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Woodland vegetation history and human impacts in south-central Anatolia 16,000 – 6500 cal
BP: Anthracological results from five prehistoric sites in the Konya Plain

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1 Woodland vegetation history and human impacts in south-central Anatolia 16,000 – 2 6500 cal BP: Anthracological results from five prehistoric sites in the Konya Plain

3 4 **Abstract**

5 This article addresses the development and palaeoecological history of woodland vegetation
6 in the inland high-altitude plateaux of south-central Anatolia using wood charcoal remains
7 from the sites of Pınarbaşı, Boncuklu, Can Hasan III, Çatalhöyük East, and Çatalhöyük West
8 spanning the period ~16,000-6,500 cal BP. The anthracological evidence highlights the role
9 of *Juniperus*, *Amygdalus* and *Pistacia* as pioneer species during periods of woodland
10 expansion in south-central Anatolia when temperatures started to increase following the Last
11 Glacial Maximum (evidenced at Epipalaeolithic Pınarbaşı). During the early Holocene, three
12 habitation sites (Boncuklu, Can Hasan III, Pınarbaşı A) provide evidence for the presence of
13 diverse semi-arid and riparian woodland habitats in the Konya plain of south-central
14 Anatolia. The anthracological data provide insights into the establishment and spread of
15 regionally significant woodland vegetation types such as the oak and juniper-dominated
16 semi-arid steppe woodlands. It is argued that within the context of early Holocene climatic
17 amelioration, and the first sedentary communities practising agro-pastoral economies,
18 anthropogenic woodland habitats were established.

19 20 **Keywords**

21 Quaternary; palaeoecology; Anatolia; anthropogenic woodlands; anthracology; Southwest
22 Asia

23 24 **1. Introduction**

25 This paper investigates the vegetation history of south-central Anatolia through charcoal
26 analysis (including new and previously published assemblages) originating from five
27 prehistoric habitation sites in the Konya plain: Pınarbaşı, Boncuklu, Can Hasan III,
28 Çatalhöyük East and Çatalhöyük West. Together, these sites cover the timespan between the
29 late Pleistocene and the mid-Holocene (~16,000-6500 cal BP). In south-central Anatolia, this
30 period witnessed a series of environmental, socio-cultural and economic transformations that
31 framed the appearance of early settled life and the onset of plant cultivation and animal
32 herding (Asouti, 2006, Baird et al., 2013). These transformations occurred against a
33 background of abrupt climatic shifts that exerted significant impacts on water and vegetation
34 resources (Roberts, 2016). Until recently, in Southwest Asia little emphasis has been placed

35 on using the potential of archaeological charcoal data for reconstructing long-term diachronic
36 vegetation change, which (with few exceptions, e.g., Asouti et al., 2015, Willcox, 1974,
37 2002) remains the preserve of pollen analyses. However, when considering the poor
38 preservation, low spatio-temporal resolution and general rarity of uninterrupted pollen
39 sequences available from the semi-arid regions of inland Southwest Asia, multi-period
40 anthracological assemblages originating in radiometrically-dated and closely controlled
41 archaeological contexts emerge as an invaluable source of palaeovegetation data (Asouti and
42 Austin, 2005). These conditions are especially pertinent to researching the vegetation history
43 of prehistoric central Anatolia. Apart from deciduous *Quercus*, central Anatolian woodlands
44 are dominated by taxa that are either absent from, or under-represented in pollen sequences
45 (i.e. Rosaceae, Salicaceae, *Fraxinus*, Ulmaceae, *Juniperus*, *Pistacia*). Furthermore, wood
46 charcoal macrofossils representing the remains of prehistoric fuel wood use derived from
47 well-dated archaeological contexts, can provide direct evidence on the manner and intensity
48 of anthropogenic impacts on woodlands, and the environmental conditions affecting tree
49 growth (Kabukcu, 2017).

50 The paper explores the evolution of the regional woodland vegetation starting from
51 the earliest known periods of woodland vegetation expansion in south-central Anatolia during
52 ~16,000-14,000 cal BP (evidenced in Epipalaeolithic Pınarbaşı) which provide important
53 insights into the nature of early woodland formations on the south-central Anatolian plateau.
54 Early to mid-Holocene anthracological assemblages from the Neolithic sites of Pınarbaşı A
55 and B, Boncuklu, Can Hasan III and Çatalhöyük East, the Chalcolithic mound of Çatalhöyük
56 West, and Chalcolithic to Early Bronze Age phases of Pınarbaşı B, cover the timespan
57 between ~10,700-6500 cal BP. They provide evidence for the establishment of diverse semi-
58 arid and wet/riparian woodland habitats in the Konya plain and its environs during this
59 period, alongside the development of increasingly specialised fuel economies at each site. It
60 is argued that against the background of early Holocene climatic amelioration anthropogenic
61 woodland habitats became more prevalent through time. This pattern reached a peak during
62 the Neolithic occupation of Çatalhöyük East with the intensive management of local and
63 more distant woodlands for fuel, timber and fodder. Furthermore, post-Neolithic woodland
64 composition on the Konya plain points to a remarkable degree of ecological resilience of the
65 regional woodlands in the context of heightened mid-Holocene climatic fluctuations. In
66 addition to diachronic taxon frequencies, dendroecological evidence of tree growth
67 conditions, seasonality of rainfall, and vegetation successional dynamics are also considered.

68 The paper concludes by placing the Konya plain anthracological record in the wider context
69 of the late Pleistocene to mid-Holocene vegetation history of Southwest Asia through detailed
70 comparisons to published anthracological archives from other regions of inland Southwest
71 Asia.

72

73 **2. The study area: climate, soils and vegetation**

74 South-central Anatolia comprises the Konya basin, a high-altitude (~1000 m a.s.l.) inland
75 plateau and the surrounding foothills of the north-facing slopes of the Taurus range (Fig. 1).
76 The basin floor, formed by the drying-up of a large late Pleistocene palaeolake, contains
77 sediments accumulated during the Tertiary and Quaternary sourced from the surrounding
78 uplands, most of which consist of Palaeozoic and Upper Cretaceous limestone. At lower
79 elevations, especially on the northern outskirts of the Karaman plain, the original lake bed
80 marl is exposed. From the southern upland zone (the Taurus and anti-Taurus foothills) several
81 streams and rivers enter the basin depositing alluvial sediments in the shape of wide fans such
82 as the Çarşamba and May fans near Çumra, the Meram and Sille fans, on which the modern
83 city of Konya is built, and the Selerecki fan near Karaman (De Ridder 1965, De Meester
84 1970, Bozyiğit and Güngör 2011).

85 The region is characterised by a markedly continental climate, with cold winters and
86 hot and dry summers giving rise to semi-arid steppe vegetation that has been continuously
87 impacted by millennia of human activities, especially pastoral production (Firincioğlu et al.
88 2007). Precipitation on the Konya plain ranges from ~270-350 mm/p.a. with the majority of it
89 falling in winter and early spring (Fig. 2). The strong seasonal gradients of rainfall (especially
90 summer aridity) and temperature limit the growth season of plants, thus dictating to a great
91 extent the ecology and distribution of the main vegetation types that are found in the Konya
92 Basin today. The predominance of treeless steppe on the plain itself largely reflects its very
93 low annual rainfall, which has a severe effect on plant growth; ~150mm of annual
94 precipitation are received during the 220 days out of a year with temperatures >8°C (i.e., the
95 necessary requirements for successful plant growth). There is a strong orographic gradient in
96 precipitation values, which increase gradually with elevation to reach levels between ~500-
97 650 mm/p.a. near Hadim, Çat and Bozkır on the north-facing Taurus foothills. At Akşehir
98 and Seydişehir near the Anatolian Lake District, on the southwestern outskirts of the Konya

99 plain catchment area, mean rainfall values can be as high as ~700 mm/p.a. (Fig. 2, Çetik
100 1985: 59, Devlet Meteoroloji İşleri 2011).

101 South-central Anatolia is located in the biogeographic region referred to as Irano-Turanian by
102 Davis (1965-1988) and Çetik (1985), coinciding to some extent with the Irano-Anatolian
103 classification of Zohary (1973). At lower altitudes (and areas with lower annual precipitation)
104 vegetation comprises predominantly herb and grass steppe, which has been heavily impacted
105 by intensive agro-pastoral activity. Towards the foothills of the north-facing slopes of the
106 Taurus mountain range steppe vegetation is replaced by a belt of semi-arid deciduous and
107 mixed deciduous-coniferous woodlands (Asouti and Kabukcu, 2014). Deciduous *Quercus*-
108 dominated woodlands are found today in areas with >350mm annual precipitation, whereas
109 *Quercus-Juniperus* woodlands are found at higher altitudes and isohyets. At present,
110 members of the Rosaceae and the Anacardiaceae families (e.g., *Pistacia*, *Rhus coriaria*)
111 rarely form dominant components of the regional woodland vegetation. *Amygdalus*,
112 *Crataegus*, *Rosa canina*, *Prunus* spp. and *Pyrus* are commonly found as isolated trees or
113 groups of trees in the lowland steppes and the edges of arable, or in association with *Quercus*
114 and *Quercus-Juniperus* woodlands on the foothills. Rosaceae-dominated woodlands are very
115 rarely observed today; when they do, they mostly comprise stunted and/or spiny individuals
116 likely the result of severe anthropogenic impacts (including pastoral production).

117 The ecological tolerances and the extent of Rosaceae and *Pistacia* woodlands (occasionally
118 accompanied by *Celtis*) are very important from an archaeobotanical point of view, as they
119 form an important element of edible fruit and nut gathering resource base in central Anatolia
120 (Woldring and Cappers 2001, Fairbairn et al. 2005). At present, two of these
121 archaeobotanically important taxa, *Pistacia* and *Celtis*, have a rather limited range in central
122 Anatolia. Çetik (1985: 254, 104) stresses that *Pistacia* and also *Celtis* can persist near lakes,
123 riverbanks, streams and sheltered valleys by taking advantage of higher moisture in such
124 microclimates and local hydrological regimes. Asouti and Kabukcu (2014) have also reported
125 the presence of *Pistacia* and *Celtis* (alongside other moisture-dependent taxa such as *Ulmus*,
126 *Fraxinus* and Salicaceae) in similar habitats in Cappadocia, and of *Celtis* in secondary
127 anthropogenic habitats (e.g., arable boundaries, gardens, etc.) These authors have thus
128 hypothesised that the main causes of the currently limited distribution of *Pistacia* and *Celtis*
129 in central Anatolia are increasing climatic aridity and their progressive disappearance from
130 the species-poor, heavily managed riparian woodlands (Asouti and Kabukcu, 2014).

131 Nowadays most riparian woodlands in Anatolia comprise mostly planted and heavily
132 managed poplar and/or willow species. No significant expanses of old growth riparian
133 woodlands persist anywhere in central Anatolia due to their destruction by agricultural
134 activities and expanding urban and rural settlement. *Salix* (willow), *Populus* (poplar), *Acer*
135 (maple), *Fraxinus* (ash), *Ulmus* (elm) and *Lonicera* (honeysuckle) have all been reported
136 from river valley woodlands and protected wetlands (Çetik, 1985: 104, 293; Asouti and
137 Kabukcu, 2014). Such woodlands growing on alluvial soils around water bodies, along rivers
138 and streams, and in humid areas may also contain *Celtis*, *Pistacia* and *Crataegus* (Çetik 1985:
139 104, Asouti and Kabukcu 2014).

140

141 **3. The archaeological sites**

142 All the archaeological sites from which materials were studied are located on the Konya
143 plain: Çatalhöyük and Boncuklu on the Çarşamba fan, within ~9.5 km of each other;
144 Pınarbaşı on the foothills of Karadağ near the centre of the plain c. 25km SE of Çatalhöyük
145 and Can Hasan III on the Selerecki fan near Karaman (see Fig. 1). Excavations of the multi-
146 period open-air site and the rock shelters of Pınarbaşı have revealed four periods of
147 occupation: Epipalaeolithic (16-14 ka cal. BP), aceramic Neolithic (10.7-10 ka cal. BP), late
148 Neolithic (8.5-8 ka cal. BP) and Chalcolithic (6th millennium cal. BP) (Watkins 1996, Baird
149 et al 2013, Asouti 2003, Fairbairn et al. 2014). The aceramic Neolithic habitation at Boncuklu
150 (10.4-9.4 ka cal. BP) consists of a small mound and displays clear cultural affinities with the
151 11th millennium cal. BP occupation at Pınarbaşı and with the aceramic phases at Can Hasan
152 III and Çatalhöyük East (Baird et al. 2012). The aceramic Neolithic occupation of Can Hasan
153 III was uncovered in trench 49L and is dated to 9.6-8.4 ka cal. BP (French et al. 1972; for the
154 re-evaluated radiocarbon dates see Thissen, 2002). Neolithic Çatalhöyük (East mound) is one
155 of the largest mounds dating to the period in Southwest Asia (~13 ha) and was occupied
156 between ~9.1-8 ka cal BP (Bayliss et al., 2015). Excavations at the site by James Mellaart in
157 the 1960s (1967) and Ian Hodder since 1993 (Hodder, 1996) have identified several
158 occupation phases: 12 levels (I-XII) as identified by Mellaart's excavations, and 14 levels (T-
159 G) in the South Area, 5 levels (J-F) in the North Area and a further 7 levels in the Team
160 Poznan (TP) excavation area (M-S) identified during by the Hodder excavations (Hodder
161 2013). The Çatalhöyük East mound anthracological assemblage presented in this paper has
162 derived solely from the South Area and TP excavation areas and covers the timespan between

163 9.1-8 ka cal. BP (see Table 1). The Chalcolithic Çatalhöyük West mound lies just 300 metres
164 to the west of the Neolithic east mound and dates to ~8-7.5 ka cal. BP (Biehl et al. 2012).

