CLIMATE CHANGE, NILE FLOODS AND RIPARIA[1]

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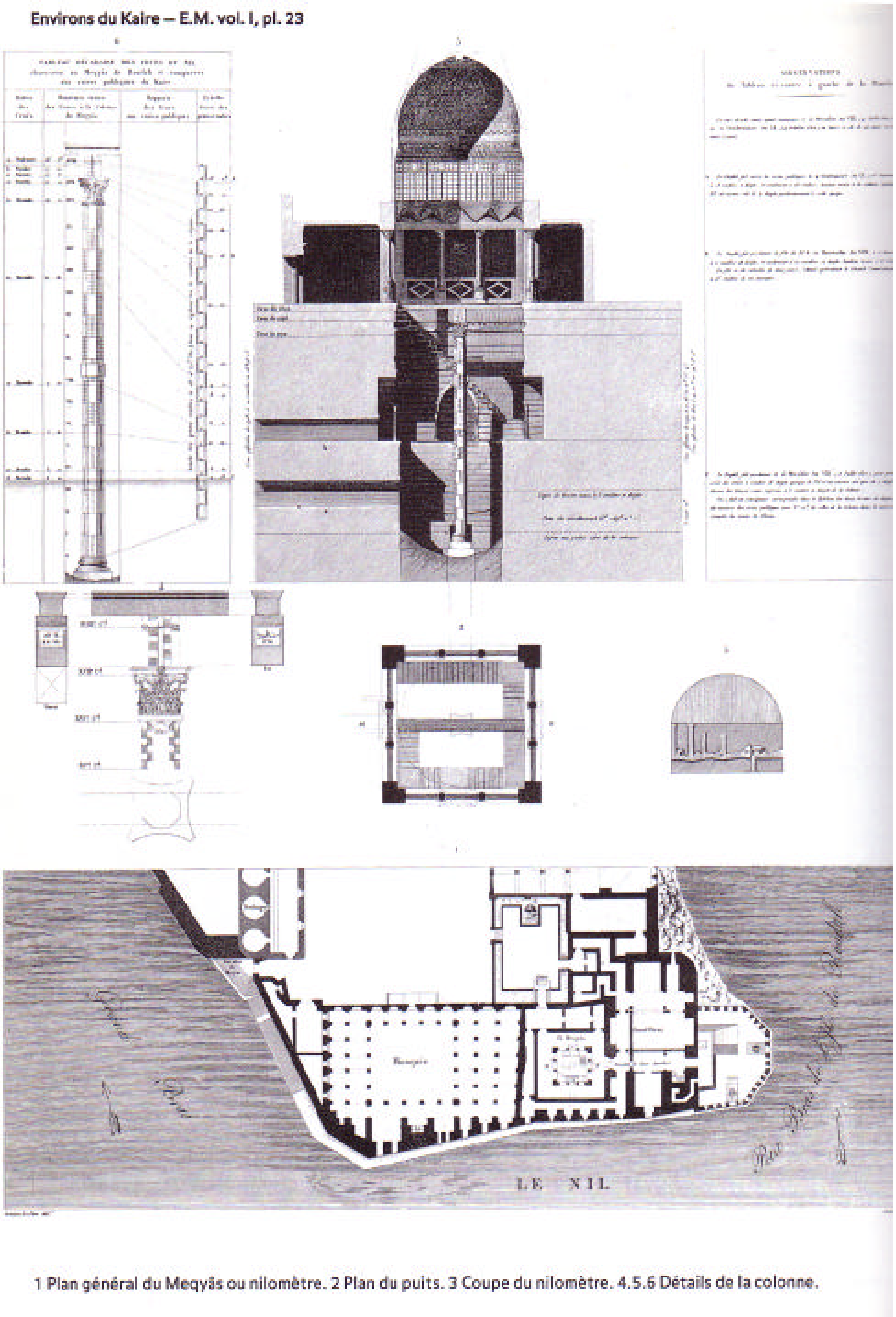

The Rhoda Nilometre. – A gauge on the Island of Rhoda near Cairo established in the 7th century AD as the last nilometre in a long series of such flood gauges dating back t the beginning of Egyptian civilization.

[1] Hassan, F. A. 2010 in RIPARIA DANS L EMPIRE ROMAIN. Edited by Ella Hermon. BAR S2066,Oxford.

Abstract :
In this contribution, I aim to shed light on the complex interaction between climate, *riparia* and the course of Egyptian civilization. I examine in the first part the characteristics of the floodplain and its dynamics in response to climate change and in the second part, the cultural history of Egyptian civilization as a human achievement by farming communities in an unpredictable environment. Although climatic fluctuations have been a principal catalyst for cultural change, the course of Egyptian civilization was primarily the result of social processes. We cannot underestimate the role of an elite who may have in the beginning served as coordinators and managers of aggregates of communities banded together in order to minimize the risk of unpredictable floods and their consequences for *riparia*. The elite developed an ideology of divine kingship buttressed by monumental architectural structures and did not have much to do with centralized management of irrigation. However, for a brief moment, after a catastrophically low Nile caused by a global climatic event ca. 4200 BP, a new dynasty undertook major hydraulic projects but they were subsequently destroyed by high floods. It was not until the Ptolemaic period that such state-sponsored hydraulic projects were undertaken but they also suffered from destruction by high floods. The Romans continued to repair such structures. Climatic events attested around the Mediterranean during the Roman period would have contributed to fluctuations (100-200 year scale) which would have caused variations in Nile flood discharge and hence agricultural production. Since Rome depended on food supply from Egypt, low agricultural yield would have adversely affected Rome.

Résumé :
Cette contribution vise à mettre en lumière l'interaction complexe entre climat, *riparia* et l'évolution de la civilisation égyptienne. Dans sa première partie, j'examine les caractéristiques de la plaine inondée et de sa dynamique en réponse aux changements climatiques, et dans sa deuxième partie, l'histoire culturelles de la civilisation égyptienne en tant qu'un exploit humain réalisé par des communautés agricoles dans un milieu imprévisible. Bien que des fluctuations climatiques aient été un catalyseur principal de changement culturel, l'évolution de la civilisation égyptienne fut surtout le résultat d'un processus social. Nous ne pouvons pas sous-estimé le rôle d'une élite, qui aurait pu initialement servir comme des coordinateurs et des gestionnaires des communautés qui se sont agrégées afin de minimiser le risque imprévisible d'inondations et de leurs conséquences pour les *riparia*. L'élite a développé une idéologie de royauté divine étayée par des structures architectoniques monumentales et n'avait pas grande chose à voir avec la gestion centralisée de l'irrigation. Cependant, pour un bref moment, après l'occurrence d'un niveau catastrophiquement bas du Nil causé par un événement climatique global ca. 4200 BP, une nouvelle dynastie entreprit des projets hydrauliques majeurs mais qui furent ultérieurement détruits par des inondations importantes. Ce ne fut que dans la période ptolémaïque que de tels projets appuyés par l'État furent lancés, mais ceux-ci ont subi également la destruction par des grandes inondations. Les Romains ont continué à entretenir de telles structures. Des événements climatiques attestés autour de la Méditerranée dans la période romaine auraient contribué aux fluctuations (à l'échelle de 100-200 ans) ayant causé des variations de la décharge des inondations du Nil et par conséquent de la production agricole. Puisque Rome dépendait de l'Égypte de l'approvisionnement en nourriture, des faibles rendements agricoles auraient des effets adverses sur Rome.

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Introduction

The Egyptian civilization emerged and developed on the banks of the Nile. To this day, the Nile remains its main source of water. It was certainly shaped by human actions, but these actions were influenced by the way they perceived the environment in which they chose to live (Hassan 2000), as well as the by the mode of subsistence they practiced. This mode was predominantly agrarian. Accordingly, they were at the mercy of climatic fluctuations that determined the amount of Nile flood discharge and hence the areas that may by cultivated.

Changes in Nile flood discharge had also a major role in constantly changing the features of the floodplain making it a very dynamic geomorphological environment. This interaction between climate and *riparia* imposed a variety of problems such as availability of water, distance from channel, location of harbours, protection of fields and villages from floods, water-logging, falling water groundwater table, disappearance of river-front properties, river transport, contact between villages when floodwater covered the floodplain, pest infestations, and rise of land relative to level of Nile floods.

