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E-mail: claroscuro.cedcu@gmail.com

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Autor(es): Judith Bunbury; Piers Litherland; Jenny Litherland; Kelly Accetta Crowe; Bryony Smerdon; Alexis Pantos; Graham Smith

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Climate Resilience in the Desert Areas of Egypt

Judith Bunbury[*] *Piers Litherland*[†] *Jenny Litherland*[‡]
Kelly Accetta Crowe[§] *Bryony Smerdon*[¶] *Alexis Pantos*[‖]
Graham Smith[**]

Abstract

Today the Saharan region is known as a hyper-arid environment with minimal human activity outside the few oases. However, archaeological evidence suggests that, in the past, the landscape was more accessible and that settlements sprang up around springs and wells that were linked by well-used routes. Our studies suggest that this activity was concentrated into historical periods when fresh water was available, particularly the Eighteenth Dynasty of the New Kingdom and the Graeco-Roman Period. Comparison with records of global temperature proxies in the *Greenland Ice Sheet Project* show that these periods of activity were also times of high global temperatures, leading to the conclusion times of

[*]Corresponding author. Department of Earth Sciences, University of Cambridge, CB2 3EQ. E-mail: jmb21@cam.ac.uk

[†]Department of Earth Sciences, University of Cambridge, CB2 3EQ. E-mail: nebmaatre@gmail.com

[‡]Department of Earth Sciences, University of Cambridge, CB2 3EQ. E-mail: litherland@laidlawstiel.com

[§]Department of Earth Sciences, University of Cambridge, CB2 3EQ. E-mail: kellyannaccetta@gmail.com

[¶]Department of Earth Sciences, University of Cambridge, CB2 3EQ. E-mail: bryonysmerdon@hotmail.co.uk

[‖]Department of Earth Sciences, University of Cambridge, CB2 3EQ. E-mail: gapantos@gmail.com

[**]Department of Earth Sciences, University of Cambridge, CB2 3EQ. E-mail: gcs1983@gmail.com

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global warming produce increased rainfall in the Saharan region that supports ecosystems and activity in the desert.
Key-words: Egypt; Desert; Adaptation; Climate change; Rainfall

Resiliencia Climática en las Zonas Desérticas de Egipto

Resumen

Hoy en día, la región del Sahara es conocida como un entorno hiperárido con una mínima actividad humana por fuera de los pocos oasis. Sin embargo, la evidencia arqueológica sugiere que, en el pasado, el paisaje era más accesible y que los asentamientos surgieron alrededor de manantiales y pozos que estaban conectados por rutas muy transitadas. Nuestros estudios sugieren que la actividad se concentró en períodos históricos en los que había agua dulce disponible particularmente en la Dinastía XVIII durante el Reino Nuevo y en el período greco-romano. La comparación con los registros de indicadores de temperatura global en el *Greenland Ice Sheet Project* (Proyecto Inlandsis) muestra que estos períodos de actividad también fueron épocas de altas temperaturas globales, lo que lleva a la conclusión de que los períodos de calentamiento global producen un aumento de las precipitaciones en la región del Sahara que sustentan los ecosistemas y la actividad en el desierto.
Palabras clave: Egipto; Desierto; Adaptación; Cambio climático; Precipitaciones

1 Introduction

The Sahara is one of the world's largest deserts and today sparse settlements cling to the region's oases. The largest populations are on the coast and in the Nile Valley, where the river is sustained by rainfall from the Ethiopian Monsoon, brought during the summer from the equatorial belt (Woodward et al. 2007). However, archaeological evidence shows that, at certain periods in the past, the population in the deserts grew and spread throughout the Sahara (Creasman 2020; Garcea 2006; Kuper and Kröpelin 2006). In our work these effects are particularly strong in the Eighteenth Dynasty of the New Kingdom (Bunbury in press a) and during the Graeco-Roman Period (Bunbury in press b). These Saharan communities were sustained by local rainfall that produced springs, wells or even lakes, leaving the refugia of the oases and Nile Valley (Kuper and Kröpelin 2006).

