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Woodland vegetation and fuel exploitation at the prehistoric campsite of Pınarbaşı, south-central Anatolia, Turkey: the evidence from the wood charcoal macro-remains

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Abstract

This paper presents the results of the analysis of wood charcoal macro-remains from the multi-period prehistoric rock shelters of Pınarbaşı in the Konya plain, south-central Anatolia. Retrieval and analytical methods are also reported in detail, together with some methodologies previously untested in the field of charcoal analysis aiming at the quantitative description of context-related variation in the preservation status of archaeological wood charcoal assemblages. The patterns observed in the charcoal record are interpreted as a reflection of the prehistoric strategies for firewood exploitation in their local and regional palaeoenvironmental context.

Keywords: Archaeobotany; Charcoal analysis; Firewood; Taphonomy; Central Anatolia; Neolithic; Turkey

1. The site of Pınarbaşı

Pınarbaşı (37°29′N, 33°02′E) is located near the centre of the Konya basin, in south-central Anatolia (Karaman province), some 30 km to the southeast of the Neolithic tell site of Çatalhöyük (Fig. 1). The site occupies the base of a cliff at the foothills of the volcanic massif of Karadağ, which rises from the nearly flat plain to an elevation of 2900 m, and is bordered by a small spring-fed lake and seasonally flooded depressions receiving runoff from Karadağ.

Presently, the area receives annually no more than 250 mm of rainfall at the plain level, most of which occurs in winter and early spring. Evaporation is high (c. 6 mm/day) due to the low relative humidity and the steady northerly winds. The climate is semi-arid with distinctly dry and hot summers and cool winters [8, pp. 7–9]. Arboreal cover is restricted on the slopes of Karadağ, mainly in the form of open deciduous oak forests. On the plain itself, wetland environments are rapidly diminishing due to global environmental change coupled with the continuously expanding irrigation works, the appropriation of land for the cultivation of cash crops and the practicing of large-scale animal husbandry. Today, the impact of modern economic activities is most evident in the channelling of water-courses for irrigation purposes and the overgrazing and burning of reed vegetation. At Pınarbaşı in particular, reed marshes have all but disappeared within the last five years, whereas formerly major lakes such as Hotamiş gölü immediately to the west of the site have also been reduced to stretches of very shallow, saline reed marshes.

The areas with archaeological deposits comprise four rock-shelters set against the cliff face which overlooks the plain, and a short peninsula extending into the former marshlands [22]. Excavation work was undertaken by a team from the University of Edinburgh under the direction of Trevor Watkins and in collaboration with the Karaman Museum over two consecutive seasons (1994–1995) on two separate locations: Site A (situated on the neck of the peninsula next to a recently dried spring-fed pool) and Site B (one of the rock-

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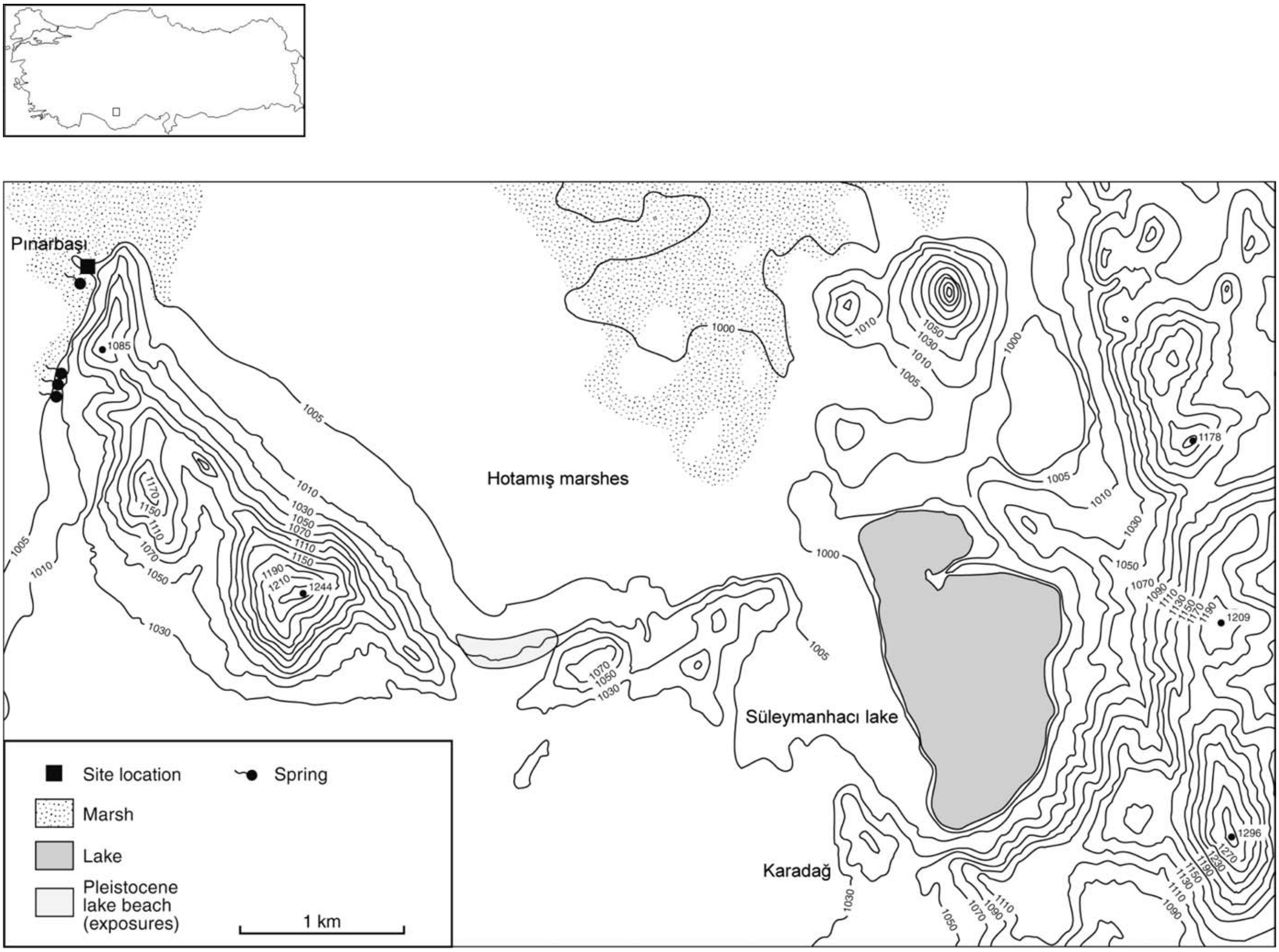


Fig. 1. Map showing the location of Pınarbaşı and the main topographic features of the area.

