ENVIRONMENTAL CHANGE AND HUMAN CULTURE
IN THE NILE BASIN AND NORTHERN AFRICA
UNTIL THE SECOND MILLENNIUM B.C.
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HUIB E. DE WIT

The evolution of the Eastern Nile Delta as a factor in the development of human culture

Introduction

The work of the Netherlands Foundation for Archaeological Research in Egypt (NFARE), the successor of the Amsterdam University, Survey Expedition (AUSE) focuses on the earliest settlement patterns in the Eastern Nile Delta, the area close to the Sharqiya desert border (Fig. 1). The archaeological research is dealt with by van den Brink (1988 and this volume). Palaeo-geographical research forms an integrated part of this work and is intended to back-up archaeologists' insights in the cultural development in the area. Topics specifically addressed by the archaeo-environmental research are the drainage pattern of ancient Nile distributors, suitability of terrains for the various exploitations by ancient man, natural causes for changes in settlement patterns and so on. The results of the first years of the survey are described in van Wesemael and Dirksz (1986), Sewuster and van Wesemael (1987) and de Wit and van Stralen (1988a; 1988b).

The survey area of *ca.* 1,000 square kilometres is confined to the Delta plain, defined as that part of the Nile Delta which lies permanently out of reach of coastal processes, between the Delta front (the Mediterranean shore) and the Delta apex (Cairo). Yet, this typical environment forms an integrated part of the Delta as a whole. Numerous professional studies were devoted to the geology and morphodynamics of delta systems in general. These have resulted in models and empirical quantifications of relevant factors (Reading 1986) which, while valid for the entire Nile Delta, also are applicable to the NFARE survey area on a much smaller scale. Reversely, the survey area may have predictive value for the Nile Delta as a whole. Palaeo-environmental studies of the survey

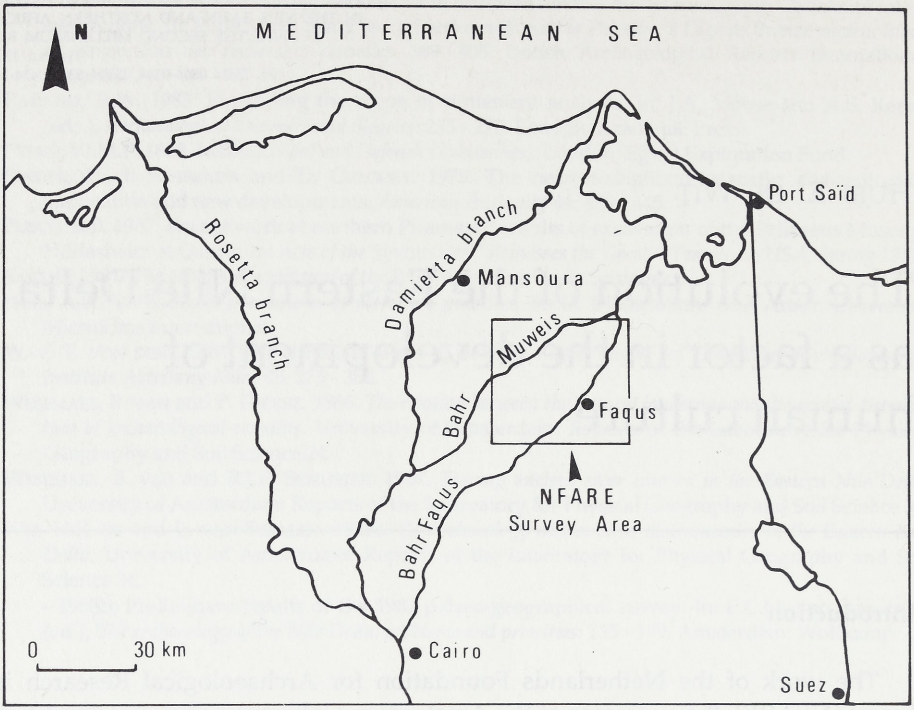

Fig. 1. The NFARE survey area in the Nile Delta.

area therefore should incorporate regional factors such as fluctuations of Nile discharge, Mediterranean sea level and climate. Also cultural factors should be regarded, as they will have invoked changes of the natural conditions. For instance, patterns of sedimentation and erosion may have adapted to socio-economic developments such as increased cultivation and irrigation or to neglect and abandonment.

In archaeology the Nile Delta is a relatively new area of interest, but research is rapidly expanding (van den Brink 1988). Equally, investigations in the natural evolution of the Nile Delta have intensified (Hamroush, Krzyżaniak and Wunderlich, this volume). In literature concerning the Nile Delta, the Delta front is described in most detail (*e.g.* Rizzini *et al.* 1978; Stanley 1983; 1988; Sneh *et al.* 1986; Coutellier and Stanley 1987). Several studies were published concerning the composition of Nile sediments in relation to provenance, age, type and location of deposition (Shukri 1950; Kholief *et al.* 1969; Hassan 1976; Stanley and Liyanage 1986; for an overview see Frihy and Stanley 1988). The Delta plain, however, often simply is referred to as the area where the Nile diverged into seven branches from which the "well-known Nile muds" were deposited during annual floodings. When mentioned, most attention is paid to the overall thickness of the alluvial deposits, the magnitude of the annual floodings and the reasons for the silting up of five of the former branches (*e.g.* Butzer 1975; 1976). Recent field campaigns indicated that the subsoil of the Delta plain is highly complex (el-Fawal 1975; Andres and Wunderlich 1986; van Wesemael and Dirksz 1986; Hamroush 1987; de Wit and van Stralen 1988a; 1988b; Dorner 1985; Wunderlich, pers. comm.). This brought up the need for an overall palaeo-geographic model as a framework for more specific archaeo-environmental questions. In this paper such a model for the Eastern Nile Delta plain is presented, based on the compiled field stratigraphy of the AUSE/NFARE survey area. A thusfar unknown formation of this stratigraphy is introduced, called the Nile 2 formation. Its deposits were preserved possibly as a result of the area's location at the Delta-desert interface. The Nile 2 deposits and the special position of the survey area are explored with a view to the environmental conditions just before the present Nile regime settled and gave the area (as a final expansion of the entire Nile Delta) its present shape. In a separate paragraph the model for the natural evolution is interpreted in terms of its potentials for the development of human culture.

