

# GEOMORPHOLOGICAL DEVELOPMENT OF THE MEMPHITE FLOODPLAIN OVER THE PAST 6,000 YEARS

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## Abstract

The Memphite ruin mounds around the modern town of Mit Rahina in northern Egypt form a part of a region around which the capital of Egypt migrated through time. Some of these migrations were the responses to landscape changes and the area is one that is subject to a number of types of landscape change. The delta and river systems as well as the deserts that surround Memphis changed profoundly as global temperatures rose at the end of the last ice age. This paper summarises the main landscape processes that affected the area and proposes a model for river migration and delta-head change in the Memphite floodplain.

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**Key words:** Memphis, floodplain, river migration, delta head, climate change

## INTRODUCTION

The city of Memphis was famed in antiquity as the Capital of Egypt and was renowned for its active scribal school. The large ruin mound of Mit Rahina is part of Egypt's Capital Zone, which extends from Cairo and Giza in the north to as far south as Maidum and the entrance to the Faiyum. The whole of this stretch is studded with pyramids and contains the locations of many palaces and cities. In this paper I consider the fortunes of Memphis as part of this capital zone and examine how a number of environment factors have affected the area and may have impacted upon the city as its fortunes waxed and waned (Fig 1).

## LOCATION AND LANDSCAPE

From a geographical perspective, Memphis is located at the point where the desert cliffs of the Nile Valley broaden out and the delta starts to form, an area often described as the delta head. This location, at a landscape tipping point, means there is a complex interplay of geomorphological processes, mostly arising from climate changes that act upon the site. These include:

- I) Sea-level change swamping the deltaic coast and the Nile hinterland
- II) Migration of the delta-head in response to sea-level changes
- III) Lateral migration of the river around the site
- IV) Vertical aggradation of the floodplain
- V) Incursions of wadi sand into the Nile valley in response to changing rainfall and erosion
- VI) Aeolian sand-flux into the valley and the river around Memphis.

Much is known about the approximate geometry of each of these processes and the timescales in which each was active. However reference to detailed archaeological studies of

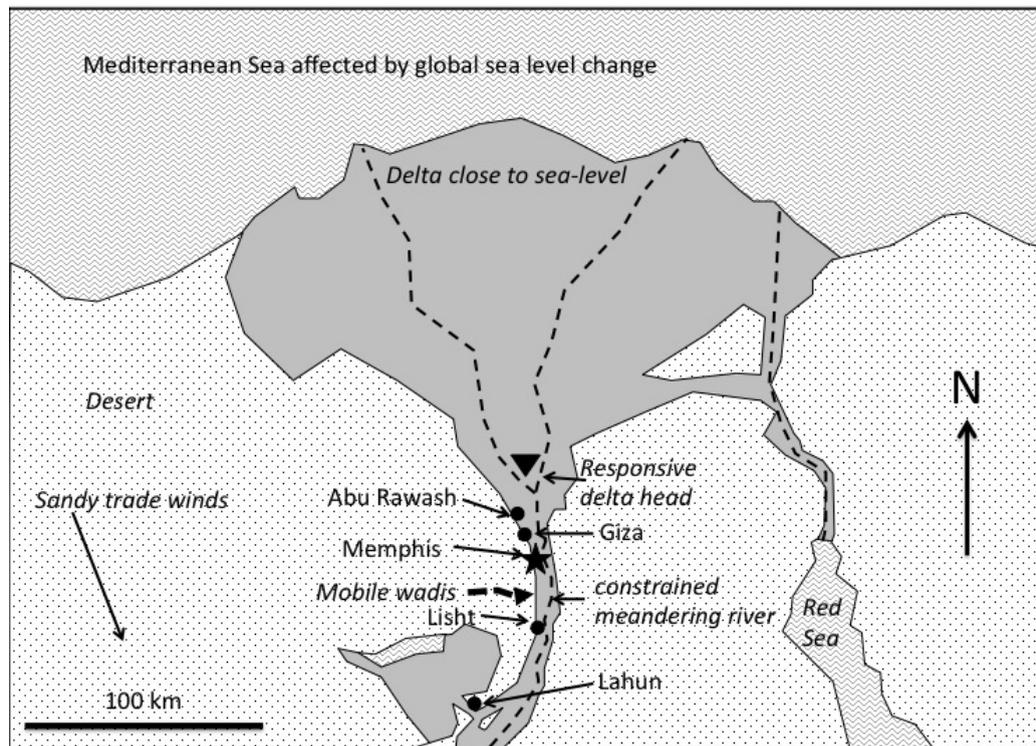
key localities within the ancient capital zone of Egypt are required to integrate the effects and assess their influence on the development of the site (Fig. 2).

