Received: 29 January 2017 | Revised: 5 May 2017 | Accepted: 8 May 2017
DOI: 10.1002/gea.21631

RESEARCH ARTICLE

WILEY Geoarchaeology An International Journal

Holocene fluvial history of the Nile's west bank at ancient Thebes, Luxor, Egypt, and its relation with cultural dynamics and basin-wide hydroclimatic variability

Willem H. J. Toonen[1] | Angus Graham[2] | Benjamin T. Pennington[3] | Morag A. Hunter[4] | Kristian D. Strutt[5] | Dominic S. Barker[5] | Aurélia Masson-Berghoff[6] | Virginia L. Emery[7]

[1]Department of Geography and Earth Science, Aberystwyth University, Aberystwyth, UK
[2]Department of Archaeology and Ancient History, Uppsala University, Uppsala, Sweden
[3]Department of Geography and Environment, University of Southampton, Southampton, UK
[4]Department of Earth Sciences, University of Cambridge, Cambridge, UK
[5]Department of Archaeology, University of Southampton, Southampton, UK
[6]Department of Greece and Rome, British Museum, Bloomsbury, London, UK
[7]Carthage College, Kenosha, WI, USA

Correspondence
Willem H. J. Toonen, Department of Geography and Earth Science, Aberystwyth University, Aberystwyth, UK.
Email: w.h.j.toonen@gmail.com

Scientific editing by Jamie Woodward

Abstract

In the Theban area around modern Luxor (Egypt), the River Nile divides the temple complexes of Karnak and Luxor from New Kingdom royal cult temples on the western desert edge. Few sites have been archaeologically identified in the western flood plain, despite its presumed pivotal role in the ancient ritual landscape as the territory that both physically divided and symbolically connected the areas inhabited by the living and the areas occupied by the dead. Using borehole data and electrical resistivity tomography, the current investigation of subsurface deposits reveals the location of an abandoned channel of the Nile. This river course was positioned in the western, distal part of the Nile flood plain. Over 2100 ceramic fragments recovered from boreholes date the abandonment of the relatively minor river channel to the (late) New Kingdom. This minor river branch could have played an important role in the cultural landscape, as it would have served to connect important localities in the ritual landscape. Changes in the fluvial landscape match with established periods of basin-wide hydroclimatic variability. This links cultural and landscape changes observed on a regional scale to hydroclimatic dynamics in the larger Nile catchment, in one of the focal areas of Ancient Egyptian cultural development.

KEYWORDS
abandoned channel, ancient Egypt, avulsion, flood plain, New Kingdom, Nile, paleosol

1 | INTRODUCTION

Thebes (Luxor, Egypt; Fig. 1) is famous for its major ancient monuments, being one of the primary cities of ancient Egypt from the Middle Kingdom (MK; late 11th–13th dynasties, *c.* 1980-1630 B.C.E.; Hornung, Krauss, & Warburton, 2006) until the end of the Roman period (overview of historical periods in Supplementary Material 1). The central axis of the Nile valley is marked by Karnak and Luxor Temples. Geoarchaeological investigations at Karnak suggest that the temple complex was founded during the First Intermediate Period (FIP; *c.* 2118–1980 B.C.E.: Gabolde, 2000; Hornung et al., 2006) on former bars or islands of the river Nile (Bunbury, Graham, & Hunter, 2008; Graham, 2010a; 2010b). The other focal area for temple building, dedicated primarily to the cult of the deceased king and the god Amun, is situated on the western desert edge. These "Mansions of Millions of Years" are all positioned within a *c.* 3.5-km long strip of land (Fig. 2). Their construction began early in the New Kingdom (NK; c. 1539–1077 B.C.E.). There seems to have been a strong preference for placing temple complexes on the edge of the desert, where it meets the flood plain, of which the royal cult temples of Merenptah, Ramesses II (the Ramesseum), Thutmose III, and Seti I are clear examples (Fig. 2). These royal cult temples were constructed throughout the NK. While the temple locations are not known for several kings, textual sources and titles of priests indicate the existence of temples for almost all kings during the NK with the exception of some who ruled for brief periods; during the Amarna period (*c.* 1353–1334 B.C.E.) when the capital along with many of its functions was moved to Akhetaten, modern Amarna (Kemp, 2006; 2012); and four of the last five rulers at the end of the

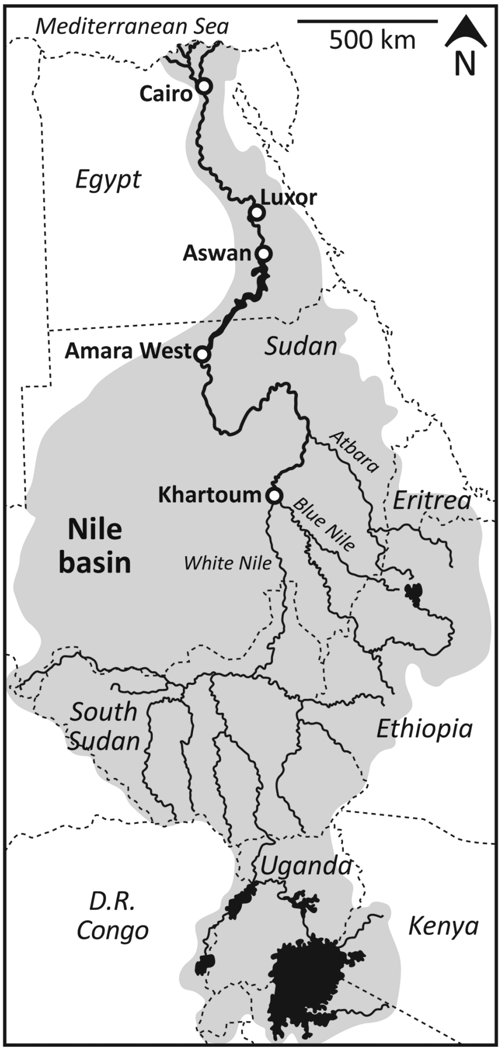

FIGURE 1 The modern catchment of the river Nile (modified from Woodward et al., 2015)

Highlights

- Fluvial deposits were dated using 2100+ ceramic sherds.
- The New Kingdom Theban flood plain featured a minor channel of the Nile.
- Hydroclimatic variability influenced both the cultural and fluvial landscapes.

NK (*c.* 1138-1077 B.C.E.; Ullmann, 2016), when political and economic instability increased in the late 20th Dynasty, announcing the fragmentation of the state that ended the NK period (Van Dijk, 2000).

Johnson (1998) argues that NK Thebes was divided into four interlinked localities; (i) Luxor Temple, where the primeval creator god, Amun, was born and reborn; (ii) Karnak, where Amun lived in palatial splendor; (iii) the Mansions (Temples) of Millions of Years (royal cult temples) on the West bank, where Amun was worshipped along with the king; and (iv) the Small Temple of Amun (later enclosed by Medinet Habu, the royal cult complex of Ramesses III) where Amun was regenerated by merging with his own chthonic form (Fig. 2). Three festivals linked these places: the annual Opet Festival between Karnak and Luxor, which celebrated the local triad of Amun, Mut, and Khonsu and their connection with (and blessing of) the king; the annual Beautiful Festival of the Valley between the Karnak complex and the Mansions of Millions of Years on the West Bank, which served as an act of symbolic reunion and reintegration between the living and the dead; and the decadal festival (held every 10 days)—a procession between Luxor Temple on the East Bank and the Small Temple of Amun on the West Bank, which memorialized the life cycle of Amun (Bell, 1997; Cabrol, 2001; Foucart, 1924; Graefe, 1986; Murnane, 1980, 1982; Schott, 1953; Ullmann, 2016). For the latter of these festivals, travel between the temples is only securely attested during the later years of the NK although the festival itself is known from earlier in the NK (Cabrol, 2001; Doresse, 1979; Wente, 1967). The barge in which Amun traveled during these festivals was pivotal in linking the sacred monuments (O'Connor, 1998). Hence, by extension, the Nile could have played a key role both physically and symbolically in the interconnected ritual landscape.

NK textual sources and tomb scenes suggest the former existence of (royal) canals fronting some of the Temples of Millions of Years (Jaritz, 2005; Lacau & Chevrier, 1977; Schlüter, 2009), which has led to the hypothesis that natural or human-made waterways may have connected the main channel of the Nile with the desert edge (Graham et al., 2014). This could explain the concentration of temples in the zone between Medinet Habu and the Ramesseum, as waterways would have provided easy means of transport and connection between the different localities visited during the Beautiful Festival of the Valley. Waterways also would have been important in the construction of the large temples, which required sandstone building blocks from quarries located *c.* 150 km upstream, and which housed colossal statues quarried near modern Cairo (downstream) and Aswan (upstream) that were transported to their destinations via barges on the Nile (Goyon, Golvin, Simon-Boidot, & Martinet, 2004; Kitchen, 1991; Klemm & Klemm, 2008; Stadelmann, 1984; Wehausen, Mansour, Ximenes, & Stross, 1988).

Presently no detailed study of preexisting channel networks exists in the region, leaving a gap in current knowledge regarding the configuration and use of the ancient flood plain in the Theban region. This paper presents the results of an interdisciplinary approach that aims to map and date ancient waterways in the Theban region and understand their origins. Borehole and electrical resistivity tomography (ERT) data were used to survey geological deposits and geomorphological elements that could identify the location of formerly active channels on the current western bank of the Nile. Due to restrictions in exporting sample material for radiometric dating, information from the abundant ceramic fragments retrieved from the boreholes has been used (exploratively) to date the sedimentary infill of abandoning waterways and to create age-depth models for flood plain deposition. This has allowed a comparison of important changes in the fluvial landscape with the regional configuration of archaeological sites and places some of these dynamics in a general framework of hydroclimatic variability in the larger Nile catchment.

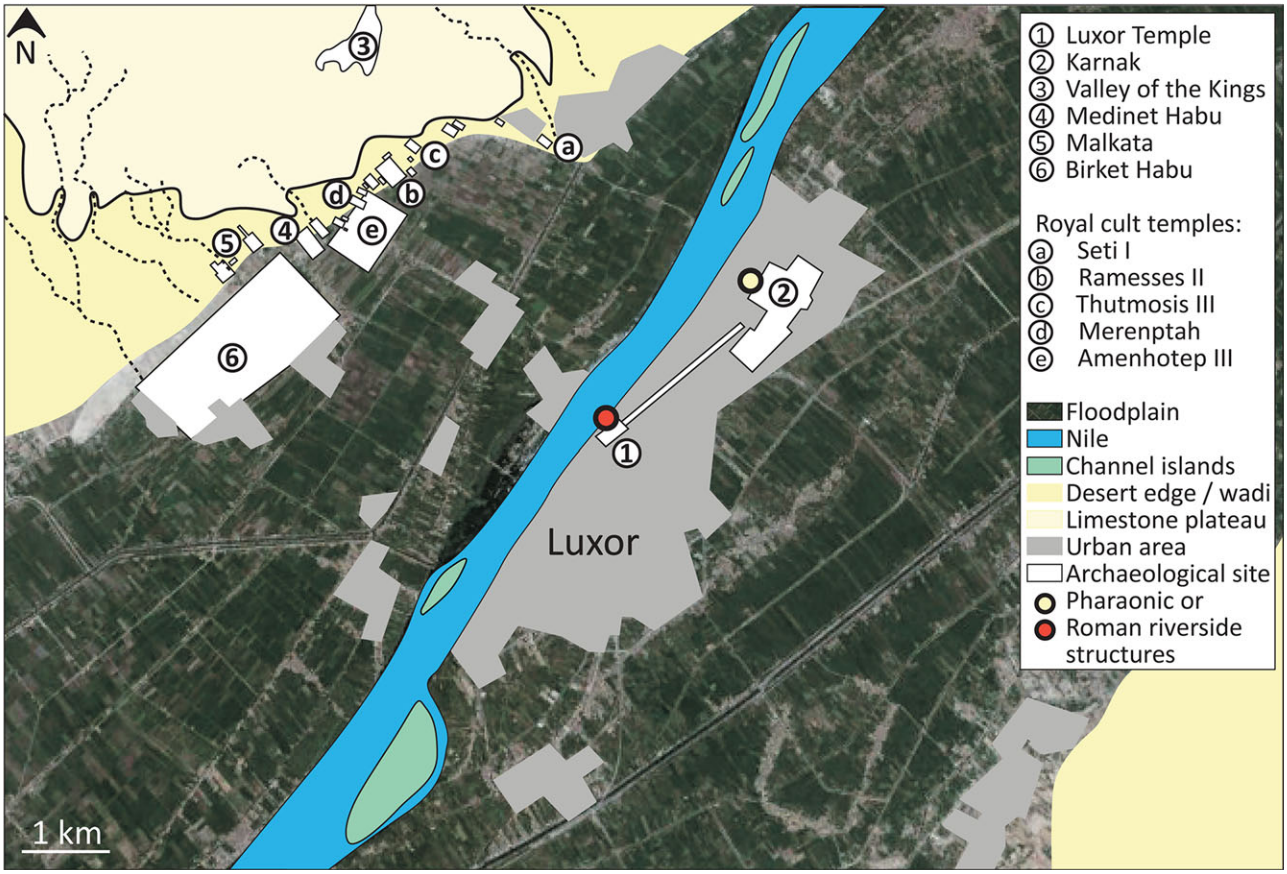

FIGURE 2 The Luxor region in Egypt with the location of a selection of archaeological sites
Notes: Riverside archaeology near Karnak temple includes 25–26th Dynasty (*c.* 760–525 B.C.E.) quay walls and mooring loops (Boraik et al., 2017), and west of Luxor Temple a Roman age structure has been interpreted as a Nilometer (Borchardt, 1906).
[Color figure can be viewed at wileyonlinelibrary.com]