Methods

The palaeo-environmental research for the AUSE/NFARE project is split up in two parts: one aiming at the development of a model for the natural evolution with implications for living conditions in the past, and a second concerning more specific archaeo-environmental questions. In many respects the two approaches are complementary. Inasmuch as the difference between the two merely is a matter of scale, both may profit from common practical techniques.

Survey techniques comprise hand- and mechanical drillings, whereby primary sedimentological and pedological features are evaluated, besides geo-electrical methods and interpretation of remote sensing data (aerial pictures and satellite images). As a policy, laboratory analyses (radiocarbon datings, grain-size distributions and mineral assemblage determinations) only are carried out when indispensable for specific purposes. Methods and progress of the research were described in the reports by van Wesemael and Dirksz (1986), Sewuster and van Wesemael (1987) and de Wit and van Stralen (1988a). Augerings initially were made to a medium depth of 3 metres, along transects perpendicular to the inferred (Bietak 1975) ancient Nile streamchannels. During the 1987 and 1988 seasons the augerings had to serve the general palaeo-environmental research, for which reason the auger depths were increased to 5 - 8 metres with a maximum of 12 metres. Moreover, the initial regular layout of transects was abandoned in favor of *ad hoc* grids which served particular stratigraphical objectives and detailed mappings. Radiocarbon datings were calibrated according to Stuiver and Kra (1986). The results of satellite imagery interpretations are not yet included explicitly in this paper.

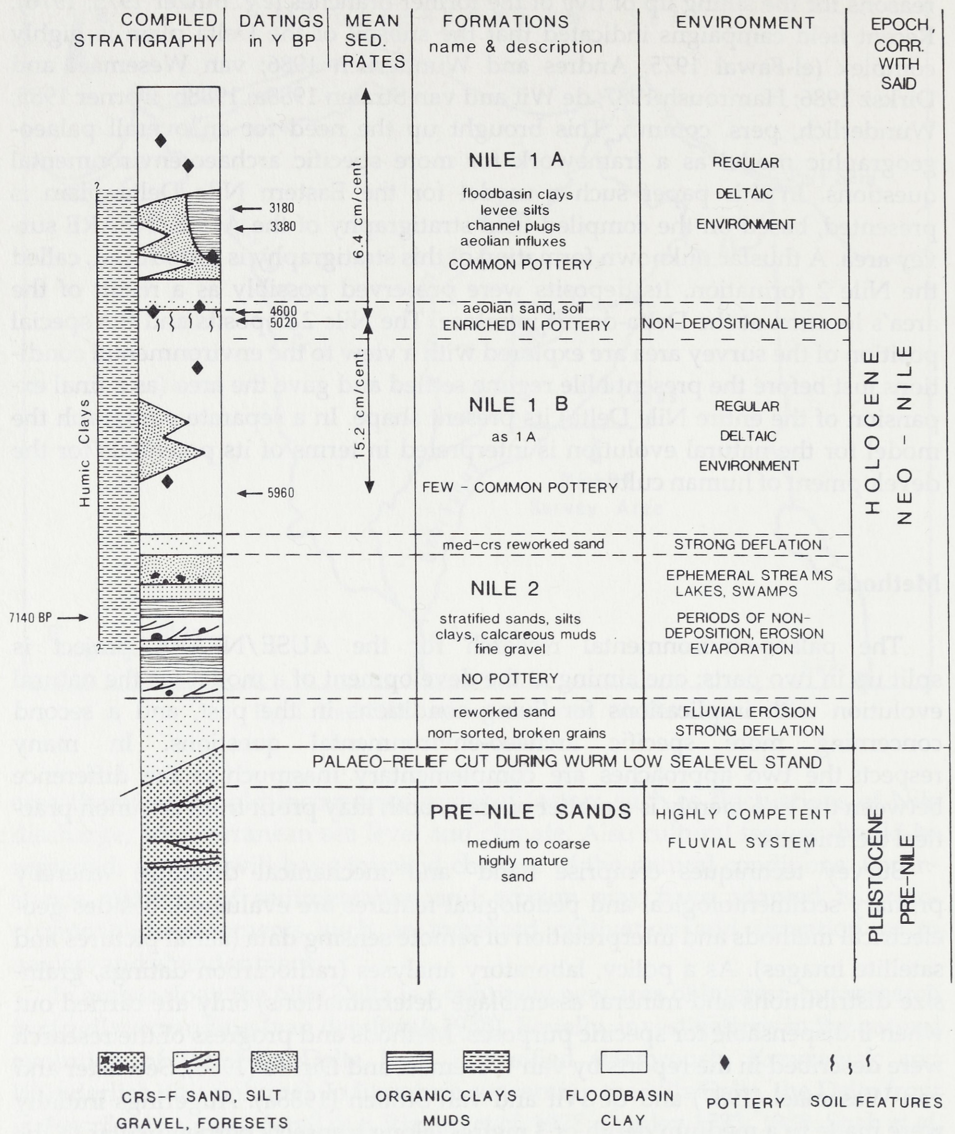

Fig. 2. Compiled Upper Quaternary Nile Delta stratigraphy;

The stratigraphical column to the left gives a pictural summary of lithologies, sedimentary characteristics and stratigraphic correlations of the different formations. Being a compilation, the column is not to scale; in reality the thicknesses of the formations vary widely over the area. For the same reason, arrows at the radiocarbon ages indicate relative positions of dated samples in different formations. The ages are calibrated according to Stuiver and Kra (1986). The period of low sealevel stand, separating Pre- and Neo-Nile deposition is named after the last glacial period in Europe, the Würm. As a stratigraphical formalism, the Nile 1a and Nile 1b are members of the Nile 1 formation rather than formations of their own. Descriptions and environmental interpretations are given in the text.