165

166 **4. The Palaeoecological setting**

167 Late Quaternary climatic records in Southwest Asia indicate that there was a degree of
168 regional correlation with the global trends in temperatures and precipitation (Kallel et al.
169 1997, Ariztegui et al. 2000, Rohling et al. 2002, Schilman et al. 2002). Climatic conditions
170 shifted from cold and arid to warmer and wetter with the onset of the GI-1 (Glacial
171 Interstadial 1, Bølling-Allerød). This warming and wetting trend was later interrupted by the
172 abrupt cooling and arid GS-1 (Glacial Stadial 1, Younger Dryas) oscillation, which is
173 reflected in various terrestrial and marine records (Bottema 1991, Rossignol-Strick 1995,
174 Bar-Matthews et al. 2003, Robinson et al. 2006, Dean et al. 2015). The beginning of the
175 Holocene (~11,5 ka cal. BP) marked a sharp increase in precipitation and temperatures across
176 Southwest Asia (Bar-Matthews et al. 1997, 1999, Roberts et al. 2001, 2008, Wick et al. 2003,
177 Sbaffi et al. 2004, Ziegler et al. 2010, Stevens et al. 2012, Roberts et al. 2016).

178 During GS-1 the Eski Acıgöl crater lake records (Cappadocia, central Anatolia)
179 indicate cold and dry climatic conditions (positive $\delta^{18}\text{O}$ values); at the onset of the Holocene
180 there was a rapid shift to negative $\delta^{18}\text{O}$ values, suggesting that the temperatures rose sharply,
181 along with higher precipitation (Roberts et al. 2001). According to Roberts et al (2008) these
182 values mark the wettest phases in central Anatolia, which lasted for nearly three millennia
183 (~12-9 ka cal. BP). However, similar conditions at lake Van, in eastern Anatolia, were not
184 reached until ~8-7 ka cal. BP (Wick et al. 2003, Litt et al. 2014). Recent evidence from Nar
185 lake, also in Cappadocia, point to extended periods of aridity centred around the 9.3ka BP
186 and 8.2ka BP northern hemisphere cold/arid events (Dean et al. 2015). In inland Southwest
187 Asia, including central and eastern Anatolia, tree/shrub pollen sums remained very low by
188 comparison to herbaceous pollen (steppe and/or herbaceous pollen) throughout the late
189 Pleistocene (Roberts et al. 1999, Pickarski et al. 2015, Litt et al. 2009, Djamali et al. 2010).
190 The earliest phases of the central Anatolian palynological sequences at Eski Acıgöl and Nar
191 (GS-1) correlate well with the Lake Van sequence, showing high values of *Artemisia*-
192 *Chenopodiaceae* pollen (Roberts et al. 2001 and 2016). In both central and eastern Anatolia,
193 *Artemisia*-dominated steppe was rapidly replaced by grassland vegetation at the onset of the
194 Holocene. For nearly 2000 years, the Eski Acıgöl pollen sequence registers low levels of

195 deciduous *Quercus*, *Pistacia*, and *Juniperus*. The first AP maximum is not observed until ~8
196 ka cal. BP (Roberts et al. 2001, Woldring and Bottema 2001/2). At Nar (Roberts et al. 2016),
197 the earliest part of the Holocene registers a more pronounced rate of *Pistacia* spread (phase
198 3), with a subsequent gradual increase in deciduous *Quercus* pollen (phase 4).

199 The Akgöl Adabağ pollen sequence (Konya plain) covers the period between 13-9 ka
200 cal. BP (Bottema and Woldring 1984; see also Turner et al. 2010). This sequence is
201 interrupted at ~9.5 ka cal. BP due to a hiatus in lake sedimentation as a result of the drying up
202 of the lake and paleosol formation (cf. Eastwood et al. 1999, 2007, Roberts et al. 1999,
203 Charles et al. 2014). The early part of the Akgöl sequence confirms the trends observed at
204 Eski Acıgöl and Van: *Artemisia*-Chenopodiaceae steppe prevailed in the Konya region until
205 about 12.5 ka cal. BP, followed by a rapid increase in grass cover. A gradual retreat of
206 grasslands from ~9.5 ka cal. BP is indicated by the reduction of micro-charcoal influx at both
207 the Eski Acıgöl and the Akgöl Adabağ sequences, which has been attributed to the
208 suppression of grass fires due to lower fuel loads in the environment (Turner et al. 2010).
209 Woldring and Bottema (2001/2) interpret the grass pollen decline at Eski Acıgöl as the result
210 of increasing aridity due to a concurrent increase in *Artemisia* pollen especially during Phase
211 4 of the Eski Acıgöl pollen sequence. However, they also note that there is an increase, at the
212 same time, in the values of spiny and unpalatable taxa (*Centaurea*, *Noaea*, *Cirsium* and
213 *Matricaria*). The co-occurrence of *Artemisia*, with these taxa suggests increasing grazing
214 pressure on grassland habitats, possibly resulting from more extensive pastoral activities in
215 the landscape (Asouti and Kabukcu 2014). Deciduous oak continued its expansion in central
216 Anatolia until ~6.5-6 ka cal. BP, significant negative impacts on woodland vegetation can be
217 detected for the first time between 4.5-4 ka cal. BP (cf. Roberts et al. 2001, Woldring and
218 Bottema 2001/2). At Lake Van in eastern Anatolia, the onset of large-scale anthropogenic
219 deforestation dates even later at ~2.5k cal. BP (Wick et al. 2003, Litt et al. 2009).

220

221 **5. Materials and methods**

222 Archaeological sample selection for anthracological analysis was carried out following the
223 protocols set out by Chabal (1992), Chabal et al. (1999) and Théry-Parisot et al. (2010). The
224 main aim was to reconstruct fuelwood use and collection strategies and obtain a diachronic
225 view of changes in woodland vegetation composition and use. Thus sample selection focused
226 on dispersed fuel waste deposits from each site (termed '*charbon de bois dispersés*' cf.

227 Chabal 1992, Chabal et al. 1999; or ‘synthetic deposits’ cf. Théry-Parisot et al. 2010). These
228 deposits contained long-term accumulations of fuel waste, predominantly retrieved through
229 water flotation from midden and midden-like contexts, also including in some cases infill
230 accumulated in abandoned buildings. Wood charcoal specimens from each archaeological
231 unit of excavation were sub-sampled using a rarefaction curve, as recommended by Chabal et
232 al. 1999. A range of dispersed contexts (e.g., middens, building infills) were selected, with
233 the aim of producing a representative sequence covering all phases of occupation at each site.

234 All examined wood charcoal fragments derived from the > 4mm and > 2mm dry-
235 sieved fractions of the flotation samples. At Çatalhöyük sub-sampling focused on the >4mm
236 fraction; at Boncuklu and Pınarbaşı due to the absence (or very low numbers) of fragments
237 >4mm, analysis focused on the >2mm fraction. Charcoal specimens were fractured with a
238 razor blade in order to produce a fresh section in the three anatomical planes (transverse,
239 radial longitudinal and tangential longitudinal). Each section was examined under anepi-
240 illuminating brightfield/darkfield metallurgical microscope at magnifications of x50, x100,
241 x200, x400 and x500. Scanning Electron Microscope imaging was applied to select
242 specimens. Identifications (to species, genus or family level) were made by using published
243 identification manuals, dichotomous wood anatomy keys and wood anatomical descriptions
244 of specimens from Southwest Asia and Europe (Western 1971, Fahn et al. 1986,
245 Schweingruber 1990, Greguss 1955, 1959, Akkemik and Yaman 2012, Crivallero and
246 Schweingruber 2013). In addition, carbonised remains were compared to the modern wood
247 reference charcoal collection housed in the Archaeobotany Laboratory of the University of
248 Liverpool.

249 The Can Hasan III samples (including both wood and non-wood carbonised
250 macroremains) were retrieved in the 1960s by Gordon Hillman (French et al. 1972) and are
251 currently stored in the British Institute in Ankara Archaeobotany Laboratory. Previous
252 analyses by Willcox (1977, 1978, 1979, see also Willcox 1991, 1992) concentrated on
253 charcoal fragments collected from dry sieving. In these studies quantification by fragment
254 counts was not applied, while taxon ubiquity (presence per sample) has been only partially
255 reported. For the purpose of the present study all >2mm wood charcoal remains were sorted
256 from the flotation samples stored in Ankara, in order to produce a more representative dataset
257 for comparison with those derived from Pınarbaşı, Boncuklu and Çatalhöyük.

258 For each charcoal sub-sample, individual taxon counts were recorded, in addition to
259 counts of indeterminate fragments and taxa identified with some level of uncertainty (i.e.,
260 those identified as cf.). Samples from dispersed deposits are presented according to
261 stratigraphic phasing in order to construct the anthracological sequences; absolute fragment
262 counts for each taxon were converted to percentage fragment counts, calculated on the basis
263 of the total number of identified charcoal fragments (after excluding indeterminate fragment
264 counts and cf. identifications from the charcoal sums). Per-phase percentage fragment counts
265 were used to produce anthracological diagrams using the R statistical software (version 3.3.3,
266 package ‘*rioja*’, function ‘*strat.plot*’). The anthracological diagrams include previously
267 unpublished datasets produced by Kabukcu (2015); they also incorporate other previously
268 published datasets from the Konya plain (Asouti 2002, 2003, 2005, 2013).

269 Multivariate analyses (Correspondence Analysis; CA) were applied to per-sample
270 charcoal taxon counts from all sites, in order to explore further temporal and ecological
271 patterning in the datasets. For the purpose of multivariate analyses only contexts containing
272 >25 identified fragments were considered, in order to limit redundancy and noise in the
273 dataset. Only positive identifications (to genus, species or family level) were included (cf.
274 identifications were excluded from the data matrix). CA has been applied to various
275 archaeological and archaeobotanical datasets (cf. Shennan 1997, Colledge 2001, Baxter
276 2003) with the aim of detecting patterning in large and complex sample populations. As one
277 of the most widely used ordination techniques, CA allows for a 2-dimensional evaluation of
278 complex patterning in a dataset by means of geometric representation along two axes. In the
279 present study, CA was applied on the taxon count matrix using R (version 3.3.3, packages
280 ‘*ca*’ and ‘*FactoMineR*’). In the resulting plots, individuals (i.e., charcoal samples) close to the
281 origin (the intersection of the two axes plotted) reflect minimal variability, hence *average*
282 composition. Separation on either side of axis 1 or 2 reflects dissimilarity in the samples and
283 variables (i.e., taxa) included in the matrix (see also Wildi 2013: 43-47).

284

285 **6. The anthracological datasets**

286 This study provides results from 214 samples totalling 16,331 identified fragments including
287 previously unpublished datasets analysed by Kabukcu (2015) and published datasets analysed

288 by Asouti (2002, 2003, 2005, 2013) that have been assembled using the same sample
289 selection and sub-sampling methodologies (see above Materials and Methods section).

290 Figure 3 presents the anthracological sequence from all sampled Pınarbaşı sites
291 (including Site B-Epipalaeolithic, Site A-Early (aceramic) Neolithic, and Site B-Late
292 Neolithic & Chalcolithic phases). The Pınarbaşı anthracological diagram demonstrates clearly
293 the predominance of *Amygdalus* wood as a source of fuel throughout the prehistoric sequence
294 sampled at Pınarbaşı. Notably, in the earliest known phase of occupation, corresponding to
295 the Epipaleolithic period, *Juniperus* is also regularly present mostly in the form of small
296 branches and twigs. During the Holocene, *Juniperus* was not used and it might have become
297 very rare in the local vegetation. However it should be noted here that, although all the
298 samples available from the Epipalaeolithic phases were analysed (including both hand-picked
299 and flotation samples and all fragments within them) the Epipalaeolithic sample population is
300 nevertheless small. Consequently this may have impacted the ecological representativeness of
301 the anthracological results. For example, the low number of samples available from the
302 earliest habitation phase, alongside the fact that a majority of the *Juniperus* specimens from
303 this phase derived from twigs/branch wood may possibly indicate a case of over-
304 representation of this taxon.

305 Overall the available evidence suggests that a diverse *Pistacia*-Rosaceae-dominated
306 woodland vegetation (including *Amygdalus*, *Prunus* and Maloideae) prevailed in the Karadağ
307 foothill zone throughout the sampled prehistoric sequence at Pınarbaşı. Some riparian
308 woodland taxa (Salicaceae, Ulmaceae, *Tamarix*) are also present with very low frequencies
309 (especially in the better preserved charcoal samples of the Epipaleolithic, Late Neolithic and
310 Chalcolithic phases) alongside some woody herbs and shrubs characteristic of drier habitats
311 (e.g., *Artemisia*, Chenopodiaceae, Leguminosae) (see Table 2). Deciduous *Quercus* is also
312 found only in the early-mid Holocene deposits at the site, again in low numbers. Notably,
313 *Amygdalus* and *Pistacia*, the two most prominent taxa of the sampled sequence at Pınarbaşı,
314 are also present in all anthracological assemblages examined from other prehistoric sites in
315 the Konya plain, irrespective of time period, although never as abundant and ubiquitous as in
316 the Pınarbaşı anthracological assemblage.