## HOLOCENE CLIMATE CHANGE AS A DRIVER OF EGYPTIAN LANDSCAPE CHANGE

Combined studies of climate change proxies (Robert Rohde 2006) suggest that the Holocene period has been characterised by a sharp rise in temperature from the last glacial maximum that peaked around 8,000 years ago during the wet phase in Egypt, designated the Saharan Neolithic. Following this peak there was a gradually oscillating decline in temperature until around 300 years ago when industrialisation caused temperatures to rise again. These global temperature changes generated two main effects on the Memphite area. The first was an increase in marshiness resulting from sea-level change in the Mediterranean coupled with adaptation of the distributary system to accommodate an elevation in base-level of the river (Pennington et al paper in prep). The other effect of temperature change was humidification of the Saharan region as the equatorial belt widened and summer monsoon rains fell over a wider part of what is now the Sahara desert (Kropelin et al. 2008, Rodrigues et al. 2000, Stanley and Warne 1993 & 1994, Kuper and Kropelin 2006) with a subsequent decay of habitat as the rains retreated south. The equatorial monsoon in Ethiopia also affected the supply of water in the Blue Nile and hence the intensity and sediment content of the Nile Flood (Woodward et al. 2007).

## SEA-LEVEL CHANGE SWAMPING THE DELTAIC COAST AND THE NILE HINTERLAND

Global sea levels compiled from a number of sources



**Fig. 1.** Location map of the Capital zone showing the main locations including Abu Rawash, Giza, Memphis, Lisht and Lahun. Also indicated are the processes of landscape and climate change that have affected the development of the Memphite floodplain; sea-level change with attendant swamping of the delta and displacement of the delta head, aridification of the Saharan region with resultant wadi wash-outs and later trade winds with sand flux coupled with migration of the Nile channels.

(Rohde 2006, Fairbanks 1989) show a steep rise as ice-caps melted after the end of the last glacial maximum. This continued until around 6,000 years ago and was then followed by a period of very gentle rises in sea-level until present time. The coastal areas of deltas across the world were inundated (Stanley and Warne 1994), as was the Egyptian Delta (Stanley and Warne 1998). While there is some local tectonic activity in the delta and along the scarps that form the edge of the Nile Valley, these changes are relatively slow (around 1 m/millennium) when compared with the rapid sea-level rise during the early Holocene of some tens of metres per millennium. Stanley and Warne's work (1994) shows that the eastern delta subsided relative to the western delta and that, as a result of this tectonic activity, marine conditions persisted in the north-eastern delta for longer than in the west.

While marine incursion did not reach as far south as Memphis, fresh water in the Nile was retained in the valley in response to the elevated sea-level making the area more marshy and increasing the number of channels in the floodplain. Habitation seems to have been restricted to the Pleistocene sand 'Gezirehs' (Tristant 2004) remaining from the previous high stand and to the flanks of the Nile Valley (Jeffreys and Tavares 1994) where the wadi mouths and low desert edge provided a refuge from the waters. After the marine incursion, new sediment started to rebuild the delta and the number of distributaries gradually fell.

