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1 **Comparing pollen and archaeobotanical data for Chalcolithic cereal agriculture at**
2 **Catalhöyük, Turkey**

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19

20 **Abstract**

21 Establishing agricultural activity using pollen analysis is one of the prime challenges of a
22 palaeoecological investigation. Here we report combined pollen and archaeobotanical data
23 originating from a waterlogged off-site organic-rich fill radiocarbon dated to ~8 ka Cal BP
24 located between the two occupation mounds at Neolithic-Chalcolithic Catalhöyük, south
25 central Turkey in order to investigate the record of Early Chalcolithic agricultural activity.
26 Pollen results indicate extremely high abundances of Cerealia-type pollen (30->70%) and

27 critical measurements of these show them to be *Triticum*-type, *Avena/Triticum*-type, *Secale*-
28 type and *Hordeum*-type. Pollen data are also compared with archaeobotanical data retrieved
29 from the same sediment matrix and show high abundances of *Triticum* and *Hordeum* grains,
30 awns, spikelet forks and glume bases. Archaeobotanical and pollen data are therefore
31 unequivocal in showing the presence of cereals throughout the period of deposition, and
32 although preservation of archaeobotanical cereal plant remains is typically poor, the presence
33 of glume wheats, including emmer/‘New Type’ wheat and domesticated barley, is consistent
34 with cereal data from on-site excavation deposits at Çatalhöyük. Pollen data also include high
35 occurrences of clusters of Cerealia-type, Chenopodiaceae, Poaceae and Asteraceae and point
36 to local deposition that is best explained as the anthers being deposited at the coring site
37 attached to cereal or other herbaceous waste material. Archaeobotanical data in addition to
38 very high percentage values of individual Cerealia-type pollen grains and clusters of
39 Cerealia-type pollen and other non-arboreal pollen types suggest that the margins of the
40 Çatalhöyük site were probably used for early stage crop processing activities as well as a
41 waste site. Although radiocarbon dating of this organic-rich fill suggests that it was deposited
42 over a very short time period (~300 years) during the Early Chalcolithic, the data highlight
43 the importance of adopting complementary palynological and archaeobotanical approaches in
44 order to better understand the taphonomy of micro and macrofossil deposits associated with
45 archaeological sites. While more distant, regional pollen sites in south-central Anatolia have
46 difficulty registering Neolithic-Chalcolithic cereal cultivation, this study shows that if a
47 pollen core site is located too close to an archaeological site, then pollen assemblages can be
48 overwhelmed and ‘swamped’ by the products of local cereal processing and the inclusion of
49 domestic waste material thus rendering it difficult to elucidate meaningful data on local
50 agricultural activity.

51 **Highlights**

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

61

62 **Keywords**

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

64

65 **1 Introduction**

66 Archaeological research has revealed, in considerable detail, the emergence of Neolithic
67 farming societies in southwest Asia, and their subsequent spread across Europe (Hofmanová,
68 *et al.* 2016; Horejs, *et al.* 2015; Baird *et al.* 2018). Archaeozoological and especially
69 archaeobotanical evidence from excavated plant remains, notably of wheat and barley,
70 indicates that the main transition from foraging to farming was complete by ~8000 BP
71 (uncal) in the core region of domestication (Harris 1998; Colledge *et al.*, 2004; 2013).

72 Despite this wealth of bioarchaeological data, off-site evidence (i.e. from non-archaeological
73 excavation contexts) for early prehistoric agriculture in the eastern Mediterranean region in
74 particular has remained elusive. Willis and Bennett (1994) highlighted the significant
75 discrepancy in time between the arrival of Neolithic agriculture, as testified archaeologically,
76 and the first appearance of cultural indicators in pollen diagrams from Greece and the

77 Balkans, a time delay amounting to >2000 years. It has been proposed that many of the
78 earliest Neolithic farming communities in southeast Europe and Anatolia practised a
79 relatively input-intensive horticulture on alluvial soils (Sherratt 1980; van Andel and Runnels
80 1995; Bogaard *et al.* 2013). Such garden-scale cultivation would not have required large-
81 scale clearance of the pre-existing natural vegetation, and these activities would not have
82 been detectable in pollen sequences unless they were located in close proximity to prehistoric
83 settlements. Most crops (wheat, barley, etc.) are severely under-represented palynologically,
84 and may only find limited (or zero) expression in pollen diagrams located some distance from
85 prehistoric sites. Additionally, many palynological indicators of cultural activity are present
86 naturally in southwest Asia and the secondary anthropogenic indicators (e.g., weeds) can
87 often provide diagnostic evidence of pastoral and cultivation. Cerealia-type pollen, for
88 example, which is an exotic in northern Europe, has been used to identify prehistoric crop
89 husbandry, but there are some wild cereals and other grasses in the Mediterranean region that
90 have Cerealia-type properties (e.g., grain diameter >40 μm) and therefore need not provide a
91 diagnostic indicator of prehistoric farming activity (Bottema 1992). The analysis of pollen
92 derived from on-site archaeological excavation contexts also presents a range of problems
93 from biases associated with preservation and taphonomy. Pollen grains do not survive well in
94 the usually dry sediments associated with archaeological sites in southwest Asia; they are
95 prone to differential microbial attack and corrosion. Furthermore, in order for pollen studies
96 to yield worthwhile results, the palynologist must have knowledge of the likely source or
97 origin of the pollen and its pathways from production and dispersal to deposition; i.e., its
98 taphonomy. For example, pollen extracted from archaeological excavation contexts may have
99 been brought to the site in bedding or fodder, in the sediments or attached to vegetation used
100 as temper in mudbrick manufacture or transported from one context to another by soil fauna,
101 e.g., digger bees (*cf.* van Zeist & Bottema 1991; Bottema 1975). Because there are many

102 difficulties surrounding pollen analysis from archaeological contexts, it is generally accepted
103 that off-site research may yield more informative results (Edwards 1991; Bottema 1992). The
104 aims of this paper are twofold. Firstly, we report combined pollen and archaeobotanical
105 results from a sediment core retrieved from an off-site, organic-rich and waterlogged location
106 adjacent to and therefore in close proximity to Neolithic-Chalcolithic Çatalhöyük, south
107 central Turkey (Figure 1) in order to establish a palynological signal of agricultural activity.
108 By comparing pollen and archaeobotanical results together, we are able to examine indicators
109 of prehistoric food procurement and processing activities, while each mutual approach is
110 better able to provide information on and provide an independent check on taphonomic
111 pathways of pollen and plant remain data. Secondly, we compare the proximal off-site pollen
112 data reported here from Çatalhöyük with Cerealia-type pollen data for Neolithic-Chalcolithic
113 agricultural activity recorded in more distant, regional pollen sequences in south-central
114 Anatolia in order to establish a regional signal of agricultural activity for this time period.

115

116 **2 Çatalhöyük archaeological site and previous work**

117 The tell site of Çatalhöyük is located 50 km southeast of Konya in south-central Turkey on
118 the shallow alluvial fan of the Çarşamba river (Figure 1). The site, which comprises two
119 mounds: the Neolithic ‘East Mound’ and Chalcolithic ‘West Mound’, was originally
120 excavated by James Mellaart between 1961 and 1965 and is well known for its complex
121 settlement layout, elaborate art and early religious symbolism (Mellaart, 1967). New
122 excavations under the directorship of Ian Hodder between 1992 and 2017 (Hodder, 1996,
123 2000, 2014) and the recovery of a broad range of botanical assemblages from the Neolithic
124 East Mound has revealed a flourishing early agricultural economy based on the exploitation
125 of domesticated and cultivated plants (Asouti, 2005, 2013; Asouti and Austin, 2005; Asouti *et*
126 *al.*, 1999; Bogaard *et al.*, 2013, 2017; Fairbairn, *et al.*, 2002, 2005, 2007; Filipovic, 2014),

127 radiocarbon dated to have started between 7150 and 7100 cal. BCE (~9075 Cal BP; Bayliss *et*
128 *al.*, 2015). By the foundation of Catalhoyuk, agriculture had been present for at least 1200
129 years on the Konya Plain, with low-level food production first being evidenced at Boncuklu
130 c. 8300-7,800 Cal BCE (Baird *et al.* 2018), and a wider suite of crops being exploited in the
131 8th millennium Cal BCE at Canhasan III (French 1972; Hillman 1978). Evidence for
132 agriculture also continues through the Early Chalcolithic settlement of Catalhoyuk's West
133 Mound, dated c.6150 to 5500 Cal BCE (~7775 Cal BP; Orton *et al.*, 2018; Higham *et al.*,
134 2007; Cessford *et al.*, 2001).

135 Archaeobotanical research at Çatalhöyük has provided a comprehensive
136 understanding of plant use over the c.1,500 year occupation of this farming community. The
137 crop suite consists of four wheat species; emmer (*Triticum dicoccum*), einkorn (*Triticum*
138 *monococcum*), 'new type' glume wheat (*Triticum* sp.) and free-threshing wheat (*Triticum*
139 *aestivum/durum*), three barley varieties (2-row hulled barley - *Hordeum vulgare*, and 2- and
140 6-row naked barley - *Hordeum vulgare* var *nudum*) and four pulse species – lentil (*Lens*
141 *culinaris*), bitter vetch (*Vicia ervilla*) grass pea (*Lathyrus sativus*) and chickpea (*Cicer*
142 *arietinum*). Use of wild species is common throughout the assemblage, with use of wild nuts
143 such as almond/plum (*Amygdalus/Prunus*), pistachio (*Pistacia*), hackberry (*Celtis*) and acorn
144 (*Quercus*), as well as the collection and consumption of an oil-rich wild mustard, *Descurania*
145 *sophia* (Fairbairn 2007; Bogaard *et al.*, 2017; Stroud *et al.*, *in prep*). The wild species
146 included within the archaeobotanical samples indicates the practice of burning dung as a fuel
147 (Fairbairn *et al.* 2005), commonly used in outside fires on the Neolithic East mound (Bogaard
148 *et al.*, 2014). The suite of dung derived species indicates the grazing of animals on a range of
149 environments including wet and/or saline, as well as steppe vegetation, and coupled with the
150 arable and other flora indicates that a mosaic of wet and dry locations were exploited within
151 the landscape (Charles *et al.*, 2014).