317 Figure 4 presents the anthracological sequence derived from all sites except Pınarbaşı,
318 comprising the sampled early-mid Holocene prehistoric sites of the Konya plain. As the
319 anthracological diagram demonstrates, in the earliest sampled phases at Boncuklu (trenches

320 K, H, N) and in the aceramic Neolithic occupation represented by Can Hasan III (treated as a
321 single phase), *Amygdalus* and *Pistacia* contribute to charcoal sample composition, although
322 in much lower frequencies when compared to the Pınarbaşı phases. Instead, the wetland and
323 riparian woody taxa were dominant. In the earlier phases (i.e., the 11th and 10th millennia cal
324 BP represented by the assemblages of Boncuklu, Can Hasan III and Çatalhöyük South G) the
325 majority of wood fuel originated in riparian and wet woodland habitats dominated by
326 Salicaceae (Boncuklu) and Ulmaceae including both *Celtis*, *Ulmus* and undifferentiated
327 Ulmaceae (Can Hasan III and parts of the Çatalhöyük early phases). Overall, a decrease in
328 the frequencies of riparian taxa is observed at Çatalhöyük in the transition from South G to
329 G–H, although their relative abundance and ubiquity remained fairly stable throughout the
330 later part of the Çatalhöyük sequence. Towards the end of the Çatalhöyük East South Area
331 sequence (i.e., in South Q, R, S, T) Ulmaceae and Salicaceae become less abundant, while the
332 frequency of another riparian taxon, *Fraxinus*, increase. In the Çatalhöyük East TP phase and
333 the Chalcolithic Çatalhöyük West occupation the frequencies of Ulmaceae and Salicaceae
334 increase again, while those of *Fraxinus* decrease.

335 Deciduous *Quercus* is present in all early-mid Holocene phases sampled from the
336 Konya plain, with the notable exception of Pınarbaşı (Figures 3, 4). The earliest phases of the
337 Çatalhöyük sequence (South G) and the end of the Boncuklu sequence (M) reflect the onset
338 of a gradual increase in the frequency of deciduous *Quercus* (Figure 4). While *Quercus*
339 values represent 3% of charcoal sample composition in South G, a rapid increase is observed
340 during the final phase of South G and in South H up to 53%. This increase is also matched by
341 a concurrent increase in *Quercus* ubiquity scores (see Table 2). From South G–H, *Quercus*
342 becomes a dominant element of the Çatalhöyük anthracological assemblage until the end of
343 South P, accounting for ~50% of charcoal sample composition. In the transition between
344 South P–Q, deciduous *Quercus* values drop from 43% to 27% and continue to decrease
345 gradually in South R, S, T and in the TP and West mound assemblages. In these final phases
346 of the Çatalhöyük sequence *Juniperus* becomes more abundant and ubiquitous.

347

348 As mentioned already, *Juniperus* is found in noteworthy proportions in the Pınarbaşı
349 Epipalaeolithic assemblage. *Juniperus* is present in the anthracological assemblages of all
350 Holocene sampled sites in the Konya plain (with the exception of Boncuklu trench H and the
351 Pınarbaşı Chalcolithic phases); however it only becomes a prominent component at
352 Çatalhöyük, in phases post-dating the mid-9th millennium cal BP. Until South K, *Juniperus*

353 accounts for <5% of charcoal sample composition. Its apparent increase in South O to 20%
354 may represent, at least in part, an artefact of the low number of samples available for analysis
355 from this phase, given also that its frequency decreases again in South P. From South P-Q,
356 *Juniperus* abundance values increase to 34% and reach their peak in South S (67%). In South
357 T, *Juniperus* abundance values and ubiquity scores drop once more and remain fairly low
358 during the TP phase. *Juniperus* becomes once more common in the West mound Chalcolithic
359 charcoal samples, accounting for 42% of the total charcoal count and being present in all
360 samples (see also Table 2).

361 In order to gain a better understanding of patterns of taxon representation through
362 time and investigate possible patterns of co-variation in taxon fluctuations between different
363 sites, per-sample charcoal taxon counts from all sites were explored further through
364 Correspondence Analysis (CA) performed on a data matrix comprising 178 contexts derived
365 from dispersed deposits from all sampled sites and phases. In the resulting CA biplot the first
366 two dimensions account for 49% of the observed variation (Figure 5, Supplementary Table
367 1). A great share of the contribution to variation in dimension 1 is by *Amygdalus*, *Quercus*
368 and *Pistacia* along the axis that separates the majority of the Pınarbaşı samples (all phases)
369 from the Çatalhöyük and Boncuklu samples. A small number of Pınarbaşı Epipalaeolithic
370 samples cluster more closely with the later Çatalhöyük samples, which is mostly due to the
371 prominence of *Juniperus* in these samples. The Can Hasan III samples are spread along
372 dimension 1, between the *Amygdalus*-dominated Pınarbaşı samples and the Ulmaceae-
373 dominated Çatalhöyük samples. The majority of the early and middle Çatalhöyük phases
374 (South G (early)-P) are clustered at the bottom right-hand side of the plot with *Quercus*,
375 Ulmaceae and Salicaceae. On the opposite side of axis 2, the late phases of Çatalhöyük East
376 (South Q-T), and the TP and Çatalhöyük West samples are distributed. On the whole, it
377 appears that temporal patterning in the dataset is fairly well manifested, accounting for most
378 of the variation observed in charcoal taxon counts.

379 There is very little evidence for any ecological patterning and/or separation along
380 purely ecological gradients in the dataset. For example, in the portion of the plot containing
381 Ulmaceae and Salicaceae (characteristic of riparian habitats) *Artemisia* (associated with dry
382 steppe vegetation) and deciduous *Quercus* (a semi-arid to moist steppe woodland species) are
383 also represented. Similarly *Juniperus* (a typically montane and mid-elevation slope species)
384 appears to be more closely associated with *Fraxinus*, a riparian indicator. In addition, taxa
385 more characteristic of semi-arid steppe woodlands such as *Amygdalus* and *Pistacia* are

386 represented on the same part of the axis as *Tamarix*, a halophytic taxon typical of wetland
387 edges. This situation is likely to reflect long-lasting wood fuel selection practices in the
388 Konya plain, commonly including a mixture of species derived from different ecological
389 catchments, including proximate steppe, semi-arid and riparian habitats, as well as and more
390 distant catchments in the hills and mid-elevation slopes surrounding the plain. These
391 observations appear to be corroborated when considering sample-by-sample data not only
392 from dispersed deposits containing fuel waste accumulated over long periods of time, but also
393 short-lived fire features containing “primary” burning events (e.g., external fire spots,
394 domestic hearths, ovens, etc.) which are also characterised by diverse charcoal assemblages
395 comprising taxa belonging to different ecological catchments (Kabukcu 2015, forthcoming).

396

397 7. Discussion

398 The anthracological results presented in this paper provide a reconstruction of woodland use
399 and tree growth conditions in prehistoric south-central Anatolia. The presence of *Juniperus*
400 and *Amygdalus* in the region already from the end of the GS-2 is evidenced by the
401 anthracological assemblage of Epipalaeolithic Pınarbaşı, which provides the earliest
402 palaeovegetation record for both taxa currently available from south-central Anatolia. The
403 Pınarbaşı evidence indicates that pioneer woodland communities dominated by *Juniperus* and
404 *Amygdalus* were already established on the foothills of Karadağ before and during the
405 transition to the GI-1, under rather unfavourable environmental conditions. The frequency of
406 *Juniperus* increases from the base of the sampled sequence alongside that of *Amygdalus*. This
407 observation provides additional support for an interpretation suggesting that both taxa were
408 early colonisers of the foothill zone surrounding the Konya plain during the transition from
409 GS-2 (21.2-14.7 ka cal. BP) to the GI-1 (14.7-12.9 ka cal. BP) likely forming very open, low-
410 density stands. *Juniperus* charcoals from Epipalaeolithic Pınarbaşı were found predominantly
411 in the form of twigs and small branch wood that bore abundant signs of traumatic canals and
412 deformed tracheids (see Fig. 6). *Juniperus* does not form resin canals under normal growth
413 conditions. However, the occurrence of such features is documented by wood anatomical
414 studies of *Juniperus* trees/shrubs growing under conditions of ecological stress and/or
415 subjected to the impacts of destructive agents (such as frost damage, insect and fungal attack,
416 etc.; see Schweingruber 2007: 185, 195). The occurrence of such features in the Pınarbaşı

417 Epipalaeolithic specimens therefore points to the possibility that *Juniperus* grew primarily in
418 the form of low, stunted shrubs.

419 Taking into account the potential distribution of woodland vegetation zones in the
420 Konya plain and its surrounding upland areas, as indicated by the available palaeoecological
421 evidence and present-day vegetation, and the available anthracological evidence, a clear
422 temporal trend can be detected in the exploitation of the different woodland zones during the
423 Holocene: woodland exploitation during the earlier phases (11th-10th millennia cal BP:
424 Boncuklu, Can Hasan III, Çatalhöyük East South G (early)) focused on riparian and wet
425 woodland habitats located around habitation sites; by contrast, later phases (9th-7th millennia
426 cal BP: Çatalhöyük South G (late)–H through to the end of South T; Çatalhöyük West
427 mound) indicate the routine exploitation of more distant vegetation zones (dominated by
428 *Quercus* and *Juniperus*). Riparian and steppe woodland habitats located around habitation
429 sites continue to be used throughout this period, as indicated by the ubiquity of Ulmaceae and
430 Salicaceae throughout the Çatalhöyük sequence, alongside *Pistacia*, *Amygdalus*, Maloideae
431 and *Prunus*.

432 In the off-site pollen records (Eski Acıgöl, Akgöl and Nar lake) the phases of
433 occupation dating to the first two millennia of the Holocene (Çatalhöyük South G (early),
434 Boncuklu, Can Hasan III) appear as periods of low woodland density, although insect-
435 pollinated taxa (Rosaceae, Maloideae) and poor/sporadic pollen producers (*Pistacia*,
436 *Juniperus*, *Celtis*) are under-represented or absent from the pollen spectra. The onset of
437 increasing values for *Quercus* pollen (dated at ~9000 cal. BP in the Eski Acıgöl core) is more
438 or less synchronous with the sharp increase in *Quercus* charcoal frequency and ubiquity
439 values at Çatalhöyük South G (late)–H. Despite the continuously increasing *Quercus* pollen
440 values, after South P *Quercus* is substituted by *Juniperus* as the dominant charcoal taxon.
441 After South Q-R-S, *Juniperus* charcoal values decline. During TP the evidence points to
442 more intensive use of local riparian woodlands with Ulmaceae dominating charcoal sample
443 composition. This pattern is reversed during the Chalcolithic West mound occupation, which
444 points to the return of a mixed strategy of exploiting distant/semi-arid (*Juniperus*) and
445 local/riparian (Ulmaceae, Salicaceae) woodlands. The abrupt shifts in the representation of
446 *Juniperus* during the latest part of the Çatalhöyük sequence (South T-TP and the West
447 mound) is interpreted here as reflecting temporal changes in fuelwood preferences rather than
448 changes in wood availability due to clearance and/or deforestation. Further support for this
449 interpretation comes from the continued increase in tree/shrub pollen values (mostly

450 deciduous *Quercus* pollen) indicating woodland expansion across central Anatolia during the
451 period coinciding with the late Neolithic and Chalcolithic occupation at Çatalhöyük, and the
452 subsequent AP maxima dated to ~6000 cal. BP (Roberts et al. 2001).

453 Narrow and discontinuous growth rings and traumatic canals were frequently
454 observed in *Juniperus* charcoal fragments (see Fig. 6) throughout the sampled Konya plain
455 anthracological sequence. This suggests that, on the whole, *Juniperus* stands grew under
456 considerable environmental stress well into the Holocene. *Juniperus* ring width was
457 consistently narrow across all sampled early to mid-Holocene phases. Average growth ring
458 width data available from dendrochronological timber samples at Çatalhöyük previously
459 analysed by Newton (1996) and charcoal specimens measured by Asouti (2013) have
460 indicated low average ring width values (0.25-0.77mm). Compared to *Juniperus* specimens,
461 the dendroecological features of the examined *Quercus* specimens do not indicate similar
462 slow growth rates; they do however indicate occasional browsing impacts and eco-anatomical
463 signs of competition in stand dynamics (see Fig. 7; Kabukcu 2015, 2017). Previous analyses
464 have highlighted the possible woodland management (e.g., coppicing) signatures observed in
465 *Quercus* charcoals from Çatalhöyük (see Fig. 7 and Kabukcu 2017). Studies of the wood
466 anatomy of deciduous oaks and junipers aimed at understanding species response to climatic
467 conditions and drought have shown that winter precipitation may result in improved annual
468 growth in *Juniperus* and *Quercus* in various habitats across the Mediterranean (Cherubini et
469 al. 2003, Corcuera et al. 2004, Tessier et al. 1994). To date, no detailed anatomical study is
470 available from semi-arid inland Southwest Asia. Research on the wood anatomical
471 characteristics of *Juniperus excelsa* in relation to climatic conditions in central Anatolia by
472 Touchan et al. (2007) has suggested that juniper annual growth is closely linked to, and
473 improved by, May/June precipitation. These observations on the importance of May/June
474 precipitation are matched by studies on other *Juniperus* species in different world regions: the
475 high altitude *Juniperus* woodlands in the central Tibetan Plateau (Liang et al. 2011) and *J.*
476 *thurifera* stands in central Spain (Esper et al. 2015). Studies of *J. thurifera* and *Quercus*
477 *faginea* by Granda et al. (2013) also suggest that deciduous oaks are better adapted to taking
478 advantage of winter precipitation, whereas junipers respond more positively to rainy spring
479 conditions. Research on *J. thurifera* by DeSoto et al. (2011) indicates that annual growth may
480 also be limited by cold conditions at the beginning of the growing season (spring) in addition
481 to growth reduction resulting from late spring and early summer drought.

482 Set against this research background, the anthracological observations on the wood
483 anatomical characteristics of *Juniperus* and *Quercus* charcoals from the Konya plain provide
484 some evidence for the pronounced seasonality of early Holocene climate in south-central
485 Anatolia, which was likely characterised by distinctly dry and hot late spring/summer seasons
486 and more winter-focused precipitation. Recent evidence from *Unio* shell $\delta^{18}\text{O}$ from
487 Çatalhöyük appears to provide additional support to this interpretation of rainfall and
488 temperature seasonality in the Konya plain during this period (Lewis et al. 2017). The same
489 authors have also suggested that in the later phases of Çatalhöyük (TP and the early
490 Chalcolithic West mound) may have witnessed a shift in annual rainfall amounts and/or
491 seasonality, resulting in reduced summer evapotranspiration. To date, such a shift has not
492 been detected in the anthracological record, although such a possibility cannot be altogether
493 excluded pending a larger scale study of *Juniperus* charcoal wood anatomy that is currently
494 ongoing.

