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It Never Rains but It Pours:

The Impact of Intraregional Climate Change on the Ancient Egyptian Old Kingdom Collapse

Introduction

A thriving kingdom that had ruled Ancient Egypt for more than five centuries collapsed in a matter of decades around 4200 BP. Researchers and historians have tried to untangle this mystery by seeking social, political, and economic causes for the upheaval. However, several lines of evidence, including geological, archaeological, and paleoecological, suggest climate change may have been chiefly responsible. A brief overview of the climate history of the area shows that gradual trends toward warmer, dryer climates had been taking place for thousands of years. Following the relatively wet Green Sahara Period, from 9000 BP to 6000 BP, the region grew increasingly arid and the belt of savanna moved southward. By 5000 BP, arid to hyperarid climate conditions prevailed in Egypt, setting the stage for the climate variability that played out over the latter half of the Old Kingdom and the social implications that came with it (Welc and Marks 2014). Predictability of agricultural seasons was central to crop growth in Ancient Egypt and, by extension, the stability of society. By upsetting the reliability of annual Nile floods and crop seasons, climatic variability disrupted the social order. This paper presents recent geoarchaeological data to argue that environmental factors related to climate change within northern Africa, including both gradual aridification and a decline of monsoonal storms as well as anomalous wet intervals in northern Egypt, played a predominant role in the destabilization of the Old Kingdom.

Desertification of the Northern Sahara and Decline of Nile Flood Levels

During the last two centuries of the Old Kingdom, evidence from both the geological and archaeological records reflects an overall trend in the northern Sahara and Syropalestinian region toward increasingly arid and warm climates and a resulting decline in annual Nile flood levels, coinciding with and, as this paper argues, in large part causing the social turmoil and devastating famine that led to the collapse of the royal administration. Several lines of interdisciplinary evidence show a rise of dry and warm conditions before the collapse of the Old Kingdom, the first of which comes from caves in Israel. A study of speleothems in both the Soreq and Galilee caves reveal a clear trend toward climate aridification from about 4500 BP onward. Researchers measured stable isotopes ^{18}O and ^{13}C in depositional layers of stalagmites with a mass spectrometer. An increase in rainfall is inversely proportional with dissolved ^{18}O in the precipitation; thus higher values of ^{18}O in the carbonate speleothem layers reflect drier climate periods. ^{13}C corresponds similarly to wet and dry intervals but depends largely on photosynthetic pathways and therefore the make-up of soil organic matter. Measurements of each of these stable isotopes independently show a gradual rise of arid conditions a few centuries before the fall of the Old Kingdom (Bárta 2015; Bar-Matthews and Ayalon 2011).

Evidence of this aridification is also reflected by paleoecological data from a tomb complex in Abusir, where beetle remains reveal desertification near the Nile valley at least 180 years prior to the Old Kingdom collapse. Beetles serve as useful paleoecological data because they cannot travel far distances, nor can they quickly adapt to changing environmental conditions; therefore, they are locally and environmentally specific. In the burial chamber of the vizier Qar, dated to the early Sixth Dynasty, Miroslav Bárta discovered a beetle specimen in the limestone sarcophagus that belonged to the genus *Scarites*, which inhabits sandy soils on seashores and the banks of salt lakes. In the tomb of Inti also from the Sixth Dynasty, beetles of the genus *Poecilus pharao* were found caught within a bowl of resin involved in the mummy's embalming ritual. Like genus *Scarites*, these beetles are exclusively associated with saline habitats (Bárta 2013). The mummification ritual for the mummies buried in the Abusir complex required access to water and would have mostly likely occurred near the complex on the banks of the Lake of Abusir. The exclusive saline habitat of the beetles found in association with the embalming ceremony suggests that it was conducted in a dry, salty environment, most likely in a desert. Desert conditions on the banks of the Lake of Abusir show that by the early Sixth Dynasty the desert had encroached closely upon the Nile valley and support the idea of gradual desertification throughout Egypt (Bárta 2013). Interpretations of the scientific data are corroborated by iconography in a number of tomb paintings from Memphis from the mid-Fifth Dynasty and Sixth Dynasty, which depict a range of human activity. Bárta's analysis of the evolution of content in these scenes revealed an increase in the desert motif, particularly in hunting scenes where a variety of desert fauna are also illustrated. Bárta suggests that the motif became more popular as a desert setting grew more relatable and familiar to Ancient Egyptians as a result of climate-induced desertification of the northern Sahara (Bárta 2015).

