The Dynamics of a Riverine Civilization: A Geoarchaeological Perspective on the Nile Valley, Egypt
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The dynamics of a riverine civilization: a geoarchaeological perspective on the Nile Valley, Egypt

Fekri A. Hassan

Abstract

Egyptian civilization depended on the bounty of the River Nile. Frequent fluctuations in the height of summer floods influenced both floodplain geomorphology and the area cultivated. Thus agricultural yield oscillated as a function of pronounced interannual variability, as well as episodic variations in response to abrupt climatic changes in the watershed of the Nile tributaries. This situation also created a dynamic landscape and a variety of cultural responses depending on the specific cultural-historical circumstances. The aggradation of the floodplain has also influenced the recovery of archaeological remains. Predynastic settlement sites in the Delta are 4–6m below the surface and Graeco-Roman settlements are 1–2m deep. Subsidence of the Delta and sea-level change were responsible for pronounced changes in the geomorphology of the Delta, the distribution of waterways and hence trade.

Keywords

Egypt; rivers; Nile; geoarchaeology; Delta; floods; floodplain.

The archaeology of a riverine civilization: on theory and method

On the banks of some of the great rivers of the world, in Egypt, Mesopotamia, India and China, humanity undertook a leap into a new dimension of social relations, embarking on a journey that led to a world that contrasted radically with that of foragers and hunters. In that sense, riverine agriculture was an enabling force providing humanity with the means to alter nature and mobilize enormous resources for achievements in art and intellectual pursuits. The potential for food producers to generate much more food than was needed for their subsistence enabled the emergence of full-time managers and craft specialists who could devote their time and energy not only to assisting in minimizing agricultural failures and keeping settled, large groups together, but also to exploring in depth the intellectual and artistic domains of the human mind.

World Archaeology Vol. 29(1): 51–74 *Riverine Archaeology*

Egypt was a riverine civilization. Regardless of the magnitude of irrigation, Egypt depended on the summer inundation that naturally irrigated the floodbasins. The legacy of civilizations nursed in the womb of great rivers, such as Egypt, has not only influenced humanity well beyond those rivers, but is still a living heritage of most of the world population. In fact, improving and extending irrigation is one of the very few options available today as humanity, especially in developing countries, faces the imminent threat of climate change. Hydropolitics, today, as in the past, may shape a new political order based on the international management of river basins (Ohlsson 1995).

Civilization, a phenomenon of large societies with highly differentiated sectors of activities interrelated in a complex network of exchanges and obligations, is not restricted to riverine environments (contrast, for example, different societies along the Nile Valley, the Amazon or the Rio Grande). Egypt, and other riverine civilizations, emerged and survived because of certain cultural-historical circumstances and specific ecological conditions. For example, the differences between the geomorphology of the Delta, the lower Nile Valley in Egypt and the Gezira in the central Sudan were important factors in the cultural development of these regions. One may also list differences in location relative to adjoining resources and neighbours. Connections between the Delta and the Near East, the wadis that connect Upper Egypt with the mineral resources of the Red Sea Hills and the proximity of pastures for cattle in the Central Sudan were key factors in the history of these regions.

The emergence of Egyptian civilization along the banks of the Nile was a response neither to geographic circumscription (Carneiro 1970) nor to artificial irrigation (Wittfogel 1957). Carneiro suggested that population increase within the restricted space of the Nile Valley, as elsewhere when agricultural land is limited and circumscribed, led to warfare and conquest, which then led to the rise of the state. However, there is no evidence of a lack of cultivated land in Egypt until perhaps the New Kingdom, 3,000 years after the emergence of the nation state (Butzer 1976). There is also no evidence for population pressure (see Hassan 1981a, for an extended discussion of this controversial concept). Helck (1975) has argued, in fact, that the rise of bureaucracy during the Old Kingdom (2700–2200 BC) created a demand for more food producers and craftsmen.

Wittfogel's (1957) theory of 'Oriental Despotism' claims that the dependence of China, India, Mesopotamia and Egypt on large-scale irrigation led to the rise of despotic, bureaucratic, centralized states (for criticisms, see e.g. Haas 1982; Mitchell 1963; Kappel 1974; Lees 1974). However, there are no indications that the main function of centralized government in Egypt or its bureaucracy was the management of artificial irrigation. In spite of references to occasional waterworks in response to droughts, and the digging of local canals for drainage or irrigating uplands, the magnitude of waterworks in Ancient Egypt hardly compares with the undertakings of Mohammed Ali in the nineteenth century. The centralized government in Egypt was more concerned with collecting taxes and attending to the monumental display of royal power and religious institutions than with irrigation. Basin irrigation on a local scale was more than sufficient to meet the needs of the early population of Ancient Egypt. Lloyd clearly states that:

> Large-scale crop cultivation relied at all periods upon the relatively primitive but efficient basin system of irrigation. This was organized at a local rather than a national

level, but the ease and success of the process was always dependent upon the volume of the Nile which varied considerably in antiquity.

(Lloyd 1983: 326)

Although I emphasize here the relationship between the dynamics of riverine conditions and various aspects of Ancient Egyptian civilization, I do not wish to suggest that Egypt was solely a function of its riverine habitats or of its immediate responses to, or interactions with, the floodplain. Economic pursuits are inseparable from cultural norms and expectations. Human decisions and actions, whether well-reasoned or not, create ecological situations that otherwise would not exist. The Nile flowed through Egypt for millennia before some communities decided to adopt farming and herding. This created a situation that placed people at greater risk, especially when they became settled. The congregation of large groups in settled communities created conditions of social conflict. Some communities probably opted to manage conflict through mediators and 'healers'. They also probably opted for exchanging stored food with others during periods of food shortages. Although the volume of floods fluctuated annually, its impact on various localities in Egypt was not uniform. Agriculture does not depend just on floods. Variations in yield, for example, may result from differences in scheduling sowing, the management of labour or pest infestations. Topography influencing water availability will vary locally because of the dynamics of fluvial processes. Hence intra-regional and subsequently inter-regional cooperation can facilitate the rise of hierarchical management. Although conflicts may have emerged and did emerge in this context, we are not clear about the motives behind the battle scenes on late Predynastic palettes (3300–3000 BC). I am of the opinion that such scenes are iconic and symbolize the duality of order and disorder (cf. Kemp 1989). The iconography was probably a carryover from feuds and limited violent conflicts between marauders and settlers, and was appropriated to signal the role of the leader as the champion of order: the hero who smites the enemies (disorder). It is my contention that the psychological need to overcome the uncertainties of Nile floods, the vagaries of infestations and agricultural failures (even when all what could be done was done), and the disturbing incidence of violent encounters with desert nomads pressed by hunger or taking advantage of another 'sustainable' game, was a formative factor in shaping Egyptian civilization. People were inclined to generate 'myths' of an orderly universe and to accept those who promised or symbolized order. Coercion had to develop much later in the history of civilization, when those elected or empowered by their equals were distanced from the constituency and could reward and punish. When such leaders could take lives at will as a means of instilling order, violence became institutionalized and the transition to the state, as a force superior to individuals and communities, was well under way. These remarks are proffered here as a warning against simplistic ecological approaches that over-emphasize environmental factors and place them outside the domain of culture and independent variables. With this in mind, I focus next on the role of Nile hydrology on agriculture, the economic foundation of Egyptian civilization.