These problems could not be resolved on a small community or village level because some solutions led to conflicts among neighbours. In addition, neighbours could have realized the benefits of co-operating in building levees or digging canals. But against this cooperative spirit, the opportunity for the rise of leaders and managers presented itself as soon as cooperative groups became too large to be managed on kinship or neighbourly relations. Once the managers appeared, and this must have happened as we can tell from archaeological evidence by 4000 years ago, or perhaps earlier, they began to develop a hierarchical organizational configuration superimposed in the earlier egalitarian organizational formats. They also began to look for their own interests and not that of the people at large, people who were no longer kin or neighbours. They eventually formed a top elite who transformed their secular mandate to a mandate of Heaven, positioning themselves with the help of elaborate rituals and theologies that topped their organizational structure with a king who was regarded as the "son of God" (Horus son of Osiris) descended from a Holy mother (Isis).

The rituals and religious polemics were buttressed with awe inspiring pyramids during the Old Kingdom and by elaborate monumental temples in later times. The riparian landscape was transformed not by hydraulic works sponsored by the state, but by the monuments that proclaimed the power and might of the king who had the divine right of receiving tributes from the populace as gifts. An elaborate bureaucracy was instituted not to supervise the construction, operation and maintenance of governmental water works, but to manage the building of monumental structures, and to secure the funds needed for the royal house, the governmental functionaries, and for monument building. People gained faith which alleviated their anxieties as life hanged in the balance in anticipation of a flood that could be too high, too low, too late, or too early. And even with a good flood, there was the risk of loosing crops to pests, rats, unseasonal heat, wind, or dust storms.

Water management of the floodplain, which is not too wide and often with lateral secondary channels was not conducive to long canals that could have demanded the intervention of the state. The population was limited to 2-3 million with an extremely low population growth rate maintaining a balance between the number of people and agricultural productivity under natural basin conditions and the prevailing perceptions of "good" flood levels.

The state kept records of the height of floods in order to provide a "just" system of collecting tributes/gifts commensurate with the area cultivated. The state was also shaken by extremely low floods caused by a global climatic event ca. 4200 years ago. The state mechanisms collapsed and the centralized government disintegrated. The state system was resurrected after 150 years of rehabilitation by a new cadre of kings who still claimed to be descended from gods, but who also were sufficiently savvy to create a new political platform as benefactors who were sent by the Gods to help the poor and uphold justice and truth. Ushering in a revolution in the way people perceived gods and society. They were also sufficiently wise to reform the bureaucracy, set ideals against corruption and abuse of poor peasants, and moreover to attempt to undertake the first great hydraulic projects.

Within a few hundreds of years, a combination of high disastrous floods and perhaps weak kings ended the grandiose hydraulic projects of the state.

In this contribution, I aim to shed light on this complex interaction between climate, *riparia* and the course of Egyptian civilization. I examine in the first part the characteristics of the floodplain and its dynamics in response to climate change and in the second part, the cultural history of Egyptian civilization as a human achievement by farming communities in an unpredictable environment. This analysis in now way explains the particularity of the cultural achievements of ancient Egypt, its philosophy, mythology, literature, and arts. In the most part, these human achievements had more to do with the mind than the environment, and are therefore distinctly different from one civilization to another. However, no comprehensive explanation or understanding of Egyptian civilization can fail to take into account the role of the Nile and agriculture not only in sustaining Egyptian civilization, but also in stimulating ideas related to chaos and order, death and resurrection, and not least notions of justice, beauty, and goodness.

Agriculture and increasing dependence on cultivated cereals for subsistence placed people at greater risk. Farming was also conducive to year-round residence in hamlets and villages that were within a millennium to be found in many parts of the Delta and all along the Nile floodplain. Agriculture was also conducive to the aggregation of families in relatively large settlements because cooperative farming endeavours (seeding, harvesting, and other chores) ensured higher yield than if small groups farmed separately. However, 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. Variations in yield, for example, may result from differences in scheduling sowing, the management of labor 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.

I submit here that these were the first steps in the making of Egyptian civilization. Initial decisions that fostered cooperative ventures led to economic, demographic, political and religious developments that were dynamically interlinked. The riparian landscape co-evolved with Egyptian society changing from a pristine natural habitat to a remarkable cultural landscape.

I. Floodplain and its dynamics of Nile River in response to climate change

Temporal variations in Nile flood discharge

Changes in the total discharge as well as the relative contribution from the main tributaries are frequent and rather significant as shown by the records of Nile floods from the Roda Nilometer over the last 1300 years and other hydrographic measurements (Hassan 1981, Hassan and Stucki 1987).

Nile flood discharge fluctuates at different time scales; decadal, centennial, and millennial (Hassan 1997, Woodward et al. 2007). The average discharge during the period from 1870 to 1899 was 110 billion cu.m/yr compared with an average of 84 billion cu.m/yr from 1900 to 1988. However, discharge in 1916 and 1917 was 109.8 and 110.2 billion cu.m/yr, respectively. By contrast in 1913, discharge was as low as 45.3 billion cu.m/yr (Said 1993). This emphatically underscores the decadal and interannual variability that can have very serious cultural implications for food production and transport.

This is further substantiated by the analysis of the historical flood sequence from the Road Nilometer which was kept annually since 645 AD. In 1981, I calibrated the record taking into account a variety of factors to provide the height of Nile flood maxima and minima above sea levels (Hassan 1981). The results revealed that on average the Nile discharge was low before 1070, with major episodes of high Nile at 1070 to 1180 and 1350 to 1470. The duration of the low of Nile episodes ranged from 35 to 170 years, with a mode about 100 years.

Analysis of the historical Nile record from the Roda Nilometer for anomalous high and low Nile floods which are likely to cause serious economic problems revealed that from ca. 950 to 1450 AD, the percentage of anomalous floods was higher than 15%.

Historical texts reveal that this period was also characterized by the worst known famines on record. Exploratory comparison of variations in Nile flood with high-resolution data on sea surface temperature of the North Atlantic climate (Hassan 2007) suggest that rainfall at the sources of the Nile was influenced by the North Atlantic Oscillation. However, there are apparently flip-flop reversals from periods when variations in Nile flood discharge are positively related to North Atlantic warming to periods where the opposite takes place. The key transitions occur at ~ AD 900, 1010, 1070, 1180, 1350 and 1400.

The putative flip-flop junctures, which require further confirmation, are quite rapid and some seem to have had dramatic effects on Nile flood discharge, especially if they recur at short intervals, which were characteristic of the period from the 9th to the 14th century, coincident with the so-called Medieval Warm Period in Europe.

The transition from one hydrographic state to the other was characterized by incidents of low, high or a succession of both low and high extreme floods. The cluster of extreme floods was detrimental, causing famines and economic disasters that are unmatched over the last 2000 years. This period of unsettled climatic conditions appears to have been a millennial event, and has parallels in earlier times, especially at 4200 years ago (see below).

The riverine floodplain

The Nile River in Egypt is fed by distant sources in Equatorial Africa and Ethiopia. Numerous tributaries draining equatorial Africa supply water to the White Nile which joins near Khartoum the Atbara and the Blue Nile which supply the main Nile in Egypt with most of its water and silt during the summer.

The Nile channel in Egypt is a slightly meandering sinuous 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 2 km at Aswan to 17.6 km at Minia. The Nile channel is on average about 740 m wide ranging from 643 in Aswan to 808 m. near Cairo. The depth of the channel varies from 6.76 to 8.52 m. The current channel of the Nile and its valley are superimposed on earlier Nile sediments belonging to remote geological periods. Ancestral rivers flowed in a deep canyon formed in part by the tectonic forces that created the Great African Rift. The deposits of these ancestral rivers rim the current floodplain as relict terraces of coarse to medium grained sand at different elevations. Lower terraces include fine grained sand and darker silt deposits formed when the Ethiopian tributaries began to make a significant contribution to the water and sediments carried by the main Nile River some hundreds of thousand years ago. However, a series of climatic events have led to a series of depositional [aggradational] phases often followed by erosional episodes. The current floodplain consists of the most recent depositional phases.