The increase in aridity during the late Old Kingdom demonstrated by geological, palaeoecological, and archaeological research correlates with evidence of a decline in annual Nile flood levels, which reached a minimum in 4200-4100 cal BP, right around the collapse of the Old Kingdom. Annual Nile floods in Ancient Egypt relied on summer monsoonal rainfall over the catchment basin of the Blue Nile in the Ethiopian highlands, the main contributor to the Nile (Welc and Marks 2014). As climatic conditions grew drier and warmer, a decrease in monsoonal storms led to a decrease in Nile floods. This logical relationship is confirmed by a study of the hydro-geomorphology of the Nile delta during the Holocene, which reflects in the geologic record the expected decline in annual flood levels toward the end of the Old Kingdom. A spatially averaged sedimentation record shows a marked decrease in deposition from Nile floods around 4400-4100 cal BP, corresponding with the last two dynasties of the Old Kingdom. The Nile-fed Lake Fayum provides a particularly good record of sediment deposited by Nile inflows and also reflects a gradual decline of annual flood levels due to intraregional aridification (Marriner *et al*. 2012).

Archaeological investigations of the southern Egyptian settlement on the island Elephantine in the Nile River provide evidence of Nile fluctuations as well. The settlement's shift toward the shoreline during the late Old Kingdom indicates that Nile flood levels were dropping over this period. Settlement structures which date to the First Dynasty lie 96 meters above sea level while a Second Dynasty fortress sits at 94 meters above sea level, and by the Sixth Dynasty some city houses are only 91 meters above sea level. The movement of permanent structures to lower elevations testifies that Nile floods were becoming increasingly less impactful. The observations of the archaeologists at Elephantine are verified by seventy-two entries of annual Nile flood levels recorded on the Palermo Stone, an administrative stele, which shows a decline in Nile floods from the mid-Fourth Dynasty to the end of the Old Kingdom (Bárta 2015). Geological and archaeological evidence showing an increase in desert conditions and a decline of monsoonal storms and consequently Nile flood levels suggests strongly that climate conditions were growing more arid and warmer during at least the last two centuries of the Old Kingdom. A society reliant on annual Nile floods for crop production, Ancient Egyptians suffered from intraregional aridification and the deteriorating agricultural conditions that came as a result, likely contributing to the social instability and upheavals at the end of the Old Kingdom.

Anomalous Intervals of Heavy Winter Rainfall

While gradual aridification plagued Ancient Egypt in the late Old Kingdom, almost as devastating were numerous wet intervals that swept through northern Egypt, the most intense of which occurred around the Old Kingdom collapse, about 4200 BP. Research conducted by the Polish-Egyptian mission in the Saqqara necropolis provides valuable climatic data documenting these wet intervals which took place over the course of the Old Kingdom since the early Third Dynasty. Excavation largely took place at an ancient quarry site, where Third Dynasty workers mined a bedrock plateau of Eocene limestones into a series of rock terraces. Covering the bedrock terraces is an undisturbed sequence of natural and anthropogenic sedimentary layers. The rock layers hold clues about the climate in which they were deposited and, therefore, provide a record of climatic change since the Third Dynasty (4700-4600 cal BP). The researchers focused on a complete stratified sequence of sedimentary rock layers on the lower terrace. A layer of ash radiocarbon dated to 4820-4670 cal BP near the bottom of the sequence supplies the earliest age of deposition. The most recent rock layers were dated to 4100 cal BP with ceramics that corresponded to particular dynasties of the Old Kingdom. This sequence proved a good case study for Fabian Welc and Leszek Marks because it reflects the local depositional environments from the early Old Kingdom until after its end (Welc and Marks 2014).