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

161 Allied to on-site excavation, archaeobotanical and anthracological research,
162 programmes of off-site coring have been carried out to investigate the alluvial
163 geoarchaeology in greater detail (Roberts *et al.* 1996, 1999, 2007; Boyer *et al.*, 2006, 2007;
164 Ayala *et al.*, 2017). Core sequence CH95F/G, located between the two occupation mounds at
165 Çatalhöyük (Figure 1), is especially significant because, in contrast to the excavation
166 deposits, it contained an organic-rich deposit that was still waterlogged and in which pollen
167 was preserved. Preliminary pollen analytical results for core CH95F were reported by
168 Eastwood *et al.* (2007) and included the occurrence of coenobia of *Pediastrum* (~25%),
169 confirming the presence of eutrophic standing water at this location. Significantly, the
170 CH95F/G core sequence recorded very high percentage values of Cerealia-type pollen
171 (>70%) and occurrences of groups or clusters of pollen grains – essentially pollen grains
172 deposited while still in the anthers. A bulk radiocarbon age of 6760±80 BP (Table 2), derived
173 from the organic unit in core CH95F, produced a calibrated age of c. 5650 cal. BC which
174 places the top part of the CH95F sequence as Early Chalcolithic. In addition, the CH95F/G
175 cores are bracketed by two OSL dates (5400±1019 BP (230-245 cm); 6496±1777 BP (420-
176 435 cm; see Roberts *et al.*, 1999). Because core CH95F is coeval with the dates for the east

177 and west occupation mounds, the site was recored to retrieve sufficient sediment for
178 archaeobotanical analyses. Alongside this, a rigorous size and measurement analysis of each
179 Cerealia-type pollen grain from the CH95F/G sequence was undertaken.

180

181 3 *The palaeoecological and palaeoclimatological setting*

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

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

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

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

211 Stable isotope data for Eski Acıgöl, Akgöl Adabağ and Nar Gölü in particular
212 (Roberts *et al.*, 2008) indicate cold and dry climatic conditions during the Late Glacial
213 Younger Dryas stadial (=Greenland Stadial; ~12.9-11.7 ka Cal BP); the cold- and dry-
214 adapted *Artemisia*-Chenopodiaceae steppe reflecting these climatic conditions. At the onset
215 of the Holocene a marked shift to more negative stable isotope values is recorded indicating
216 increased moisture availability alongside increasing temperatures that mark the wettest phase
217 in central Anatolia (Roberts *et al.*, 2016). However, the Nar isotopic data suggest that this
218 relatively wetter early Holocene period was interrupted by two phases of drier climate, as
219 indicated by shifts in oxygen and carbon isotope composition, Ca/Sr ratios, a switch from
220 calcite to aragonite precipitation (Roberts *et al.*, 2016) and also in $\delta^2\text{H}$ values of lipid
221 biomarkers preserved in pottery from the Neolithic site of Çatalhöyük (Roffet-Salque *et al.*,
222 2018). These dry phases appear to be broadly correlative with the 9.3- and 8.2-ka events
223 recorded in Greenland ice cores, but they lasted significantly longer at Nar (Dean *et al.*,
224 2015). The latter arid event coincided with a change in the flood regime of the Çarşamba
225 river (Roberts and Rosen, 2009). It also coincided with the shift in the settlement at

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

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

240 Alongside archaeological and archaeobotanical data from Çatalhöyük, Kabukcu
241 (2017) provides a synthesis of regional woodland history based on anthracological data. At
242 the onset of the Holocene (from ~11,700 Cal BP) semi-arid woodlands comprising *Quercus*,
243 *Juniperus*, *Amygdalus*, *Pistacia*, Maloideae and *Prunus* were already established in the
244 vicinity of the Konya Plain. At lower elevations and on the Konya Plain itself,
245 anthracological data suggest a range of riparian and wetland taxa including Salicaceae,
246 Ulmaceae, *Tamarix*, *Fraxinus* and perhaps *Celtis* were important sources of fuel wood to
247 prehistoric settlements living in the Konya plain for a considerable period of time and may
248 have been one of the influential factors leading to the establishment of settlements.
249 Anthracological data for the Late Ceramic Neolithic (6400-6000 Cal BC) at Çatalhöyük show
250 more intensive use of local riparian (Ulmaceae, Salicaceae) woodlands along with *Amygdalus*

251 and *Pistacia* with trace amounts of weedy taxa such as *Artemisia*, Chenopodiaceae and
252 *Capparis*. During the Early Chalcolithic at Çatalhöyük (6000-5500 Cal BC) when occupation
253 shifted to the West Mound, the data show a return to a mixed strategy of exploitation of semi-
254 arid *Juniperus* woodlands (42% charcoal values) on the higher hillsides surrounding the
255 Konya Basin as well as the exploitation of local riparian woodlands. *Amygdalus*, *Pistacia*,
256 *Prunus*, Maloideae with trace amounts of weedy taxa such as *Artemisia*, Chenopodiaceae,
257 along with Leguminosae and *Capparis* are also represented in the charcoal assemblages
258 (Kabukcu, 2017). Regional pollen data are able to record some, but not all of the
259 anthracological taxa; whereas *Pinus* and deciduous *Quercus* are expressed, poor and/or
260 sporadic pollen producers such as *Pistacia*, *Juniperus* and *Celtis* tend to be under-represented
261 or absent in pollen diagrams from SW Asia. Riparian taxa (e.g., *Fraxinus* and *Salix*) are
262 generally well-recorded in pollen diagrams as well as weedy, steppic taxa such as *Artemisia*
263 and Chenopodiaceae, but other insect pollinated taxa (e.g., Rosaceae, including *Amygdalus*
264 and *Prunus*, Maloideae) are generally not expressed in regional pollen diagrams.

265 The relatively low deciduous *Quercus* wood charcoal values (~10%) and higher
266 *Juniperus* values (42%) for the Late Ceramic Neolithic and Early Chalcolithic is interpreted
267 by Kabukcu (2017) as reflecting temporal changes in fuelwood preferences rather than
268 changes in wood availability. Regional pollen data from Eski Acıgöl and Nar (Roberts *et al.*,
269 2001; 2016; Woldring and Bottema, 2001/2) show increasing deciduous *Quercus* pollen
270 values indicating woodland expansion across central Anatolia during this time period.

271

272

273 **4 Methods**

274 Sediment cores comprising the CH99H/J series were retrieved adjacent to Çatalhöyük and in
275 close proximity to the CH95F coring site (Figure 1) using a Eijkelhamp vibro-corer with

276 exchangeable open gouge and lined sample heads. Sediments for core CH99H/J were
277 described in the field and in the laboratory using a modified version of the scheme of Troels-
278 Smith (1955) as proposed by Aaby & Berglund (1986) (Table 1). The sediments were also
279 assigned Munsell soil colours, although these can become modified upon exposure to air
280 (Munsell, 1994).

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

286 Core CH99H was subsampled (1cm³) for microcharcoals at 8 cm intervals.
287 Microscopic charcoal particles (<180 µm) were extracted from the sediments using a heavy
288 liquid extraction procedure (see Turner *et al.* (2004) for details) and counted until 250
289 *Lycopodium* spores were recorded; this number being based on the work of Finsinger &
290 Tinner (2005).

291 Subsamples of sediment (typically 2 cm³ in volume) were taken for pollen analysis
292 between 8-12 cm intervals throughout the length of core CH99H. Extraction of pollen follows
293 the standard procedure of Faegri and Iversen (1989) and involved digestion in 10% HCl,
294 followed by 10% NaOH treatment, sieving and 60% HF acid before Erdtman's acetolysis.
295 Exotic *Lycopodium* tablets of a known concentration were added for pollen concentrations to
296 be calculated (Stockmarr, 1971). Samples were dehydrated with Tertiary Butyl Alcohol
297 (TBA) before being added to silicone oil (Faegri and Iversen, 1989). Pollen grains were
298 counted until the pollen sum of 250 grains was reached (excluding spores and exotics), and
299 although some levels yielded extremely low amounts of pollen, their inclusion is justified on
300 the grounds that at least some palaeoenvironmental information is forthcoming. Pollen

301 identifications were aided by the keys, descriptions and microphotographs contained within
302 Moore et al. (1991), Reille (1992, 1999) and reference grains; Coenobia of *Pediastrum* were
303 identified using the key in Komárek and Jankovská (2001). Pollen of aquatic plants, together
304 with algal microfossils are expressed as percentages of total microfossils. Conventions for the
305 degree of taxonomic certainty follow Berglund and Ralska-Jasiewiczowa (1986); pollen
306 nomenclature follows Davis (1965-1985). The delimitation of local pollen assemblage zone
307 boundaries was aided by a stratigraphically constrained incremental sum-of-squares cluster
308 analysis (CONISS; Grimm, 1987) and used a square-root transformation and chord-distance
309 dissimilarity measure for all terrestrial pollen taxa. Pollen diagrams were constructed using
310 TILIA and TILIAGRAPH (Grimm, 1991) and do not show pollen types with very low (trace)
311 percentage values.

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

325 Twenty sediment samples of approximately 50 cm³ in size were analysed from two
326 cores (CH95G and CH99H) for plant macrofossils. Samples were soaked in water and wet-
327 sieved using a 250 µm mesh to evaluate the preservation status of plant remains in the
328 samples. Anaerobically-preserved (cf. waterlogged) organic material, including plant
329 macrofossils, was not present in the sample set so the samples were dried and the plant
330 remains recovered from the dried residue using a binocular dissecting microscope. In addition
331 to the whole sediment samples, two groups of seeds were collected from core CH99H 466-
332 472 cm and 558 cm. Only small quantities of highly fragmented charred (partially burnt)
333 plant remains were recovered among a larger assemblage of siliceous specimens (preserved
334 due to the natural deposition of silica in the plant cells during life). The siliceous remains
335 were mainly cereal-awn fragments or glume-tips; and were recorded using a relative five-
336 figure scale of abundance. Charred cereal macrofossils, including chaff and grains, plus seeds
337 and nutshell fragments were identified and quantified using standard methods (see Fairbairn
338 et al. 2005). Small quantities of tiny wood charcoal fragments were also present, alongside
339 unidentifiable plant material and small fragments of charred stem, probably from reed.