2 | REGIONAL SETTING

The Nile is the second largest river system in the world by catchment size (*c.* 3,400,000 km^2), and its channel network spans from the tropical highlands in Uganda (White Nile) and Ethiopia (Blue Nile and Atbara River) to the Mediterranean Sea (Fig. 1). The flood regime of the Nile downstream from Khartoum in the Sudan (Woodward, Williams, Garzanti, Macklin, & Marriner, 2015) is controlled by important components of the global climate system such as the Northern Hemisphere Summer Monsoon (NHSM) and the Intertropical Convergence Zone (ITCZ: Macklin et al., 2013; Woodward, Macklin, & Welsby, 2001). Until the construction of the Aswan High Dam in the 1960s, annual floods occurred during summer (June to September). These were mainly generated in the upstream region of the Blue Nile and were strongly correlated with the El Niño Southern Oscillation (ENSO; positively correlated with strong La Niña years; Indeje, Semazzi, & Ogallo, 2000).

The current Nile in the Luxor region is a low-gradient alluvial river system, which migrates within the limits of the limestone bedrock cliffs and wadi fans that flank the 10-km wide Nile Valley. Migration of the main channel occurs through a combination of gradual lateral meander bend migration with the formation of typical point bars (Hillier, Bunbury, & Graham, 2007) and the formation of mid-channel bars that cause switching of the main channel route as water gradually gathers in one dominant channel to by-pass the bar. Although there are many examples of the formation of large islands recorded historically (e.g., Engelbach, & Macaldin, 1938), geomorphologically interpreted from satellite imagery (Hillier et al., 2007), and revealed in surveys of the subsoil (Bunbury et al., 2008), the net spatial movement of the main channel axis in the Theban region is believed to have been rather limited during the Late Holocene. Archaeological excavations have uncovered Pharaonic quays near the present Nile at Karnak (Boraik, 2010; Boraik et al., 2010; Chevrier, 1947; Lauffray, Traunecker, & Sauneron, 1975) and a Roman Nilometer at Luxor Temple (Daressy, 1920; Lacau, 1934; Legrain, 1917). Geological investigations (Bunbury et al., 2008; Ghilardi & Boraik, 2011) further indicate that the main channel of the Nile has been flowing in the central part of the flood plain of the Theban region for at least the last four millennia. In this period, the distal parts of the convex flood plain were mainly occupied by flood basin backswamps (Butzer, 1976), which steadily aggraded through deposition of fine sediments (clay-rich silts) during overbank flows of the annual floods. It was within these environments, with fairly predictable and regular supplies of water and sediment, that floodwater farming developed; the agricultural basis of the ancient Egyptian economy (Butzer, 1976; Said, 1993).

FIGURE 3 (A) Map showing: anomalous field patterns and cropmarks (1), channels and waterways (4–5), the historical position of the Nile channel (2) and mid-channel island (3). The white lines indicate the position of ERT survey transects (P46, P32-36). The dots indicate the locations of boreholes undertaken. (B) Cropped section from the Description de L'Egypte map, showing the position of Nile channels and islands in the late 18th century (Jacotin, 1821). (C) Position of historical waterways in the Thebes region (Murray, 1888—after Wilkinson's 1830 survey). The position of the Mortuary Temples of Seti I (a), Ramesses II (Ramesseum) (b), Thutmosis III (c), Amenhotep III (e), and Birket Habu (6) are indicated in the frames for reference
[Color figure can be viewed at wileyonlinelibrary.com]

3 | METHODS AND MATERIALS

3.1 | Mapping of flood plain deposits

Geoarchaeological surveying techniques were combined to investigate the Holocene history of the present Nile flood plain. An inventory was made of channels visible on georectified historical maps, as well as cropmarks (local differences in vegetation) and anomalous field patterns on satellite imagery to identify the possible location of former channel routes (Fig. 3). Small canals and ditches with an anomalous layout compared to the linear configuration of 19th century fields and large canals were noted (Willcocks & Craig, 1913). These were used to prioritize zones for further investigation of the subsurface. This followed the assumption that anomalous field patterns, cropmarks, and irregular ditches can signal preexisting archaeological features or a differing local subsoil that may have influenced later zonation efforts to structure agricultural field systems or caused differential plant growth (e.g., Trampier, Toonen, Simony, and Starbird, 2013; Wilson, 2000).

Lithological information was gathered from boreholes and ERT profiles along a 3 km transect across the western flood plain (Fig. 3). The exact positions of boreholes and ERT profiles were recorded using a Leica Real Time Kinetic (RTK) base-rover global positioning satellite system, with elevations referenced to the Survey of Egypt Datum (Graham et al., 2014). Boreholes were spaced at an average distance of no more than 250 m apart, which is a length-scale smaller than the characteristic dimension of geomorphological features in the Nile flood plain and thus ensures that no major natural subsurface elements were missed. The borehole transect was undertaken in tandem with ERT profiles along the same line. ERT results were used to identify the location of (sedimentary) anomalies or general lithological changes in the subsurface, and provided information for deposits beyond the reach of the coring; up to 20 m instead of a maximum coring depth of *c.* 10 m.

The ERT transects (settings in Supplementary Material 2) were conducted using the principle of earth resistance survey, measuring the apparent resistivity below the surface of the ground (Schmidt, 2013; Zakrzewski, Shortland, & Rowland, 2016). The nature of lithology, sediments, and inclusions below the ground surface allows the passing of an electrical current through the earth to measure the resistance to the current in Ohms (Ω). The inclusion of the volume of material that the current is passed through in the calculation of measurements allows the apparent resistivity in Ohm meters (Ωm) to be measured (assuming the homogeneity of the subsurface). This facilitates the survey of profiles of resistivity values to assess the changing resistivity of subsurface deposits at increased depth (Schmidt, 2013; Scollar, Tabbagh, Hesse, & Herzog, 1990). A Wenner probe array (C,P,P,C current/potential probe configuration) was used (Clark, 1996) with a probe spacing along the ERT profiles at 2 m intervals, giving a horizontal data resolution of 2 m and a vertical resolution of 1 m. The resulting apparent resistivity data were processed with Res2DInv software. Outlying values were removed manually through the data edit function. This included removal of the third level of data in the profiles, which contained unusually high resistivity values across profiles, potentially caused by the water table levels and erroneous readings by individual probes. The profile data were then passed through the least squares inversion modeling, with up to 12 iterations used to produce a model of the subsurface resistivity along each traverse (Graham et al., 2012; Loke, & Dahlin, 2002). The ERT profiles are presented at a very basic level, discriminating between sands, and fine (clayey) silt deposits using an arbitrary twofold division; calibrated to <8 (fine silts), and >8 Ωm (sands) based on lithological information from boreholes. Three different color ramp images of each profile are also presented in the Supplementary section of this paper for comparison.

Boreholes were drilled using a standard Edelman augering kit (coded AS; borehole diameter 70 mm) and a percussion corer (coded PC; borehole diameter 75 mm). Sediments retrieved in 100 mm intervals were logged in terms of their basic lithological characteristics. Each sediment sample was bagged and weighed. Clasts were sieved out from the matrix in classes of 2–4 mm and >4 mm.

3.2 | Ceramic analysis and age-depth modeling

More than 2100 ceramic fragments larger than 4 mm were separated from the sieved clasts for further study and used to establish a chronology for the sediments. The dating of each fragment produces a maximum age for the facies that host it. Sherd diagnostics (e.g., fabric, fabrication techniques, shape, surface treatment) were compared with local well-dated reference collections developed from excavations and documentation of finds at nearby Karnak and Luxor Temples (David et al., 2016; Le Bohec & Millet, 2012; Masson, 2007, 2011, 2013, 2015, 2016; Millet, 2007, 2008) and many systematic ceramic studies in the wider region (Arnold & Bourriau, 1993; Aston, 1999; Aston, Dominicus, Ford & Jaritz, 2008; Bourriau, 2010; Bourriau, Nicholson, & Rose, 2000; Rose, 2007). The ceramic corpuses included in these studies are dated through a combination of relative stratigraphic dating, absolute dating through the association of inscribed objects, and radiocarbon dating of ceramic material and other nonceramic artifacts from the same stratigraphic contexts (Bronk Ramsey et al., 2010; Shortland & Bronk Ramsey, 2013). Age ranges were estimated in a conservative manner to avoid over-interpretation based on relatively small and sometimes abraded sherd fragments. Some fabrics are typical for very specific periods in this region, while others are far more common and were produced over long periods of time, often MK-Rom (Middle Kingdom to the Late Roman Period). As a trial for developing an approach to ceramic information in age-depth correlations, the estimated age ranges of all sherds retrieved from individual boreholes were plotted versus depth. This was done on three basic assumptions. First, no major age inversions should occur naturally. Second, an overwhelming number of similar finds is more indicative of a certain age than a single diagnostic sherd that may have moved down the sedimentary sequence by bioturbation or downhole contamination during coring. Third, the upper meter of deposits may contain evidence of *sebakh*—fertilizing fields with nitrogen-rich archaeological matrix removed from nearby sites; a practice that may have begun as early as the Roman Period (Quickel & Williams, 2016; Wallace, 1938), but which is known to have taken place at an industrial scale throughout Egypt in the 19th and first half of the 20th centuries with, for example, the temple of Medinet Habu being heavily dug during this time (Bailey, 1999; Hölscher 1934; Quickel & Williams, 2016).

Sedimentation rates were estimated from the resulting ceramic age-depth diagrams and related to the interpreted fluvial setting (e.g., channel fill or flood basin) in order to test the general validity of the age–depth models. This approach worked well at sites with an abundance of ceramic finds, generally exceeding 100 pieces per borehole. At other locations, lithostratigraphic correlations of sedimentary units across the flood basin allowed assignment of ages to deposits despite a local lack of abundant direct dating material. These lithostratigraphically derived ages were locally verified with sporadic diagnostic ceramic finds. Periods of decreased sedimentation were inferred from the presence of two distinct paleosols with a concentration of calcareous and manganese nodules. The ages of these paleosols were estimated based on a combination of directly ceramic-dated cultural horizons and at other places on reconstructed sedimentation rates. Their presence and age is relevant in discussions of the effects of basin-wide hydroclimatic signals on cultural dynamics and major changes in the regional fluvial landscape.