Intensive studies of the Rhine delta in the Netherlands, involving some 250,000 boreholes (Berendsen, 2007, Toonen, 2011), have shown that in an area of low gradient such as

a river floodplain, a sea level increase of tens of metres can cause water to travel a hundred or more kilometres inland. The fresh-water marshes that are created inland of the estuarine and coastal zone are a rich habitat and have a high nutrient availability. Thus at the same time that the Saharan region was interspersed with lakes and playa basins (Drake and Bristow 2006, Kuper and Kropelin 2006) there was also a rich habitat in the delta region. High levels of sediment accumulation in the area mean that much of this prehistoric inhabitation is cryptic but a few sites are known including Sais (Wilson 2006), and several from the north-eastern delta that include Minshat Abou Omar (Tristant in preparation IFAO).

In Egypt, the environment of diverse habitat with many interconnecting channels started to deteriorate from around 2000 BCE with the marshes becoming marginalised towards the coast. At the same time, the many anastomosing channels of the delta started to be replaced by more discrete meandering channels that divided from an upstream focus, the delta head. At around this time (Jeffreys and Tavares 1994) there was a movement of settlements from the edges of the Nile Valley to the levees of the meandering Nile channel in the region of Memphis. Borehole work by the Survey of Memphis seems to suggest that there were two channels in the region of Memphis at this time, of which the western channel persisted until the Middle Kingdom (Bunbury and Jeffreys 2011). However, constrained by the Nile Valley that narrows to around 7 km at this point, the two channels were strategically close together and the Capital zone starts to focus on Memphis.

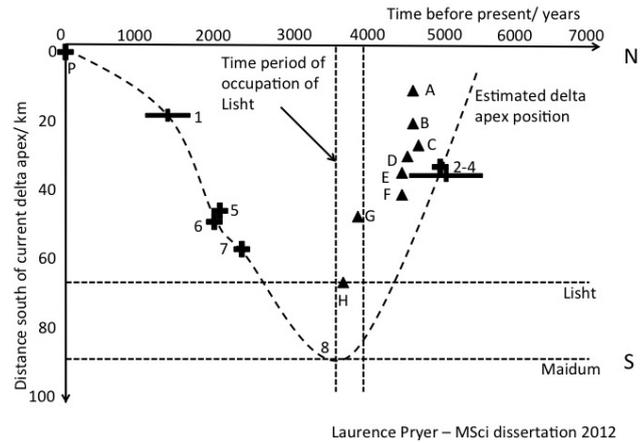
**MIGRATION OF THE DELTA-HEAD IN RESPONSE TO SEA-LEVEL CHANGES**

A distributary system is initiated as the base of a river channel reaches sea level when the channel divides into two smaller and shallower channels. These can continue to flow seawards until their bases reach sea-level and they, in turn, bifurcate. Thus the location of the delta head in the Nile is an interplay between the amount of water in the river which determines the size and depth of the channel, and sea-level. Factors causing migration of the delta-head inland include sea-level rise and increased water in the river, while factors that push the delta head sea-wards include aggradation of the floodplain, reduction in river water and sea-level fall.

Observations of floodplain elevation suggest a rapid rise between the Old and the New Kingdom at Dahshur, which we expect to be reflected in a migration of the delta head seawards. Records of the location of the delta head from literature (Bunbury et al in preparation BMSAES) can be combined with observations of Parcak (BBC1 research project) that the village of Lisht may have been located at the contemporary delta head, thus establishing a pattern of migration for this landscape feature during the development of Memphis (Fig. 3). We seem to see two episodes during which the delta head was located at Memphis, broadly corresponding to the peaks of known activity in the area; the OK necropolis of Saqqara coupled with the New Kingdom development of Memphis.

