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Herding then farming in the Nile Delta

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The Nile Delta in Egypt represents a valuable location to study the history of human societal development and agricultural advancement. However, the livelihood patterns of the earliest settlers – whether they were farmers or herders – remains poorly understood. Here we use non-pollen palynomorphs and pollen grains from a sediment core taken at Sais, one of the earliest archaeological sites in the west-central Nile Delta, to investigate the livelihood patterns and transition of early settlers there. We find that animal microfossils (dung and hair) occur in substantial quantities from around 7,000 years ago in our high-resolution-dated non-pollen palynomorphs spectrum, while domesticated cereals emerge in the spectrum around 300 years later. We also identify evidence of fire-enhanced land exploitation after this time. We interpret our microfossil evidence to indicate that the earliest settlers in the Nile Delta were herders and that this then developed into a combination of herding and farming.

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The Nile Delta, where the river flow originates from a humid area in the highlands of eastern Africa, has played a key role in building the political system and promoting social development of Egypt[1,2] (Fig. 1a, b). This has attracted a worldwide focus on early human migration and occupation, and the origins of agricultural and social advancement. This discussion covers not only the river-delta itself, but also includes the wider Mediterranean and much of SW Asia[3–5]. Intriguing but highly contentious arguments persist, related to who were the earliest settlers, when they moved into the delta, whether they were farmers or herders, and what dynamics this livelihood transition underwent. Although substantial effort has been made by geoarchaeological communities to clarify these questions in the past decades, the drivers of the processes of cultural transition remain poorly understood.

In this study, we examine these issues by reporting our geobiological observations, made at the type archaeological site of Sais (Sa el-Hagar, 30° 58′ 05″ N, 30° 45′ 56″ E) (Fig. 1a). The site is located in the west-central delta, which is defined archaeologically as one of the earliest Neolithic sites (ca. 6.5–6.2 ka)[6]. An 8.50 m sediment core (SH-1) was taken on the margin of the Sais site for this study (Figs. 1c, 2). The basal material of the core, below 8.25 m (Fig. 2), is an Early Holocene flood levee composed of sandy sediment, known as 'Gezira' (Turtleback) in Arabic. A gray silty clay and yellow fine sand occurs in core depth 8.25–6.70 m, and is considered to be a natural sediment layer. This is overlain by a thicker muddy sediment (6.70–1.70 m) containing fragmented pottery and sherds, identified as a cultural layer (Fig. 2). An agriculturally disturbed layer occurs at 1.70–0 m, which was not analyzed in this study.

We use non-pollen palynomorphs (NPP) and pollen grains in our examinations. NPP includes microfossil remains of vascular plants as well as a great variety of degradation-resistant remains of fungi, algae and invertibrates[7,8]. NPP studies started in the 1970s and have since advanced significantly[7–13], and those descriptions, identifications, morphotype code numbers and related ecological information were examined as relevant studies progressed[10–13]. However, our search of the literature has shown that very few NPP studies have been reported from the Nile Delta in a geoarchaeological context. The findings of this study are multidisciplinary, being new assessments to complement knowledge in the geoarchaeological field of the Nile Delta.