Stratigraphy

The Upper Quaternary stratigraphy of the survey area is given in Figure 2. Referring to the earlier mentioned continuity of natural environments on a regional scale (the survey area being part of the entire Nile Delta) it may be expected that much of this stratigraphy is valid also outside the survey area.

The stratigraphy comprises three formations separated by non-depositional or erosion horizons. Each formation is made up of several types of deposits reflecting the variability of the environment at the various epochs. For environmental reconstructions the stratigraphic boundaries (or boundary-layers) between formations are equally important; they represent stratigraphic gaps or, in a chronological sense, periods of non-deposition or erosion, and consequently, they too represent environments which may have been stable for considerable periods of time.

Nile 1 formation

The Nile 1 formation consists of what traditionally is called the Nile muds or Nile alluvial sediments, formed in a standard deltaic environment under regular flow regime of the Nile (the Neo-Nile phase: Said 1981; for historical descriptions of the flow regime of the Nile see Hassan and Stucki 1987). The formation comprises uniform floodbasin clays, levee silts, channelplugs (organic muds, often with shells, formed when a channel is abandoned and silted up) and intermittent eolian sandy influxes.

The Nile 1a and 1b is separated by a repeatedly observed stratigraphic boundary. The horizon on which the distinction of the Nile 1a and 1b members is based is characterized by increased soil formation and often by enrichment of anthropic material and fine laminated sands. Such features point to prolonged exposure without deposition, for which reason the horizon is interpreted as a stratigraphic boundary. The horizon is not always apparent, but can be inferred; for instance in one continuous core of pure floodbasin clays the mean sedimentation rate in the lower half of the augering was calculated at 15.2 cm per century until at least 5,020 years B.P. (cal.; based on radiocarbon dated samples at 3.17 and 4.60 m respectively below the surface), more than twice as high as in the upper half of the augering (6.4 cm per century; datings incorporated in Figure 2 are not at true depths). This either could mean that sedimentation before the fifth millennium B.P. indeed took place at a much higher rate than in more recent times, or that the auger core contains an (invisible) stratigraphic gap. Each interpretation sympathizes with an inferred boundary separating the Nile 1a and 1b members, as each points to a marked break in environmental conditions. By extrapolation of the mean sedimentation rate of 15.2 cm per century up to the top of the core, the time gap would amount to nearly three millennia, which seems unrealistic. Rejecting the idea of a stratigraphic gap, on the other hand, one should accept a drop of the mean sedimentation rate to 6.4 cm/century, which is lower than anywhere else estimated for the Neo-Nile deltaic sediments. The average of four (other) calculated mean sedimentation rates for the entire Nile 1 formation in the survey area amounts to 13.6 cm/century, while for upper deltaic sediments closer to Lake Manzala mean sedimentation rates lie between 10 and 20 cm/century (calculated from data from cores S6 - S8 of the Smithsonian Institution, published by Coutellier and Stanley 1987 and Stanley *et al.* 1988). Butzer (1975) estimates the average sedimentation rate at 20 cm per century.

It is realized that a sudden decrease of the calculated mean sedimentation rate from a certain point upward, as registered in one single augering, could point to de-activation of the nearest distributary channel. However, a well defined boundary indeed was observed in many other augerings, at the depth of about three metres below the surface (de Wit and van Stralen 1988a; 1988b). Probably the drop of the calculated mean sedimentation rate in this one core represents a combination of the two factors: non-deposition followed by reassumed deposition at a lower rate. From one core where the boundary was clearly visible, a sample directly above it was radiometrically dated at 4,560 B.P. (cal.). For comparison, Horowitz (1979) draws the lower boundary of the period with present climatic conditions in Israel at 4,500 B.P. According to this author, the preceding period would have been characterized by milder climatic conditions. Evidence for milder conditions were not found in the Nile 1b deposits, but in the underlying Nile 2 deposits. Bietak (1975) postulates a period of zero Nile sedimentation between the 34th and 29th century B.P.

As stated above, the lithologies of the Nile 1b member are similar to those of the Nile 1a member and point to identical, standard Nile-deltaic conditions. The two deepest samples of the Nile 1b member which were radiometrically dated both yielded an age of 5,960 years B.P. (cal.). Butzer (1975) dates the abrupt lower boundary of the "alluvial muds" at 6,500 B.P.

Nile 1 – Nile 2 boundary

The boundary between Nile 1 and underlying formations (Nile 2 or Pre-Nile formations, respectively) is marked by a sharp unconformity. The underlying lithologies form a strong contrast to the Nile 1 deposits, pointing to entirely different environmental conditions from those known from the modern Nile. Since environmental conditions do not change overnight, the observed differences suggest that the unconformity represents a time gap. Indeed often the unconformity is erosional and may be accentuated by a thin (several cm) layer of coarse sand with milky blue minerals, which is interpreted as a deflation horizon (formed by wind or rainstorms). Based on the age of the lowermost Nile 1b deposits, the gap would date before the sixth millennium B.P. It is not known what length of time the gap represents.

Nile 2 formation

The Nile 2 deposits are clearly different from the Nile 1 deposits as they are not uniform but distinctly bedded instead. The merely stratigraphical name "Nile 2 formation" is unfortunate, it might suggest that the deposits were derived from the Nile itself. The contrary is the case: the Nile 2 deposits are distinguished from the Nile 1 deposits because by no means can they be interpreted as normal deltaic sediments. Different beds consist of different lithologies, and display a variety of sedimentary structures. The lithologies comprise (gravelly) sands, silts, clays and organic or pure calcareous muds. Sand and silt beds are graded, crosslaminated or lenticular (ephemeral stream sediments, characteristic of a turbulent flow regime). The muds are mostly homogeneous: organic (deposited in swamps) or calcareous (formed in well- or wadi-fed stagnant pools). The silts to fine sands mostly form thin intercalations which are parallel laminated with a high content of heavy minerals (eolian and sheetflow deposits, the latter being formed by catastrophic runoff from topographic heights). The different kinds of deposits alternate rapidly in a lateral and vertical sense. In general, the Nile 2 deposits have a high content of syn-depositional carbonates, which point to substantial water influxes from allochtonous sources, and strong evaporation. The carbonates are not of pedogenous origin, as they are lacking in similar Pre-Nile and Nile 1 deposits at comparable depths. Considering the foregoing, the formation cannot be attributed to a regular, major fluvial system comparable to the present Nile: a spatially and chronologically much more varied environment (as will be described furtheron) should be inferred.