340

341 **5 Results**

342 *Sediments and lithology*

343 The lithology of core CH99H (Table 1) comprises a basal unit of marl (566->700 cm),
344 deposited during the Late Pleistocene Palaeolake Konya. Overlying this (291-566 cm) is a
345 unit of silt with alternating sandy or clay-rich layers containing abundant cultural debris
346 including animal bone, potsherds, obsidian flakes and charcoal. Within this is a sub-unit
347 (396-420 cm) containing a particularly black organic-rich silt-clay with abundant cultural
348 debris. The uppermost lithological unit (0-291 cm) includes alternating sands, gravels and
349 silt-clays and comprises the ‘upper alluvium’ unit, devoid of cultural artefacts and is

350 palaeoecologically sterile. Core CH99H has relatively high percentage values of CaCO₃ and
351 low organic matter content, apart from elevated organic matter content during the black
352 organic-rich silt clay unit (396-420 cm). Magnetic susceptibility values remain low until 440
353 cm and then gradually increase towards the top of the sequence (Figure 2). The lithology of
354 core CH95F was described by Eastwood *et al.* (2007) and essentially contains the same
355 lithological units, albeit with slight variations. Both sediment cores record the peak in organic
356 matter: in the CH95F core sequence, this is at 380-395 cm while in CH99H, is at 390-410 cm.
357 Magnetic susceptibility values in each core begin to increase just before deposition of the
358 black organic-rich silt-clay unit; in CH95F this is 450 cm (see Figure 15.1 in Eastwood *et al.*,
359 2007) and in CH99H this is 440 cm. Organic matter content and magnetic susceptibility data
360 are useful for core correlation and show that there is an approximate 10 cm offset between the
361 CH95F and CH99H sediment cores.

362

363 ***Radiocarbon dating and chronology***

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

375 These ages therefore provide a total of five reliable dated levels within the core
376 sequence, which fall into two principal groups: samples 1–3 between 294 and 325 cm core
377 depth, date to around 5630-5770 Cal BC; while samples 5, 6 and 8 between 475 and 558 cm
378 core depth, date to between 5770 and 5990 Cal BC. This is consistent with two main phases
379 of infilling, with deposition taking place rapidly, implying that this ~264 cm thick organic
380 unit was relatively short-lived (~300 years). In archaeological terms, although all of the ages
381 are slightly older than the previous range-finder ¹⁴C age of 6760±80 BP on core CH95F, the
382 new dating evidence strongly suggests that the entire organic fill belongs to the Early
383 Chalcolithic period, rather than extending back to Neolithic times. The deposit thus seems to
384 have been coincident only with the occupation of the West Mound at Çatalhöyük. A charcoal
385 sample from the base of cultural levels in core CH96W from the West Mound produced
386 radiocarbon ages of 6940±80 BP (PL980524A) and 7040±40 BP (AA27981), or around
387 5840-5930 Cal BC, which is statistically identical to the lower part of the organic fill in core
388 CH99H (see Roberts *et al.* 1996, 1999, 2007; Boyer *et al.*, 2006, 2007 for details). The fill
389 appears to be slightly younger than charcoal from a buried soil sequence in the KOPAL 97
390 and 99 Trenches (see Roberts *et al.*, 1996, 1999, 2007 for details).

391

392 ***Pollen and charcoal results***

393 Pollen data for core CH99H (Figure 3; Table 3) are divided into three fossil pollen assemblage
394 zones (CH99H-1 to CH99H-3) High NAP for the entire ~300-year sequence suggests an open
395 landscape. *Typha angustifolia*-type and Cyperaceae suggests that the core site was relatively
396 close to standing water (possibly in an oxbow lake occupying a meander cutoff). *Typha* spp.
397 in particular grow in shallow water of lakes, rivers, ponds, marshes, and ditches and have
398 many edible uses and along with *Phragmites* are important for thatch. Trace values of the
399 aquatic alga, *Pediastrum* for the upper part of the sequence suggests an increase in nutrient

400 enrichment of this water body. High percentage values of Cerealia-type for the entire
401 sequence, together with a range of weeds associated with arable agriculture, particularly in
402 zone CH99-2, suggests that cereals were grown in close proximity to the core site and thus
403 near to Çatalhöyük. However, high values of cereal pollen suggest that other taphonomical
404 pathways may have been important with some allocthonous input from crop processing
405 and/or waste from Çatalhöyük (discussed more fully in later sections). Increases in AP during
406 the upper part of the sequence (zone CH99-3) are most certainly the product of long distance
407 transport reflecting the establishment and development of open pine-oak woodlands in the
408 Taurus mountain range surrounding the Konya Basin (see below). The abrupt and marked
409 increase in Chenopodiaceae during the upper part of the sequence (zone CH99-3) may reflect
410 a local expansion of semiarid herb-steppe alongside a slight increase in *Artemisia*; however,
411 taxa of this family also include local halophytic plants, therefore no firm palaeoecological
412 interpretation can be placed on the local habitat for this zone.

413

414

415 *Archaeobotanical results*

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

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

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

449 becoming a major crop in the Chalcolithic levels of Çatalhöyük West (Bogaard *et al.* 2017;
450 Stroud *et al.* in prep).

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

466 Archaeobotanical data indicate noticeable increases in the abundance of all charred
467 remains and silicified awns towards the top of the sequence (325 to 347 cm) compared with
468 remains in the lower levels, whereas elevated percentage values of Cerealia-type pollen
469 (Figure 3) are found throughout the CH99H sequence. Furthermore, there is no corresponding
470 increase in Cerealia-type pollen corresponding with increased abundances of *Triticum* sp.
471 glume bases towards the top of the sequence. Of the arable and steppic weeds, there are slight
472 increases in Brassicaceae pollen percentage values for zone CH99H-3, but these in no way
473 match the elevated abundances of *Descurainia sophia* (Brassicaceae) recorded in the

474 archaeobotanical data. This may suggest that Brassicaceae are severely under-represented in
475 pollen diagrams or signify a different source for the pollen and the seed macrofossils, as
476 could also be the case with the cereals. Similarly, seeds of *Bolboschoenus glaucus*, a member
477 of the Cyperaceae family are present throughout the CH99H sediment sequence as is the
478 pollen of Cyperaceae; trace percentage values in the lowermost part of the sequence (zones
479 CH99H-1 and -2) increasing to ~10% for the uppermost part (zone CH99H-3).

480 Critical measurements of Cerealia-type pollen grains and subsequent designations
481 (Figure5) are recorded for two of the four zones in core CH95F; zones CH95F-2 and CH95F-
482 3 which corresponds to the ‘cultural alluvium’, ‘alluvium’ and ‘in situ cultural’ lithological
483 units (see Eastwood *et al.*, 2007 for details of sediment lithological units for core CH95F).
484 There is an absence of Cerealia-type pollen grains in the lowermost ‘marl’ and the upper part
485 of the ‘in situ cultural’ lithological units. In particular, for Zone CH95F-2 (538-452 cm)
486 percentage values of 78% Cerealia-type are recorded with many of these designations being
487 assigned to *Hordeum*-type, *Avena-Triticum*-type, *Triticum*-type and less so for *Secale*-type.
488 Crucially, the numbers of clusters of Cerealia-type pollen grains and the total number of
489 grains in each cluster was also quantified and shows that zone CH95F-2 also scores highly
490 with respect to individual domesticated cereal pollen grains and clusters of Cerealia-type as
491 well (Figure6). Due to limited sediment amounts, archaeobotanical analysis was carried out
492 on two bulk samples only for core CH95F/G (394-412; 412-420 cm; Table 3) in a section of
493 the core where pollen data are lacking. However, elevated Cerealia-type pollen brackets the
494 archaeobotanical samples and Cerealia-type pollen designations show that these are mostly
495 *Hordeum*-type and *Avena/Triticum*-type.

496

497 **6 Discussion**

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

511

512 6.1 *Comparison of proximal off-site pollen and archaeobotanical results*

513 Regionally interpreted pollen data for core CH99H show that the landscape was relatively
514 open with the sequence recording the development and establishment of pine-oak woodlands
515 in the Taurus Mountains surrounding the Konya Basin during the early Chalcolithic period.
516 Locally, pollen data indicate the presence of standing water and this together with
517 sedimentological and lithological data, suggest that both the CH95F and CH99H core
518 sequences reflect a combination of overbank alluvial deposition, standing-water conditions
519 (possibly in an oxbow lake occupying a meander cutoff), and running water river channel
520 sedimentation. Deposition of early Holocene fine-grained alluvium was followed by a phase
521 of organic-rich sedimentation that was contemporary with Çatalhöyük West (Chalcolithic).
522 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

548 3-4% when agriculture is practised within about 2 km of the sampling site; percentage values
549 only rise above 4-5% when cereal crops are grown in the immediate vicinity of the site (Heim
550 1962). Similarly, modern pollen-vegetation studies for southwest Asia (Bottema and
551 Woldring, 1990) suggest that Cerealia-type pollen attains a maximum of around 5%, while
552 surface soil samples sourced from cereal fields in southwest Turkey yielded Cerealia-type
553 pollen percentage values of 2-3% (Eastwood, 1997).

554 New, modern pollen Tauber trap data from the Cappadocian region of Turkey, which
555 has a similar bioclimatic regime to the Konya Plain region, show that percentage values for
556 *Secale* range from 0.3% to 1.99% with Cerealia-type percentage values ranging from 0.4% to
557 3.3% with a maximum percentage value of 9.68% being recorded for a Tauber trap located at
558 the edge of an agricultural field. *Hordeum* scores even less (0.2%), while surface sediment
559 sample data record general Cerealia-type pollen values ranging 1.9-4.1% (Şenkul
560 unpublished data).

