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Abstract

Establishing agricultural activity using pollen analysis is one of the prime challenges of a palaeoecological investigation. Here we report combined pollen and archaeobotanical data originating from a waterlogged off-site organic-rich fill radiocarbon dated to ~8 ka Cal BP located between the two occupation mounds at Neolithic-Chalcolithic Çatalhöyük, south central Turkey in order to investigate the record of Early Chalcolithic agricultural activity. Pollen results indicate extremely high abundances of Cerealia-type pollen (30->70%) and critical measurements of these show them to be *Triticum*-type, *Avena/Triticum*-type, *Secale*-type and *Hordeum*-type. Pollen data are also compared with archaeobotanical data retrieved from the same sediment matrix and show high abundances of *Triticum* and *Hordeum* grains, awns, spikelet forks and glume bases. Archaeobotanical and pollen data are therefore unequivocal in showing the presence of cereals throughout the period of deposition, and although preservation of archaeobotanical cereal plant remains is typically poor, the presence of glume wheats, including emmer/'New Type' wheat and domesticated barley, is consistent with cereal data from on-site excavation deposits at Çatalhöyük. Pollen data also include high occurrences of clusters of Cerealia-type, Chenopodiaceae, Poaceae and Asteraceae and point to local deposition that is best explained as the anthers being deposited at the coring site attached to cereal or other herbaceous waste material. Archaeobotanical data in addition to very high percentage values of individual Cerealia-type pollen grains and clusters of Cerealia-type pollen and other non-arboreal pollen types suggest that the margins of the Çatalhöyük site were probably used for early stage crop processing activities as well as a waste site. Although radiocarbon dating of this organic-rich fill suggests that it was deposited over a very short time period (~300 years) during the Early Chalcolithic, the data highlight the importance of adopting complementary palynological and archaeobotanical approaches in order to better understand the taphonomy of micro and macrofossil deposits associated with archaeological sites. While more distant, regional pollen sites in south-central Anatolia have difficulty registering Neolithic-Chalcolithic cereal cultivation, this study shows that if a pollen core site is located too close to an archaeological site, then pollen assemblages can be overwhelmed and 'swamped' by the products of local cereal processing and the inclusion of domestic waste material thus rendering it difficult to elucidate meaningful data on local agricultural activity.

Highlights

- Comparison of archaeobotanical and pollen analytical data from on- and off-site deposits at Neolithic-Chalcolithic Çatalhöyük
- Replicated very high percentage values (30-78%) of Cerealia-type pollen recorded from two sediment cores
- Quantitative measurements of Cerealia-type pollen grains
- Highlights the importance of taphonomical pathways for microfossil (pollen) and macrofossil (archaeobotanical) material
- Importance of site selection when undertaking palaeoecological investigations in close proximity to archaeological sites

Keywords

Çatalhöyük; cereal pollen; archaeobotany; Chalcolithic; Neolithic; agriculture; Turkey

1 Introduction

Archaeological research has revealed, in considerable detail, the emergence of Neolithic farming societies in southwest Asia, and their subsequent spread across Europe (Hofmanová, *et al*. 2016; Horejs, *et al*. 2015; Baird et al. 2018). Archaeozoological and especially archaeobotanical evidence from excavated plant remains, notably of wheat and barley, indicates that the main transition from foraging to farming was complete by ~8000 BP (uncal) in the core region of domestication (Harris 1998; Colledge et al., 2004; 2013). Despite this wealth of bioarchaeological data, off-site evidence (i.e. from non-archaeological excavation contexts) for early prehistoric agriculture in the eastern Mediterranean region in particular has remained elusive. Willis and Bennett (1994) highlighted the significant discrepancy in time between the arrival of Neolithic agriculture, as testified archaeologically, and the first appearance of cultural indicators in pollen diagrams from Greece and the

Balkans, a time delay amounting to >2000 years. It has been proposed that many of the earliest Neolithic farming communities in southeast Europe and Anatolia practised a relatively input-intensive horticulture on alluvial soils (Sherratt 1980; van Andel and Runnels 1995; Bogaard *et al*. 2013). Such garden-scale cultivation would not have required large-scale clearance of the pre-existing natural vegetation, and these activities would not have been detectable in pollen sequences unless they were located in close proximity to prehistoric settlements. Most crops (wheat, barley, etc.) are severely under-represented palynologically, and may only find limited (or zero) expression in pollen diagrams located some distance from prehistoric sites. Additionally, many palynological indicators of cultural activity are present naturally in southwest Asia and the secondary anthropogenic indicators (e.g., weeds) can often provide diagnostic evidence of pastoral and cultivation. Cerealia-type pollen, for example, which is an exotic in northern Europe, has been used to identify prehistoric crop husbandry, but there are some wild cereals and other grasses in the Mediterranean region that have Cerealia-type properties (e.g., grain diameter >40 µm) and therefore need not provide a diagnostic indicator of prehistoric farming activity (Bottema 1992). The analysis of pollen derived from on-site archaeological excavation contexts also presents a range of problems from biases associated with preservation and taphonomy. Pollen grains do not survive well in the usually dry sediments associated with archaeological sites in southwest Asia; they are prone to differential microbial attack and corrosion. Furthermore, in order for pollen studies to yield worthwhile results, the palynologist must have knowledge of the likely source or origin of the pollen and its pathways from production and dispersal to deposition; i.e., its taphonomy. For example, pollen extracted from archaeological excavation contexts may have been brought to the site in bedding or fodder, in the sediments or attached to vegetation used as temper in mudbrick manufacture or transported from one context to another by soil fauna, e.g., digger bees (*cf*. van Zeist & Bottema 1991; Bottema 1975). Because there are many difficulties surrounding pollen analysis from archaeological contexts, it is generally accepted that off-site research may yield more informative results (Edwards 1991; Bottema 1992). The aims of this paper are twofold. Firstly, we report combined pollen and archaeobotanical results from a sediment core retrieved from an off-site, organic-rich and waterlogged location adjacent to and therefore in close proximity to Neolithic-Chalcolithic Çatalhöyük, south central Turkey (Figure 1) in order to establish a palynological signal of agricultural activity. By comparing pollen and archaeobotanical results together, we are able to examine indicators of prehistoric food procurement and processing activities, while each mutual approach is better able to provide information on and provide an independent check on taphonomic pathways of pollen and plant remain data. Secondly, we compare the proximal off-site pollen data reported here from Çatalhöyük with Cerealia-type pollen data for Neolithic-Chalcolithic agricultural activity recorded in more distant, regional pollen sequences in south-central Anatolia in order to establish a regional signal of agricultural activity for this time period.

2 Çatalhöyük archaeological site and previous work

The tell site of Çatalhöyük is located 50 km southeast of Konya in south-central Turkey on the shallow alluvial fan of the Çarşamba river (Figure 1). The site, which comprises two mounds: the Neolithic 'East Mound' and Chalcolithic 'West Mound', was originally excavated by James Mellaart between 1961 and 1965 and is well known for its complex settlement layout, elaborate art and early religious symbolism (Mellaart, 1967). New excavations under the directorship of Ian Hodder between 1992 and 2017 (Hodder, 1996, 2000, 2014) and the recovery of a broad range of botanical assemblages from the Neolithic East Mound has revealed a flourishing early agricultural economy based on the exploitation of domesticated and cultivated plants (Asouti, 2005, 2013; Asouti and Austin, 2005; Asouti *et al.*, 1999; Bogaard *et al.*, 2013, 2017; Fairbairn, *et al.*, 2002, 2005, 2007; Filipovic, 2014), radiocarbon dated to have started between 7150 and 7100 cal. BCE (~9075 Cal BP; Bayliss *et al*., 2015). By the foundation of Catalhoyuk, agriculture had been present for at least 1200 years on the Konya Plain, with low-level food production first being evidenced at Boncuklu c. 8300-7,800 Cal BCE (Baird *et al.* 2018), and a wider suite of crops being exploited in the 8th millennium Cal BCE at Canhasan III (French 1972; Hillman 1978). Evidence for agriculture also continues through the Early Chalcolithic settlement of Catalhoyuk's West Mound, dated c.6150 to 5500 Cal BCE (~7775 Cal BP; Orton *et al*., 2018; Higham *et al*., 2007; Cessford *et al*., 2001).

Archaeobotanical research at Çatalhöyük has provided a comprehensive understanding of plant use over the c.1,500 year occupation of this farming community. The crop suite consists of four wheat species; emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), 'new type' glume wheat (*Triticum* sp.) and free-threshing wheat (*Triticum aestivum/durum*), three barley varieties (2-row hulled barley - *Hordeum vulgare,* and 2- and 6-row naked barley - *Hordeum vulgare* var *nudum*) and four pulse species – lentil (*Lens culinaris*), bitter vetch (*Vicia ervilla*) grass pea (*Lathyrus sativus*) and chickpea (*Cicer arietinum*). Use of wild species is common throughout the assemblage, with use of wild nuts such as almond/plum (*Amygdalus/Prunus*), pistachio (*Pistacia*), hackberry (*Celtis*) and acorn (*Quercus*), as well as the collection and consumption of an oil-rich wild mustard, *Descurania sophia* (Fairbairn 2007; Bogaard *et al.,* 2017; Stroud *et al., in prep*). The wild species included within the archaeobotanical samples indicates the practice of burning dung as a fuel (Fairbairn et al 2005), commonly used in outside fires on the Neolithic East mound (Bogaard *et al*., 2014). The suite of dung derived species indicates the grazing of animals on a range of environments including wet and/or saline, as well as steppe vegetation, and coupled with the arable and other flora indicates that a mosaic of wet and dry locations were exploited within the landscape (Charles *et al.,* 2014).

The range and emphasis on crop species changed during the occupation of the site and when settlement moved from the East to West mounds (Bogaard *et al*., 2017), the latter showing continuity in both the crop suite exploited but also in the gradual change in crop exploitation, such as the replacement of 6-row naked barley with 2-row hulled barley started on the East mound. Wild taxa continue to be used from the surrounding dry areas, with pistachio, hackberry and *Prunus* species, as well as wild mustard, a continued occurrence (Stroud et al., in prep). Wetland and saline taxa continue in their presence, indicating the continued burning of dung and the continued utilisation/occurrence of such environments within the vicinity of the site (Stroud et al., in prep).

Allied to on-site excavation, archaeobotanical and anthracological research, programmes of off-site coring have been carried out to investigate the alluvial geoarchaeology in greater detail (Roberts *et al*. 1996, 1999, 2007; Boyer *et al*., 2006, 2007; Ayala *et al*., 2017). Core sequence CH95F/G, located between the two occupation mounds at Çatalhöyük (Figure 1), is especially significant because, in contrast to the excavation deposits, it contained an organic-rich deposit that was still waterlogged and in which pollen was preserved. Preliminary pollen analytical results for core CH95F were reported by Eastwood *et al*. (2007) and included the occurrence of coenobia of *Pediastrum* (~25%), confirming the presence of eutrophic standing water at this location. Significantly, the CH95F/G core sequence recorded very high percentage values of Cerealia-type pollen (>70%) and occurrences of groups or clusters of pollen grains – essentially pollen grains deposited while still in the anthers. A bulk radiocarbon age of 6760±80 BP (Table 2), derived from the organic unit in core CH95F, produced a calibrated age of c. 5650 cal. BC which places the top part of the CH95F sequence as Early Chalcolithic. In addition, the CH95F/G cores are bracketed by two OSL dates (5400±1019 BP (230-245 cm); 6496±1777 BP (420-435 cm; see Roberts *et al*., 1999). Because core CH95F is coeval with the dates for the east and west occupation mounds, the site was recored to retrieve sufficient sediment for archaeobotanical analyses. Alongside this, a rigorous size and measurement analysis of each Cerealia-type pollen grain from the CH95F/G sequence was undertaken.

