million years). Early in the middle Miocene time, the Nile ceased dumping its deposits in its delta. Instead, it lengthened its course flowing northward where it occupied a course similar to the present one. The reason for such a sudden change in course and length of the Nile is likely related to a major uplift that started in the Oligocene time and continued until the early Miocene. This phase of uplift is the same phase that caused the extensive rifting tectonics of the Gulf of Suez region and the extrusion of basalts. It is noteworthy that the majority of the exposed Oligocene basalts in Egypt lie within the ancestral Nile Delta or delimit parts of its boundaries. It is also important to note that the southern tip (V-shaped end) of the ancestral Nile Delta has two large basaltic outcrops (ref. 2) suggesting a possible partial role of volcanic extrusives in blocking the course of the Nile.

The abandonment of the ancestral Nile Delta is beyond doubt related to tectonics. Periodic changes that occur in the distributary patterns of deltas involve a variety of geomorphic reasons (ref. 16), and their effects lead mainly to facies changes. Quaternary changes in the depositional regimes of the present Nile Delta are documented by Said (ref. 5).

The northern boundary of the ancestral Nile Delta (figs. 1 to 3) is straight and continuous for

approximately 500 km. This may indicate that the northern boundary represents a fault line whose downthrown side is to the north. As indicated earlier, this fault line was probably marking the shelf margin during the deposition of the Oligocene/lower Miocene rocks.

Color and textural variations observed within the identified delta are related to either the patchy occurrence of overlapping younger sediments (e.g., Pliocene and Quaternary deposits) or to the characteristics of the discontinuous and patchy lithofacies of the deltaic sedimentation pattern.

The eastward decrease in color intensity (fig. 1) may partly be due to the thinning out of these deltaic deposits east of Cairo because of increasing distance away from the source. The offset of the ancestral Nile Delta to the east may be explained by a longshore current acting along the shorelines of Egypt from west to east (ref. 15).

The detailed mineralogy and geochemistry of the upper Eocene, Oligocene, and lower Miocene rocks may vary locally. Such variations may specifically be noticeable in that part of the delta east of Cairo, because of the influence of tributary drainage lines that drain the basement rocks of the Gulf of Suez area.

The present study should end a long-lasting debate on two theories concerning the origin of the Nile (ref. 14). Blanckenhorn (refs. 8 and 9) believed that there was an older Nile (Ur-nil) that flowed to the west of the present Nile. He obtained support for his theory from the presence of deltaic deposits west of Faiyûm. Arguments against his hypothesis, however, included the absence of a river channel south of that delta. Ball (refs. 10 and 11) and Hume (ref. 12), on the other hand, maintained that the present-day Nile had existed since the early Miocene-Oligocene time and that it followed a course very similar to the present Nile course.

The present study has identified the limits, shape, position, and age of the ancestral Nile Delta; therefore, the authors believe that the two parts of the Nile have different ages. The part of the Nile south of Asyût dates back to the late Eocene time and its delta is the ancestral Nile Delta identified in the present study. The part of the Nile to the north of Asyût is younger because it was cut in "post" early Miocene time after the

deposition of the lower Miocene terrigenous deposits. This finding is in agreement with Salem (ref. 15) but is in contradiction with Said (ref. 5). According to Salem (ref. 15, p. 46), "the Nile apparently changed its course dramatically in middle Miocene time and debouched its sediments near the present Nile delta. This change most probably resulted from faulting. Thus, deltaic deposition started near its present site at least as early as middle Miocene time." Said (ref. 5, p. 9), however, maintains that "the cutting of the valley of the Nile seems to have taken place during the Messinian (Upper Miocene)."

The authors disagree with Salem (ref. 15, p. 34) on two issues:

1. According to Salem, "progradation during the Oligocene and Miocene was from southwest to northeast" . . . and . . . "longshore currents aided in the redistribution of sediments in an easterly direction toward the present Nile delta." The present study has defined the full extent and shape of the ancestral Nile Delta and its point of junction with the Nile; therefore, it is pertinent that the progradation of the deltaic sedimentation occurred from southeast to northwest and that the effects of the longshore currents (from west to east) resulted in the offset of the ancestral Nile Delta (fig. 2).

2. Despite the fact that Salem (ref. 15, p. 54) has identified a sedimentological pattern that coincides with the central and northern parts of the ancestral Nile Delta identified in the present study (fig. 2), he attributed the deltaic deposits to "ancestral Nile deltas near the present Nile delta" (ref. 15, p. 34). Therefore, he did not consider the whole pattern as one delta. This shows the importance of the synoptic view provided by space photographs. Probably the reason that Salem (ref. 15) did not identify a "one delta" pattern is that his study area did not extend far enough south for him to identify the southernmost extension of the deltaic pattern and its relationship with the Nile Valley. However, the fact that Salem's model was based entirely on sedimentological and stratigraphic analysis demonstrates beyond doubt the validity of ASTP photographs and Landsat images, if properly used, in depicting regional depositional patterns.

The history of the river Nile is an unfinished

story. Despite the fact that Egypt is the gift of the Nile, published work on that river is scarce and its geology is still far from being well understood. This study may have added just a sentence to the unfinished story of the Nile.

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