The hyper-arid Sahara is categorised in the Köppen-Geiger climate classification (1936) as a hot, arid desert (BWh). However, evidence from drill cores off the west coast of Africa (Tierney et al. 2017) indicates that there were times when local rainfall in the western Sahara increased and the area became a hot semi-arid environment (BSh). The increased rainfall, inferred from the cores (Tierney et al. 2017), does not match classic climate models (Claussen et al. 2017) based on orbital precession; however, work by Tierney et al. (2017) shows that including the effect of vegetation and dust in the model can explain the observed discrepancy for the climate in the western Sahara (Claussen et al. 2017).

Climate proxies for Egypt, more than 4000km further east of the area studied by Tierney et al. (2017), are more problematic. Typical sources of climatic information are glaciers, dendrology and speleothems, none of which are available in Egypt. The muted topography and high temperature of the region precludes snow and therefore the formation of glaciers. The nearest suitable example in Africa is on Mt Kilimanjaro (Thompson et al. 2002). Yet, the low rate of deposition leads to poor time resolution due to high residence time of ice in the firn (the layer in which air can still exchange with the ice) and, when warming episodes are also considered, that produce no deposit or even melting of the glacier, poor time constraints on the deposits (Thompson et al. 2002).

Dendrochronological records for the Egyptian region are also rare. This is partly because few of the well-calibrated tree species are present, due to the low rainfall, and partly because there is continued debate about what proportion of the wood in Egypt is native and how much is imported from other areas (Gersande Eschenbrenner Diemer personal communication; Schram 2021). Examination of cave records shows that there are some good speleothems in Egypt (Brook et al. 2002; 2003), but, although Pleistocene and earlier records are known, the precipitation during the Holocene was insufficient to restart the growth of the speleothems.

Faced with this dearth of suitable climate proxies, and noting that we are examining whether global climate shifts have affected the environment in Egypt, we have selected the Greenland Ice Sheet Project GISP2 core as a suitable global reference. The advantages of this core are that (i) it is well-studied and (ii) that the data are in the public domain (Alley et al. 1995 and The Greenland Summit Ice Cores CD-ROM 1997, available from the National Snow and Ice Data Center, University of Colorado at Boulder, and the World Data Center-A for Paleoclimatology, National Geophysical Data Center, Boulder, Colorado). The high level of ice accumulation in Greenland means that the residence time in the firn is low, leading to a high resolution (bi-decadal) record. Relatively high rates of ice-accumulation also mean that the date of each analytical result is well-determined as far back as our periods of interest. A nearby, comparable core NGRIP (NGRIP members 2004) is also available in the public domain with sub-annual resolution and gives a similar pattern of change, over the longer term, as the GISP2 core (Alley 2014).

The hydrology of the Nile has been intensely studied (Macklin et al. 2015; Stanley et al. 2003; Woodward et al. 2007; Murakami 1995) and managed (Butzer 1976; Bunbury and Rowe 2021) since antiquity (e.g. Antoine 2017; Parsons 2007). Its headwaters rise in equatorial Africa, flowing north towards the Mediterranean Sea (Figure 1), and are augmented in the summer by the Ethiopian monsoon. The region's geological history (Said 1993; Sampsell 2014; Reader 2023) means that the current Nile is constrained within the walls of an ancient canyon that was eroded when sea-level was lower and the river's precursors cut deeply into the sediments of north Africa. Later, between 700,000 and 120,000 years ago, this earlier canyon filled with sediment to form the floor of the Nile Valley.

As sea-level rose after the end of the last ice-age (from 11,500 years ago), the surface of the Nile Valley sediments was covered with dark mud, brought by the Blue Nile from the Ethiopian highlands. The mud created a fertile floodplain across which the Nile meandered and within which the ancient Egyptian civilisation burgeoned. The populous civilisation of the Nile Valley was ever-ready to explore and exploit its desert hinterland and devised ingenious methods of harvesting water and stretching the supplies to the maximum possible extent. These include, for example, the introduction of *qanats* (or *manawir*) to harvest water over long distances around Kharga (see Figure 3), supplying desert settlements like Dabadib (Rossi and Ikram 2018) or the water depots, placed along the Abu Ballas trail (Hendrickx et al. 2013).

