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Pyramid building and collapse

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Pyramid Building

The 22 Egyptian Old Kingdom pyramids (2675–2250 BCE), notably those of the Giza plateau, were massive monuments to the kings entombed within them and to their stone quarriers, block transporters, and exact builders who were supported by the concentrated barley yields of seasonal Nile inundation agriculture—famously without the construction and manipulation of riverside canals as required in contemporary southern Mesopotamia. The mysterious mechanics of those pyramid constructions are now solved, in part, by the recent Wadi al-Jarf papyri discoveries that document contemporary Nile boat transport of stone blocks for pyramid construction from the cliffs opposite Giza and from the Red Sea (1). Today, the Nile flows more than 7 km east of the Giza pyramids. But Nile flow through a channel that linked the Giza plateau to the Nile, termed the "Khufu channel" after the famed Khufu pyramid at Giza (2,583,283 m^3, 146 m high), has been hypothesized from a modern wastewater project's corings and its 1.8-km-long trench that cut through an ancient channel—even perhaps through Khufu's palace (2). In PNAS, Sheisha et al. (3) provide the Giza channel flow data within an 8,000-y record derived from sediment cores analyzed for pollen and lithic stratigraphy and radiocarbon dates.

The Giza cores indicate that the earliest Egyptian dynasties contended with a major fall in Nile flow, while subsequent Old Kingdom pyramid builders, from the third to fifth dynasties, utilized a stable Khufu branch flow. The cores also document the greatest decrease in Nile flow at the end of the Third Intermediate Period dynastic interruption in the eighth century BCE. The cores thus provide environmental context for several archaeological problems dependent upon definition of Nile flow dynamics including Khufu channel flow for Giza pyramid construction.

Old Kingdom Collapse

Giza cores 1 and 4 also provide startling data for the collapse of the Old Kingdom and its pyramid building projects. At the end of the Sixth Dynasty and between 2250 and 2045 BCE, the First Intermediate Period saw the abrupt politico-economic fragmentation and end of the Old Kingdom's generation and deployment of Nile inundation cereal harvests. Symbolized later with the onset of "70 kings in 70 days," this period witnessed division of the Old Kingdom state into northern and southern domains, termination of pyramid construction, major abandonment of Nile delta settlements, abandonment of the Memphis capital, temple complexes, and "The White House" royal treasury, and abandonment of the Nile-distributed royal centers (Egyptian *ḥwt*) for goods, labor, and tax collection—all while provincial elites were being empowered.

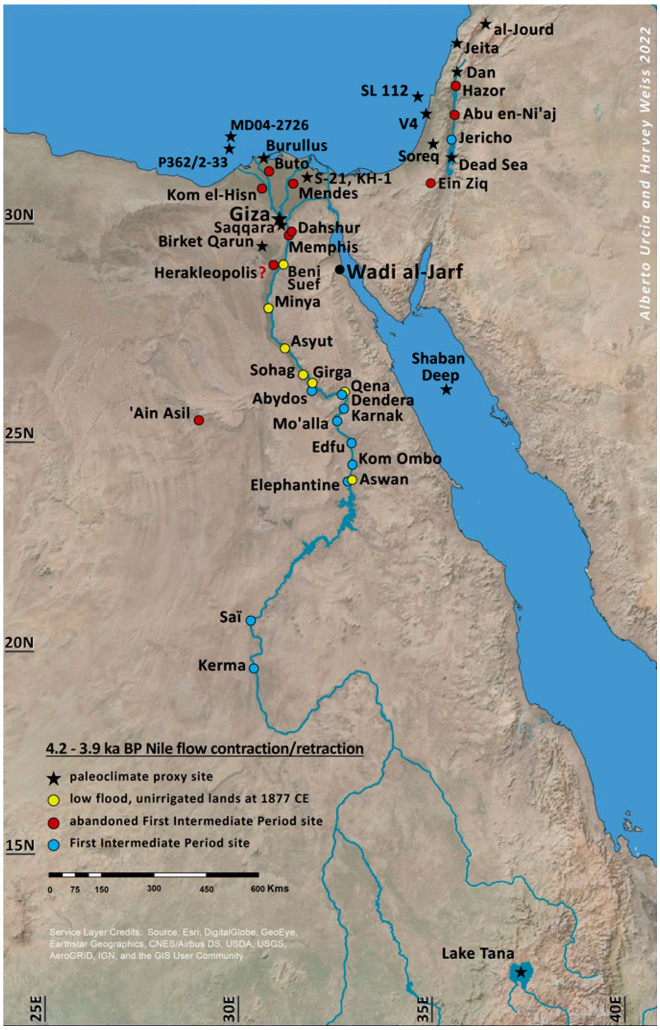

Fig. 1. The 4.2 ka BP to 3.9 ka BP Nile flow contraction/retraction.

Major research attention has, therefore, focused upon the explanation for this collapse. One explanation offered is the disruption of Old Kingdom long-distance trade in gold, copper, and aromatic myrrh. For instance, the numerous

