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Geoarchaeology; agriculture; domesticates; Egypt; Fayum Basin; palaeo-lake levels.

A fundamental question in Near Eastern Archaeology is why agriculture in Egypt was introduced four millennia later than in the adjacent Eastern Mediterranean and Southwest Asia.[1] Phillipps et al.[2] suggest that adoption of Near Eastern animal and plant domesticates by Neolithic societies in Egypt around 7000 cal. BP occurred during a period with increased winter rainfall, comparable to southwest Asia. Environmental change after 6000 cal. BP meant however, that the growing of wheat and barley was no longer sustainable in Egypt and required significant shifts in agricultural strategy before they were viable long term.[3] The main aim of this geoarchaeological research is to test the environmental explanation for the apparent lag in the entry of agriculture into Egypt.

The Fayum Basin, northern Egypt (Fig. 1), has long been recognised as representing the earliest example of agriculture in Egypt, as domesticated Emmer wheat and barley were discovered in hearths at two Neolithic occupation mounds and in nearby grain storage pits.[4] Prehistoric people in the Fayum Depression occupied palaeo-shores of a series of large freshwater lakes that were controlled by the variable inflow of Nile water since the early Holocene.[5] Palaeo-lake water levels fluctuated in response to changes in Nile flood heights, the result of the highly seasonal Blue Nile flow from monsoonal rainfall in the volcanic uplands of Ethiopia, and White Nile flow from rainfall in the lake plateau of Uganda.[6] Archaeological evidence for past human occupation in the Fayum Depression is concentrated in distinct topographic bands across the northern palaeo-shores of the modern, brackish terminal Lake Qarun, the shrunken remnant of the larger palaeo-lakes (Fig. 1). Rises and falls of palaeo-lake levels in different periods through the Holocene have been established through association of lacustrine deposits with distributed cultural material since the early 20th century.[7]

Hiatus in human occupation of the depression is explained by sudden declines in palaeo-lake levels, controlled by position of the Inter-Tropical Convergence Zone (ITCZ) and Sub-Saharan climatic changes.[8] Palaeo-climatic reconstructions however, indicate a brief period of sustained mid-Holocene winter rains in Northeast Africa from the eastern Mediterranean,[9] which correlate with the relative short period of intense Neolithic habitation in the Fayum Basin between 7000–6000 cal. BP.[10] The adoption of domesticates

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[1] Allen 1997; Zeder 2008.
[2] Phillipps et al. 2012.
[3] Phillipps et al. 2012.
[4] Caton-Thompson and Gardner 1934; Wendrich and Cappers 2005.
[5] Caton-Thompson and Gardner 1934; Wendorf and Schild 1976.
[6] Hassan 1986; Hassan 1997; Williams 2009.
[7] e.g., Caton-Thompson and Gardner 1934; Hassan 1986; Wendorf and Schild 1976.
[8] Hassan 1997.
[9] Arz et al. 2003.
[10] Phillipps et al. 2012.

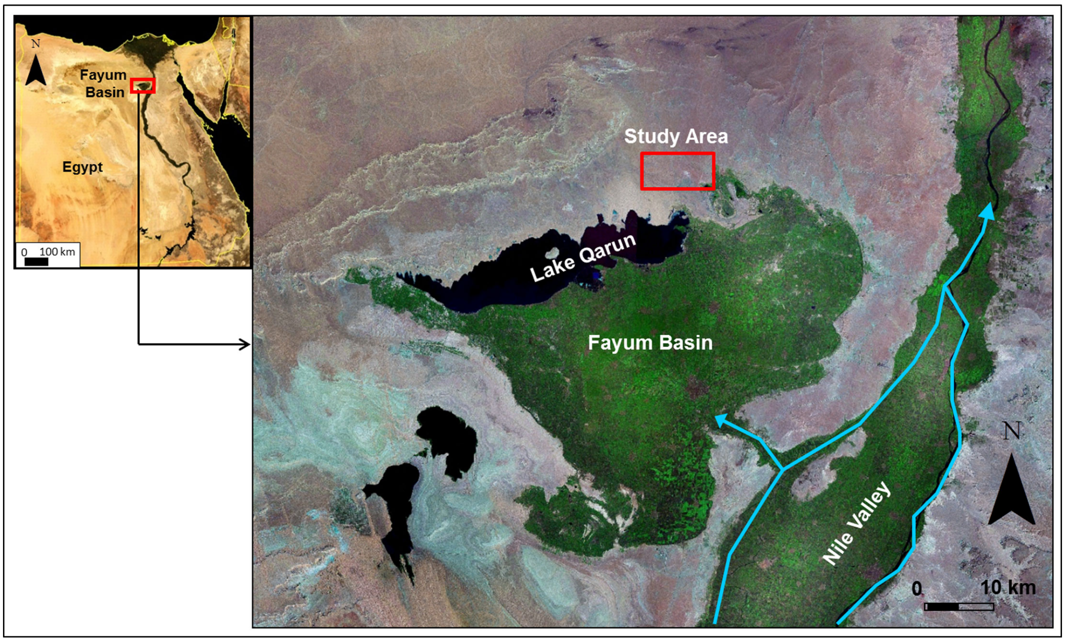

Fig. 1 | Study area in the Fayum Basin, northern Egypt (NASA World Wind 1.4).

by Neolithic occupants of the depression can be viewed as one of a range of unique low-level food producing societies that developed around the Mediterranean mid-Holocene, in which domestic species added to, rather than replaced, existing subsistence strategies dependent on wild food resources.[11] A reliance on winter rains for cereal cultivation may explain the efflorescence of Neolithic occupation in the depression, as well as its subsequent rapid decline, as the winter rain belt shifted back to the north and climatic changes led to the start of the present-day hyper-arid state of the Sahara.[12] In addition, new data on the micro-dynamics of the Fayum palaeo-lake level fluctuations during the Early Holocene[13] suggest that a greater detail of higher temporal resolutions in lake level reconstructions is required for correlations between lake level history and periods of human occupation.