In Egypt, the development of agriculture cannot be properly understood without an understanding of Nile hydrology and the geomorphic dynamics of the Nile floodplain, since these dynamics influence subsistence activities, settlement location and social relations (Butzer 1976, 1984, 1995). Of particular significance are the annual cycle of inundation, the decadal, centennial and millennial fluctuations in Nile flood discharge, the shape and landforms of the Nile floodplain and their implications for the location of settlements and field plots, irrigation and drainage, and long-term sustainability of yield in any given locality. The channel of the Nile was also essential for navigation, serving as an artery circulating food and goods from one part of Egypt to another, and linking Egypt with its neighbours to the south, north and east. Even today, the hydrology of the Nile plays a major role in the economy and politics of Egypt (Waterbury 1979; Said 1993). A major study of Egyptian irrigation at the beginning of this century (Willcocks and Craig 1913) was essential for the development of irrigation practices in modern Egypt.

Consequently, the archaeology of riverine societies requires a multiplex approach based on the construction of theoretical models framed by reference to historical analogies (Bell 1970, 1971; Butzer 1976, 1995; Said 1993; Hassan 1981b, 1993), determinations of ancient flood regimes from proxy data (Hassan 1986b), archaeological investigations (Hassan 1988), landscape palaeoenvironmental reconstruction (Bietak 1975; Butzer 1976; Wunderlich 1993) and bioarchaeological research (Wetterstrom 1993).

In a riverine environment such as Egypt, the survival of archaeological remains was closely linked with the nature of building materials available and selected, and the choice for placing settlements given certain logistic consideration dictated by proximity to fields, irrigation water, transport, avoidance of flood hazards and social and ideological considerations. It is also a function of the re-utilization of the floodplain over more than 5,000 years of intensive exploitation.

In the light of these introductory remarks, this contribution will provide a perspective on Egyptian civilization based on a consideration of the dynamics of riverine floodplain agrarian economy, and will thus emphasize the specific parameters of a low-gradient, meandering riverine environment. We can never gain a deep understanding of a riverine civilization or make sense of its artefactual repository without a knowledge of the hydrological, depositional and geomorphological dynamics of the river. It is only then that we can begin to fathom the achievements of the Egyptian civilization and the sense of order, serenity and tranquillity it has generated, and to appreciate the social wisdom of a social organization based on a fundamental concept of justice (*Ma'at*) that conjoins elements of truth, goodness, beauty and regeneration (see Assmann 1990 for a discussion of this complex concept and different interpretations of it).

In weaving together the history and dynamics of the Nile river we will rely on an array of geoarchaeological methods, from drill cores in the northern Delta (Stanley 1988) to an examination of the lake sediments and pollen of Birket Qarun in the Faiyum Depression (Hassan 1986b; Mehringer et al. 1979). The search for archaeological remains in a riverine environment, as we shall show below, requires special techniques because many of the early sites are likely to have been buried, obliterated or disturbed. Methods to locate sites include, in addition to standard surface surveying, subsurface investigations using drill cores, augering and geophysical methods. The work of Wunderlich (1989), Andres and Wunderlich (1986), Brink (1987, 1988) and Way (1993) in the western and north-eastern Delta are good examples of these methods. These methods are also especially important, in conjunction with remote sensing using satellite imagery, in locating old channels.

Excavation is indispensable for obtaining information on the contents and patterning of archaeological sites. Unfortunately, because the majority of settlements in a floodplain environment (see below) are not preserved or are covered by a thick layer of mud, excavation of settlement sites is problematic. There are only a few settlement sites from the Pharaonic period (3000–333 BC) and they are mostly at the edge of the desert adjacent to the floodplain. Settlements from the Predynastic periods (4200–3000 BC) are also mostly restricted to the edge of the desert adjacent to the floodplain and belong mostly to the Badarian and Nagada I (4200–3500 BC). In the Nagada region, villages and hamlets from the Nagada II (3500–3300 BC) are mostly covered by Nile silt, since only two urban sites, the South Town and North Town, are known from that region. Remains of Predynastic settlements in the Delta are several meters (up to 6m) below the surface of the floodplain and in general well below the water table. Techniques for excavating water-logged artifacts and dwellings will be required to deal with these sites.

The culture, history and dynamics of human ecology in a riverine environment also require detailed investigations of plant and animal remains, land use and technology. Unfortunately, the Egyptological discourse has been concerned *primarily* with political succession and dynasties, philology and linguistics, religion, and art history. Recently, a concern with social history and anthropological domains of inquiry is becoming evident (Trigger et al. 1983; Kemp 1989; O'Connor 1991). Quantitative data on plants and animals are now available mostly for the Predynastic period (Wetterstrom 1993). The Egyptians depended in Predynastic times, as well as in the nineteenth century, on the cultivation of barley and emmer wheat. The ratio of barley to wheat at Nagada Predynastic sites was 2:1 (ibid.). Although emmer wheat is preferred, barley is more resistant to salinity and fluctuations in ground moisture and was for this reason most probably cultivated more widely than wheat. Although our knowledge of this issue during the Dynastic period (after 3000 BC) is hampered because of disagreements on the botanical names of Egyptian words, and because botanical and faunal remains were neither systematically collected nor analysed, barley seems to have been more common that wheat (Darby et al. 1977: 482). According to Lloyd (1983: 327) emmer wheat gained over barley only at the end of the New Kingdom. The Egyptians used the word '*it*' for barley and '*bdt*' for emmer wheat. The word '*swt*' is often translated as wheat but it possibly refers to a variety of barley (Germer 1985; but see Darby et al. 1977: 490–1).

Until the introduction of a perennial system in the nineteenth century, irrigation depended on natural forces. Although artificial canals on a local scale might have been practised since the Early Dynastic period (3000–2700 BC), if not before, there are no indications of a state-controlled irrigation system. Surprisingly, water-lifting devices such as the simple *shaduf* were used (based on the lever principle) were unknown until the New Kingdom, 1550–1070 BC. Irrigation works were probably thus undertaken on a local or a regional scale, and might have become of particular importance during episodes of low Nile floods. The following inscriptions from the third millennium BC, when the Nile flood level was low, suggest that canals were dug to bring water to the edge of the floodplain where water was in short supply.

Tomb V, Line 7
'I made the high land (upland) into a Delta marsh,
I let the flood of Hapi inundate the mounds or ancient places (fallow land?).'

Tomb VII, Lines 22–3
'It was to the high land of your fields that I brought the Nile from (or as)///
I watered your plots so that you did not know it.'

(Herakleopolitan Tombs V and VII from Assyut: Brunner (1937) and Griffith (1889) for sources, translation by L. Troy, pers. comm.; see also Schenkel 1978)

The Egyptians herded cattle and sheep/goats, and kept pigs from Predynastic times (Gautier 1984; Hassan 1988). A record from early Dynasty XVIII (1552–1295 BC) from El-Kab indicates that the *nomarch* levied 122 cattle, 100 sheep, 1,200 goats and 1,500 pigs (Sethe 1906). A mortuary priest of the Pyramid of Khephren records his possessions as 1,055 cattle, 2,235 goats and 974 sheep (Lepsius Denkmäler cited in Kees 1961: 87). A priest in Dandara gave a count of 33 bulls and 100 goats, compared with 260 goats by another priest (Petrie Dandara pl. II in Kees 1961: 88).