The rise of the floodplain as a result of accumulation of silt from Nile flood water, almost every year under natural conditions, was accompanied by a rise in the level of the channel floor due to the deposition of sand. 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 9 m above the bottom of the channel. Irrigation canals in Upper Egypt are situated at 4.5 m above the bottom of the channel. A high flood with as much as 10 m water height above the channel can thus flow over the bank and inundate the floodplain. In general the height of water above the floodplain in the Delta during periods of high floods is 4 m, with an average of 1 m. However, if the Nile flood is low, irrigation canals become essential to deliver water to the fields since low floods may not be more than 7.5 m above the bottom of the channel. During the times of drought the level of Nile water is at 9 m below the level of the floodplain in Aswan, 5 m in Cairo, and 3 m in the central part of the Delta.

During the flood water seeps into the ground. The amount of water feeding this subterranean water depends on the permeability of Nile sediments (which vary from 8 to 20 m) and their stratigraphy as well as the level of Nile flood discharge. The water table of the subterranean [ground] water is high following the inundation. It falls after the flood season. Away from the river and where the ground is high, wells are often dug to reach the subterranean water level.

However, this water is brackish because it contains salts dissolved by the water as it moves away from the channel.

Typically, the Nile floodplain is delimited near the channel by either a high ridge (levee) on the concave, deep side of the channel or a narrow sandy point-bar, often submerged, on the shallow convex side of the channel. A levee is formed during the season of inundation when 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. 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.

Movement of the Nile Channel

One of the prominent features of the Nile River affecting riparia is its movement**.** Butzer (1976) examined historical maps to detect shifts in the position of the Nile channel from 1800 and 1935. He concluded that the sinuosity ratio of the channel from 1.33 in 1800 to 1.25 in 1935. He attributes this straightening of the channel to a decline in Nile volume and increased "sediment starvation" due to impounding of water behind barrages and dams. He also detected a lateral shift in the position of the channel of 1.5 km near Qaw. He further extrapolates that the sinuosity would have been 1.36 km in the 1600s with as much as 2.3 km shift in the position of the channel. Butzer, in addition, suggests that in the majority of cases (11 of 17 observations), the channel migrated eastwards. This assumes that the hydraulic conditions between 1800 and 1935 were the same as those during the 17th century which cannot be true since this was a period of global cooling (the Little Ice Age) and Nile flood discharge would have been reduced.

The position of Ptolemaic/Roman towns and villages in the Akhmim area reveals that the Nile ran immediately west of a series of prominent levees in Hellenistic times. The course of the Nile was at least 3 km west of the position of the Nile at present.

Nile movement since the 1st century BC may be estimated from the textual mention by Diodorous Siculus (1st century BC) of the location of the ancient capital of Egypt, Memphis near the Nile (Murphy 1990)[2].

The movement of the Nile River in the Memphis area has recently been examined by David Jeffreys who demonstrated that Memphis, now indicated by the ruins at Meit Rahina, overlooked the Nile, as reported by Classical writers. The course of the river had since shifted to the east.

More recent investigations by Lutley and Bunbury (2008) used Google Earth satellite imagery and field foot surveys to detected movements of the Nile in the Memphis area. They assumed that the Nile River ran along the western margin of the floodplain. Accordingly, they claimed that the Nile River had shifted at a rate of up to 9 km/1000 years (9 m/yr). I will provide below revised estimates based on recent empirical studies consisting of geoarcaheological investigations based on a systematic coring programme and interpretation of landsat Google imagery clearly reveals that during late Predynastic/Early Dynastic times, the Nile ran along the eastern margin of the floodplain. This accounts for the presence of key late Predynastic/Early dynastic sites on the eastern bank of the Nile close to the desert edge at Heliopolis, Maadi, Tura and Helwan. These investigations are a part of a broader project in collaboration with Roger Flower and M. Hamdan.

In order to understand the movement of the Nile River in the Memphis region we may benefit from a clarification of the relationship between the ancient settlements in the region and the older courses of

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[2] *Now the eighth descendant of King Osymandias, who was called Uchoreus after his father, founded Memphis, the most illustrious city in Egypt. For he sought out the most fitting site in all the land, the place where the Nile divides into many branches to create the Delta (so called by reason of its shape); wherefore it came to pass that the city, opportunely situated, as it were, at the gateway to Egypt, was master of the commerce, passing upstream to the country above. And indeed he gave the city a circuit of a hundred and fifty stades, and he rendered it exceedingly secure and of marvellous convenience in the following way: since the Nile flowed near the city and used to flood it during the period of high water, he threw up before the south side an earthen rampart of the river and a citadel against the enemies from the land. On the other sides he dug a lake great and deep which absorbing the force of the river and covering all the space round the town (except where he had built the mound), afforded unparallel protection.*

the Nile (Jeffreys 1985, 2008, Jeffreys and Tavarse 1994). One of the most important settlements in the region is Memphis, the most ancient and long-lasting national capital of Egypt. Today, this national capital is identified as the ruins called Meit Rahina. Although it is historically known that the first capital was founded in this region during the Early Dynastic period (3200- 2800 BC), the foundation of Memphis at Meit Rahina is attributed to Pepi I (2321-2287 BC). The city derives its name Memph, Grecisized to Memphis, from the name of the pyramid of Pepi I, Men-Nefer, meaning "Established and Beautiful. It is often conflated with older royal towns that must have predated the end of the Old Kingdom. However, the presence of early dynastic mastaba tombs near Abu Sir and the detection of a buried rock promontory in that area indicates that the earliest royal town was located close to the modern town of Abu Sir. This would have been the town with the ancient name, Ineb-Hedj ("White Wall" or "White Fortress"). It was most likely a town with a royal palace surrounded with a white wall on top of the white limestone hill promontory. It would have indeed been worthy of the name the White Fortress standing high with dazzling white colors above the black floodplain with its green vegetation and trees. The royal Ineb-Hedj was founded by kings who were not native to the Memphite region-Heliopolitan region with its main settlements on the east bank of the Nile. They were descended from kings who had established themselves earlier near Abydos (50 km south of modern Sohag, and 415 km along the Nile north to Memphis). They most likely chose the west bank, according to their religious beliefs, to locate their royal necropolis.

As at present and in historical times, on broader floodplain segments, minor, secondary Nile branches (50-70 m in width and 4 m in depth) that run for very long distances. One of the best known tributaries is "Bahr Yusouf". Today, this artificially modified channel still retains a conspicuous meandering pattern (more conspicuous than that of the main channel of the Nile in a range from 1.25 to 1.9 m). It is connected to the Nile near Deirut. Formerly, it appears to have consisted of several secondary branches that were connected to form one main secondary branch. Formerly, Bahr Yusouf branched off between Asyut and Manfalout along the western edge of the floodplain for a distance of about 265 km before it debouches into the Faiyum Depression via the Hawara gap. Similar secondary branches include the Sohagiya Canal, which originates at Sohag, and the now defunct Bahgouryia Canal, which diverged near Nag Hamadi (Butzer 1976, 16). Butzer suggests that these three major bifurcations occur just below valley constrictions imposed by bedrock constraints to the Valley. In each case the river axis turns to the east, a divergent branch swings westward across the broad floodplain immediately down stream. These branches are likely to run dry because they are situated at relatively higher elevation compared with the main channel and are thus likely to dry out in midwinter when Nile water discharge is low. In addition they are more subject to silting up because they are considerably shallower and narrower than the main Nile channel, and located closer to the influx of windblown sand carried by northwesterly wind they are likely to experience. Butzer (1976, 17) notes further that the multiple abandoned channel traces and meander scars as well as the location of sites such as Aphroditopolis, Oxyrhynchus, and Herakleopolis, in addition to allusions by classical writers such as Strabo (17:1.4) and Diodorus (1:52), indicate that similar branches existed throughout the historical era.

