# Monuments on a Migrating Nile

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**Abstract**

River courses migrate, but many Egyptologists plot the present-day River Nile on maps of the valley in archaeological times. This may have misled interpretations of ancient monuments and settlements. We show a river migrating rapidly on historical time-scales in the Luxor region, sweeping >5 km across the valley at rates on the order of 2-3 km per 1,000 years. Satellite elevation data (SRTM), processed by a novel method, and Landsat imagery are used to trace ancient river levees and extend trends present in 200 years of archive maps thousands of years into the past. This supplements observations by Ptolemy (121-141 AD) and places local geo-archaeological studies in a wider spatial and temporal context. Satellite data is demonstrated to be a relatively quick and easy constraint upon ancient river courses, and a basis for investigations along the Egyptian Nile, even in logistically inaccessible regions.

*Key words:* Nile, SRTM topography, Egypt, course migration

## 1 Introduction

### *1.1 Geological Context*

Carved into the African Plateau ∼5-8 million years ago and then mostly re-filled with sediment, the ∼10 km wide Nile Valley is cliff-bounded and flat-bottomed [1–3]. From 200,000 years ago, a transition began to the present regime of arid climate and a summer flood [4,2], leaving a river with no significantly active Egyptian tributaries. So, the Nile is a constrained and relatively

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simple river. Many Egyptologists plot the present-day River Nile on maps of archaeological times [5,6], probably because the exact nature of the Nile's movements remain poorly known. This is likely to be a simplification and may have misled interpretations of ancient monuments and settlements.

### *1.2 River Migration*

It has long been known that the Nile migrates. St Pachomius founded a monastery on the island of Tabenna in the $4^{th}$ century (323 AD) "*but the shifting course of the river has long since annexed the island to the mainland*" (Butler, 1884) [7]. However, in ∼920 km of the Egyptian Nile Valley [1], such migration and its relationship to archaeological sites remains sparsely studied.

Between 124-141 AD, Claudius Ptolemaeus (a.k.a. Ptolemy) astronomically located 54 currently identifiable Nile Valley sites (Memphis to the Great Cataract at 21°50'N) and described their position relative to the river [8]. By placing Ball's reconstruction [8] onto modern cartography, Butzer [4] highlighted a predominantly eastward river migration since Hellenistic times. Extrapolating back, Butzer labelled the postulated course of the Ptolemaic river "*probable axis of dynastic (2950-332 B.C.) Nile*".

Butzer [4] verified his observation using maps (1798 AD to recent) and satellite photography, in a 70 km stretch of the valley north of Sohag (∼26°30'N, 31°40'E), finding 11 of 17 bends moving east. Unfortunately, even here, his much-reproduced cross-section [6] (vertical transect showing sub-surface structure across the valley) must extrapolate between 6 boreholes [1] in a 70 km by 10 km area and generalise migration rates.

Most recently, the two local geo-archaeological studies to have considered river migration in the Nile valley proposed eastward migration at Memphis [9] but westward drift at Luxor [10]. This paper seeks to reconstruct a continuum of past meanders and investigate the apparently anomalous behaviour near Luxor, starting with observations from 0-200 BP (before present).

## 2 Method

Maps from the last 200 years are used to establish the rate at which the river's course has migrated, and the directions of the movement. Interpreted in this context, the satellite-observed landscape is then used to extend trends thousands of years into the past.

Satellite derived elevation data (Satellite Radar Topography Mission, or SRTM)

[11] are a regularised lattice, or grid, with 3 arc-second resolution. Namely, each 90 m by 90 m rectangular area of land has a single measured height representing it. When the SRTM data is sampled (linear interpolation) at the locations of 67 valley-floor spot-heights on modern survey maps [12], the r.m.s difference is 1.9 m (2 s.f.); a measure of the accuracy of the SRTM data. A regional vertical shift of -2.7 m from map to SRTM data is also present, due to differences in the reference geoid used. So levees, typically 1-3 m high [12], are potentially resolvable. However, the down-river slope of the valley floor across the studied region (Figure 1) is 3-4 m. Processing is therefore necessary to account for relatively large-scale 'regional' trends such as these.