The use of the floodplain for the cultivation of cereal poses a conflict with the cattle and sheep herding. Because cereal cultivation is more productive per unit area, cattle herding would have been favoured in the Delta marshlands and along the inner wetland margin of the floodplain. Sheep and goats were raised on the edge of the floodplain. In addition, they were allowed to graze in the fields after the harvest.

The population of Ancient Egypt that could be supported by basin irrigation and cereals is estimated at 1.2 million during the Old Kingdom (3000–2200 BC), 2.1 million in the New Kingdom (1550–1070 BC) and 3.2 million in the Graeco-Roman period from 332 BC to AD 395 (Hassan 1993:170). Although these figures are dramatically below the modern population size of 60 million, they are consistent with estimates of 2.5 million in the seventh century AD and 3.4 million during the late thirteenth century. Population increase during the Old Kingdom is estimated at 0.13 per cent per year, analogous to estimates in Neolithic contexts, slackening to 0.057 per cent for the New Kingdom. The rate was still lower from the New Kingdom to the Roman period at 0.024 per cent per year. The population of Egypt did not exceed the Graeco-Roman peak of 3.4 million until the nineteenth century. Rapid population increase was possible only after the adoption of perennial irrigation in 1820. Perennial irrigation placed more land under cultivation and allowed the cultivation of new crops, as well as the participation in a world economy of cash crops. By 1907 the population reached 11.3 million, and by 1960 it became 26 million, ten times the population size of New Kingdom Egypt.

The Nile floodplain provided opportunities for development that were possible only with a combination of human management and technology. The 'archaic' pattern of management depended on local management within administrative districts (*nomes*). Irrigation technology was traditional and fairly simple. Nome capitals were linked to the national capitals by riverine navigation delivering to the royal store-rooms annual revenues that supported the Pharaoh and his court, to be invested in mortuary temples and monuments to bolster the hegemonic ideology of the state. Contacts with Egypt's neighbours provided trade goods, including raw materials and commodities for the mortuary cult which was at times closely linked to the ideology of kingship. Artisans were supported to produce highly prized craft items that were used to mark the status of the king and the nomarchs (nome chief administrators). When Egypt was subjugated by the Hyksos (c. 1674 BC), the effect was, within a couple of generations, a strengthening of the army. This marked a transition that was later to turn Egypt into a society that emphasized military generalship as an aspect of the divine king.

Although it is commonplace to refer to Egypt as the gift of the Nile, the emergence and resilience of Egyptian civilization rested on the persistence of a certain mode of social organization grounded in a sacred ideology. The productivity of early farming also permitted Egypt to sustain a fairly large population and an urban population of skilled craftspeople, priests and artists (perhaps totalling 150,000) that was responsible for the remarkable artistic and intellectual achievements of Ancient Egypt.

In the following sections, I explore some of those issues further, emphasizing at the outset the role of fluctuations on Nile flood levels.

Nile flood fluctuations

The scale of human achievements as a consequence of the advent of riverine agriculture was a function of two major factors: 1) the great potential for increasing agricultural yield and 2) the enormous variability inherent in agricultural productivity. The trajectory from horticulture, or the adoption of cereal crops as a supplement to other subsistence pursuits, was at first mainly a response to the occasional and recurrent food shortages. Mechanisms to cope with fluctuations in agrarian food yield included a spectrum of practices including: 1) increasing the area of cultivable land; 2) weeding; 3) selection of high-yielding cultigens; 4) selection of sets of cultigens that minimized severe loss; and 5) development of tools, facilities and techniques for preparing the ground, sowing and harvesting. Storage made food available at the end of the year, before the new crop was harvested. Storage for two years or more also made food available during times of occasional food shortage. Simulations by the author, however, have revealed that storage was not sufficient to overcome the impact of several disadvantageous floods in close succession. Nevertheless, the role of storage should not be under-emphasized as a state activity. In addition, the role of the state in transporting food by boats from one place to another was essential for its buffering effect.

In the long run these developments were not sufficient to cope with famines as a result of climatic oscillations at a scale beyond that of social memory and the human range of accumulated experience and knowledge. Today, as a consequence of our expert knowledge of climatic change, using an array of proxy data and dating methods, we are able to discern various temporal scales of climatic oscillations. For example, examination of the annual record of Nile floods over a period of approximately 1,300 years, recorded by Arab scholars since the seventh century AD, clearly reveals an alternation of episodes of low and high Nile floods (Hassan 1981b; Hassan and Stucki 1987; Said 1993) that range from a few decades to a few centuries (Table 1).

Of special significance for our discussion of the impact of climatic oscillations on riverine agrarian societies are the widely spaced, severe, disruptive climatic events that strike swiftly and unexpectedly because they recur at intervals greater than that of several human generations. In examining the record of the last 1,300 years (Table 1) we can clearly detect that the period AD 930–1470 was particularly unstable, with severe droughts between 930 and 1070, and again after a century from 1180 to 1350. These fluctuations are

Table 1 Episodes of fluctuations in Nile flood levels from Hassan (1981b) and new data for the period from 1880 to 1990.

Years AD	*Nile floods*
Before 650–930	Generally low (with minor highs)
931–1070	Major low
1071–1180	Major high
1181–1350	Major low
1351–1470	Major high
1470–1500	Minor low
1500–1700	Incomplete record
1725–1800	Minor high
1800–1830	Minor low
1830–1885	Minor high
1885–1898	High
1899–1960	Low (with significant droughts at 1913 and 1925)
1961–1968	High
1969–1990	Low

related to displacement of the Intertropical Convergence Zone (ITCZ). When the ITCZ shifts southward rainfall in the source areas of the Nile tributaries decreases, thus reducing the volume of Nile flood discharge (COHOMAP 1988; Flohn and Nicholson 1980). Nile floods are derived from Ethiopia and Equatorial Africa; they are mostly associated with summer monsoonal rain (Griffiths 1972).

An examination of the Nile record based on estimation of Nile flood heights from a study of the sediments of Lake Qarun in the Faiyum Depression (Fig. 1) revealed that severe droughts occurred repeatedly during the last 10,000 years (Hassan 1986b). The sediments in this lake provide a proxy to the height of Nile floods since it was connected and fed by the Nile during the inundation. Low lake levels thus corresponded with low Nile floods (droughts) which resulted from a reduction in rainfall in Ethiopia and Equatorial Africa where the sources of the Nile are located.

Significant reduction in lake level occurred at approximately 8500, 7500/7000, 6000, 4600, 3600, and 3000 uncalibrated radiocarbon years before present. The recurrence intervals between these severe droughts were about 1,600, 1,000 and 900 years. These data are corroborated by the changes in the levels of lakes in Ethiopia and equatorial Africa (Bonnefille and Hamilton 1986; Bonnefille and Umer 1994; Bonnefille et al. 1990; Bonnefille et al. 1991; Casanova and Hillaire-Marcel 1992; Gasse and Van Campo 1994; Grove 1993; Hamilton 1982; Jolly and Bonnefille 1992; Jolly et al. 1994; Kendall 1969; Mohammed and Bonnefille 1991; Taylor 1993; Hassan 1996).