561 Thus, modern pollen Tauber trap data for the south-central region of Turkey confirm
562 extremely 'low' percentage values of Cerealia-type pollen; this being attributable to the fact
563 that the cereals, with the exception of the genus *Secale* (which is wind pollinated), are
564 partially or completely self-pollinating and therefore tend to produce low amounts of pollen.
565 Furthermore, their large size and the tendency of *Triticum*, *Hordeum*, and *Avena* pollen grains
566 to remain in their hulls, means that cereal pollen grains – apart from *Secale* – are poorly
567 dispersed and are usually only deposited locally and tend to be grossly under-represented in
568 pollen diagrams. Therefore, it is possible that a *proportion* of the high percentage values of
569 Cerealia-type pollen may be the result of intensive cereal agriculture within the immediate
570 vicinity of the sampling site (cf. Heim, 1962), a credible hypothesis given the new data by
571 Ayala *et al.* (2017) which suggest that there were drier localised areas of the floodplain
572 surrounding Çatalhöyük. However, the elevated percentage values of Cerealia-type pollen

573 reported by this study and Eastwood *et al.* (2007) – far in excess of 4-5% as suggested by
574 Heim (1962) – suggests that other taphonomical pathways need to be examined.

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

586 Significantly, Robinson and Hubbard (1977) and Bottema (1992) explicitly mention
587 the absence of clusters or groups of Cerealia-type pollen grains and suggest that this absence
588 is due to threshing, winnowing or some other processing technique(s), which provides the
589 mechanism for disaggregation and dispersal of individual cereal pollen grains from the
590 anthers into the air. Elevated abundances of clusters of cereal and non-cereal pollen grains
591 (Figure 6) as recorded in the CH95F sequence (Figure 5; Supplementary Material – Table 1)
592 tend to support the inference that a large proportion of the Cerealia-type pollen was deposited
593 at the core location as waste attached to cereal or other vegetative matter, perhaps deposited
594 alongside the chaff as represented by the siliceous awns and glume tips that are abundant in
595 the archaeobotanical data for these levels. Given the high percentage values of Cerealia-type
596 pollen, the palynological data suggest a combination of three taphonomical pathways: (i)
597 attached to waste cereal and other plant matter; (ii) processing of cereal products may have

598 occurred at the settlement margins; (iii) there may have been some cereal cultivation within
599 the immediate vicinity of the sampling site on drier terrain as indicated by Ayala *et al.*
600 (2017).

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

621 The charred plant remains are less easy to source and were burned in fires before
622 accumulating in the source deposits. They may well derive from the burning of crop-

623 processing residues in waste, animal dung, oil extraction or the eroded remains of hearth
624 debris dumped in middens on the site edge; Çatalhöyük midden deposits of hearth debris can
625 contain a range of charred botanical material including later stage crop processing residue,
626 wood fuel and a particular suite of wild seeds derived from the burning of dung (Bogaard *et*
627 *al.*, 2013; Bogaard *et al.*, 2014 Stroud *et al.*, in prep). There are a high proportion of wild
628 mustard seeds (*Descurainia*) in the upper part of the CH99H sequence, significantly
629 outnumbering the crop remains in those samples and also running somewhat counter to the
630 relatively low presence of *Descurainia* in mixed midden deposits from the West Mound
631 (Stroud *et al.*, in prep). The *Descurainia* concentration in CH99H could be refuse from
632 eroded midden deposits or alternatively is from the processing of this species.

633

634 6.2 ***Regional Cerealia-type pollen evidence for Neolithic-Chalcolithic cereal agriculture***

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

647 sequences are located adjacent to, or in close proximity (i.e., <1 km) to archaeological sites
648 bearing the same name.

649 The longer and more detailed pollen record from Akgöl Adabağ (Ereğli marshes) at
650 the eastern end of the Konya Basin ~85 km east of Çatalhöyük (Bottema and Woldring, 1984;
651 van Zeist *et al.*, 1991; Turner *et al.*, 2010; Figure 7) has a radiocarbon age of 8040±140 yr BP
652 (~8780 Cal BP). Only trace percentage values (<1%) for Cerealia-type pollen for the early
653 Holocene aceramic Neolithic period are recorded (Bottema and Woldring, 1984).

654 In the Eski Acıgöl pollen sequence located in Cappadocia (Woldring and Bottema,
655 2001/2; Roberts *et al.*, 2001). Cerealia-type pollen percentage values for the early Holocene
656 (Neolithic) part of the sequence register <4%, while only trace values (<1%) are recorded for
657 *Hordeum*-type; these increase to 6% and 4% respectively for the mid Chalcolithic period
658 (Figure 8). Also located in Cappadocia and ~15 km from Eski Acıgöl, pollen data from Nar
659 Gölü indicate that Cerealia-type pollen for Nar Gölü for the ceramic Neolithic part of the
660 early Holocene is not registered and percentage values of Cerealia-type (0.6%) and *Secale*
661 (0.3%) are recorded for the early Chalcolithic part of the sequence (Figure 9; Eastwood
662 unpublished data).

663 Cerealia-type pollen data for south-central Anatolia for the Neolithic and early
664 Chalcolithic periods for the limited number of coring locations for this period discussed as
665 part of this study have important implications for Neolithic-Chalcolithic cultivation of
666 cereals. Unequivocal evidence for widespread or extensive cultivation of cereals for the
667 Neolithic-Chalcolithic periods does not find clear expression in the palaeoecological record
668 from south-central Anatolia and Cerealia-type pollen fails to register above 1.5%. This is
669 more in line with the hypothesis advanced by Sherratt (1980), van Andel and Runnels (1995)
670 and Bogaard *et al.* (2013) who suggest that human subsistence activities were smaller scale,
671 in close to proximity of habitation sites and higher intensity. However, this is not to say that

672 there was an absence or a lack of people on the landscape; rather their agricultural activities
673 specifically regarding the cultivation of cereals in particular was such that cultivation failed
674 to cross a palaeoecological threshold for it to be registered and detected in regional lake
675 sediment records for a variety of reasons. The same applies for those coring sites located in
676 close proximity to archaeological sites: the pollen records for both Kızıl Höyük and
677 Avrathanı Höyük registers either zero or only trace values of Cerealia-type pollen. Only at
678 Çatalhöyük are elevated Cerealia-type pollen values recorded and this is attributable to
679 taphonomical factors related to the coring location being too close to the archaeological site
680 with the deposition of secondary pollen from cereal processing activities, attached to waste
681 cereal and other plant matter as well as some primary pollen perhaps linked to cereal
682 cultivation within the immediate vicinity of the sampling site on drier terrain as indicated by
683 Ayala *et al.* (2017).

684

685 **7 Conclusion**

686 The importance of combining on-site and off-site research at Çatalhöyük has been
687 demonstrated by palynological and archaeobotanical analysis of an organic-rich, fill sequence
688 that accumulated rapidly during the Early Chalcolithic, ~6000 to ~5600 Cal BC, associated
689 with occupation of the West Mound at Çatalhöyük. Pollen and plant remains from this fill
690 contained abundant cultural debris, crop processing waste and food by-products (cereal-awns,
691 glume-tips, wheat chaff, glume bases, spikelet forks, wild mustard seeds, *Pistacia* and
692 Prunoideae nutshell fragments) along with very high levels of Cerealia-type pollen (up to
693 78%). Quantitative grain measurements of Cerealia-type pollen show that most is *Hordeum*-
694 type, *Avena-Triticum*-type, *Triticum*-type and *Secale*-type. Cerealia-type pollen abundances
695 reported here for core CH99H, although recording lower overall percentage values (~30%),
696 do nonetheless compare well with the record of cereal remains in the archaeobotanical data

697 from the same core sequence. Although the taphonomy of the charred plant remains in the
698 CH99H core is not easy to pinpoint, archaeobotanical data suggest that the margins of the
699 settlement were used for processing activities and refuse dumps. The high amounts of cereal-
700 awns and glume-tips indicates the possible use of the site's margins for the early stages of
701 cereal processing and other plants including wild mustard. Archaeobotanical data also show
702 that the core site area was used as a midden for household debris. Very high percentage
703 values of individual Cerealia-type support archaeobotanical inferences and further suggest
704 that there may have been localised cereal cultivation on the drier floodplain areas adjacent to
705 Çatalhöyük in addition to some cereal processing activities at the settlement fringe areas.
706 However, it is virtually impossible to separate deposition of Cerealia-type pollen representing
707 primary pollen from actual cereal cultivation from secondary pollen which has been
708 introduced to the core site as a result of processing or deposited as waste vegetative matter.
709 High occurrences of clusters of cereal and non-cereal NAP pollen suggest that this was
710 secondary pollen and further indicates that settlement fringe areas were used as middens and
711 refuse dump areas. The evidence of a wide range of activities occurring on the margins of the
712 occupation area indicates the advantages of combined palynological and archaeobotanical
713 research to understanding both on-site and off-site events.

714 As recorded for some sites in SE Europe and beyond, pollen evidence from regional
715 sites suffer from difficulties in detecting and highlighting Neolithic-Chalcolithic cereal
716 cultivation. Although the number of distant or regional pollen sites discussed here for south-
717 central Anatolia is limited, Cerealia-type pollen data nonetheless only register very low
718 percentage values (~1%) and it is not until later periods (e.g., Bronze, Iron Ages) that
719 Cerealia-type pollen data are able to register increased human impact reflecting increasing
720 numbers of settlements and population densities and more widespread use of the landscape
721 by pastoral and agricultural activities (Figure 8; Woldring and Bottema, 2001/2; Roberts *et*

722 *al.*, 2016; Allcock, 2017; Allcock and Roberts, 2014). Where more distant or regional pollen
723 sites generally have difficulty in registering Neolithic-Chalcolithic cereal cultivation, this
724 study shows also that if a pollen core site is located too close to an archaeological site then
725 pollen assemblages can be overwhelmed and swamped by the products of local cereal
726 processing and the inclusion of domestic waste material. Ideally, a series of transects leading
727 away from an archaeological site is most probably the best approach in order to investigate
728 cereal agriculture and to tease apart the pollen signal that represents actual cereal cultivation
729 from pollen which may have been introduced to the core locality due to cereal processing
730 techniques or attached to waste vegetative matter. However, such an approach would require
731 the presence of sufficient depositional basins which are particularly lacking in the drier,
732 seasonally arid parts of the world.