SRTM data are processed by locally evaluating upper and lower envelopes around the data, and then displaying the topography according to colour scale stretched between these limits. Specifically, processing of topography uses a 1 km $\times$ 1 km sliding window, returning the evaluated number to a central point (`grdfilter` of the GMT software package [13]). Initially, smoothed topography is produced by a sliding window returning a median, then upper and lower envelopes are the highest and lowest points in windows passed across the smoothed topography. Unprocessed SRTM topography, smoothed by 400 m wide Gaussian-weighted sliding-window filter to reduce measurement noise, is then coloured by a scale stretching between the envelopes (Figure 2). Landsat imagery is also enhanced; details Figure 1.

## 3 Results

### *3.1 Maps: Motions 0-200 Years B.P.*

Maps produced since the 1897-1907 survey of Egypt are based upon a full triangulation network and astronomical data, and can be regarded as accurate [14]. Modern river behaviour (Figure 1) validates and underpins our interpretation of more ancient times. The behaviour is deduced from a time-series of maps published in 1914 [15], 1943 [16] and 1991 [12]. River, island and side-channel locations are used to deduce where new land has been created during each time-step as islands form and old channels silt up. Islands, "*Jazirat*" or "*Geizret*" in Arabic, named on the maps but drawn annexed to the mainland, (1-3 & 5 on Figure 1) also indicate the direction in which the river's course has moved.

Three mechanisms of river migration seem to be represented: i) Near-bank small-island creation, causing channel motion oblique to the channel. For instance, using island numbers to also label bends, at 1 & 5; ii) Channel switching, i.e. from that NW of island 2 to that near Karnak, with island 4 perhaps representing an analogous intermediate step; iii) Point bar construction at bend 3 evidenced by geomorphology visible from aerial photography [10]. Older, semi-schematic maps and anecdotal evidence can help to quantify rates of river migration by extending the observed time span.

The Napoleonic map of 1798 [17] and derivatives [18,19] are detailed but inaccurate, and suffer linear and areal distortions [14]. In the Luxor region at least, we cannot replicate Butzer's [4] method and "*reliably unscramble*" the waterways of this map by reference to village sites. However, selective local detail seems useful. For example, ex-island 5, *Jazirat Mitayrah*, had a broad channel to its east in 1798, which is now filled (Figure 1 inset), suggesting a period of about 200 years to annex an island to the river bank.

Land SW of Luxor consists of islands decreasing in age to the southwest, relating a similar story. Ex-island 1*, Geziret el Auwamiya* (pre-1914), is probably formed of *G. Biadieh* and *G. El Gedideh* detailed in 1798. Its limits are defined by a remnant channel in 1943, a channel whose presence is attested to by an 1838 painting by David Roberts of Luxor Temple [20]. To the southwest again, *Banana Island* of the 1943 map has been annexed within living memory, and the modern island of *Jazirat al-'Awamiyyah* is almost certainly a continuation of this process.

So, examining Figure 1, switching a channel around an island ∼1 km wide takes ∼200 yrs. If island creation takes as long as channel switching, this gives a migration rate on the order of 1 km in 400 years, or 2.5 km per 1,000 years. This rate is greater than 1-2 km per 1,000 years [4] (implied by *Sohag* area cross-section), 250 m per 1,000 yrs at Karnak [JMB, AG & Hunter, in prep.], and 1 km per 1,000 years near Memphis [9]. Evidently, the Nile exhibits a range of activity.

These observations permit an interpretation of valley-floor geomorphology that arguably preserves, anthropologically or otherwise, movements that may have occurred over longer timescales (e.g. 200-2,000 B.P.).

### *3.2 Satellite Data: Ancient Motions*

Figure 2a displays relative elevations in the *Luxor* region deduced from satellite topography data. Judging from the amplitude, width and curvature of the ridges in the *Qamula-Danfiq* bend, the Nile appears to have left 3 traces of its earlier raised banks. Figure 2b is a topographic profile across the ridges.