A high resolution study of Lake Arsi in Ethiopia (Bonnefille and Umer 1994) also reveals low lake levels at approximately 2000 BP (AD 75), and a hiatus between 1800 and 850 BP (AD 500 ±200). Also, a very recent rise and fall of lake levels is recorded by a belt of dead trees found up to 8m above Lake Shala and down to 1m below water level. Similar dead trees around Lake Wonchi have been dated to 1400±140 BP, c. AD 550 (Grove et al. 1975). These data suggest that severe droughts since the 1300 BC droughts have been separated by intervals of approximately 650, 575 and 855 years. Thus the range of the intervals

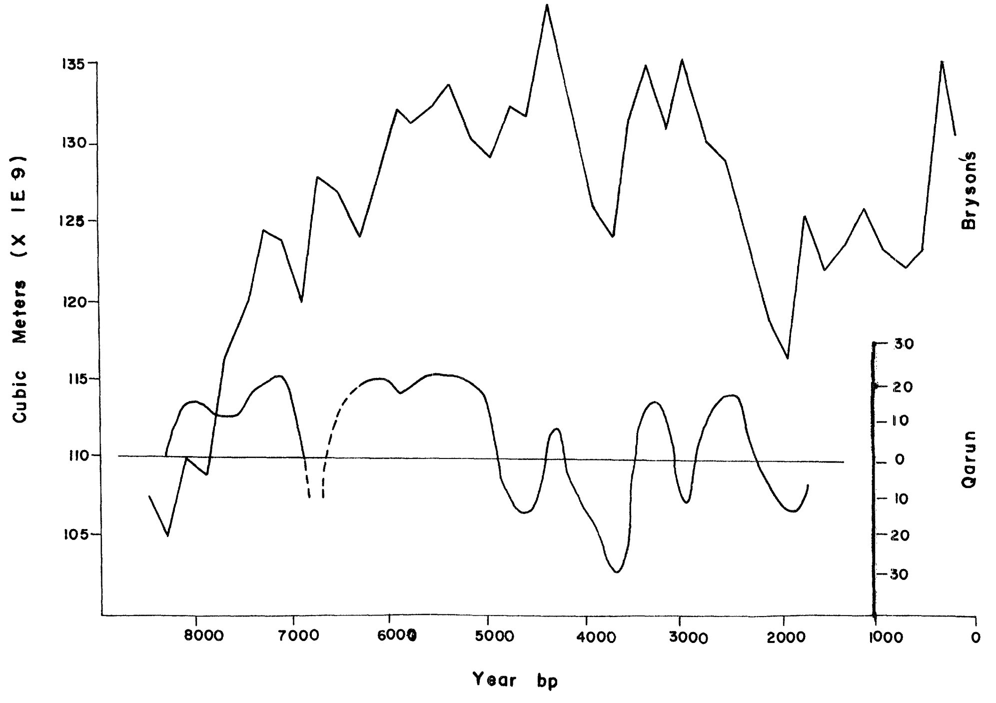

Figure 1 Fluctuations in Nile flood height indicated by variations in the levels (in metres above sea level) of Lake Qarun, Faiyum Depression, and as inferred (as discharge in billion cubic metres) from a palaeoclimatic model by R. Bryson (pers. comm.).

between episodes of adverse, if not catastrophic, low Nile floods was from 1600 to 575 years, well beyond human reckoning.

Even when the floods were on average relatively high, as in the period from 1725 to 1800 (Hassan 1981b; Said 1993), successive years of catastrophically low floods were not unknown, as indicated by very low floods in 1783, 1784 and 1792 (Zakry 1926: 59).

From these data and the records of famines, plagues and civil disorder at times of droughts (Hassan 1997), the impact of Nile flood fluctuations on the developments of Egyptian civilization can hardly be ignored. By emphasizing the unpredictability of Nile floods, I hope to underscore the role of cultural mechanisms associated with riverine agriculture that emerged as a means to minimize risk and enhance food security.

The riverine floodplain: a moveable landscape

In addition to temporal variability and unpredictability, another aspect of ecology that enhances the instability of agrarian subsistence in a riverine environment is the instability of floodplain geomorphological features. The Nile is a slightly meandering stream that carries an annual load of silt estimated on average at 57 million tons per year, with a range from 40 to 100 million tons (Ball 1939; Said 1993). The Nile floodplain is rather narrow, ranging from 2km at Aswan to 17.6km at Minia. It is formed by an accumulation of silt

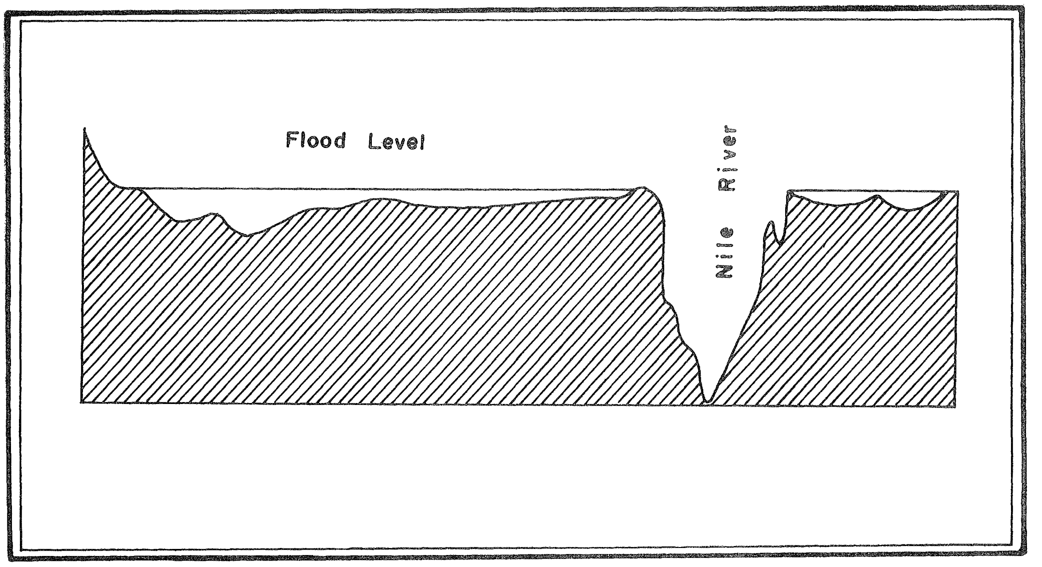

Figure 2 Cross-section of Nile floodplain at Saqqara showing a very high Nile flood level. Note the convex shape of the floodplain. Back swamps often develop on the outer margin of the floodplain in low areas.

(aggradation, alluviation or siltation) and erosional episodes (degradation). The rise in the floodplain is often accompanied also by a rise in the level of the channel deposits.

The rate of siltation is not uniform and has varied dramatically through time. The change in siltation rate is, in general, associated with significant changes in the position and geometry of the channel as well as the various landforms of the floodplain, which have major implications for agriculture. At present, the cultivated floodplain lies about 9m above the bottom of the channel (Fig. 2). Irrigation canals in Upper Egypt are situated at 4.5m above the bottom of the channel. A high flood with as much as 10m water height can thus flow over the bank and inundate the land. Canals are thus essential to deliver water when the Nile flood is low, since low floods may consist of no more than 7.5m.