3 *The palaeoecological and palaeoclimatological setting*

Palaeoecological and palaeoclimatological sites in south-central Anatolia provide important data for a relatively detailed overview of regional changes in climate and vegetation response for the early Holocene. Pollen sequences from Kızıl Höyük and Avrathanı Höyük located near to Çatalhöyük (~5km and 6.5 km respectively; Figure 9), are only short sequences, but they both date to the Neolithic period and show the development and establishment of pine-oak woodlands in the Taurus Mountains in the western part of the Konya Plain at ~9700 Cal BP.

A longer and more detailed pollen record from Akgöl Adabağ (Ereğli marshes) ~85 km east of Çatalhöyük (Figure 9; Bottema and Woldring, 1984; van Zeist *et al*., 1991; Turner *et al*., 2010; Figure 9) has a hiatus for the Late Neolithic-Early Chalcolithic, the pollen data however, are informative for late glacial-early Holocene environmental and vegetation changes for the eastern end of the Konya Basin and Çatalhöyük. The pollen record shows the late glacial period dominated by high NAP comprising *Artemisia*-Chenopodiaceae steppe with this extending into the early Holocene albeit at lower percentage values. A marked and abrupt increase in *Betula* (20%) is recorded at the beginning of the Holocene with this gradually giving way to *Quercus* (~20%) and then a marked increase in *Pinus* (~40%) and a gradual increase in *Cedrus* (~5%) radiocarbon dated to 8040±140 yr BP (~8780 Cal BP). Thus, the pollen record for the early Holocene on the hills surrounding the Konya Basin generally and Akgöl Adabağ in particular shows the transition from *Artemisia*-

Chenopodiaceae steppe through an initial birch and Poaceae phase and to the development of oak and pine woodland.

At other central and eastern Anatolian sites, *Artemisia*-Chenopodiaceae steppe was replaced rapidly by grassland vegetation during the early Holocene. At the site of Eski Acıgöl in Cappadocia (Figure 9) arboreal pollen (AP) comprising deciduous *Quercus*, *Pistacia* and *Juniperus* records low percentage values and it is not until ~8000 Cal BP that maximum AP is achieved (Woldring and Bottema, 2001/2; Roberts *et al.*, 2001). Pollen data from Nar Gölü, ~15 km from Eski Acıgöl, show a more pronounced increase of *Pistacia* and a similar delay and gradual increase in deciduous *Quercus*; again, as at Eski Acıgöl maximum AP values being achieved at around 8 ka Cal BP (Roberts *et al.*, 2016).

Stable isotope data for Eski Acıgöl, Akgöl Adabağ and Nar Gölü in particular (Roberts *et al.*, 2008) indicate cold and dry climatic conditions during the Late Glacial Younger Dryas stadial (=Greenland Stadial; ~12.9-11.7 ka Cal BP); the cold- and dry-adapted *Artemisia*-Chenopodiaceae steppe reflecting these climatic conditions. At the onset of the Holocene a marked shift to more negative stable isotope values is recorded indicating increased moisture availability alongside increasing temperatures that mark the wettest phase in central Anatolia (Roberts *et al.*, 2016). However, the Nar isotopic data suggest that this relatively wetter early Holocene period was interrupted by two phases of drier climate, as indicated by shifts in oxygen and carbon isotope composition, Ca/Sr ratios, a switch from calcite to aragonite precipitation (Roberts *et al.*, 2016) and also in δ^2H values of lipid biomarkers preserved in pottery from the Neolithic site of Çatalhöyük (Roffet-Salque et al., 2018). These dry phases appear to be broadly correlative with the 9.3- and 8.2-ka events recorded in Greenland ice cores, but they lasted significantly longer at Nar (Dean *et al.*, 2015). The latter arid event coincided with a change in the flood regime of the Çarşamba river (Roberts and Rosen, 2009). It also coincided with the shift in the settlement at

Çatalhöyük from the east bank to the west bank of the river (Orton *et al*., 2018) and more broadly may have helped trigger cultural changes at the Neolithic/Chalcolithic transition in central Anatolia (Biehl, 2015).

As outlined above, the relatively wet early Holocene period triggered a rapid increase in grass cover across much of central and east Anatolia followed by a gradual retreat from about 9.5 ka Cal BP. Micro-charcoal influx data for Eski Acıgöl and Akgöl Adabağ (Turner *et al*., 2010) attribute the suppression of grass fires to lower fuel loads, while Woldring and Bottema (2001/2) interpret the decrease in Poaceae and the delayed increase in AP and deciduous oak to increasing climatic aridity. An alternative hypothesis by Asouti and Kabukcu (2014) and Kabukcu (2017) suggests that the decrease in Poaceae alongside the percentage increases of pollen types of spiny and unpalatable taxa together with the co-occurrence of *Artemisia* all point to increased grazing pressure on grassland habitats commencing at this time associated with increasing Neolithic populations (Asouti and Kabukcu, 2014; Roberts *et al*., 2017).

Alongside archaeological and archaeobotanical data from Çatalhöyük, Kabukcu (2017) provides a synthesis of regional woodland history based on anthracological data. At the onset of the Holocene (from ~11,700 Cal BP) semi-arid woodlands comprising *Quercus*, *Juniperus*, *Amygdalus*, *Pistacia*, Maloideae and *Prunus* were already established in the vicinity of the Konya Plain. At lower elevations and on the Konya Plain itself, anthracological data suggest a range of riparian and wetland taxa including Salicaceae, Ulmaceae, *Tamarix*, *Fraxinus* and perhaps Celtis were important sources of fuel wood to prehistoric settlements living in the Konya plain for a considerable period of time and may have been one of the influential factors leading to the establishment of settlements. Anthracological data for the Late Ceramic Neolithic (6400-6000 Cal BC) at Çatalhöyük show more intensive use of local riparian (Ulmaceae, Salicaceae) woodlands along with *Amygdalus* and *Pistacia* with trace amounts of weedy taxa such as *Artemisia*, Chenopodiaceae and *Capparis*. During the Early Chalcolithic at Çatalhöyük (6000-5500 Cal BC) when occupation shifted to the West Mound, the data show a return to a mixed strategy of exploitation of semi-arid *Juniperus* woodlands (42% charcoal values) on the higher hillsides surrounding the Konya Basin as well as the exploitation of local riparian woodlands. *Amygdalus*, *Pistacia*, *Prunus*, Maloideae with trace amounts of weedy taxa such as *Artemisia*, Chenopodiaceae, along with Leguminosae and *Capparis* are also represented in the charcoal assemblages (Kabukcu, 2017). Regional pollen data are able to record some, but not all of the anthracological taxa; whereas *Pinus* and deciduous *Quercus* are expressed, poor and/or sporadic pollen producers such as *Pistacia*, *Juniperus* and *Celtis* tend to be under-represented or absent in pollen diagrams from SW Asia. Riparian taxa (e.g., *Fraxinus* and *Salix*) are generally well-recorded in pollen diagrams as well as weedy, steppic taxa such as *Artemisia* and Chenopodiaceae, but other insect pollinated taxa (e.g., Rosaceae, including *Amygdalus* and *Prunus*, Maloideae) are generally not expressed in regional pollen diagrams.

The relatively low deciduous *Quercus* wood charcoal values (~10%) and higher *Juniperus* values (42%) for the Late Ceramic Neolithic and Early Chalcolithic is interpreted by Kabukcu (2017) as reflecting temporal changes in fuelwood preferences rather than changes in wood availability. Regional pollen data from Eski Acıgöl and Nar (Roberts *et al.*, 2001; 2016; Woldring and Bottema, 2001/2) show increasing deciduous *Quercus* pollen values indicating woodland expansion across central Anatolia during this time period.

4 Methods

Sediment cores comprising the CH99H/J series were retrieved adjacent to Çatalhöyük and in close proximity to the CH95F coring site (Figure 1) using a Eijkelhamp vibro-corer with exchangeable open gouge and lined sample heads. Sediments for core CH99H/J were described in the field and in the laboratory using a modified version of the scheme of Troels-Smith (1955) as proposed by Aaby & Berglund (1986) (Table 1). The sediments were also assigned Munsell soil colours, although these can become modified upon exposure to air (Munsell, 1994).

Organic matter and carbonate content were quantified at approximately 10 cm intervals using loss-on-ignition (LOI) at 550°C and 925°C, following the standard methodology of Dean (1974). Magnetic susceptibility was undertaken on a Bartington MS-1 single sample detector. Particle size analysis was carried out using a Micromeritics X-ray sedigraph 5100 (for details see Boyer 1999).

Core CH99H was subsampled (1cm^3) for microcharcoals at 8 cm intervals. Microscopic charcoal particles (<180 μm) were extracted from the sediments using a heavy liquid extraction procedure (see Turner *et al*. (2004) for details) and counted until 250 *Lycopodium* spores were recorded; this number being based on the work of Finsinger & Tinner (2005).

Subsamples of sediment (typically 2 cm^3 in volume) were taken for pollen analysis between 8-12 cm intervals throughout the length of core CH99H. Extraction of pollen follows the standard procedure of Faegri and Iversen (1989) and involved digestion in 10% HCl, followed by 10% NaOH treatment, sieving and 60% HF acid before Erdtman's acetoloysis. Exotic *Lycopodium* tablets of a known concentration were added for pollen concentrations to be calculated (Stockmarr, 1971). Samples were dehydrated with Tertiary Butyl Alcohol (TBA) before being added to silicone oil (Faegri and Iversen, 1989). Pollen grains were counted until the pollen sum of 250 grains was reached (excluding spores and exotics), and although some levels yielded extremely low amounts of pollen, their inclusion is justified on the grounds that at least some palaeoenvironmental information is forthcoming. Pollen identifications were aided by the keys, descriptions and microphotographs contained within Moore et al. (1991), Reille (1992, 1999) and reference grains; Coenobia of *Pediastrum* were identified using the key in Komárek and Jankovská (2001). Pollen of aquatic plants, together with algal microfossils are expressed as percentages of total microfossils. Conventions for the degree of taxonomic certainty follow Berglund and Ralska-Jasiewiczowa (1986); pollen nomenclature follows Davis (1965-1985). The delimitation of local pollen assemblage zone boundaries was aided by a stratigraphically constrained incremental sum-of-squares cluster analysis (CONISS; Grimm, 1987) and used a square-root transformation and chord-distance dissimilarity measure for all terrestrial pollen taxa. Pollen diagrams were constructed using TILIA and TILIAGRAPH (Grimm, 1991) and do not show pollen types with very low (trace) percentage values.

We measured grain and pore diameters of all the larger Poaceae pollen grains in CH95F. These were conducted under oil immersion at ×1000 magnification together with phase contrast microscopy using an eye-piece graticule and follows Andersen (1979). Andersen's measurements for Cerealia-type pollen grains are based on grains mounted in silicone oil. While some workers have reported swelling of grains with concomitant increases in grain and annulus diameter for grains mounted in glycerine jelly, Bottema (1992) reports negligible swelling of pollen grains in glycerine jelly, and we also find negligible swelling of pollen grains mounted in this medium. Some palynologists also suggest calibration of Cerealia-type pollen grains against a standard; *Corylus* pollen is usually adopted by northwest European pollen workers due to its abundance in pollen sequences throughout the Holocene (Dickson, 1988). Unfortunately, in southwest Asia, and Turkey in particular, there are very few pollen types that are consistently found, spatially and temporally throughout the Holocene, so the adoption of a pollen grain as a standard was not used.

Twenty sediment samples of approximately 50 cm^3 in size were analysed from two cores (CH95G and CH99H) for plant macrofossils. Samples were soaked in water and wet-sieved using a 250 µm mesh to evaluate the preservation status of plant remains in the samples. Anaerobically-preserved (cf. waterlogged) organic material, including plant macrofossils, was not present in the sample set so the samples were dried and the plant remains recovered from the dried residue using a binocular dissecting microscope. In addition to the whole sediment samples, two groups of seeds were collected from core CH99H 466-472 cm and 558 cm. Only small quantities of highly fragmented charred (partially burnt) plant remains were recovered among a larger assemblage of siliceous specimens (preserved due to the natural deposition of silica in the plant cells during life). The siliceous remains were mainly cereal-awn fragments or glume-tips; and were recorded using a relative five-figure scale of abundance. Charred cereal macrofossils, including chaff and grains, plus seeds and nutshell fragments were identified and quantified using standard methods (see Fairbairn et al. 2005). Small quantities of tiny wood charcoal fragments were also present, alongside unidentifiable plant material and small fragments of charred stem, probably from reed.