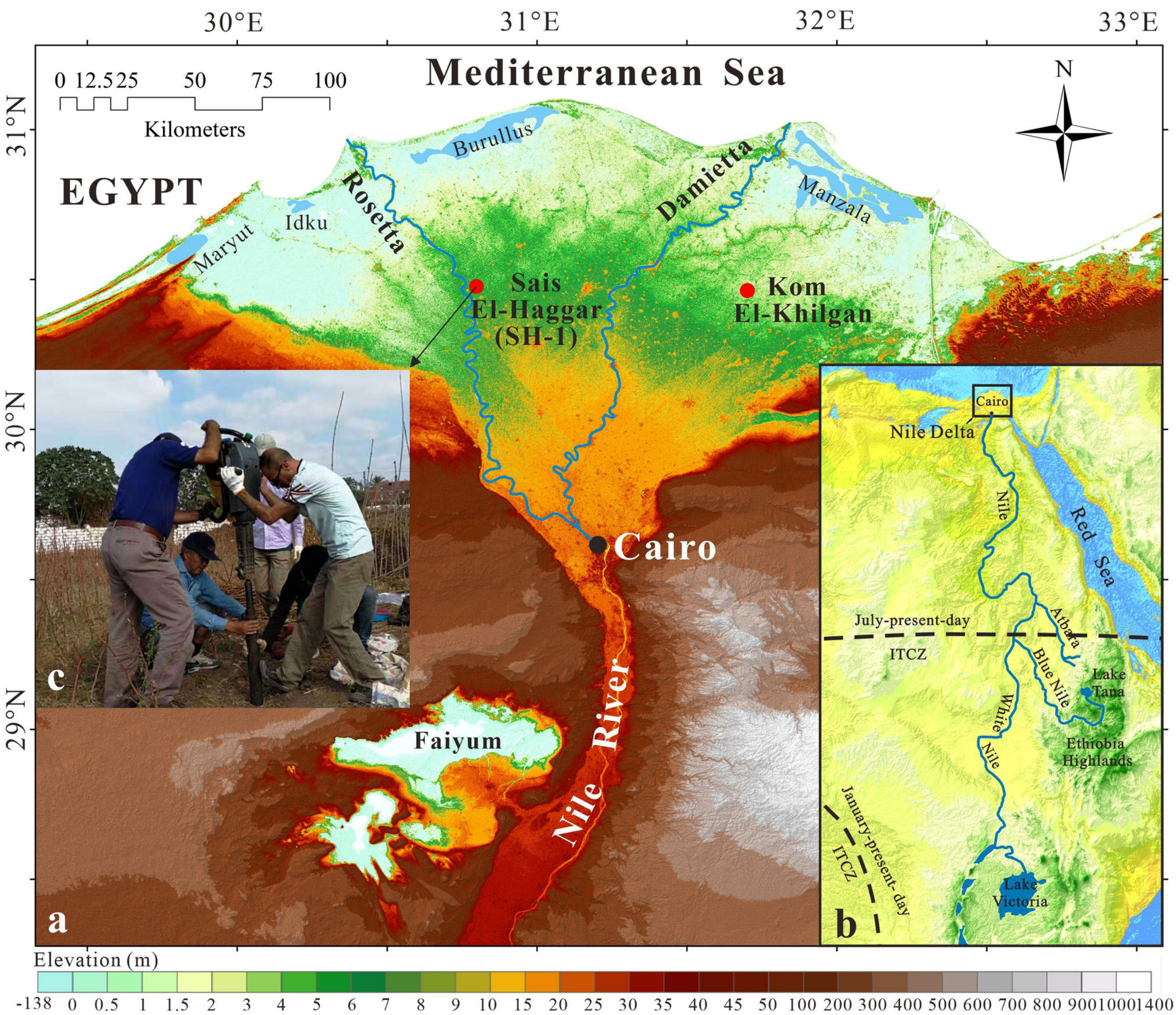

Fig. 1 Map of the Nile Delta and the Nile River Basin. In this map shown are the archaeological sites of Sais El-Haggar (Predynastic) and Kom El-Khilgan (Predynastic) (**a**), the entire Nile River Basin (**b**), and coring at Sais (**c**) (delta images were formed by authors with SRTM open source at: https://srtm.csi.cgiar.org/).