Rarely static, a floodplain is delimited near the channel by either a high ridge (levee) on the concave, deep side of the channel or a sandy point-bar on the shallow convex side of the channel. A levee is formed during an inundation as the floodwater tops the bank, rapidly depositing its load of fine sand and coarse silt. As floodwater flows away from the channel, water velocity diminishes and sediments accumulate with greater thickness closer to the channel. Following the initial surge of the flood, finer silt accumulates in depressions (floodbasins). Water also percolates through the ground creating a groundwater reservoir. Groundwater then seeps laterally to sustain backswamps (*birkets*) bordering the outer edge of the floodplain (Fig. 2). With frequent changes in floodwater discharge and the amount of suspended silt load, the channel and floodplain undergo significant changes that can radically alter the distribution and extent of arable areas as well as access to irrigation water and drainage. It may thus be surmised that one of the earliest consequences of riverine agriculture, following the establishment of land ownership, was the resolution of social conflicts that may have arisen as a result of the dynamics of floodplain

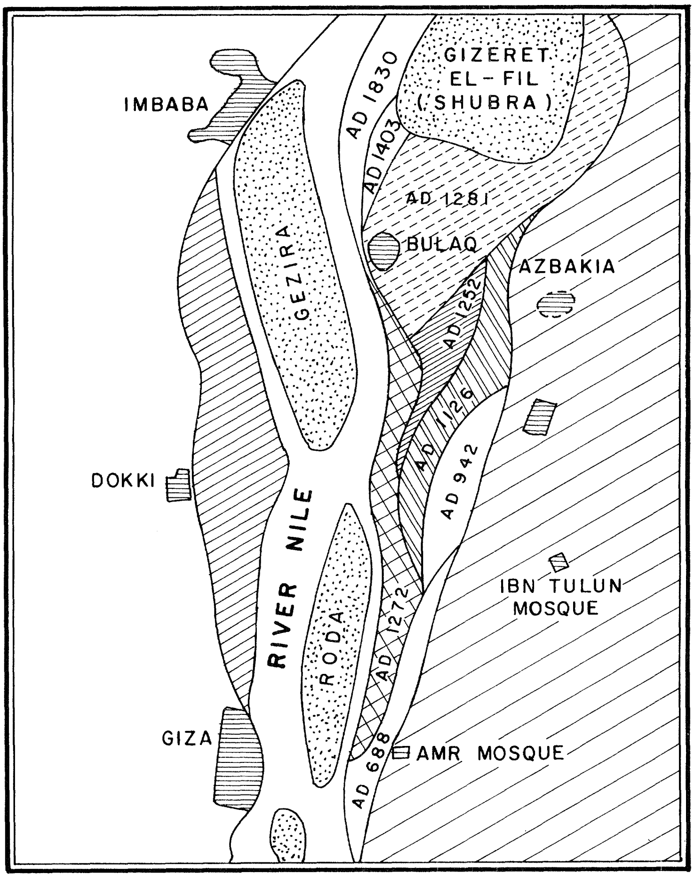

Figure 3 Map showing the effect of the movement of the channel near Cairo in response to low floods from AD 930 to 1070 and from 1180 to 1350. Major additions to Cairo land area appeared in AD 942, 1252, 1272 and 1281.

geomorphology. The emergence of mediators to resolve conflicts probably developed eventually into an organizational structure that served as an element in the making of early states.

An example of the dramatic changes in floodplain geomorphology is provided by the changes in the Cairo area (Raymond 1993; Museilhy 1988) mostly between AD 942 and 1281, coincident primarily with the major episodes of low Nile floods (AD 930–1070 and 1180–1350). Large areas of Cairo today (the north-western region) were not in existence before the Nile shifted westward (Fig. 3).

The gradient of the river (about 1:10,000 to 1:15,000) controls the flow of floodwater over the floodplain from south to north; in historical times this required a coordination of activities between communities to control the flow of water downstream by the building of artificial dykes, which could then be opened to release floodwater down stream. Floodwater could also be diverted to side channels from which feeder canals might be extended to the uplands. The continued build-up of the floodplain may deprive outer parts of the floodplain of water. Episodes of low Nile flood discharge may also have the same effect, and the combination of the two can be disturbing.

Nile navigation: the unification of Egypt

The development of Egyptian civilization would not have been possible without riverine navigation. It was fortunate that the Nile flowed from south to north with an average speed of four knots (about 7.4km per hour) during the season of inundation. The trip from Thebes to Cairo, a distance of 900km by the Nile would thus have been travelled in approximately two weeks. Travelling at night was in general avoided because of shallow sand islands. By contrast, during the season of drought when the water level was low, the speed of the current was much slower (about 1 knot) and the same trip would have taken at least two months. The trip from north to south would have been extremely slow except when sails were developed to take advantage of the northerly and north-westerly winds blowing off the Mediterranean. The bend near Qena, where the Nile flows from east to west and then back from west to east, considerably slows down riverine travel. This in fact marks a geographic discontinuity which separates the Thebaid region from the region to the north. Sails were probably first invented during the late Nagada II, approximately 3400–3300 BC or immediately thereafter (Vinson 1994: 16).

Navigation in the Nile Valley was faster during the inundation because the water was on average about 7.5 to 10m deep. In Upper Egypt, the water during the low Nile level season (with a minimum in June) was no more than 2m in Aswan compared with 5.3m near Cairo.

By Nagada II (maybe earlier?), the Egyptians also transformed their boats from bundles of reed into big ships constructed from wood planks. The boats depicted in petroglyphs suggest that some were over 15m long with a crew of thirty-two men (Vinson 1994: 14–16). Boats with numerous oars were already known during Nagada I (3800 BC) and clay models of boats were found at Merimde Beni Salama in the Delta dating to the fifth millennium BP.

In the First Dynasty (c. 3000 BC) boat pits at Abydos reveal a fleet of twelve boats between 15 and 18m long. Pits and remnants of boats are also recorded from the cemeteries at Helwan, Saqqara and Tarkhan (Vinson 1994). One of the most impressive findings is the boat recovered from a pit adjacent to the Pyramid of Khufu. The boat now reconstructed and on display is 43.3m long. Sailing boats from the Fifth Dynasty (2510–2460 BC) were already seaworthy (ibid.).

From the earliest times, boats were used to transport people between villages during the inundation, ferry across the channel and haul cattle, grain and other substances from one place to another. They were also used in military campaigns. Boats thus played a major role in unifying the country. Besides the donkey, which was used for overland transport, boats made possible the economic integration of the country. Food from one district could be delivered to another struck by famine. Food stored from several districts in a central granary could be used to secure the welfare of people in the region. The emergence of kingship in Egypt might have been linked with coordinating the collection of grain and relief activities as the most viable strategy to cope with unpredictable crop failures in any of the districts. The fundamental administrative unit in Graeco-Roman Egypt (332 BC–AD 395) was the nome. Egypt was subdivided into approximately forty-two nomes. There are indications that territorial units existed in late Predynastic times, perhaps analogous to the 'nomes' of Graeco-Roman times. However, such units were independent before they were aggregated into provincial states prior to the unification of Egypt into a single political state (Kemp 1989). Towns emerged in administrative units as cult centres and capitals of political power. After the unification, in historical times the nome capitals were linked to the nation's capital, such as Memphis and later Thebes, by Nile boats and barges that carried the revenues to the royal store houses. Artificial harbours and ports to accommodate large cargo boats were thus an essential feature of the riverine landscape. Towns took advantage of the deeper side of the channel close to levees to establish ports and used rock jetties a short way out into the Nile, perhaps in response to changes in the course of the Nile. Near old Cairo, the port at Athar el-Nabi was relocated in response to the westward movement of the channel.