Table 1
List of radiocarbon dates from Pınarbaşı (after Watkins [22])

Laboratory	^{14}C yrs BP	Material	Context label	Features
OxA-5501	9140 ± 80	charcoal	ABU	Stone-built features
OxA-5500	9290 ± 80	charcoal	ABR	Chipped stone assemblage
OxA-5499	9050 ± 80	charcoal	ABJ	Chipped stone assemblage
OxA-5504	7450 ± 70	charcoal	BBA	Fill in the curving wall-charcoal lens
OxA-5503	7145 ± 70	charcoal	BAT	Fill in the curving wall-charcoal lens
OxA-5502	5725 ± 65	charcoal	BAI	Charcoal lens below capping of stones in shallow pit

shelters). The excavated deposits have been radiocarbon dated to the early Neolithic (Site A) and the late Neolithic/Chalcolithic (Site B) ([22]; Table 1). Lithics and animal bone were the principal finds, the latter comprising mainly caprovines, pigs, equids, birds and various small mammals. The faunal evidence and the lack of permanent habitation structures have suggested that both areas were used on a seasonal basis, as hunting and/or herding campsites (Denise Carruthers, pers. comm.)

2. Choice of samples and subsampling

During both excavation seasons, all deposits were systematically sampled for the recovery of plant and animal remains [22]. In total, 38 flotation samples were selected for charcoal analysis from the 67 originally submitted by Mark Nesbitt, the archaeobotanist responsible for the retrieval of charred plant remains in the field. No particular context type was singled out for analysis, since the overall lack of clearly defined features

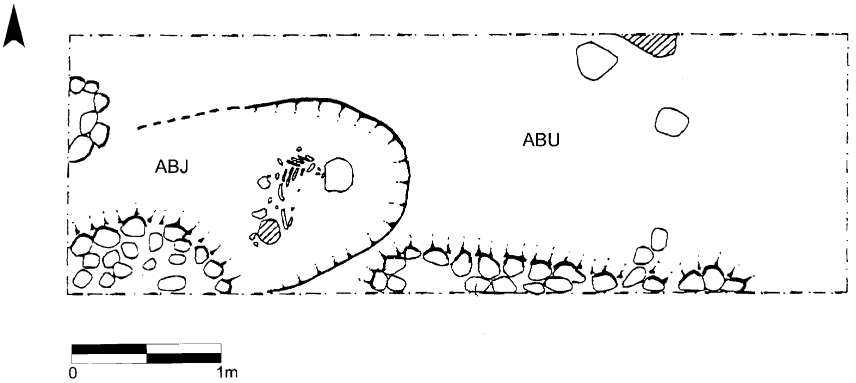


Fig. 2. General plan of Site A showing the early Neolithic deposits (modified from excavation archives).

suggested that some intermixing of the deposits might have occurred. Flotation samples were omitted from analysis only if there was too much uncertainty concerning the dating of the deposits, when a high number of samples were available from the same locus, or when there were extremely low quantities of charcoal remains in the samples submitted for analysis.

Given the large quantities of wood charcoal retrieved from most of the Pınarbaşı samples it was decided to examine at least 200 fragments from each, comprising 100 fragments from each of the >4 mm and >2 mm fractions of the dry-sieved flot. The aim was to allow for the better representation of potentially rare taxa (e.g. small-sized woods such as shrubs). Samples containing less than 200 fragments were examined in their entirety.

3. Description of sampled contexts

The early Neolithic assemblages examined from Site A include two loci, ABJ and ABU. ABU was the earliest excavated stratum and consisted of dark, humic loamy layers associated with the remains of three possible structures and a pit-cut (Fig. 2; [22]). ABJ was a thin stratum of fine, brown soil into which a small grave had been cut containing an infant inhumation. ABR (not shown in the plan of Fig. 2), a thin lens of reddish-brown soil, was located between these two strata. All three loci were sealed by a sterile layer of dark brown sands, which preceded the Chalcolithic, Roman and Byzantine deposits excavated in the same area.

Although all these early layers gave substantial quantities of very well preserved animal bone, the situation with charred plant remains was quite the opposite. ABR did not produce any charcoal remains at all. From a total of 60 litres processed from ABU and ABJ, only 0.47 g of charcoal were retrieved when dry-sieved. The limestone sediment matrix and the proximity of the site to the lakeshore may be responsible for the poor preservation of wood charcoal (e.g. through abrupt fluctuations in sediment moisture and the excessive accretion of minerals). Bioturbation from roots and insects was also evident amongst the upper late prehistoric strata. Hence, it was decided to limit laboratory analysis to the early Neolithic contexts that had produced secure radiocarbon dates (ABJ, ABU, ABR did not contain charcoal; see Table 1).

The deposits examined from Site B (the rock-shelter) can be broadly separated in three different groups:

1. A substantial late Neolithic assemblage was recovered from the infill of a curvilinear dry-stone structure (see Figs. 3 and 4). The latter appears to have been built as a revetment wall around a very large depression cut into pre-existing refuse deposits, and was infilled with steeply sloping layers of clayey and ashy soil interdigitating with thicker lenses of wood charcoal and animal bone. The overall lack of wear and/or weathering signs on the animal bone suggests that infilling had been a rather speedy process. No traces of floors or trampled surfaces were revealed at the base of this structure [22, pp. 52–53]. The sampled loci from this area include (from top to bottom) BAT, BAW, BAX, BBA and BBH (amounting to a total of 9 samples).
2. Another series of deposits originated from areas external to the curvilinear structure (BAV, BAY, BBC, BBD, BBE, BBG, BBH, BBI, BBJ; 19 samples). These included ashy grey layers, rich in animal bone and charcoal, interspersed with grey silty ash lenses (see Figs. 4 and 5). However, the lack of clearly demarcated features (hearths, walls, etc.) renders an attempt to attribute these layers to specific occupation phases somewhat doubtful. Based on the study of the lithic material, the suggestion has been put forward that an early Neolithic component is traceable in Site B (although of a seemingly different date from that of Site A) as well as late Neolithic and post-Neolithic elements [22, p. 55].
3. The latest deposits excavated so far in Pınarbaşı comprised two shallow, sub-circular pits with upper