Such branches also existed in the Memphite area; one of these branches is Bahr el Lebeini. In the Memphis area this "Bahr" (River in Arabic) runs between two canals, Shabrament Canal to the west and the Muheit Drain (Masraf) to the east. There is also a canal that terminates near Abu Sir, known as Dahshur Canal, where it runs close to the western edge of the floodplain. Bahr el Lebeini is most likely a continuation of Bahr Yusouf or the trace of a secondary Nile branch that bifurcated from the main Nile channel upstream from Memphis. This channel was thought by Goyon (1971) to represent a "grand canal", most likely because pyramid towns were placed on its banks. However, this secondary channel was subject to disappearance periodically and to dry out during the winter. Accordingly, it was most probably maintained as a transport and irrigation canal. I submit here that the Dahshur Canal runs along an ancient secondary Nile channel that shifted to the position of Shabrament Canal which in turn shifted to the position now occupied by Bahr el-Lebeini and the Muheit Drain. The older channels were repeatedly rejuvenated in order to supply older towns, especially pyramid towns with water, and in order to provide irrigation water to farmsteads that would otherwise be deserted

According to Hawass (1997), the Wall of Khufu was located 450 m east of Bahr el Lebeini[3]. The Bahr el Lebeini would have thus existed during the Old Kingdom at the time of Khufu (2589-2566 BC). If Bahr el Lebeini during the Old Kingdom is the result of an eastward shift of a channel that ran parallel to the western edge of the floodplain below the Giza plateau, the rate of movement would come to about 3.58 m/year (1.78 km over the period from ca. 3100 to ca. 2600 BC). In the Memphite area, I arrive also at a rate of 3.2 m/yr for the eastern movements of the secondary channel (1.64 km over 500 years).

In the model proposed here, the western secondary branch of the Nile moved eastwards, while at that time the Main Nile channel moved to the West (as did the Nile since the 7th century AD). The movement of the Nile to the west was arrested after the foundation of Memphis because, as Herodotus narrates, the city was protected from flooding by embankments to prevent the city from being flooded. It was also described as an island because it was the visualization by Sharkawy (2007, 279) reveals bounded from the East by the Main Nile from the West by Bahr el-Lebeini and by two transverse canals one south of the city and another north of it.

The movement of the Main Nile, which has also been detected through geophysical prospecting, from west to east would have started soon after the reign of Pepi I. The movement covered a distance of ca. 3.3 km (with an average of 0.82 m/year). The movement of the Nile River eastward would have been initiated under a new hydraulic regime dominated by lower flood discharge, mostly fed by Ethiopian tributaries (current unpublished investigations by the author, R. Flower, and M. Hamdan). This would explain the lower rate of lateral shift.

It would be also informative to examine the movement of the Nile in the area of Cairo which became the national capital of the country in later historical periods.

Another example of the dramatic changes in floodplain geomorphology is provided by the changes in the Cairo area (Raymond 2000) 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 northwestern region) were not in existence before the Nile shifted westward.

The demise of Memphis as the nation's capital began with the conquest of Egypt by the Greek Ptolemies who moved Egypt's capital to Alexandria. Subsequently, the Romans, who displaced the Ptolemies and changed the status of the country to a colony, established a fortress town along the east bank of the Nile. This fortress, known as Babylon, remains the oldest structure in what is now Old Cairo (*Misr el-Qadima*). This area became the nucleus of Egypt's Coptic Christian community, which separated from the Roman and Byzantine church in the late 4th century. In 641 AD, the Arabs founded Al Fustat 20 km north of Memphis.

Ali Mubarak[4] also gave us the first detailed account of the movements of the Nile channel in historical times in his monumental work on the geography of Egypt (*Al-Khitat al-Tawfiqiya*). From a compilation of historical accounts from classical and Arab writers, Mubarak calculated with precision the distance of the movement of the Nile channel in the Fustat area as its course shifted from east to west.

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[3] "While certainly not a breakwater wall, this ancient construction could have served to delimit the Khufu harbor on the east. It should be noted that the wall is about 450 m. west of the Lebeini channel which has been thought to be a vestige of an Old Nile channel. The area between the wall and the lower temple location could have included both a harbour and a secondary Nile channel. Otherwise, it could have served as a stream-discharge channel that remained filled with water longer than the general flood plain when the annual inundation receded."

[4] Ali Mubarak (1996, 113, orig. 1888) "After the Arabs took over Egypt and founded Al-Fustat, the Nile began to move westward with many changes. This also happened after the founding of "Al-Qahira" (969 AD) which also overlooked the Nile and is now very far from it so that he who does not know would think that it was founded far away from the Nile because of the location of the ruins of the old city. The changes were gradual over successive periods of time."

From his account of the changing position of the Nile, The movements of the Nile were sufficiently rapid to be noticed within the time scale of historical observations. In the area now occupied by modern Cairo, for example, the course of the Nile shifted to the west significantly from 1126 to 1281 AD in the area north of Old Cairo at Fustat. The rate of the movement was as high as 5.5 m/year from 1126 to 1252, 20 m /year from 1252 to 1272, and as much as 200 m/year from 1272 to 1281, with an average of 13 m/year during this period and about 4-5 m since 941. However, at Al Fustat, the Nile course had moved away from Babylon and Al-Fustat a short distance of 400 m averaging 0.3 m/year. In addition, the Nile channel moves, depending on local situation, either to the East or to the West. For example, it has moved since the Middle Kingdom to the West (Bunbury et al. 2008), but to the East in the East in the Memphis area. In general, the Nile channel runs today closer to the eastern margin of the floodplain suggesting that the Nile had predominantly been moving to the East, perhaps since the Middle Kingdom after the reconfiguration of the floodplain during the 4200 BP event. It is likely that it was moving westwards during the Old Kingdom until it reached a position either close to the center of the floodplain or, where the floodplain is narrow, the western edge of the floodplain.

Clearly then, the rate of movement depends both on the duration of the period under consideration with short periods of very high or extremely low movements, and the local geomorphic setting. However, what is certain is that the channel is almost constantly on the move.

Such movements had a great effect on local communities. The inhabitants of Old Cairo suffered from the movement of the Nile both for the increasing distance needed to fetish water and because of the siltation the city harbor at *Al-Maqs*. This necessitated digging a canal (Khalig) to supply the city with water and to relocate the harbor. The changes also introduced the danger of flooding to the newly reclaimed land. Consequently, an embankment (Gisr) was established to protect the new city.

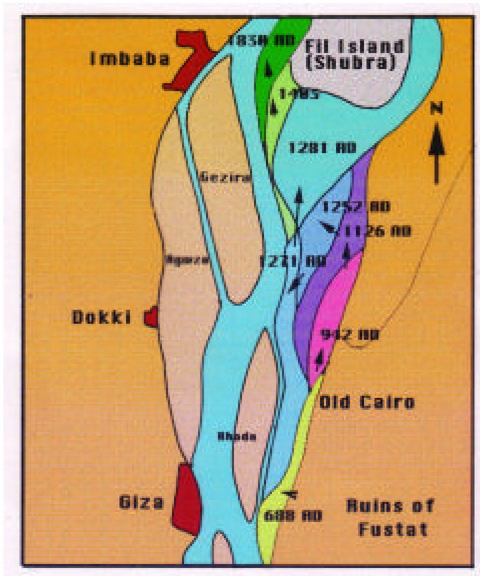

Fig. 1. Diagram illustrating the successive movements pf the Nile since the 10th century AD westward in the Cairo area.

Delta and Nile Branches

Interpretation of the number and location of branches mentioned by Herodotus (5th century BC), Ptolemy (2nd century BC), and Strabo (Ist century BC) by Ball (1942) indicates that the main pattern developed in Dynastic times still prevailed with some adjustments. The main clusters of branches consist of a western-central cluster that included the Rosetta and Sebenneytic-Damietta branches and their subbranches, and an eastern cluster that consists of the Pelusaic and the Tumeilat branches.

The basic pattern of western, central, and eastern stock branches developed in early dynastic times prevailed with some changes due to lateral movements of some channels joining or separating from nearby channels. One of the main observations concerns the Peripheral Tumeilat branch which appears to have been deprived of water during the episode of low Nile flood discharge ca. 4200 cal BP when the Nile flood discharge was vastly reduced.