In case of the Nile 2 deposits consisted of organic or humic clays (stained black by fine dispersed organic material), no boundary can be observed between presumed Nile 2 and Nile 1 formations. The humic deposits have their base at equivalent depths, but their top at much shallower depths than the Nile 2 formation (see Fig. 2); hence their correlation with both Nile 1 and Nile 2 formations. Laterally the deposits measure several hundreds meters across. The base of the humic clays at one location was dated by radiocarbon method at 7,140 years B.P. (cal.), which is older than any deep sample taken from the Nile 1 deposits thusfar. For lithologically more strictly defined Nile 2 deposits no datings are available yet; based on stratigraphic correlations, for the Nile 2 formation a similar age is expected.

Nile 2 – Pre-Nile boundary

The base of the Holocene Nile Delta is an erosional unconformity, formed during the low sealevel stand of the last glaciation, which had its maximum between 18,000 and 11,000 B.P. (Horowitz 1979; Brinkmann 1986; Coutellier and Stanley 1987 give an age of 18,000 B.P.). It is not clear when exactly the eastern delta became part of the modern so called Neo-Nile distributary system. Based on datings from the survey area, this happened early in the sixth millennium B.P. (lowermost samples from Nile 1b). Consequently the Pre-Nile erosion surface and the Nile 2 deposits represent the period of 18,000 to *ca* 6,000 B.P. In fact, it is likely that the relief dates close to the 6th millennium B.P. because the burried Pre-Nile sand surface still shows a topographical gradient, pointing at active erosion until the palaeorelief eventually was covered. During the glacial maximum, sealevel was over 100 m lower than at present (Butzer 1975;

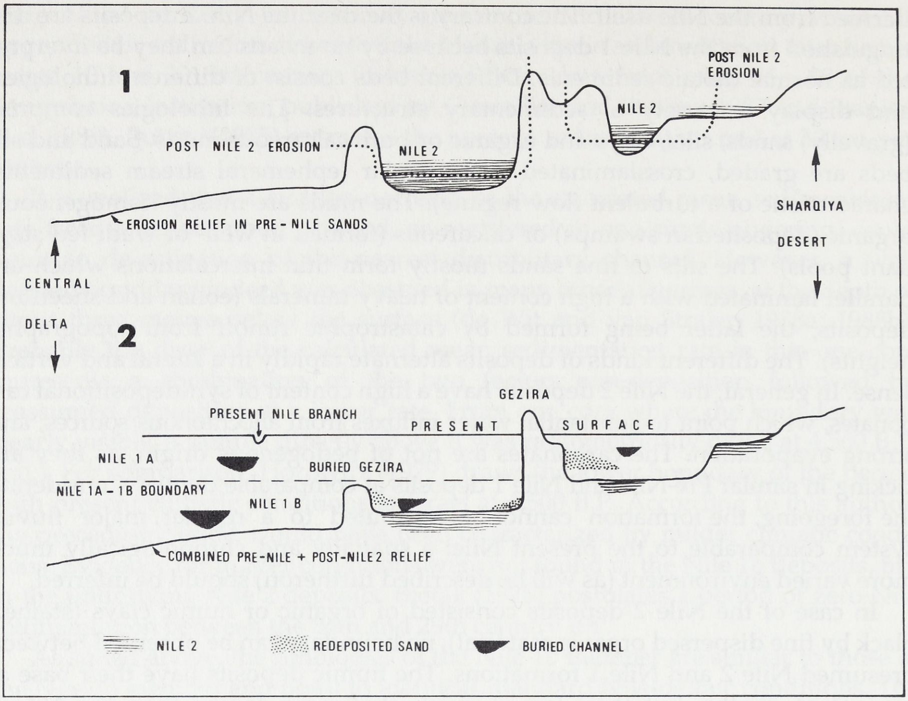

Fig. 3. Development of the Eastern Nile Delta since the Late Pleistocene;
1: Early Holocene, deposition of the Nile 2 formation upon a palaeo-relief cut in Pre-Nile sands. After the Nile 2 depositional phase the entire area again was submitted to erosion, reducing Nile 2 outcrops and further cutting back erosion relics of the Pre-Nile sands.
2: Present situation. The combined Pre-Nile and post-Nile 2 erosion relief (*cf.* top figure) is buried by Nile 1 deltaic sediments. The erosion relics of the Pre-Nile sands are reduced in size, but still stand out above the present-day surface as so called *geziras*. The Nile 1a - 1b boundary (indicated) represents the stable land surface during a period (5th millennium B.P.?) of low to zero deposition as mentioned in the text

Horowitz 1979). Central parts of the Nile Delta basin may have been carved out as deeply; the unconformity is burried to an observed depth of 40 to 80 m below the present surface in the central and northern Delta (Attia 1954; Butzer 1975; Madkour 1988; IWACO 1988; Stanley 1988), gradually decreasing to zero at the Delta edges. The *geziras*, isolated sand mounds standing out above the Delta plain close to the Delta fringes, are the last exposed relics of this erosion surface (Fig. 3:2).

Pre-Nile formation

The older deposits in which the palaeo-relief was cut, consist of mature (texturally and compositionally pure) sands. As can be established in *gezira*-outcrops, the sands are devoid of sedimentary structures but may form large mega-crossbeddings. The formation pertains to the Pre-Nile phase (Middle Pleistocene; Said 1981), and accordingly will be called Pre-Nile formation. The frequently used name "*Gezira* sands" is misleading as it only refers to a physiographic unit of plurigenetic origin. Geo-electrical soundings leave room for an interpretation that a deeper levels in the formation silts and clays are intercalated (de Wit and van Stralen 1988a; IWACO 1988).