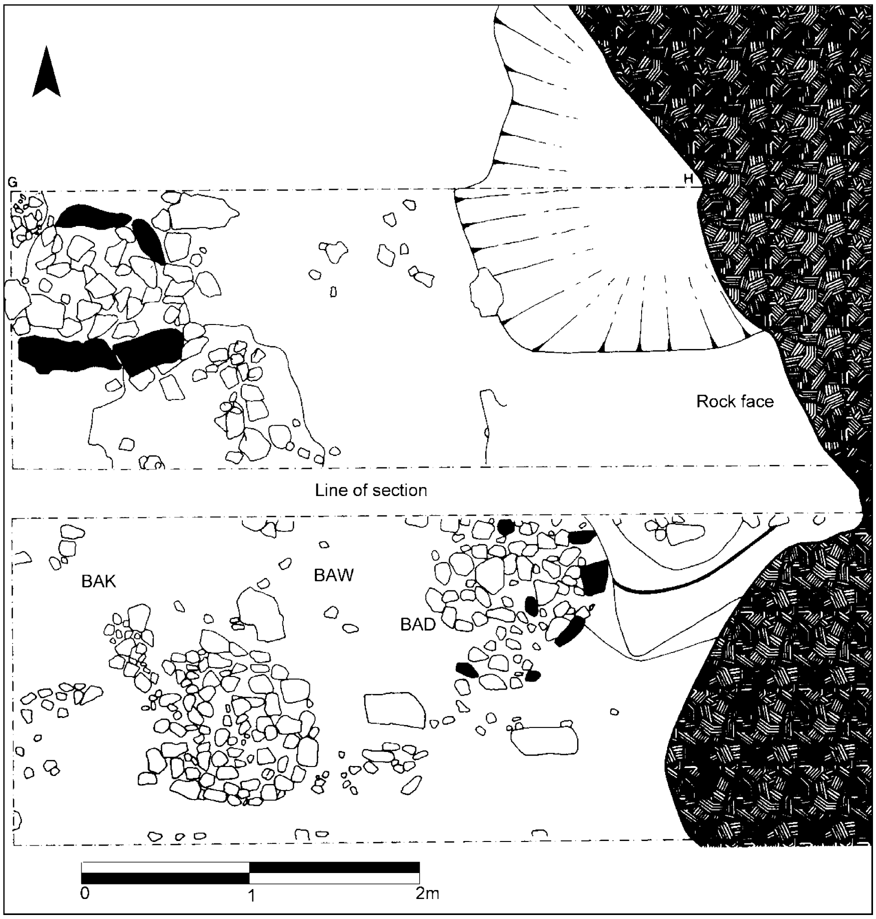


Fig. 3. Plan of Site B showing the upper layers of the infill of the curvilinear structure and the Chalcolithic fire-pits (modified from excavation archives).

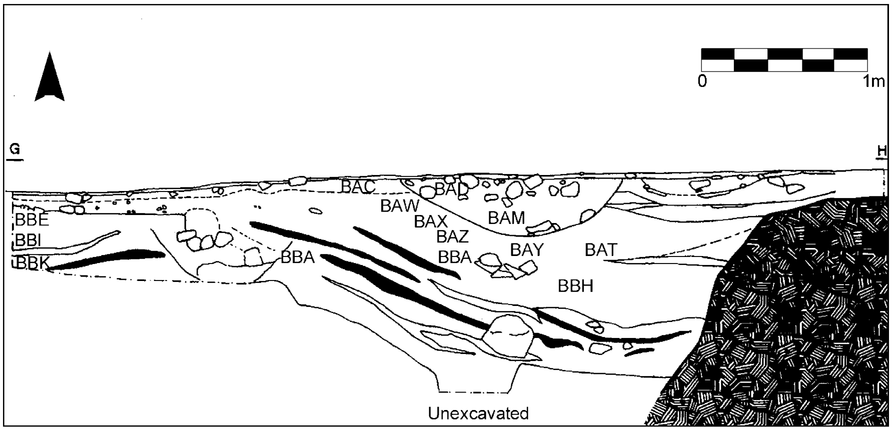


Fig. 4. Section showing the location of all sampled deposits in Site B (modified after excavation archives).

fills of medium-sized stones, some of which bore traces of burning (8 samples; see Figs. 3 and 4). The easternmost pit cut through the base of an earlier fire installation and was lined with a series of upright stones. Its fill layers (BAD, BAI, BAM) gave one radiocarbon date of 5725 ± 65 ^{14}C yr BP (BAI). However, the precise dating of BAM remains somewhat uncertain, since it produced no artefactual evidence. Nearby this feature, on the western side of the trench, a shallow pit was unearthed (BAJ, BAK), which cut through an area rich in charcoal lenses (BBC, BBI, BBE). The excavators have interpreted

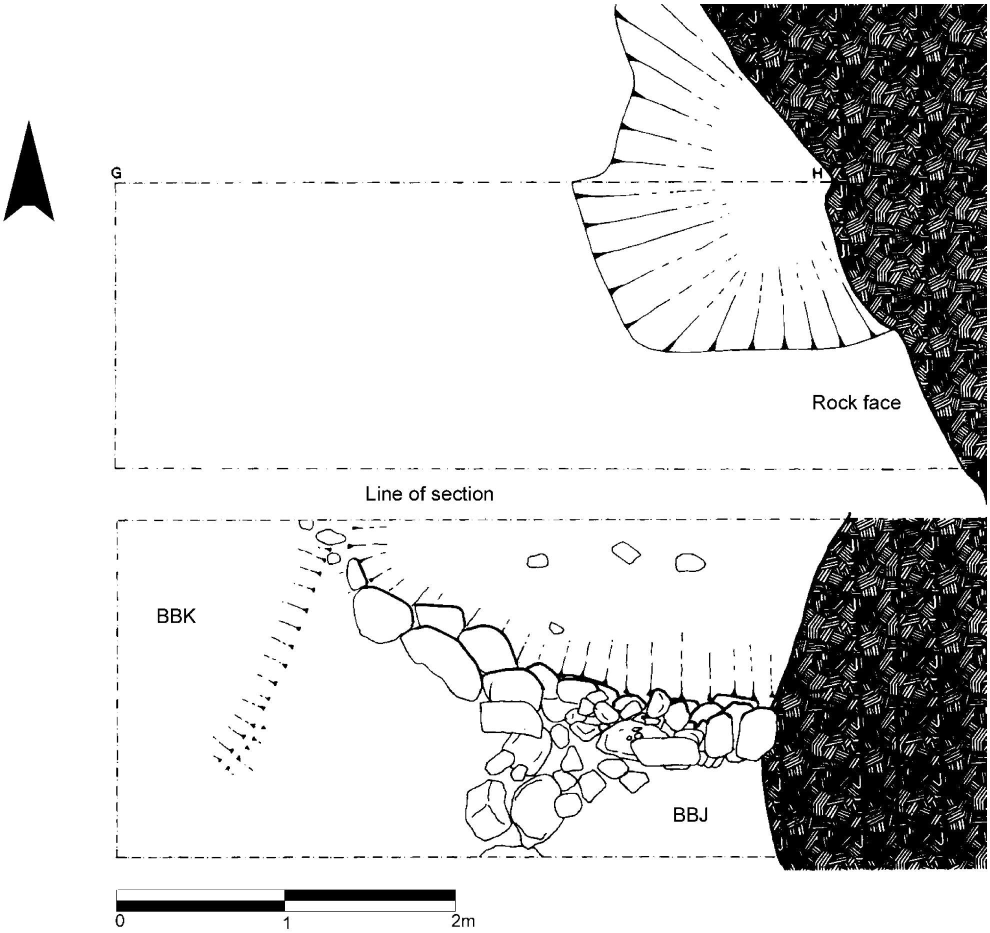


Fig. 5. Plan showing the location of some of the earliest excavated deposits outside the curvilinear structure in Site B (modified after excavation archives).

both these features as cooking installations (hearths and/or fire pits). The latest locus to be sampled was BAC, a layer of stony friable soil sealing the aforementioned deposits and the first archaeological stratum encountered after the removal of the topsoil.