5 Results

Sediments and lithology

The lithology of core CH99H (Table 1) comprises a basal unit of marl (566->700 cm), deposited during the Late Pleistocene Palaeolake Konya. Overlying this (291-566 cm) is a unit of silt with alternating sandy or clay-rich layers containing abundant cultural debris including animal bone, potsherds, obsidian flakes and charcoal. Within this is a sub-unit (396-420 cm) containing a particularly black organic-rich silt-clay with abundant cultural debris. The uppermost lithological unit (0-291 cm) includes alternating sands, gravels and silt-clays and comprises the ‘upper alluvium’ unit, devoid of cultural artefacts and is palaeoecologically sterile. Core CH99H has relatively high percentage values of $CaCO_3$ and low organic matter content, apart from elevated organic matter content during the black organic-rich silt clay unit (396-420 cm). Magnetic susceptibility values remain low until 440 cm and then gradually increase towards the top of the sequence (Figure 2). The lithology of core CH95F was described by Eastwood *et al*. (2007) and essentially contains the same lithological units, albeit with slight variations. Both sediment cores record the peak in organic matter: in the CH95F core sequence, this is at 380-395 cm while in CH99H, is at 390-410 cm. Magnetic susceptibility values in each core begin to increase just before deposition of the black organic-rich silt-clay unit; in CH95F this is 450 cm (see Figure 15.1 in Eastwood *et al*., 2007) and in CH99H this is 440 cm. Organic matter content and magnetic susceptibility data are useful for core correlation and show that there is an approximate 10 cm offset between the CH95F and CH99H sediment cores.

Radiocarbon dating and chronology

Radiocarbon ages were obtained in order to date the organic fill sequence located adjacent to the Neolithic-Chalcolithic settlement mounds at Çatalhöyük, and to correlate and compare the analytical results from this sequence with the well-dated records of cereal cultivation recovered from on-site excavation contexts (Table 2). Of these ages, OxA-14784 (CH99H 7) is clearly anomalous and can be disregarded. A second age OxA-14779 (CH99H 4) is somewhat older than the other ages, and its age also lies out of chronological sequence. The probability is that this sample also has been subject to reworking, although it may indicate local human activity during the time interval around the end of occupation of the east mound, and the beginning of the west mound (see below). Of the remaining ages, two (OxA-14780 and 14781) were determined on different materials from the same stratigraphic level, and they show ages that are reassuringly similar.

These ages therefore provide a total of five reliable dated levels within the core sequence, which fall into two principal groups: samples 1–3 between 294 and 325 cm core depth, date to around 5630-5770 Cal BC; while samples 5, 6 and 8 between 475 and 558 cm core depth, date to between 5770 and 5990 Cal BC. This is consistent with two main phases of infilling, with deposition taking place rapidly, implying that this ~264 cm thick organic unit was relatively short-lived (~300 years). In archaeological terms, although all of the ages are slightly older than the previous range-finder ^{14}C age of 6760±80 BP on core CH95F, the new dating evidence strongly suggests that the entire organic fill belongs to the Early Chalcolithic period, rather than extending back to Neolithic times. The deposit thus seems to have been coincident only with the occupation of the West Mound at Çatalhöyük. A charcoal sample from the base of cultural levels in core CH96W from the West Mound produced radiocarbon ages of 6940±80 BP (PL980524A) and 7040±40 BP (AA27981), or around 5840-5930 Cal BC, which is statistically identical to the lower part of the organic fill in core CH99H (see Roberts *et al*. 1996, 1999, 2007; Boyer *et al*., 2006, 2007 for details). The fill appears to be slightly younger than charcoal from a buried soil sequence in the KOPAL 97 and 99 Trenches (see Roberts *et al*., 1996, 1999, 2007 for details).

Pollen and charcoal results

Pollen data for core CH99H (Figure3; Table 3) are divided into three fossil pollen assemblage zones (CH99H-1 to CH99H-3) High NAP for the entire ~300-year sequence suggests an open landscape. *Typha angustifolia*-type and Cyperaceae suggests that the core site was relatively close to standing water (possibly in an oxbow lake occupying a meander cutoff). *Typha* spp. in particular grow in shallow water of lakes, rivers, ponds, marshes, and ditches and have many edible uses and along with *Phragmites* are important for thatch. Trace values of the aquatic alga, *Pediastrum* for the upper part of the sequence suggests an increase in nutrient enrichment of this water body. High percentage values of Cerealia-type for the entire sequence, together with a range of weeds associated with arable agriculture, particularly in zone CH99-2, suggests that cereals were grown in close proximity to the core site and thus near to Çatalhöyük. However, high values of cereal pollen suggest that other taphonomical pathways may have been important with some allocthonous input from crop processing and/or waste from Çatalhöyük (discussed more fully in later sections). Increases in AP during the upper part of the sequence (zone CH99-3) are most certainly the product of long distance transport reflecting the establishment and development of open pine-oak woodlands in the Taurus mountain range surrounding the Konya Basin (see below). The abrupt and marked increase in Chenopodiaceae during the upper part of the sequence (zone CH99-3) may reflect a local expansion of semiarid herb-steppe alongside a slight increase in *Artemisia*; however, taxa of this family also include local halophytic plants, therefore no firm palaeoecological interpretation can be placed on the local habitat for this zone.

Archaeobotanical results

The CH95G and CH99H sediment samples contained charred and siliceous plant remains throughout, with noticeable increase in the abundance of remains towards the top of the CH99H sequence, these being most abundant between c. 325 cm and 347 cm (Table 4; Figure 4). High abundance in charred plant remains was accompanied by an increase in mammal bone fragments, obsidian chips, fishbone and other artefactual material, including a clay ball fragment. Sediments in the lowest samples were stiff clays, while those from the upper levels were looser, with many more sandy and larger inclusions indicating significant inputs from the archaeological strata and human activity.

Dominant were the siliceous remains of cereal-awns and glume-tips from *Triticum* (wheat) or *Secale* (rye) species, with several samples containing thousands of such fragments. These remains are the surviving elements of cereal chaff that were uncharred and decayed in the sediment, leaving behind the siliceous remains and their presence signifies significant quantities of cereal by-products at the site. While the rye and wheat glume tips were not separated in the analysis it is likely that the specimens derived from wheat species as they dominate the chaff and cereal record at the site, including three glume wheats species (Emmer (*Triticum dicoccum)*, Einkorn (*Triticum monococcum*) and 'New type' glume wheat) as well as bread wheat (*Triticum aestivum*) and rye is only present in tiny quantities as a weed/crop contaminant.

The charred macrofossil assemblage was dominated by wheat chaff, mainly wheat (*Triticum*) glume bases and a few spikelet forks. Many specimens had suffered significant physical damage and were unidentifiable, though a few were identified as either emmer or 'New Type' wheat, the latter a common find during the mid to late levels at Çatalhöyük East and the occupation of Çatalhöyük West (Bogaard *et al*. 2017, Stroud *et al.* in prep) and possibly deriving from *Tritium timopheevi*. No specimens were identified from domesticated or wild einkorn wheat (*Triticum monococcum/T. boeoticum*). Cereal grain remains were poorly preserved and scant in the samples, but were present throughout the deposits. Few were identifiable beyond the general cereal grouping (Table 4). A single wheat grain, possibly deriving from a naked wheat (*Triticum aestivum* or *durum*), was recovered from CH99H 466-473cm, though identification of naked wheat on the basis of grains only is unreliable and, lacking chaff, this determination cannot be confirmed. Domesticated barley grains were identified in two samples, including a hulled specimen in CH99H 357-366 cm. This find is consistent with the on-site crop history as hulled barley is uncommon at Çatalhöyük East but does increase in occurrence during the later levels of the East mound becoming a major crop in the Chalcolithic levels of Çatalhöyük West (Bogaard *et al*. 2017; Stroud *et al*. in prep).

Also abundant in the upper part of core H were the seeds of wild mustard – (*Descurainia sophia*);. *Descurainia* is found by the million in some levels at Çatalhöyük East and is common in general rubbish deposits (Fairbairn *et al*. 2007; Bogaard *et al*. 2013). It is present throughout the Çatalhöyük West sequence but has not been found in the quantities seen in the stores from the East Mound (Bogaard *et al*. 2017; Stroud *et al*. in prep). These seeds dominate the assemblage from CH99H (325-347 cm) and elsewhere in the cores are present in small quantities. Other brassicas, such as *Erysimum*-type and *Alyssum* sp. were associated with these seeds and were among a range of wild or weedy species dispersed through the cores in small quantities. These and the other wild/weed taxa found are all common elements of the Çatalhöyük archaeological flora, deriving from weedy, arable and wetland habitats (Fairbairn *et al*. 2002; Bogaard *et al* 2013; 2017; Stroud *et al*. in prep). Also found in small quantities in the cores, and well known in other studies at the site, are nutshell fragments of *Pistacia* (terebinth) and the Prunoideae sub family of the Rosaceae, probably from wild almond (*Amygdalus orientalis/graeca*) or plum (*Prunus* species), the latter being well represented in the Çatalhöyük West and the later part of the Çatalhöyük East sequences.

Archaeobotanical data indicate noticeable increases in the abundance of all charred remains and silicified awns towards the top of the sequence (325 to 347 cm) compared with remains in the lower levels, whereas elevated percentage values of Cerealia-type pollen (Figure 3) are found throughout the CH99H sequence. Furthermore, there is no corresponding increase in Cerealia-type pollen corresponding with increased abundances of *Triticum* sp. glume bases towards the top of the sequence. Of the arable and steppic weeds, there are slight increases in Brassicaceae pollen percentage values for zone CH99H-3, but these in no way match the elevated abundances of *Descurainia sophia* (Brassicaceae) recorded in the archaeobotanical data. This may suggest that Brassicaceae are severely under-represented in pollen diagrams or signify a different source for the pollen and the seed macrofossils, as could also be the case with the cereals. Similarly, seeds of *Bolboschoenus glaucus*, a member of the Cyperaceae family are present throughout the CH99H sediment sequence as is the pollen of Cyperaceae; trace percentage values in the lowermost part of the sequence (zones CH99H-1 and -2) increasing to ~10% for the uppermost part (zone CH99H-3).

Critical measurements of Cerealia-type pollen grains and subsequent designations (Figure5) are recorded for two of the four zones in core CH95F; zones CH95F-2 and CH95F-3 which corresponds to the 'cultural alluvium', 'alluvium' and 'in situ cultural' lithological units (see Eastwood *et al*., 2007 for details of sediment lithological units for core CH95F). There is an absence of Cerealia-type pollen grains in the lowermost 'marl' and the upper part of the 'in situ cultural' lithological units. In particular, for Zone CH95F-2 (538-452 cm) percentage values of 78% Cerealia-type are recorded with many of these designations being assigned to *Hordeum*-type, *Avena-Triticum*-type, *Triticum*-type and less so for *Secale*-type. Crucially, the numbers of clusters of Cerealia-type pollen grains and the total number of grains in each cluster was also quantified and shows that zone CH95F-2 also scores highly with respect to individual domesticated cereal pollen grains and clusters of Cerealia-type as well (Figure6). Due to limited sediment amounts, archaeobotanical analysis was carried out on two bulk samples only for core CH95F/G (394-412; 412-420 cm; Table 3) in a section of the core where pollen data are lacking. However, elevated Cerealia-type pollen brackets the archaeobotanical samples and Cerealia-type pollen designations show that these are mostly *Hordeum*-type and *Avena*/*Triticum*-type.

