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Judith Bunbury , Reim Rowe
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1 Introduction

The ancient Egyptian kingdoms, at their greatest extent, stretched more than 2,000 kilometres along the Nile and passed through diverse habitats (Figure 1). In the north, the Nile traversed the Mediterranean coast and the Delta while further south a thread of cultivation along the Nile Valley passed through the vast desert of the Sahara. As global climate and landscapes changed and evolved, the habitable parts of the kingdoms shifted. Modern studies suggest that episodes of desertification and greening swept across Egypt over periods of 1,000 years. In order to present a narrative of landscape and climate change in Egypt, we have explored the changes to the Nile Valley along with its fringing wadis and the Northern Delta.

It is also paramount to understand the human context in which these long-term climate trends occurred. With climate and landscape change as a backdrop, we explore the geo-political fortunes of Ancient Egypt as they waxed and waned through the centuries from the rather inhospitable conditions of the Nile in the wet phase of the Holocene to the population adaptions identified during cooler, arid times as sand from desert encroachment changed the Nile environment forever.

The thread that runs through this Element remains the Nile and its valley but the key theme of the Element is without doubt human. Past and current research and thinking are brought together to give a chronological timeline of the landscape of the Nile Valley, using what has been learnt from the geological history of the area and what has been discovered of ancient communities that once called the Nile their home. At its heart, this Element is also a history of geo-archaeology in Egypt, charting the development of methodologies and the key research projects that have helped shape our understanding of the Nile Valley and will continue to do so for years to come.

This Element is a dedication to the early resilience and resourcefulness of ancient Egyptians and to those who have devoted their time to understanding the Nile and her landscape.

2 Humans and Climate Change

Egypt, part of the cradle of civilisation, is a product of the Nile, the world's longest river. Since the majority of the country is desert, its people live mainly along the Nile on the fertile floodplain and delta of the river. For millennia, the population of Egypt has been subject to the river's behaviour and geography and has evolved largely in response to this great waterway. Ever since hominids in the early prehistoric period first radiated from the Rift Valley along the Nile Valley and Saharan region, the area has developed and been recognised

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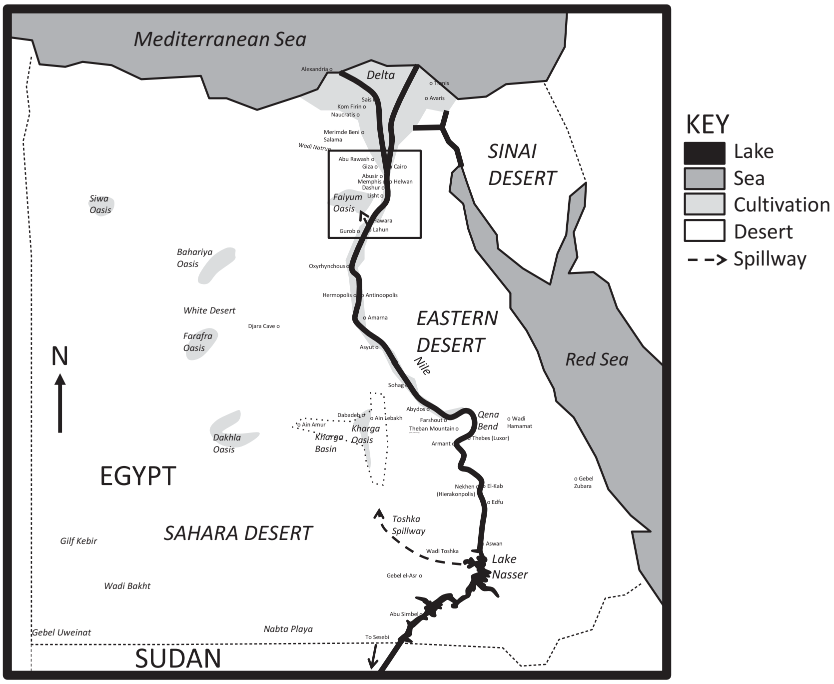

Figure 1 Map of the main places mentioned in the text.

alternatively as an important route out of Africa, a home to one of the greatest civilisations the Earth has known, and one of the most continuously inhabited and historically important tracts of land.