The Polish team studied samples from the site in a laboratory, using a number of methods, including microscopic analysis of particle size, shape, and chemical composition, to

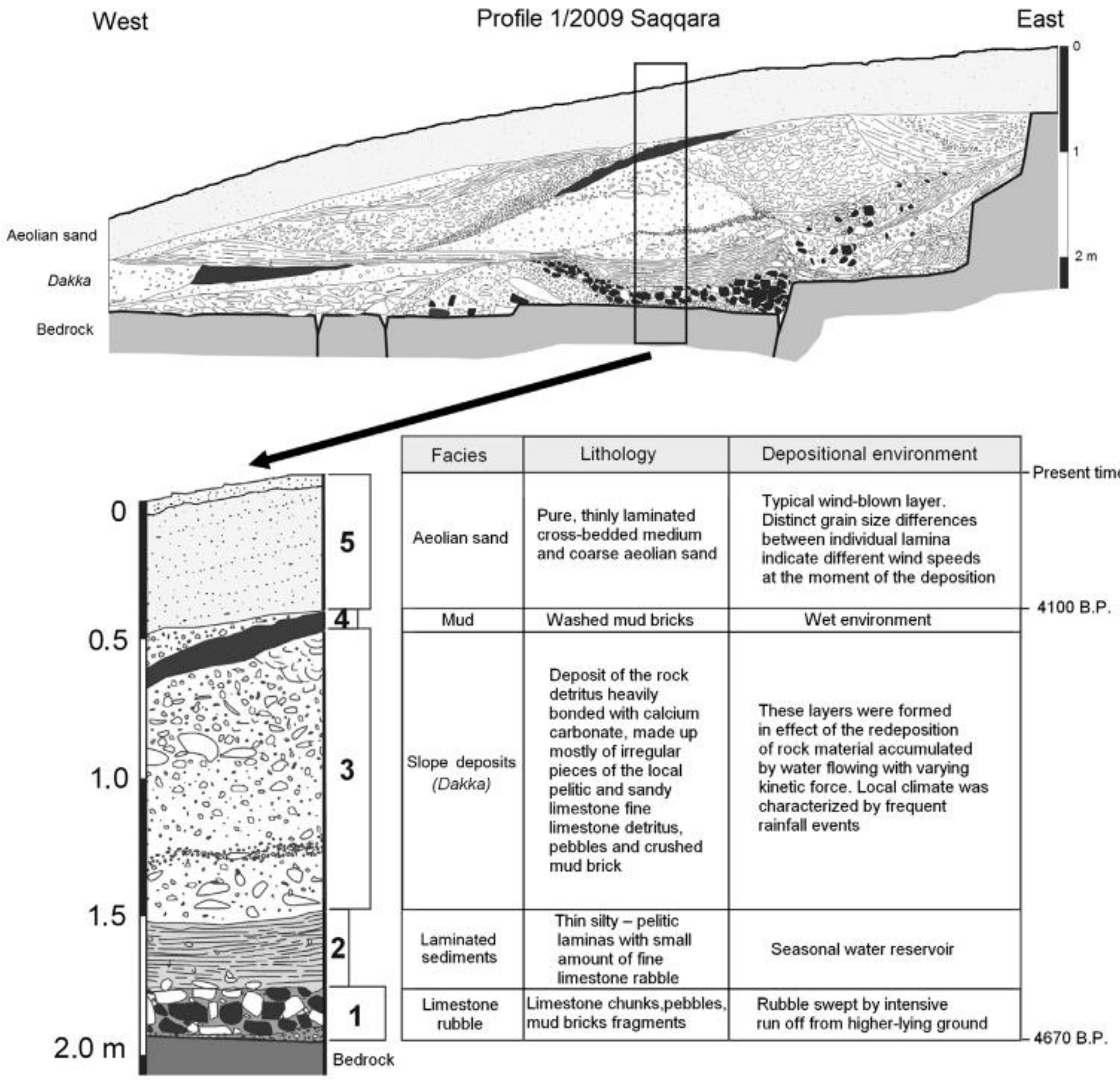


Fig. 1. Cross-section of sedimentary rock layers at West Saqqara area, organized into five distinct series (Welc and Marks 2014)