495 Differences were observed in the wood anatomy of *Amygdalus* charcoal specimens
496 from Çatalhöyük and Boncuklu, and Pınarbaşı (see also Figure 8). The Pınarbaşı specimens
497 generally display wider rays ((5)8-10 cells wide as observed in the TLS: Tangential
498 Longitudinal Section) and more densely packed vessels (often also smaller in diameter and
499 solitary in their arrangement) in the TS: Transverse Section. *Amygdalus* charcoals from
500 Çatalhöyük and Boncuklu display narrower rays ((1)3-5(6) cells) and comparatively less
501 densely packed vessels. It is currently not possible to be certain if these anatomical features
502 reflect the presence of two different species (and/or species groups) of wild *Amygdalus* or,
503 instead, the effects of different growth conditions (e.g., different precipitation regimes, soils,
504 etc.) and/or growth forms (e.g., dwarf vs. developed shrubs). Studies of wood anatomical
505 variation in wild and feral tree/shrub populations (Terral 2002, Terral and Durand 2006,
506 Terral and Arnold-Simard 1996, Terral and Mengüal 1999) have indicated that variations in
507 ray width, vessel density, and growth ring width could be signalling the effects of different
508 climatic conditions or the impacts of management practices. For example, lower vessel
509 density has been observed in wild olives growing in conditions of higher moisture availability
510 (Terral and Arnold-Simard 1996). Moreover, irrigated olive trees display significantly wider
511 growth rings when compared to unmanaged trees growing in the wild. It should be noted here
512 that the growth rings of the Çatalhöyük *Amygdalus* specimens derived from the mid-late
513 phases of the site (i.e., mid-9th-8th millennia cal BP) are overall wider when compared to the
514 Boncuklu *Amygdalus* specimens (see Fig. 8). This might indicate that the Çatalhöyük

515 almonds were growing in locations of higher ground moisture availability. Interestingly, both
516 *Amygdalus* and *Pistacia* wood charcoals become increasingly ubiquitous (i.e., they register
517 higher sample presence if not always high charcoal counts) in the later phases of Çatalhöyük
518 (see also Fig. 4). This might suggest the increasing presence of these taxa on the Çarşamba
519 alluvial fan, possibly as a result of increasing alluvium deposition that raised the level of the
520 fan through time, thus facilitating the colonisation of better-drained alluvial soils and the
521 edges of riparian woodland habitats by *Amygdalus* and *Pistacia*. All these observations of
522 local variations in *Amygdalus* wood anatomy and their potential ecological significance need
523 to be verified by further analysis of a much larger dataset of *Amygdalus* charcoal fragments
524 from all sites. In addition, studies of modern wild, cultivated and managed *Amygdalus* eco-
525 anatomy might provide further insights into the nature of the variability observed in the
526 Konya plain prehistoric anthracological assemblages.

527 Based on the existing body of research on the fluvial dynamics and local sediment
528 deposition (see Boyer et al. 2006, Doherty et al. 2007) it is likely that riparian and wet
529 woodlands could have grown at the edges of seasonally flooded wetlands and marshes, along
530 seasonal and permanent watercourses, and on the alluvial floodplains and fans accumulated
531 on the Konya plain from inflowing rivers and streams. The anthracological evidence indicates
532 that these woodlands comprised primarily Salicaceae (*Salix/Populus*), *Ulmus*, *Fraxinus*,
533 *Tamarix* and Chenopodiaceae. Several species of *Salix* and *Populus* are pioneers in wetland
534 environments due to their quick germination, regeneration (i.e., resprouting following cutting,
535 burial and/or uprooting) and rapid growth rate, and their tolerance of waterlogged soils
536 following episodes of flooding. Salicaceae represent early colonisers of alluvial and wetland
537 edge habitats (Nilsson and Svedmark 2002, Naiman and Décamps 1997). In these habitats, as
538 a thicker understorey develops, the shade-intolerant Salicaceae can co-exist with shade-
539 tolerant taxa such as *Ulmus* and *Fraxinus*. The ubiquity and abundance of the shade-
540 intolerant Salicaceae and their remarkably stable relative proportions through time at
541 Boncuklu thus suggest that wetland habitats around the site might have been subject to
542 frequent disturbances slowing down vegetation succession beyond the pioneer stage. The
543 high frequency of *Phragmites* and Salicaceae (rather than *Fraxinus* or Ulmaceae) in the
544 Boncuklu wetland environment might indicate that significant parts of the woodland
545 catchment were flooded, possibly on a seasonal basis. Thus the comparatively higher
546 tolerance of Salicaceae to periodic waterlogging could have been an important element
547 determining their prominence in the local wetlands. While both Can Hasan III and the earliest

548 phases of Çatalhöyük also show a strong reliance on Salicaceae as a source of domestic
549 fuelwood, the structure of these woodlands appear to have been different compared to
550 Boncuklu. The data show that at both sites both shade-tolerant *Ulmus* and Ulmaceae and
551 shade-intolerant Salicaceae were used, indicating more developed riparian woodlands. This
552 may be due to the presence of better-drained alluvial soils supporting diverse riparian
553 woodland habitats, and/or more sporadic and/or lower magnitude flooding-related
554 disturbances affecting woodland vegetation growing on the alluvial fans.

555 The prevalence of Salicaceae at Boncuklu is analogous to results of charcoal analyses
556 reported from several sites in the Euphrates basin of northern Syria. With the exception of
557 Jerf el Ahmar, the anthracological data available from sites in the northern Euphrates basin
558 (i.e., Abu Hureyra, Tell Halula, Dja'de; see Roitel 1997) suggest that wood fuel collection
559 focused on the riparian woodland habitats that were probably fairly extensive at the end of
560 the Pleistocene and the beginning of the Holocene. In the seasonally/annually unstable
561 alluvial regimes of the northern Euphrates (Geyer and Besançon 1996, Wilkinson 2004), taxa
562 characterised by rapid vegetative regeneration rates dominate the wood charcoal assemblages
563 (e.g., Salicaceae, *Tamarix*, and *Fraxinus*, e.g. Roitel 1997). Comparable woodland
564 exploitation strategies focusing on riparian woodlands are seen at other early Holocene sites
565 that occupied marshy or highly unstable alluvial settings, such as Boncuklu in the Konya
566 plain, and sites in Eastern Anatolia and the Zagros including Cafer Höyük (Willcox 1991)
567 and M'lefaat (Savard et al. 2003).

568 Two Epipalaeolithic sites on the southern Anatolian coast, Öküzini and Karain B,
569 display some similarities in woodland exploitation when compared to Epipalaeolithic
570 Pınarbaşı. At both Öküzini and Karain B, fuel wood use is focused on *Amygdalus* alongside
571 *Acer*, *Fraxinus* and a minor component of deciduous *Quercus*. Although *Juniperus* is
572 registered in the palynological study conducted in the vicinity of the site, it is not commonly
573 used as a source of fuelwood (Martinoli 2004, Emery-Barbier and Thiébauld 2005). In
574 southwest Syria, at Baaz (spanning the late Pleistocene and the early Holocene) again
575 *Amygdalus* and *Pistacia* are the dominant charcoal taxa, alongside riparian woodland species
576 (Deckers et al. 2009). The importance of *Juniperus* in the development of woodland
577 vegetation during the late Pleistocene and early Holocene is also supported by evidence from
578 sites located in the arid zone of the southern Levant (in the Negev and in Jordan) (Baruch and
579 Goring-Morris 1997, Austin 2007).

580 *Quercus* is attested at several early Holocene sites in eastern and southeast Anatolia
581 and northern Syria (e.g., Çayönü, Hallan Çemi, Körtik Tepe, Göbekli Tepe, Cafer höyük,
582 Abu Hureyra, Mureybet, Jerf el-Ahmar, Dja'de, Tell Halula) and becomes more commonly
583 used as fuelwood in later phases alongside *Pistacia*, Salicaceae, *Amygdalus*, Maloideae and
584 *Celtis* (cf. van Zeist and de Roller 1991/2, Willcox 1992, 1999, 2002, Rosenberg et al. 1995,
585 Roitel 1997, Helmer et al. 1998, Neef 2003, Riehl et al. 2012) (see also Table 2.2). This
586 gradual increase in *Quercus* resonates with the evidence from the Konya plain (see also
587 discussion in Asouti and Kabukcu 2014). A similarly late appearance of *Quercus* is observed
588 at early Holocene sites on northwest Zagros, with deciduous oak appearing during the 8th-7th
589 millennia cal. BC (Asouti pers. comm.).

590

591 **8. Conclusions**

592 The results presented in this paper, incorporating previously unpublished and
593 published anthracological datasets from the sites of Pınarbaşı, Boncuklu, Can Hasan III, and
594 the Çatalhöyük East and West mounds in the Konya plain of south-central Anatolia, provide
595 a rich palaeovegetation archive of a single geographical region within Southwest Asia
596 spanning the late Pleistocene and the early to mid-Holocene. The anthracological results from
597 Epipalaeolithic Pınarbaşı provide insights into the early development woodlands following
598 the onset of the warm-wet GI-1, including the spread of *Juniperus*, *Amygdalus* and *Pistacia*
599 into the region from a very early stage, which was previously undetected in the regional
600 pollen records. At the onset of the Holocene, the key semi-arid woodland taxa of the region
601 were already established in the landscape: *Quercus*, *Juniperus*, *Amygdalus*, *Pistacia*,
602 *Maloideae* and *Prunus*. The charcoal datasets also point to the presence of a range of riparian
603 and wetland edge habitats comprising taxa such as Salicaceae, Ulmaceae, *Tamarix*, *Fraxinus*
604 and possibly *Celtis* as well. It is hypothesized that these woodland habitats were particularly
605 productive providing a steady supply of fuel wood to the prehistoric communities living in
606 the Konya plain for a considerable period of time. During the early stages of settled life and
607 the establishment of the first agropastoral economies the availability of riparian woodlands in
608 close proximity to habitation sites likely formed an important consideration for settlement
609 location. It is argued here that shifts observed in the use of *Quercus* and *Juniperus* through
610 the occupation of Çatalhöyük East and West relate to fuel selection and use practices and the

611 development of anthropogenic woodlands closely related with agro-pastoral activities in the
612 landscape.

613 The anthracological evidence, viewed in the context of the regional paleoecological
614 proxies, suggests that temporal shifts in woodland vegetation and climate were asynchronous
615 in the continental inland regions of Southwest Asia, as the responses of woodland vegetation
616 to climate change appear to have been gradual. The existence of robust regional trends in the
617 ubiquity and frequencies of fuel wood taxa across different habitation sites and phases in the
618 Konya plain is significant. It confirms that, at a regional scale, anthracological remains
619 deriving from domestic fuel wood waste accumulated over the long-term in archaeological
620 habitation sites, have the potential to reflect temporal consistency in the timing of the
621 appearance and spread of key woodland indicators across the region. Anthracological remains
622 can thus capture major shifts in woodland vegetation composition with a degree of spatial and
623 temporal precision that is currently unmatched by palynological archives in Southwest Asia,
624 which do not register insect-pollinated taxa and poor/erratic pollen producers. Therefore, they
625 constitute a unique source of direct evidence for reconstructing past woodland composition
626 alongside providing invaluable insights into woodland growth conditions, woodland
627 exploitation, management and human impacts on vegetation resources.

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Figure 1 Konya plain and surrounding region elevation map with locations of archaeological sites. Map generated by author using R (package *raster*, *rgeos*); data source Shuttle Radar Topography Mission.

Figure 2a Konya plain and surrounding region annual precipitation map with locations of archaeological sites. Map generated by author using R (package *raster*); data source WorldClim (Hijmans et al. 2005).

Figure 2b Annual distribution of precipitation and average temperatures in Konya, data source Turkish State Meteorological Service (www.mgm.gov.tr).

Figure 3 Anthracological diagram from all sampled phases at Pınarbaşı (dispersed contexts) (dark dots represent fragment counts <2%, white circles fragment counts <1%). (n=number of units/contexts, see also Table 2).

Figure 4 Anthracological diagram from all sampled phases at Boncuklu, Can Hasan III and Çatalhöyük East and West mounds (dispersed contexts) (dark dots represent fragment counts <2%, white circles fragment counts <1%). (for n=number of units/contexts analysed in each phase see Table 2).

Figure 5 Plot of Dimensions 1 and 2, CA run on per sample wood charcoal taxon counts from all sites included in the present study.

Figure 6 a) Juniperus (Pınarbaşı Epipalaeolithic) showing narrow growth rings and deformed tracheids **b-c)** Juniperus (Çatalhöyük Neolithic) showing narrow growth rings, deformed tracheids and traumatic resin canals.