The drop in Nile flood discharge and the neglect of the maintain Nance of the river and its banks during the First Intermediate Period would have led to the siltation of most of the minor branches. One of the main older branches to have been affected would have been the branch that flowed into Wadi Tumeilat. This area was abandoned as a result of the invasion of Egypt by "Asiatics". At that time the seat of power had shifted to Herakleopolis situated on Bahr Yuosuf just before it enters the Faiyum depression. Because of his branch in connecting Memphis with Heliopolis and its role for defense against the Asiatics as well as traffic into the Sinai (Kees 1961, 192) it was most likely re-excavated during the XIIth Dynasty Middle Kingdom (Murphy 1990, 42, footnote 71). This is perhaps the source of the account by Pliny that the legendary king Sesostris had begun the construction of the canal that connected the Nile Valley with the Red Sea. According to Redmount (1995), the canal was maintained during the New Kingdom

The canal is likely to have been re-excavated by Necho II (610-595) BC. It was completed under Darius and Xerxes. The canal ran from Bubastis eastward passed Patumous and through wadi Tumilat and reached its terminus in the neighborhood of Lake Timsah and the Bitter lakes and then to the Red Sea (Kees 1961, 114). The canal would have originated at Memphis following the course of the older branch of the Nile to Heliopolis and from there to Bilbis/Bubastis and from there to Wadi Tumilat at Tell el Kebir. This canal would not only have allowed the fleet of Hatshepsut to flow up the Nile and then to the Red Sea via the Tumilat canal, but also explains the use of the port and dockyard of Peru-Nefer close to Memphis for the preparation of the fleet used by Tuthmosis III (Kees 1961, 187).

After the Persian interlude, and the transfer of the national capital by the Ptolemies from Memphis to Alexandria in 311 BC, the greater importance was assigned to the eastern branches, especially the Rosetta stock branch that would have been better maintained and deepened allowing it to survive at the expense of other branches. However, Ptolemy II Philadelphus (280/279 BC) finished the digging of the Necho canal and installed an ingenious lock at the most appropriate spot (Diodorus, 34). By the end of the Ptolemaic period the canal had silted up reducing its depth and width so that Cleopatra's ships could not navigate it (Ali Mubarak, 133). It was definitely not navigable by AD 70 since a Roman military contingent in its way to Jerusalem did not go via Wadi Tumilat but was transported by boats along the Mendesian branch up to Temi el-Amdid (Themwis) where they disembarked and traveled the remaining distance by foot).

Under the Romans, Hadrian dug a canal to connect the Nile at the fortress of Bablyon with the Tumilat-Necho canal. The canal was maintained later by Trajan. A small dockyard was apparently established at Memphis under the Romans. Its masonry recalls that of the fortress walls of Babylon (Jeffreys 1985). This suggests that Memphis was once again connected with Heliopolis and Bilbeis. A canal from Bilbeis to Tall Basta , which already seem to have existed during the Ramessid period and perhaps as early as the Middle Kingdom would have allowed movement from the Peulsaic branch to Heliopolis and from there to Memphis. This accord with the statement by Diodrus Siculus (Book 34) that a man-made canal was dug from the Pelusaic mouth to the Gulf of Arabia and the Red [Erythraean] Sea and that Necho son of Psammatichos initiated the construction of the canal. Following the conquest of Egypt by 'Amr ibn El 'Ass and at a time when the inhabitants of the Arabian Peninsula were suffering from famine, the Caliph Omar ibn El-Khattab informed Amrou that he had learned that merchant ships came to Arabia before Islam via a "khalig" (canal) that connected the Nile with the Red Sea, and since this then khalig has been cut off. He then expressed his wish to have the khalig to be re-excavated so that food can be brought to the Hijaz by ships. 'Amr ibn El 'Ass obliged and dug the canal from the neighborhood of Fustat to Suez (Ali Mubarak p.130). Amrou excavated the canal in six months. The canal was maintained until the reign of Abdel Aziz ibn Marawan. The canal was ordered closed by Abu Jafa'ar Al-Mansour in 767 AD to prevent the transport of food supplies to a rebel. It was a millennium later that the Ismailyia canal was dug following the course of Necho canal (Ali Mubarak 133).

The Disappearance of Nile branches

The demise of the western branches of the Nile which culminated in the dominance of the Rosetta and the Damietta branches, with the greater share of water (70%) carried by the Rosetta Branch, appears to have begun already by the reduction of Nile flood discharge during the 2700 BP event. By the time Herodotus visited Egypt (500 BC) there were three principal branches : the Pelusaic, the Sebennytic and the Canopic. Other branches had diminished in importance and were artificially maintained. By 300 BC, the Canopic branch disappeared (Said 1993), and by 25 AD, the mouth of the Pelusaic branch silted up.

The situation was aggravated again at 542-600 AD as a result of reduced Nile water discharge. Some other factors seem to have been at work at that time: these include the sea beginning to gain over land. The coastal configuration of the Delta is a function of: (1) the amount of sediments deposited by the Nile which is highly reduced during periods of low Nile discharge, (2) the rate of land subsidence, and (3) the relative level of sea level.

If the rate of siltation is the same as that of subsidence and the sea level is stationary, the shoreline remains stable. But if the sea is rising then the northern parts of the Delta would be submerged. After 7000 years ago the sea level remained more or less stable and we may assume that the rate of subsidence is also constant. Accordingly, the encroachment of the sea on the northern parts of the Delta causing severe damage as happened between 1330 and 1630 AD (coincident with the Little Ice Age) was most probably a result of the reduction of Nile flood discharge and the amount of its load of sediments. This would have also happened during the period ca. 2700 BP, placed by Buzer (1976) around 3200 - 2950 BP, when the Nile flood discharge was sufficiently low in Nubia to cause the formation of a salt crust and abandonment of cultivable land. This might also have happened during the 4200 BP crisis.

The disappearance of most of the Delta branches by the 12th century AD was in all likelihood a result of the Medieval climatic anomaly that led to extreme fluctuations in Nile flood discharge (Hassan 2007) and major change in the course of the Nile in Cairo (see above).

Climate, Riparia and Culture

The history of Egyptian civilization is shaped by human actions in a riparian environment. Following the advent of agriculture, this new mode of subsistence was confronted with wild variations in agricultural yield as a result of unpredictable fluctuations in the volume of Nile flood discharge as well as significant modifications of the floodplain.

The introduction of agriculture into the Nile Valley coincided with the beginning of an aggradational phase associated with the rise of sea level due to post-glacial global warming. A decline in Nile floods by the end of the 4th millennium BC stimulated attempts to unify neighboring polities leading ultimately to the emergence of a united kingdom. Good floods during the Old Kingdom, characterized by royal programs of pyramid building, came to end ca. 4200 years ago contributing to famines, civic disorder, and eventually the demise of centralized governments. Other significant events in the history of the modern Nile river include catastrophically high floods during the Middle Kingdom, a major drop in Nile flood discharge during the Ptolemaic period, and as well known from Arabic historical sources, low floods causing atrocious famines at the end of the 10th and beginning of the 12th century AD.

The Egyptians employed a simple system of natural flood basin irrigation that depended primarily on the summer annual Nile flood discharge. This "natural" system was primarily a means by which people took advantage of the natural setting and the annual recurrence of floods. Levees, raised ridges adjacent to the channel, provided natural protection from low-lying areas further away from the river. However, they were subject to rupture by aggressive floods and required repairs and strengthening to ensure protection from floods. They were also elevation by the addition of mud as an insurance against very high floods. The levees are discontinuous and hence had to be linked by natural embankments. These longitudinal ridges parallel to the Nile also served as roads which remained above water during the season of inundation. Their proximity to water encouraged the growth of trees which were both a source of wood and shade. One of the prominent trees that thrived close to the channel and water ways were sycamore trees which were linked with the goddess Hathor.

The low relief and deceptively flat floodplain was nevertheless critical in the exploitation of the Nile Valley for agriculture. Low floodbasins stored water after the flood recedes and thus have higher moisture content lending them a greater potential for agriculture especially during years of lower Nile floods. To enhance this potentiality, dykes transverse to the direction of river flow were constructed to retard water drainage downslope guided by the gradient of the river (about 1:10,000 to 1:15,000) from south to north. However, this situation runs the risk of water-logging if the floods were excessively high. In addition, arrangements had to be made to ensure that downstream neighbors are not deprived of water if it is hoarded in front to the transverse dykes. Before any state could be involved, local farmers had to develop cooperative measures not only to ward off high floods by collaborating on strengthening levees, but also in the construction of transverse dykes and water gates within an elaborate system of timing the closure of these gates and the release of water in a timely fashion. These local initiatives led to a regional system of floodwater management in a chain of floodbasins that extended over more than a thousand kilometer.

There was also a need for drains to return excess floodwater to the Nile River, and to carry back water seepage after the flood.