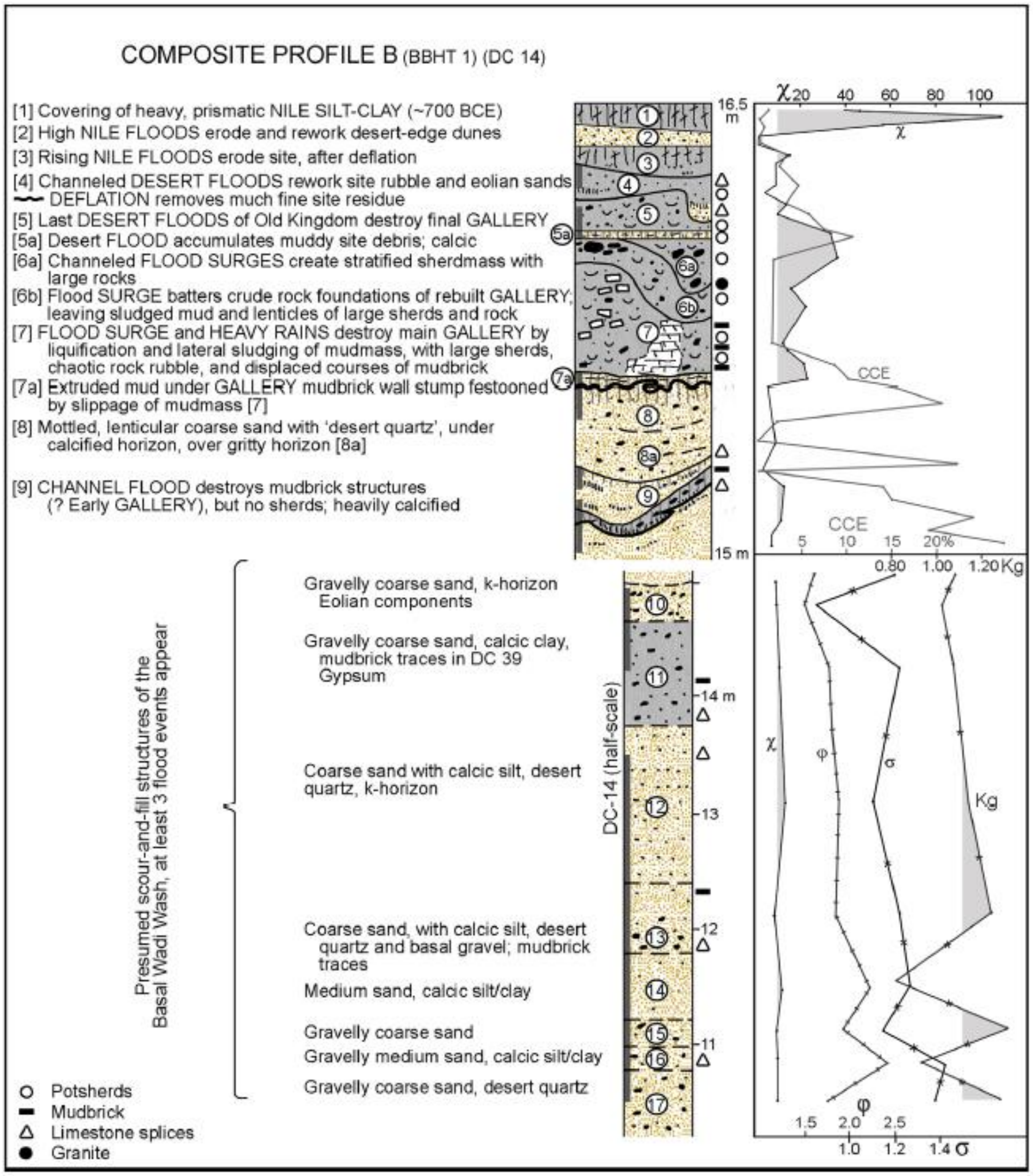
determine the chemical content of the sediments and the mechanisms that deposited them. Through this process, the researchers identified five distinct layers of the stratigraphic sequence, seen in Figure 1. These layers are significant to Welc *et al.*'s hypothesis because each reveals a stage of climatic change over time. Series 1 consists of pebbles, sand, limestone rubble, and pieces of mudbricks. The latter constituents were presumably from ancient mining activities: the quarrying of bedrock and construction of structures, respectively. Researchers also identified fragments of sponge spicules in Series 1. These spicules, structural elements of sponges, were deposited in the prehistoric Eocene reef and occur in the modern Eocene limestone. Their appearance in Series 1 indicates that weathering and short transport redeposited Series 1 material from the higher-lying bedrock. This conclusion is consistent with the identification of bedrock quartz grains in Series 1. Welc *et al.* attribute the redeposition to the occurrence of intensive run off, which swept rubble and sediment to its present location. This hypothesis of transport requires that wet conditions prevailed during the time of Series 1 and is supported by abundant plant macrofossils found in the layer, as vegetation would have been richer in this proposed environment.