4 | FLOOD PLAIN DEPOSITS OF THE THEBAN REGION

4.1 | Lithology and nesting of sedimentary units

The borehole information (Fig. 4B) indicates three main lithological zones: (i) fine-grained deposits in the central western flood plain, (ii) relatively coarse-grained deposits in a ~1.2 km zone adjacent to the present Nile, and (iii) sandy deposits centered around a fine-grained

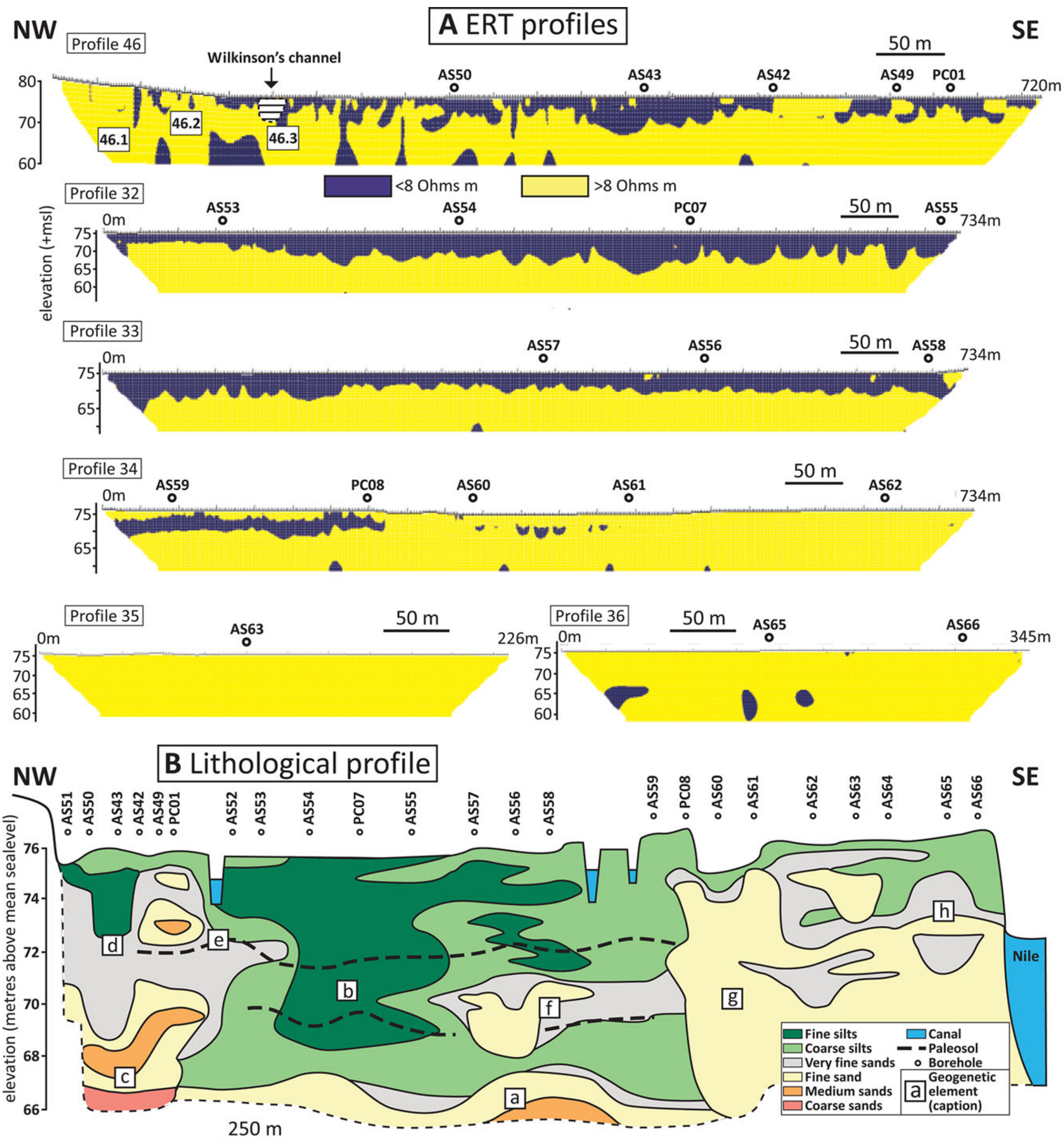

FIGURE 4 (A) Inverse model from ERT readings with tag numbers for reference in the main text (upper frames). The black arrow in P46 marks a confined area of very high resistivity (>200 Ω m; Supplementary Material 3), which corresponds with the location of a small ditch or channel in Wilkinson's (1830) survey (Fig. 2C); probably filled with rubble in the 20th century but not further investigated in this study. (B) A schematic (generalized) lithological profile of the western flood plain region; (a) coarse-grained substratum with fining upward sequence, (b) central flood basin, (c) NK channel lag, (d) laminated channel-fill sequence and clay plug, (e) levee, (f) crevasse splay, (g) Nile channel deposits, sandy channel fill, and (h) mid-channel bar (gezira)
[Color figure can be viewed at wileyonlinelibrary.com]

unit in a 400-m wide zone adjacent to the western flood plain–desert transition. In this third zone, samples contained numerous ceramic fragments occasionally down to 10 m below the present surface.

The central part of the flood plain (AS52 to PC08) is dominated by relatively fine-grained deposits with a dark brown to very dark grayish brown color (7.5YR 3/3 – 10YR 3/2), characteristic for Nile overbank mud. Starting from ~10 m depth, there is a gradual fining upward trend with slightly loamy fine to medium-coarse sands (80-350 μm) at ~ 67 m above mean sea level (+msl) that grade within 1 m into loamy fine sands and coarse silts (30–80 μm; Fig. 4B). This transition is also clearly reflected in the ERT data (Fig. 4A). The upward fining is accompanied by a decrease in the occurrence of millimeter-sized mica minerals. The sands in the deepest part of the boreholes are poorly sorted, contain up to 5% rounded gravels (max. Ø ∼5 mm), and are characterized by millimeter to centimeter scale laminations. Between AS54 and AS55, the upper ∼7 m consists of homogeneous fine silts ranging in texture from silty clay loams to silty clays (5–30 μm). Toward the west (AS52 to AS53), deposits are generally coarser with higher resistivities (P32; Fig. 4A). Coarse silts reach up to ∼73 m +msl and only the upper 3 m are dominated by finer silty clay deposits. Further east (AS57 to AS58), the general fining upward trend is interrupted between 68 and 71 m +msl by fine sands and loams (70–150 μm) that are relatively rich in mica minerals. This unit is separated from the lowest sandy stratum by more than 1 m of silty loams. Throughout all the cores of the central flood plain, small quantities of distinctive, individual sand grains are dispersed within the fine-grained matrix. Based on their polished appearance, it was assumed that these quartz grains are of local desert origin and transported onto the flood plain during (frequent) dust storms (Garzanti, Ando, Padoan, Vezzoli, & El Kammar, 2015).

The 1.2 km zone adjacent to the current Nile features considerable variability in surface topography, contrasting with the flat landscape to the west. From west to east, the surface level first rises to ∼77 m +msl (AS59 and PC08), then sharply drops to ∼75 m +msl in a well-defined 200-m wide elongated surface depression with a north-south alignment (AS60 and AS61; Fig. 3) that corresponds with the position of the Nile in the 19th–early 20th century (Fig. 3B). Then the surface abruptly rises again to the east and gradually increases in elevation to its highest point close to the current river Nile. Between AS59 and PC08, there is a strong eastward coarsening in deposits: AS59 is dominated by coarse silts with minor variations in texture and sorting, but PC08 features repetitions of well-sorted sandy intervals (Fig. 4B) with a high mica content. Below 70 m +msl cross-bedded sands (250 μm) were encountered with a distinctive richness in mineralogy (e.g., feldspar, epidote, amphibole, and pyroxene minerals in contrast to the otherwise almost pure quartz sands; Garzanti et al., 2015) that is similar to sands found in cores AS60 to AS66. The deposits encountered between AS60 and AS61, both positioned within the topographic depression, are relatively coarse-grained (150-250 μm) and fairly well sorted. Visually distinct sub centimeter scale laminations, evidenced by subtle changes in texture and mineralogy of the sand, are frequent. Due to liquefaction of the sands below the groundwater level (generally between 3–4 m below the present surface), coring depth was limited in these locations. ERT data (P34), however, suggest a continuation of coarse deposits at greater depths (Fig. 4A). Further to the east of AS61, as the surface rises between the surface depression and the current Nile channel, five cores all featured a sequence of well-sorted distinctive quartz and feldspar-rich sands (150-300 μm) below ∼72 m +msl, overlain by a unit of finer sediments ranging from coarse silts to brown-yellow sands with frequent laminations.

Between AS51 and PC01, a central fine-grained sedimentary "plug" is surrounded by sandy deposits that reach higher up in the profile. The central plug of fines (core AS43; Fig. 4B) follows a general fining upward trend over ∼10 m from small gravels (2 mm) below 67 m +msl to clays in the upper meter. Below 69 m +msl, sediments are highly laminated at a centimeter scale with gravelly layers and sandy and loamy beds containing up to 20% clay. Above ∼69 m +msl a rather abrupt (non-erosive) transition to finer-grained deposits occurs, which persist for the upper 7 m of the core. These fine silts (16–32 μm) are well sorted and lack clear visual laminations.

To the west and east between 70 and 74 m +msl, the central plug of fine silts is flanked by well-sorted deposits of coarse silts to fine sands (32–105 μm), which show repetitive internal fining upward trends in several stacked 1–2 m thick sets. The occurrence of sands up to the surface is also clearly visible in the ERT profile, along with high resistivity measurements that correspond to the sandy deposits of the desert edge (labeled 46.1–46.3 in Fig. 4A). Eastward of AS49, the sets display an increased heterogeneity, but generally they fine and grade into the silts of the central flood plain. Above ∼74 m +msl, the uppermost fining upward set is covered by a drape of fine silts of a similar texture to the silts in core AS43. This drape thins to the east; it is 2-m thick in core AS50, only 1-m thick in AS42, and absent in AS49 and PC01 (Fig. 4B).

4.2 | Paleosols and ceramic fragments

The flood plain yields indicators for soil formation at two distinct levels that comprise traceable zones of particularly frequent occurrences of calcareous (and manganese) nodules and streaky white mottling (amounting up to as much as 40% of the matrix). The calcareous nodules are often dendritic in shape and contain a central hollow axis, which suggests that they are rhizoliths of calcium carbonate that precipitated around rootlets of plants that have taken up calcium-rich groundwater (Klappa, 1991; Retallack, 1990; Wright & Tucker, 1991). The highest concentrations of nodules and mottling occur between 71–73 m +msl, and 69–70 m +msl (Fig. 4). The upper zone is consistently found in all cores from the western desert edge to PC08. The lower zone is, however, not found west of borehole AS52, and is less well developed than the upper zone at nearly all locations. To the east of PC08, nodules were largely absent, and no signs of paleosol formation have been identified in this region.

Ceramic material is distributed irregularly along the transect. Parts of the fine-grained flood plain deposits contain relatively few sherds: between AS54 and AS56 only 7–15 pieces were extracted per core after sieving, not taking into consideration very small (<2 mm) or degraded fragments. Increased sherd occurrence is observed toward the western part of the flood plain, west of AS54 (Fig. 5; Table I). The vertical distribution of sherd material also varies. Between AS49 and AS56, sherds are rarely encountered below 4 m depth (∼72 m +msl); they are most densely concentrated in the top meter, presumably partly as a result of *sebakh*, and at 3–4 m below the present surface (∼72–73 m +msl).

Between boreholes AS51-53 and AS58-59, sherds occurred in greater density and up to depths of 10 m below the present surface. Especially in AS50, PC01 and AS53 sherds occur in far greater density than elsewhere: 839 sherd fragments larger than 4 mm were recovered from AS50 alone (Table I), with highest concentrations between 68 and 72 m +msl (Fig. 5).