733

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746

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- 997

998 **Captions for Tables and Figures**

999

1000 **Table 1.** Generalised sediment lithology for core CH99H. Munsell soil colours were
1001 ascertained while sediments were damp.

1002

1003 **Table 2.** Bulk and AMS dates for cores CH95F/G† and CH99H/J. Ages were calibrated using
1004 the INTCAL13 data set of Reimer *et al.* (2013).

1005

1006 **Table 3.** Local pollen assemblage zone descriptions and interpretations for core CH99H from
1007 Çatalhöyük.

1008

1009 **Table 4.** Summary of archaeobotanical plant remains data for cores CH95F/G† and
1010 CH99H/J.

1011

1012 **Figure 1.** Location map of site and coring positions of cores CH95-F/G and CH99-H/J.

1013

1014

1015

1016 **Figure 2.** Lithostratigraphy and measured physical parameters for core CH99H from
1017 Çatalhöyük.

1018

1019 **Figure 3.** Summary percentage pollen and charcoal data for core CH99H from Çatalhöyük.

1020

1021 **Figure 4.** Summary of archaeobotanical plant remains data for core CH99H from
1022 Çatalhöyük.

1023

1024 **Figure 5.** Percentage pollen data for Poaceae (<40 µm) and Cerealia-type (>40 µm) for core
1025 CH95F from Çatalhöyük.

1026

1027 **Figure 6.** Microphotograph of a cluster of Cerealia-type pollen grains. Measurement of the
1028 pore and annulus is 11 µm.

1029

1030 **Figure 7.** Cerealia-type pollen for the Early Chalcolithic for sites in south-central Anatolia.
1031 No pollen data exist for the site of Pınarbaşı for the Early Chalcolithic and there is an Early
1032 Chalcolithic hiatus at Akgöl Adabağ.

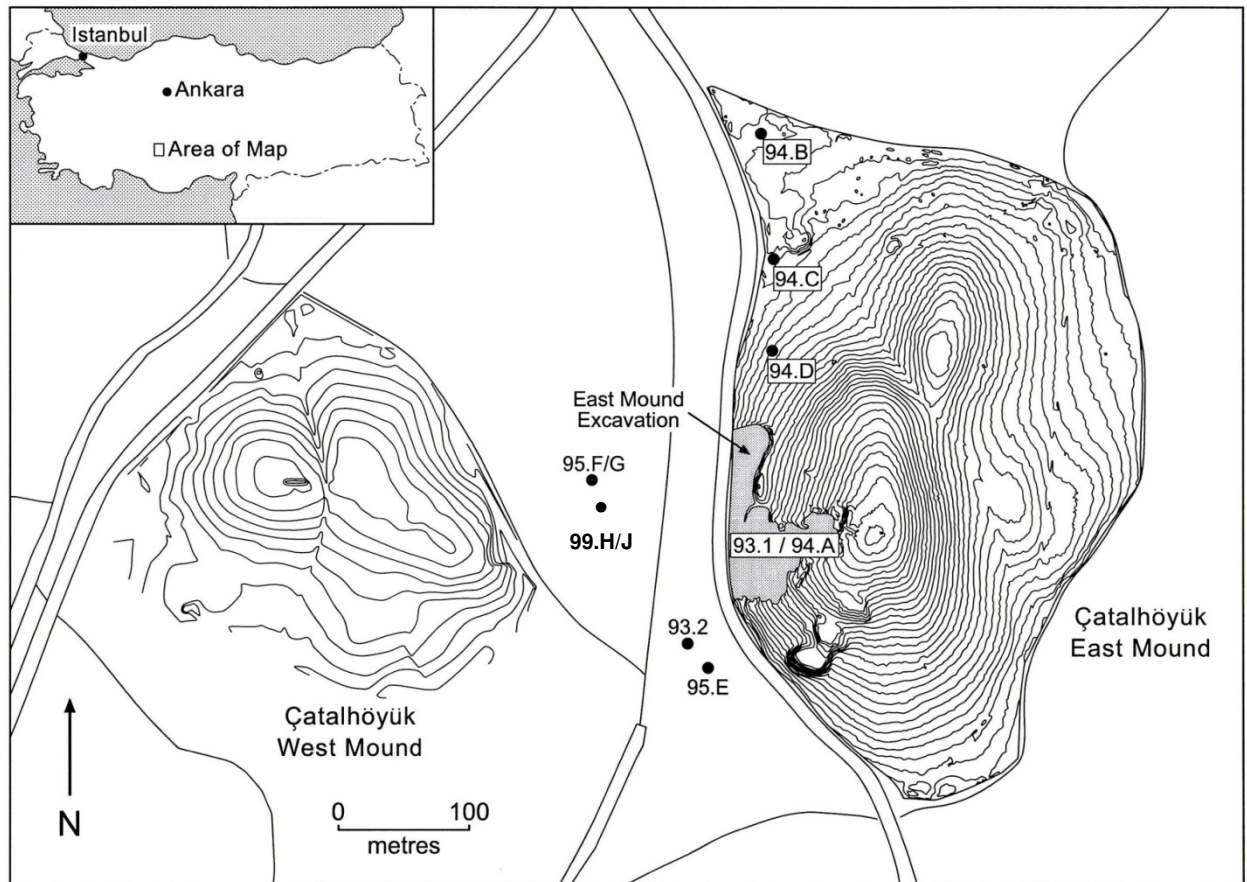
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1034 **Figure 8.** Cerealia-type and *Hordeum/Triticum* pollen for Eski Acıgöl for the early Holocene.

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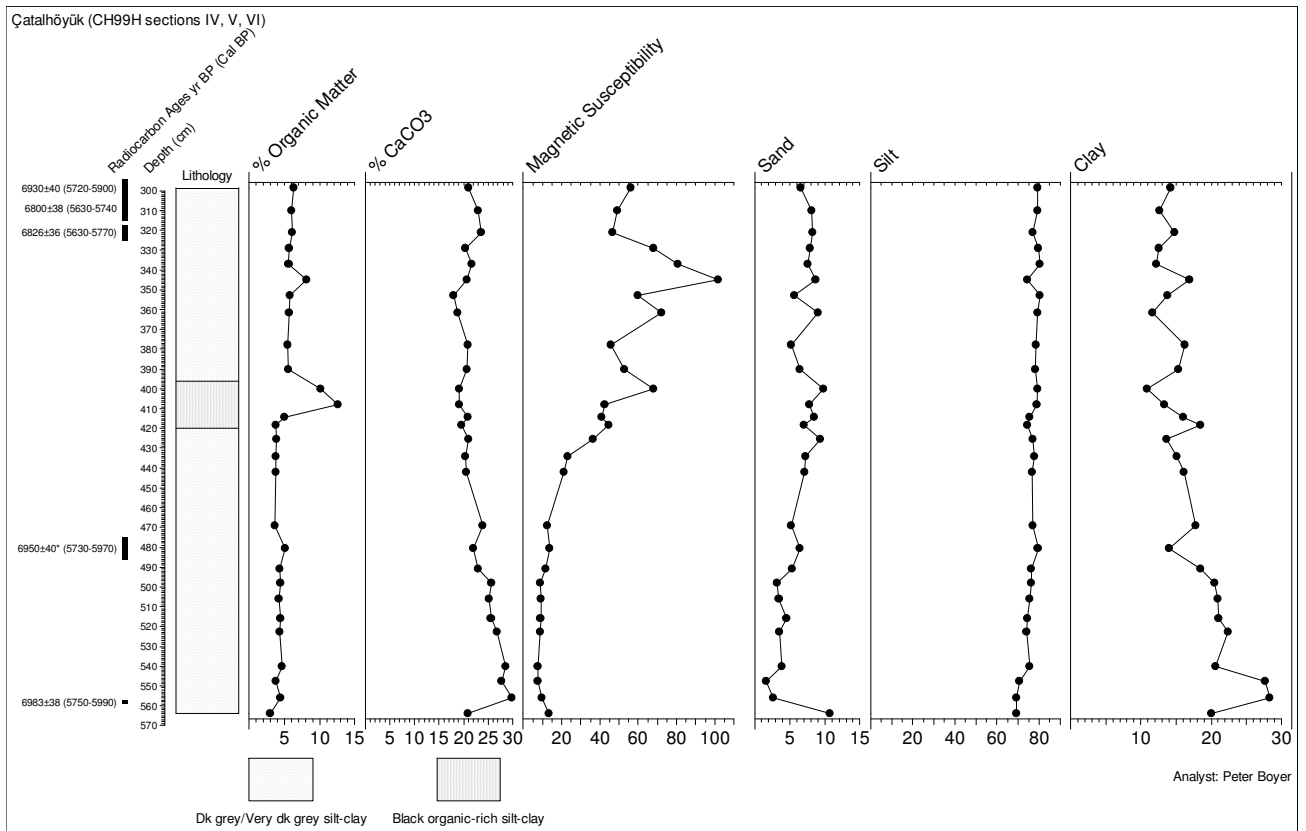
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Figure 1
Figure 1. Location map of site and coring positions of cores CH95-F/G and CH99-H/J.