The researchers discovered similar evidence for wet climate intervals in the next two series. Thin, stratified layers of sand and silt make up Series 2. It also exhibits small chunks of local limestone and mudbrick rubble, as in Series 1. Based on the depositional pattern of Series 2 (i.e. laminar layers), Welc *et al.* ascribe its source to seasonal reservoirs of water, reservoirs that could have only existed in a relatively wet climate. Series 3 is comprised mostly of limestone debris which is associated with Sixth Dynasty mining activities. Like in Series 1, flowing water redeposited this rock material from higher terraces of the plateau, again indicating a wetter climate and frequent rainfall. Series 4, relatively thin and given little attention in Welc *et al.*'s research, is a layer of mud deposited in stagnant seasonal pools from mudbricks. Finally, Series 5 marks the transition from wet environments to dry, comprised of wind-blown, stratified sand, typical of arid desert deposition. This layer reflects modern conditions and represents a drastic climatic shift, key evidence for Welc *et al.*'s argument that climate had a significant impact on Old Kingdom society.

Welc *et al.* point out the appearance in some quantity of spicules of Eocene sponges in the first three series, proving that all three layers were deposited mainly by sheet flows and, moreover, that the climate conditions of the Old Kingdom were characterized by more or less intensive surface flows. Considering the far greater thickness of Series 3 in comparison to 1, Welc *et al.* further claim that surface flows became more frequent and longer toward the end of the Old Kingdom. Additionally, the seasonal pools evident in the stratigraphic sequence are indicative of a relatively high water table and, thus, high water content (Welc and Marks 2014). The source of these rains cannot, however, be attributed to monsoonal summer precipitation and flooding typical to the southern Sahara. As Karl Butzer *et al.* point out, desert rains in northern Egypt rely exclusively on winter storms, and paleoclimate modeling shows that there were no summer monsoonal rains as far north as Saqqara in the early Holocene. Instead, Butzer *et al.* explain wet anomalies in the northeastern Sahara with storms brought by the mid-latitude jet stream (Butzer *et al.* 2013). The sharp boundary between the water-deposited and wind-deposited sediments, which corresponds to the decline of the Old Kingdom, reveals a relatively rapid change in climate conditions, from dry with wet interruptions of the first three to typical desert conditions of the fifth (Welc and Marks 2014).