To give a flavour of the persistence of habitation in this area, we need to consider the time before the last ice age, around 30,000 BC, when permanent populations were already present in Egypt. Evidence remains of extensive deposits of stone tools and workshops around the Faiyum and Kharga oases. We know from redeposited tools that they also made use of habitats in the Nile Valley but subsequent river activity has destroyed traces of this period of human history.

During the glaciations of the last ice age (around 110,000 to 9640 BC), as global temperatures dropped, the Sahara became arid and inhospitable. At the same time, the Nile shrank and became more approachable as its water supply from the annual Ethiopian monsoon dwindled. At the north and south poles, cooler temperatures meant that water was locked away in the ice caps lowering global sea level and consequently reducing the water level in the Mediterranean. The Nile, eroding down to the new sea level, formed narrow canyons shrinking the habitable area of Egypt considerably.

These glacial processes were reversed during the interglacial periods, with rising temperatures causing the reinvigoration of the Ethiopian monsoon.

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They also caused melting of the ice caps and hence rising sea level. The delta was flooded as the sea rose and fresh water was held back in the Nile Valley which became wet and marshy. These marshes, liable to flooding and inhabited by hippos and other large mammals, were a rich, if dangerous, habitat. Upstream, the rising Nile also extended its floodplain and, in places, overflowed into the Sahara creating a patchwork of lakes that formed an almost perfect habitat for early humans and ushered in the Holocene, the time since around 11,000 years ago. In the lake-shore environments there was access to fresh water, fish, game and, as lakes receded during dryer times, calorie-rich grains.

Throughout history, climate oscillations caused the Nile to rise and fall as well as periodically drying and rewetting the Nile margins and the Saharan lakebeds. In the wetter times, the Nile, as all rivers do, responded to the rise by rebuilding its delta and floodplain and developing into a meandering river. As the meandering river matured, the inhabitants of Egypt became increasingly dependent upon the Nile as the deserts dried. They left the deserts and migrated into the oases and to the Nile Valley flanks. With time, the Nile coalesced into fewer channels and humans came even closer to the river.

No finer example exists of the effect of climate events on the human collective psyche than the experiences of those who lived through the chaos of the First Intermediate Period (FIP). The damage caused can be seen in the Famine Stela, thought to be Ptolemaic, written about the chaos of this time when Egypt was adapting to the sudden reduction of rainfall and the lower Nile waters: “All Upper Egypt is dying of hunger . . . everyone ate his children one after the other . . . they have begun to eat people here . . . The river of Egypt is dry and men cross the water on foot . . . The place of water has become a riverbank” (Lichtheim 2006).

Closer proximity meant that the Nile dwellers began to understand how the Nile swelled and diminished through its annual cycle and also how the channels and islands behaved over the generations. This emerging knowledge was captured in myths, ceremonies and agricultural practices as well as the more empirical calendars and Nilometer records. These developments were particularly common as they were directed towards the collection of taxes. With growing expertise, an increasing number of practices designed to manage and control the Nile flood developed and accreted. In modern times, with the construction of the Aswan Dam, the Nile level can be held steady throughout the year, maximising the potential for transport and irrigation although simultaneously creating problems of salination and water supply.

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2.1 Geological Origins of Egyptian Landscape

The geological canvas upon which this history of the Nile Valley is placed is one of extreme variation. Full details appear in Said (1981) and are excellently summarised by Sampsell (2014) but, in brief, the rocks of most of Egypt are a stack of more-or-less flat-lying, sedimentary deposits resting upon an ancient crystalline basement. At the base of the sediment layers lie the important aquifers of the Nubian sandstone and above this, layers of chalk and limestone. These were laid down during the geological era of the Cretaceous, around seventy million years ago, in a warm shallow sea. During ice ages when the water level was low in the Mediterranean basin, the Nile cut down through this sandwich of sediments to form a deep canyon with tributary canyons, similar in size to the Grand Canyon. The Egyptian canyon stretched from Aswan in the south to the Mediterranean, or rather the salty and dried-up remains of what was left of it, in the north.