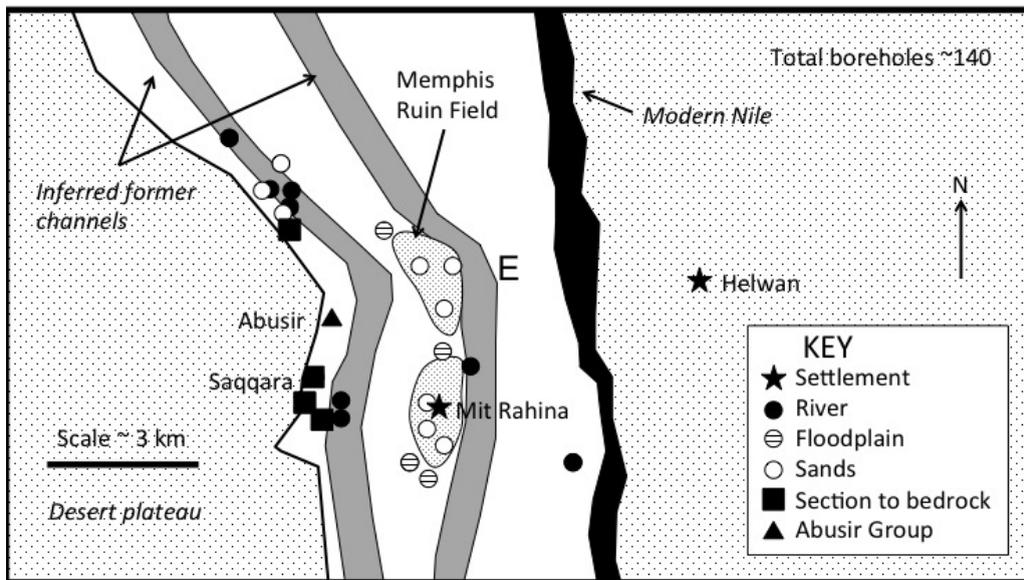
**LATERAL MIGRATION OF THE RIVER AROUND THE SITE**

Lateral migration of the meandering Nile within the river floodplain was described by Butzer (1976), observed at



**Fig. 2.** Delta head migration diagram with delta head locations taken from the work of 1 – Jones 1997, 2 – Diodorus via Rennel 1830, 3 – Lutley 2007 and Bunbury et al 2009, 4 – Jeffreys 1985 and 5 – Pliny via Rennel 1830.

Memphis (Jeffreys 1985) and studied further at Karnak (Bunbury, Graham and Hunter 2008) and in the Giza area (Bunbury and Lutley 2008). Lateral migration of river bends, outwards and downwards across the floodplain, have a mean rate in Egypt of around 2 km/ millennium, though lateral rates may reach up to 9 km/millennium in some areas and are frequently characterised by island production and capture (Hillier et al. 2006). The Survey of Memphis has bored around 150 cores amounting to some 2 km of sediment in a variety of locations across the mounds and in the surrounding floodplain (figure 4). Facies analysis of these cores has suggested that in the Memphis area there has been broadly eastwards migration of the Nile across the floodplain during the past 6,000 years.



**Fig. 3.** Summary of cores augered by Survey of Memphis 1983-2013 showing the locations of the main settlements at Helwan and Mit Rahina within the context of the modern Nile and two former locations of the river channel or channels. The Abusir group, marked with a triangle, contain cores that have mixed facies that are indicative of an Early Dynastic settlement on a river levee that was subsequently overwhelmed by sand.