Interpretation: Chronologic evolution of the Quaternary Nile Delta

On the general geological setting of the Nile Delta the following inferences are based. The geographical limits of what was to become the Neo-Nile Delta were set when the palaeo-relief was cut in Pre-Nile sands during the low sealevel stand of the last glaciation (Said 1981). With sealevel rising again after the glacial maximum, sediment began to accumulate in the eroded basin, gradually burying the palaeo-relief. It may be safely assumed that true Delta-type deposition was initially confined to the Delta front and the central, deepest parts of the basin. Direct clues regarding environmental conditions in the Delta during the Early Holocene are hard to obtain. Coutellier and Stanley (1987) describe basal Delta sediments, notably older (Pre-Nile?) riverine sands which have been reworked in an erosive fluvial or coastal setting during the Late Pleistocene to Early Holocene. The oldest Neo-Nile clays of the central Delta would date to *ca.* 10,000 B.P. However, being suspension sediments of the Nile, these clays are of allochtonous origin (Said 1981; Butzer 1974) and do not tell much about local conditions. The range of Early Holocene Delta-front deposits tell much about environmental conditions inland, as these are genetically related to coastal processes. Hence the central Delta and the Delta front provide restricted stratigraphic evidence regarding local conditions during the period between 18,000 and 6,000 B.P. The local stratigraphy from the AUSE/NFARE survey area indicates that at that time Delta edges were still beyond the reach of the regular Nile branches. The Nile 2 deposits, found in the area, are of local origin. The Early Holocene conditions in the eastern Nile Delta are reconstructed from that stratigraphic evidence.

Lithologies and facies characteristics of the Nile 2 deposits point to a variety of (coeval) small scale environments. Many of the small depositional systems seems to have been fed by intermittent (ephemeral), high-energy water influxes of local provenance and by heavy rainstorms (wadis from the adjacent desert). At the same time the area suffered strong evaporation (calcareous muds). Eolian activity was not dominant. Secondly, more permanent water-bearing systems existed, such as larger rivers, swamps and lakes. Though these rivers were not capable of producing overbank clays, the swamps (at least several of them) were stable enough to outline the Nile 2 phase. Most lake deposits show no obvious traces of temporal desiccation.

The coeval existence of these kinds of depositional environments can only be accounted for by assuming an arid climate with a total water-influx or amount of precipitation which was considerably higher than at present (*cf.* the "pluvial" period with rich vegetation and paludine environments which Horowitz [1979] postulates for the Middle East from 7,000 to 4,500 B.P.). The depositional environments depending on intermittent water-influxes would fit to arid climatic conditions as known today in the Eastern Desert, but this is contradicted by the lack of major eolian deposits. Moreover, the scale of the ephemeral and other deposits points to a higher intensity and frequency of tempestuous precipitation than at present. The presence of larger, perennial waterbearing systems, which clearly were no ordinary Nile distributors, may be explained in several ways. Perhaps singular Nile branches already had reached the area, simply traversing it and cutting such deep channels that they precluded spillover and flooding during the annual high stage. Instead, sediment taken up by scouring of the subsoil was transported downstream to be deposited at the Delta front. (*Cf.* new

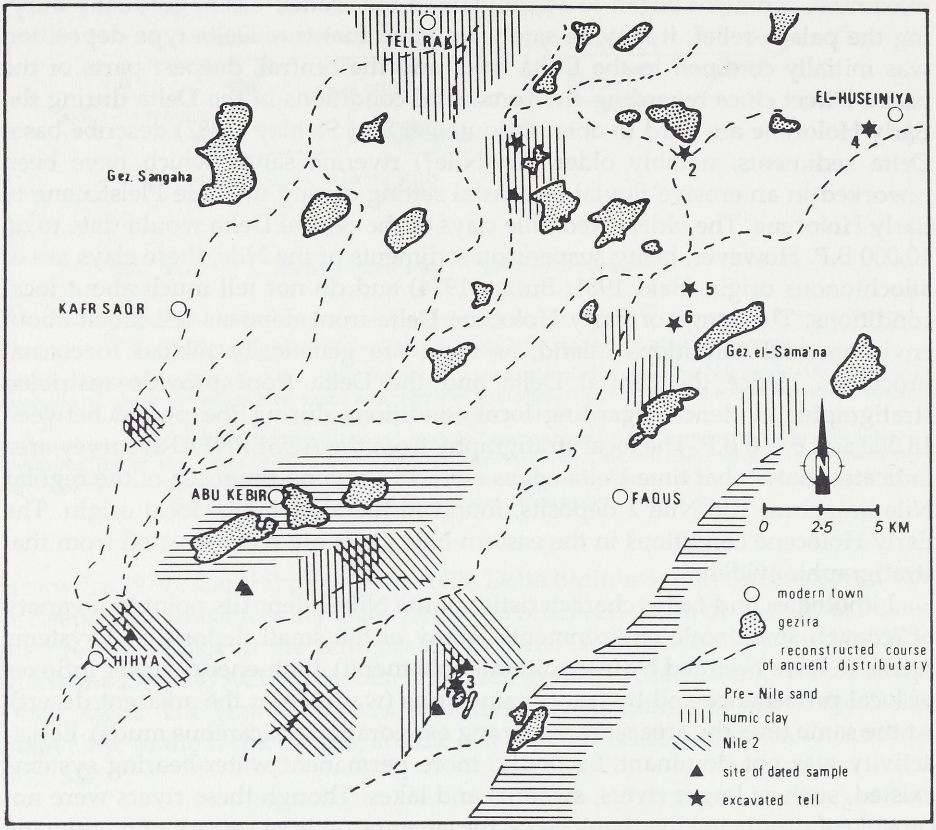

Fig. 4. Map of survey results;