Although the Nile currently has no tributaries in Egypt, in the distant past, when sea level was much lower than today and there was more rain locally, the tributary river valleys were deeply incised into the walls of the canyon through which the Nile flowed (Said 1962,1981 and 1993). Later, when sea levels rose, these valleys became inactive and were choked with sand and gravel from the desert to become the wadis. In the Eastern Desert, these wadis continue to host drought-tolerant plants and fauna as well as the local tribes, creating additional habitable land beyond the Nile Valley (Hobbs 1990). Although rains are rare, perhaps once in ten years, they can cause flash floods when the wadi gravels become fluidised and collapse, carrying gravel, roads and other material with them.

While the wadis form mainly in the flanks of the Nile Valley, to the north in the delta, as sediment was eroded away, mounds of sand were left between the branches of the delta's distributary system. The relict mounds still emerge from the Nile floodplain in the north of Egypt today and are known as the gezirehs, from the Arabic word for island. With rising sea level, the old river valleys refilled and a thin veneer, around 10–20 m thick of rich, black mud was deposited on top of the gravels and around the gezirehs. It is this thin layer of mud upon which the majority of the modern inhabitants of Egypt rely for agriculture and from which they derived the early name for Egypt, *kmt*, the black land. The sandy mounds of the gezirehs became some of the earliest inhabited parts of the delta.

The Nile, as a large river system affected by climate change, responds according to the laws of physics, as any large river does. Borehole investigations reveal that although early humans tracked habitats as the landscape

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changed, with time they started to understand the river and its behaviour, and intervene, adapting it to their own needs for transport, drinking water, food and irrigation. In exploring this history, we adopt the traditional designations of periods of Egyptian history. For consistency, we have used the ancient chronology used by Shaw (2003) in his *Oxford History of Ancient Egypt* which is summarised as a timeline in Table 1.

2.2 Landscape and Early Egyptology

In a broad sense, it took some time to realise that the landscape provided the missing piece of the archaeological puzzle. Our understanding of Egyptian landscape processes was slow to develop and came from the gradual discovery of the validity of non-written source materials, the development of meaningful methodologies to record these and, finally, a broader knowledge base within the context of historical and geological findings. We note that the earliest excavations in Egypt were preoccupied with the exploration of the then-undeciphered hieroglyphs (Thompson 2015), visible on monuments in Egypt. These

Table 1 The main periods of Egyptian history referred to in this text (with commonly used abbreviations) taken from the timescale of Shaw (2003)

Palaeolithic	*c*. 700,000–5,000 BC
Saharan Neolithic Period	*c*. 8800–4700 BC
Predynastic Period	*c*. 5300–3000 BC
Early Dynastic Period (ED)	*c*. 3000–2686 BC
Old Kingdom (OK)	2686–2160 BC
First Intermediate Period (FIP)	2160–2055 BC
Middle Kingdom (MK)	2055–1650 BC
Second Intermediate Period (SIP)	1650–1550 BC
New Kingdom (NK)	1550–1069 BC
Ramesside Period (subdivision of NK)	1295–1069 BC
Third Intermediate Period (TIP)	1069–664 BC
Late Period	664–332 BC
Ptolemaic Period	332–30 BC
Roman Period	30 BC–395 AD
Byzantine Period	395–619 AD
Persian Empire	619–639 AD
Muslim Dynastic Period	639–1517 AD
Arab and Ottoman Period	639–1882 AD
Khedivate	1882–1953 AD
Republican Period	1953 AD–

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monuments, known throughout the world, have long been a subject of scholarship and many ancient visitors recorded their wonder at the achievements of the past in their inscriptions. However, modern Egyptology was initiated in the politics of the late eighteenth century. In 1798, Napoleon, as part of adding Egypt to his Empire, landed a force of 160 scholars alongside the army to collate and propagate knowledge. The 'savants' as they were known, published newspapers and made maps and plans creating a fascinating and detailed catalogue of Egypt at the time. They also discovered the Rosetta Stone which was the key to deciphering hieroglyphs.