Figure 7 Growth variability under woodland management. 1. *Fraxinus excelsior*, crown lopping (e.g., pollarding), results in successive growth reduction indicated by arrow. 2. *Fraxinus excelsior*, coppiced stem, arrow indicates growth release period. 3. *Quercus* (Çatalhöyük), arrow indicates growth release. 4. *Quercus* (Çatalhöyük), arrow indicates growth suppression. 5. *Quercus* (Çatalhöyük), suppressed/dwarfed sapling or shoot with brief periods of growth improvement. (1-2: images by author, reference material kept by the WSL, F.H. Schweingruber; 3-5: images by author)

Figure 8 Amygdalus wood anatomical variability observed in the Konya plain anthracological assemblage **a)** Pınarbaşı, 9th millennium **b)** Boncuklu **c)** Çatalhöyük

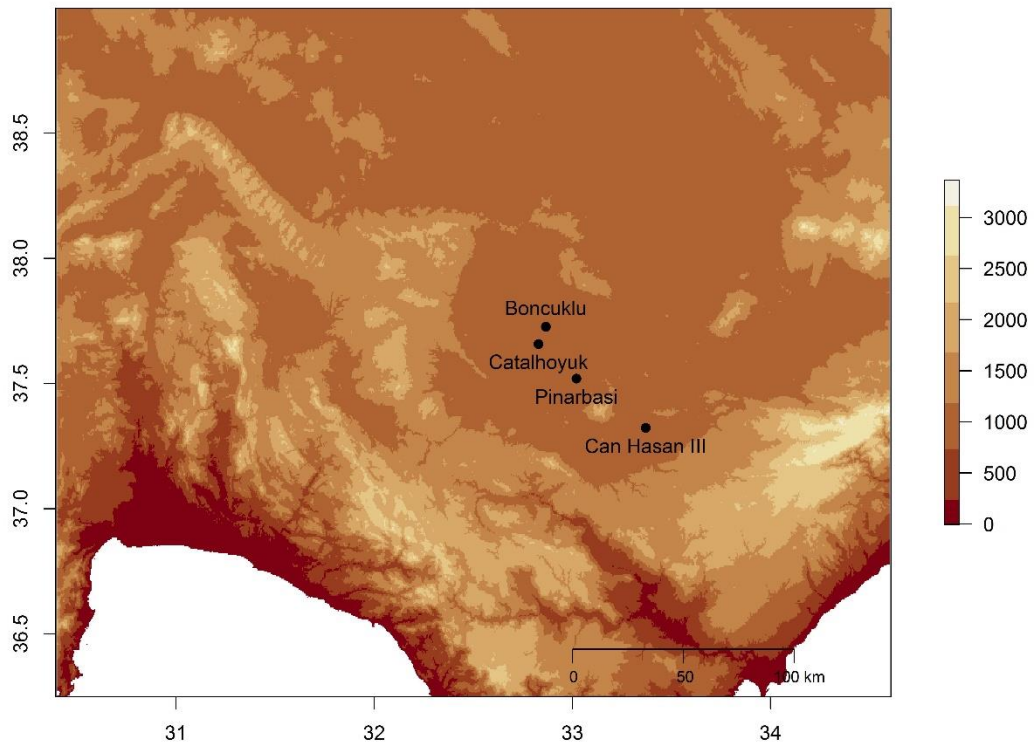


Figure 1

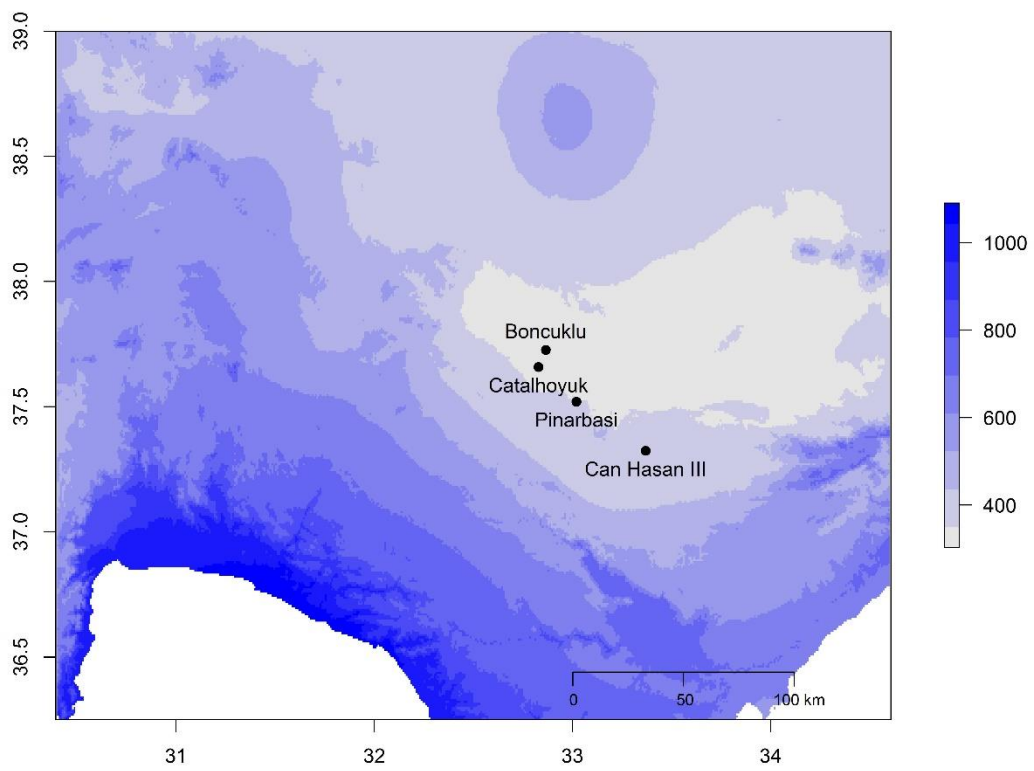


Figure 2a

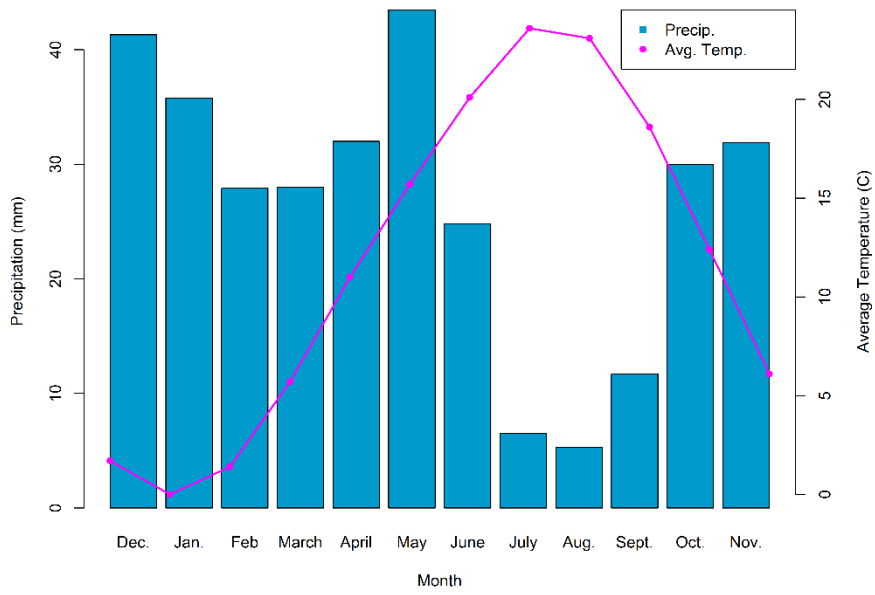


Figure 2b

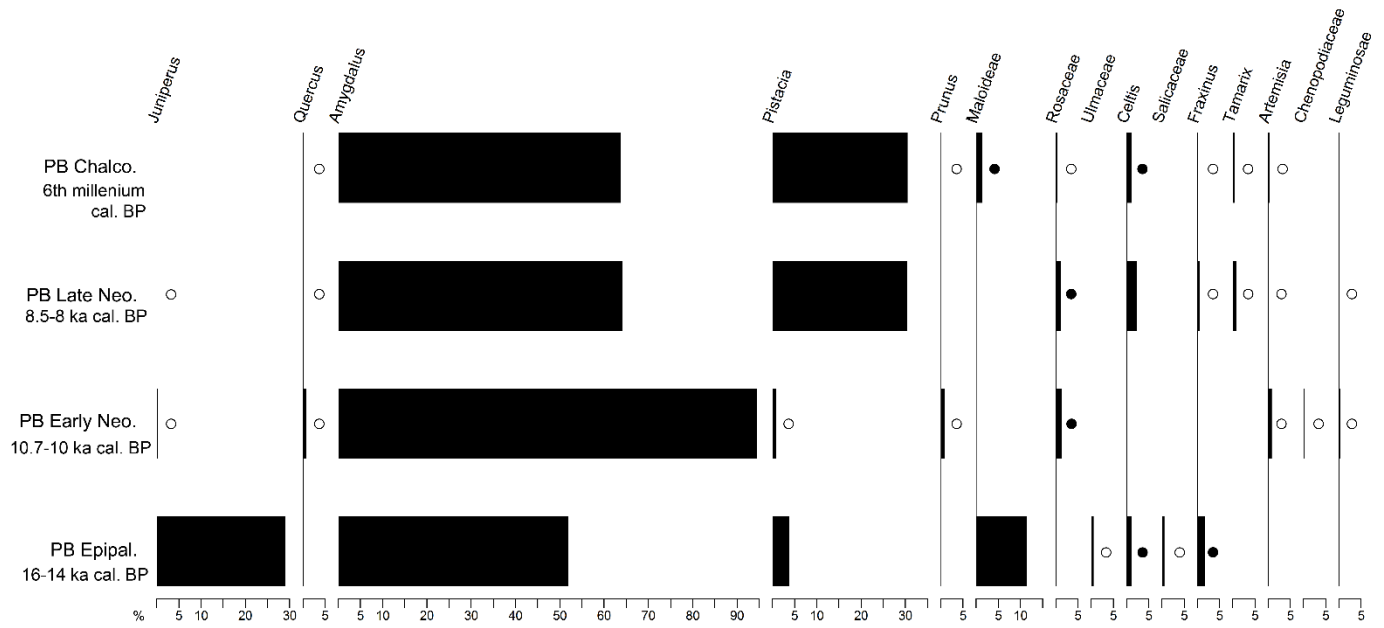


Figure 3

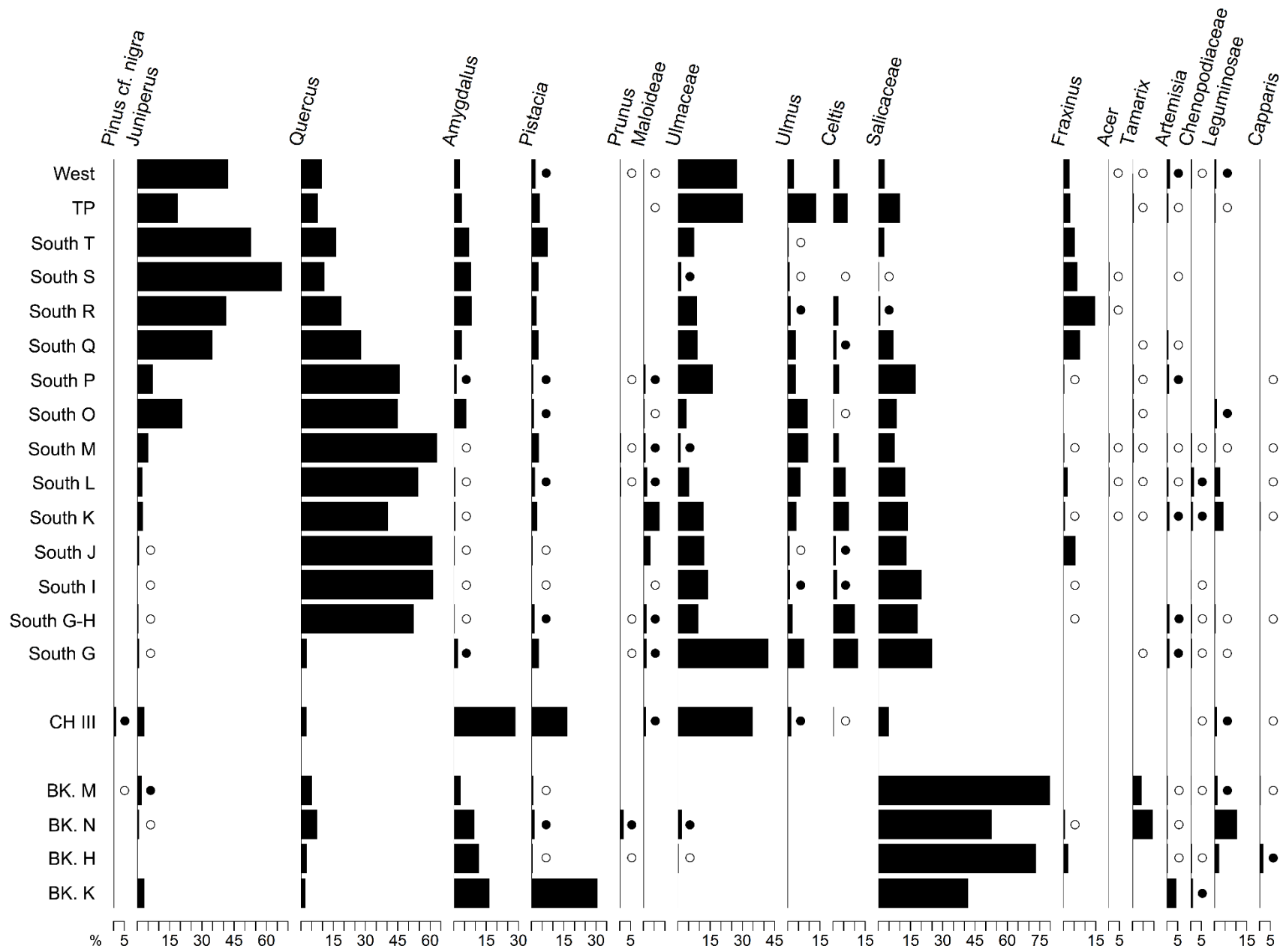


Figure 4

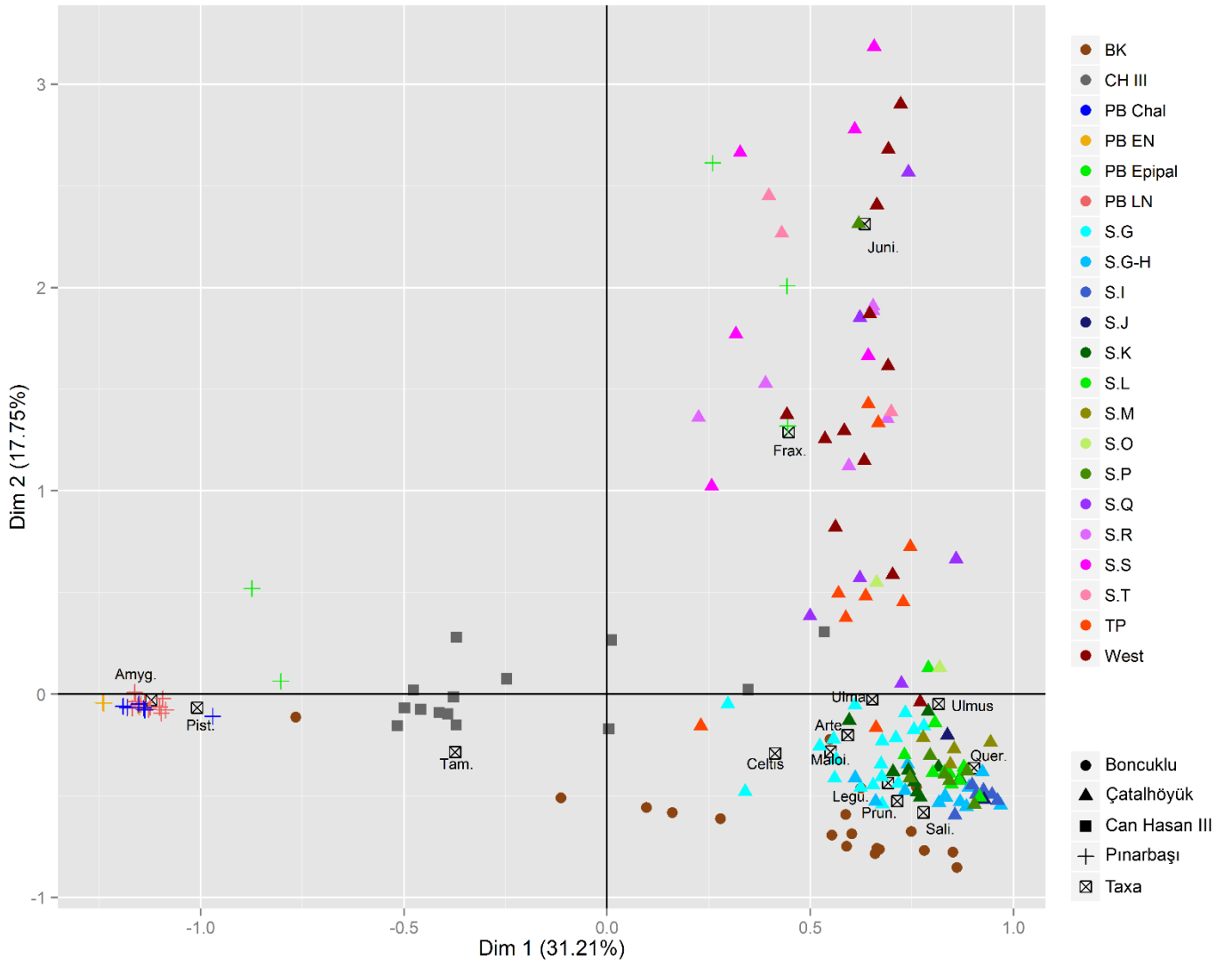


Figure 5

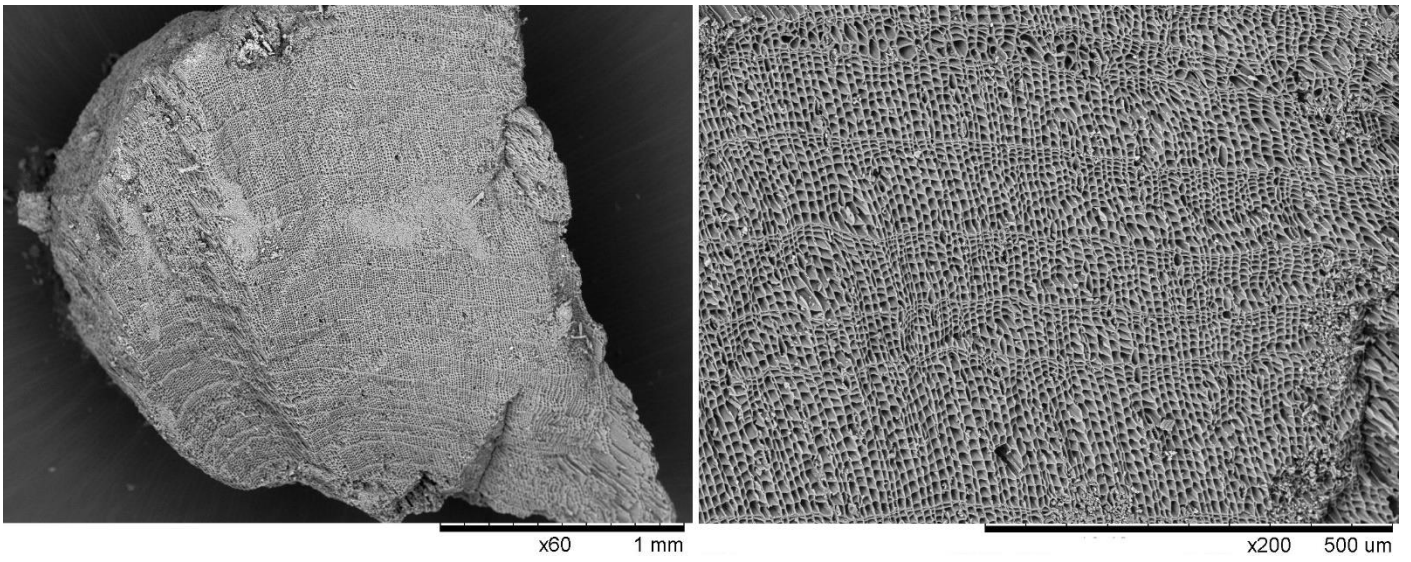


Figure 6a

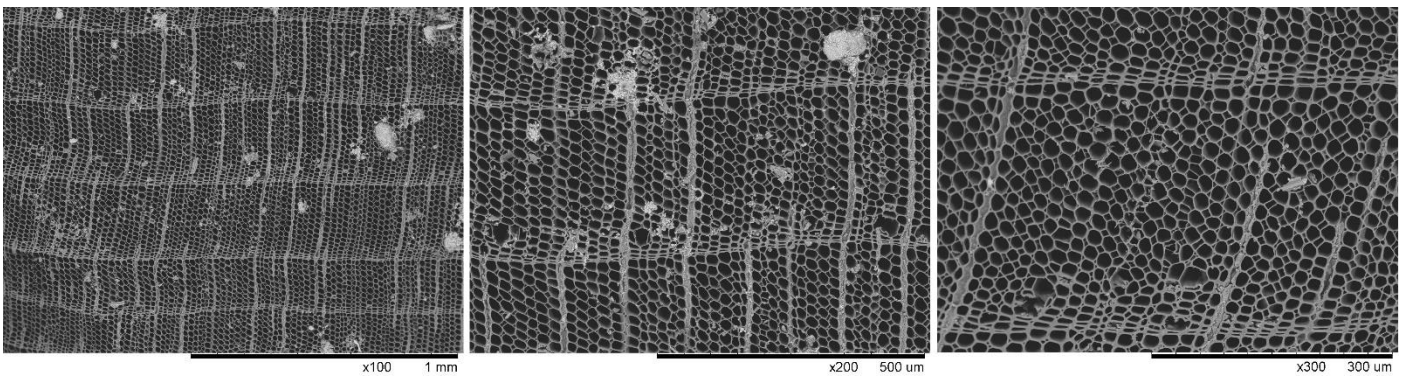


Figure 6b

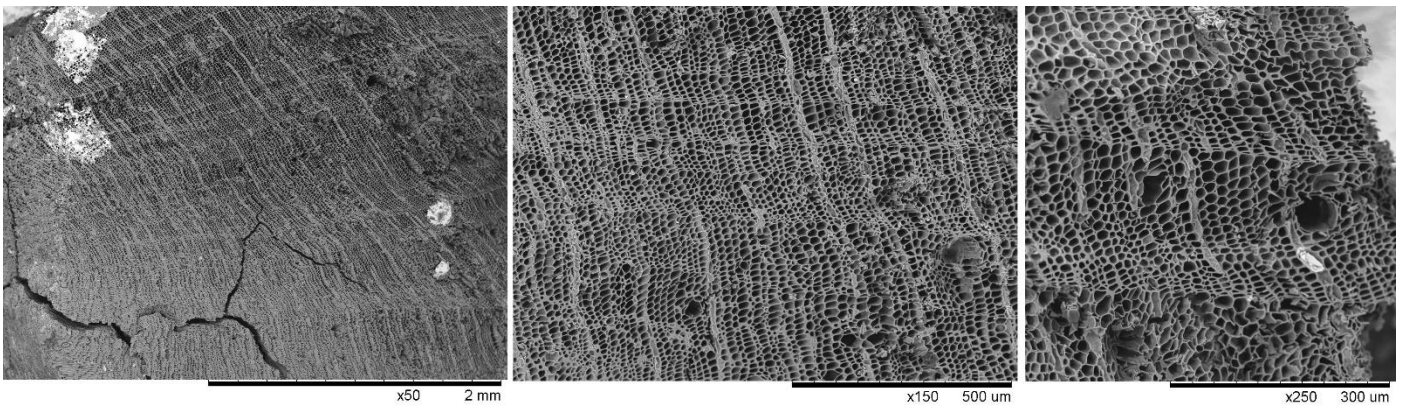


Figure 6c

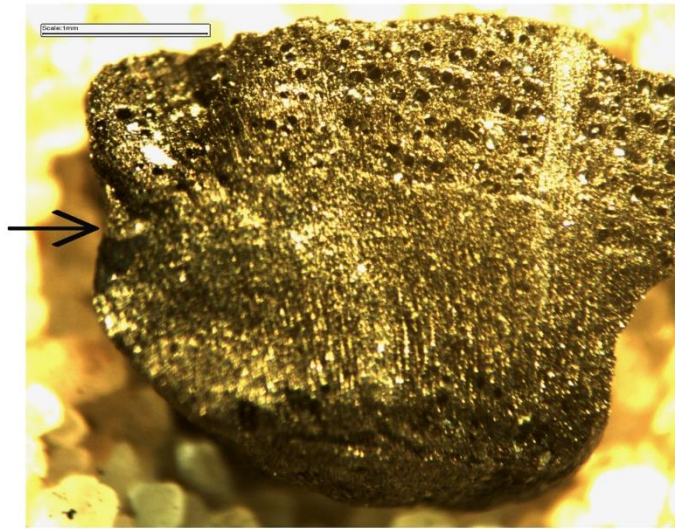
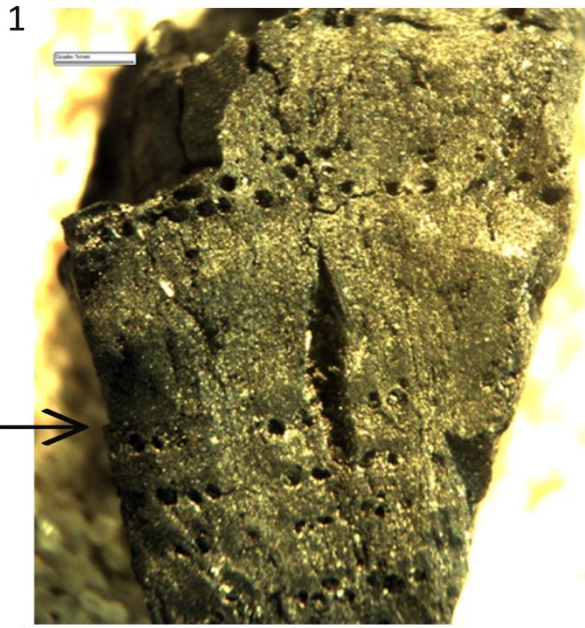
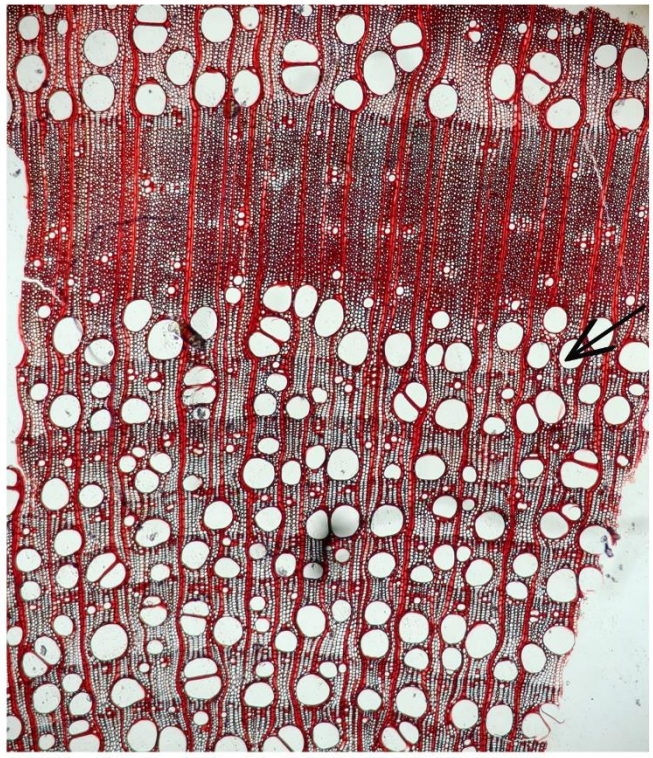
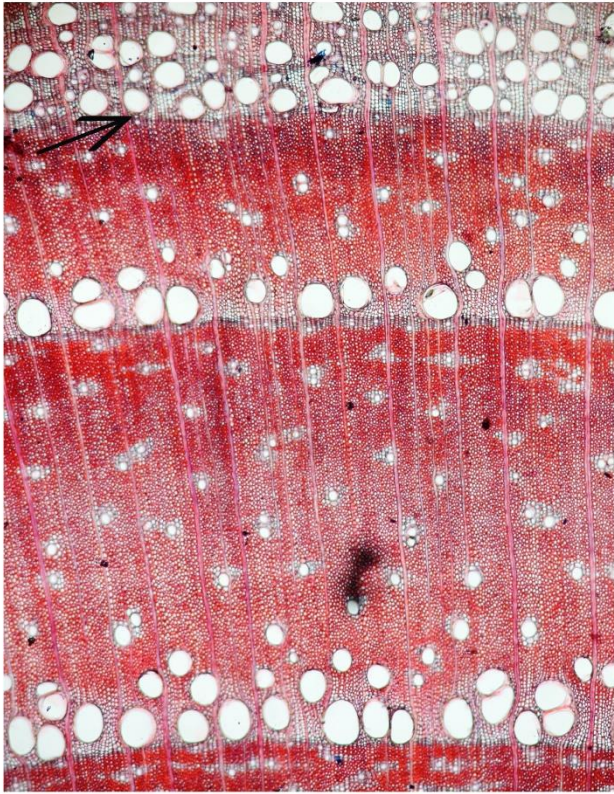