4. Quantified results

4.1. Presence of taxa

Eighteen different taxa were positively identified amongst the Pınarbaşı wood charcoal macro-remains. The commonest taxa were *Pistacia* and *Amygdalus* (100% presence in all areas, apart from locus ABU; see Tables 2 and 3 and Fig. 6). *Celtis* followed short, with presence scores ranging from 75% (external late Neolithic and Chalcolithic deposits) to 88% (late Neolithic infill of the curvilinear structure).

Several taxa were present only in particular phases and/or contexts. These were *Acer* (BAV: late Neolithic) and Maloideae (BAC, BAJ: Chalcolithic). It is also worth noting that Chenopodiaceae gave a single fragment (ABU) whilst *Prunus* was recorded once in the early Neolithic deposits (ABU) and in a Chalcolithic context (BAC). Similarly, *Quercus* and *Juniperus* occurred only twice across the entire sequence (BAZ, BBG: late Neolithic; BBJ/BAD: late Neolithic–Chalcolithic, respectively). *Rosa* and *Tamarix* were represented by higher presence scores. Interestingly, the frequency of occurrence of both taxa decreases by some 30% to 40% from the Neolithic to the Chalcolithic levels. It is suggestive of a general pattern that the same phenomenon applies to the presence scores of *Fraxinus* as well.

Overall, apart from the trends discussed above, very little patterning can be discerned in the Pınarbaşı wood charcoal assemblages. A wide array of taxa including *Rhamnus*, Fabaceae, Asteraceae and *Capparis* have very low sample presence. Of these, only Asteraceae occurred in all three phases. At the same time, the presence scores of the rest of the hygrophilous taxa (e.g. *Clematis*, *Phragmites*) were too low to allow a positive evaluation of their potential significance.

Table 2
Percentage presence scores of taxa occurring in all Neolithic and Chalcolithic contexts from Site B

Phase	Number of samples in which taxa were present			% presence scores		
	LN/Infill	LN/External	CHL	LN/Infill	LN/External	CHL
Pistacia (terebinth)	9	19	8	100	100	100
Amygdalus (almond)	9	19	8	100	100	100
Rosa (rose)	7	12	3	78	63	38
Prunus (wild plum)			1			13
Maloideae (hawthorn/pear)			2			25
Celtis (hackberry)	8	14	6	89	74	75
Quercus (oak)		1	1		5	13
Acer (maple)		1			5	
Juniperus (juniper)	1	1		11	5	
Fabaceae (legumes)	1	3		11	16	
Capparis (caper)	1	2		11	11	
Asteraceae (wormwood)	1	3	1	11	16	13
Tamarix (tamarisk)	7	12	2	78	63	25
cf. *Clematis* (clematis)	1	2	1	11	11	13
Fraxinus (ash)	6	7	1	67	37	13
Phragmites (reed)	1	2	3	11	11	38
Rhamnus (buckthorn)	1		4	11		50
Total number of samples	9	19	8	100	100	100

Table 3
Summary absolute and percentage fragment counts for Site A and Site B (percentage fragment counts have been calculated after excluding indeterminate fragments from the sums)

Phase	Absolute fragment counts				% fragment counts			
	EN	LN/Infill	LN/External	CHL	EN (%)	LN/Infill (%)	LN/External (%)	CHL (%)
Pistacia (terebinth)	1	284	1071	327	1.64	19.68	35.57	30.36
Amygdalus (almond)	20	1011	1706	667	32.79	70.06	56.66	61.93
Rosa (rose)	5	24	25	3	8.20	1.66	0.83	0.28
Amygdalus/*Rosa*	26	47	94	16	42.62	3.26	3.12	1.49
Prunus (wild plum)	3			1	4.92			0.09
Maloideae (hawthorn/pear)				15				1.39
Celtis (hackberry)		43	61	12		2.98	2.03	1.11
Quercus (oak)			1	1			0.03	0.09
Acer (maple)			1				0.03	
Juniperus (juniper)		1	2			0.07	0.07	
Fabaceae (legumes)	1	1	3		1.64	0.07	0.10	
Capparis (caper)		1	2			0.07	0.07	
Asteraceae (wormwood)				1				0.09
Artemisia (wormwoods)	3	1	4	2	4.92	0.07	0.13	0.19
Chenopodiaceae (chenopods)	1				1.64			
Tamarix (tamarisk)		12	24	4		0.83	0.80	0.37
Clematis (clematis)		1	6	1		0.07	0.20	0.09
Fraxinus (ash)		15	9	2		1.04	0.30	0.19
Phragmites (reed)	1	1	2	5	1.64	0.07	0.07	0.46
Rhamnus (buckthorn)		1		20		0.07		1.86
Indet.	78	357	789	381				
Total	139	1800	3800	1458	100	100	100	100
Total (-Indet.)	61	1443	3011	1077				

4.2. Absolute and percentage fragment counts

Absolute and percentage fragment counts (comprising as mentioned earlier all fragments >2 mm of the dry-sieved flots) from all phases are presented in Table 3 and Figs. 7 and 8. In order to give a clearer picture of the fluctuations in the abundances of individual taxa, percentage fragment counts were calculated after excluding