The archaeological remnants of the huge harbour of Birket Habu in ancient Thebes built in the reign of Amenophis III (Eighteenth Dynasty) is now marked by huge elongate mounds of earth dug during the excavation of the harbour (Kemp and O'Connor 1974). Other large harbours are known from Memphis, the northern capital of the country.

Fragments of the past

Following an initial stage during the Predynastic period (4200 to 3000 BC) settlements were established at the edge of the floodplain, as the evidence from Badri, Nagada and Hierakonpolis shows. During later Predynastic and early Dynastic times (3500–2700 BC), in response to a drop in Nile levels, settlements shifted to the floodplain on old levees. Since mud was used as the building material for bricks and daub, occasional high floods are likely to have destroyed many floodplain settlements. Building over collapsed building was thus advantageous for flood protection. This is particularly significant because of the rise of the floodplain as a result of aggradation. The rate of siltation varies depending on the geographic and geomorphic location of the floodplain. Estimates by the author suggest an overall average of c. 0.9mm/yr, with a higher rate (1.2mm/yr) for the central strip of the floodplain, with a reduction from south to north, and from the central region to the edge of the floodplain (c. 0.85mm/yr). However, the rate can occasionally reach 6.5mm/yr, as during the period from 1841 until the end of the nineteenth century (Said 1993: 59).

According to a reconstruction of sea-level changes in the northern Delta on the basis of a series of drill cores, Stanley and Warne (1993) conclude that the deceleration in sea-level rise occurred at 6500 BC, thus allowing a build-up of alluvial silt; they discount the effect of climate on Nile flood discharge. Since the rate of siltation is estimated at 1.2mm/yr at the latitude of Samanoud where the thickness of Holocene alluvium is 12m, the formation of the Holocene silt may be dated back to 10,000 BP. In Upper Egypt the average thickness of Holocene alluvium is 9.8m and the long-term average rate of siltation is 0.86/0.91 mm/year. The beginning of the formation of the modern floodplain may thus be dated to 11,400–10,700 BP. Estimates for the beginning of alluviation both in the

Delta and Upper Egypt are thus concordant, providing a range from 11,400 to 10,000 BP coinciding with the onset of wetter conditions in north-east Africa, as suggested by lake levels in East Africa (Street-Perrott and Roberts 1983). Beginning at 12,500 BP a broad belt of expanded lakes developed in Africa and Arabia. Playa lake deposits in the Eastern Sahara began to accumulate after 9500 BP. Estimates for the beginnings of the formation of the modern floodplain are also in accordance with the accumulation of the Nile silt formation referred to as the Arkin formation in Nubia and the El-Kab formation near Idfu dating after 11,500 BP.

A period of aridity, coinciding with the Younger Dryas in Europe, seems to have caused major recession and prolonged drought at about 10,200 BP (Street-Perrott and Roberts 1983: 331; Lamb et al. 1995: 136). Late Quaternary alluvium after 12,500 BP and before 10,200 BP is thus likely to have been subjected to severe erosion. The bulk of the basal layers of the modern alluvium may thus date to about 10,000 BP, as suggested by the estimates from rates of siltation. Contrary to the claims of Stanley and Warne (1993), which had interesting implications for the beginnings of farming life in the Delta (Holmes 1993), the Delta floodplain was hospitable to farming and certainly pastoralism as early as 8000 BC, some 3,000 years before the emergence of the earliest known Neolithic site at Merimda Beni Salama on the south-western margin of the Delta. The thickness of the alluvium would have been about 3.4m, which is as much as has accumulated since the erection of the obelisk in Heliopolis. However, the sediments would have been mostly sand. Silt and mud appear to have been predominant after 7500 BP when flood discharge and water velocity decreased. This is confirmed by a sedimentological change with an increase in terrigenous influx from the Nile in the north-eastern margin of the Delta at 8500 BP (Sneh et al. 1986), and would indicate that early farming communities arriving at about 6300 uncalibrated radiocarbon years BP (about 5000 BC) would still have had access to farming land. The top silt would have been about in excess of 1m.

The continued progradation of the Delta over the last 10,000 years in response to an increase in floodwater discharge and sea-level changes primarily from 12,500 to 4500 BP suggests that the northern parts of the Delta were dramatically different in Predynastic times than they are today. Between 5000 and 2500 BP, a period characterized by severe droughts and low Nile floods, marshlands, wetlands and swamps were far more extensive than at present. Stanley (1988) suggests that the sea-level rise during the early Holocene slowed down and the Delta prograded northward in the north-eastern part of the Delta over a distance of about 50km at a rate of about 10m per year over the last 5,000 years. This may be attributed both to a decrease in water discharge and to a series of sea regressions at 3800–3600, 3200–2940, 2650–2420 and 2100–1800 BP, according to Rhodes Fairbridge (pers.comm.).

By c. 6500 BP, Delta morphology assumed a configuration that persisted until its modification by irrigation and intensive cultivation in the Graeco-Roman period. In general, the seaward part of the Delta was fringed by beach sand and aeolian deposits. According to Wunderlich (1993), the maximum extent of the lagoon and marsh environments, north of Buto in western Delta, was reached shortly before 6000 BP. Subsequently, sedimentation of Nile mud prevailed and the southern border of peat development was pushed farther north. The formation of the latter is related to an increase in aridity since 7000 BP. Landward behind the beach and dunal ridges, brackish water deposits accumulated in extensive lagoons. Farther landward, wetlands, marshes and floating thickets extended well into the central delta. Along the Nile channels and farther south, alluvial sand and silt accumulated in floodplain basins and levees. The alluvial sand and silt blanketed the erosional surface of older sand, except where erosional remnants remained higher than the floodstage, forming sand hillocks known locally as *gezira* (sand islands or turtle-backs).

In the north-eastern Delta, some sites were located at the base of *gezira* which appear to have accumulated during episodes of a different hydrographic regime with a greater influx of water, high energy and a large proportion of sand in the suspended load, perhaps from the period dating at the latest from 14,000 to 8000 BP or earlier. These islands are now at a level of 14m above the Deltaic plain. Predynastic cemeteries in several places are located near the top of these hillocks. Settlements were perhaps placed more often at a lower elevation (Wunderlich 1993: 264). Indications of Predynastic settlements are retrieved from coring suggesting that the settlement sites are now several metres below the surface of the Delta. Rates of siltation (1.2mm/year) would suggest that sites located at 2m above the deltaic plain at the time of Nagada II (3500 BC) would have been covered by 4.6m of silt. Neolithic sites by comparison to Merimda Beni Salama would date to a time between 5000 and 4000 BC and would thus be expected to be overlain by 8.4 to 7.2m of silt. If they were from a settlement located 2m above the Delta floodplain, the potsherds from these sites would be about 6.4 to 5.2m below the floodplain. However, if they were reworked from their higher level to a lower level by erosion then they could be found at a somewhat lower level.