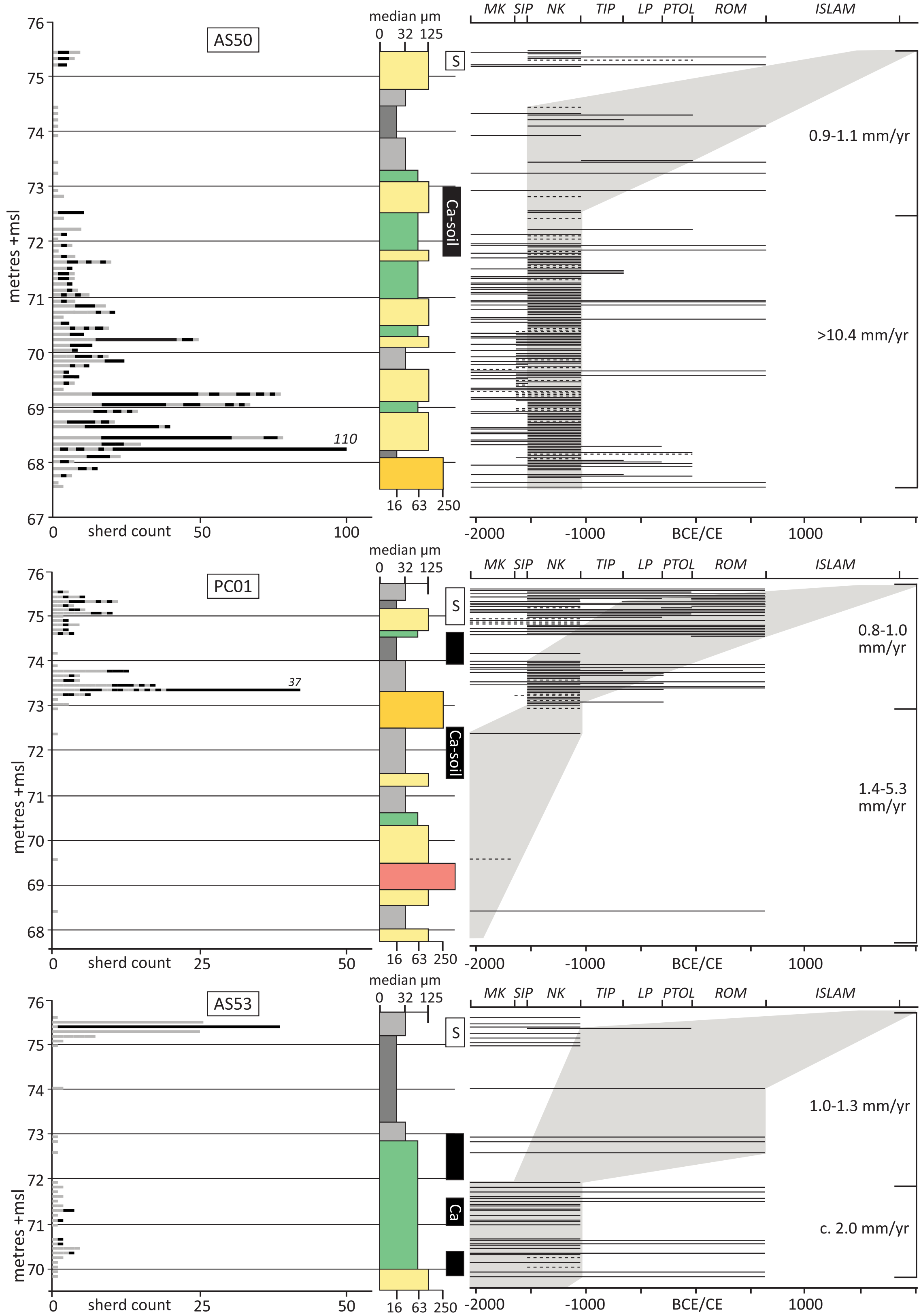

FIGURE 5 Ceramic fragments and age-depth models for selected cores (AS43 in Supplementary Material 4)
Notes: The left frame shows the number of diagnostic sherds, grouped per ceramic type (potentially coming from the same vessel, broken in multiple fragments) and plotted on its depth of recovery. In the middle, the general lithology and indications for calcareous (Ca-soil: black bars) soil formation and sebakh (S: white bars) are indicated. The right frame plots the age range for each individual type of fabric at the depth of recovery. Dashed lines indicate uncertain determinations, often due to poor preservation of the ceramic fragments. Conservative age-depth inferences are depicted in a gray shade. Along the right axis, estimated accumulation rates are shown for increments that could be distinguished based on the available age information.
[Color figure can be viewed at wileyonlinelibrary.com]

TABLE I Summary of ceramic finds larger than 4 mm in boreholes after sieving

Borehole	Surface Elevation (m + msl)	Sherd Count (>4 mm)	Total Weight (g)	Maximum Depth of Occurrence (m Below Surface)
AS51	75.2	31	15	5.7
AS50	75.7	839	591	8.1
AS43	76.0	129	89	10.2
AS42	75.6	50	32	6.2
AS49	75.7	38	31	6.8
PC01	75.8	187	474	7.3
AS52	75.7	66	65	9.2
AS53	75.8	154	39	6.1
AS54	75.7	15	6	5.3
PC07	75.9	12	2	5.3
AS55	75.6	7	3	6.8
AS57	76.0	7	1	3.1
AS56	75.9	10	2	7.4
AS58	75.8	36	12	8.4
AS59	76.6	42	18	10.0
PC08	76.5	6	3	8.8
AS60	75.2	6	1	1.7
AS61	75.6	8	4	5.3
AS62	76.2	7	2	4.4
AS63	76.4	9	3	5.5
AS64	76.3	7	10	4.7
AS65	76.5	15	6	5.6
AS66	76.5	1	<1	4.6

Boreholes are arranged from west to east (top to bottom in table). Boreholes coded AS were hand-augered, while those coded PC were cored with the percussion corer.

4.3 | Age–depth inference

Because of the spatial sedimentary heterogeneity, due to different formation processes (Section 5), a single age–depth model for the entire flood plain would be imprecise and incorrect. Hence, sedimentation rates are likely to be spatially and temporally inconsistent, and the ages of deposits at similar depths are likely to vary. Age–depth models and the resulting estimated sedimentation rates are largely based on the three cores with highest sherd occurrences (AS50, PC01, and AS53), each representing different geomorphological elements in the landscape (channel-fill, levee, and flood basin respectively; Section 5). These three locations can be used to provide age information for deposits found elsewhere in the same general setting, because of the spatial consistency of some sedimentary units (Fig. 4).

In the westernmost part of the flood plain, 101 sherds of an exclusive NK age were found in AS50 between 67.5 and 72 m +msl (Fig. 5), strongly suggesting an NK age for these deposits. The same interval is marked by many fabrics that were in use continuously from the MK-Rom Period, which thus do not contradict a specific NK age. In the same interval, only five MK-Second Intermediate Period (SIP) fragments potentially conflict with a NK age (Fig. 5). However, the concentration of these MK-SIP sherds in a confined 0.5 m thick interval located at ~69.5 m +msl could be related to the NK dumping of older ceramic material—perhaps the clearing of nearby land littered with older archaeological remains.

From 72 to 75 m +msl there are fewer sherds and (with the exception of the uppermost meter) no sherds with a specific NK age were found. Dates of the fragments range from MK-Rom, but MK–NK ages for these deposits are implausible based on the NK age of the deeper strata. The scarcity of diagnostic fabrics complicates the establishment of a precise age of these deposits. Nonetheless, the relatively high frequency of sherds with an age range including the late period (LP), Ptolemaic (Ptol), and Roman periods suggest such an age for the deposits. An LP-Rom age for this sedimentary unit (Fig. 4) is more evident in cores AS43 (Supplementary Material 4) and PC01 (Fig. 5), located ~250 m to the east (Fig. 3). At all coring locations, the upper meter consists of an inhomogeneous mixture of MK-Rom sherd material, which is most likely in part the result of deposition of *sebakh*.

Sedimentation rates can be estimated based on the chronostratigraphic control afforded by the sherds. The ceramics in cores AS50 and AS43 suggest that, locally, 5 m of fine-grained deposits accumulated during the NK (67.5–72.5 m +msl: Fig. 5), which equates to accumulation rates of at least 10.4 mm/yr (considering the full duration of the NK period for deposition). Following this, the upper ~3.3 m must have accumulated from the end of the NK until the Aswan High Dam was completed in the 1960s. This equates to an average accumulation rate of ~1.1 mm/yr since 1069 B.C.E. The difference in accumulation rates is supported by the general lithology, with the upper meters recording more fine-grained deposits (Fig. 4), indicating low energetic distal backswamp conditions in a fluvial context.

Core PC01 returned a total of 187 ceramic fragments. Nearly all the sherds in this core are concentrated between 74.5–75.5 m +msl and 73–74 m +msl (Fig. 5). The lower cultural layer is dominated by NK fragments, amidst fabrics with a broader age range. No sherds were specifically diagnostic to any period later than the NK; thus an NK date seems plausible for this horizon. The upper cultural layer yields sherds with much more diverse dating ranges. A Roman–late Antiquity date (30 B.C.E.–640 CE) seems most plausible for this horizon as there is a strong increase in LP-Rom sherds with various specimens that are attributed exclusively to the Roman and the Late Roman periods. Below 73 m +msl, ceramic fragments are very scarce but the diagnostic fabrics are consistent with an MK date. The data are, however, too limited to unambiguously assign the sediments to this period. Thus, assuming an NK age at ~73 m +msl, the upper 3 m of sediment must have formed since 1539–1077 B.C.E., which equates to a mean accumulation rate of ~0.8–1.0 mm/yr (based on the start and end dates of the NK and the termination of deposition following the construction of the Aswan High Dam). Accumulation rates further down the core are more difficult to assess because independent dating information is largely absent.

In core AS53, within the central fine-grained flood plain region, 153 sherd fragments were recovered. Again, there are two levels of increased ceramic concentration; between 70 and 72 m +msl and in the uppermost meter. The upper meter in this core is interpreted to have been disturbed by *sebakh*, but MK–NK ages are strongly supported between 70 and 72 m +msl. Based on the ceramic age-depth information, it is clear that the upper ~4 m (72–76 m +msl) of sediment has accumulated since the NK at an average rate of ~1.0–1.3 mm/yr. The lower 2 m of deposits may yield higher sedimentation rates with maximum ~2.0 mm/yr (Fig. 5), based on the dispersed occurrence of MK–NK ceramics. The exact sedimentation rates in the lower part are, however, more difficult to constrain because all ceramics are of similar age range.

Further to the east (between AS54 and PC08), ceramic recovery and thus available age information decreases. The few diagnostic sherds that have been recovered in this zone correspond generally with the cultural stratification at cores AS53 and PC01. The uppermost meter contains mixed material and has most likely been enriched with relatively old ceramics from *sebakh*, but similar to PC01 there is still a strong indication for a Roman date in the upper meter. The data suggest NK levels are certainly lower than ~74.5 m +msl, with most MK–NK ceramics scattered between 69 and 72.5 m +msl. Based on the lateral correlation of sedimentary units and cultural horizons, supplemented by local ceramic finds, estimated accumulation rates range between 0.8 and 1.4 mm/yr for the upper meters.

5 | GEOGENETIC INTERPRETATION

5.1 | A new kingdom branch of the Nile

The sediments between boreholes AS50 and AS49 (Fig. 3) are interpreted as having been formed by a minor branch of the Nile, which was active during (and probably at least some centuries before) the NK. The nesting of deposits and sedimentary sequences are typical for an infilled channel (Toonen, Kleinhans, & Cohen, 2012), with (i) bed-load deposits at the base representing the channel lag during active flow (AS43 and AS50), (ii) fine-grained levee deposits that fine and thin toward the east (70–74 m +msl; AS42, AS49, and PC01), and (iii) a fine-grained sedimentary plug with sandy individual flood units (AS43 and AS50). The successive transformation from an active river channel to common flood plain is marked by a fining upward trend, which confirms a gradual declining influence of river flow and decreasing energetic conditions and sedimentation rates. The chronostratigraphic information from the sherd material lends further weight to the interpretation of an infilled river channel in this area, as it confirms an NK palaeotopography comprising a local depression at 67.5 m +msl (AS43 and AS50) flanking elevated levees at 73 m +msl (AS42, AS49, PC01), and a relatively low backswamp area at 70–72 m +msl (AS52 and further east). Deposition was very rapid as the channel silted up with rates averaging up to 10.4 mm/yr, which is of a magnitude larger than the deposition of fines on the elevated levees and the surrounding lower lying flood basin (around 1.0–1.3 mm/yr).

It is difficult to establish when and how this minor branch came into existence, because deposits of the initial phase are not preserved due to later fluvial erosion. Levee formation prior to the NK is suggested by the presence of coarser material (105–250 μm) directly underneath the NK levels in AS42, AS49, and PC01 (Figs. 4 and 5). The relatively well-developed levees and incised channel base suggest fluvial activity and bed formation for a prolonged period, potentially placing the onset of fluvial activity in the MK, but conclusive information is lacking.

The channel seems to have migrated little, as sandy deposits do not extend much beyond the zone of ceramic infill (AS43 and AS50; Fig. 5). Furthermore, no coarse bed-load deposits were found between PC01 and PC08 nor were they detected on the ERT profiles, which indicates that no river channel has occupied this part of the flood plain in the last few millennia (see also Section 5.2). As no continuous lateral migration from the central valley axis to the desert edge has occurred, an upstream avulsion must have forced the diversion of river flow. In a typical convex flood plain of low-gradient river systems, ongoing levee development can result in low-lying, sediment-deprived backswamp areas (Butzer, 1976; Lewin, & Ashworth, 2014). Presumably triggered by large flood events, such as those recorded in the Nubian Nile Valley during the early part of the MK (Butzer, 1997; 1998; Macklin et al., 2015; Vercoutter, 1966), levees could have been breached and new channel routes established, exploiting the lowest regions in the backswamp area.