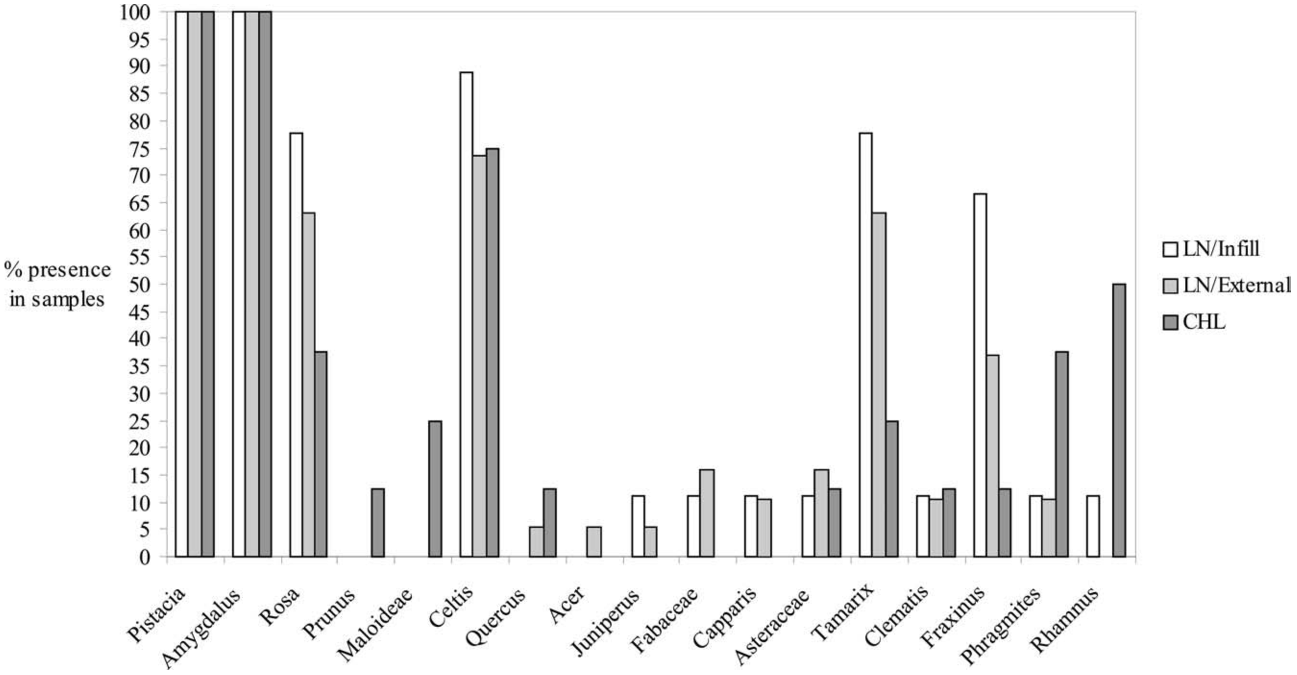


Fig. 6. Bar chart showing percentage presence scores of all taxa occurring in late Neolithic and Chalcolithic contexts from Site B (no. of samples=36; LN/infill=9, LN/external=19, CHL=8).

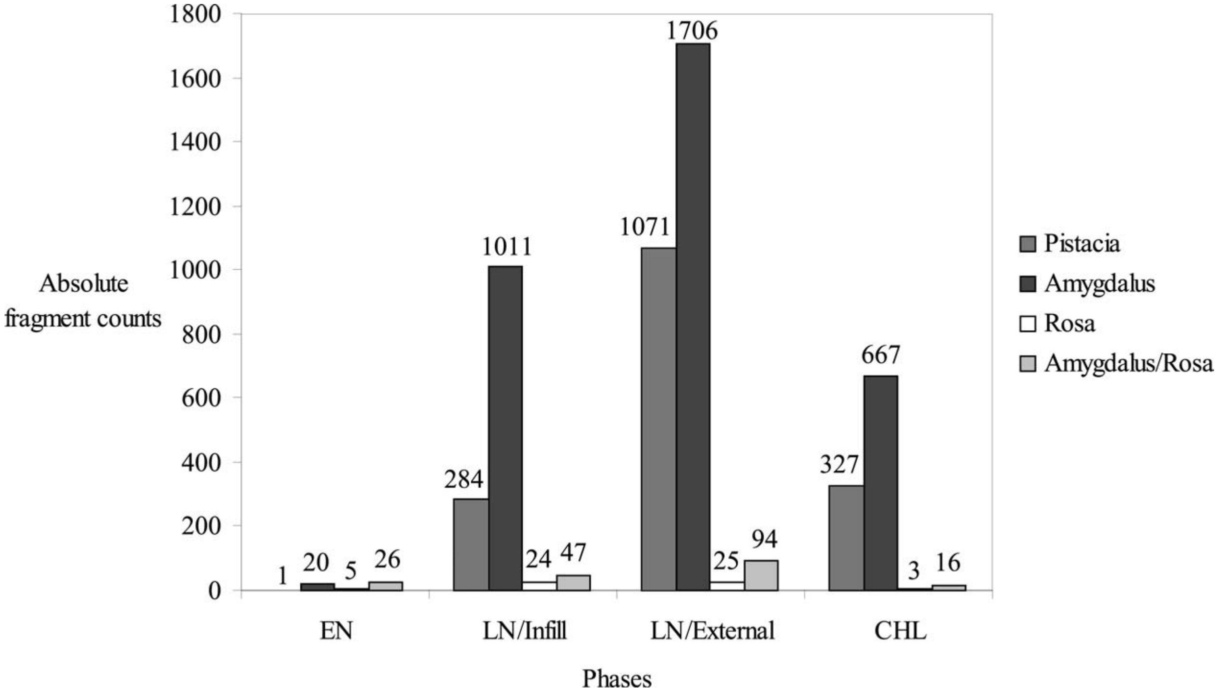


Fig. 7. Bar chart showing summary absolute fragment counts of the main taxa for Site A and Site B (no. of samples=38; numerical values for all taxa are listed in Table 3).

indeterminate fragments from the sums (which in all cases represented unidentified fragments and not indeterminate taxa).

There were remarkable similarities in the relative proportions of the three dominant taxa (*Pistacia*, *Amygdalus*, *Rosa*) in all four assemblages. Together they accounted for approximately 95% of the sample composition within each assemblage. For the early Neolithic samples from Site A, one should also note the high percentages of *Amygdalus*/*Rosa* (i.e., those specimens