The greater part of the archaeological record in the Fayum Depression however, is uncovered, aggregated on today's eroded desert surfaces, and this hampers conventional geoarchaeological research. Deflation processes active along today's hyper-arid northern palaeo-shores of Lake Qarun have exposed a Neolithic archaeological record at the present-day surface, comprised of extensive deposits of stone artefacts, bones, and pottery. The archaeological deposits are associated with heat-retainer hearths at the present-day surface, visible as concentrations of burnt stones that often protect charcoal, and two stratified Neolithic occupation mounds, known in the literature as Kom W and Kom K.[14] Although archaeological artefacts at the present-day surface are commonly difficult to relate to their stratigraphic context,[15] they provide fundamental data on past geomorphic changes and human land use if analysed with attention to history of deposition of the

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[11] Holdaway, Wendrich, and Phillipps 2010; Phillipps et al. 2012; Smith 2001; Wenke, Long, and Buck 1988, 44–46.

[12] Phillipps et al. 2012.

[13] Koopman 2010.

[14] Caton-Thompson and Gardner 1934.

[15] e.g., Aerts et al. 2003, 138; Buck, Kipp, and Monger 2002, 683; Ward and Larcombe 2003; Fanning, Holdaway, and Rhodes 2007.

sediments on which they currently rest.[16] Systematic comparisons between the depositional history of sediments at Earth's surface and areal presence of surface archaeology enables understanding of (palaeo-)processes of erosion and deposition that lead to the formation of the surface artefact record, and of the significance of the quantity of artefacts visible.[17] Holdaway[18] made use of the extensive surface archaeological record in the arid interior of Australia to interpret rapid climatic changes and human response during Late Holocene, by means of correlating optically stimulated luminescence (OSL) and radiocarbon age estimates with high-resolution palaeo-environmental records from outside the region. The use of archaeological records at the present-day surface can be further enhanced by combining them with elemental techniques from the Earth sciences used to study the local sedimentary record.

In order to understand the relation between past environmental shifts and initial use of domesticates in Egypt, the following research questions are addressed:

1. What were the rates and spatial variability of dominant geomorphic processes in the Fayum Basin that were critical to Neolithic occupation?
2. How do sedimentary facies at the present day surface in the Fayum Depression correlate with exposure, preservation, visibility, and content of archaeological evidence for Neolithic occupation at the present-day surface?
3. How do stratigraphic sequences with archaeological evidence for Neolithic occupation in the Fayum Basin correlate with local geomorphology and palaeo-lake level reconstructions?

To answer the research questions we use a multi-proxy approach of basic techniques from the Earth Sciences, with incorporation of published Late Quaternary regional and global climate proxies and information on the Holocene flow regime of the River Nile. Lithological field investigations and systematic sediment sampling across the hyper-arid northern palaeo-shores of Lake Qarun (Fig. 1) provide a high-resolution geomorphic framework for the study of the Neolithic archaeological record in the Fayum Basin. To allow for systematic comparisons between surface sediments and surface archaeology across the study area, investigations of lagged or winnowed geomorphology are performed at areas containing surface archaeological evidence for Neolithic occupation, as well as at barren surfaces. Outcrop investigations and selective hand-drilling (Dutch and Riverside Augers, ø7cm) at the Neolithic occupation mounds Kom W and Kom K, as well as at lower surrounding geomorphic surfaces provide data on the relationship between local geomorphology, palaeo-lake level fluctuations and Neolithic occupation.

Analytical studies, focused on grain size, are performed at the Sediment Analysis Laboratory of the Faculty of Earth and Life Sciences at the VU University Amsterdam. Because grain size is the most fundamental property of sediment particles, affecting their entrainment, transport and deposition,[19] grain size distributions (GSDs) from sampled deposits of geomorphic units are measured by Laser Particle Sizer (Helos KR Sympatec/Windox 5.6). Observed frequencies are decomposed through a numerical-statistical inversion,[20] in order to obtain environmental diagnostic features from the observed sediment populations.[21] End-member modelling coupled with weight-percentages of organic matter and $CaCO_3$ (TGA-701 Leco Corporation Germany) provide new data on geomorphic processes and source areas responsible for spatial-temporal variability of litho-types in the Fayum Basin, controlled by palaeo-lake levels and (regional) climatic changes.

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[16] Buck et al. 1999; Huckleberry and Billman 2003, 505; Fanning et al. 2009; Holdaway and Fanning 2010.
[17] e.g., Fanning et al. 2009; Holdaway and Fanning 2010; Huckleberry and Billman 2003, 505.
[18] Holdaway et al. 2010.
[19] e.g., Blott and Pye 2001; Folk and Ward 1957.
[20] Algorithm EMMA: Weltje 1997; Weltje 2001.
[21] Weltje and Prins 2003; Weltje and Prins 2007.

Chronology of the geomorphic reconstructions is provided by AMS Radiocarbon determinations on organic material preserved in natural and cultural deposits, complemented by optically stimulated luminescence (OSL) age determinations on sediment at key areas. To allow for systematic comparisons between geomorphology and archaeology, both datasets are integrated in a GIS-environment (ArcGIS 10). Our systematic multi-scalar approach leads to a new method to study geomorphic contexts of archaeological records in the Eastern Sahara that can be applied elsewhere. The results fill a major gap in archaeological knowledge, as “the southern margin of the Mediterranean Basin along coastal North Africa is essentially *terra incognita* for understanding the course of Neolithic emergence.”[22]

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[22] Zeder 2008, 11603.

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