The extent of sandy deposits and channel infill indicate that this channel had a maximum width of ~250 m. This channel width could not have been sufficient to carry the full discharge of the Nile and must have been a minor branch (Butzer, 1976; Willcocks, and Craig, 1913). During its active phase, maximum depth during bankfull discharge would have been ~7 m (~74.5–68 m +msl: height difference between the channel lag and the top of levees), which implies that this channel may have carried flow throughout the year because the annual flood at Thebes is thought to have had a similar magnitude (Said, 1993; Seidlmayer, 2001; Willcocks, & Craig, 1913). For the local landscape, this meant that the current western flood plain area would have been a "water-locked" region during the NK, located between the minor channel near the desert edge and the main Nile channel that was present in the central axis of the Nile Valley, based on the quay structures and sedimentary record at Karnak (Fig. 2; Boraik, Gabolde, and Graham, 2017; Bunbury et al., 2008).

Abandonment of the channel was probably rather gradual in its initial stage, as a considerable part of the channel has filled with fine-grained sandy deposits (63–150 μm; AS43 and AS50). This requires a maintained open connection with the active Nile branch to convey bed load from upstream into the abandoning channel where deposition could occur due to waning energetic conditions (Toonen et al., 2012). During abandonment, the channel was used for the dumping of refuse from the NK temples located nearby (Fig. 2), based on the vessel types and low abrasion of ceramics (Graham et al., 2016).

5.2 | Flood basin formation and deposition

The substrate of the Nile flood plain is coarse-grained and must have formed in a strikingly different setting compared to the flood basin setting with deposition of overbank fines of the last millennia. Various studies have suggested a transition in fluvial style during the Holocene in response to climate change, mainly aridification (Butzer, 1998; Macklin et al., 2015; Said, 1993), that occurred roughly between *c.* 5000–2500 B.C.E. (Castañeda et al., 2016; deMenocal et al., 2000; Gasse, 2000; Hennekam, Jilbert, Schnetger, and de Lange, 2014; Krom, Stanley, Cliff, and Woodward, 2002; Woodward, Macklin et al., 2015). While the modern Nile system with its low-sinuosity channel and mid-channel bars is typical for the middle and late Holocene (Butzer, 1976; Said, 1993), there was a different Nile system with a more violent discharge regime, a braided channel pattern, and coarser deposits (with large sediment inputs from wadi systems; Woodward, Macklin et al., 2015) prior to this time. This shift in fluvial style seems to correspond with the transition from coarse to fine sediments observed around ~67 m +msl in the boreholes and ERT profiles (Fig. 4) and is corroborated regionally by the geological survey of Attia (1954), who similarly found coarse-grained deposits >11 m below the present surface in the Luxor region. The onset of flood plain formation is thought to coincide with a reoccupation of the flood plain by humans in the Nile Valley (Honegger & Williams, 2015; Kuper & Kröpelin, 2006). If the 5000–2500 B.C.E. age (range) for the lithological transition is adopted in the age–depth model for PC01, conservatively estimated sedimentation rates range between 1.4 and 5.3 mm/yr for the lower part of the flood basin (between 68 and 73 m +msl).

The fine-grained deposits found in the upper ~8 meters between AS52 and AS59 are typical of a flood basin environment in which sediment has accumulated during annual overbank events. The sandy deposits between 68 and 71 m +msl at boreholes AS57–58 are the only exception but may have been formed by a crevasse splay (based upon the minor size of the sand body), which concords with the overall impression of a low-lying flood basin environment (in which avulsions can also occur). The well-sorted fine to coarse silts settled in low-energetic flow or standing water during the waning stages of annual Nile floods. The overall fining upward sequence may be a logical trend following a slight incision of the meandering channel, in combination with the gradual formation and growth of levees following the major shift in discharge regime and fluvial pattern, and a steadily declining Nile discharge since 5000 B.C.E. with smaller floods resulting in finer overbank deposits. Rising levees would increasingly limit the deposition of (coarse) sediments across the river valley, and result in the typical convex flood plain of the Nile (Butzer, 1976). These patterns in deposition and sedimentation rates could also have potentially been caused by lateral eastward migration of the main Nile channel. However, such a driver can be largely ruled out in regard to the fining upward of flood basin deposits on the west bank. Direct evidence from sedimentary information from the east bank is largely lacking but various archaeological structures suggest the presence of a Nile channel in the central axis of the valley in the last four millennia (Fig. 2). Even if an anabranch existed in the present east bank region, sediment conveyed into the flood basin on the west bank would be derived from the branch in the central valley axis and the NK branch at the western desert edge. The activity and abandonment of the NK branch probably influenced sedimentation rates only locally, as suggested by the reconstructed sedimentation rates and general flood basin lithology; the central part of the flood basin seems largely unaffected by reconfigurations of the local fluvial landscape (NK channel and establishment of the 19th century channel), as these do not significantly overprint the overall fining upward trend. Therefore, the central part of the flood basin could thus be representative for the general (minimum) background sedimentation rates in the region.

The reconstructed 0.8–1.4 mm/yr of flood basin deposition in the upper meters fits well with generally assumed or inferred accumulation rates in the Theban region and Nile Valley more generally (e.g., Ball, 1939; Bunbury et al., 2008; Pacha, 1896). Using this range in rate of sediment accumulation, the cessation of deposition of much coarser deposits at 67 m +msl can be exploratively suggested to date between 9,000 and 4,700 B.C.E. This most certainly is, however, a maximum age as accumulation rates were higher in the period before the NK, suggested by the notions that a general fining of sediments usually goes hand in hand with a decrease in sedimentation rates (the deeper strata are uniformly coarser than the top), and that other studies have demonstrated a decrease in sedimentation rates over the last few millennia (Butzer, 1959; Ghilardi & Boraik, 2011). Considering these observations, the major transition in fluvial style thus approximately matches the aridification between 5000 and 2500 B.C.E. (e.g., Butzer, 1980; deMenocal et al., 2000; Krom et al., 2002).

6 | DISCUSSION

6.1 | Cultural dynamics and the fluvial landscape

The Nile valley has been occupied by humans during much of the Late Pleistocene and Holocene periods (Butzer, 1976; Honegger, and Williams, 2015; Said, 1993). Archaeological sites of prehistoric date are clustered on what is currently the desert edge (Honegger, & Williams, 2015; Takamiya, 2008; Vermeersch, Paulissen, and van Neer, 1990; Wendorf, & Schild, 1976), perhaps situated out of reach of turbulent Nile flows that prevailed during the earlier part of the Holocene (Butzer, 1998). The cultural migration into the Nile Valley broadly corresponds in time with the establishment of the modern (fine-grained) Nile flood plain after 6000 B.C.E. (Butzer, 1976; Honegger, and Williams, 2015; Said, 1993). It was upon this flood plain that the inhabitants of the valley then developed methods of floodwater farming, cultivating emmer wheat and barley (Wengrow, 2006). These crops formed the agricultural basis for development of the Ancient Egyptian state, which arose in the late fourth millennium B.C.E. (Butzer, 1976; Macklin, & Lewin, 2015).

In the Theban region, there is little evidence for flood plain utilization and widespread floodwater farming before the MK. Archaeological sites of a Predynastic (PP) to Old Kingdom (OK) (4000-2120 B.C.E.) age are uncommon in the area (Dorman, & Bryan, 2007; Gabolde 2013; Takamiya, 2008). Obviously, silt deposition and flood plain formation started before the MK–NK in the research area, because thick silty strata were found below cultural deposits of this age (Fig. 5). Therefore, it seems unlikely that the fluvial landscape exerted a pivotal role in the local cultural dynamics between the PP–MK; the flood plain was already in existence before the MK–NK and not susceptible to catastrophic changes, as shown by the gradual changes in lithology (Fig. 4). In addition, no cultural response (e.g., major changes in settlement locations or utilization of the riverine landscape) can locally be correlated with the major change in fluvial style between 5000 and 2500 B.C.E.—but such observations depend hugely on the data availability in the region, which is currently limited.

It is evident that a waterway was active during the NK in the western periphery of the Nile flood plain. This waterway was probably a natural channel: the nesting of deposits and the dimensions of the infill give no reason to suspect anthropogenic forcing of the abandonment of this waterway (Fig. 4). However, theoretically the channel could have its origins in a human-made feature, such as a canal that was taken over by regular river flow, since the lithology only provides an insight into the later stages of activity and channel abandonment. Although examples for this are not available from the Nile flood plain, human manipulation of waterways and the construction and maintenance of canals is known from contemporaneous ancient Mesopotamia (Heyvaert, & Baeteman, 2008). It is likely that ancient Egyptians exploited the opportunities that this branch offered and that the channel came to play an important role in the development of the Theban ritual landscape. This could explain apparent representations, albeit highly stylized, in NK tomb scenes (e.g., in the Khons TT31 and Neferhotep TT49 tombs: Davies, 1933; Schlüter, 2009; Wreszinski, 1923).

This minor river branch would have facilitated the transport and on-site delivery of construction material in the form of stone blocks. The existence of this channel would, however, probably not be wholly required for these constructions as the extensive labor force available for these projects could have allowed for the transport of blocks over considerable distances anyway—albeit with more effort through the construction of roads and ramps (e.g., Bloxam, Heldal, and Storemyr, 2007; Klemm, & Klemm, 2008). However, delivery of construction stone to the royal cult complex of Ramesses II by boat is known from texts found in the temple (Kitchen, 1991). The river branch would have also greatly facilitated the delivery of colossal statues, such as those known from the Temples of Amenhotep III and Ramesses II. Furthermore, the existence of this river branch enables reconsideration of the procession of Amun in his sacred barge during the Beautiful Festival of the Valley and allows for the reinterpretation of the elusive location of the *mryt* (riverbank-marketplace). The *mryt* was a place where goods were exchanged, where washermen did the laundry and the "court" was located. It is referred to in many texts from the Workers' Village of Deir el-Medina nestled in the Theban hills west of Amenhotep III's temple (Černý, 1973; Eyre, 1992; Kemp, 2006; McDowell, 1990, 1994; Ventura, 1986).

The gradual abandoning of the branch during or at the end of the NK was probably not a causal factor in the cessation of construction of royal cult temples. Even without new temples, the importance of the Theban cosmogonical landscape with its symbolic festivals persisted long after the end of the NK. This suggests that the developing political instability and eventual devolution, along with the accompanying cultural changes at the end of the NK, were more important for the termination of temple construction on the West Bank than the abandonment of a local river branch. Nonetheless, the presence of the NK minor Nile branch could still have played an important role in the configuration of human activities in the ancient landscape, at least at a local level. The specific planning and layout of temple complexes on the adjacent desert edge and the high-density clustering of royal cult temples at the location where the river channel was very close to the higher grounds (Fig. 6) could be largely related to the local land- and waterscape. Large complexes such as the royal cult Temple of Amenhotep III, the Ramesseum, and potentially Medinet Habu seem positioned to face the location of the abandoned channel (Fig. 6). Amenhotep III's Temple even extends into the flood plain and may have approximated the former levee of the river branch, which probably signifies the symbolic importance regarding rejuvenation and rebirth reflected by the river and floods to the ancient Egyptian civilization (Assmann, 2005).

Currently no data or indications from anomalous field patterns are available to trace the upstream and downstream route of the minor channel. For the downstream route, the channel must have curved back at some point toward the main axis of the Nile valley to join up with the main river because the Holocene alluvial valley narrows directly to the north (Fig. 2). It would thus have been positioned closely to the wadi outwash that connects to the Valley of the Kings and reveals that the Royal Cult Temple of Seti I could also have been close to the waterway (Fig. 6).