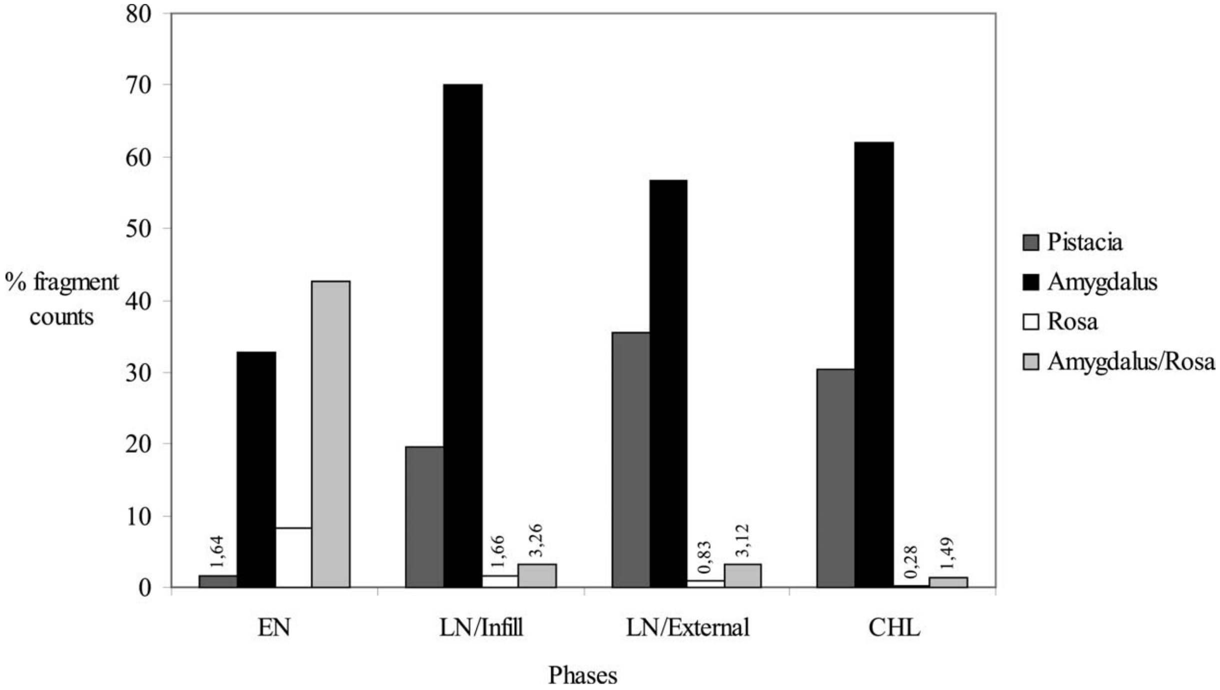


Fig. 8. Bar chart showing summary percentage fragment counts for major taxa from Site A and Site B (no. of samples=38; percentages have been calculated after excluding numbers for indeterminate fragments from the sums; numerical values for all taxa are listed in Table 3).

that were too small and/or too crumbled to be positively ascribed to either taxon) and the fact that out of 139 examined fragments only 61 were identified.

Celtis, Asteraceae, *Tamarix* and *Fraxinus* all displayed remarkably low percentage fragment counts compared to their presence scores. For *Celtis* (1–3%), *Tamarix* and *Fraxinus* (overall less than 1%) these low relative frequencies seem to be more or less evenly distributed across samples. The same cannot be said however for other taxa, as for example *Prunus*, *Quercus*, *Acer*, *Juniperus* and *Rhamnus* (compare Tables 2 and 3). Overall, with the exception of the dominant taxa, the assemblages deriving from the Chalcolithic fire installations and their associated external layers displayed very uneven taxon frequencies across samples compared to the Neolithic contexts.

4.3. Taphonomic analysis

In order to describe quantitatively the taphonomic characteristics of the Pınarbaşı charcoal assemblages, a series of quantitative measurements were applied to these datasets. For the purpose of the present study two indices, normally reserved for the analysis and interpretation of charred seed assemblages, were used: density (expressed as the total weight of charcoal material per litre of floated sediment) and diversity (Shannon–Weaver index) (cf. [16,17]). Density measurements can provide a useful means for identifying and evaluating variations in the deposition, preservation and rates of recovery of charcoal remains. Diversity indices (although caution is urged by many analysts in their interpretation) can serve the purpose of distinguishing between “generalised” and “specialised” plant assemblages [17]. “Generalised” plant assemblages may represent for example midden layers (usually expected to hold charcoal refuse originating activities and accumulated over long periods) as opposed to “specialised” ones such as hearths (which could stand for single events, specialised functions or their last phase of use prior to abandonment; for a full discussion of the impact of context type on the taxonomic composition of charcoal assemblages see [6, pp. 61–63]). Hence, diversity measurements could assist in separating different botanical “signatures” which may or may not be characteristic of particular context types.

Recent research in the taphonomic analysis of charred seed remains has further indicated that it is feasible to construct indices describing their preservation and fragmentation status (cf. [7]). For the purpose of this study, dealing exclusively with wood charcoal macro-remains, it was deemed appropriate to devise a comparison ratio (called the Fragmentation/Preservation index) in which the denominator is the total number of identified items (>2 mm) per sample and the numerator is the sum of indeterminate fragments from the same sample. Undoubtedly, the occurrence and frequency of indeterminate fragments in a charcoal assemblage (excepting those cases where the botanical identification of particular taxa is not possible, e.g. due

Table 4
List of details on all sampled context from Site A and Site B, including phasing, context code, litres of soil floated, total flot weight (TotalW), numbers of ID and indet. fragments, and density (STDW), fragmentation/preservation (Fr/Pr index) and diversity (SW index) values

	Phase	Locus	Litres	Sample no.	Total	STDW	Total (-Indet)	Indet.	Fr/Pr Index	SW Index
1	EN	ABJ	30	31	0.28	0.01	54	46	0.85	0.50
2	EN	ABU	30	36	0.19	0.01	7	32	4.57	0.44
3	LN/Infill	BBH	18	116.2	21.88	1.22	144	56	0.39	0.44
4	LN/Infill	BBH	18	118.2	126.84	7.05	171	29	0.17	0.45
5	LN/Infill	BBH	19	119.3	27.96	1.47	150	50	0.33	0.56
6	LN/Infill	BBH	20	122.2	36.11	1.81	178	22	0.12	0.36
7	LN/Infill	BBA	120	38	111.18	0.93	175	25	0.14	0.37
8	LN/Infill	BAZ	10	37	11.13	1.11	162	38	0.23	0.47
9	LN/Infill	BAX	76	34	74.24	0.98	155	45	0.29	0.32
10	LN/Infill	BAW	20	30	50.09	2.50	160	40	0.25	0.28
11	LN/Infill	BAT	40	32	62.06	1.55	148	52	0.35	0.35
12	LN/External	BBK	20	129.1	19.52	0.98	128	72	0.56	0.42
13	LN/External	BBJ	20	128.1	169.46	8.47	149	51	0.34	0.45
14	LN/External	BBI	20	114.1	17.33	0.87	157	43	0.27	0.43
15	LN/External	BBI	20	120.2	39.13	1.96	159	41	0.26	0.39
16	LN/External	BBG	20	113.1	185.2	9.26	177	23	0.13	0.44
17	LN/External	BBG	19	126.2	81.56	4.29	163	37	0.23	0.59
18	LN/Extemal	BBG	20	127.2	51.41	2.57	154	46	0.30	0.29
19	LN/External	BBE	17	109.1	52.93	3.11	154	46	0.30	0.21
20	LN/Extemal	BBE	10	110.3	14.14	1.41	157	43	0.27	0.33
21	LN/External	BBE	18	111.2	42.89	2.38	149	51	0.34	0.31
22	LN/Extemal	BBE	18	112.2	212.63	11.81	160	40	0.25	0.48
23	LN/Extemal	BBD	40	103	51.74	1.29	160	40	0.25	0.42
24	LN/Extemal	BBD	22	106	84.24	3.83	167	33	0.20	0.34
25	LN/Extemal	BBD	20	107	131.23	6.56	182	18	0.10	0.38
26	LN/Extemal	BBD	20	108	99.78	4.99	159	41	0.26	0.43
27	LN/Extemal	BBC	25	101	80.68	3.23	165	35	0.21	0.42
28	LN/Extemal	BAY	36	33	108.48	3.01	161	39	0.24	0.34
29	LN/Extemal	BAV	36	27	12.08	0.34	146	54	0.37	0.37
30	LN/Extemal	BAV	36	28	18.02	0.50	164	36	0.22	0.45
31	CHL	BAK	60	18	80.96	0.732	161	39	0.24	0.39
32	CHL	BAJ	40	17	27.27	0.68	131	69	0.53	0.50
33	CHL	BAI	40	15	246.05	6.15	166	34	0.20	0.42
34	CHL	BAD	20	14	37.16	1.86	158	42	0.27	0.39
35	CHL	BAM	40	21	32.05	0.80	127	73	0.57	0.42
36	CHL	BAM	38	22	66.6	1.75	152	48	0.32	0.19
37	CHL	BAC	20	5	42.26	2.11	147	53	0.36	0.40
38	CHL	BAC	20	8	24.44	1.22	35	23	0.66	0.38
					Mean	2.76			0.42	0.40
					Median	1.78			0.27	0.41