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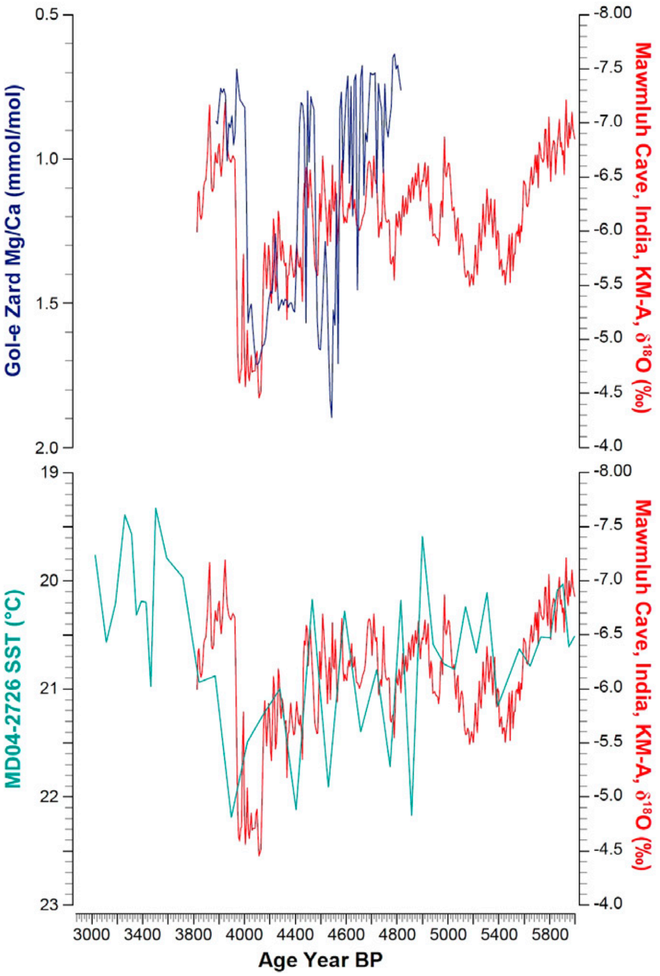

Fig. 2. Indian Summer Monsoon, midlatitude westerlies, and Nile deep sea fan paleoclimate proxies at 4.2 ka BP

settlements at and surrounding Ein Ziq in the Negev desert, associated with the Wadi Arabah Feynan and Timna copper mines, were also abandoned at this time (Fig. 1) (4). But this causal argument suffers from the post hoc fallacy; the exotic trade collapse was likely an effect, not a cause, of the Old Kingdom collapse.

More important than exotic trade expeditions were the synchronisms with “the devastating effects from a severe famine towards the end of the Old Kingdom” for which “many near contemporary texts from different parts of the country describe the same situation” (5). Coincident are the extensive lake and marine sediment core data for the ~4.2 ka BP (2200 BCE) abrupt Nile flow reductions. These data include the Nile deep sea fan marine core MD04-2726 (Fig. 2) (6), the sediment cores at Burullus Lagoon (7), Saqqara (8), and the Faiyum (9), and the Kom el-Khilgan east delta core KH-1 that documents “severe decline, to the point of local extinction, in cereal pollen, a drastic reduction in dung fungi and other non-pollen palynomorphs” (10).

Nile flow is a function of seasonal Indian Summer Monsoon (ISM) precipitation over the Ethiopian highlands that provides an average 80% of the Lake Tana sources of the Blue Nile and Tekeze-Atbara Rivers measured by air mass back trajectories, which then provide 90% of Nile flow (11–13). The proximate cause of the abrupt ~4.2 ka BP Nile flow reduction was the ISM megadroughts at 4.2 ka BP to 4.17 ka BP, 4.14 ka BP to 4.08 ka BP, and 4.06 ka BP to 3.97 ka BP, now measured to subdecadal and seasonal resolution in Indus speleothem, marine (14, 15), and lake cores (16).

Lithology evidence for the Nile flow 4.2 ka BP event is presented by Sheisha et al.’s (3) SI Appendix, figure S1, where cores Giza 1 and 4 document the abrupt intrusion of sand strata into otherwise unbroken Nile channel flow silts. The interpolated radiocarbon dates for the interruption begin ∼4250 y BP and end ∼3900 y BP (±85 y), similar to the higher-resolution Nile flow and ISM megadrought records. Coincident records obtain to the east at the Red Sea Shaban Deep marine core where the major spike in $\delta^{18}O_{\text{foram}}$ occurred “within 100 years” (17) and to the west at Lake Teli, northern Chad, where ratios of Ca/Ti and Mn/Fe indicate the 4.2 ka BP event “may represent the most extreme drought that the Sahara desert has experienced in the last 11,000 years” (18).

Sheisha et al. (3) estimate, from their proxy pollen data, a 10% reduction at ∼4.2 ka BP in local Khufu channel flow. Another estimate is provided by the transfer of measured ISM speleothem alterations to ISM precipitation reductions for Nile flow. An example is the 1877 ISM failure recorded in an Oman speleothem (19). That 1877 ISM event left unirrigated 40% of Nile irrigated land, mostly delta and northern Nile settlements (ref. 20, figure 176). Middle and southern Nile settlements, extending to Nubia, were spared this Nile flow reduction because Nile flow retraction occurred at the delta terminus when its ISM Ethiopian source was diminished (Fig. 1) (21). These were the Old Kingdom and First Intermediate Period settlement patterns: collapse and abandonment at the Nile delta with river retraction while settlement continuity and expansion occurred at still irrigated southern Middle Egypt. Synchronous ~4.2 ka BP river flow retraction and settlement abandonment occurred along the southernmost Euphrates in Mesopotamia when the midlatitude westerlies disrupted the source precipitation measured at the Gol-e Zard speleothem core (Fig. 2) (22, 23).

Conclusions

Paleoclimate proxy data, including those from lake, speleothem, and marine cores, provide the dynamic environmental stage for the archaeological space–time theater. In great detail, they define the changing environments within which some ancient societies deployed irrigation agriculture surpluses and then reacted adaptively to their abrupt and inalterable diminution. At the construction of the High Aswan Dam 50 y ago, Nile flow seasonal inundation ceased forever, but, as Sheisha et al. (3) document, its dynamic Holocene history remains preserved within its riparian sediments.

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