Exploration into the Saharan region was facilitated by wetter periods in the Sahara, linked to episodes of higher global temperature. Hence, while sea-level was rising during the early Holocene, direct rainfall across the Saharan region led to a period known as the Green Sahara (approximately 10,500-4,200 years ago) (Garcea 2006). The rich habitat created by the additional rain allowed bands of hunter-gatherers to range across the area.

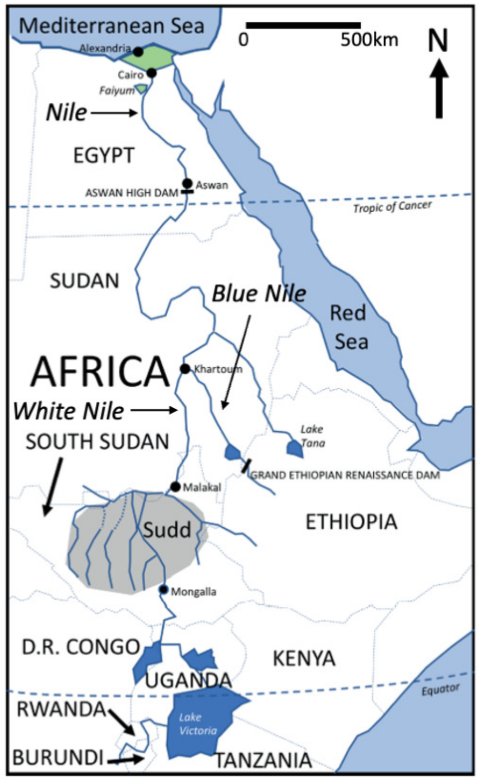

Figure 1: Map of the Nile Basin after Google Earth.

The increased rainfall, during Holocene warm periods, also affected the equatorial regions, increasing the water supply in the Nile. During its annual cycle, the Nile is supplied from equatorial Africa, via the White Nile and, during the summer monsoon, augmented by additional rainfall from the Blue Nile and Atbara Rivers (Woodward 2007; see Figure 2). The Blue Nile that rises in the Ethiopian Highlands is fed by monsoon rainfall and delivers fertile sediment from the basaltic uplands of Ethiopia. Macklin et al. (2015) showed how the high floods also expanded the floodplain within Egypt. Hence, the warm period of the Green Sahara was accompanied by high Nile floods, described by Said (1993) as the 'Wild Nile'. Little archaeological evidence survives in the Nile Valley from this period and the surviving Predynastic sites are often located in the wadi mouths impinging on the Nile Valley, rather than in the floodplain (Bunbury 2019; El-Sanussi and Jones 1997; Dufton and Branton 2009).