6 Discussion

Firstly, we will discuss the core lithological data and its relevance to the depositional environment around Çatalhöyük. Discussion will then focus on the extremely high percentage values of cereal pollen alongside the archaeobotanical data recovered from core CH99H alongside the results of clustered cereal pollen data quantified as part of an earlier study (Eastwood *et al.,* 2007). The final part of the discussion will compare the cereal pollen data from Çatalhöyük with those reported from sediment sequences from more distant or regional locations in south-central Anatolia. Given that the high percentage results of cereal pollen recovered from the Çatalhöyük pollen core are dated to the early Chalcolithic, our discussion will include the palynological signal for both the Neolithic and Chalcolithic periods. Doing this will allow the Chalcolithic to be placed in an antecedence context with the preceding Neolithic period as well as taking into account that some of the earlier radiocarbon dated sequences have large errors and pollen data may be smeared across the Neolithic-Chalcolithic boundaries.

6.1 *Comparison of proximal off-site pollen and archaeobotanical results*

Regionally interpreted pollen data for core CH99H show that the landscape was relatively open with the sequence recording the development and establishment of pine-oak woodlands in the Taurus Mountains surrounding the Konya Basin during the early Chalcolithic period. Locally, pollen data indicate the presence of standing water and this together with sedimentological and lithological data, suggest that both the CH95F and CH99H core sequences reflect a combination of overbank alluvial deposition, standing-water conditions (possibly in an oxbow lake occupying a meander cutoff), and running water river channel sedimentation. Deposition of early Holocene fine-grained alluvium was followed by a phase of organic-rich sedimentation that was contemporary with Çatalhöyük West (Chalcolithic). The original interpretation of a wetland environment with seasonal flooding (Roberts *et al*., 1996, 1999, 2007; Boyer *et al*., 2006) had important implications with respect to viable areas for cereal cultivation adjacent to or in close proximity to Çatalhöyük. Roberts and Rosen (2009) and Rosen and Roberts (2005) have suggested that much of the cereal cultivation would have had to have been undertaken on the drier flanks of the Taurus Mountains ~12 km from Çatalhöyük. However, new high spatial resolution core data around Çatalhöyük reported by Ayala *et al*. (2017) indicate a highly variable micro-scale landscape during the early Holocene and their data suggest a fluvial regime characterised by seasonally-flooded anabranching conditions. This coincides with the earliest occupation of Çatalhöyük East (~9075 Cal BP) and a very localized wetter area to the southeast of Çatalhöyük West in the general location of the CH95 and CH99 sediment cores as identified by Ayala *et al*. (2017). They further show that there were drier localised areas of the floodplain that would have provided significant opportunities for 'local' cereal cultivation within the Konya Basin and thus agricultural processing at or closer to Çatalhöyük.

The high percentage values of Cerealia-type pollen recorded in both the CH99H (Figure 3) and CH95F (Figure 5) sequences (30-78% respectively) together with archaeobotanical data strongly suggest the presence of cereal plants in large quantities on the site margin, probably from cultivation nearby and/or processing of cereals, combined with the deposition of waste containing cereal remains, including the charred remains that must have derived from fires. This inference is drawn from the many previous studies that show Cerealia-type pollen abundances usually only attain 1-2% in pollen diagrams. Therefore, pollen records with 'higher' occurrences of Cerealia-type pollen such as those recorded for this study, are usually interpreted as indicating either an increase in cereal cultivation (Vuorela, 1970) or due to the effects of nearby harvesting or other processing techniques (Robinson and Hubbard, 1977; Hall, 1988). Likewise, modern pollen-vegetation studies reported for northwest Europe indicate that Cerealia-type pollen percentage values only attain

3-4% when agriculture is practised within about 2 km of the sampling site; percentage values only rise above 4-5% when cereal crops are grown in the immediate vicinity of the site (Heim 1962). Similarly, modern pollen-vegetation studies for southwest Asia (Bottema and Woldring, 1990) suggest that Cerealia-type pollen attains a maximum of around 5%, while surface soil samples sourced from cereal fields in southwest Turkey yielded Cerealia-type pollen percentage values of 2-3% (Eastwood, 1997).

New, modern pollen Tauber trap data from the Cappadocian region of Turkey, which has a similar bioclimatic regime to the Konya Plain region, show that percentage values for *Secale* range from 0.3% to 1.99% with Cerealia-type percentage values ranging from 0.4% to 3.3% with a maximum percentage value of 9.68% being recorded for a Tauber trap located at the edge of an agricultural field. *Hordeum* scores even less (0.2%), while surface sediment sample data record general Cerealia-type pollen values ranging 1.9-4.1% (Şenkul unpublished data).

Thus, modern pollen Tauber trap data for the south-central region of Turkey confirm extremely ‘low’ percentage values of Cerealia-type pollen; this being attributable to the fact that the cereals, with the exception of the genus *Secale* (which is wind pollinated), are partially or completely self-pollinating and therefore tend to produce low amounts of pollen. Furthermore, their large size and the tendency of *Triticum*, *Hordeum*, and *Avena* pollen grains to remain in their hulls, means that cereal pollen grains – apart from *Secale* – are poorly dispersed and are usually only deposited locally and tend to be grossly under-represented in pollen diagrams. Therefore, it is possible that a *proportion* of the high percentage values of Cerealia-type pollen may be the result of intensive cereal agriculture within the immediate vicinity of the sampling site (cf. Heim, 1962), a credible hypothesis given the new data by Ayala *et al*. (2017) which suggest that there were drier localised areas of the floodplain surrounding Çatalhöyük. However, the elevated percentage values of Cerealia-type pollen reported by this study and Eastwood *et al.* (2007) – far in excess of 4-5% as suggested by Heim (1962) – suggests that other taphonomical pathways need to be examined.

The elevated Cerealia-type pollen values (30-78%) reported in this and previous studies (Eastwood *et al*., 2007) have striking parallels with those reported elsewhere. For example, Robinson and Hubbard (1977) interpreted 'high' percentage values of Cerealia-type pollen (60%) from a waterlogged layer at the bottom of a 4th C AD pit at Farmoor, Oxford as the introduction of cereal pollen to the pit directly attached to cereal plant fragments. Similarly, Barber (1975) reported 80% Cerealia-type pollen in sediments from a medieval pit at Southampton; and inferred that they were most probably introduced on the smashed *Agrostemma* seeds that were also recovered from the deposit. O'Brien *et al*. (2005) and Brown *et al*. (2005) reported 50% *Hordeum* pollen from a lake sediment core taken adjacent to the palisade of Ballywillin Crannog, Ireland interpreted as the storage and/or processing of barley on the crannog.

Significantly, Robinson and Hubbard (1977) and Bottema (1992) explicitly mention the absence of clusters or groups of Cerealia-type pollen grains and suggest that this absence is due to threshing, winnowing or some other processing technique(s), which provides the mechanism for disaggregation and dispersal of individual cereal pollen grains from the anthers into the air. Elevated abundances of clusters of cereal and non-cereal pollen grains (Figure 6) as recorded in the CH95F sequence (Figure 5; Supplementary Material – Table 1) tend to support the inference that a large proportion of the Cerealia-type pollen was deposited at the core location as waste attached to cereal or other vegetative matter, perhaps deposited alongside the chaff as represented by the siliceous awns and glume tips that are abundant in the archaeobotanical data for these levels. Given the high percentage values of Cerealia-type pollen, the palynological data suggest a combination of three taphonomical pathways: (i) attached to waste cereal and other plant matter; (ii) processing of cereal products may have occurred at the settlement margins; (iii) there may have been some cereal cultivation within the immediate vicinity of the sampling site on drier terrain as indicated by Ayala *et al.* (2017).

General increases in human-derived macrofossil material towards the top of the CH99H sedimentary sequence is consistent with an increase in human activity at the sample site, either because of extension of activity areas onto the surrounding floodplain or through expansion of adjacent habitation areas. Archaeobotanical and pollen data are unequivocal in showing the presence of cereals throughout the period of deposition. Although preservation of cereal macrofossil remains was typically poor, the presence of glume wheats, including emmer/'New Type' wheat, and domesticated barley, is consistent with the on-site records from Çatalhöyük East and West (Bogaard *et al*. 2017, Stroud *et al*. in prep). The identification of hulled barley conforms to the detected temporal changes in barley species between the two mounds, with hulled barley the dominant barley species by the time of occupation of Çatalhöyük West (Bogaard *et al*. 2017, Stroud *et al*. in prep). Similar assemblages of silicified awns and glume tips were also present in the pits excavated into the lake marl discovered in the KOPAL 1999 trench (Fairbairn *et al*. 2005). These latter remains are likely to derive from the remains of the early stages of crop processing that may have occurred around the periphery of the inhabited area. Settlement fringe areas are commonly used across southwest Asia as the site of crop processing activities and the occurrence of only late stage processing activities in the on-site archaeobotanical assemblages of both East and West Mounds suggests that early stage crop processing, the threshing and winnowing of the cereal crops, occurred outside the settlement area (Fillipovic 2014; Bogaard *et al*., 2013; Stroud *et al*., in prep).

The charred plant remains are less easy to source and were burned in fires before accumulating in the source deposits. They may well derive from the burning of crop-processing residues in waste, animal dung, oil extraction or the eroded remains of hearth debris dumped in middens on the site edge; Çatalhöyük midden deposits of hearth debris can contain a range of charred botanical material including later stage crop processing residue, wood fuel and a particular suite of wild seeds derived from the burning of dung (Bogaard *et al*., 2013; Bogaard *et al*., 2014 Stroud *et al*., in prep). There are a high proportion of wild mustard seeds (*Descurainia*) in the upper part of the CH99H sequence, significantly outnumbering the crop remains in those samples and also running somewhat counter to the relatively low presence of *Descurainia* in mixed midden deposits from the West Mound (Stroud *et al*., in prep). The *Descurainia* concentration in CH99H could be refuse from eroded midden deposits or alternatively is from the processing of this species.

6.2 ***Regional Cerealia-type pollen evidence for Neolithic-Chalcolithic cereal agriculture***

Other off-site, regional pollen sequences can be examined for abundances of Cerealia-type pollen and evidence of cereal agriculture. However, very few pollen records exist for the Konya Plain due to the paucity of suitable depositional basins and the generally arid conditions that do not favour pollen preservation. The Kızıl Höyük pollen sequence (~5 km from Çatalhöyük) shows low TLP due to poor pollen preservation and has a radiocarbon age of 8330±120 yr BP (~9470 Cal BP; ~7520 BCE) which indicates that this core predates cores CH95F and CH99H from Çatalhöyük and is Neolithic in age. Cerealia-type pollen percentage values record only trace values (<1%; Eastwood *et al*., 2007; Figure 7). The Avrathanı Höyük pollen sequence (~ 6.5 km from Çatalhöyük) again has low TLP values and a radiocarbon age of 8700±100 yr BP (~9720 Cal BP; 7770 BCE) indicates that the core is more or less contemporary with Kızıl Höyük and therefore Neolithic in age, but Cerealia-type pollen is not registered at this site (Figure 7). Both the Kızıl Höyük and Avrathanı Höyük pollen sequences are located adjacent to, or in close proximity (i.e., <1 km) to archaeological sites bearing the same name.

The longer and more detailed pollen record from Akgöl Adabağ (Ereğli marshes) at the eastern end of the Konya Basin ~85 km east of Çatalhöyük (Bottema and Woldring, 1984; van Zeist *et al*., 1991; Turner *et al*., 2010; Figure 7) has a radiocarbon age of 8040±140 yr BP (~8780 Cal BP). Only trace percentage values (<1%) for Cerealia-type pollen for the early Holocene aceramic Neolithic period are recorded (Bottema and Woldring, 1984).

In the Eski Acıgöl pollen sequence located in Cappadocia (Woldring and Bottema, 2001/2; Roberts *et al*., 2001). Cerealia-type pollen percentage values for the early Holocene (Neolithic) part of the sequence register <4%, while only trace values (<1%) are recorded for *Hordeum*-type; these increase to 6% and 4% respectively for the mid Chalcolithic period (Figure 8). Also located in Cappadocia and ~15 km from Eski Acıgöl, pollen data from Nar Gölü indicate that Cerealia-type pollen for Nar Gölü for the ceramic Neolithic part of the early Holocene is not registered and percentage values of Cerealia-type (0.6%) and Secale (0.3%) are recorded for the early Chalcolithic part of the sequence (Figure 9; Eastwood unpublished data).