Although farming and herding emerged in the Near East by 10,000 BP, there is no evidence in the Nile Valley for farming activities before 6300 uncalibrated radiocarbon years BP (Hassan 1988). Recent work in the Delta (Brink 1993) and elsewhere has not revealed any older sites. It seems the appearance of farming and herding in Egypt during the seventh millennium BP, using wheat and barley well as sheep and goats from the Levant, was a result of a movement of a number of families and individuals across the Sinai to the Nile Valley (Smith 1989), as a result of droughts in that region at about 7500–6000 years BP (Hassan 1986a). A change in climatic conditions in the Levant during the late Holocene is indicated by a reduction in the proportion of deciduous oak pollen and other trees. The climate was wetter 9,000 years ago than 6,000 years ago (Wright and Roberts 1993; see also Goldberg and Miller-Rosen 1985; Goodfriend 1990). It may be also assumed that, if emigrants from the Near East were driven by droughts towards Egypt at 7000 BP (the Neolithic at Merimda on the west side is dated to 6300 BP, with emmer wheat and barley as well as sheep and goats from south-west Asia), they are likely to have arrived along the Tumilat branch, moving southward along the ancestral Pelusaic branch to Heliopolis and then westward up the ancestral Canopic to Merimda, or across the southern part of the Delta at about the level of Benha. The easternmost site of the Predynastic/Archaic period in Egypt (Kafr Hassan Dawood) is near el-Tell el-Kebir on the southern margin of Wadi Tumilat. It consists of a huge cemetery with Graeco-Roman elements. Founding communities dating to 7400–7000 BP may well be covered by 8m of silt. We must thus take seriously the finding of potsherds at about 6m below the present surface of cultivated fields at Minshat Abu Omar attributed to the Neolithic by Krzyzaniak (1992: 153).

Younger settlements dating to the beginning of the Middle Kingdom (c. 2000 BC) situated at 2m above the floodplain at the time are likely to be now found at 4.5m below the modern floodplain of the north-eastern Delta. This explains why sherds older than Middle Kingdom potsherds do not appear in the uppermost 2m of alluvial silt in the Delta (Wesemael 1988).

It should be also noted that continued exploitation of the Delta and Nile floodplain, involving repeated ploughing, canal digging and excavation for settlement or harbours, is likely to have led to disturbances that may have dispersed archaeological remains into lower or higher levels. This explains the incongruity between radiocarbon dates and potsherd typology observed by Warne and Stanley (1993) in the Delta cores.

Disturbance of archaeological remains would have also occurred at the time of degradation (vertical and lateral erosion) of the Delta and Nile Valley floodplain. For example, severe downcutting would have occurred at about 4500 radiocarbon years BP and again at 3700 BP as well at 3000–2500 BP and 2000 BP (3200 BC, 2200 BC, 1300–650 BC and AD 75 respectively). These episodes would correspond with undercutting of lower layers of sand islands and the collapse of debris from overlying layers intermixed with archaeological material. This would account for the fan-like deposits (clay/silt/sand mixture) encountered through drilling in the north-eastern Delta at El-Farahatiya. The Predynastic remains associated with these talus deposits predate the dark (bluish) grey silty clay dated to 2585–2405 cal. BC. The accumulation of the talus deposits and reworking of Predynastic materials would have thus occurred after 3500 BC and before 2585/2405 BC, and may thus date to the 3200 BC erosional interval. The talus deposits with Graeco-Roman debris overlain by about 2m of alluvial silt would have thus formed during the 75 BC (2000 BP) erosional phase. The erosional (degradational) events thus not only would have had significant implications for subsistence and settlement activities but are also likely to have influenced the distribution and integrity of archaeological traces.

The Nile Delta: subsidence, siltation and sea-level changes

The most pronounced change in the geomorphic evolution of the Nile Delta in historical times is the disappearance of several distributaries (Ball 1942; Bietak 1975; Holladay 1982; Said 1993; Sneh and Weissbrod 1973). According to Herodotus, there were three principal branches of the Nile at his time (fifth century BC): the Pelusaic, the Sebennytic and the Canopic; and four secondary distributaries: the Saitic, the Mendesian, the Bucolic and the Bolbitine (Fig. 4). Both the Bucolic and the Bolbitine were regarded as artificial. There are several historical accounts of the subsequent changes in the number and courses of the Nile branches, but it is evident that the Pelusaic branch disappeared before the seventh century AD, to be followed by the Tanitic and the Mendesian which became defunct by the tenth century (Guest 1912). The remarkable changes in the branches of the Delta over a span of 1,500 years highlight the instability of the Delta landscape. The subsidence which caused the extinction of the Tanisian and Mendesian branches by the tenth century AD was also responsible for the formation of lagoons and salt marshes in the northern Delta which destroyed the agricultural resources of that region, as indicated by the fate of Tanis, which was in ruins by the seventh century AD (see below).

The progradation of the Delta and the changes in the number, orientation and direction of the Nile distributaries (Fig. 4) must have been particularly troubling for the transport

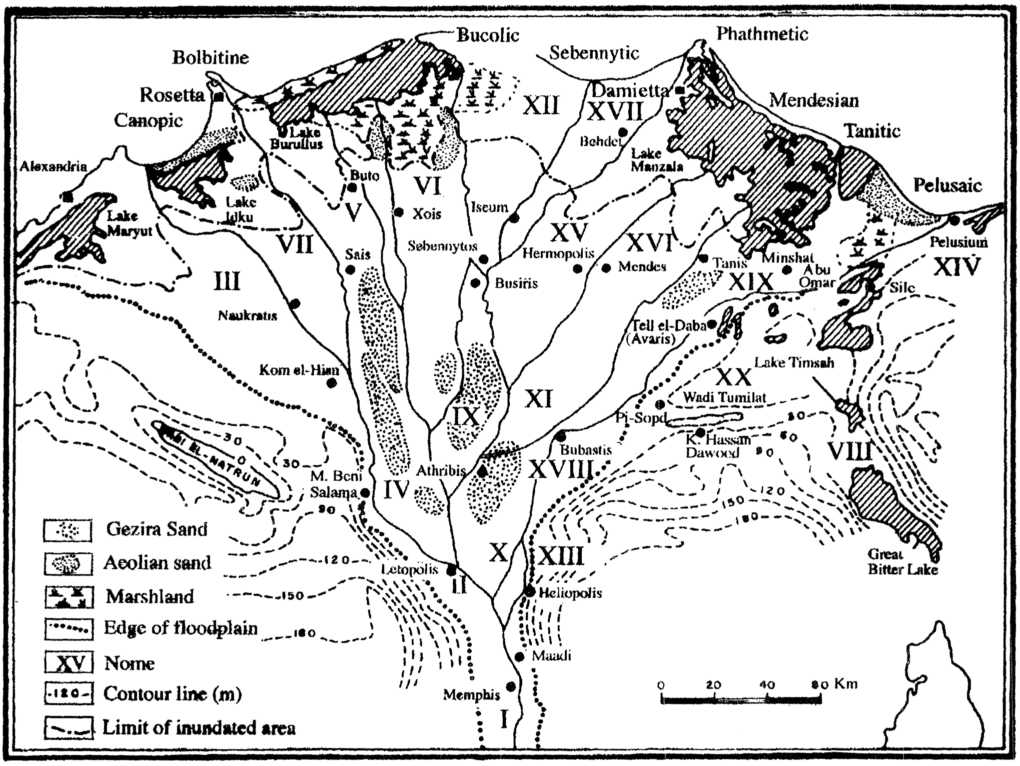

Figure 4 Map showing ancient Nile branches (distributaries) and major archaeological sites in the Nile Delta. The landscape, including the number of distributaries, was highly variable through time. At present only the Rosetta and Damietta branches are active.

network between the nome capitals, and between the nome capitals and Memphis, as well as the connections between sea ports and the outside world. Herodotus mentioned two artificial canal distributaries which he refers to as the Bucolic and the Bolbitine. The Bucolic branch extended seaward from Busiris and Sebennytos (modern Samanoud). Busiris and Sebennytos (west of the Dammieta branch) were among the great capitals of the Delta which also included Mendes (east of the Damietta Branch) and Pi-Sopd (south-east of the Pelusiac Branch) (Grimal 1994: 331).