Higher parts of the floodplain consisting mostly of the remnants of old levees accentuated by the ruins of older settlements were attractive to human habitation because it provided protection from floods. Continuous use of such localities for long time periods led to the emergence of high mounds (*tells*) of anthropogenic origin. Our investigations reveal that at times some of these settlements were abandoned and subsequently buried by Nile silt.

In the higher parts of the floodplain and when floods were low, it was advantageous to dig wells to secure water from the shallow groundwater fed by seepage from the Nile.

In places, the low areas at the outer edge of the floodplain wetlands and backswamps were fed by seepage from Nile floods. The water table oscillated up and down tracking the annual variation from high Nile water level during the summer to the lower level during the season of drought.

It was also advantageous to divert floodwater to side channels from which feeder canals might be extended to higher grounds or to large tracts of the floodplain that were beyond the reach of the summer floods.

The floodplain was extremely dynamic in response both to natural variations in Nile floods and human interventions. In addition to the above mentioned modifications of the floodplain, the continued build-up of the floodplain added another long-term factor that required rethinking of settlement strategies, the location of harbors, and irrigation schemes. In some instances, the deepening of canals was required. Plantations supplied with water from artificial canals were also known (Eyre 1994). Surprisingly, water lifting devices such as the Shaduf were not used until the New Kingdom, suggesting that until then there was plenty of land relative to the small Egyptian population that rarely exceeded two million people.

Responding to the vagaries of frequent and occasionally extreme fluctuations in floodwater discharge due to climatic change and variations in the hydrographic regime of the Nile River have led to pronounced shifts in the course of the Nile (Hilier *et al*. 2006).

The history of Egyptian civilization was accordingly bound to the effects of climate change on rainfall in Ethiopia and Equatorial Africa – the sources of the Main Nile. However, the lineaments and particularities of Egyptian civilization are primarily a result of successive generations of Egyptians who perceived and responded to the changes in the flood regime and the riparian landscape. The responses were in turn, influenced by an evolving socio-religio-political system that is distinctly Egyptian.

II. Climatic Change and Origins of Egyptian Civilization

The period from 14,500 to 13,000 BP in North Africa and Southwest Asia was particularly wet and warm. However, the "good" life under centuries of relatively lush vegetation and abundant resources came to an abrupt end with the onset of cold climatic conditions known as the Younger Dryas which lasted from 13,000 to 11,600 BP, a cold interval of 1400 years, which in turn led to strategic responses and innovations (Hassan 2008). This period, however, also came to an abrupt end with the return of warmer and wetter conditions. The appearance of sedentary farming communities in the Levantine corridor during the 10th millennium BP coincided with the practice of cattle keeping and intensive utilization of sorghum in Eastern Sahara (Hassan 2002). Both developments were synchronous with fairly stable wet conditions that lasted with minor interruptions until the transition to cold climate ca. 8200 cal BP with inclement weather conditions until ca. 7800 cal BP (encompassing the 8200 cal BP cold events). This event hastened the collapse of Pre-Pottery Neolithic communities in the Levant and a dispersal of populations from the Levant into the Eastern Desert and the Egyptian Sahara, as well as the dispersal of African cattle westwards into central Sahara (Hassan 2002).

A millennium afterwards, apparently in response to a severe abrupt climatic event ca. 6900-6800 cal BP, agriculture and cattle kept finding their way into the Nile Valley. This climatic event is marked by the disappearance of desert lakes and the onset of a freezing cold desert climate, which are attested at Farafra Oasis at that time (Hassan 2001). It is precisely at that time that agriculture is attested at Merimde Beni Salama in the East Delta as well. The agricultural package consisted of domesticated sheep/goats, cattle, pigs and cultivated cereals and pulses (Hassan, 1988; Wetterstrom, 1998).

For perhaps as long as a millennium from 6800 to 5800 BP, in the Nile Valley at Merimde and farther south in the Faiyum depression, the Nile dwellers adopted a mélange of communities with various subsistence strategies dominated by hunting, fishing, or herding. By 5800 BP, settled farming communities appear still farther south in the Nagada region. Within a century, food production in the Nile Valley was practiced as far north as Edfu.

This transition to a predominantly agrarian mode of subsistence by 5800 cal BP, marked the emergence of the economic foundation of the Egyptian civilization. Within the relatively short span from 5800 to 5300 cal BP, Egyptian farming communities made a rapid transition to a state society. A political transformation was set in motion as local communities merged into regional polities that were eventually fused to form a unified pan-Egyptian state. The process of unification appears to have been stimulated by yet another episode of climatic change causing a reduction in Nile floods ca. 5500 BP. Although the political transformation appears to have begun before that climatic event, the stress of low Nile floods and associated reduction and severe fluctuations in agricultural yield, as happened during the 18th century AD, seem to have hastened a process of territorial annexation and federation.

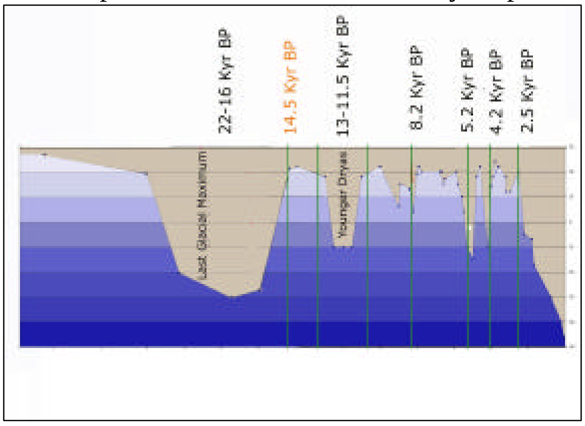

Fig. 2. Diagram showing the variations in the level of Qarun Lake, Faiyum, relative to sea level. The levels are primarily due to changes in the volume of Nile flood discharge. Hydraulic control of Nile.

All along, the enlargement of collectively managed polities was advantageous as a buffer against crop failures, even if small managerial elite extracted from the agrarian products more than ordinary farmers did. Boats taking advantage of the Nile facilitated the integration of Nile communities and enabled food transport as a means of inter-group sharing. Gifts, donations, and other forms of food transfer from farmers to managers marked a shift in political organization. A segment of the population was being transformed into social elite responsible for the maintenance of alliances, resolving disputes, overseeing economic integration, defending communities from raiders, and organizing social events and religious rituals. One of the main tenets of a new religio-social development was the elaboration of funerary rituals and a metaphysical ideology revolving around a cult of life after death. The nascent elite supported "cottage" crafts and industries that provided for the display of status among the living and the dead. They sought objects that were rare, exotic, or finely made which were eventually to set them apart from and above the rest. Fancy pots, exquisitely carved stone vessels and bowls, ivory bracelets, cosmetic palettes, wild animal skins, gold and copper items among others were not only symbols of wealth, they were also markers and elements of elaborate rituals that helped both to bind communities together but also to buttress social hierarchy.

The Old Kingdom - Pyramid Building and Political Centralization

The first kings of Egypt of the unified Egyptian state were perceived as human beings descended from the gods. Their divine link not only legitimated their sovereignty, but also ensured that in the eyes of the chiefs of the provinces of Egypt they fulfilled their duties as mediators between the people and the gods, that they commanded Justice and kept the rituals that prevented the world from reverting to Chaos. The first kings were descended from a long line of chiefs and princes who ruled various districts in Egypt. These first rulers later developed into kings who ruled large provinces before the emergence of a nation that extended from Nubia to the frontiers of the Delta ruled by a single sovereign monarch (Kemp 2006)

Within a span of three hundred years from the coronation of the first king of the Egyptian nation, the kings of the fourth dynasty of the period referred to as the "Old Kingdom" were erecting monumental pyramids that proclaimed both the prosperity of the nation and the monarch's ability to mobilize a workforce from all parts of Egypt.

Concrete evidence for a concern with Nile flood heights is revealed by the Palermo Stone slab which goes back to the reign of King Djer (ca. 3200-3150 BC). The slab gives measurements of Nile flood heights in association with accounts of events during each year of reign of several named early kings. The height is indicated in cubits, spans, palms and fingers (Wilkinson 2000). Concern with Nile flood variations thus generated a system of standardized measurements and scientific observations before 5200 BP.