Cerealia-type pollen data for south-central Anatolia for the Neolithic and early Chalcolithic periods for the limited number of coring locations for this period discussed as part of this study have important implications for Neolithic-Chalcolithic cultivation of cereals. Unequivocal evidence for widespread or extensive cultivation of cereals for the Neolithic-Chalcolithic periods does not find clear expression in the palaeoecological record from south-central Anatolia and Cerealia-type pollen fails to register above 1.5%. This is more in line with the hypothesis advanced by Sherratt (1980), van Andel and Runnels (1995) and Bogaard *et al*. (2013) who suggest that human subsistence activities were smaller scale, in close to proximity of habitation sites and higher intensity. However, this is not to say that there was an absence or a lack of people on the landscape; rather their agricultural activities specifically regarding the cultivation of cereals in particular was such that cultivation failed to cross a palaeoecological threshold for it to be registered and detected in regional lake sediment records for a variety of reasons. The same applies for those coring sites located in close proximity to archaeological sites: the pollen records for both Kızıl Höyük and Avrathanı Höyük registers either zero or only trace values of Cerealia-type pollen. Only at Çatalhöyük are elevated Cerealia-type pollen values recorded and this is attributable to taphonomical factors related to the coring location being too close to the archaeological site with the deposition of secondary pollen from cereal processing activities, attached to waste cereal and other plant matter as well as some primary pollen perhaps linked to cereal cultivation within the immediate vicinity of the sampling site on drier terrain as indicated by Ayala *et al*. (2017).

7 Conclusion

The importance of combining on-site and off-site research at Çatalhöyük has been demonstrated by palynological and archaeobotanical analysis of an organic-rich, fill sequence that accumulated rapidly during the Early Chalcolithic, ~6000 to ~5600 Cal BC, associated with occupation of the West Mound at Çatalhöyük. Pollen and plant remains from this fill contained abundant cultural debris, crop processing waste and food by-products (cereal-awns, glume-tips, wheat chaff, glume bases, spikelet forks, wild mustard seeds, *Pistacia* and Prunoideae nutshell fragments) along with very high levels of Cerealia-type pollen (up to 78%). Quantitative grain measurements of Cerealia-type pollen show that most is *Hordeum*-type, *Avena*-*Triticum*-type, *Triticum*-type and *Secale*-type. Cerealia-type pollen abundances reported here for core CH99H, although recording lower overall percentage values (~30%), do nonetheless compare well with the record of cereal remains in the archaeobotanical data from the same core sequence. Although the taphonomy of the charred plant remains in the CH99H core is not easy to pinpoint, archaeobotanical data suggest that the margins of the settlement were used for processing activities and refuse dumps. The high amounts of cereal-awns and glume-tips indicates the possible use of the site's margins for the early stages of cereal processing and other plants including wild mustard. Archaeobotanical data also show that the core site area was used as a midden for household debris. Very high percentage values of individual Cerealia-type support archaeobotanical inferences and further suggest that there may have been localised cereal cultivation on the drier floodplain areas adjacent to Çatalhöyük in addition to some cereal processing activities at the settlement fringe areas. However, it is virtually impossible to separate deposition of Cerealia-type pollen representing primary pollen from actual cereal cultivation from secondary pollen which has been introduced to the core site as a result of processing or deposited as waste vegetative matter. High occurrences of clusters of cereal and non-cereal NAP pollen suggest that this was secondary pollen and further indicates that settlement fringe areas were used as middens and refuse dump areas. The evidence of a wide range of activities occurring on the margins of the occupation area indicates the advantages of combined palynological and archaeobotanical research to understanding both on-site and off-site events.

As recorded for some sites in SE Europe and beyond, pollen evidence from regional sites suffer from difficulties in detecting and highlighting Neolithic-Chalcolithic cereal cultivation. Although the number of distant or regional pollen sites discussed here for south-central Anatolia is limited, Cerealia-type pollen data nonetheless only register very low percentage values (~1%) and it is not until later periods (e.g., Bronze, Iron Ages) that Cerealia-type pollen data are able to register increased human impact reflecting increasing numbers of settlements and population densities and more widespread use of the landscape by pastoral and agricultural activities (Figure 8; Woldring and Bottema, 2001/2; Roberts *et* *al*., 2016; Allcock, 2017; Allcock and Roberts, 2014). Where more distant or regional pollen sites generally have difficulty in registering Neolithic-Chalcolithic cereal cultivation, this study shows also that if a pollen core site is located too close to an archaeological site then pollen assemblages can be overwhelmed and swamped by the products of local cereal processing and the inclusion of domestic waste material. Ideally, a series of transects leading away from an archaeological site is most probably the best approach in order to investigate cereal agriculture and to tease apart the pollen signal that represents actual cereal cultivation from pollen which may have been introduced to the core locality due to cereal processing techniques or attached to waste vegetative matter. However, such an approach would require the presence of sufficient depositional basins which are particularly lacking in the drier, seasonally arid parts of the world.

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Captions for Tables and Figures

Table 1. Generalised sediment lithology for core CH99H. Munsell soil colours were ascertained while sediments were damp.

Table 2. Bulk and AMS dates for cores CH95F/G† and CH99H/J. Ages were calibrated using the INTCAL13 data set of Reimer *et al*. (2013).

Table 3. Local pollen assemblage zone descriptions and interpretations for core CH99H from Çatalhöyük.

Table 4. Summary of archaeobotanical plant remains data for cores CH95F/G† and CH99H/J.

Figure 1. Location map of site and coring positions of cores CH95-F/G and CH99-H/J.

Figure 2. Lithostratigraphy and measured physical parameters for core CH99H from Çatalhöyük.

Figure 3. Summary percentage pollen and charcoal data for core CH99H from Çatalhöyük.

Figure 4. Summary of archaeobotanical plant remains data for core CH99H from Çatalhöyük.

Figure 5. Percentage pollen data for Poaceae (<40 µm) and Cerealia-type (>40 µm) for core CH95F from Çatalhöyük.

Figure 6. Microphotograph of a cluster of Cerealia-type pollen grains. Measurement of the pore and annulus is 11 µm.

Figure 7. Cerealia-type pollen for the Early Chalcolithic for sites in south-central Anatolia. No pollen data exist for the site of Pınarbaşı for the Early Chalcolithic and there is an Early Chalcolithic hiatus at Akgöl Adabağ.

Figure 8. Cerealia-type and *Hordeum*/*Triticum* pollen for Eski Acıgöl for the early Holocene.

Figure 1

Figure 1. Location map of site and coring positions of cores CH95-F/G and CH99-H/J.

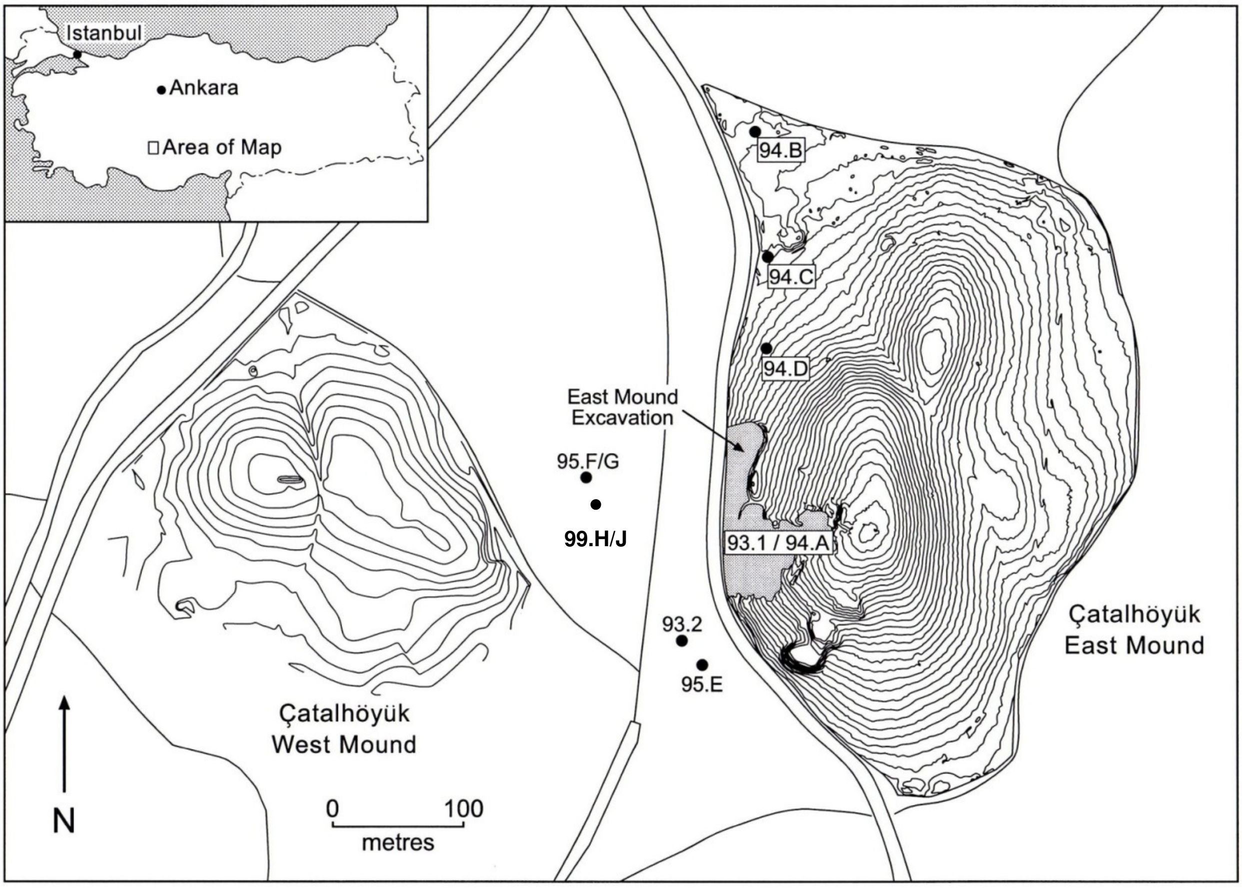


Figure 2

Figure 2. Lithostratigraphy and measured physical parameters for core CH99H from Çatalhöyük.