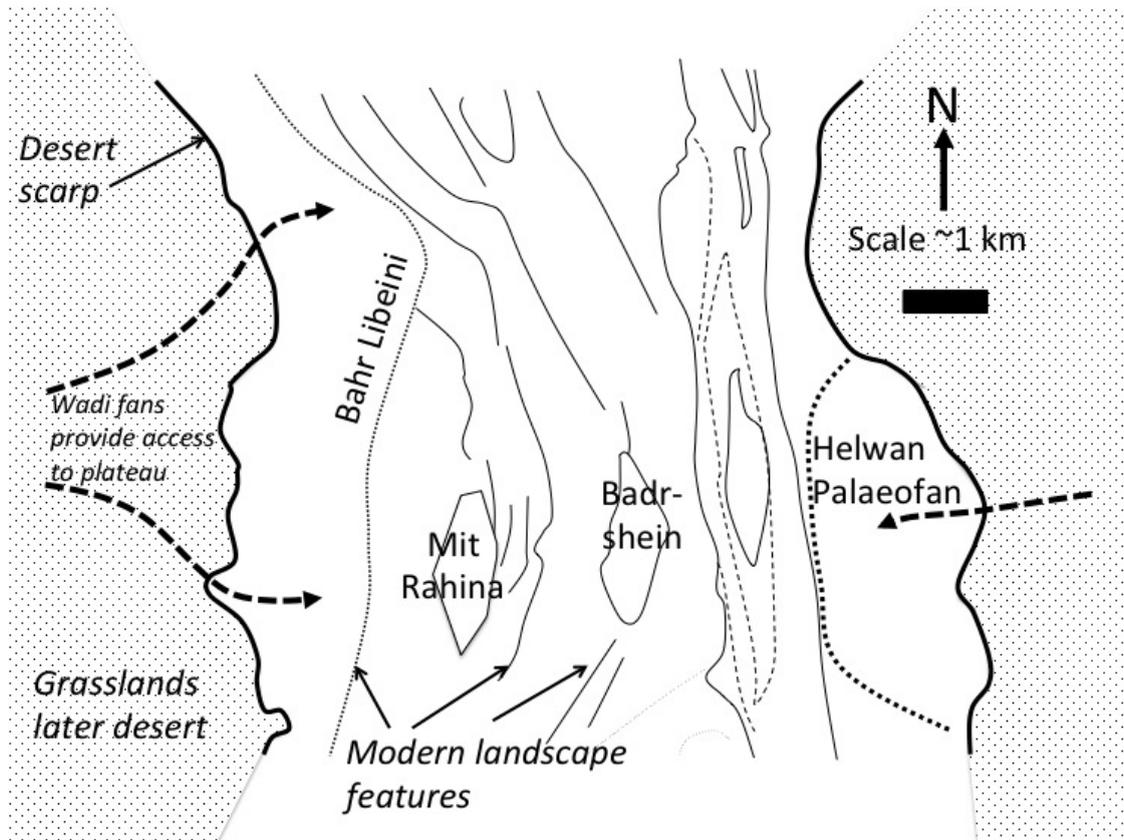


Fig. 4. Summary of landscape features in the area of Mit Rahina (location of Memphis Ruin Mounds) and across the Memphite floodplain.