A set of 91 annual measurements clearly indicates that Nile floods were wild during the reign of Den with a range from just over a meter above the floodplain to a record high of 4.25 m. This would have been a devastating deluge, measuring more than 1.45 m above the average, reminiscent of the extremely high floods referred to as deluge in AD 1088, 1148-1150, 1183/4 which were about a meter higher than the average and that destroyed houses, property and drowned orchards (Zakry .1926).

Variability during the period from the 3rd to the 5th Dynasty ranged from approximately 1 to 3 m with one dramatically low flood of just 52 cm in the year 14 of King Ninetjer.

Preliminary results from ongoing geoarchaeological investigations in the Faiyum region (by R. Flower, A. Hemdan, Y. Yasuda and the writer), coupled with earlier results (Hassan 1986) lead me to tentatively conclude that the 5500 low Nile event was followed by a slight increase in Nile flood discharge during the 1st dynasty with perhaps a slight reduction of the volume of floods during the 2nd dynasty which was followed by a peak during the 3rd and 4th dynasties. The transition from the 4th to the 5th dynasty might have been linked to a drop in a Nile flood followed in turn by higher floods during the 6th dynasty.

The desert hills just north of Qarun lake in the Faiyum were the source of black basalt quarried in Ancient Egypt during the Old and Middle Kingdom to adorn temples along with the granite fetched from Aswan. The quay at 20 m above sea level where the boats docked to transport the quarried blocks is still visible with potsherds that date it to the 5th to 6th Dynasty (Hassan and Hamdan 2007).

This latter dynasty came to an end ca. 4200 BP as a result of catastrophic reduction in Nile floods caused by global climate change (O'Connor 1974, Hassan 1994, Seidelmayer 2000). The ensuing famines led to civic disorder and the dissolution of centralized government. Although normal floods returned within a few decades, the country remained disunited with regional political contentions for two centuries.

Water shortages and the Collapse of the Old Kingdom

Recent investigation in the Faiyum depression reveal that early Holocene deep lake sediments are separated from the younger lake sediments with a hiatus which marks the interruption of Nile flood discharge between the Old and the Middle Kingdom (ca. 4200 BP). This discontinuity is also evident from the geoarchaeological investigation currently ongoing in the Memphite region by the writer, R. Flower, and M. A. Hamdan.

The discontinuity was also revealed in a recent study of the Delta at ca. 4150 BP (Stanely *et al.* 2003). A distinctly thin layer of reddish-brown silt dating to 4200-4000 BP indicates that the delta floodplain dried up for a long period of time allowing reddish-brown oxides to accumulate at the surface.

The extremely low floods at the time between 4200 and 4150 BP are correlated with markedly low levels in Ethiopia and Equatorial Africa and a Sahel drought caused by a global climatic event (Hassan 2008). The drop in Nile floods was rapid and traumatic.

During a turbulent period of 150 years, Egypt was plunged into "chaos" and social disorder. National unity disintegrated, and kings and dynasties were short-lived so that it was said in later times, that in one brief dynasty (the seventh) there were seventy kings in seventy days (Grimal 1995)

During the Old Kingdom, the country was ruled by a divine king supported by his court and provincial rulers. The system was predicated upon investing in monumental architecture as an expression of a cosmogonic royal ideology. The sustainability of the monarchy depended on the flow of revenues from the provinces to the royal household to support the court and monument building activities.

The last king(s) of the Old Kingdom after Pepy II, destitute and powerless, could no longer govern the country or provide for his household; not to mention provide for the lavish royal funerary projects that legitimized his rule. Faith in the divinity of the king, and at least his ability to intervene with the gods to restore order and prosperity, was eroded. Within a couple of generations and with the return of normal floods, local polities began to emerge, and after close to 180 years of local alliances, pacts, and armed conflicts, rulers of a polity in Thebes succeeded in overtaking the whole country, setting the stage for the spectacular water works of the Middle Kingdom.

Middle Kingdom Hydraulic Project

After an initial phase of anarchy, order was restored by two polities that succeeded in re-establishing monarchical control. One was in the south centered around Thebes, while the other was farther north in the vicinity of the Faiyum. A prolonged clash between the two ended when the Theban king, Mentuhotepe II (2040-2010 BC), subdued his northern foes. His successors included Senusert II (1897-1878) and his grandson Amenemhet III (1844-1797 BC) had the foresight to embark on Egypt's, and the world's, first ambitious hydraulic project.

The low floods and desert sand of the great drought had choked a minor branch of the Nile that supplied the Faiyum depression with water. The floods were previously sufficiently high to spill over into the depression creating a huge lake. When the inlet was locked, the lake shrank and practically disappeared.

Senusert II decided to reconnect the depression with the Nile, but to control the water inflow in order to keep water level in the lake sufficiently low so that he may reclaim the lake bottom as a royal estate. He built a dyke at el-Lahun and re-established connection with the Nile allowing freshwater to re-enter the depression. The king himself oversaw the project and the king's pyramid and royal necropolis, the holiest place of kingship, were located at El-Lahun at the entrance to the Faiyum. The first organized town discovered in Egypt nearby at Kahun belongs to the organized community of workers who were engaged in the great Faiyum project. This industrial village provided papyri that provide a wealth of information that range from mathematical calculations to gynaecological treatise. Senusert II was later immortalized in the works of classical writers as "Sesostris" (Hassan and Hamdan 2007).

Before the kings of the Middle Kingdom began their unprecedented large hydraulic projects, kings of the First Intermediate Period realized that sustainable social order can not be sustained merely by referring to the divine descent of the king, especially at a time when scepticism prevailed. They proclaimed instead that the king was sent by the gods to help the weak and feed the hungry and valorized the Justice and good deeds as represented by the goddess *Maat* (Assmann 2002).

The covenant between God, king, and people during the Middle Kingdom included reference to Nile water and good order (Assmann 2002).

Ptolemaic-Roman Hydraulic Works

It seems that floods were in general bountiful until the 19th dynasty (1550-1200 BC) of the New Kingdom. While this might explain Egypt's prosperity at that time, there is no indication that the political problems indicated by a rapid succession of kings during the end of the Middle Kingdom (some seventy rulers from 1795 to 1650 BC) were due to failure of Nile floods (Said 1993).

Bountiful floods, however, were interrupted during the 20th and 21st dynasties (1186-1069 AD) as indicated by the degradation of the floodplain in Nubia and salinization of agricultural soil. It is also assumed that low floods at that time were responsible for the siltation of the Pelusaic Nile branch in the East Delta (see above). No sufficient research has been achieved to link the political problems at that time to the reduction of Nile flood discharge. However, it is likely that it had contributed to some riots, inflation in the price of grain, and enhanced protection of the royal grain silos.

Subsequently, records of Nile flood levels at Karnak indicate a return to normal floods with occasional very high floods at the time of Taharqa (690-664 BC).

During this long period from the Middle Kingdom (2055-1650 BC) to the Late Period (747-332 BC) no information is available of any further hydraulic water works (Said 1993). The hydraulic works at the Faiyum were in disrepair and the land once reclaimed by Middle Kings was deep under water.

It was not until the Ptolemaic period (under Ptolemy II Philadelphos, 283-247 BC), about a millennium and a half later, that the Faiyum region became the ground of another major phase of land reclamation and waterworks. According to Garbrecht (1996), the dam might have been constructed by Ptolemy I (305-283 BC).

Access to the depression was closed by a dam at El-Lahun, which led to a dramatic decrease in the size of the lake and a corresponding increase in cultivable land. Lake level fell to – 5 m under Ptolemy II, - 7 m in the 2nd century AD, to – 17 m in the 3rd century AD, – 30 m. There are also indications that another dam between Itsa and Shedmu (1st-2nd century AD) was erected to create a reservoir [for the storage of irrigation water] in the southeast of the depression in Roman times. The remains of the dam in the southeast Faiyum at Shedmu and Sheikh Abu El-Nur clearly reveal repairs by the Romans (Garbrecht 1996). The dam was repeatedly breached by floods to be repaired in successive historical periods (3rd century, 7th century, 12th century, and the second half of the 18th century).

The Ptolemies also dug numerous canals in the Delta, and ensured that a canal supplied Alexandria with water from the Canopic branch after a later migration of this Nile branch eastwards during the 6th century BC (Blouin 2009, 475 with references). There is also convincing evidence from the descriptions by Herodotus, Ptolemy I, and Strabo that the Delta branches were experiencing pronounced shifts (see above) which would have required intensive intervention to maintain existing irrigation systems.