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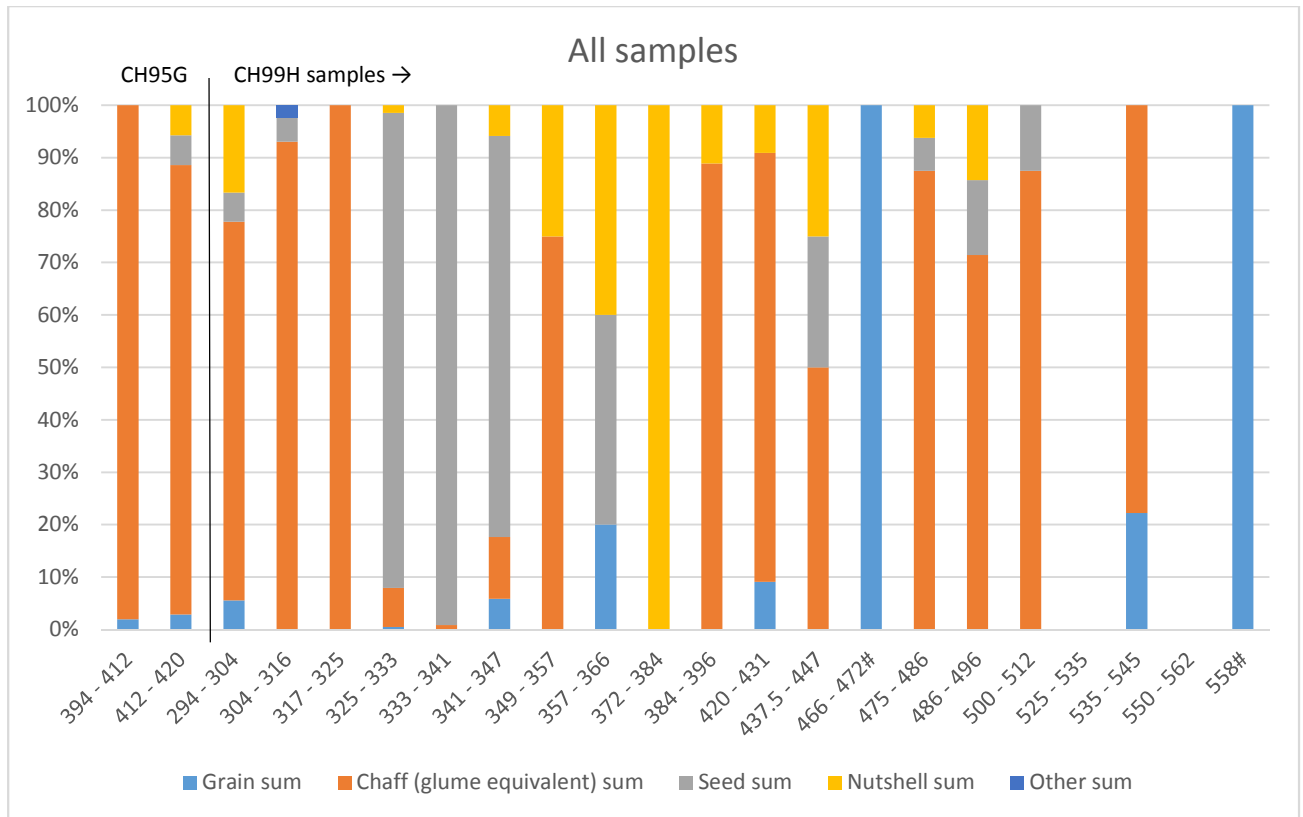
1041 Figure 2
 1042 **Figure 2.** Lithostratigraphy and measured physical parameters for core CH99H from
 1043 Çatalhöyük.
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1050 Figure 4

1051 **Figure 4.** Summary of archaeobotanical plant remains data for core CH99H from
1052 Çatalhöyük.



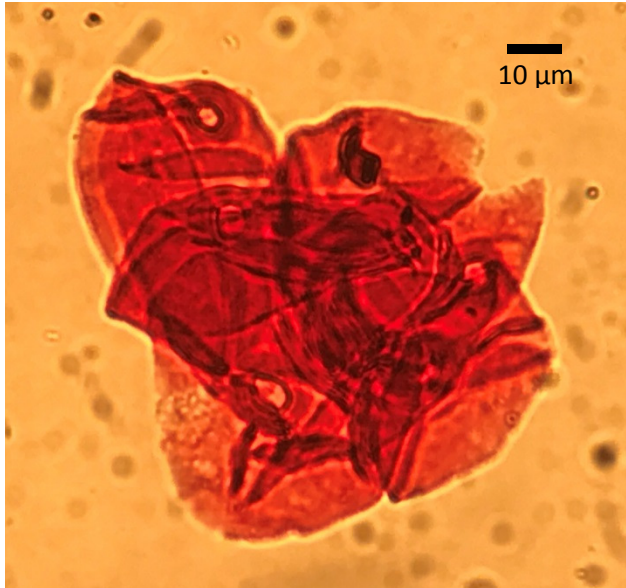
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1056 Figure 6

1057 **Figure 6.** Microphotograph of a cluster of Cerealia-type pollen grains. Measurement of the
1058 pore and annulus is 11 μm .

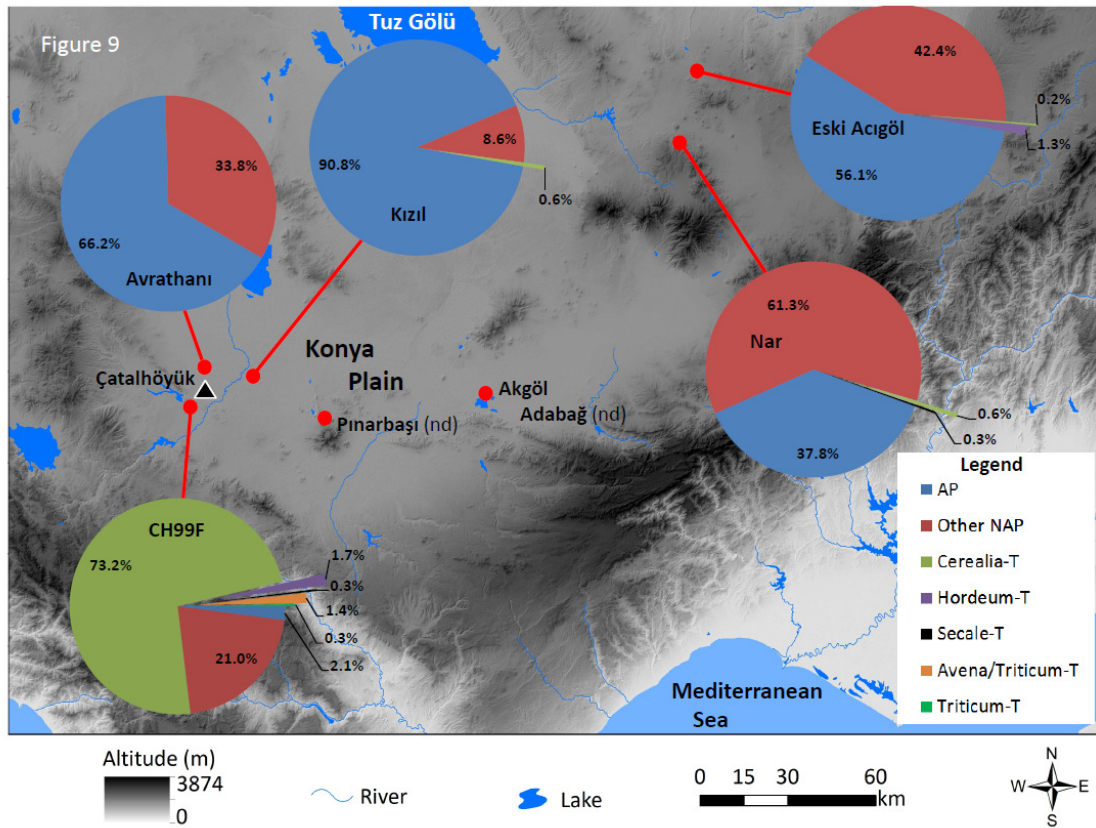


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1061 Figure 7

1062 **Figure 7.** Cerealia-type pollen for the Early Chalcolithic for sites in south-central Anatolia.
1063 No pollen data exist for the site of Pınarbaşı for the Early Chalcolithic and there is an Early
1064 Chalcolithic hiatus at Akgöl Adabağ.