Butzer *et al.*'s research at the Lost City of the Pyrimds, Heit el-Ghurab, a seasonal "Workmen's Town," supports Welc *et al.*'s conclusions, proving that the wet climate intervals were not local to a specific site but occurred to some extent throughout the region. Centered at the desert and floodplain margins of Giza in the Menkaure wadi, the Lost City was home to thousands of Fourth Dynasty workmen, artisans, and administrators during the Nile flood season to facilitate the construction of Menkaure's pyramid. Butzer *et al.* identify evidence for intense flood surges at the site that correspond to wet conditions evinced by Series 1 and 2 of the

Fig. 2. Composite sedimentary sequence profile B from the northeast quadrant of the Lost City (Welc and Marks 2014)



geologic sequence from Saqqara. Drill-cores from the northeast quadrant of the Lost City (profile B pictured in Figure 2) provide the best records of climate variability during the Fourth Dynasty, particularly of a period of unusually heavy rainfall which may have lasted around 120 years. At the cores' bases are commonly five to seven meters of wadi sands. Upon them lie thin layers containing fragments of limestone, potsherds, and charcoal, revealing the initial construction and occupation of the formal Gallery, the first elaborate mudbrick structures built on the site. Evidence of a devastating surge appears above these desert deposits and occupational lenses.

Excessive precipitation and flooding liquified mudbricks that composed the structures of the Lost City, leaving behind a mass of mud, large sherds, limestone rubble, and whole pieces of mudbrick walls in the geologic record. Multidirectional flow lines and scattered clasts in the rock layer are consistent with high-intensity debris-flow deposition. Butzer *et al.* describe the resulting damage of the flood surge as "truly catastrophic." Archaeological evidence shows that the Fourth Dynasty administration responded to this devastation by rebuilding the formal Gallery and, in addition, constructing a large, stone-block wall, the Wall of Crows, on the northwestern end of the town. Despite their efforts, however, five subsequent flood surges swept through the area, causing widespread destruction in the Lost City. Each is identifiable by sherd rubble horizons and water-reworked desert sand deposits (Butzer *et al.* 2013). The appearance of water deposited debris indicative of a wet interval in the geologic record at the Lost City lines up with the earliest wet conditions revealed by the sequence from Saqqara, corroborating Welc *et al*.'s assumption that the flood events at Saqqara were not local but regional and reiterating the havoc they could wreak.

On top of the climate history recorded in stratigraphic sequences, Welc *et al.* also cite evidence from the tombs of the Saqqara necropolis themselves to support their claims about ancient environmental conditions. The Polish researchers found redeposited rock material from intensive sheet flow transport in shafts and burial chambers, mostly dated to the Sixth Dynasty. Additionally, thin deposits of clay, silt, and mud in the tombs provide evidence that stagnant water was present for extended periods of time. On top of this, funerary structures at Saqqara show signs of damage consistent with colliding rock material carried by intensive surface flows. All these signs of flooding testify to a wetter climate (Welc and Marks 2014). A final piece of evidence from Saqqara comes from tomb paintings depicting hunting scenes. Unlike the paintings at Memphis where the desert motif is frequent, these Fifth Dynasty murals show landscapes with numerous trees and bushes in what is now a sandy desert. This abundant vegetation could have only existed in relatively wet conditions, consistent with those Welc *et al.* propose for the end of the Old Kingdom (Welc and Marks 2014). Geoarchaeological data from two distinct locations, supported by this iconographical evidence, point decidedly toward the interruption of arid conditions in northern Egypt by wet intervals brought by jet-stream behavior unrelated to monsoonal storms. The damage done by these climate anomalies, with a particularly long and heavy one around the decline of the Old Kingdom, in conjunction with overall drying conditions, would have been a substantial factor in the destabilization of social order that led to the collapse of the royal administration.