Water shortages leading to a famine at ca. 2200 BP is indicated by a stela on the Seheil Island, Aswan, which recalls a famine at the time of Djoser (Barguet 1953). This event may be related to the transition from colder to warmer climate ca. 2300 BP in the Mediterranean region (Ortolani and Pagliuca 2009, 58). The shift to colder climate later at ca. 350 or 300 AD in the Mediterranean could have been matched with a reduction in Nile flood discharge (see Hassan 1981 re climatic correlation) which would have aggravated the worsening political situation in Rome at that time. Rome depended on Egypt for a considerable part of its wheat supply (Bowman *et al.* 2005). Low floods would have reduced agricultural productivity in Egypt and hence the volume of wheat that could be shipped to Rome.

The importance of irrigation systems in Egypt to the Romans is evident from the employment of Roman troops as soon as Egypt was annexed by Augustus to repair the canals which had lapsed in ruinous state under the later Ptolemies (Boak 1926). Attention to the Faiyum continued as indicated by a rededication of a temple dedicated to the crocodile titulary gods of the Faiyum to Nero. Under Vespasian, a new aqueduct was added to the temple area. Prosperous colonies of Romans thrived in the Faiyum until the first quarter of the third century as indicated at Karanis and by the breakdown of the irrigation system. This may be related to a reduction of Nile floods. However, repairs of the irrigation system were attempted by emperor Probus during his stay in Egypt (280-281 AD) who like Augustus employed the Roman troops to dig canals and construct dykes. Nevertheless as Boak (1926, 363) remarks, "The oppressive system of taxation, the spread of graft and inefficiency among all ranks of the imperial bureaucracy, the civil disturbances in Egypt caused by religious strife, and weakening of the central imperial authority all combined to bring about a decline in the efficient operation of the irrigation system and to make agriculture a less and less profitable occupation." Supply of water by high level canals ceased in many settlements in the Faiyum.

One of the significant achievements during the Roman period was the restoration of the earlier Tumeilat canal (see above) under Trajan (98-117 AD). The canal was at least 8 m deep and involved excavation of older parts of the canal and its extension over a distance of 205 km. Hadrian (117-138 AD) invested in its rebuilding and upkeep as well.

After the Romans

Restoration of the Lahun dam under the Romans was undertaken under the Mameluke rulers Al-Zahir Baybars, Al-Salih Nassr el-Din, Al-Ashraf Barsbay, and Al-Ghuri in 1260-1277, 1421, 1439, 1512 AD, respectively. Annual records of variations in Nile flood levels provide sufficient information on that period. Records were kept from the 7th century AD to the middle of the 20th century from the Roda Nilometer near Cairo (see above). The record reveals episodes of alternating high and low Nile floods (Hassan 1981). Numerous famines from the 10th to the 13th century AD were associated with very low Nile floods.

During this period, the writings of medieval historians reveal that severe famines were experienced at 1025-1074 AD (Maqrizi 1854; Sawy 1988; Zakry 1926; Allouche 1994). Famines caused by catastrophically low Nile floods led to the diminution of centralized authority (40 viziers in succession in nine years after 1058). The power of the "king" (Caliph) was undermined. Viziers and high government officials aggrandized their power at his expense. The episode was followed by the rise of military rulers. Princes and country "barons" were replaced with "new rich" of high government officials and soldiers. As during the First Intermediate Period when weakened Egypt was attacked by raiders from Southwest Asia (the so-called "Asiatics", Egypt was raided by Bedouins, as well as by the rulers of Syria. Egypt lost Sicily and Cyprus. At that time the Crusaders captured Antioch, Acre and Jerusalem. They also proceeded to attack Tanis in Egypt (Sawy 1988, 75-131)

Barely 125 years later, Egypt was hit by another catastrophic drought in 1201-1202 AD. It was witnessed by *Al-Baghdadi* (1964, 223 ff) who reported that the famine destroyed all the resources of life and means of subsistence forcing the poor to eat carrion, corpses, dogs, and the filth of animals. After the famine went for a long time, he reported that people began to eat children. Murder and assassination were committed in various provinces. Women offered themselves and their children for sale. A hen was sold for 500 dinars; while a girl was offered for only one dinar. Over 111,000 persons died in a matter of 22 months (not including those who were eaten or died outside Cairo and on the road to Damascus). It is noteworthy that villagers emigrated to Syria, the Maghreb and the Hijaz (Arabia).

This period coincided with the Medieval Climatic Anomaly in Europe and was characterized by a high frequency of exceptionally low Nile floods alternating with abnormally high floods (Hassan 2007).

Although no major hydraulic projects were undertaken from the 7th to the 19th century, numerous urban water works included the digging of water supply canals, water cisterns, embankments and aqueducts. One of the most notable water establishments of this period was the *Sebil*, a charitable foundation dedicated to fetching water from the Nile to water dispensaries for use of passersby in the streets of Cairo. They were often joined with a school for children – *Kuttab.*

Summary and Concluding Remarks

Climatic changes on decadal and millennial scales were influential in shaping the course of the Egyptian civilization on its banks. To begin with, it was a global climatic event ca. 8200 and unstable climatic conditions from that time until 6900 BP that induced the introduction of the cultivation of wheat, barley and pulses in the Nile Valley and the Delta. Herds of goats and sheep from Asian provenance were also introduced at the same time. Subsequently, food shortages, initially related to water scarcities in part due to the inter-annual variability in flood discharge, led to the emergence of regional cooperative polities that eventually led to the rise of an Egyptian state society. It also appears that a climatic event ca. 5500 years ago may have hastened the pace of unification which occurred ca. 5200 years ago. The logic here is that as more people entered into cooperative food exchange and water management practices, the greater the yield for each party. However, as the number of parties increases, formal mechanisms for coordinating efforts and food exchanges come into play. This eventually paves the way to the emergence of leaders and increasing social complexity.

The development of social complexity was linked to the increase in the size of population and number of polities as well as the growing number of functionaries involved in food exchanges, conflict resolution, social events and defence. The emerging elite gathered sufficient power, prestige, and wealth at a certain point to make it possible to establish formal governmental and religious institutions marking the rise of the state. Through taxes, tributes, and revenues from a large agrarian population, the elite were able to garner by different means sufficient funds to finance a bureaucratic system and elaborate funerary and religious monuments that legitimized the rule of a supreme king as a god-given gift to humanity through a theo-cosmogonic ideology and pervasive and sophisticated rituals enacted by a cadre of priests. The royal court, administrative functionaries and scribes, priests, country noblemen and governors lived comparatively well from the revenues they were instrumental in exacting from the peasantry.

The sustainability of Egyptian civilization with its extravagant monumental materiality depended on the flow of enough food resources from the countryside to the royal storerooms. An elaborate tax extraction and transport system was essential for the legitimization and continuity of kingship. However, at times of severe famines during unanticipated catastrophic centennial or millennial droughts, centralized government did not fare well, as happened during the First Intermediate Period (4200 BP) and under the Mamelukes from the 10^{th} to the 13^{th} century AD.

It is indeed remarkable that the national hydraulic and water projects of the Middle Kingdom were not to last for very long. Overwhelmed by extraordinary high floods, dams and embankments were swept away. For more than a millennium, no projects equal to those of the Middle Kingdom kings were attempted. However, the memory of their achievements was no less legendary when Herodotus visited Egypt ca. 450 BC. Aware of such great achievement and hopeful to maximize the agrarian wealth of Egypt, the Ptolemies embarked on a revival of Middle Kingdom hydraulic engineering feats. Repeatedly, dams and embankments were battered by unanticipated extraordinary high floods. They were continually repaired by the Romans and again by some rulers after the Arab conquest of Egypt. However, except for the Faiyum province, the role of centralized government was minimal. Accordingly, the population remained fairly stationary around 2-3 million with occasional peaks. Indeed, the waterworks of the Ptolemies and the use of water lifting devices like the shaduf and the waterwheel may have allowed population to increase, but under the oppressive taxation by the Romans and later the Mamelukes and the Ottomans, the population was diminished to 2.5 million level until the 19^{th} century when Mohamed Ali and subsequently Khedive Ismail began to introduce modern irrigation systems to Egypt.

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