If the ridges represent levees, they suggest an eastward migration of the Nile causing the bend. The ridges also truncate, at a comparatively high angle, against the river in the north of the bend, consistent with the recent SW migration of bend 5.

Buildings crest the ridges (Figure 1), so the satellite might have only been registering houses. However, portions of these 1-2 m high ridges are discernable from the 0.5 m valley-floor contours of the 1943 map [15] (Figure 1), so this is not the case.

Origins that are not natural, however, remain. Below the river, but above the fields, the banks are excellent locations for irrigation canals (Figure 1). The ridges have a width of ∼500 m [16] (Figure 1), giving them a larger cross-sectional area than a canal, precluding an origin directly related to canal excavation. Alternatively, the canals may build their own banks during flood, partially creating the ridges, but a scale of curvature similar to that of the present-day river favours Nile levees as an initial cause for their location.

Field boundaries (indicating *hôd* geometries), digitised from Landsat data (Figure 1), tend to orientate approximately perpendicular to the river on new land, thus may indicate old river-channel orientations. Alternatively, the boundaries align to present canals on old levees, and remain a useful guide.

The 5 Coptic monasteries (red dots on Figure 1) were presumably originally constructed between Constatine's accession and the Islamic Arabic invasion (324-640 AD) [7,21,22]. Backtracking river migration at current rates would place the river at the westernmost levee at this time. If so, the monasteries were originally on a sliver sandwiched between desert and river, separated from the valley floor, giving isolation similar to those built on islands (e.g. *Jazirat Mitayrah* [18,19]) or in the desert. Obviously then, no pre-Christian archaeological sites remain within the *Qamula-Danfiq* bend.

South of the *Qamula-Danfiq* bend, sediment cores show dynastic (∼2050-350 BC) river motion by Karnak Temple was to the northwest [10]. Figure 1 demonstrates that recent motion to the southeast has once again placed Karnak Temple at the waterfront. In the interim, the 1798 map shows, from west to east, the main river channel, a substantial width of fields and then Karnak. Thus, the Nile has probably undergone oscillations confined in the floodplain to the west of Karnak. Such, previously unnoticed, confinement may result from the 1-2 m mounds [1,12] or "*tells*" beneath these large active sites or deliberate actions by their inhabitants to extend temple land or otherwise prevent erosion. Lining canal banks with matting, for instance, is known from the Ptolemaic period [23,24].

We also note that, whilst recent migration rates are similar across the region studied, the net result depends upon whether the migration is consistently in one direction, as in the *Qamula-Danfiq* bend, or alternates as by *Karnak*.

More ancient motions (>∼2,000 yrs BP) may be preserved in the landscape

(Figure 2) between *Luxor* and *Qamula*. Interpreting the topographic lineations NE of Luxor as those in the *Qamula-Danfiq* bend, if more tentatively, implies a large-scale NW migration. The main indicators of this are the two prominent lineations passing either side of *Medamud*, and the current position of the river. So, established during the First Intermediate Period (∼2150 BC) [25] *Medamud* may have originally had a riverside situation, and *Karnak* may have been founded on an island or spit [26].

To the north, the canal or "*fossa*" to *Qift* (Koptos) (Figures 1 & 2) is on old maps such as Ægyptus Antiqua [27] (1765) and that of J. Ziegler (1532) [28]. It may also have been an ancient course of the Nile. The length-scale of the curvature of the canal is consistent, and may explain a canal to *Qift* at least 4 times longer than the direct route to the river. So, the Nile probably migrated east to west sometime not later than the early dynastic period (∼3,000-2,700 BC).

## 4 Synthesis of the Nile's Migration

In the Luxor region, the geometry of the suspected palaeo-levees is most consistently explained in the following scenario, illustrated in Figure 3: a) The early to pre-dynastic Nile is most likely to have run SE of present Luxor, past Medamud, and up the eastern edge of the valley to modern Qift. The river then migrated west of Karnak and Luxor. Then the northern section of the Nile's course, travelling westward, passed the location of Qus and potentially Danfiq; b) The historical migration of the Qamula-Danfiq bend then occurred whilst the large, continuously active Luxor-Karnak site altered the river's migration pinning it in the west of the floodplain.