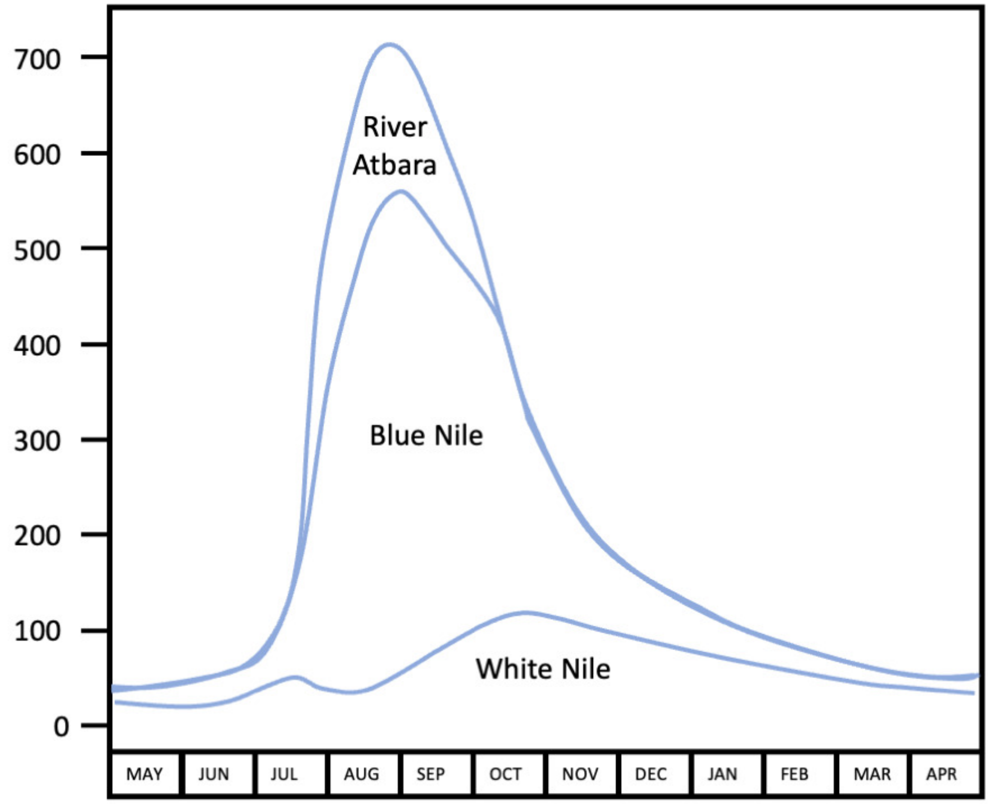

Figure 2: Hydrography for the Nile River at Aswan in million m^3/day, with monthly averages of 1871-1965 before the construction of the Aswan High Dam. After Murakami 1995.

In our work in the Kharga Oasis (Rossi and Ikram 2018) and the Theban Mountain (Litherland 2015; 2018), we notice that, although there are abundant signs of activity preserved in the deserts, there are also periods for which there are none. In this paper, we explore the reasons for these episodes and the basis for climate resilience or otherwise. We also consider whether more recent climate excursions were sufficient to re-invigorate some of the habitats in the Sahara, drawing people back out into the desert. North African rainfall is strongly controlled by latitude so to minimise the effect of local geography, we have particularly explored sites around the 25°N in the Theban Mountain and the Khargan area. We also draw on excavations from the Dakhla Oasis that can be expected to have experienced similar climatic conditions.