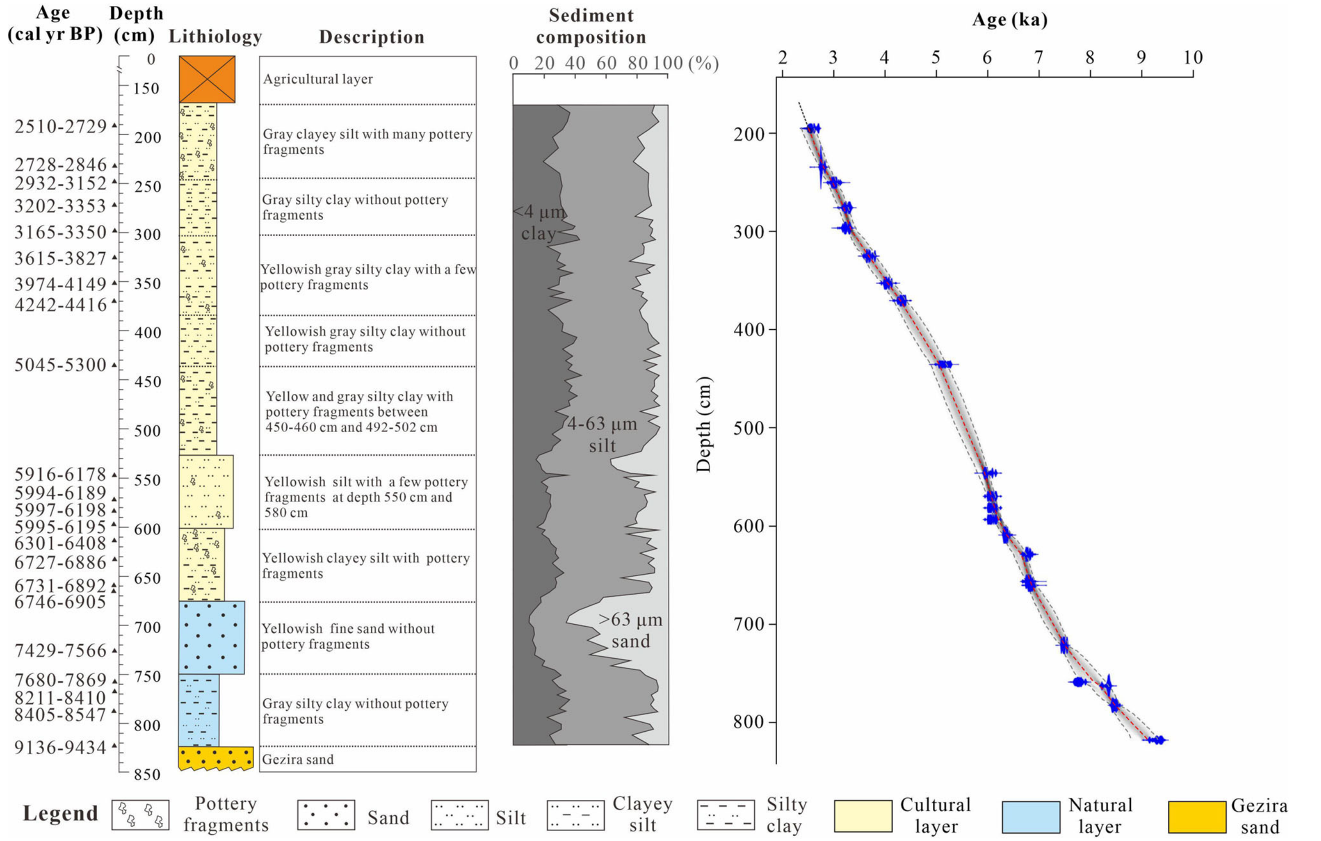

Fig. 2 Lithology description and age-depth model of core SH-1. Lithology and age-depth model of core SH-1 from archaeological site Sais (see Fig. 1a). 22 AMS-^{14}C dates from SH-1 form the basis of this high-resolution study (the envelop of age-model represents the range between minimal and maximal dating value at final 95% confidence intervals). The "natural layer" (without pottery and sherds) and the "cultural layer" (with pottery and sherds) are shown in the core log. The basal sand layer of SH-1 is termed as "Gezira" (Turtleback) in Arabic. Sediment log SH-1 was modified from our previous study[37].

Study area. The Nile Delta (*ca*. 2.4 × 10^4 km^2) of NE Africa is a significant component of the Egyptian landscape. The delta formed *ca*. 7000 years ago, when the sea reached closer to its present level[14]. The delta is topographically elevated from 1–2 m above mean sea level (amsl) along the delta-coast, but quickly rises to *ca*. 3–15 m amsl inland, primarily due to catastrophic flood-related aggradation during the Africa Humid Period (AHP)[15] (Fig. 1a). The site of Sais covers an area of 0.16 km^2 and stands on the floodplain with an elevation *ca*. 5–6 m amsl. The site is *ca*. 1.8 km east of the Rosetta Branch, one of the two main tributaries of the present delta (Fig. 1a), but many paleo-Nile branches existed during the Early-Middle Holocene[1]. The Nile Delta has an arid climate setting with a precipitation of *ca*. 100 mm per year[16]. This contrasts with its watershed, the Africa Highlands, and the Ethiopian Plateau, where high rainfall (>1500 mm per year) is driven by the African monsoon[17,18]. The delta surface is sparsely vegetated with a few natural shrubs and herbs.