For the upstream region it is more uncertain where the channel was positioned and where it branched off the main river. In this respect

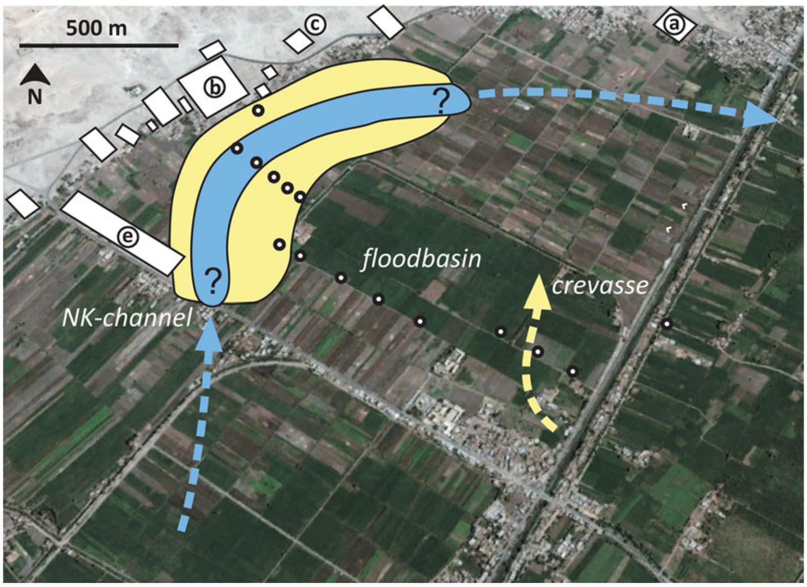

FIGURE 6 Reconstruction of the NK fluvial landscape with the main geomorphological elements and suggested upstream and downstream locations of the NK Nile branch
Notes: Dots indicate borehole locations, labels for archaeological sites are provided in Figure 1. Blue colors suggest the maximum open channel width, yellow indicates the width of sandy deposits (levees and crevasse splay deposits).
[Color figure can be viewed at wileyonlinelibrary.com]

the location of Birket Habu (Fig. 2), thought to be an ancient harbor or ceremonial lake (Kemp & O'Connor, 1974), is interesting because it has not yet been associated with a Nile channel running in its proximity. Future studies are planned to tie this location and other important archaeological sites to the fluvial landscape and which could offer further explanation regarding the selection of site locations and how the Nile influenced cultural dynamics in the Nile Valley.

6.2 | Hydroclimatic variability in the Nile basin

Several studies have reported on the relationship between hydroclimatic change in the Nile basin, the occurrence and magnitudes of floods, and periods of cultural flourishing, resilience, and breakdown (e.g., Butzer, 2012; Macklin, & Lewin, 2015). Hydroclimatic change is often registered in the fluvial record, for example, as individual sedimentary units associated with extreme floods, depositional hiatuses, and soil or crust formation in periods of failing floods and drought, and phases of channel contraction and entrenchment versus episodes of aggradation (Macklin et al., 2013; Macklin et al., 2015; Toonen, Foulds, Macklin, & Lewin, 2017). The geoarchaeological information of the Theban region presented here demonstrates that there have been periods of river avulsion and abandonment, and that the flood basin features several distinct calcareous paleosols, which are all potentially related to periods of hydroclimatic change.

The two distinct calcareous paleosols were identified based on an increased occurrence of calcareous nodules and a white coloring of the sediment matrix. A well-developed upper paleosol is located between 71 and 73 m +msl and a second, slightly less developed zone around 69 and 70 m +msl (Fig. 4). These horizons are consistent across the transect in the western flood plain, except at the location of the minor branch of the Nile where only a single well-developed (upper) paleosol horizon was found (Figs. 4 and 5). The occurrence of NK ceramics at similar levels as the upper paleosol suggests that very limited overbank deposition occurred in the late NK (Figs. 4 and 5), contemporaneous with the drying out of the NK river branch. The late NK date for paleosol development corroborates evidence from other studies for low Nile flows in the second half of the NK (*cf*. Butzer, 2012; Macklin et al., 2015; Said, 1993), and coincides with the decline of the NK. Similar to the Theban region, a period of channel abandonment was dated to shortly after 1300 B.C.E. in Northern Sudan, near Amara West (Fig. 1; Woodward, Macklin et al., 2015). There, the change in flood plain configuration is suggested to have had a major impact on the local riparian societies (Spencer, Macklin, & Woodward, 2012; Woodward et al., 2017). The same period is also marked by dunefield migration into the Nile flood plain and regional development of salt crusts (de Heinzelin, 1968).

The lower paleosol is found only in the flood basin deposits (Fig. 4), located roughly 1–2 m below the NK horizon. Its precise age is unknown due to a lack of archaeological material or independent dating information, but based on the suggested sedimentation rates in the deeper part of the flood basin (1.4–5.3 mm/yr; Fig. 5), it can be assumed to be between *c.* 200 and 1400 years older than the NK. This places the age of this lower paleosol conservatively between 2950 and 1750 B.C.E., which broadly overlaps with the period of failing floods and drought that coincided with the end of the OK period (2200 and 2150 B.C.E.; Butzer, 2012; Said, 1993; Stanley, Krom, Cliff, & Woodward, 2003). In the same period, declining discharges of the Nile have been recorded in Nile delta deposits and Mediterranean marine sediments (Blanchet et al., 2013; Krom et al., 2002) and have been linked with the widespread 2200 B.C.E. climate event (e.g., Gasse, 2000). The correlation between the lower paleosol and historical droughts is tentative, due to the relatively large uncertainty in age, and requires more detailed study. If it can be confirmed that the lower paleosol is indeed of OK age, it directly ties Mediterranean (marine) records to geoarchaeological observations and climate proxy records from upstream riverine regions and lakes in the upstream part of the Nile basin (e.g., Krom et al., 2002; Williams, 2009).

7 | CONCLUSIONS

The subsoil of the flood plain west of the present Nile at ancient Thebes (Luxor, Egypt) is characterized by the presence of fluvial deposits that provide evidence for the former existence of a minor branch of the river Nile that silted up at the end of the NK period. A flood basin divided the NK channel from the main channel belt of the Nile in the central axis of the valley, and indicates that the minor branch came into existence by a regional partial river avulsion and not by gradual lateral migration of the river bed. The preserved facies of the abandonment phase give no reason to suspect human manipulation of the fluvial system. However, initial stages of channel establishment cannot be fully investigated as later (natural) flow has eroded and obscured previous deposits, and the former avulsion node still has to be located.

The presence of a waterway would have been important for cultural dynamics in the region by tying together the ritual places in the various parts of the fluvial landscape by facilitating transport between them by providing a way of easy access by boat to royal cult temple complexes and construction sites that had to be supplied with huge building blocks from distant quarry sites. The presence or absence of a channel would probably not have affected the ability to undertake large construction projects during the NK, but the concentration of contemporaneous archaeological sites adjacent to the NK channel does suggest an important role of the local fluvial landscape in the configuration of the cultural and ritual landscape.

Although many fabrics of the recovered ceramics returned a broad range of age estimates, the extremely high abundance of ceramic material constrained the ages of deposits in many intervals to relatively narrow windows. This made it possible to date the infill of the minor Nile branch during the later part of the NK, to constrain flood plain sedimentation rates, and to date a NK paleosol and to approximate the age of a lower (older) paleosol. Reconstructed sedimentation rates, ranging between 0.8 and 1.4 mm/yr in the (upper part of the) flood basin, agree with previous estimates for overbank mud accumulation in the Nile Valley. Importantly, there seems to be a major decrease in sedimentation rates after the NK, which is also evidenced by a gradual upward fining trend in deposits, reflecting less energetic flow conditions on the flood plain. The abandonment of the minor channel of the Nile and the regional formation of a well-developed calcareous paleosol are dated to the same late NK Period, and could be contemporaneous with the decline of the NK state. Hydroclimatic change in the Nile basin most likely drove the general changes in the river configuration at Thebes and contributed along with other internal and external factors to major socioeconomic and political change in Egypt. A lower calcareous paleosol, located at least 1 m below the NK horizon, hints at a previous period of severe drought and is tentatively inferred to be of OK age. The age of this lower paleosol needs to be confirmed by more precise dating, but if correlative it would add to the ongoing debate on the fragmentation of the OK.

ACKNOWLEDGMENTS

This research was made possible through a Wallenberg Academy Fellows grant from the Knut and Alice Wallenberg Foundation and Uppsala University (2014-19) to AG. WT acknowledges the support of the NWO Rubicon grant (825.14.005). The project operates through the auspices of Egypt Exploration Society (London) and the Ministry of State for Antiquities (MSA, Egypt). The project thanks the MSA for their continued support of our research and our Luxor MSA Inspectors for facilitating the smooth running of the fieldwork. Ray Johnson (Director, Epigraphic Survey, University of Chicago Oriental Institute) is cordially thanked for his support. Our thanks go to Reis Alaa Farouk and his superb team (West Bank coring and sieving crews) for their conscientious hard work and good humor. Thanks also to Reis Ali Farouk and Reis Omar Farouk for their logistical support of our work. We are indebted to all the landowners for allowing access to their paths and fields. Martin Williams and an anonymous reviewer are thanked for their constructive and supportive comments.

REFERENCES

Arnold, D., & Bourriau, J. (1993). *An introduction to ancient Egyptian pottery*. Mainz am Rhein: Philipp Von Zabern.

Assmann, J. (2005). *Death and salvation in ancient Egypt*. Ithaca and London: Cornell University Press.

Aston, D. A. (1999). *Elephantine XIX. Pottery from the Late New Kingdom to the Early Ptolemaic Period*. Archäologische Veröffentlichungen, 95. Mainz am Rhein: Philipp Von Zabern.

Aston, D. A., Dominicus, B., Ford, P. O., & Jaritz, H. (2008). Untersuchungen Im Totentempel Des Merenptah in Theben, Band IV: The Pottery. *Beitrage Zur Agyptischen Bauforschung Und Altertumskunde*. Mainz am Rhein: Philipp Von Zabern.

Attia, M. I. (1954). *Deposits in the Nile valley and the delta*. Cairo: Geological Survey of Egypt.

Bailey, D. M. (1999). Sebakh, sherds and survey. *Journal of Egyptian Archaeology*, *85*, 211–218.

Ball, J. (1939). *Contributions to the geography of Egypt*. Cairo: Goverment Press Bulaq.

Bell, L. (1997). The New Kingdom divine temple: The example of Luxor. In B. E. Shafer (Ed.), *Temples of ancient Egypt* (pp. 127–184). New York: Cornell University Press.

Blanchet, C. L., Tjallingii, R., Frank, M., Lorenzen, J., Reitz, A., Brown, K., … Brückmann, W. (2013). High- and low-altitude forcing of the Nile River regime during the Holocene inferred from laminated sediments of the Nile deep-sea fan. *Earth and Planetary Science Letters*, *364*, 98–110.

Bloxam, E., Heldal, T., & Storemyr, P. (2007). Characterisation of complex quarry landscapes; an example from the West Bank quarries, Aswan. *QuarryScapes Report 4:4*. Trondheim: Geological Survey of Norway.

Boraik, M. (2010). Excavations of the quays and the embankment in front of Karnak temples: Preliminary report. *Cahiers de Karnak* 13 (pp. 65–78). Cairo: Ministry of Antiquities Press.

Boraik, M., Gabolde, L., & Graham, A. (2017). Karnak's quaysides: Evolution of the embankments from the Eighteenth Dynasty to the Graeco-

Roman period. In H. Willems & J.-M. Dahms (Eds.), *The Nile: Natural and cultural landscape in Egypt* (pp. 97–144). Proceedings of the Nile–Natural Landscape and Cultural Landscape 22nd–23rd February 2013, Forschungsschwerpunkt Historische Kulturwissen-schaften, Mainz, Historische Kulturwissenschaften series. Bielefeld: Transcript.

Boraik, M., Ghilardi, M., Abdel-Hafiz, S. B., Hatim Ali, M., El Masekh, S., & Mahmoud, A. G. (2010). Geomorphological investigations in the western part of the Karnak temple (quay and ancient harbour): First results derived from stratigraphical profiles and manual auger boreholes and perspectives of research. *Cahiers de Karnak* 13 (pp. 101–109). Cairo: Ministry of Antiquities Press.

Borchardt, L. (1906). *Nilmesser und nilstandsmarken*. Berlin: Verlag der Konigl. Akademie der Wissenschaften in Kommission bei Georg Reimer.

Bourriau, J. (2010). The survey of Memphis IV: Kom Rabia—The New Kingdom Pottery. *Excavation Memoir, 93*. London: Egypt Exploration Society.

Bourriau, J., Nicholson, P. T., & Rose, P. (2000). *Pottery*. In P. T. Nicholson & I. Shaw (Eds.), *Ancient Egyptian materials and technology* (pp. 121–147). Cambridge: Cambridge University Press.

Bronk Ramsey, C., Dee, M. W., Rowland, J. M., Higham, T. F. G., Harris, S. A., Brock, F., … Shortland, A. J. (2010). Radiocarbon-based chronology for dynastic Egypt. *Science*, *328*, 1554–1557.

Bunbury, J. M., Graham, A., & Hunter, M. A. (2008). Stratigraphic landscape analysis: Charting the Holocene movements of the Nile at Karnak through Ancient Egyptian time. *Geoarchaeology*, *23*, 351–373.

Butzer, K. W. (1959). Environment and human ecology in Egypt during Predynastic and early Dynastic times. *Bulletin de la Societe de Geographie d'Egypte*, *32*, 43–87.