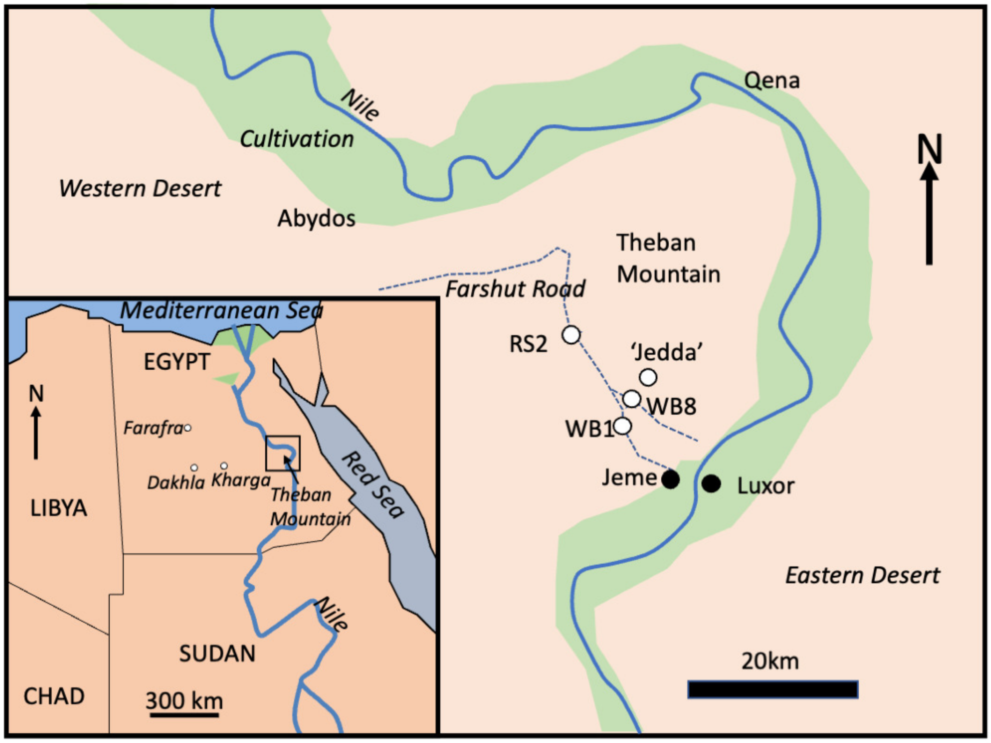

Figure 3: Map showing the sites discussed in this text (inset) with a detailed map of the Theban Mountain, including the Farshut Road as it crosses the desert along the Qena bend of the Nile Valley. Theban sites mentioned in the text are shown with white dots and Roman towns with black dots.

2 Evidence for climate change

It is widely accepted that, in the early Holocene (11,700 to 4,200 years ago), the Saharan Neolithic (Garcea 2006) was a period of greening of the Saharan Region. This warm period is visible as a global phenomenon in the Greenland Ice Sheet Project data (Alley et al. 1995), presented in Figure 4. Excavations in the Farafra Oasis (Barich et al. 2014), occupied during this warm period, recovered botanical material consistent with two rainy seasons, one in the summer and another during the winter. Kröpelin explored these climate changes further (Kröpelin et al.) and Kuper and Kröpelin (2006) described the cycles of greening and desertification as the 'motor of evolution' in the region.

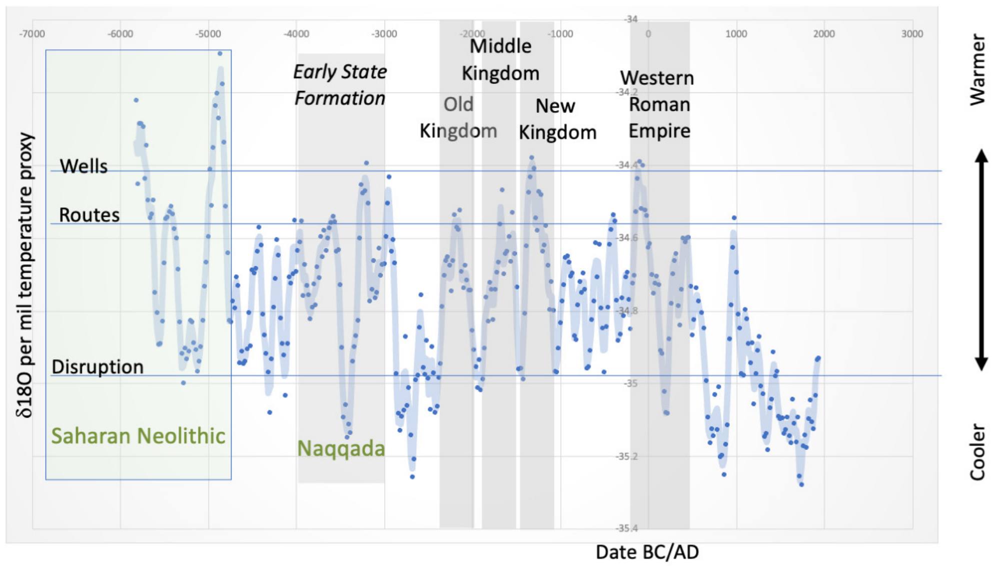

Figure 4: Century moving-average of the GISP2 bi-decadal Oxygen isotope temperature proxy by time. Data collated from Alley et al. 1995 with data from the National Snow and Ice Data Center, University of Colorado at Boulder, and the World Data Center-A for Paleoclimatology, National Geophysical Data Center, Boulder, Colorado. Horizontal lines labelled wells, routes and disruption are approximations, based on our data.

During periods of global warming, both the high Nile floods and the increased rainfall in the Saharan region provided a push out of the Nile Valley during the flood season and a pull into the desert due to new habitats created during rains (Kuper and Kröpelin 2006). At the same time, increased fertility from the rich sediment originating in the Ethiopian Highlands enhanced the carrying capacity of the Nile Valley.