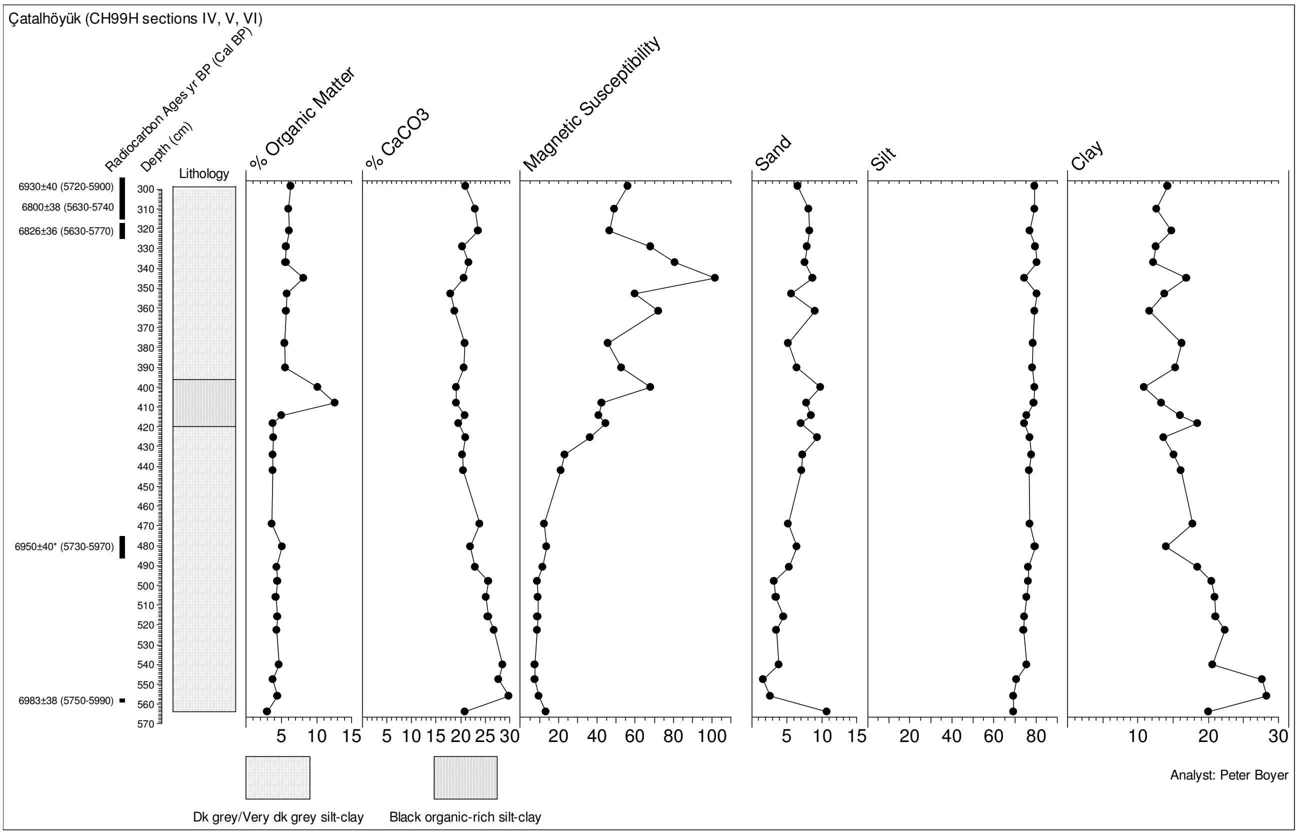


Figure 4

Figure 4. Summary of archaeobotanical plant remains data for core CH99H from Çatalhöyük.

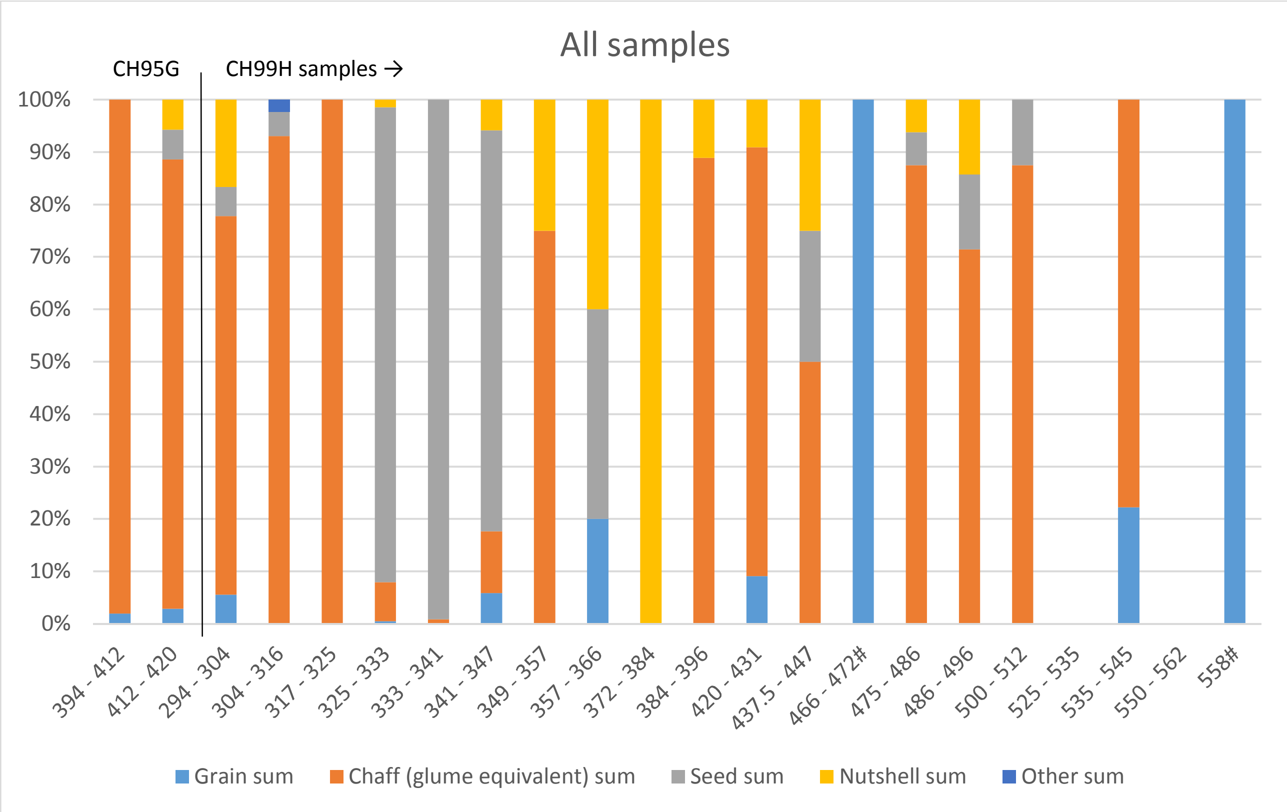


Figure 6

Figure 6. Microphotograph of a cluster of Cerealia-type pollen grains. Measurement of the pore and annulus is 11 μm.

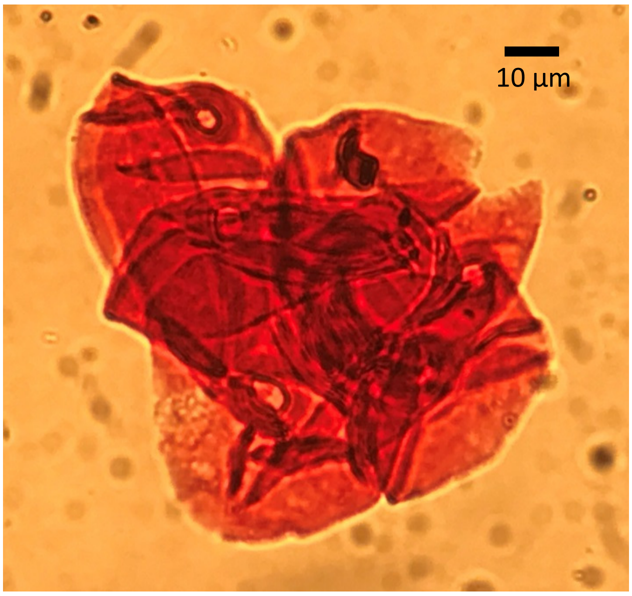


Figure 7

Figure 7. Cerealia-type pollen for the Early Chalcolithic for sites in south-central Anatolia. No pollen data exist for the site of Pınarbaşı for the Early Chalcolithic and there is an Early Chalcolithic hiatus at Akgöl Adabağ.

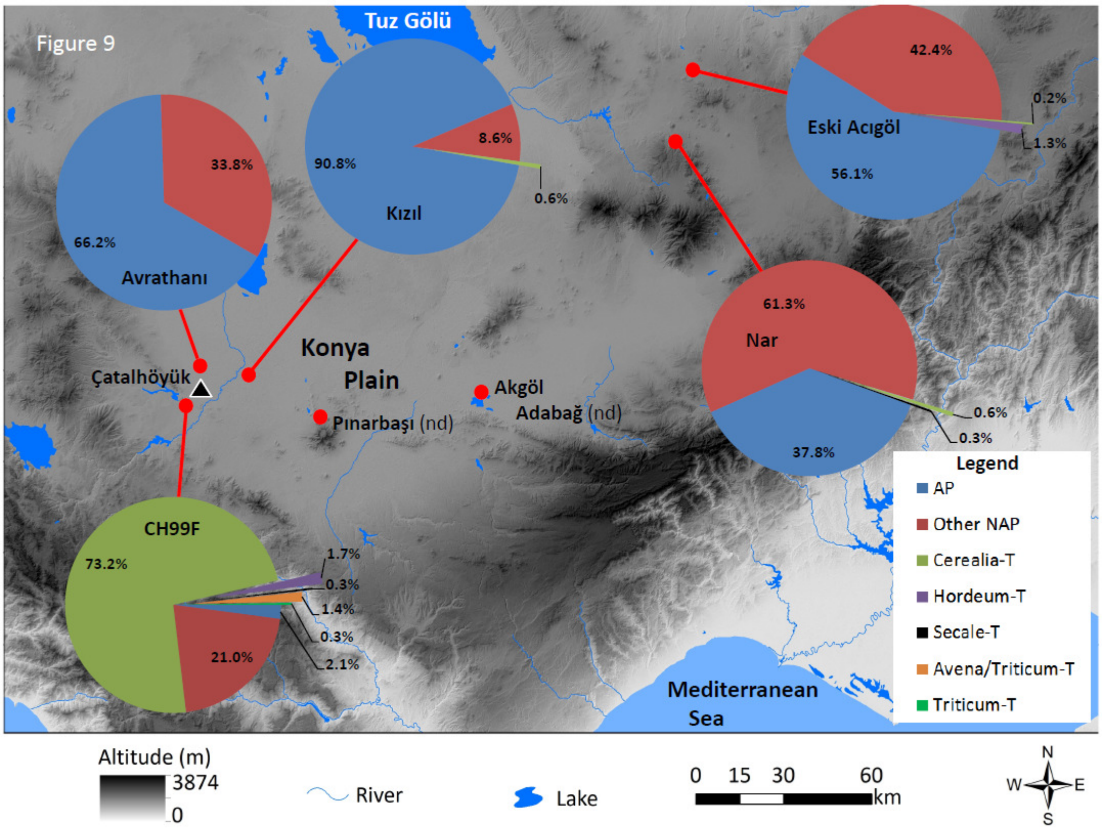


Figure 8

Figure 8. Cerealia-type and *Hordeum/Triticum* pollen for Eski Acıgöl for the early Holocene.

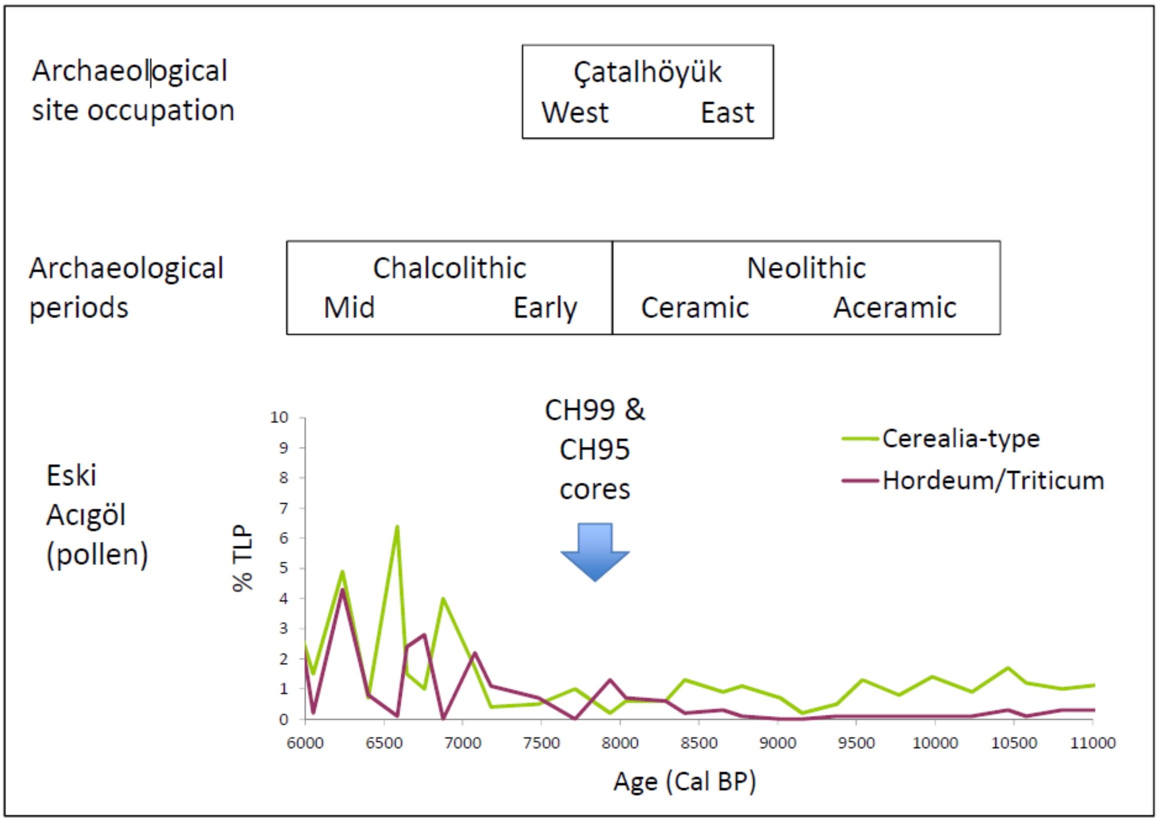


Figure 3

Figure 3. Summary percentage pollen and charcoal data for core CH99H from Çatalhöyük.