Results and discussion

There has been considerable discussion of the origins and development of the livelihood patterns of the early settlers who migrated to the lower Nile valley, including the Faiyum basin and the delta-coast (Fig. 1a), during the Early-Middle Holocene[3–5]. Our high-resolution dated NPP zones (I–VII) defined in this study provide significant insights into this discussion. Clearly, no intense land use activities occurred in the NPP Zone I, a natural layer (Figs. 2 and 3), before 7.0 ka, and this is seen in archaeological studies, in which no archaeological site >7.0 ka has yet been reported in the Nile Delta[4,5].

What we saw in NPP Zone II (the cultural layer) was the largely emerged and peaked animal dung/hair (Fig. 4_No. 2, 4, 7; No. 14–18), that begins at ca. 7.0 ka (Figs. 2 and 3). High concentrations of animal dung often imply stock animals mostly associated with systematic pastoral patterns[13,19], suggesting herd animals brought to the site. Sporadically distributed animal dung/hair in Zone I (Fig. 4_No. 1, 13) indicates wild indigenous animals existed in the study area before 7.0 ka[4], and they seem to have been at the site in the Neolithic period, based on excavated rib bones of a wild bull (*Bos primigenius*)[20], perhaps representing a regime of mixed hunting and husbandry.

It is also noted from the previous study that the Nile Delta was not included in the human migration circum-Mediterranean during the period 11.5–7.0 ka[1], perhaps due to insufficient dated geoarchaeological caveats in previous studies. The high-resolution-dated NPP of Sais in the present study that shows the human activities at 7 ka can fill in this geochronological gap.

Our pollen grain analysis of the Sais found that Poaceae (35–37; 37–40; >40 µm) appeared abruptly and coevally in the consequent NPP Zone III dating back to 6.7 ka (Fig. 3). Poaceae >35–40 µm is generally used to imply domesticated farming activities elsewhere in the world[21–24], although there has been debate over the separation of larger grains of pollen of cereals from wild grasses of smaller size[25–29]. In this study, we do not intend to be definitive while applying classified sizes of Poaceae to cereal cultivation/domestication. However, we touch on the argument of early farming activities by using the little correlated