Butzer, K. W. (1976). *Early hydraulic civilization in Egypt: A study in cultural ecology*. London and Chicago: University of Chicago Press.

Butzer, K. W. (1980). Pleistocene history of the Nile valley in Egypt and lower Nubia. In M. A. J. Williams & H. Faure (Eds.), *The Sahara and the Nile* (pp. 253–280). Rotterdam: Balkema.

Butzer, K. W. (1997). Sociopolitical discontinuity in the near east *c.* 2200 B.C.E.: Scenarios from Palestine and Egypt. In: H. N. Dalfes, G. Kukla & H. Weiss (Eds.), *Third millennium BC climate change and old world collapse: NATO ASI series I: Global environmental change* (Vol. 49, pp. 245–296). Berlin, Heidelberg: Springer.

Butzer, K. W. (1998). Late Quaternary problems of the Egyptian Nile: Stratigraphy, environments, prehistory. *Paléorient*, *23*, 151–173.

Butzer, K. W. (2012). Collapse, environment, and society. *Proceedings of the National Academy of Sciences*, *109*, 3632–3639.

Cabrol, A. (2001). *Les Voies Processionnelles de Thèbes*. Orientalia Lovaniensia Analecta, 97. Leuven: Peeters.

Castañeda, I. S., Schouten, S., Pätzold, J., Lucassen, F., Kasemann, S., Kuhlmann, H., & Schefuß, E. (2016). Hydroclimate variability in the Nile River basin during the past 28,000 years. *Earth and Planetary Science Letters*, *438*, 47–56.

Černý, J. (1973). *A community of workmen at Thebes in the Ramesside period*. Bibliothèque d'Étude, 50. Le Caire: Institut français d'Archéologie orientale.

Chevrier, H. (1947). Rapport sur les travaux de Karnak. *Annales du Service des Antiquitiés de l'Egypte*, *46*, 147–161.

Clark, A. (1996). *Seeing beneath the soil: Prospecting methods in archaeology*. London: Batsford.

Daressy, G. (1920). Notes sur Louxor de la période romaine et copte. *Annales du Service des Antiquitiés de l'Egypte*, *19*, 159–175.

David, R., Barahona Mendieta, Z., Consonni, A., Lecuyot, G., Marangou, A., Marchand, S., … Simony, A. (2016). Theban ceramics in Hellenistic context—Fabrics classification. In R. David (Ed.), *Céramiques ptolémaïques de la région thébaine, Cahiers de la Céramique Égyptienne 10* (pp. 11–22). Cairo: IFAO.

Davies, N. de G. (1933). *The tomb of Nefer-hotep at Thebes. Vol. I*. Publications of the Metropolitan Museum of Art Egyptian Expedition, 9. New York: Metropolitan Museum of Art.

de Heinzelin, J. (1968). *Geological history of the Nile valley in Nubia*. In F. Wendorf (Ed.), *Prehistory of Nubia* (pp. 19–55). Dallas, TX: Southern Methodist University Press.

deMenocal, P., Ortiz, J., Guilderson, T., Adkins, J., Sarnthein, M., Baker, L., & Yarusinsky, M. (2000). Abrupt onset and termination of the African Humid Period: Rapid climate responses to gradual insolation forcing. *Quaternary Science Reviews*, *19*, 347–361.

Doresse, M. (1979). Le Dieu voilé dans sa châsse et la fête du début de la décade. *Revue d'Égyptologie*, *31*, 36–65.

Dorman, P. F. & Bryan, B. M. (2007). Preface. In P. F. Dorman & B. M. Bryan (Eds.), *Sacred space and sacred function in ancient Thebes* (pp. xiii–xviii). Studies in ancient oriental civilization 61. Chicago, IL: Oriental Institute of the University of Chicago.

Engelbach, R., & Macaldin, J. W. (1938). The great lake of Amenophis III at Medinet Habu. *Bulletin de l'Institut d'Égypte*, *20*, 51–61.

Eyre, C. J. (1992). Review: Raphael Ventura, *Living in a City of the Dead. A selection of topographical and administrative terms in the documents of the Theban Necropolis*. Freiburg (Schweiz), Universitätsverlag/Göttingen, Vandenhoeck & Ruprecht, 1986. *Chronique d'Égypte* 67, 134, 277–281.

Foucart, G. (1924). Études thébaines: la belle fête de la vallée. *Bulletin de l'Institut Français d'Archéologie Orientale*, *24*, 1–209.

Gabolde, L. (2000). Origines d'Amon et origines de Karnak. Égypte. *Afrique et Orient*, *16*, 3–12.

Gabolde, L. (2013). Les origines de Karnak et la genèse de la théologie d'Amon. *Bulletin de la Société Française d'Égyptologie*, *186–187*, 13–35.

Garzanti, E., Ando, S., Padoan, M., Vezzoli, G. & El Kammar, A. (2015). The modern Nile sediment system: Processes and products. *Quaternary Science Reviews*, *130*, 9–56.

Gasse, F. (2000). Hydrological changes in the African tropics since the Last Glacial Maximum. *Quaternary Science Reviews*, *19*, 189–211.

Ghilardi, M., & Boraik, M. (2011). Reconstructing the Holocene depositional environments in the western part of Ancient Karnak temples complex (Egypt): A geoarchaeological approach. *Journal of Archaeological Science*, *38*, 3204–3216.

Goyon, J. C., Golvin, J. C., Simon-Boidot, C., & Martinet, G. (2004). *La construction pharaonique du Moyen Empire à l'époque gréco-romaine: context et principies technologiques*. Paris: Éditions Picard.

Graefe, E. (1986). Talfest. In W. Helck & E. Otto (Eds.), *Lexikon der Ägyptologie, VI. Stele—Zypresse* (pp. 187–189). Wiesbaden: Otto Harrassowitz.

Graham, A. (2010a). Islands in the Nile: A geoarchaeological approach to settlement locations in the Egyptian Nile valley and the case of Karnak. In M. Bietak, E. Czerny & I. Forstner-Müller (Eds.), *Cities and Urbanism in ancient Egypt* (pp. 125–143). Denkschriften der Gesamtakademie, LX. Untersuchungen der Zweigstelle Kairo des Österreichischen Archäologischen Instituts, XXXV. Vienna: Verlag der Österreichischen Akademie der Wissenschaften.

Graham, A. (2010b). Ancient landscapes around the Opet temple, Karnak. *Egyptian Archaeology*, *36*, 25–28.

Graham, A., Strutt, K. D., Hunter, M. A., Jones, S., Masson, A., Millet, M., & Pennington, B. T. (2012). Theban Harbours and Waterscapes Survey 2012. *Journal of Egyptian Archaeology*, *98*, 27–42.

Graham, A., Strutt, K. D., Hunter, M. A., Pennington, B. T., Toonen, W. H. J., & Barker, D. S. (2014). Theban Harbours and Waterscapes Survey 2014. *Journal of Egyptian Archaeology*, *100*, 41–53.

Graham, A., Strutt, K. D., Toonen, W. H. J., Pennington, B. T., Löwenborg, D., Masson, A., … Johansson, C. (2016). Theban Harbours and Waterscapes Survey 2015. *Journal of Egyptian Archaeology*, *101*, 37–49.

Hennekam, R., Jilbert, T., Schnetger, B., & de Lange, G. J. (2014). Solar forcing of Nile discharge and sapropel S1 formation in the early to middle Holocene eastern Mediterranean. *Paleoceanography*, *29*, 343–356.

Heyvaert, V. M. A., & Baeteman, C. (2008). A middle to late Holocene avulsion history of the Euphrates river: A case study from Tell ed-Dēr, Iraq, lower Mesopotamia. *Quaternary Science Reviews*, *27*, 2401–2410.

Hillier, J. K., Bunbury, J. M., & Graham, A. (2007). Monuments on a migrating Nile. *Journal of Archaeological Science*, *34*, 1011–1015.

Hölscher, U. (1934). *The excavation of Medinet Habu. Vol. I. General plans and views*. Oriental Institute Publications, 21. Chicago, IL: University of Chicago Press.

Honegger, M., & Williams, M. (2015). Human occupations and environmental changes in the Nile valley during the Holocene: The case of Kerma in Upper Nubia (northern Sudan). *Quaternary Science Reviews*, *130*, 141–154.

Hornung, E., Krauss, R., & Warburton, D. (2006). *Ancient Egyptian chronology*. Handbook of Oriental Studies, 83. Section 1: The Near and Middle East. Leiden: Brill.

Indeje, M., Semazzi, F. H. M., & Ogallo, L. J. (2000). ENSO signals in East African rainfall seasons. *International Journal of Climatology*, *20*, 19–46.

Jacotin, M. 1821. *Carte Topographique de l'Égypte et de plusieurs parties des pays limitrophes; levée pendant l'Expédition de l'Armée Française par les Ingénieurs - Géographes, les Officiers du Génie Militaire et les Ingénieurs des Ponts et Chaussées; assujettie aux Observations des astronomes, Construite par M. Jacotin. Gravées au depot Général de la Guerre, à l'Echelle de 1 Millimètre pour 100 Mètres*. Paris: Publiée par ordre du Gouvernement.

Jaritz, H. (2005). Die Tribünen vor ägyptischen Tempeln der 18. Dynastie bis zur Römerzeit. Ein Deutungsversuch zur Funktion. In P. Jánosi (Ed.), *Structure and significance: Thoughts on ancient Egyptian architecture* (pp. 341–400). Denkschriften der Gesamtakademie, 33. Untersuchungen der Zweigstelle Kairo des Österreichischen Archaölogischen Institutes, 25. Vienna: Verlag der Österreichischen Akademie der Wissenschaften.

Johnson, W. R. (1998). Monuments and monumental art under Amenhotep III: Evolution and meaning. In D. B. O'Connor & E. H. Cline (Eds.), *Amenhotep III: Perspectives on his reign* (pp. 63–94). Ann Harbor, MI: University of Michigan Press.

Kemp, B., & O'Connor, D. (1974). An ancient Nile harbour: University Museum excavations at the Birket Habu. *International Journal of Nautical Archaeology*, *3*, 101–136.

Kemp, B. J. (2006). *Ancient Egypt: Anatomy of a civilisation* (2nd ed.). London: Routledge.

Kemp, B. J. (2012). *The city of Akhenaten and Nefertiti*. London: Thames and Hudson.

Kitchen, K. A. (1991). Building the Ramesseum. *Cahier de Recherches de l'Institut de Papyrologie et d'Égyptologie de Lille*, *13*, 85–93.

Klappa, C. F. (1991). Rhizoliths in terrestrial carbonates: Classification, recognition, genesis and significance. In V. P. Wright & M. E. Tucker (Eds.), Calcretes. *International Association of Sedimentology* (pp. 149–165) Oxford: Blackwell Publishing (Reprinted from *Sedimentology* (1980) 27, 613–629).

Klemm, R., & Klemm, D. D. (2008). *Stones and quarries in Ancient Egypt*. London: British Museum Press.

Krom, M. D., Stanley, J. D., Cliff, R. A., & Woodward, J. C. (2002). River Nile sediment fluctuations over the past 7000 yr and their key role in sapropel development. *Geology*, *30*, 71–74.

Kuper, R., & Kröpelin, S. (2006). Climate-controlled Holocene occupation in the Sahara: Motor of Africa's evolution. *Science*, *313*, 803–807.

Lacau, P. (1934). Inscriptions Latines du Temple de Louxor. *Annales du Service des Antiquitiés de l'Egypte*, *34*, 17–46.

Lacau, P., & Chevrier, H. (1977). Une chapelle d'Hatshepsout à Karnak I. Le Caire: Le Service des Antiquités de l'Égypte avec la collaboration de l'Institut français d'Archéologie orientale du Caire.

Lauffray, J., Traunecker, C., & Sauneron, S. (1975). La tribune du quai de Karnak et sa favissa: Compte rendu des fouilles menées en 1971–1972 (2e campagne). In *Centre Franco-Égyptien d'Étude des Temples de Karnak*, Karnak V: 1970–1972 (pp. 43–76). Le Caire: Mission permanente du C.N.R.S. en Egypte.

Le Bohec, R., & Millet, M. (2012). Karnak, Le Temple d'Amon. Étude de la poterie et des contextes stratigraphiques de la cour nord du 4e pylône. *Bulletin de la Céramique Égyptienne*, *23*, 147–170.

Legrain, G. (1917). Rapport sur les nouveaux travaux exécutés à Louqsor à l'ouest du temple d'Amon (octobre 1916–mars 1917). *Annales du Service des Antiquitiés de l'Egypte*, *17*, 49–75.