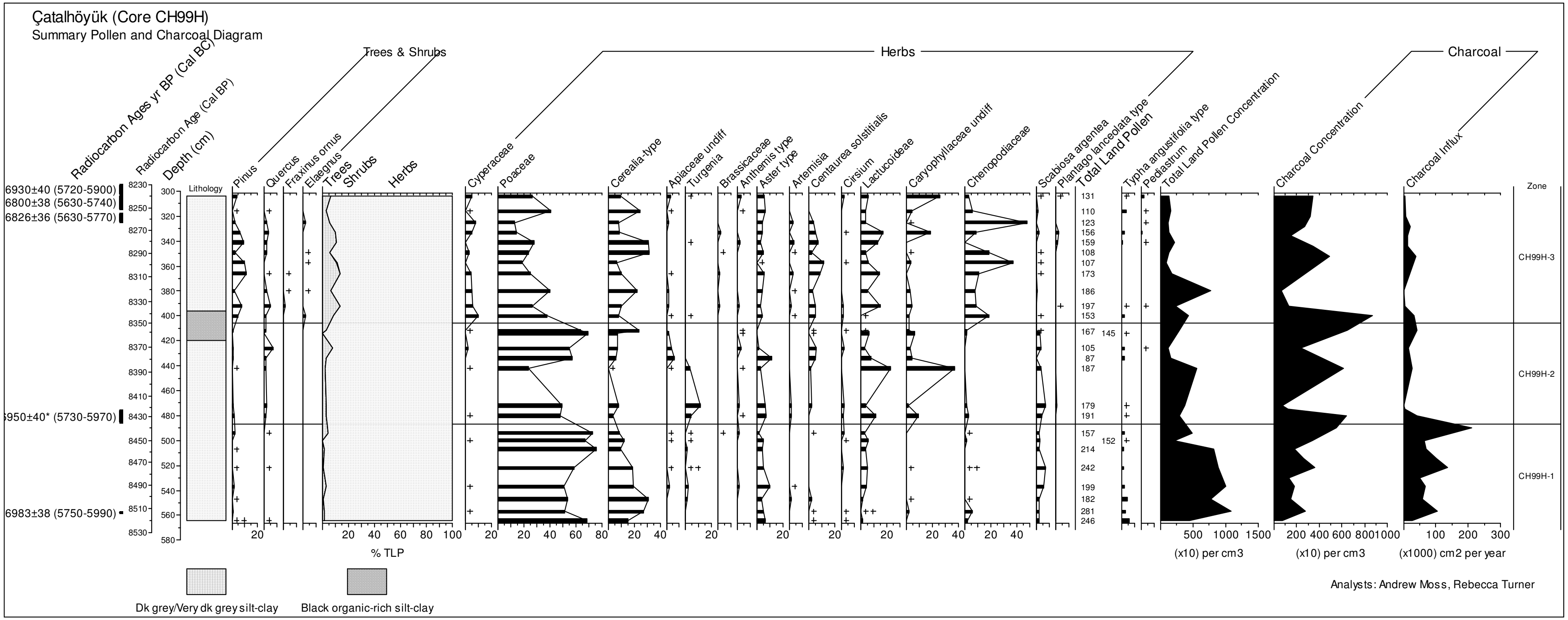


Figure 5

Figure 5. Percentage pollen data for Poaceae (<40 µm) and Cerealia-type (>40 µm) for core CH95F from Çatalhöyük.

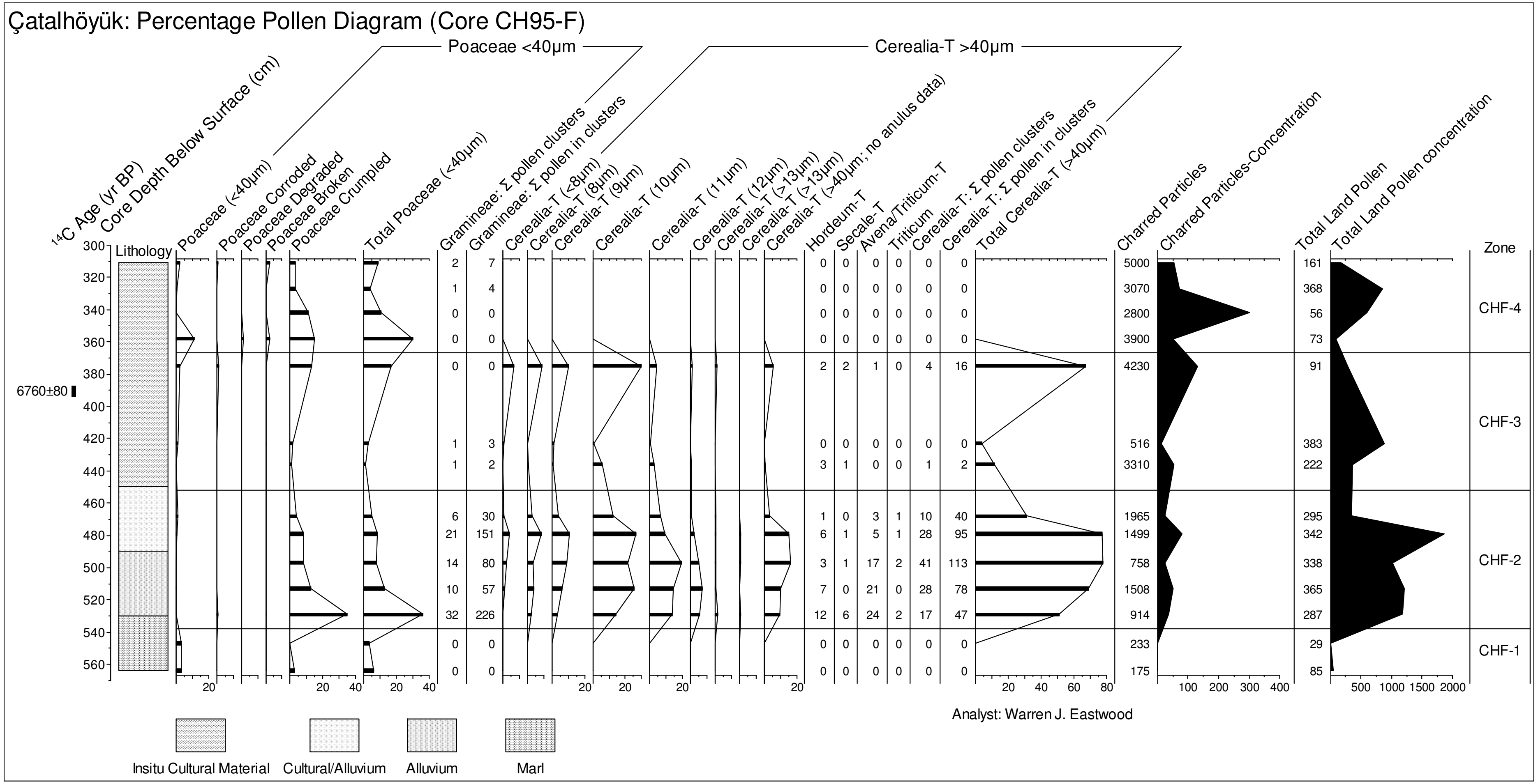


Table 1. Generalised sediment lithology for core CH99H. Munsell soil colours were ascertained while sediments were damp.

Depth (cm)	Çatalhöyük Datum masl	Description
0-291	1003.38-1000.47	Alternating sands, gravels, and 10YR 4/1 dark grey silt-clays of alluvial origin. These are sterile culturally and palaeoecologically.
291-396	1000.47-999.42	10YR 4/1 Dark grey to 10YR 3/1 very dark grey silt-clay with some sand. Abundant cultural debris including animal bone and potsherds.
396-420	999.42-999.18	10YR 2/1 Black to 10YR 3/1 very dark grey organic-rich silt-clay with some coarse sand. Abundant cultural debris including animal bone and potsherds.
420-566	999.18-999.72	10YR 3/1 very dark grey to 10YR 4/2 greyish brown organic silt, locally sandy or clay-rich, containing abundant cultural debris, including animal bone, potsherds, obsidian and charcoal.

Table 2. Bulk and AMS dates for core CH95F/G† and CH99H/J. Ages were calibrated using the INTCAL13 data set of Reimer *et al*. (2013).

Sample number	Depth (cm)	Laboratory number	Material dated	Age BP uncal	Calendar age range BC, 2SDs
CH95F/G†	387-394	Beta90020	bulk organic matter including charcoal	6760±80	5735-5480
CH99H 1	294-304	OxA-14778	Cereal grain (?*Triticum*)	6930 ± 40	5720-5900
CH99H 2	304-316	OxA-14695	Cereal chaff (?*Triticum*)	6800 ± 38	5630-5740
CH99H 3	317-325	OxA-14696	Cereal chaff (?*Triticum*)	6826 ± 36	5630-5770
CH99H 4	357-366	OxA-14779	Single Cerealia grain, *Hordeum*	7215 ± 50	6000-6220
CH99H 5	475-486	OxA-14780	Cereal chaff (?*Triticum*)	6950 ± 40	5730-5970
CH99H 6	475-486	OxA-14781	Nutshell, *Prunoides* or *Pistacia*	6995 ± 40	5770-5990
CH99H 7	535-545	OxA-14784	Cereal chaff and grain (?*Triticum*)	>51,900	n.a.
CH99H 8	558	OxA-14697	Single Cerealia grain	6983 ± 38	5750-5990

Table 3. Local pollen assemblage zone descriptions and interpretations for core CH99H from Çatalhöyük.