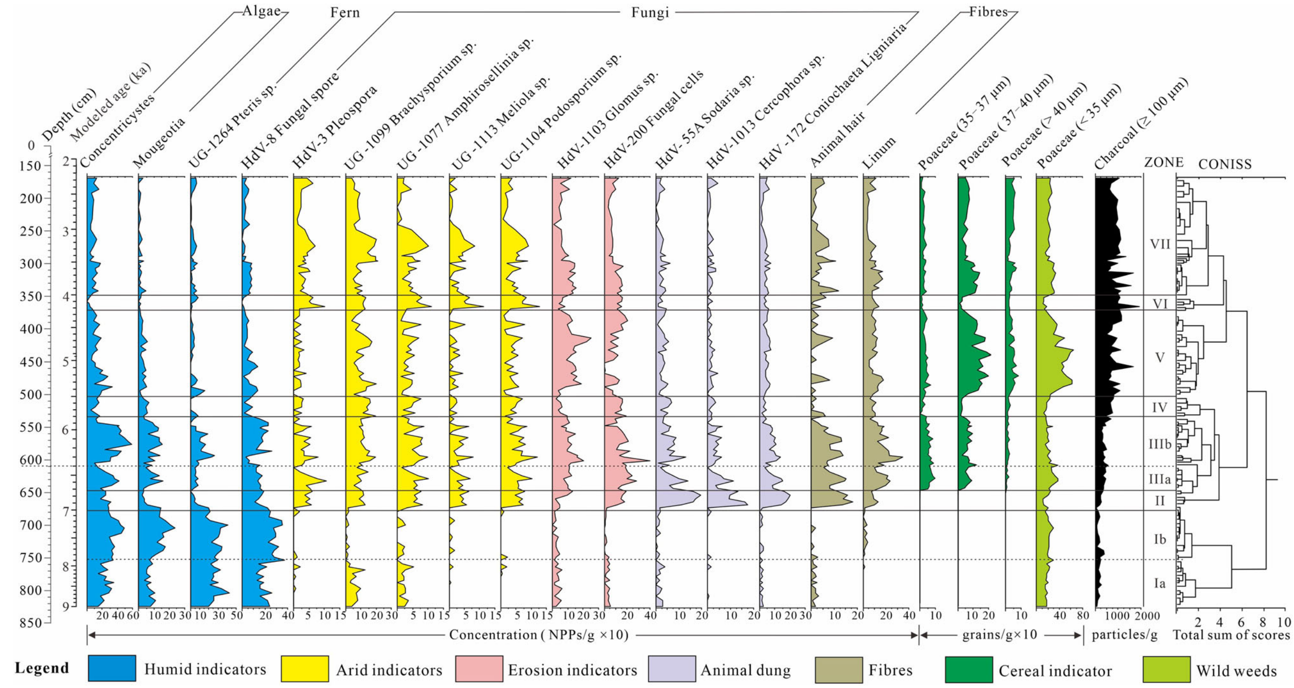

Fig. 3 NPP pollen spectrum of SH-1. Seven (7) indicators identify the signatures of the Holocene environmental change in the Nile Delta. Animal dung and fibres appear noticeably in Zone II (7 ka), and the classified Poaceae (35–37; 37–40; >40 μm) representing domesticated cereal appear first in Zone III (6.7 ka), indicating that herding predates farming at the site. Increasing charcoal (>100 μm) indicates the use of fires in cropping-base farming. The little correlated relationship between wild Poaceae (<35 μm) and classified Poaceae indicates domesticated cereal imported from outside. Poaceae <35 μm and charcoal >100 μm was cited from our previous study[37].

relationship between Poaceae <35 μm and Poaceae >35–40 μm at the site. The classified Poaceae sizes occurring from the Zone III–VII (the bottom of Zone III dates to 6.7 ka) (Figs. 2 and 3) contrasts to Poaceae <35 μm, the wild weeds seen throughout the Holocene spectrum (Fig. 3). This unique relationship, which was also reported by our preliminary study at another type archaeological site of Kom El-Khilgan in the NE Nile Delta[30] (Fig. 1a), suggests that Poaceae of >35–40 μm (Fig. 4_No. 21–25), especially >40 μm (Fig. 4_No. 26–28) was imported by migrants into the study area. This further indicates that the larger sizes of Poaceae (>35 μm) that emerged at the site were domesticated cereal, which had developed already in SW Asia and the east Sahara Desert prior to 6.7 ka[31–33]. We therefore propose that herding predates farming at the site by at least 300 years (Fig. 3).

We found husbandry being undertaken at the site since 6.7 ka, indicated by concomitant fluctuation of animal microfossils and Poaceae >35–40 μm in the Zones III–VII (Fig. 3). The proportional change of animal microfossils and Poaceae (>35–40 μm) through time, on other hand, suggests that herding may have weakened while cropping-based activities intensified (Fig. 3). Intensifying land exploitation is seen after 6.7 ka, indicated by the increasing intensity of micro-charcoal (≥100 μm) and NPP erosion indicators, together with Poaceae (>35–40 μm). Fire-enhanced land exploitation could have helped cope with increasing pressure from population growth as society advanced (Fig. 3).

It is widely acknowledged that domesticates (goat/sheep, and barley/wheats) were brought into the lower Nile valley early in the history of human occupation[4]. The hot-dry climate in NE Africa, including the lower Nile, did not support broader occupation of indigenous domesticates[34]. Our NPP and pollen grains provide firm biological evidence to support this hypothesis.

Interestingly, *Linum* (flax) was also found in SH-1, in a similar distribution pattern to animal microfossils (Fig. 2). *Linum* occurrence indicates the need of this material for the early settlers' livelihood[35,36]. It is reported that *Linum* was found as a food resource in the Levant as early as 8000 years ago[36], the major route of early settlers who migrated into the lower Nile Valley[4,5]. The sparse *Linum* in Zone I prior to 7.0 ka (Figs. 3 and 4_No. 9) could give rise to an assumption that it was local plants that were cultivated for handcraft products as demanded by the early settlers.

The freshwater algae, ferns, and fungi, associated with wet environments, indicate a wetter climate setting before 7.0 ka followed by a drying climate towards recent time[37] (Fig. 3). Presumably, unexpected Nile floods occurred prior to 7.0 ka, making the delta area uninhabitable. The subsequent short-term (300 years) climate drying (Zone II, Fig. 3) led to herding starting at the site, a phenomenon also recognized at the site of Kom El-Khilgan. Perhaps, herding was economically more productive than cropping-based land use activities during the drier climate period. Obviously, cropping began when the climate became wetter[37] (Zone III, Fig. 3) and the settlers had developed the capability to sustain themselves during the post-AHP climate drying.