## 5 Conclusions

Results facilitated by our processing method establish that old riverbanks remain fossilised on the floor of the Nile Valley and are visible to satellites in topography and imagery. Constraints are strongest away from clustered monuments and temples, and so complement geo-archaeological digs. Obviously, geo-archaeological ground-truthing of deductions based upon the remotely sensed data is desirable (i.e. sediment cores, WWII aerial photos, differential GPS, ground-penetrating radar, shallow reflection seismic data, legal land documents).

The story deduced concerning the movements in the course of the Nile in the Luxor region is more complex than Butzer's [4] commonly applied summary observation of general eastward Nile migration. So, providing the palaeo-environmental context of river motion specific to a vicinity is important when interpreting an archaeological or historical locality. A context can also serve to predict the threat the river poses to ancient sites, such as *el-Kab*, or modern concerns such as infrastructure.

The wider utility of satellite data for rapid analysis of Nile motion, pioneered here, is easily demonstrated outside the immediate Luxor area by examining GoogleEarth! Data there are similar to the inset in Figure 1. Potential applications to other inhabited river systems exist.

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Fig. 1. Summary of the river migration preserved in accurate modern-style survey maps (1914, 1:50,000 [15]; 1943, 1:25,000 [16]; 1991, 1:50,000 [12]) in the Luxor region of the Nile valley. Annotations on the bounding box are longitude and latitude in decimal degrees. For orientation, modern settlements and selected canals are also shown. Migration directions (arrows) are estimated from newly made land (sandy shades) and old river boundaries (thin dark-blue lines). Inset is a Landsat image (panchromatic band, i.e. all spectral frequencies) enhanced by locally equalising the intensity contrast, a standard image processing technique. Local equalisation, by pulling the lightest grey towards white and the darkest towards black, which causes all grey shades (black to white) to be utilised within each sub-region of the image. Spatial resolution is 14.25m.

Fig. 2. SRTM (NASA shuttle mission topography) land elevation, processed to reveal local variations in elevation (Section 2). a) Plan view. Area and aspect ratios are identical to Figure 1. The sinuous raised lineations are interpreted as ancient levees, expected to stand 1-3 m above the flood plain, and deduced directions of river migration (since ~3,000 BC) are indicated by arrows. Yellow star indicates the remains of a huge rectangular mudbrick wall with a truncated NW corner enclosing a harbour area (~1.6 km by 1 km) 'Birket Luxor' believed to date to the $18^{th}$ Dynasty [29,30]. b) Latitudinally averaged height profile across the 3 levees of the *Qamula-Danfiq* bend. Data are from within the red box in panel a).

Fig. 3. Summary of a possible history of river migration in the Luxor region, described in the text (Section 4). a) & b) show an older and a younger time period respectively. Darkest blue shade in each picture represents the youngest river course. Arrows illustrate motions of the Nile's course. D, Danfiq; Qu, Qus; Qi, Qift; Qa, Qamula; K, Karnak; L, Luxor; M, Medamud. Area and aspect ratios are identical to Figure 1.