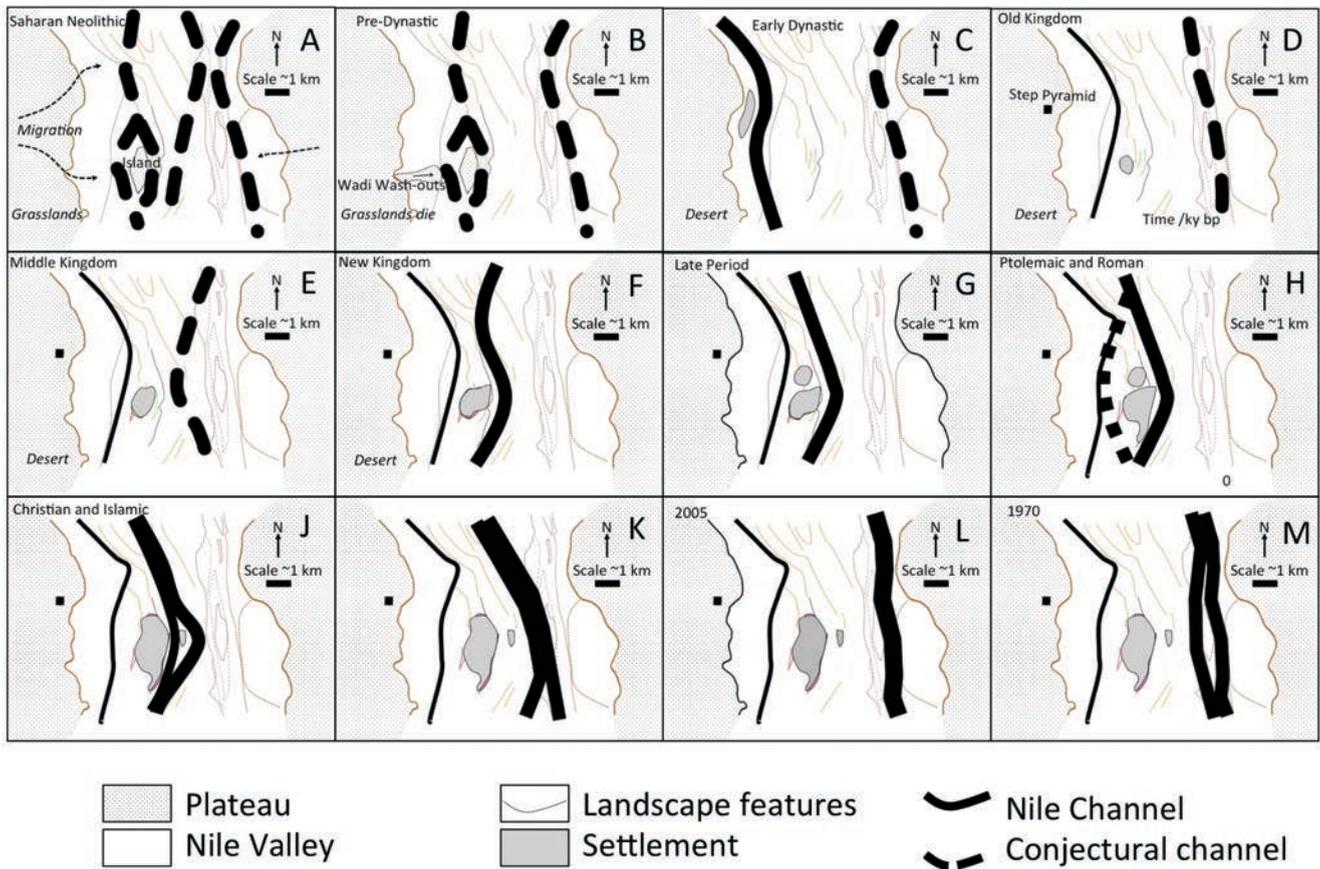
#### VERTICAL AGGRADATION OF THE FLOODPLAIN

The earliest work at Memphis, by Joseph Hekekyan in the 1850s (Jeffreys 2010), was focussed on determining the rate of flood-plain silt accumulation in order to calculate the time since the recorded biblical flood. During his excavations Hekekyan made comprehensive notes and detailed observations of the sediments and monuments he encountered, making him arguably the first geo-archaeologist of Egypt. Hekekyan was unable to determine the time since the flood but observations of sediment accumulation rates (Borchardt 1907, Jeffreys and Tavares 1994, Ball 1939 and Hassan 1997) give mean values around 1 m/millennium. This is a mean rate so there are areas such as river levees and settlement mounds where rates exceed this as well as areas like distal parts of the river plain where the sedimentation rate is lower. Comparison of the typical rate of vertical aggradation of the floodplain with the typical rates for lateral migration of the river channel, suggest that the latter is more rapid than the former (cf 1 m/millennium rise vs 2 km/millennium migration). None-the-less results from the late Old Kingdom at Dahshur (Alexanian et al. 2011) suggest that floodplain rise was faster than that since the New Kingdom, which may be a product of an asymptotic approach to the base level of the river and a large influx of sandy sediment to the Nile Valley during the Late Old Kingdom and Middle Kingdom (Alexanian et al. 2011). This is considered at greater length below.