Figure 7

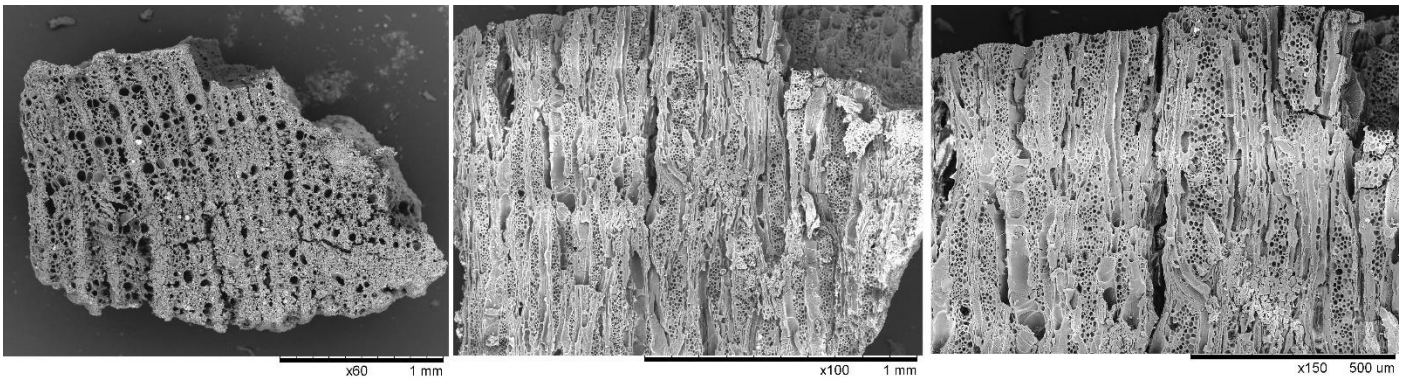


Figure 8a

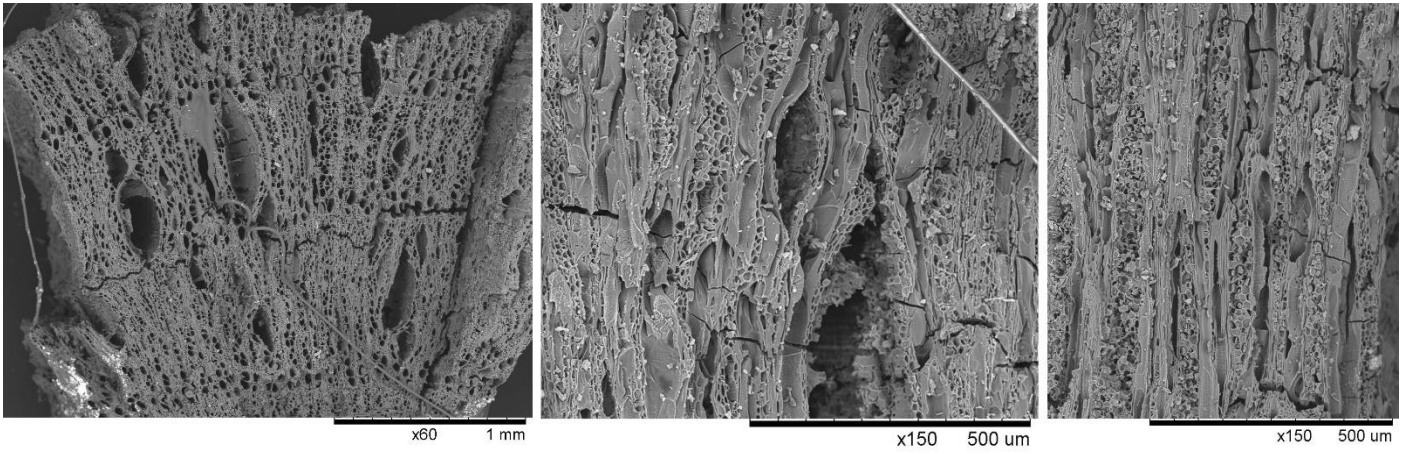


Figure 8b

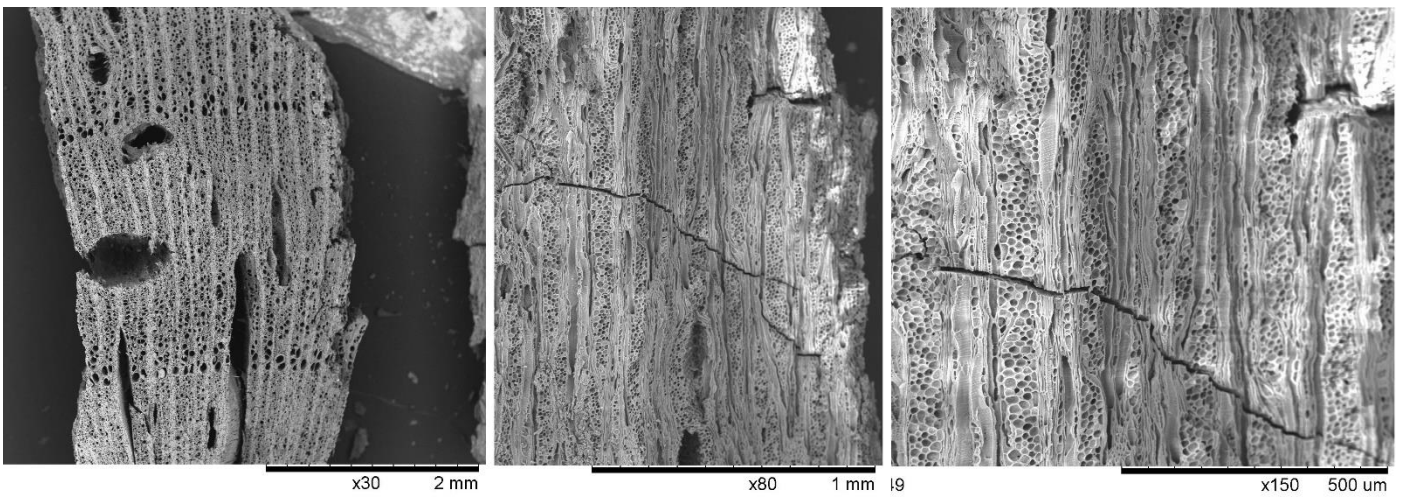


Figure 8c

| Phases studied | Phases (according to ceramic tradition) | Dates cal BC |
|----------------|---|--------------|
| West Mound | Early Chalcolithic | 6000-5500 |
| TP | Late Ceramic Neolithic | 6400-6000 |
| South T | | |
| South S | | |
| South R | Middle Ceramic Neolithic | 6500-6400 |
| South Q | | |
| South P | | |
| South O | | |
| South N | | |
| South M | Early Ceramic Neolithic | 7100-6800 |
| South L | | |
| South K | | |
| South J | | |
| South I | | |
| South H | | |
| South G | | |

Table 1: New provisional phasing, pottery stratigraphy and associated radiocarbon dates for all excavated levels at Çatalhöyük.

| Site/Phase | PB Epipal. (N=13) | | PB Acer. NL NL (N=25) | | PB Late NL (N=28) | | PB Chalco. (N=8) | | Can Hasan III (N=23) | | BK Trench K (N=11) | | BK Trench H (N=23) | | BK Trench N (N=10) | | BK Trench M (N=23) | |
|------------------------------|----------------------|--------------|--------------------------|--------------|----------------------|--------------|---------------------|--------------|-------------------------|--------------|-----------------------|--------------|-----------------------|--------------|-----------------------|--------------|-----------------------|--------------|
| | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C |
| <i>Pinus cf. nigra</i> | | | | | | | | | 8 | 1.22 | | | | | | | 1 | 0.40 |
| <i>Juniperus</i> | 53 | 28.96 | 1 | 0.27 | 3 | 0.07 | | | 21 | 3.21 | 3 | 3.30 | | | 2 | 0.73 | 5 | 1.98 |
| <i>Quercus</i> | | | 3 | 0.82 | 1 | 0.02 | 1 | 0.09 | 17 | 2.60 | 2 | 2.20 | 8 | 2.61 | 21 | 7.64 | 13 | 5.16 |
| <i>Amygdalus</i> | 95 | 51.91 | 346 | 94.54 | 2858 | 64.21 | 683 | 63.71 | 187 | 28.55 | 15 | 16.48 | 36 | 11.73 | 26 | 9.45 | 8 | 3.17 |
| <i>Pistacia</i> | 7 | 3.83 | 3 | 0.82 | 1355 | 30.44 | 327 | 30.50 | 109 | 16.64 | 28 | 30.77 | 2 | 0.65 | 4 | 1.45 | 2 | 0.79 |
| Anacardiaceae | | | | | | | | | | | | | | | 1 | 0.36 | | |
| <i>Prunus</i> | | | 3 | 0.82 | | | 1 | 0.09 | | | | | 1 | 0.33 | 5 | 1.82 | | |
| Maloideae | 21 | 11.48 | | | | | 15 | 1.40 | 7 | 1.07 | | | | | | | | |
| Ulmaceae | 1 | 0.55 | | | | | | | 227 | 34.66 | | | 1 | 0.33 | 5 | 1.82 | | |
| <i>Ulmus</i> | | | | | | | | | 12 | 1.83 | | | | | | | | |
| <i>Celtis</i> | 2 | 1.09 | | | 104 | 2.34 | 12 | 1.12 | 2 | 0.31 | | | | | | | | |
| Salicaceae | 1 | 0.55 | | | | | | | 33 | 5.04 | 38 | 41.76 | 225 | 73.29 | 145 | 52.73 | 201 | 79.76 |
| <i>Fraxinus</i> | 3 | 1.64 | | | 24 | 0.54 | 2 | 0.19 | | | | | 7 | 2.28 | 2 | 0.73 | | |
| <i>Acer</i> | | | | | 1 | 0.02 | | | | | | | | | | | | |
| <i>Tamarix</i> | | | | | 36 | 0.81 | 4 | 0.37 | | | | | | | 26 | 9.45 | 11 | 4.37 |
| <i>Platanus</i> | | | | | | | | | | | | | | | | | | |
| <i>Alnus</i> | | | | | | | | | | | | | | | | | | |
| <i>Vitex</i> | | | | | | | | | | | | | | | | | | |
| Labiatae | | | | | | | | | | | | | | | | | | |
| <i>Rhamnus</i> | | | | | 1 | 0.02 | 20 | 1.87 | | | | | | | | | | |
| <i>Artemisia</i> | | | 3 | 0.82 | 5 | 0.11 | 3 | 0.28 | | | 4 | 4.40 | 1 | 0.33 | 1 | 0.36 | 1 | 0.40 |
| Chenopodiaceae | | | 1 | 0.27 | | | | | 2 | 0.31 | 1 | 1.10 | 2 | 0.65 | | | 1 | 0.40 |
| Leguminosae | | | 1 | 0.27 | 4 | 0.09 | | | 7 | 1.07 | | | 7 | 2.28 | 29 | 10.55 | 4 | 1.59 |
| <i>Capparis</i> | | | | | 3 | 0.07 | | | 2 | 0.31 | | | 5 | 1.63 | | | 1 | 0.40 |
| <i>Ephedra</i> | | | | | | | | | | | | | 1 | 0.33 | | | | |
| Caprifoliaceae | | | | | | | | | | | | | | | | | | |
| <i>Ficus carica</i> | | | | | | | | | | | | | | | | | | |
| <i>Clematis</i> | | | | | 7 | 0.16 | 1 | 0.09 | | | | | | | | | | |
| Rosaceae | | | 5 | 1.37 | 49 | 1.10 | 3 | 0.28 | | | | | | | | | | |
| cf. <i>Arbutus</i> | | | | | | | | | | | | | 1 | 0.33 | | | | |
| cf. <i>Paliurus/Ziziphus</i> | | | | | | | | | | | | | 3 | 0.98 | 4 | 1.45 | 1 | 0.40 |
| cf. Euphorbiaceae | | | | | | | | | | | | | 6 | 1.95 | 4 | 1.45 | 3 | 1.19 |
| cf. Maloideae | | | | | | | | | | | | | 1 | 0.33 | | | | |
| Ulmaceae/Anacardiaceae | | | | | | | | | 21 | 3.21 | | | | | | | | |
| Total Identified | 183 | 100.0 | 366 | 100.0 | 4451 | 100.0 | 1072 | 100.0 | 655 | 100.0 | 91 | 100.0 | 307 | 100.0 | 275 | 100.0 | 252 | 100.0 |