Methods

Age model. In this study, we took 22 samples consisting of charcoal and organic mud from SH-1 for AMS radiocarbon dating (Fig. 2). Dating was conducted at the Beta Laboratory in Florida, USA and the Institute of Earth Environment, Chinese Academy of Sciences, Xi'an, China. Calibration was applied to all the ages at 95.4% confidence intervals (2σ) in calendar years before 1950 (expressed as cal. yr BP), using the Calib 8.1.0 radiocarbon age calibration program with IntCal20 datasets (Supplementary Table 1)[38]. An age-depth model set at 10 cm intervals was constructed using the 'rbacon' package in R[39], and indicated as ka in this study.

NPP-pollen analysis. A total number of 116 samples were taken for NPP-pollen analysis with a sampling interval of 5 cm. The samples were dried at room temperature and a 10 g dry sample was taken for analysis following Moore et al.[40] and Kholeif and Mudie[41]. A tablet of exotic Lycopodium spores (27,637 N/tablet) was added to each sample to calculate the pollen and NPP concentrations. 10% HCl and 40% HF were added to remove carbonates and silicates, respectively. The samples were heated with 10% KOH to dissolve humic matter. The materials

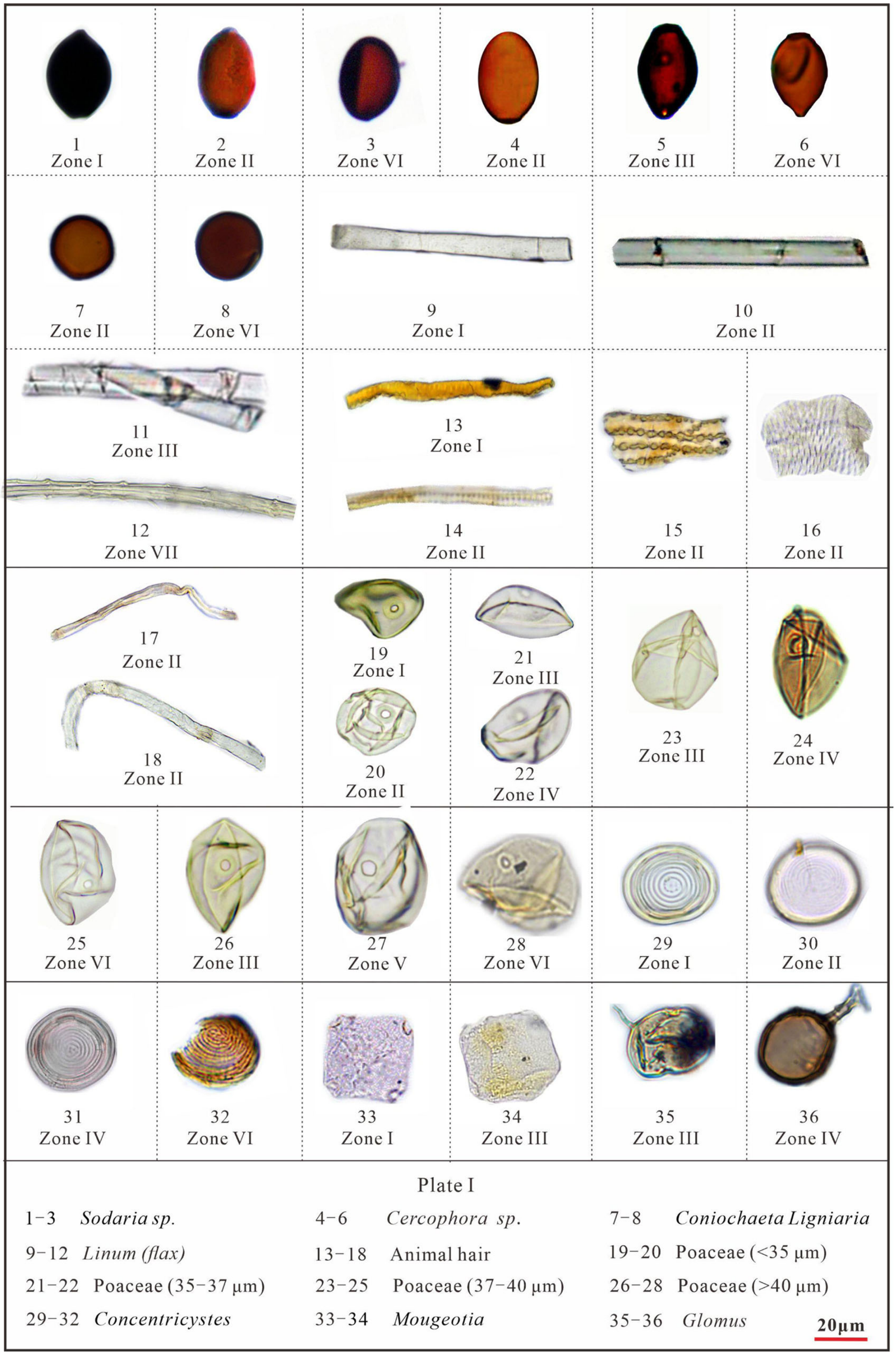

Fig. 4 Type examples of non-pollen palynomorphs and pollen grains. Type examples of non-pollen palynomorphs are numbered as No. 1–18 and No. 29–36. Poaceae grains <35, 35–37, 37–40 and >40 μm are selected from Zone I–VII of SH-1 (seeing Fig. 3 for zonation).

remaining were sieved through a 10 μm mesh in an ultrasonic instrument in order to concentrate the pollen and NPP grains.

The identification of known NPP was based on comparison with descriptions and illustrations in the literature[7,12]. The non-pollen grains were counted with a Nikon Ci-L microscope (×400 magnification). On average 220 (400 max.) algae and fungal spores were identified in each sample (Supplementary Table 2). An NPP spectrum was prepared, using the stratigraphically constrained cluster classification CONISS (Fig. 3). Pollen grains (Poaceae 35–37 μm, 37–40 μm, >40 μm) were counted in this study (Supplementary Table 2). Poaceae <35 μm and charcoals are cited from our previous study[37].