Although global temperatures have not yet reached the values obtained during the Green Saharan Period, there have been several temperature excursions, most notable of these are the New Kingdom and Roman periods.

3 Archaeological evidence in the Desert

Desert activity can be divided into four main types: graffiti recording visits, desert roads, cemeteries and settlements. There are thousands of graffiti in the Theban Mountain and the Kharga Oasis. Although many are difficult to date, some are explicit about their period, either from the text or from the artistic style. Many panels contain over-written contributions from the Predynastic Period to the present day, as, for example, the C'7 panel at the Theban Mountain (Smerdon et al. in press).

3.1 Kharga overview

3.1.1 The geography of the Kharga Basin

The landscape history of the Kharga Basin was outlined in Bunbury et al. (2020). From an area of large lakes during the early Holocene populated by Epi-Palaeolithic hunters and pastoralists, there was gradual contraction until a period of desiccation during the Late Sheikh Muftah period (3600-2100 BCE). This history broadly mirrored the findings of Barich et al. (2014) a little further north (27ºN) in the Farafra Oasis.

After the lakes dried, there remain two sources of water in the oasis (Rossi and Ikram 2018). The first is a reliable supply of fossil water from the deep Nubian aquifer while the second, more ephemeral source, is derived from local rainfall and the Surface Water Sandstone (SWS) aquifer. Artesian water supply along faults intersecting the deep Nubian Aquifer ensures a continuous supply in the core of the oasis, but the outlying districts are dependent upon water in the SWS, derived from rainfall. After rainy periods, these sources in the minor aquifer are soon exhausted. We may therefore expect that activity will expand from the core of the oasis during rainy periods. A study of the archaeological remains in the surrounds of the oasis reveals the periods when this peripheral activity was possible.

3.1.2 Old to New Kingdom activity

After the period of desiccation around 4,200 years ago, we see little activity until the New Kingdom. There is one exception to this which is the record of a visit by Harkhuf, an Old Kingdom official, who is thought to have travelled through the area (Murray 1965). Activity during the Old Kingdom also includes some minor settlements and inscriptions close to the centre of the Oasis (Rossi and Ikram 2018). This confinement to the centre of the oasis continues through to the Second Intermediate Period (Rossi and Ikram 2018). However, during the New Kingdom, there is more activity in the core of the oasis and the use of long-distance routes with wells and waterholes, some of which persists into the Third Intermediate Period (Rossi and Ikram 2018). These routes include a route via a well at Ain Amur, travelling west to the Dakhleh Oasis. Abundant inscriptions attest to the use of the routes during the New Kingdom, but many of the New Kingdom settlements were re-used and therefore obscured during the Roman Period (Rossi and Ikram 2018).

3.1.3 Roman activity

Following the New Kingdom, there is sparse evidence of activity until the Ptolemaic Period (332-30 BCE) when long-distance routes are again in use (Rossi and Ikram 2018). This period included the development of temples, settlements and cemeteries in the main oasis. It is debated whether the Persian technology of the *qanat* (*manwir*) was introduced at this time or later during the Roman period, when there was extensive activity in the oasis (Rossi and Ikram 2018). Roman activity between the 1st century BCE and the 5th century CE included a host of activities, including farming, mining, well-digging, *qanat* digging (or extension), fort, and temple and settlement construction, with the attendant cemeteries. Rossi (Rossi and Ikram 2018) speculates whether the locations of temples, so many of which are associated with springs, are linked to the availability of water, as was almost all the other activity in the area. A set of ostraca (Chauveau 2018) mentioning 'water cleaners' with associated quantities seems to refer to the procurement of water from springs.

After the 5th century CE, activity in the Kharga Oasis waned and contracted to the main oasis, although some long-distance routes continued in use and there were occasional revivals of the *qanat* systems, most notable in the 1950s. Rossi and Ikram (2018) suggest that the abandonment of the area was at least partly associated with desertification.

There are parallels with Kellis in the Dakhla Oasis (Hope and Bowen 2022). The settlement was occupied between the first to late fourth centuries and excavated in the late twentieth century by the Dakhleh Oasis Project. The remains excavated included papyrus, wood and textiles that could only have survived had the area remained dry. Although the source of water at Kellis is unclear, the inclusion of a bath house in the settlement speaks to a greater quantity of water than today.