The map is a schematization of the map given in de Wit and van Stralen (1988a), and incorporates data from van Wesemael and Dirksz (1986) and Sewuster and van Wesemael (1987). Ancient stream courses are buried to variable depths and range in age from at least 6,000 B.P. to subrecent. The large subsurface sand body with outstanding *geziras* in the centre of the survey area provides a good example of how old erosion relics have dictated the landscape evolution until to date. The contours of swamp and Nile 2 deposits are based on identification of the deposits in auger-transects. Detailed mapping of the real extensions may reveal their origin. Several presently excavated tells are indicated: 1: Iswid South; 2: Ibrahim Awad; 3: Farasha (van den Brink 1988); 4: Fara'un; 5: Qantir; 6: el Dab'a (1 and 2 date back to Pre-Dynastic times and were situated close to large swamps; see text).

channel divergences on alluvial fans [*e.g.* Miall 1985; Reading 1986], to which an incipient Delta bears some resemblance). Predominant scouring would account for the high rate of progradation of the Delta front in the Early Holocene, as reported by Coutellier and Stanley (1987), Shea (1977) and Sneh *et al.* (1986). The large swamps, stable and not suffering from droughts, may represent the Nile distributary blocked by the topography of the palaeo-relief. Similar deposits, but of subrecent age, were found close to the desert border during the 1988 field survey and need further study. The stagnant pools with calcareous mud precipitation, however, again point to higher local water-influx, as it is hard to imagine that pure calcareous muds have been deposited directly from the Nile waters.

A period of general erosion succeeded the Nile 2 phase. When plotted on a map (Fig. 4), the occurrences of former Pre-Nile erosion relics and Nile 2 deposits appear greatly reduced. The post Nile 2 erosion relief is so irregular that it is inconceivable that it was formed otherwise than by larger streams; yet, the normal Nile regime as we witness today, is not capable of such severe scouring. Probably the early Nile branches kept on scouring the area and had not yet evolved to the kind of tranquil meanders that cause sediment accumulation by annual floodings. At the same time local water-influxes and precipitation diminished and thus precluded further Nile 2 deposition. Prevailing erosion also is evidenced by the thin deflation horizon topping the Nile 2 deposits (irrespective of their type of origin) in many auger cores. Increased deflation indicates a relatively dryer period marking the end of the Nile 2 phase.

When in the Early Nile 1 phase standard depositional Neo-Nile conditions eventually reached the area, this last palaeo-relief became buried by regular deltaic deposits (Fig. 3: 2). The base of the Nile 1 formation is identical to higher parts of the formation, for which reason it is assumed that once the local distributary (Nile branch) system matured into its constructive phase, it did so for good. Standard Nile sedimentation is a well known story: during annual floodings sediments from higher upstream were left behind on the Delta plain as overbank deposits. Only the distributary pattern was determined in the Delta plain itself, other sedimentation was entirely governed by regional factors. Windblown sand influxes as well as runoff sediment-sheets closer to the *geziras* occur on a limited scale, emphasizing climatic conditions similar to the present one, since at least 5,960 B.P. (cal.). Holocene redeposition of Pleistocene sands can be deduced from incorporation of anthropic material in the sands, but also from the fact that wedges and sheets of pure, typical Pre-Neo-Nile sands regularly occur extending from the *geziras* and "floating" in the flood-basin clays. Archaeologists should be aware that even such pure sands need not necessarily constitute the virgin soil. As pilot studies have revealed that pollen preservation in the Nile 1 deposits is rather poor (Prof. van Zeist, pers. comm.) hopefully microfaunal analyses (diatoms) may help determining local environmental conditions.

The non-depositional boundary between the Nile 1a and 1b members again may be explained by regional factors. When for some period the magnitude of the Nile floodings was considerably less than usual, the natural irrigation and gradual build-up of the floodbasins was interrupted. The effects were a break in the sedimentary record (effectively a drop of calculated mean sedimentation rate), and increased soil formation and concentration of non-Nile and anthropic material on the permanently exposed land surface. Reduced Nile floodings would have occurred in the first half of the 5th millennium B.P. (see datings in Fig. 2).

Archaeological implications: The evolution of the Eastern Nile Delta as a factor for cultural development

The palaeo-environmental model can fully explain all field observations and provides an adequate framework for the cultural development in the NFARE survey area. Figure 4 is an interpretation of the observations, showing principal palaeo-environmental elements of widely different ages. The figure is not a palaeo-geographical map, but merely serves to illustrate the mechanisms of the natural evolution of the area. It shows that the Pre-Nile erosion-relief has dictated patterns of deposition and renewed erosion throughout the Holocene. Nile 2 deposits are found along the desert border and wherever they are shielded from erosion by the Pleistocene relics. Equally the erosion relics have controlled the course of the Nile 1 distributary channels until today. The Pre-Nile sands themselves, or the erosive surface of Early Holocene age at their top, have yielded no indications regarding human settlement in the area. Because of their age they are excluded from the NFARE program.

During the Nile 2 phase nomadic subsistence may have been possible in the area (*cf.* sites described from the Egyptian Sahara: *e.g.* Brookes, Kröpelin and Neumann, this volume; and the Negev: Horowitz 1979), provided that precipitation was not only more intense, but also more frequent than at present. The swamp and lake deposits (vertical- and cross-hatched in Fig. 4) indicate sites with a relatively stable watersupply, even in the period of drought and deflation before regular Nile conditions come about in the area. Such sites will have offered good opportunities for (semi)permanent settlement during Upper Palaeolithic (depending on the maximum age of the deposits), Neolithic and Early Dynastic times. For instance, the sample dated at 7,140 B.P. (cal.) was recovered from vast swamp deposits close to the AUSE archaeological site of el-Tell el-Iswid (South). Recorded settlement at this site dates back to Pre-Dynastic times, 5,350 years B.P. (van den Brink 1989). Based on stratigraphic correlations, the swamp still existed during much younger occupation periods of the tell. During the 1988 survey a similar configuration was discovered at another Pre-Dynastic site, notably Tell Ibrahim Awad. This suggests that the early settlement sites were directly related to nearby swamps or waterpools. Due to northward decreasing topographic (palaeo)elevations, more swamp deposits may be expected towards the present Delta front. These too were potential sites of human occupation (Krzyżaniak, this volume).