NPP was grouped into 5 types of indicators that are described below (Fig. 3)[7,12]. Hugo de Vries Laboratory (HdV) type numbers refer to the taxa defined by the HdV[7]. Universiteit Gent (UG) Laboratory type numbers refer to those defined by the UG[12].

Humid indicators. These consist of freshwater algae (*Concentricystes* and *Mougeotia*) (Fig. 3; Fig. 4_No. 29–34)[7], indicating freshwater conditions[7,42,43]; Fern *Pteris sp*. (Type UG-1264)[12] and fungal spores (Type HdV-8)[7] indicate wet conditions.

Arid indicators. These include fungal spores *Pleospora* (Type HdV-3), *Brachysporium sp*. (Type UG-1099), *Amphirosellinia sp*. (Type UG-1077), *Meliola sp*. (Type UG-1113), and *Podosporium sp*. (Type UG-1104) (Fig. 3), indicating dry conditions[7,12].

Erosion indicators. These include *Glomus* type fungal bodies (Type HdV-1103) and fungal cells (Type HdV-200) (Fig. 3; Fig. 4_No. 35–36)[5]. Glomus is the largest genus of arbuscular mycorrhizal fungi, occurring on a variety of host plants and indirectly indicative of soil erosion[7,10].

Animal dung indicators. These include fungal spores *Sodaria sp*. (Type HdV-55A), *Cercophora sp*. (Type HdV-1013)[5], and *Coniochaeta Ligniaria* (Type HdV-172) (Fig. 3; Fig. 4_No.1–8)[7].

Fiber indicators. *Linum* (flax) and animal hair (Fig. 3; Fig. 4_No. 9–18)[35], which is often used to imply early human-related activities[36].

Data availability
The data that support the findings of this study are openly available as supplementary tables. Supplementary Table 2 was uploaded to FigShare (https://doi.org/10.6084/m9.figshare.19212396).

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Author contributions

Z.C., A.S., Q.S., and J.C. have made the design of this study. Z.C., A.S., Y.W., X.Z., F.J., S.E.A., Q.S., and Y.L. jointly finished coring in the field. X.Z. ran the pollen-non pollen and grain size analyses. Z.C., X.Z., I.T., B.F. and P.W. wrote the paper, and all authors joined discussion and approved this submission.

Competing interests

The authors declare no competing interests.

Additional information

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