3.2 Theban Mountain overview

3.2.1 The geography of the Theban Mountain

As the Nile curves around the Qena bend between Luxor and Abydos, it circles the Theban Mountain (Figure 3), where the floodplain of the valley laps at the foot of a limestone escarpment. The prevalence of ancient activity around the mountain means that it is a natural laboratory for exploring accessibility of the desert. While most people lived in the fertile soils of the Nile Valley, others also visited and inhabited the desert within walking distance of the floodplain (Brooks Hedstrom 2009) and, at times, travelled across the mountain (Darnell 2021). The 40km route over the mountain is known as the Farshut Road and travels from Luxor to Farshut, close to Abydos. At the Luxor end, the route starts with a stiff climb before passing through waterless desert but, at some times in the past, it was popular, avoiding the longer river journey, particularly during the low season of the Nile (*shemu*), when navigation was difficult (Bunbury 2019). There are two main periods of activity in the mountain, the New Kingdom and the Graeco-Roman Period.

3.2.2 New Kingdom activity

In the area of modern-day Luxor, the most prevalent New Kingdom activities in the desert were activities surrounding funerary complexes and long-distance transport. The area had a thriving grief economy (Smerdon 2021), including the tombs of the Valley of the Kings, the Valley of the Queens and many other burial grounds, with their associated temples. Contemporary texts describe these areas as 'beautiful places' although today, tourist shops aside, they seem dry and bleak. Many of the images of funerary landscapes show the tombs accompanied by trees (Wilkinson 1998), speaking to the availability of more water in the past than today. At the edge of the cultivation and an excellent entrepot for desert activities, was the town of Jeme, of which the earliest preserved remains date to the late New Kingdom, around 1150 BCE.

Evidence for use of the Farshut Road during the New Kingdom is also found at RS2 (Figure 3), a way-station on the Farshut Road, described by Darnell (2021). The site was also visited by the Cambridge University's New Kingdom Research Foundation (NKRF), which found a large pottery accumulation, interleaved with dung from donkeys or horses, that contained part digested animal feed, according to an unpublished report to NKRF by Claire Newton. The accumulation was 1.25m thick with the pottery dating to the New Kingdom and later (Abdelmoniem 2019). At the centre of the deposit was a cistern, in which there was evidence of previous water accumulation in the form of mud drapes.

Figure 5 shows the accumulation at RS2 with the periods of accumulation labelled. The New Kingdom and Roman Periods are particularly well represented, according to an unpublished report to NKRF by Sylvie Marchand. A later effort to re-dig the cistern, after it had been choked with pottery, resulted in an inversion of the stratigraphy, and seems to have been associated with a third level that included Islamic period activity. Towards the end of each phase the pottery fragments were too small to be dated and the remnants were mixed with traces of bird activity (feathers and eggshell) as well as detritus from fig and sycamore trees, conjuring a picture of abandonment to nature followed by desiccation of the spring and extinction of the ecosystem (Claire Newton, unpublished report to the NKRF).

3.2.3 Roman activity

Later, during the Graeco-Roman period, renewed activity in the desert continued to include funerary activity and transport, while Jeme (also known as Djeme/Medinet Habu) was renewed as a fort (Burchfield 2014; Breasted 1934). After the departure of the soldiers, a Coptic community continued to support the desert residences of monks. Initially small independent units, these coalesced into more formal monasteries in the mid-4th century, when they earned international fame (Brooks Hedstrom 2009; Harmless 2004). Many of these monasteries and hermitages re-occupied earlier tombs, particularly of the New Kingdom, as the graffiti that overlies the earlier tomb decoration schemes shows (e.g. wall on left-hand-side at entry to KV11).

In a similar way, the Farshut Road saw a renewal of activity, with the upper of the deposits at RS2 described above, mirroring the earlier deposit from the New Kingdom.