The Bolbitine artificial branch, according to Herodotus, extended in a north-east direction branching from the Canopic branch. This would place Sais and Buto in proximity to this artificial branch. It would thus appear that these two artificial branches were excavated to maintain a connection between Buto and the sea as the seas continued to retreat northward. The same would apply to the Bucolic branch which would have been an attempt to extend the connection between Busiris/Sebennytos and the sea. Mendes would have also been connected to the sea in the same way. In the long run, it was a lost battle, because in addition to the progradation of the Delta and the retreat of the sea, the eastern margin of the Delta was subsiding relatively more quickly than the western side.

Differential rates of subsidence and variations in Nile floods specifically influenced the distributaries of the eastern Delta, which were deprived of their water supply and became extinct. The Tumilat distributary was particularly vulnerable. Currently a 'wadi' with an artificial canal, the Tumilat distributary branches off from the Pelusaic near Bubastis (modern Zagazig) and extends eastwards past Patumps (Pithom, modern Tell el Maskhuta), continuing farther east to Lake Timsah and the Bitter Lakes near modern Ismailiya. An artificial canal, according to Strabo, passed to the area of modern Suez following the route of a modern freshwater canal. The existence of this canal is well established by the Saitic period (672–525 BC) (Posner 1938). When Diodorus stated that the canal begun by Necho (seventh century BC) started at the Pelusian mouth, he was including within its length the whole Bubstite Arm which was a main channel for shipping (Kees 1961: 114). Following an archaeological survey of the Wadi Tumilat, Redmount (1995) concluded that a canal was perhaps maintained during the New Kingdom (1550–1070 BC), but that – if it existed – would have been limited in extent. The siltation associated with low Nile floods during the Ramesside period (1295–1069 BC) would have curtailed the use of the canal. Also, high siltation rates at about 650 BC would have motivated Necho to deepen the canal. Similar efforts were also undertaken by Darius and Xerxes (sixth and fifth century BC), and again by Ptolemy Philadelphus in 280/279 BC. By AD 70, the canal was apparently defunct since a Roman military contingent on its way to Jerusalem did not go via Wadi Tumilat, but was transported by boats along the Mendesian branch up to Themwis (modern Temi al-Amdid), where they disembarked and travelled for the remaining distance by foot.

In the western Delta, evidence for subsidence since the Roman period is indicated by submerged settlement and harbours in and around Alexandria, where the rate of subsidence over the last eighteen centuries is estimated at 1.4mm/yr (Hamdan 1980: 208). Submerged cities in this region include Heraclium, Menuthis and Canop (ibid.). In the eastern Delta, decayed vegetation and drowned settlements at 1.4m below sea level indicate that the subsidence rate was about 0.77mm/yr. Al-Maqrizi also reported that the sea has submerged many of the settlements at low elevations near Tanis, and that the area was under water in the sixth century AD (Hamdan 1980: 210).

Both Al-Mas'oudi (1982) and Al-Maqrizi (n.d., orig. 1441) report that the nome of Tanis was not unlike the Faiyum in its orchards and farms, but the sea penetrated the sand ridges and year after year covered the low land with its villages and hamlets, leaving only the towns situated on higher grounds. The destruction of the farms deprived Tanis of their resources and, by the time of the Arab conquest in AD 635, Tanis was no more than a ghost town of reed huts. However, this account does not fit with the report by Khesru in the eleventh century AD (cited in Hamdan 1980: 217) of a prosperous town with 1,000 ships in its harbour and a male population of 50,000, which is surely an exaggeration. However, he also reports that the town lived only on trade since it did not have any local source of food or even fresh water (Hamdan 1980: 217). After the tenth century AD, the town was subjected to raids by pirates and crusaders which led Saladin and his successor Al-Kamil to destroy it by the beginning of the thirteenth century (Hamdan 1980: 217).

The change in sea–land relationship that occurred at 3000 BP is documented by Sneh et al. (1986) at a borehole near Tell el Fedda, on the Sinai side of the north-eastern Delta, east of the Suez Canal. After 3000 BP, fresh-water diatoms represented in lower levels disappear and the diatoms present suggest deposition in a restricted lagoonal environment, in places probably hypersaline. 3000 BP (1300 BC) was marked by low Nile flood discharge, as indicated by low lake level in the Faiyum and at Lake Abhe in Ethiopia. Another episode of low Nile discharge, on the basis of low lake levels at Lake Arsi in Ethiopia, occurred at 650 BC (2500 BP), which accords with the total submergence of the Tanis low settlements. The beginning of the formation of the series of sand ridges seaward during the last 2,000 years (Sneh et al. 1986) coincides with the low flood discharge at 2000 BP (75 BC), indicated by low levels at Lake Arsi and Lake Langeno in Ethiopia. Thus, in spite of short-term, episodic sea regressions at approximately 3200–2940, 2650–2420 and 2100–1800 BP, coincident with low Nile flood discharge, the submergence of the Delta led to the invasion of the northern Delta by lagoons and salt marshes. Thus, since the rise in sea level has been more or less constant over the last 2,000 years, the submergence of settlement in the northern Delta was most probably a result of subsidence.

Concluding remarks

The rise and sustainability of Egypt as a nation-state with great intellectual and artistic achievements was based primarily on cultivating cereals on the floodplain of the Nile. The emergence and maintenance of Egyptian civilization was not a function of centralized management of irrigation. Egypt probably survived for so long because production did not depend on a centralized state. The collapse of government or the turnover of dynasties did little to undermine irrigation and agricultural production on the local level. However, low Nile floods caused famines, and the unpredictability of floods and agricultural yields created an ecology hospitable to notions of order and stability. The kings of Egypt, backed by a powerful religious institution, nurtured these notions. The king was portrayed in general as a mediator who intervened with the gods to ensure order and prosperity. An elaborate religious ideology, in fact, shifted the belief from the Nile to the sky and cosmic gods and goddesses.

From our vantage point, we can detect the chaotic dynamics of the Nile, which may begin to resemble 'order' only on a long-term scale far from the range of ordinary human perception and forecasting. Episodic reduction of Nile flood discharge and the subsidence of the Delta led to frequent siltation of Nile distributaries. The disappearance of the eastern branches was also caused by differential subsidence. The slowing of sea-level rise after 3000 BC made possible the expansion of settlements and farming into the northern fringe of the Delta. Eventually, reduction in flood discharge and subsidence by the tenth century AD destroyed the agricultural potential of the north-eastern region of the Delta.

The dynamics of floodplain processes are interactive with cultural activities. They also influence the survivability of archaeological remains and their condition. A fuller understanding of the archaeological past of riverine civilizations requires not only special methodological strategies for the retrieval of archaeological remains, but also sophisticated geomorphological models of floodplain dynamics.

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