The problem for modern geo-archaeologists is that although historically, many objects and artifacts remained intact and preserved, few records of the archaeological and geological context in which they were found were kept. It was not until the late nineteenth century when Hekekyan (1807–75; Jeffreys 2010) and Petrie (1853–1942), among others, began to make detailed observations of the find spots, recording in fascinating detail not only their finds but also what they saw in the surrounding area and what this might tell us. We could perhaps point at this moment in time as the birth of geo-archaeology as a discipline in its own right. Now, modern archaeology takes careful note of the 'context' or sediments in which inscriptions are found, yielding valuable information about the ancient landscape. Perhaps unsurprisingly, given the absence of context for many of the texts, translations of the texts and interpretations of the sites took it for granted that the landscape in which the sites were set had been much as it is now. When Baines and Malek (1980) compiled their atlas of ancient Egypt, they realised that, as there was so little information about how the Nile moved, they were obliged to portray it in its modern course, regardless of the period and the ancient geography.

Caton-Thompson (1932 and 1952) in the early twentieth century suggested that the environment had not always been what it is today. The geologist in her team, Gardner, observed from sediments associated with the ruins that they had been built in wetter times. Soon afterwards, during the 1960s, there was a major campaign of rescue archaeology preceding the inundation of a large part of Nubia with the waters of the reservoir, Lake Nasser. From these surveys, further prehistoric discoveries were made including those by Wendorf and Schild (1998) at Nabta Playa in the Nubian Desert some 800 km south of Cairo. From their excavations, Wendorf and Schild could see how strategic lakeshore sites were reoccupied multiple times, even though the traces of earlier occupation were shallowly buried and no longer visible. The fact that ancient sand dunes, buried in the lake mud, had contained reservoirs of fresh water provided further evidence of the importance of these fresh-water sources to prehistoric humans. In fact, the presence of these lakes was a crucial

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consideration in the occupational patterns of prehistoric humans and those that followed them, as we will show later.

The exploration in the 1980s and 1990s of the large and significant sites of Tell El-Dab'a and Piramesse by Manfred Bietak, who incidentally also participated in the Aswan Dam rescue excavations, highlighted a series of waterways that had connected these sites (Bietak 2017). Around the same time, Butzer, working in the Nile Valley at the Pyramids of Giza started to apply the evidence from sediments around historic sites to understanding their environment. A mathematician, geographer, meteorologist and archaeologist, his seminal work on the Nile Valley in 1976, *Early Hydraulic Civilization in Egypt: A Study in Cultural Ecology*, set the scene for modern investigations where sediment logs and boreholes are now considered a routine part of archaeological investigation.

This type of investigation was taken up by others (Jeffreys 1985; Stanley and Warne 1993 and 1994) who augmented the parallel explorations of Attia (1954) and his teams on behalf of the Geological Survey of Egypt. Similarly, Stanley and Warne (1994) used carbon dates and more than a hundred boreholes (the extraction of columns of soil samples to examine subsurface deposits in order to complete a picture of site use over time) to explore the development and architecture of marine deltas from different parts of the world. Around the same time, Jeffreys added a programme of auger coring to the work of the Survey of Memphis (Jeffreys 1985), in order to contextualise previous excavations into the broader landscape. Over the ensuing thirty years, his team cored and logged at hundreds of locations totalling more than two kilometres of sediment. As they went, they trained a battalion of students in the art of logging and landscape interpretation who have since worked at many sites across Egypt.