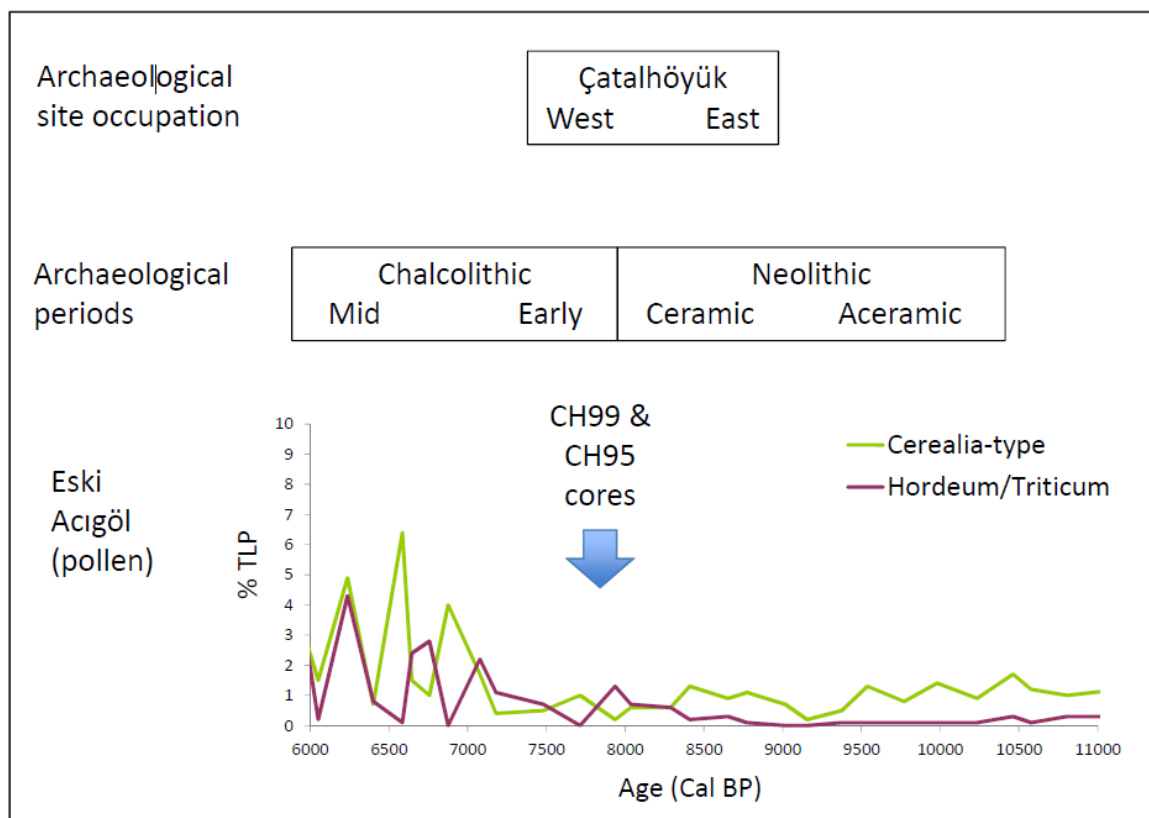


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1067 Figure 8

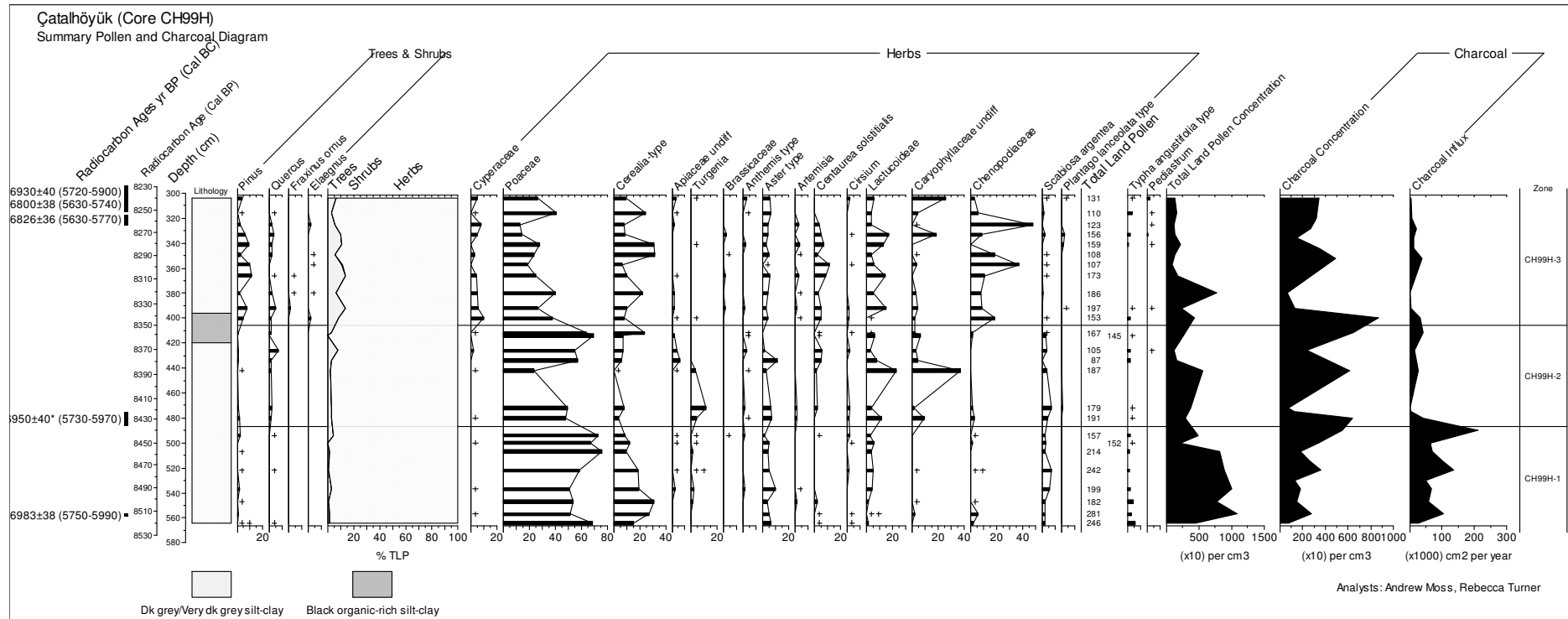
1068 **Figure 8.** Cerealia-type and *Hordeum/Triticum* pollen for Eski Acıgöl for the early Holocene.



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1070 Figure 3

1071 **Figure 3.** Summary percentage pollen and charcoal data for core CH99H from Çatalhöyük.

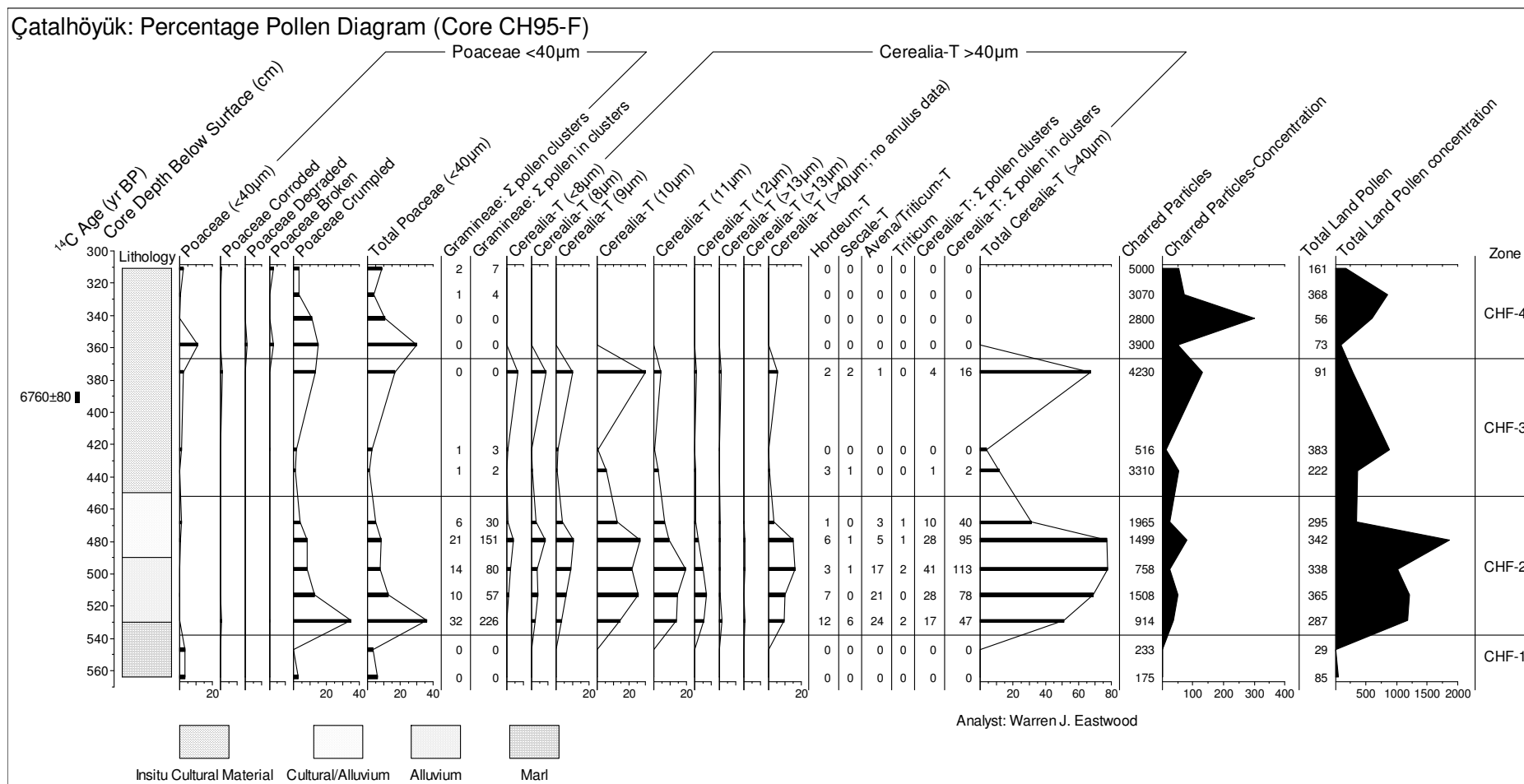


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1074 Figure 5

1075 **Figure 5.** Percentage pollen data for Poaceae (<40 μm) and Cerealia-type (>40 μm) for core CH95F from Çatalhöyük.



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1078 **Table 1.** Generalised sediment lithology for core CH99H. Munsell soil colours were ascertained while sediments were damp.

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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.

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1084 **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 (? <i>Triticum</i>)	6930 ± 40	5720-5900
CH99H 2	304-316	OxA-14695	Cereal chaff (? <i>Triticum</i>)	6800 ± 38	5630-5740
CH99H 3	317-325	OxA-14696	Cereal chaff (? <i>Triticum</i>)	6826 ± 36	5630-5770
CH99H 4	357-366	OxA-14779	Single Cerealia grain, <i>Hordeum</i>	7215 ± 50	6000-6220
CH99H 5	475-486	OxA-14780	Cereal chaff (? <i>Triticum</i>)	6950 ± 40	5730-5970
CH99H 6	475-486	OxA-14781	Nutshell, <i>Prunoides</i> or <i>Pistacia</i>	6995 ± 40	5770-5990
CH99H 7	535-545	OxA-14784	Cereal chaff and grain (? <i>Triticum</i>)	>51,900	n.a.
CH99H 8	558	OxA-14697	Single Cerealia grain	6983 ± 38	5750-5990

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1087 **Table 3.** Local pollen assemblage zone descriptions and interpretations for core CH99H from Çatalhöyük.
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Zone	Depth (cm)	Description	Interpretation
CH99H-3	406-300	Decrease in NAP to 85% driven by slight increases in <i>Pinus</i> ~12%, <i>Quercus</i> ~5%, decrease in Poaceae ~25%, sustained presence of <i>Aster</i> type ~10%, slight increase in <i>Artemisia</i> ~3%, <i>Centaurea solstitialis</i> ~10%, <i>Cirsium</i> ~2%, Lactucoideae ~15%, Caryophyllaceae ~20%, some <i>Plantago lanceolata</i> ~5%, abrupt and marked increase in Chenopodiaceae ~30%, and decrease of <i>Scabiosa argentea</i> ~3%. Aquatic alga <i>Pediastrum</i> ~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. <i>Pediastrum</i> suggest nutrient-enriched standing water.
CH99H-2	487-406	Decreasing but still high NAP (~90%) with Poaceae ~25-60%, Cerealia-type ~15%, Apiaceae ~6%, <i>Turgenia</i> ~10%, <i>Aster</i> type ~10%, <i>Centaurea solstitialis</i> ~6%, <i>Cirsium</i> ~3%, Lactucoideae ~20%, Caryophyllaceae ~35%, <i>Scabiosa argentea</i> ~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., <i>Turgenia</i>). 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%, <i>Aster</i> -type ~10%, Lactucoideae ~6%, <i>Scabiosa argentea</i> ~8%. <i>Typha angustifolia</i> -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.