Zone	Depth (cm)	Description	Interpretation
CH99H-3	406-300	Decrease in NAP to 85% driven by slight increases in *Pinus* ~12%, *Quercus* ~5%, decrease in Poaceae ~25%, sustained presence of *Aster* type ~10%, slight increase in *Artemisia* ~3%, *Centaurea solstitialis* ~10%, *Cirsium* ~2%, Lactucoideae ~15%, Caryophyllaceae ~20%, some *Plantago lanceolata* ~5%, abrupt and marked increase in Chenopodiaceae ~30%, and decrease of *Scabiosa argentea* ~3%. Aquatic alga *Pediastrum* ~3%. Sustained decrease in charcoal influx.	Open landscape with standing water nearby. Migration and establishment of pine-oak woodlands in the Taurus mountain range surrounding the Konya Basin (long distance transport). Increase in percentage values of Cerealia-type suggest some cereal cultivation with perhaps some input from crop processing and/or waste from Çatalhöyük. *Pediastrum* suggest nutrient-enriched standing water.
CH99H-2	487-406	Decreasing but still high NAP (~90%) with Poaceae ~25-60%, Cerealia-type ~15%, Apiaceae ~6%, *Turgenia* ~10%, *Aster* type ~10%, *Centaurea solstitialis* ~6%, *Cirsium* ~3%, Lactucoideae ~20%, Caryophyllaceae ~35%, *Scabiosa argentea* ~8%. Marked decrease in charcoal influx.	Open landscape with standing water nearby. Decrease in cereal pollen, but increases in agricultural weeds associated with agriculture and dry grasslands and cereal fields (e.g., *Turgenia*). High percentage values of Cerealia-type suggest some cereal cultivation with perhaps some input from crop processing and/or waste from Çatalhöyük.
CH99H-1	570-487	High NAP ~95%, Poaceae 60-70%, Cerealia-type ~30%, Aster-type ~10%, Lactucoideae ~6%, *Scabiosa argentea* ~8%. *Typha angustifolia*-type ~5%, trace Cyperaceae. High charcoal influx (200,000 particles)	Open landscape with standing water nearby. Evidence of some cereal cultivation with perhaps some input from crop processing and/or waste from Çatalhöyük due to close proximity of coring site.

Table 4. Summary of archaeobotanical plant remains data for core CH95F/G† and CH99H/J.

Core:	**G†**	**G†**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**H**
Depth (cm):	394-412	412-420	294-304	304-316	317-325	325-333	333-341	341-347	420-431	475-486
Grain sum	4	1	1			1		1	1	
Chaff (glume equivalent) sum	201	30	13	40	64	15	3	2	9	14
Seed sum		2	1	2		183	349	13		1
Nutshell sum		2	3			3		1	1	1
Other sum				1						
Total	**205**	**35**	**18**	**43**	**64**	**202**	**352**	**17**	**11**	**16**

Figure 3. Summary percentage pollen and charcoal data for core CH99H from Çatalhöyük.

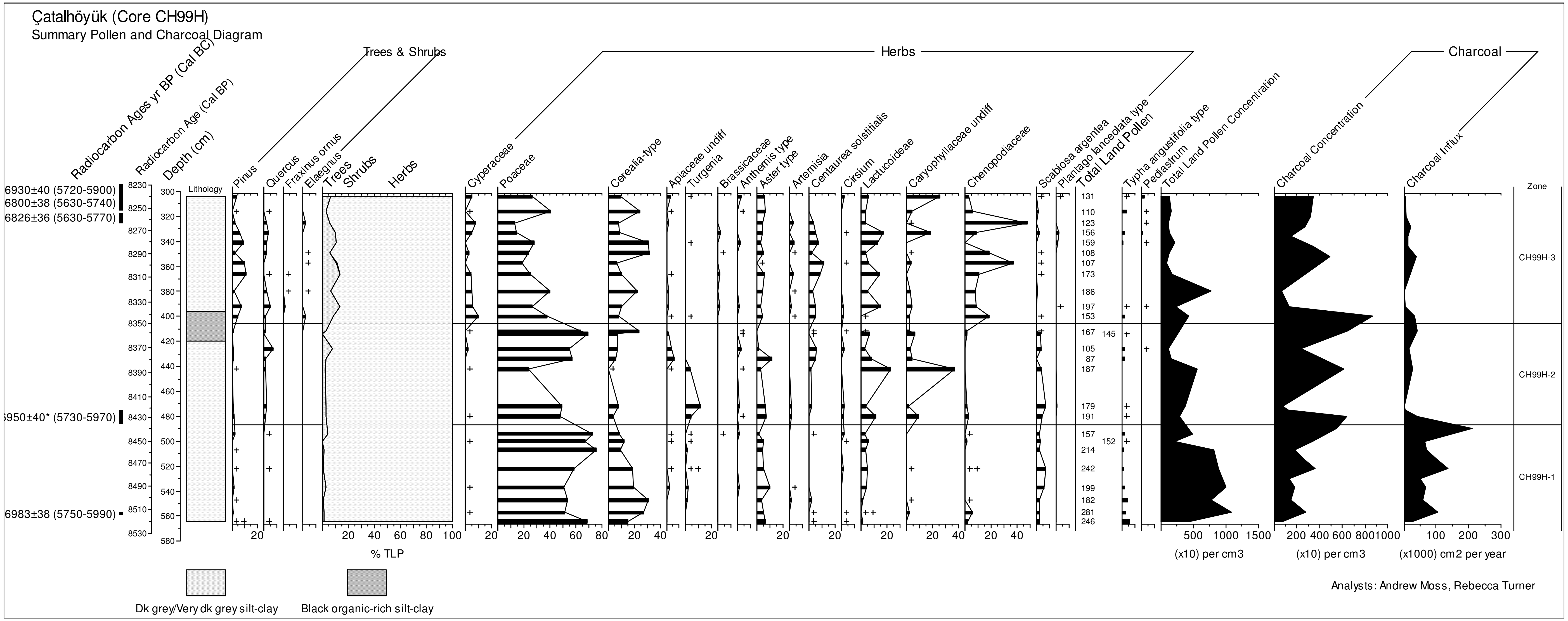
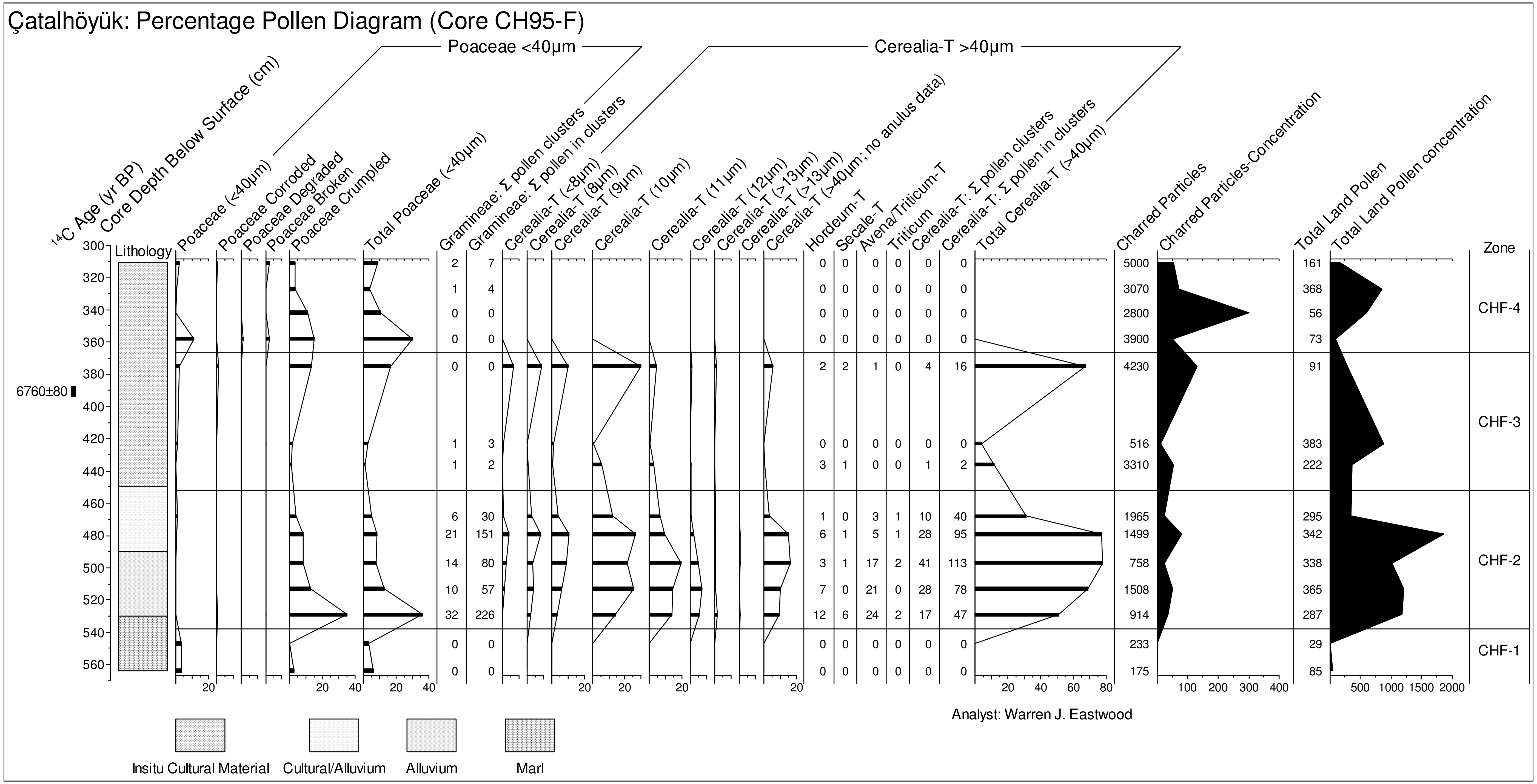


Figure 5. Percentage pollen data for Poaceae (<40 µm) and Cerealia-type (>40 µm) for core CH95F from Çatalhöyük.



Supplementary Table 1. Clusters of pollen grains for core CH95-F from Çatalhöyük. Each figure is an occurrence of a cluster of pollen grains indicating the number of grains in that cluster, while the sum in parentheses indicates the total number of pollen grains in that cluster for that particular level. Note how, in addition to high numbers of clusters of Cerealia-type pollen grains, there are also high occurrences of clusters of other pollen types including Chenopodiaceae and Poaceae and less so for Asteraceae and Lactuceae. Data for clusters of pollen grains clearly show that zone CHF-2 records the highest occurrences.

Core Depth (cm)	Local Pollen Zone	Çatalhöyük Datum (m amsl)	Chenopodiaceae	Poaceae	Asteraceae	Lactuceae	Cerealia-type
311		1011.38	4,4,12,12,12 (∑44)	4,3 (∑7)		-	-
327		1000.11	10 (∑10)	4 (∑4)	3 (∑3)	-	-
342	CHF-4	999.96	12,14,4,20,20,20, 20,8,10,20,20 (∑168)	-	3 (∑3)	-	-
358		999.80	20 (∑20)	-	-	-	-
375		999.63	4, 10 (∑14)	-	-	-	3,9,2,2 (∑16)
423	CHF-3	999.15	6 (∑6)	3 (∑3)	-	-	-
436		999.02	-	2 (∑2)	-	2 (∑2)	2 (∑2)
468		998.70	6,11,10 (∑27)	2,2,15,2,2,7 (∑30)	2 (∑2)	-	2,2,2,2,3,2,4,20,3 (∑40)
479		998.59	5,4,8,19,2 (∑38)	15,3,2,10,3,20, 3,4,6,4,4,3,15, 3,20,20,2,3,7, 2,2 (∑151)	-	-	7,2,2,2,4,6,4,2,2,3,2,4,3,2,2, 4,6,2,4,3,3,6,4,3,4,4,2,2 (∑95)
497	CHF-2	998.41	3,10 (∑13)	12,3,2,5,5,2,8, 10,3,3,5,10,6,6 (∑80)	-	-	2,3,5,3,3,3,5,3,7,3,2,2,2,2,2, 5,2,4,2,3,5,2,2,2,2,2,4,2,2,3, 2,2,2,2,2,2,2,3,2,2,3 (∑113)
513		998.25	12,4 (∑16)	12,3,3,5,3,8,3, 3,12,4 (∑57)	6 (∑6)	-	4,2,3,5,3,3,2,2,2,7,2,2,3,2,2, 3,6,2,2,2,2,2,2,2,3,3,2,3 (∑78)
529		998.09	4,3,2,2,6,2,3,4 (∑26)	5,7,4,2,3,5,2,2, 2,2,5,70,2,10, 7,20,5,2,3,6, 10,2,3,8,4,4,3, 2,8,4,10,4 (∑226)	-	-	2,3,3,2,2,2,2,2,2,2,9,3,3,3,2, 3,2 (∑47)
547	CHF-1	997.91	-	-	-	-	-
564		997.74	-	-	-	-	-