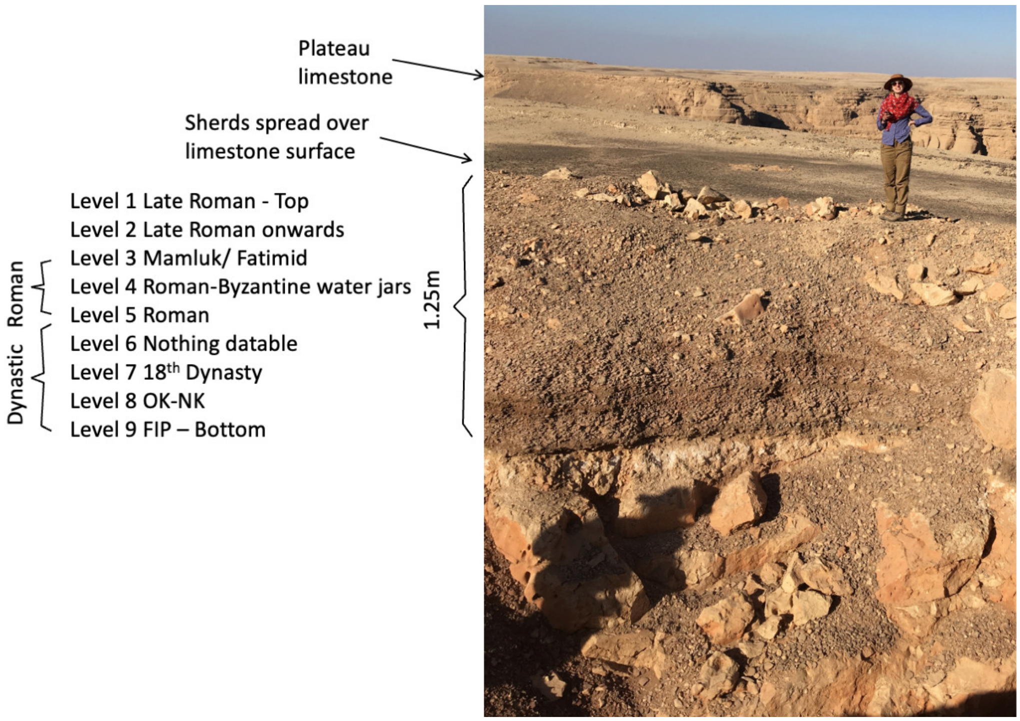

Figure 5: Accumulations of anthropogenic material at RS2 showing two distinct periods of accumulation, the New Kingdom and the Roman periods, separated by an episode of abandonment.

4 Discussion

Examination of sites located around the latitude of 25°N shows that there were focussed periods of activity in the deserts of Egypt. These were not restricted to the early Holocene North African Neolithic, as there were bursts of later activity during the New Kingdom and Roman periods. In our work we note the presence of springs, aqueducts and water channels associated with the activity that could not be sustained today. As such, we infer that the re-occupation of these desert areas was facilitated by local rainfall.

Noting the correspondence between these periods and the peaks of global temperature recorded by the Greenland ice cores, we propose that, during times of global warming, these latitudes of the Saharan region are naturally re-greened. The current archaeological information is generally not sufficiently nuanced to identify shorter wet and dry periods but there is some evidence to suggest at least two Roman Climate Optima

(Pawlikowska-Gwiazda 2023; Bunbury in preparation). Further fieldwork will be required to confirm this hypothesis.

5 Conclusions

Social and political factors are often cited as a reason for the emergence of settlements in the deserts of Egypt. In our work, we show a correspondence between these periods of increased activity and increases in global temperature, attributing the increase of rainfall as a stimulus to the populace, whether through the availability of additional water, increased ease of transport or the presence of additional sources of food, both game and vegetation.

It is striking how quickly desert springs and wells were re-occupied after these increases of rainfall. We attribute this to the knowledge of the ancient routes and the lifeways of the desert that are preserved in the desert communities (Hobbes 1990; Mahmoud 2010; Murray 1935), even if they are resident at the edge of the cultivation during dryer times. Transmission of local knowledge enhances resilience for these communities, facilitating this rapid return to the desert after rainfall.

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