#### INCURSIONS OF WADI SAND INTO THE NILE VALLEY IN RESPONSE TO RAINFALL AND EROSION

Studies of borehole cores drilled as part of the Cairo waste-water programme (AMBRIC) were examined by El-Senussi and Jones (1997) and later Branton (Cambridge University unpublished MSci dissertation). The results revealed that the Pleistocene Nile canyon was filled by coarse sandy sediments that flowed out of the wadi mouths, that impinge upon the Nile Valley as rain fell directly in the Saharan region. Early settlements at Omari and Helwan were focussed on these palao-fans. As the Holocene began and dark Nile silt accumulated above the sands the toes of the palao-fans began to be covered. The presence of a water tank associated with Khent-Khawes town at Giza (Mark Lehner personal communication) and of structures in the wadi at Dahshur (Alexanian et al. 2011) indicates that the wadis were stable during the early part of the Old Kingdom. However, around the end of the 4<sup>th</sup> Dynasty the wadis seem to become unstable and as El-Senussi and Jones (1997) and Dufton and Branton (2009) noted, successive tongues of sediment flowed out of the wadi mouths into the Nile valley. At around this time, settlement moved away from the wadi mouths and the terraces that flank the Nile Valley into the floodplain and occupied the levees of the Nile channel in somewhat extended 'ribbon' developments (Jeffreys and Tavares 1994).

Studies of erosion rates in dry deserts (Goudie and



**Fig. 5.** Time-frame map sequence based on around 140 cores augered by the Survey of Memphis superposed on the map in figure 4. **A** – During the Saharan Neolithic the plateau surrounding the Nile was green and wadis acted as access to the pasturelands. The Nile valley was wetter and, as a result of sea-level rise probably contained a number of highly mobile channels. No sediments from this period remain so channel locations are conjectural. **B** – During the Pre-Dynastic rains start to fail in the Saharan Grasslands and, as vegetation is denuded, the wadis start to wash out intruding Nile sediments with desert sands. **C** – Early Dynastic settlement to the west of the Nile Valley just south of Abusir is located on the banks of a channel. **D** – Settlement is focussed on the sides of the western channel but eastwards movement of the channel is detaching the sites from the base of the escarpment as the focus of settlement moves to remain near the Nile. **E** – Middle Kingdom Memphis seems to be on land between the two branches of the Nile at this latitude. **F** – New Kingdom Memphis, a city at a time of zenith and development, is closely surrounded on both sides by the branches of the Nile but the western branch seems to have stopped migrating. **G** – The Eastern branch starts to turn and migrate towards the east. **H** – Ptolemaic and Roman times there may have been a sharp cut back of the western branch (Qin – unpublished Cambridge University dissertation). **J** – in Christian and Islamic times an island settlement forms in the channel to the east of Memphis. **K** – The eastern branch continues to migrate eastwards. **L** – In 1970 Survey of Egypt maps show a large island to the east of Badrshein. **M** – By 2005 Badrshein island has become joined to the west bank of the Nile and the Nile is constrained to flow along the eastern edge of the floodplain.

Wilkinson 1977) show that there is little erosion at high rates of rainfall since the rain sustains plentiful vegetation that stabilises the soil. When there is no rainfall, erosion is also low. However, at intermediate rainfall, around 200 mm/yr erosion increases dramatically since the rain does not sustain sufficient vegetation to stabilise the sediment. We therefore infer that these sand tongues intruded the Nile silts of the valley at the time when the climate was in transition between the wet early Holocene conditions and the drier conditions that were reached around 2000 BCE. The loss of vegetation from all but the refugia of the Saharan region focussed populations into the oases and the Nile Valley, as was shown by Kuper and Kropelin (2006) in their study of carbon dates across the Saharan region. As trade winds became established across the area, sand dunes that had previously been locked in place

by vegetation were released and started to move across the landscape, moving generally towards the south-east.