Lewin, J., & Ashworth, P. J. (2014). Defining large river channel patterns: Alluvial exchange and plurality. *Geomorphology*, *215*, 83–98.

Loke, M. H., & Dahlin, T. (2002). A comparison of the Gauss-Newton and quasi-Newton methods in resistivity imaging inversion. *Journal of Applied Geophysics*, *49*, 149–162.

Macklin, M. G., & Lewin, J. (2015). The rivers of civilization. *Quaternary Science Reviews*, *114*, 228–244.

Macklin, M. G., Toonen, W. H. J., Woodward, J. C., Williams, M. A. J., Flaux, C., Marriner, N., … Welsby, D. (2015). A new model of river dynamics, hydroclimatic change and human settlement in the Nile valley derived from meta-analysis of the Holocene fluvial archive. *Quaternary Science Reviews*, *130*, 109–123.

Macklin, M. G., Woodward, J. C., Welsby, D. A., Duller, G. A. T., Williams, F. M., & Williams, M. A. J. (2013). Reach-scale river dynamics moderate the impact of rapid climate change on floodwater farming in the desert Nile. *Geology*, *41*, 695–698.

Masson, A. (2007). Le quartier des prêtres du temple de Karnak: Rapport préliminaire de la fouille de la Maison VII. *Cahiers de Karnak* 12 (pp. 593–655). Paris: Éditions Soleb.

Masson, A. (2011). Persian and Ptolemaic ceramics from Karnak: Change and continuity. *Cahiers de la Céramique Egyptienne*, *9*, 269–310.

Masson, A. (2013). Domestic and cultic vessels from the quarter of priests in Karnak: The fine line between the profane and the sacred. In B. Bader & M., Ownby (Eds.), *Functional aspects of Egyptian ceramics in their archaeological context. Proceedings of a Conference held at the McDonald Institute for Archaeological Research, Cambridge, July 24th–July 25th, 2009* (pp. 141–164). Orientalia Lovaniensia Analecta 217. Leuven: Peeters.

Masson, A. (2015). Toward a new interpretation of the fire at North-Karnak? A study of the ceramic from the building NKF35. *Cahiers de Karnak* 15 (pp. 189–213). Cairo: Ministry of Antiquities Press.

Masson, A. (2016). Ptolemaic ceramics of the Theban region between tradition, imitation and innovation: The priests' quarter as a study case. In R. David (Ed.), *Céramiques ptolémaïques de la région thébaine, Cahiers de la Céramique Égyptienne 10* (pp. 149–164). Cairo: IFAO.

McDowell, A. G. (1990). Jurisdiction in the workmen's community of Deir el-Medîna. *Egyptologische Uitgaven* (Vol. 5). Leiden: Nederlands Instituut voor het Nabije Oosten.

McDowell, A. G. (1994). Contact with the outside world. In L. H. Lesko (Ed.), *Pharaoh's workers. The villagers of Deir el Medina* (pp. 41–59). Ithaca and London: Cornell University Press.

Millet, M. (2007). Architecture civile antérieure au Nouvel Empire: Rapport préliminaire des fouilles archéologiques à l'est du lac Sacré 2001–2003. *Cahiers de Karnak* 12 (pp. 681–743). Paris: Éditions Soleb.

Millet, M. (2008). *Installations antérieures au Nouvel Empire au sud-est du lac sacré du Temple d'Amon de Karnak* (PhD thesis). University of Paris IV, La Sorbonne, Paris.

Murnane, W. J. (1980). *United with eternity. A concise guide to the monuments of Medinet Habu*. Chicago, IL: University of Chicago.

Murnane, W. J. (1982). *Opetfest*. In W. Helck & E. Otto (Eds.), *Lexikon der Ägyptologie, IV. Megiddo-Pyramiden* (pp. 574–579). Wiesbaden: Otto Harrassowitz.

Murray, J. (1888). *A handbook for travellers in lower and upper Egypt, part 1*. London and Alexandria: Murray and Penasson.

O'Connor, D. 1998. The city and the world: Worldview and built forms in the reign of Amenhotep III. In D. B. O'Connor & E. H. Cline (Eds.), *Amenhotep III: Perspectives on his reign* (pp. 125–172). Ann Arbor, MI: University of Michigan Press.

Pacha, V. 1896. Crues modernes et crues anciennes du Nil. *Zeitschrift für Agyptische Sprache*, *34*, 95–107.

Quickel, A. T., & Williams, G. (2016). In Search of Sibākh: Digging up Egypt from antiquity to the present day. *Journal of Islamic Archaeology*, *3*(1), 89–108.

Retallack, G. J. (1990). *Soils of the past: An introduction to paleopedology*. Boston, MA: Unwin Hyman.

Rose, P. J. (2007). *The Eighteenth Dynasty pottery corpus from Amarna*. Excavation Memoir 83. London: Egypt Exploration Society.

Said, R. (1993). *The river Nile: Geology, hydrology and utilization*. Oxford: Pergamon Press.

Schlüter, A. (2009). *Sakrale Architektur im Flachbild: Zum Realitatsbezug Von Tempeldarstellungen*. Agypten Und Altes Testament 78. Wiesbaden: Otto Harrassowitz.

Schmidt, A. (2013). *Earth resistance for archaeologists. Geophysical methods for archaeology* (Vol. 3). Lanham: Altamira Press.

Schott, S. (1953). *Das schöne Fest vom Wüstentale. Festbräuche einer Totenstadt*. Abhandlungen der Geistes- und Sozialwissenschaftlichen Klasse 11. Wiesbaden: Verlag der Akademie der Wissenschaften und der Literatur in Mainz.

Scollar, I., Tabbagh, A., Hesse, A., & Herzog, I. (1990). *Archaeological prospecting and remote sensing*. Cambridge: Cambridge University Press.

Seidlmayer, S. J. (2001). *Historische und moderne Nilstände: Untersuchungen zu den Pegelablesungen des Nils from der Frühzeit bis in die Gegenwart*. Achet A1. Berlin: Achet Verlag.

Shortland A. J., & Bronk Ramsey, C. (2013). *Radiocarbon and the chronologies of ancient Egypt*. Oxford: Oxbow Books.

Spencer, N., Macklin, M. G., & Woodward, J. C. (2012). Re-assessing the abandonment of Amara West: The impact of a changing Nile? *Sudan and Nubia*, *16*, 37–43.

Stadelmann, R. (1984). Die Herkunft der Memnon-Kolosse: Heliopolis oder Aswan? *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo*, *40*, 291–296.

Stanley, J. D., Krom, M. D., Cliff, R. A., & Woodward, J. C. (2003). Nile flow failure at the end of the Old Kingdom Egypt: Strontium isotopic and petrologic evidence. *Geoarchaeological International Journal*, *18*, 395–402.

Takamiya, I. (2008). The Thebes-Armant region during the Predynastic (Naqada) period in Egypt. *Orient*, *43*, 23–44.

Toonen, W. H. J., Foulds, S. A., Macklin, M. G., & Lewin, J. (2017). Events, episodes, and phases: Signal from noise in flood-sediment archives. *Geology*, *45*, 331–334. Retrieved from https://doi.org/10.1130/G38540.1

Toonen, W. H. J., Kleinhans, M. G., & Cohen, K. M. (2012). Sedimentary architecture of abandoned channel fills. *Earth Surface Processes and Landforms*, *37*, 459–472.

Trampier, J., Toonen, W. H. J., Simony, A., & Starbird, J. (2013). Missing koms and abandoned channels: The potential of regional survey in the western Nile delta landscape. *Journal of Egyptian Archaeology*, *99*, 217–240.

Ullmann, M. (2016). The temples of millions of years at western Thebes. In R.H. Wilkinson & K.R. Weeks (Eds.), *The Oxford handbook of the Valley of the Kings* (pp. 417–432). Oxford: Oxford University Press.

van Dijk, J. (2000). *The Amarna Period and the Later New Kingdom (c.1352-1069 BC)*. In I. Shaw (Ed.), *The Oxford history of ancient Egypt* (pp. 272–313). Oxford: Oxford University Press.

Ventura, R. (1986). *Living in a City of the Dead. A selection of topographical and administrative terms in the documents of the Theban Necropolis*. Orbis Biblicus et Orientalis, 69. Freiburg, Schweiz: Universitätsverlag/Göttingen—Vandenhoeck & Ruprecht.

Vercoutter, J. (1966). Semna South Fort and the records of Nile levels at Kumma. *KUSH*, *14*, 125–164.

Vermeersch, P. M., Paulissen, E., & van Neer, W. (1990). La Paléolithique de la vallée du Nil égyptien. *L'Anthropologie*, *94*, 435–458.

Wallace, S. L. (1938). *Taxation in Egypt from Augustus to Diocletian*. Princeton, NJ: Princeton University Press.

Wehausen, J. V., Mansour, A., Ximenes, M. C., & Stross, F. (1988). The colossi of Memnon and Egyptian barges. *International Journal of Nautical Archaeology and Underwater Exploration*, *17*, 295–310.

Wendorf, F., & Schild, R. (1976). *Prehistory of the Nile valley*. New York: Academic Press.

Wengrow, D. (2006). *The archaeology of early Egypt: Social transformations in north-east Africa, 10000 to 2650 BC*. Cambridge: Cambridge University Press.

Wente, E. F. (1967). *Late Ramesside Letters*. Chicago, IL: Oriental Institute of the University of Chicago.

Wilkinson, J. G. (1830). *Topographical survey of Thebes, Tape, Thaba, or Diospolis Magna*. London: The Royal Geographical Society.

Willcocks, W., & Craig, J. I. (1913). Egyptian irrigation *(3rd ed.)*. London: E. & F.N. Spon.

Williams, M. A. J. (2009). Late Pleistocene and Holocene environments in the Nile basin. *Global and Planetary Change*, *69*, 1–15.

Williams, M. A. J., Duller, G. A. T., Williams, F. M., Woodward, J. C., Macklin, M. G., El Tom, O. A. M., … Barrows, T. T. (2015). Causal links between Nile floods and eastern Mediterranean sapropel formation during the past 125 kyr confirmed by OSL and radiocarbon dating of Blue and White Nile sediments. *Quaternary Science Reviews*, *130*, 89–108.

Wilson, D. R. (2000). *Air photo interpretation for archaeologists* (2nd ed.). Stroud: Tempus.

Woodward, J. C., Macklin, M. G., Fielding L., Millar, I., Spencer, N., Welsby, D., & Williams, M. (2015). Shifting sediment sources in the world's longest river: A strontium isotope record for the Holocene Nile. *Quaternary Science Reviews*, *130*, 124–140.

Woodward, J. C., Macklin, M. G., Spencer, N., Binder, M., Dalton, M., Hay, S., & Hardy, A. (2017). Living with a changing river and desert landscape at Amara West. In N. Spencer, A. Stevens, & M. Binder (Eds.), *Nubia in the New Kingdom: Lived experience, pharaonic control and indigenous traditions* (pp. 227–257). Egypt and Sudan: British Museum Publications.

Woodward, J. C., Macklin, M. G., & Welsby, D. (2001). The Holocene fluvial sedimentary record and alluvial geoarchaeology in the Nile valley of northern Sudan. In D.R. Maddy, M.G. Macklin & J.C. Woodward (Eds.), *River basin sediment systems: Archives of enviromental change* (pp. 327–355). Rotterdam: A.A. Balkema.

Woodward, J. C., Williams, M. A. J., Garzanti, E., Macklin, M. G., & Marriner, N. (2015). From source to sink: Exploring the Quaternary history of the Nile Quaternary. *Science Reviews*, *130*, 3–8.

Wreszinski, W. 1923. *Atlas zur altägyptischen Kulturgeschichte. Teil I*. Leipzig: J.C. Hinrichs'sche Buchhandlung.

Wright, V. P., & Tucker, M. E. (1991). Calcretes: An introduction. In V.P. Wright, & M.E. Tucker (Eds.), *Calcretes*. International Association of Sedimentology (pp. 1–22). Oxford: Blackwell Publishing.

Zakrzewski, S., Shortland, A., & Rowland, J. (2016). *Science in the study of ancient Egypt*. London: Routledge.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Toonen W. H. J., Graham A., Pennington B. T., et al. Holocene fluvial history of the Nile's west bank at ancient Thebes, Luxor, Egypt, and its relation with cultural dynamics and basin-wide hydroclimatic variability. *Geoarchaeology*. 2018;33:273–290. https://doi.org/10.1002/gea.21631