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1091 **Table 4.** Summary of archaeobotanical plant remains data for core CH95F/G† and CH99H/J.
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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

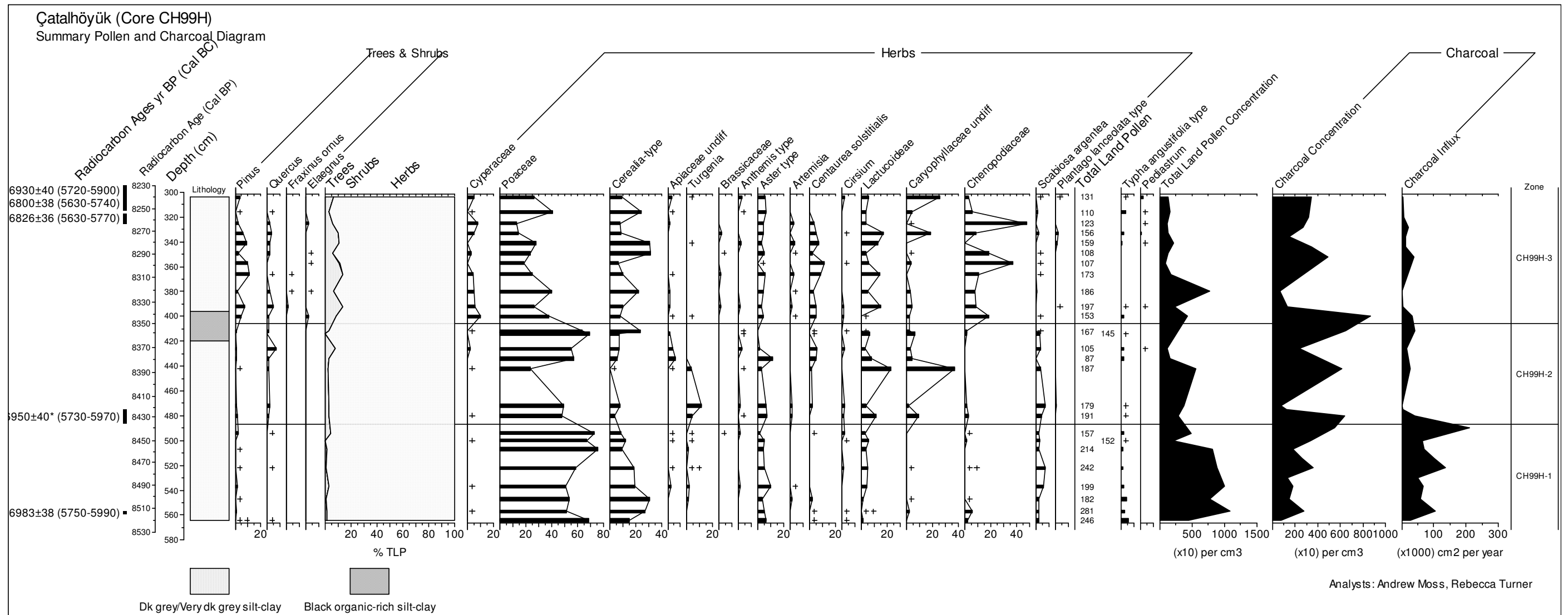
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1097 **Figure 3.** Summary percentage pollen and charcoal data for core CH99H from Çatalhöyük.

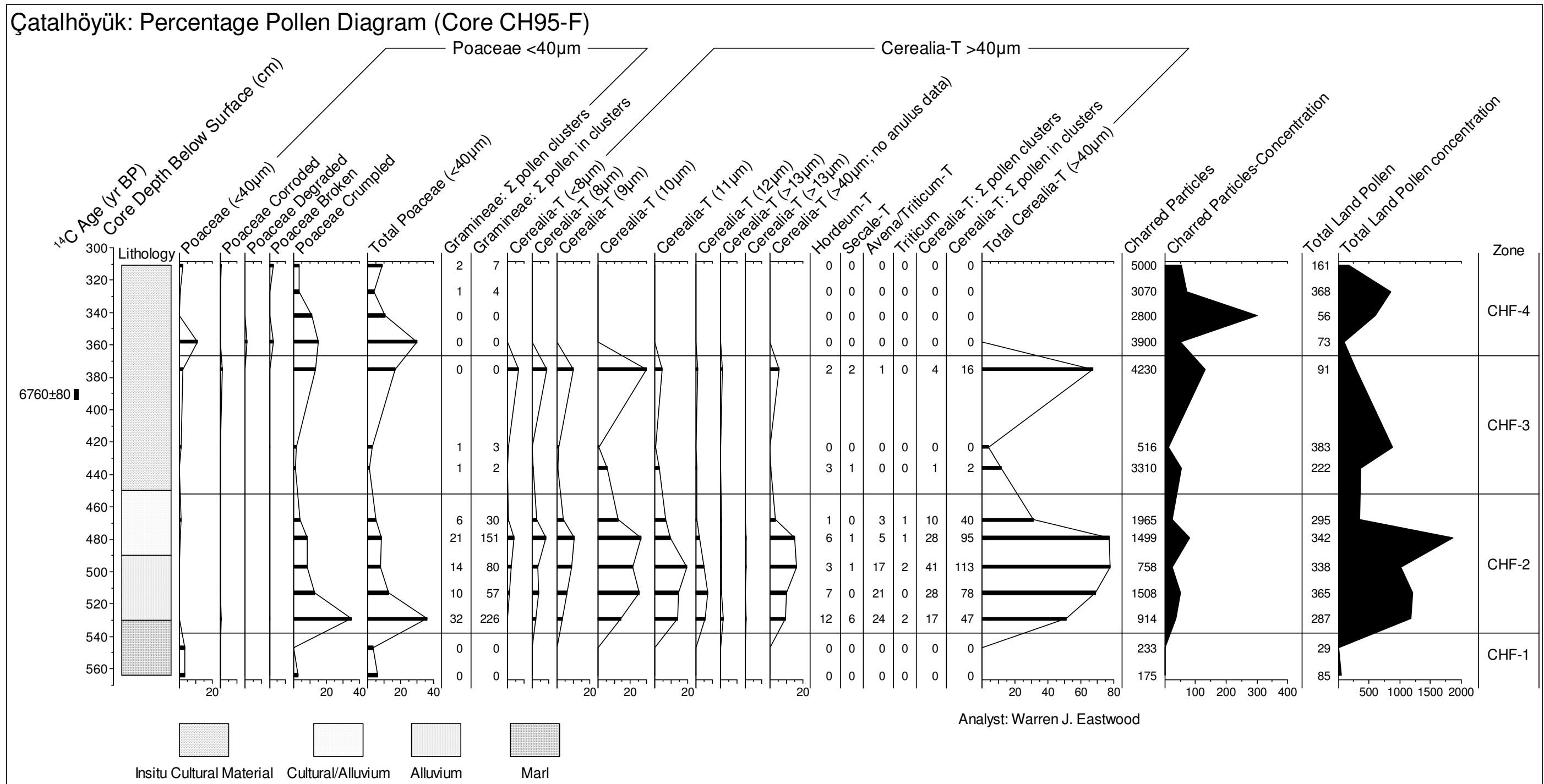


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1101 **Figure 5.** Percentage pollen data for Poaceae (<40 μm) and Cerealia-type (>40 μm) for core CH95F from Çatalhöyük.



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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 ($\Sigma 44$)	4,3 ($\Sigma 7$)		-	-
327	CHF-4	1000.11	10 ($\Sigma 10$)	4 ($\Sigma 4$)	3 ($\Sigma 3$)	-	-
342		999.96	12,14,4,20,20,20, 0, 20,8,10,20,20 ($\Sigma 168$)	-	3 ($\Sigma 3$)	-	-
358		999.80	20 ($\Sigma 20$)	-	-	-	-
375	CHF-3	999.63	4, 10 ($\Sigma 14$)	-	-	-	3,9,2,2 ($\Sigma 16$)
423		999.15	6 ($\Sigma 6$)	3 ($\Sigma 3$)	-	-	-
436		999.02	-	2 ($\Sigma 2$)	-	2 ($\Sigma 2$)	2 ($\Sigma 2$)
468		998.70	6,11,10 ($\Sigma 27$)	2,2,15,2,2,7 ($\Sigma 30$)	2 ($\Sigma 2$)	-	2,2,2,2,3,2,4,2 0,3 ($\Sigma 40$)
479		998.59	5,4,8,19,2 ($\Sigma 38$)	15,3,2,10,3,20, 3,4,6,4,4,3,15, 3,20,20,2,3,7, 2,2 ($\Sigma 151$)	-	-	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 ($\Sigma 95$)
497	CHF-2	998.41	3,10 ($\Sigma 13$)	12,3,2,5,5,2,8, 10,3,3,5,10,6,6 ($\Sigma 80$)	-	-	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 ($\Sigma 113$)
513		998.25	12,4 ($\Sigma 16$)	12,3,3,5,3,8,3, 3,12,4 ($\Sigma 57$)	6 ($\Sigma 6$)	-	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 ($\Sigma 78$)
529		998.09	4,3,2,2,6,2,3,4 ($\Sigma 26$)	5,7,4,2,3,5,2,2, 2,2,5,7,0,2,10, 7,20,5,2,3,6, 10,2,3,8,4,4,3, 2,8,4,10,4 ($\Sigma 226$)	-	-	2,3,3,2,2,2,2,2 ,2,2,9,3,3,3,2, 3,2 ($\Sigma 47$)
547	CHF-1	997.91	-	-	-	-	-
564		997.74	-	-	-	-	-

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