### AEOLIAN SANDFLUX INTO THE VALLEY AND THE RIVER AROUND MEMPHIS

Studies of the First Intermediate Period and the associated climate crisis have highlighted the influx of sand to the Nile Valley that occurred around this time (Hassan, 2005). However, from the results of Möeller (2005) and other studies further south (Bunbury 2010) it is clear that the north of Egypt was desiccated far earlier than the south of Egypt or the Sudan (Macklin et al. 2013, Woodward et al. 2001 and Rodrigues 2000). Neither can the transition be considered as instantaneous, with Kröpelin et al. (2008) seeing a lag of

some 2000 years between the death of the tropical vegetation in the area of Lake Chad and the ultimate establishment of trade winds across north Africa.

Large accumulations of wind-blown sand along the base of the escarpment at Saqqara seem to post-date the Early Dynastic occupation of the site but a much clearer picture of the amount and timing of sand arriving has been determined by Alexanian et al (2002–2010) in their excavations at Dahshur. Here sand-flux into the wadi below the Valley Temple of the bent pyramid began in the late 4<sup>th</sup> dynasty and peaked during the late Old Kingdom. Since the end of the Old Kingdom, sand has continued to accumulate but at a lesser rate. Sand accumulation along the base of the escarpment may have encouraged the early occupants of Memphis to move into the Nile Valley but there seems little evidence of aeolian sand deposited directly onto the site of Memphis from the borehole evidence and micro-morphological observations of Qin (Cambridge University unpublished MSci dissertation). Qin's results suggest that sand deposited around Memphis at this time had been transported by river before its arrival at the site but there are traces of a former history as aeolian sand was still visible on the grain surfaces indicating that the Nile was transporting sand that had recently been blown into the Nile valley. Additional islands and bars are likely to have formed in the rived beds as the extra sand was flushed towards the sea.

## DISCUSSION

Memphis, at a geographically strategic point in Egypt was subject to a range of landscape processes through time. In the early Holocene, the site was a marshy area at the head of the Egyptian delta. Recently swamped, as sea level rose, the rest of the delta was also marshy and had begun to recover when sea-level rises slowed around 6,000 years ago. At this time the Nile, fed by the equatorial monsoon and augmented by tributaries in Egypt was high and rich in sediment which, supplied to the floodplain, caused it to rise gradually with the many channels of the Nile focussing into a few channels with distinct levees suitable for habitation. During this period evidence for settlement moves from the edges of the valley onto the Nile levees and the earliest deposits at Memphis are recovered. It was also a time during which the distributary system of the delta began to give Memphis ascendance over settlements further downstream.

The late Old Kingdom saw a period of climate change during which vegetation died and sand started to blow into the Nile valley. During the Middle Kingdom there seems to have been a loss of eminence through migration of the delta head southwards but by the New Kingdom, the delta head was again in the Memphis area and the city was extended in a period of planned development. Two branches of the Nile are inferred during the Old Kingdom; one, now extinct, of which all that remains is the depression of the Bahr Libeini and the other to the east of the city. The eastern branch of the Nile that flowed to the east of the Roman city is marked by a Roman waterfront wall but since this time the Survey of Memphis (1983–2004) has tracked the river moving to the east where it now flows against the desert edge near Helwan. The capital of Egypt has also shifted with the delta head northwards to form the city of Cairo.

From these findings we may propose a model for the development of the landscape in the Memphis area as shown in figure 5 that draws together these observations of landscape processes with the results of the Survey of Memphis (Jeffreys 1985 and 2010, Jeffreys and Bunbury 2005 and Jeffreys and Tavares, 1994).

## CONCLUSIONS

The results of the borehole surveys of the Survey of Memphis when combined with observations of the processes of landscape change in Egypt suggest a time series of landscapes that have formed part of a dialogue between the city of Memphis and the landscape in which it is set.

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