to the lack of adequate reference material) is a function of more than one parameter, including the physical properties of wood, firing conditions, post depositional alterations, etc. Such an index cannot therefore account for possible variations in the preservation of individual taxa that may respond in complex ways to different burning and post depositional environments. Its usefulness lies more with identifying general trends in the taphonomic characteristics of entire archaeological charcoal assemblages, thus allowing an objective assessment of the relationship between overall preservation status and context type. Values of <0.5 of the Fr/Pr index were taken to indicate low fragmentation and overall good preservation, 0.6–0.9 moderate to high proportions of indeterminate fragments and 1–5 very high proportions of indeterminate fragments.

To assess variation within the charcoal assemblages, the values for density, diversity and Fr/Pr indices of individual samples were compared with the average values (mean and median) for all samples (Table 4, Fig. 9). The results of all three indices were compared by means of correlation coefficients (Spearman's Rank Correlation Coefficient used for comparing data that are not normally distributed [9, pp. 103–114]) (see also Table 5). Simple correspondence analysis (cf. [5]) was also used, in order to obtain a clearer picture of context-related variation in sample composition. The datasets

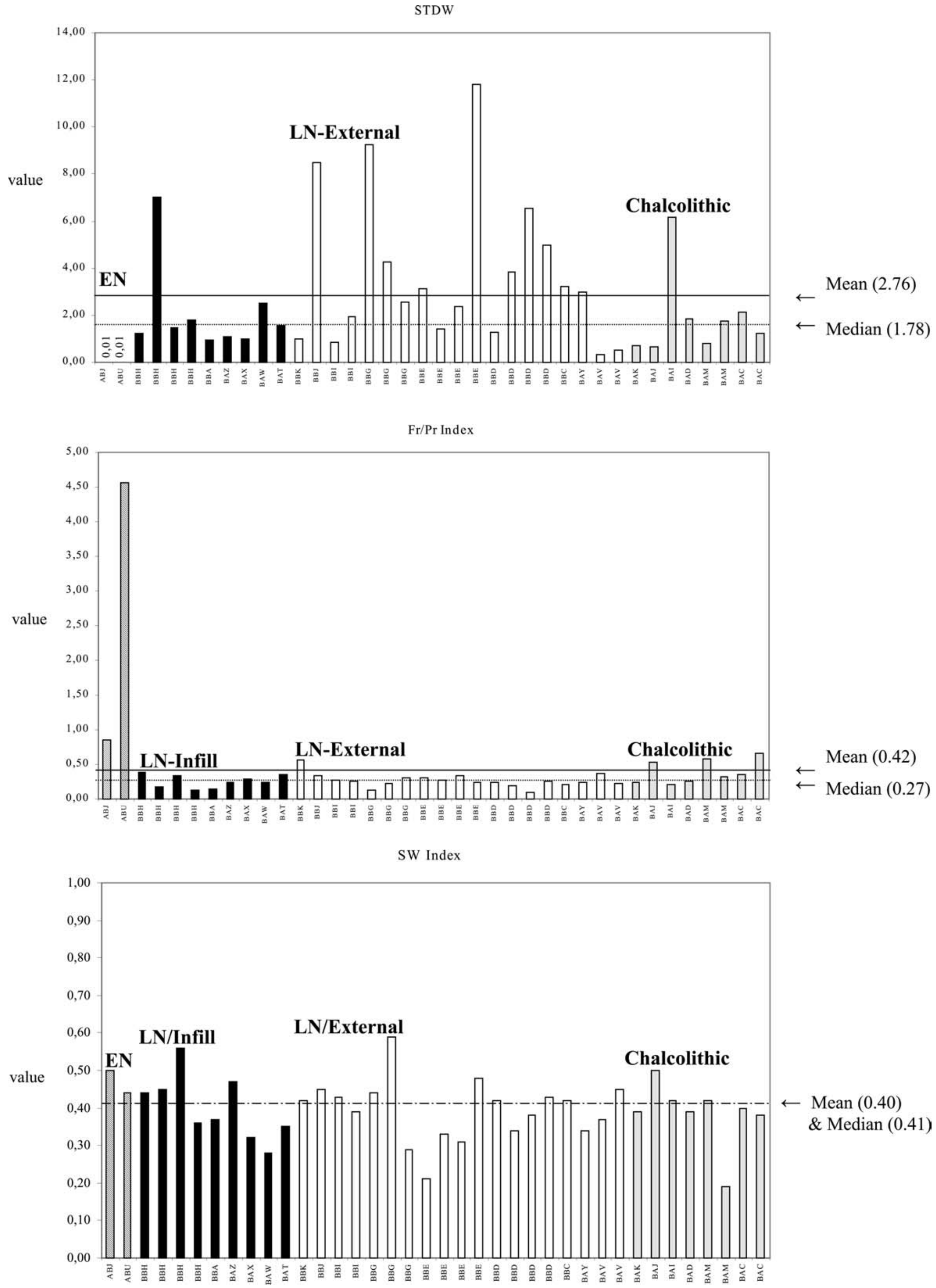


Fig. 9. Bar charts showing values of density (top), Fr/Pr (middle) and diversity (bottom) indices for all sampled contexts from Site A and Site B (x axis denotes sampled loci; no. of samples=38; for details on sample information see Table 4).

analysed by multivariate statistics consisted of the absolute fragment counts of each taxon in every examined sample. In order to obtain a clearer picture of likely patterning in sample composition, taxa present in less than 10% of all samples were not considered for correspondence analysis.