2.3 Landscape in Egypt

Broadly, Egypt can be divided into four main types of environment: the Delta to the North, the Nile Valley running through the centre, and the deserts and oases that flank it. Within these environments, landscape change is relatively slow; for example, the Nile migration that is perceptible over a few generations (Bunbury et al. 2008 ; Lutley and Bunbury 2008) or the desertification of the Sahara that lasted around a millennium (Kröpelin et al. 2008 ; Kupar and Kröpelin 2006). On an even longer timescale, the Delta, swamped by rising sea levels, reached its marshiest around 6000 BC and spent the following 3,000–4,000 years reconsolidating its channels to form the topography we see today (Pennington et al. 2016). Figure 2 shows the changes to the main habitats: the Delta, the Nile Valley, the Oases and the deserts. Black diamonds identify points at which

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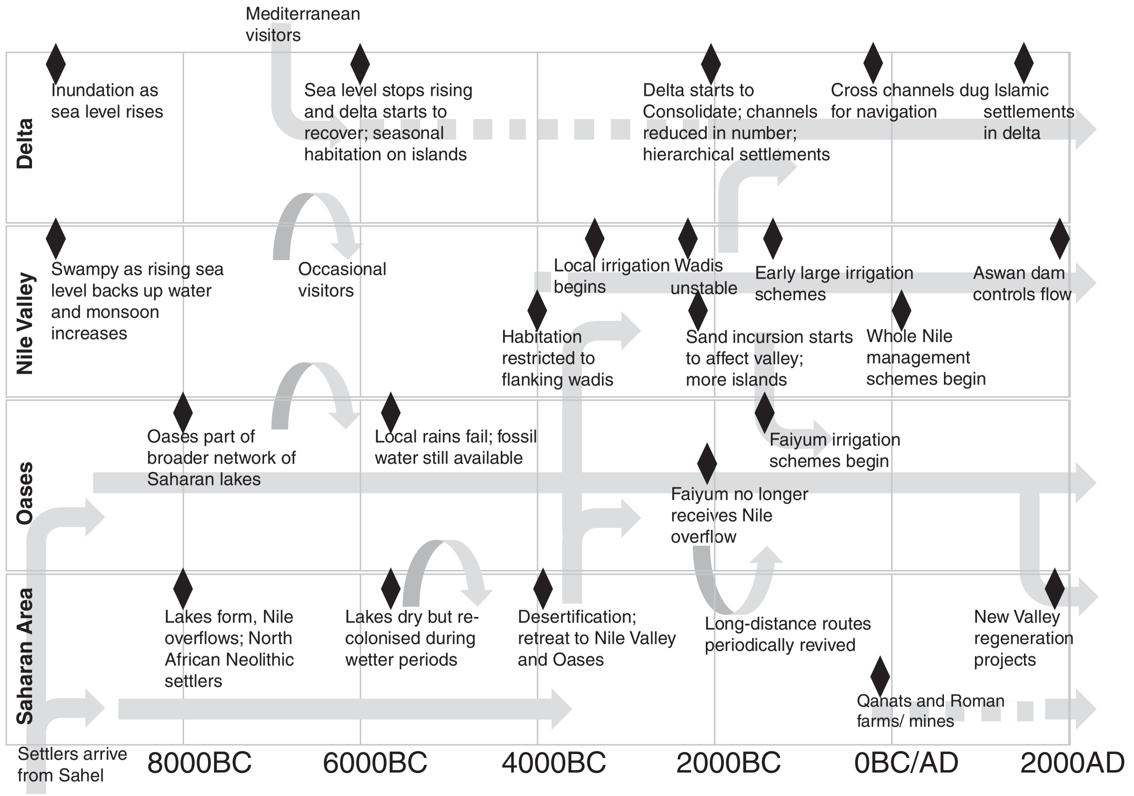

Figure 2 Diagram to show how landscapes changed with time in the main habitats of Egypt. Arrows indicate population movements between habitats and diamonds indicate events in the landscape evolution documented in the archaeological record.

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changes are recorded in the archaeological record and the grey arrows show how human patterns of habitation and migration have responded to the changing environment. The Nile Valley has been a habitat into and out of which ancient Egyptians migrated and which we will explore in more detail here. For those living in Egypt, these habitats are intimately connected and their constant attachment to these areas demonstrates the significance of these sites in providing the basics for life and the building blocks for a new civilisation.