The westernmost major distributary depicted in Fig. 4 (the so called Tanitic branch system) may already have been active during the Nile 2 phase. The assumption is based on a direct correlation of the Tanitic bedload and the underlying fluvial Nile 2 sediments. In this respect it is remarkable that most of the oldest sites are concentrated along this (pro)Tanitic branch (van den Brink, this volume, and 1989). Also due northwest of the Sharqiya desert border an incipient distributary may have existed during the Nile 2 phase; its remains, however, are too scattered to fit a consistent pattern. Depending on what major Nile 2 fluvial systems actually looked like, they may have provided favorable opportunities for human settlement. However, thusfar no archaeological remains have been recovered from any of the Nile 2 deposits.

The Nile 2 phase was concluded by a period of erosion and deflation. Prevailing dry climatic conditions will have prevented other than marginal possibilities for cultural development, except at sites with a more stable water-supply such as described above.

The Nile 1 phase was characterized by a climate and Nile flowregime such as we know today in northern Egypt. Though regional conditions were fairly constant, by no means the Nile 1 Delta itself was a static landscape. The continuous shifting of the various distributors caused a dynamic evolution of the area. This is illustrated by the variable ages (birth and extinction) of virtually each of the stream channels which are depicted in Fig. 4. Once more it should be realized that the apparent homogeneity of the Delta surface is misleading. The entire survey area, except for the desert and the *geziras,* is covered by alluvial sediments, mainly floodbasin clays. Traces of alleged backswamps, based on ancient Egyptian and historical sources (Bietak 1975; *Déscription de l'Egypte* 1809 - 1822), are obliterated. The original deposits now are identical to floodbasin clays, probably as a result of biological burrowing and oxidation during dry seasons. The unfortunate effects hereof are that the distinction of ancient agricultural fields *versus* backswamps and wasteland areas is impracticable, and that hardly any pollen have been preserved. During the 1988 season singular, highly organic swamp deposits were found which still contain pollen, that will be analyzed in the future (Bottema, pers. comm.). The clays bear numerous traces of human utilization, such as anthropic material, (cultivated) soils and even man-made canals. Settlement patterns were dictated by the *geziras* and ancient river courses: *tells, i.e.* centers of human settlement, are found preferentially on *geziras* close to stream channels. Increasingly in the course of the Egyptian history, settlement patterns became related to other than natural causes (van den Brink, this volume).

In the period represented by the Nile 1a - 1b boundary, regular deltaic deposition fell short, due to regional but possibly also human causes. Regional causes could be temporary waning of the Nile discharge or temporal climatic changes. Man-induced causes could be damming or decapitation of the eastern Nile branches somewhere upstream. Accumulation of anthropic material on the boundary surface indicates that the area remained occupied during this period.

One final point merits consideration. The continuous build-up of the Nile 1 Delta resulted in gradual burying of older deposits to increasingly greater depth, as *e.g.* can be traced at *gezira* edges. Similarly, the Nile 2 calcareous muds nowadays are buried to such depth that they had not been rediscovered thusfar. Corrected for gradual burying, the calcareous muds did rest at lesser depths and locally may have been exposed in Pre- and Early Dynastic times. The muds provide an excellent raw material (pure or admixed with clay) for ceramics. White ceramics regularly were found at excavations in the Delta, but up to now have automatically been considered imported ware: the natural occurrences of raw material for such ware (*e.g.* marl clays) were thought restricted to the area south of Cairo (Butzer 1974; Arnold 1981). The Nile 2 calcareous muds prove that white ceramics might as well have been manufactured locally in the Delta itself.

Conclusions

The Neo-Nile Delta was founded on a palaeo-relief of Late Pleistocene age. The natural evolution of the Eastern Nile Delta since then, as reflected in the stratigraphic record, comprises two constructive phases, separated by a period of erosion. The lower, Nile 2 constructive phase is characterized by abundant ephemeral deposition-environments of restricted dimensions, and possibly by the introduction of the first Nile branches which only were capable of scouring the subsoil. Climatic conditions appear to have been arid with a relative high intensity or frequency of torrential precipitation. These conditions will have permitted (semi)permanent settlement at the banks of larger waterbearing systems, and nomadic subsistence over the entire area. The age of the Nile 2 phase is not established, but stratigraphic correlations indicate that it dates to the Early Holocene, *ca.* 7,000 B.P. and older.

Between 7,000 (?) and 6,000 B.P. a phase of dry climatic conditions and deflation concluded the Nile 2 phase, inhibiting human occupation of the area.

Provisionally dated at *ca.* 6,000 B.P. the regular Nile regime settled in the Eastern Delta. The area became traversed by numerous distributors from which the floodbasin clays were deposited, gradually building up the Delta plain. At some time during the first half of the fifth millennium B.P. Nile floods fell short as a response to changes in the upstream Nile regime or possibly induced by human activities. The non-depositional surface which then developed testifies of man's uninterrupted utilization of the soil. At a later stage this horizon was buried again as Nile floodings resumed and human culture further developed.

References

Andres, W. and J. Wunderlich. 1986. *Untersuchungen zur Paläogeographie des westlichen Niledeltas im Holozän.* Marburg/Lahn: Marburger Geographische Schriften 100.

Arnold, D. 1981. Ägyptischen Mergeltone (Wüstentone) und die Herkunft einer Mergeltonware des Mittleren Reiches aus der Gegend von Memphis. In: D. Arnold (ed.), *Studien zur altägyptischen Keramik.* Mainz: Phillip von Zabern.

Attia, M.I. 1954. *Deposits in the Nile Valley and the Delta.* Cairo: Geological Survey of Egypt, Government Press.

BIETAK, M. 1975. *Tell el-Dab'a II. Der Fundort im Rahmen einer archäologischen-geographischen Untersuchung über das ägyptische Ostdelta.* Wien: Verlag der Österreichischen Akademie der Wissenschaften.

BRINK, E.C.M. VAN DEN. 1988. The Amsterdam University Survey Expedition to the Northeastern Nile Delta (1984 - 1986). In: E.C.M. van den Brink (ed.). *The archaeology of the Nile Delta: problems and priorities*: 65 - 114. Amsterdam: Wolfkamp.