Table 2: Master anthracological sequence (C: frg. counts; % C: percentage frg. counts) from all Konya Plain sites (incorporating data from Asouti 2003, 2005, 2013) (*continued overleaf*)

| Site/Phase | Ch. South G (N=18) | | Ch. South G-H (N=13) | | Ch. South I (N=6) | | Ch. South J (N=2) | | Ch. South K (N=9) | | Ch. South L (N=11) | | Ch. South M (N=4) | |
|------------------------------|-----------------------|--------------|-------------------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|-----------------------|--------------|----------------------|--------------|
| | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C |
| <i>Pinus cf. nigra</i> | | | | | | | | | | | | | | |
| <i>Juniperus</i> | 9 | 0.80 | 7 | 0.56 | 1 | 0.16 | 2 | 0.94 | 23 | 2.51 | 28 | 2.40 | 20 | 5.00 |
| <i>Quercus</i> | 31 | 2.75 | 651 | 52.46 | 384 | 61.44 | 130 | 61.03 | 371 | 40.46 | 636 | 54.55 | 253 | 63.25 |
| <i>Amygdalus</i> | 21 | 1.87 | 4 | 0.32 | 1 | 0.16 | 1 | 0.47 | 7 | 0.76 | 8 | 0.69 | 1 | 0.25 |
| <i>Pistacia</i> | 39 | 3.46 | 19 | 1.53 | 1 | 0.16 | 1 | 0.47 | 26 | 2.84 | 19 | 1.63 | 14 | 3.50 |
| Anacardiaceae | | | 1 | 0.08 | | | | | 1 | 0.11 | 1 | 0.09 | | |
| <i>Prunus</i> | 1 | 0.09 | 2 | 0.16 | | | | | | | 8 | 0.69 | 2 | 0.50 |
| Maloideae | 16 | 1.42 | 19 | 1.53 | 1 | 0.16 | 7 | 3.29 | 68 | 7.42 | 19 | 1.63 | 4 | 1.00 |
| Ulmaceae | 473 | 42.01 | 119 | 9.59 | 88 | 14.08 | 26 | 12.21 | 110 | 12.00 | 61 | 5.23 | 5 | 1.25 |
| <i>Ulmus</i> | 86 | 7.64 | 28 | 2.26 | 7 | 1.12 | 2 | 0.94 | 37 | 4.03 | 70 | 6.00 | 38 | 9.50 |
| <i>Celtis</i> | 132 | 11.72 | 126 | 10.15 | 12 | 1.92 | 3 | 1.41 | 67 | 7.31 | 69 | 5.92 | 11 | 2.75 |
| Salicaceae | 281 | 24.96 | 226 | 18.21 | 126 | 20.16 | 28 | 13.15 | 127 | 13.85 | 146 | 12.52 | 31 | 7.75 |
| <i>Fraxinus</i> | | | 1 | 0.08 | 1 | 0.16 | 12 | 5.63 | 7 | 0.76 | 24 | 2.06 | 2 | 0.50 |
| <i>Acer</i> | | | | | | | | | 2 | 0.22 | 5 | 0.43 | 2 | 0.50 |
| <i>Tamarix</i> | 3 | 0.27 | | | | | | | 1 | 0.11 | 1 | 0.09 | 3 | 0.75 |
| <i>Platanus</i> | | | | | | | | | | | 1 | 0.09 | | |
| <i>Alnus</i> | | | | | | | | | | | 1 | 0.09 | 2 | 0.50 |
| <i>Vitex</i> | 2 | 0.18 | 2 | 0.16 | | | | | | | 4 | 0.34 | 1 | 0.25 |
| Labiatae | 5 | 0.44 | | | 1 | 0.16 | 1 | 0.47 | 6 | 0.65 | 5 | 0.43 | 1 | 0.25 |
| <i>Rhamnus</i> | | | 3 | 0.24 | | | | | | | | | | |
| <i>Artemisia</i> | 14 | 1.24 | 15 | 1.21 | | | | | 11 | 1.20 | 8 | 0.69 | 2 | 0.50 |
| Chenopodiaceae | 7 | 0.62 | 9 | 0.73 | 2 | 0.32 | | | 10 | 1.09 | 18 | 1.54 | 3 | 0.75 |
| Leguminosae | 1 | 0.09 | 8 | 0.64 | | | | | 38 | 4.14 | 31 | 2.66 | 2 | 0.50 |
| <i>Capparis</i> | | | 1 | 0.08 | | | | | 4 | 0.44 | 1 | 0.09 | 1 | 0.25 |
| <i>Ephedra</i> | 1 | 0.09 | | | | | | | | | | | | |
| Caprifoliaceae | 1 | 0.09 | | | | | | | | | | | 1 | 0.25 |
| <i>Ficus carica</i> | | | | | | | | | | | 1 | 0.09 | | |
| <i>Clematis</i> | | | | | | | | | | | | | | |
| Rosaceae | 3 | 0.27 | | | | | | | 1 | 0.11 | 1 | 0.09 | 1 | 0.25 |
| cf. <i>Arbutus</i> | | | | | | | | | | | | | | |
| cf. <i>Paliurus/Ziziphus</i> | | | | | | | | | | | | | | |
| cf. Euphorbiaceae | | | | | | | | | | | | | | |
| cf. Maloideae | | | | | | | | | | | | | | |
| Ulmaceae/Anacardiaceae | | | | | | | | | | | | | | |
| Total Identified | 1126 | 100.0 | 1241 | 100.0 | 625 | 100.0 | 213 | 100.0 | 917 | 100.0 | 1166 | 100.0 | 400 | 100.0 |

(continued from previous page) **Table 2:** Master anthracological sequence (C: frg. counts; % C: percentage frg. counts) from all Konya Plain sites (incorporating data from Asouti 2003, 2005, 2013) (continued overleaf)

| Site/Phase | Ch. South O (N=2) | | Ch. South P (N=7) | | Ch. South Q (N=6) | | Ch. South R (N=6) | | Ch. South S (N=7) | | Ch. South T (N=5) | | Ch. TP (N=9) | | Ch. West (N=12) | |
|------------------------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|-----------------|--------------|--------------------|--------------|
| | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C | C | % C |
| <i>Pinus cf. nigra</i> | | | | | | | | | | | | | | | | |
| <i>Juniperus</i> | 36 | 20.81 | 42 | 7.14 | 104 | 34.90 | 116 | 41.43 | 294 | 67.28 | 91 | 52.91 | 108 | 18.78 | 198 | 42.31 |
| <i>Quercus</i> | 78 | 45.09 | 270 | 45.92 | 83 | 27.85 | 53 | 18.93 | 48 | 10.98 | 28 | 16.28 | 45 | 7.83 | 45 | 9.62 |
| <i>Amygdalus</i> | 10 | 5.78 | 8 | 1.36 | 11 | 3.69 | 23 | 8.21 | 35 | 8.01 | 12 | 6.98 | 22 | 3.83 | 13 | 2.78 |
| <i>Pistacia</i> | 2 | 1.16 | 6 | 1.02 | 10 | 3.36 | 7 | 2.50 | 15 | 3.43 | 13 | 7.56 | 23 | 4.00 | 9 | 1.92 |
| Anacardiaceae | 4 | 2.31 | | | | | | | | | | | | | | |
| <i>Prunus</i> | | | 2 | 0.34 | | | | | | | | | | | 1 | 0.21 |
| Maloideae | 1 | 0.58 | 6 | 1.02 | | | | | | | | | 1 | 0.17 | 1 | 0.21 |
| Ulmaceae | 7 | 4.05 | 96 | 16.33 | 27 | 9.06 | 25 | 8.93 | 7 | 1.60 | 13 | 7.56 | 173 | 30.09 | 129 | 27.56 |
| <i>Ulmus</i> | 16 | 9.25 | 22 | 3.74 | 11 | 3.69 | 4 | 1.43 | 4 | 0.92 | 1 | 0.58 | 76 | 13.22 | 14 | 2.99 |
| <i>Celtis</i> | 1 | 0.58 | 17 | 2.89 | 5 | 1.68 | 7 | 2.50 | 1 | 0.23 | | | 39 | 6.78 | 14 | 2.99 |
| Salicaceae | 15 | 8.67 | 102 | 17.35 | 21 | 7.05 | 3 | 1.07 | 2 | 0.46 | 5 | 2.91 | 58 | 10.09 | 14 | 2.99 |
| <i>Fraxinus</i> | | | 3 | 0.51 | 23 | 7.72 | 41 | 14.64 | 28 | 6.41 | 9 | 5.23 | 18 | 3.13 | 13 | 2.78 |
| <i>Acer</i> | | | | | | | 1 | 0.36 | 2 | 0.46 | | | | | 1 | 0.21 |
| <i>Tamarix</i> | 1 | 0.58 | 4 | 0.68 | 1 | 0.34 | | | | | | | 3 | 0.52 | 1 | 0.21 |
| <i>Platanus</i> | | | | | | | | | | | | | | | | |
| <i>Alnus</i> | | | | | | | | | | | | | | | | |
| <i>Vitex</i> | | | | | | | | | | | | | | | | |
| Labiatae | | | | | | | | | | | | | | | | |
| <i>Rhamnus</i> | | | | | | | | | | | | | | | | |
| <i>Artemisia</i> | | | 6 | 1.02 | 2 | 0.67 | | | 1 | 0.23 | | | 5 | 0.87 | 7 | 1.50 |
| Chenopodiaceae | | | | | | | | | | | | | | | 3 | 0.64 |
| Leguminosae | 2 | 1.16 | 1 | 0.17 | | | | | | | | | 4 | 0.70 | 5 | 1.07 |
| <i>Capparis</i> | | | 2 | 0.34 | | | | | | | | | | | | |
| <i>Ephedra</i> | | | | | | | | | | | | | | | | |
| Caprifoliaceae | | | | | | | | | | | | | | | | |
| <i>Ficus carica</i> | | | 1 | 0.17 | | | | | | | | | | | | |
| <i>Clematis</i> | | | | | | | | | | | | | | | | |
| Rosaceae | | | | | | | | | | | | | | | | |
| cf. <i>Arbutus</i> | | | | | | | | | | | | | | | | |
| cf. <i>Paliurus/Ziziphus</i> | | | | | | | | | | | | | | | | |
| cf. Euphorbiaceae | | | | | | | | | | | | | | | | |
| cf. Maloideae | | | | | | | | | | | | | | | | |
| Ulmaceae/Anacardiaceae | | | | | | | | | | | | | | | | |
| Total Identified | 173 | 100.0 | 588 | 100.0 | 298 | 100.0 | 280 | 100.0 | 437 | 100.0 | 172 | 100.0 | 575 | 100.0 | 468 | 100.0 |

(continued from previous page) **Table 2:** Master anthracological sequence (C: frg. counts; % C: percentage frg. counts) from all Konya Plain sites (incorporating data from Asouti 2003, 2005, 2013).

| | eigenvalue | % of variance | Cumulative % of variance |
|----------------|------------|---------------|--------------------------|
| Dim. 1 | 0.817532 | 31.21 | 31.21 |
| Dim. 2 | 0.46493 | 17.75 | 48.96 |
| Dim. 3 | 0.293986 | 11.22 | 60.19 |
| Dim. 4 | 0.21422 | 8.18 | 68.37 |
| Dim. 5 | 0.176997 | 6.76 | 75.12 |
| Dim. 6 | 0.153611 | 5.86 | 80.99 |
| Dim. 7 | 0.110744 | 4.23 | 85.22 |
| Dim. 8 | 0.099483 | 3.8 | 89.01 |
| Dim. 9 | 0.088909 | 3.39 | 92.41 |
| Dim. 10 | 0.080095 | 3.06 | 95.47 |
| Dim. 11 | 0.061016 | 2.33 | 97.8 |
| Dim. 12 | 0.036318 | 1.39 | 99.18 |
| Dim. 13 | 0.021388 | 0.82 | 100 |

Supplementary Table 1a: Results of CA run on per sample wood charcoal taxon counts from all sites included in the present study: eigenvalues and percentage of variance for dimensions.

| | Contribution to dimensions | | | | |
|------------------|----------------------------|--------------|--------------|--------------|--------------|
| | Dim 1 | Dim 2 | Dim 3 | Dim 4 | Dim 5 |
| <i>Juniperus</i> | 3.41 | 79.76 | 0.24 | 2.22 | 0.00 |
| <i>Quercus</i> | 20.55 | 5.87 | 42.25 | 3.99 | 3.12 |
| <i>Amygdalus</i> | 41.77 | 0.05 | 0.40 | 0.01 | 0.01 |
| <i>Pistacia</i> | 16.45 | 0.13 | 0.01 | 0.40 | 0.01 |
| <i>Prunus</i> | 0.10 | 0.09 | 0.01 | 0.44 | 0.17 |
| Maloideae | 0.45 | 0.21 | 0.22 | 0.15 | 34.76 |
| Ulmaceae | 5.29 | 0.01 | 41.93 | 22.31 | 0.04 |
| <i>Ulmus</i> | 2.25 | 0.01 | 3.12 | 4.87 | 0.02 |
| <i>Celtis</i> | 0.85 | 0.75 | 0.77 | 0.41 | 0.17 |
| Salicaceae | 7.70 | 7.55 | 9.34 | 46.42 | 1.43 |
| <i>Fraxinus</i> | 0.35 | 5.06 | 0.48 | 0.33 | 0.00 |
| <i>Tamarix</i> | 0.10 | 0.10 | 0.66 | 15.09 | 3.46 |
| <i>Artemisia</i> | 0.23 | 0.05 | 0.40 | 0.06 | 0.09 |
| Leguminosae | 0.51 | 0.36 | 0.18 | 3.29 | 56.70 |

Table 1b: Results of CA run on per sample wood charcoal taxon counts from all sites included in the present study: contribution of variables to dimensions.