Even though much of landscape change is slow, gradual change to a habitat may mean that it reaches a tipping point. For example, for those people living around the Saharan playas in the late predynastic (around 4000–3600 BC), the deterioration of the food source when the sites dried up, forced many people into the Nile Valley. This condensation of population also, as we will see, had a dramatic impact on those already resident there. Further north in the Delta in another example, a change from very rich and diverse habitats towards a more monotonous set of channels was a driver for a more hierarchical society managed from Memphis, the node at which they met. Or, similarly, in the Nile Valley, a period of unpredictable weather in the New Kingdom, with high Nile and flash floods in the nearby desert, inspired the development of a landscape-wide system of channels and reservoirs in Luxor.

3 The Early Holocene Climate Seesaw

The Nile Valley and Delta were rather inhospitable during the wet phases of the early Holocene since river levels were high and the annual summer flood brought by the Ethiopian monsoon was also larger. Furthermore, local rainfall in Egypt contributed to the generally wet conditions. Towards the end of the Saharan Neolithic, both flood levels and local rainfall were reduced rendering the Nile tamer while at the same time, the reduction in local rainfall in the Saharan region drove people out of the deserts making the Nile a popular destination. Flanking the Nile, the wadis were well vegetated and provided ready access to the desert as did the terraces that flanked the marshes of the Delta. A combination of hunting in the wadis, with fishing and gathering in the Nile Valley, was augmented by some herding of sheep, goats and cattle. When seasonal rains refreshed the Sahara, the wadis also provided easy access to the lakes and playas (seasonal lakes). The Nile, now the life-blood of Egypt, began its rise to supreme importance.

The Nile and its expanse of catchment have been globally significant to the civilisations and cultures of the region for millennia, providing an important corridor for the movement of people and animals throughout the Holocene. Flowing for over 6,000 km from the south of the Equator to the shores of the

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Mediterranean and covering an area of 3 million square kilometres, it is unique both in size and variety of river basin. The main contributors to the Nile in Egypt are the White Nile that rises in equatorial Africa and the Blue Nile that rises in the Highlands of Ethiopia: these join at Khartoum in Sudan. The Nile is unusual that it has few other perennial tributaries meaning that its character is remarkably similar for much of its course northwards from Khartoum. The catchment supports a vast range of ecosystems and has played a central role in the development of a rich diversity of communities.

The Nile floodplain in Egypt currently forms a green cultivated strip that cuts north–south across the Sahara Desert. To many, the river appears immutable but the current form is the result of a tempestuous past. The river today is the result of many phases of development (Said 1981) but for our purposes it is sufficient to begin six million years ago with the erosion of what is described as the Nile Canyon, the valley bounded by cliffs through which the Nile flows. The meandering of the modern Nile is constrained by this canyon to a narrow strip no more than 12 km wide.

During the annual flood cycle, the White Nile maintains a steady flow but the Blue Nile, with its highly seasonal swelling of waters from the Ethiopian monsoon, causes an annual inundation (for more details, see Woodward et al. 2007). Small wonder that life in the Nile Valley started to revolve around the flood and the seasons were determined by it. First came Akhet (June to September) when the floodwaters rose and no farming could take place although mass-transport of goods could occur since the water was deeper and more extensive than at other times of the year. As the flood receded, it ushered in the season of Peret (October to February) when as much of the land as possible was used for agriculture. Activities included sowing and reaping crops in the irrigated flood-basins as well as grazing of stock or even hunting in the thickets and marshes that fringed the valley. By March, the harvest was ready and Shemu (March to May) began. Once the crops were in, preparation for the next flood season began; clearing ditches and repairing embankments ready for the flood to return.

Although we can no longer observe the annual flood of the Nile, fortunately, we still have historic maps and travellers' accounts as well as the exceptional photographic record of Lehnert and Landrock who ran a photographic business in Cairo during the early twentieth century and who photographed the Nile from all angles and in all seasons. For example, in their image of Dashur, the settlement huddled on a piece of high ground, appears to be a ship afloat in the floodwaters of the Nile Valley while a photograph of the Pyramids at Giza taken at a similar time of year shows boats approaching the monuments. Although the inundation became a regular feature of life on the Nile, climatic

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