– 1989. A transitional Late Predynastic–Early Dynastic settlements in the North-Eastern Nile Delta. *Mitteilungen des Deutschen Archäologischen Instituts Abteilung Kairo* 45: 55 - 70.

BRINKMANN, R. 1986. *Historische Geologie* 2 (12 - 13th ed.). Stuttgart: Enke.

BROOKES, I.A. 1988. Early Holocene basinal sediments of the Dakhleh Oasis region, South Central Egypt, and their palaeoclimatic significance. *Quaternary Research* 32: 139 - 152.

BUTZER, K.W. 1974. Modern Egyptian pottery clays and predynastic buff ware. *Journal of Near Eastern Studies* 33: 377 - 382.

– 1975. *Delta Lexikon der Ägyptologie* 1: 1043-1052.

– 1976. *Early hydraulic civilization in Egypt: a study in cultural ecology*. Chicago: University of Chicago Press.

COUTELLIER, V. and J.D. STANLEY. 1987. Late Quaternary stratigraphy and palaeogeography of the Eastern Nile Delta, Egypt. *Marine Geology* 77: 257 - 275.

Description de l'Egypte, 1809 - 1882. Tome: carte topographique. Paris: Imprimerie Impériale.

DORNER, J. 1985. *Tell el Dab'a: Bohrprospection.* Unpublished report.

ELGABY, M.M. and M. KHADR. 1962. Clay minerals studies of some Egyptian desert and Nile alluvial soils. *Journal of Soil Science* 13(2): 333 - 343.

FAWAL, F. el. 1975. *Stratigraphy of the Nile Delta.* M.Sc. thesis, University of Mansoura.

FRIHY, O.E. and D.J. STANLEY. 1988. Texture and coarse fraction composition of Nile Delta deposits: facies analysis and stratigraphic correlation. *Journal of African Sciences* 7(1): 237 - 255.

HAMROUSH, H. 1987. *Geoarchaeology of Kom el Hisn.* Cairo: Cairo University.

HASSAN, F.A. 1976. Heavy minerals and the evolution of the river Nile. *Quaternary Research* 6: 425 - 444.

HASSAN, F.A. and B.R. STUCKI. 1987. Nile floods and climatic change. In: M.R. Rampino (ed.), *Climate. History, periodicity and predictability:* 588 - 600. New York: Reinhold van Nostrand.

HOROWITZ, A. 1979. *The Quaternary of Israel.* New York: Academic Press.

IWACO-RIGW, 1988. Groundwater development in the Nile Delta. *Technical Note* 70: 120-88-08. Cairo.

KHOLIEF, M.F., E. HILMY and A. SHAHAT, 1969. Geological and mineralogical studies of some sand deposits in the Nile Delta, *U.A.R. Journal of Sediment Petrology* 39(4): 1520 - 1529.

MADKOUR, A.G. 1988. *Borehole catalogue: Mansoura University Project.* Cairo: MISRAY.

MIALL, A.D. 1985. Architectural-element analysis: a new method of facies analysis applied to fluvial deposits. *Earth-Science Reviews* 22: 261 - 308.

READING, H.G. (ed.) 1986. *Sedimentary environments and facies.* 2nd ed. Oxford: Blackwell.

RIZZINI, A.F., VEZZANI, V. COCOCCETTA and G. MILAD. 1978. Stratigraphy and sedimentation of Neogene-Quaternary section in the Nile Delta area (ARE). *Marine Geology* 27: 327 - 348.

SAID, R. 1981. *The geological evolution of the river Nile.* New York: Springer.

SEWUSTER, R.J.E., and B. VAN WESEMAEL. 1987. *Tracing ancient river courses in the eastern Nile Delta.* Reports of the Laboratory of Physical Geography and Soil Science 30. Amsterdam: University of Amsterdam.

SHEA, W.H. 1977. A date for the recently discovered eastern canal of Egypt. *Bulletin of the American School of Oriental Research* 226: 31 - 38.

SHUKRI, N.M. 1950. The mineralogy of some Nile sediments. *Quarterly Journal of the Geological Society of London* 105: 511-534.

SNEH, A., T. WEISSBROD, A. EHRLICH, A. HOROWITZ, S. MOSHKOVITZ and A. ROSENFELD. 1986. Holocene evolution of the northeastern corner of the Nile Delta. *Quaternary Research* 26: 194 - 206.

STANLEY, J.D. 1983. Southeastern Mediterranean (Levantine Basin-Nile Cone) sedimentation and evolution. *National Geographic Research Reports* 15: 609-628.

– 1988. Subsistence in the North-Eastern Nile Delta: rapid rates, possible causes, and consequences. *Science* 240: 497 - 500.

STANLEY, J.D. and N. LIYANAGE. 1986. Clay-mineral variations in the North-Eastern Nile Delta, as influenced by depositional processes. *Marine Geology* 73: 263 - 283.

STANLEY, J.D., H. SHENG and Y. PAN. 1988. Heavy minerals and provenance of Late Quaternary sands. Eastern Nile Delta. *Journal of African Sciences* 7(4): 735 - 741.

STUIVER, M. and R.S. KRA (eds.). 1986. Calibration issue. *Radiocarbon* 28/29.

WESEMAEL, B. VAN, and P. DIRKSZ. 1986. *The relation between the natural landscape and the spatial distribution of archaeological remains.* Reports of the Laboratory for Physical Geography and Soil Science 24. Amsterdam: University of Amsterdam.

WIT, H.E. DE and L. VAN STRALEN. 1988a. *Geoarchaeology and ancient distributaries in the Eastern Nile Delta.* Reports of the Laboratory for Physical Geography and Soil Science 34. Amsterdam: University of Amsterdam.

– 1988b. Preliminary results of the 1987 palaeo-geographical survey. In: E.C.M. van den Brink (ed.). *The archaeology of the Nile Delta: problems and priorities:* 135-139. Amsterdam: Wolfkamp.