Discussion of the Geoarchaeological Data and Social Repercussions

It is important to understand the climate variability that preceded the Old Kingdom's decline in a historical context to gain a broader picture of the connection between climate change and social upheaval. The inability of the Old Kingdom royal administration to adequately respond to the changing environmental conditions and to, as Bárta says, "keep the norms and standards in every possible walk of life" – that is to ensure that the annual crop yield was sufficient for society to function as usual – led to its demise. As the production and distribution of crops made up the foundation of any ancient agricultural society, the failure of the ruling body to maintain stability in a time of climatic change and desertification was a fatal one (Bárta 2015). The distress felt by the Ancient Egyptians was not unvoiced. Nick Marriner *et al.* point out an inscription from the First Intermediate Period (immediately after the demise of the Old Kingdom) on the tomb of Ankhtifi, which clearly documents the suffering of Egyptians from crop failure and crippling famine due to intraregional aridification and low Nile floods (Marriner *et al.* 2012).

Though in this time of desert and famine, winter rainfall from the intervals of wet conditions in northern Egypt might seem like a blessing, the geoarchaeological evidence from Saqqara and the Menkaure wadi near Giza shows that it was anything but. At least at the site of Saqqara, the end of the Old Kingdom, around 4200 cal BP, was characterized by a relatively long and intense wet period, maybe several to a dozen years based on the thickness of Series 3. At the end of this wet period, there was a dramatic and relatively quick shift to much drier climatic conditions. As prosperous and well organized as the Old Kingdom was, it was not prepared to cope with such extreme climate variability. Agriculture around the Nile relied on regular floods and predictable seasons. Heavy winter rainfall, probably from jet-stream behavior and resultant sheet floods, threatened agricultural security. In conjunction with low Nile discharges from reduced monsoonal summer rainfall in Ethiopia, farmers would have struggled to provide for society. The abrupt change to extremely arid conditions at the end of the wet interval would have posed yet another devastating challenge to Old Kingdom citizens (Welc and Marks 2014).

Butzer *et al.*'s research not only lends credibility to Welc *et al.*'s interpretation of the data from Saqqara, showing that geological evidence for anomalous wet intervals appears at two distinct sites in northern Egypt, but it also reflects the lacking capability of the royal administration to cope with widespread surge floods and heavy winter rainfall. Butzer *et al.* go as far as to question "the will or ability of the pharaoh and his retainers to deal with severe environmental hazards" (Butzer *et al.* 2013). The initial situation of the Lost City in a wadi was vulnerable from day one. The steep channel and small size of the Menkaure wadi magnified the effect of heavy rainfall and flooding, wreaking havoc throughout the settlement. Even so, Pharaoh Menkaure and his successor rebuilt the Lost City more than five times. This may have continued even into Userkaf's reign in the beginning of the Fifth Dynasty. The inability of Fourth Dynasty rulers to establish adequate prevention measures for the repeated destruction at the Lost City may foreshadow the struggles Sixth Dynasty pharaohs faced toward the end of the Old Kingdom when northern Egypt was in the throes of another presumably devastating wet interval (Butzer *et al.* 2013). Looking at the historical material from this period, we see that the climate change supported by scientific research throughout Egypt had very real and serious consequences for the Ancient Egyptian people, whose longstanding practices failed them in the face of changing environmental conditions.

Conclusion

Though the details of the social implications of intraregional climate change require further investigation, current research illustrates that the social instability and upheavals at the end of the Old Kingdom were closely connected to climate variability. Aridification, observed in the geologic record, in paleoecology, in the archaeological record, and in iconography, affected annual Nile floods, harming Ancient Egyptian agricultural practices. While monsoonal summer rains diminished, resulting in low annual Nile floods, winter rains brought by the mid-latitude jet-stream increased during a number of anomalous intervals and exacerbated environmental problems. The Old Kingdom administration couldn't maintain stability through its domain in the face of climatic change, and ancient farmers, unable to rely on the predictability of seasonal conditions, failed to provide for society. In response, the social order fell apart internally. Though other factors may have been involved, climatic variability, given its scale and damage reflected by geoarchaeological data, must have been a predominant factor for the rapid decline of the Old Kingdom around 4200-4100 BP.

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