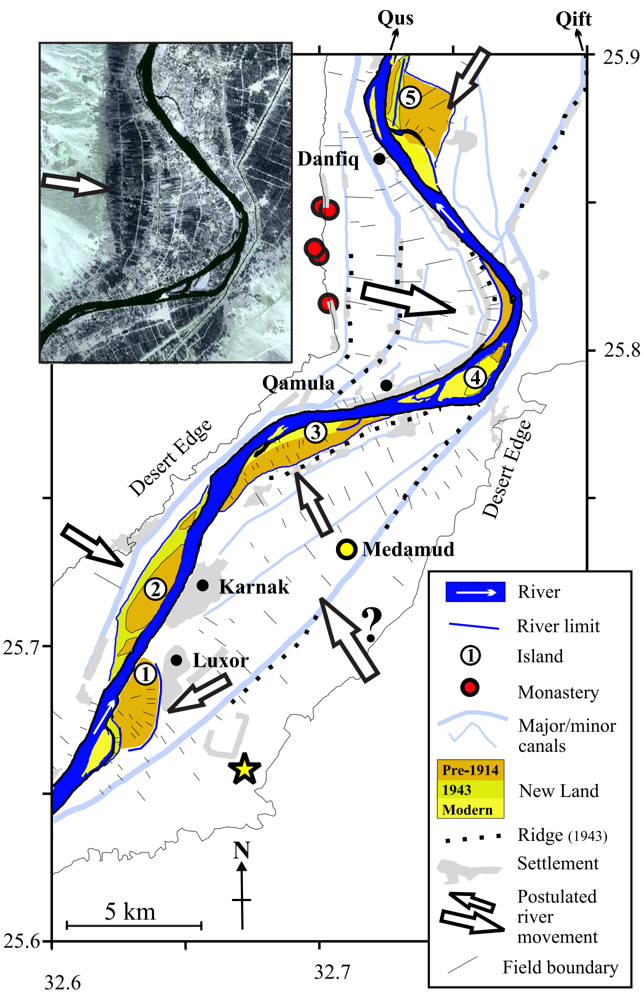


Figure 1

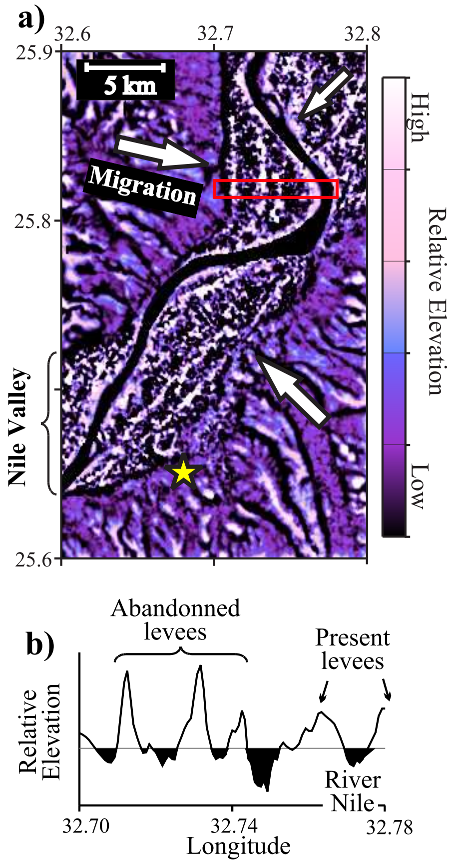


Figure 2

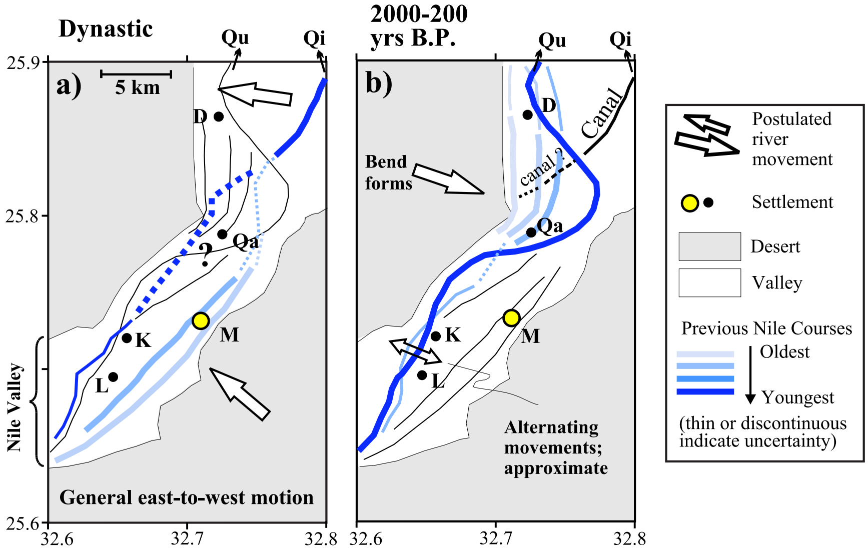


Figure 3