Table 5
Spearman's Rank correlation coefficients (rs) of comparisons between density–fragmentation/ preservation, density–diversity and fragmentation/preservation–diversity indices

	Density (STDW)–Fr/Pr	Density (STDW)–Diversity (S–W)	Fr/Pr–Diversity (S–W)
Correlations performed with all samples (*n*=38)	rs=−0.51 (*P* 0.001)	rs=−0.07 (*P* 0.683)	rs=0.04 (*P* 0.780)
Correlations performed with Late Neolithic and Chalcolithic samples (*n*=36)	rs=−0.43 (*P* 0.001)	rs=0.03 (*P* 0.844)	rs=−0.07 (*P* 0.696)
Correlations performed with Late Neolithic samples (*n*=28)	rs=−0.35 (*P* 0.068)	rs=0.13 (*P* 0.507)	rs=−0.15 (*P* 0.450)

4.3.1. Density

From the 38 samples examined, 12 gave charcoal densities above both the mean and median for all samples (see Fig. 9). These included one locus (BBH s.118.2) from the late Neolithic infill of the curvilinear structure and another (BAI) from the Chalcolithic covered fire-pits. The rest all came from the external lenses of charcoal mixed with animal bone (BAY, BBC, BBD s.106, 107, 108, BBE s.109.1, 112.2, BBG s.113.1, 126.2, BBJ) and identified by the excavators as general activity areas dating to the Neolithic. BBH (s.122.2; infill) and BAD (from the same fire installation as BAI) gave charcoal densities above the median, alongside the external Neolithic layers (BBE s.111.2, BBG s.127.1 and BBI s.120.2) and BAC (s.5).

By contrast, the early Neolithic contexts (ABJ, ABU) gave extremely low densities. Low values were also obtained from locus BAV (comprising of the uppermost external lenses of charred material). Somewhat higher were the densities of the material derived from the other Chalcolithic fire installation (the shallow fire-pit containing BAJ, BAK, BAM).

Overall, it appears that the external activity areas (with the exception of locus BAV which represents deposits closer to the surface) held the largest concentrations of wood charcoal, in contrast to the majority of the infill layers. Dense charcoal assemblages were also contained in at least one of the Chalcolithic fire installations and within the uppermost excavated layers (BAC).

4.3.2. Fragmentation/preservation

With the exception of the early Neolithic layers and some of the late prehistoric contexts, the charcoal assemblages from Pınarbaşı were remarkably well preserved. It is perhaps significant to note that most of the indeterminate fragments displayed signs of extreme thermal degradation, whereas in very few cases (Site A) identification was not achieved due to the presence of mineral inclusions. Overall, 32 samples gave values below the mean whereas 17 of these had values below the median as well. Most of the remaining samples (with the exception of those discussed above) had values slightly higher or equal to the median.

The only loci that gave very high values of the Fr/Pr index (well above the mean and the median) were ABJ and ABU. Much lower values, albeit still above the mean and the median, were obtained for BAJ and BAM (s.21) (Chalcolithic fire-pit), BBK (one of the external lenses truncated by the Chalcolithic fire installations), BAV (s.27) and BAC (s.8). Above the median were also the values of BAT, BBH (s.116.2, 119.3) from the infill layers, and BBE (s.111.2), BBJ from the external activity areas.

4.3.3. Diversity

Only 7 samples produced diversity values well below the mean and the median. About half of the examined samples (19) had values above the mean and the median, whilst the rest gave values either equal or slightly below them. This almost even distribution of diversity values points to an overall lack of differences in sample composition that could be attributed to the impact of context type.

4.3.4. Correlation between density, fragmentation/preservation and diversity measurements

The first run of correlation statistics included all 38 samples (see Fig. 10). The correlation scatterplots indicated that the Fr/Pr index values for the early Neolithic samples (ABJ, ABU) affected seriously the strength and nature of the correlations, particularly in relation to comparisons between density–Fr/Pr (rs=−0.51, *P* 0.001), since both assemblages had very low densities which were matched by high Fr/Pr values (see also Table 4). Therefore it was decided to exclude these samples from further statistical analysis.

The second run was performed with all 36 samples from the late Neolithic/Chalcolithic deposits. The comparisons made by Spearman's Rank Correlation Coefficient indicated that there was a significant negative correlation between density–Fr/Pr (rs=−0.43, *P* 0.001), a weak positive correlation between density–diversity (rs=0.03, *P* 0.844) and a weak negative correlation between Fr/Pr–diversity (rs=−0.07, *P* 0.696) (Table 5, Fig. 11.i).

In order to check whether the negative correlation between density–Fr/Pr could reflect to any extent

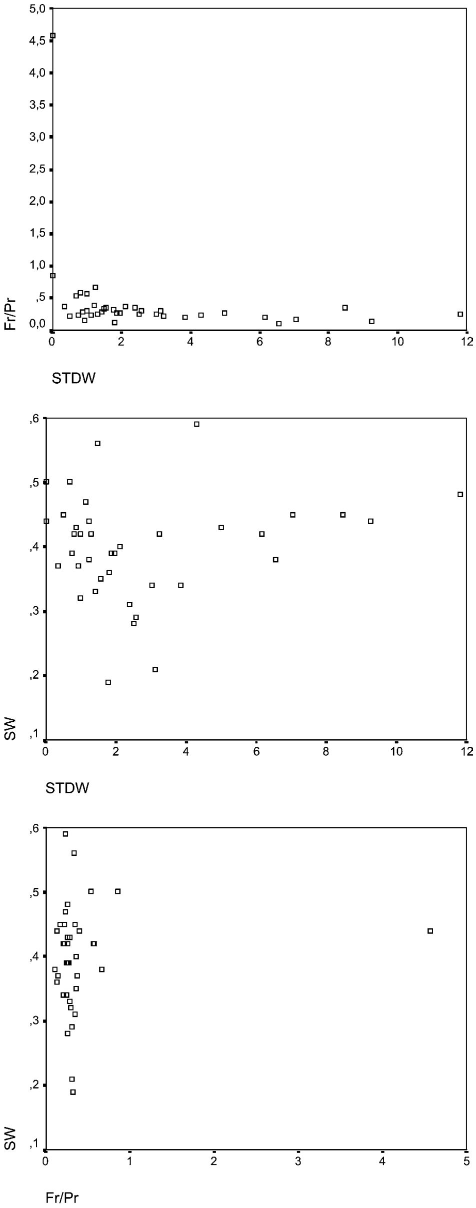


Fig. 10. Correlation scatterplots for density (STDW), fragmentation/preservation (Fr/Pr index) and diversity (S–W index) values of all samples from Site A and Site B (for correlation statistics and the correspondent probability values see Table 5).

patterning introduced by context type, a third run of the same tests was performed, this time excluding the Chalcolithic contexts and their associated deposits (BAM, BAK, BAJ, BAI, BAD, BAC). The rationale for this was that they represented short-term depositional contexts (fire installations) and for that reason very likely to have been affected by specific taphonomic parameters untypical of the assemblage as a whole. The decision to group BAM (despite the dating uncertainties) with the Chalcolithic assemblages was based on two observations: it gave overall high Fr/Pr values, which suggest similar sources of influence in what concerns charcoal fragmentation (see Fig. 9, Table 4). Furthermore, BAM had been heavily disturbed by the overlying Chalcolithic fire installation [22].

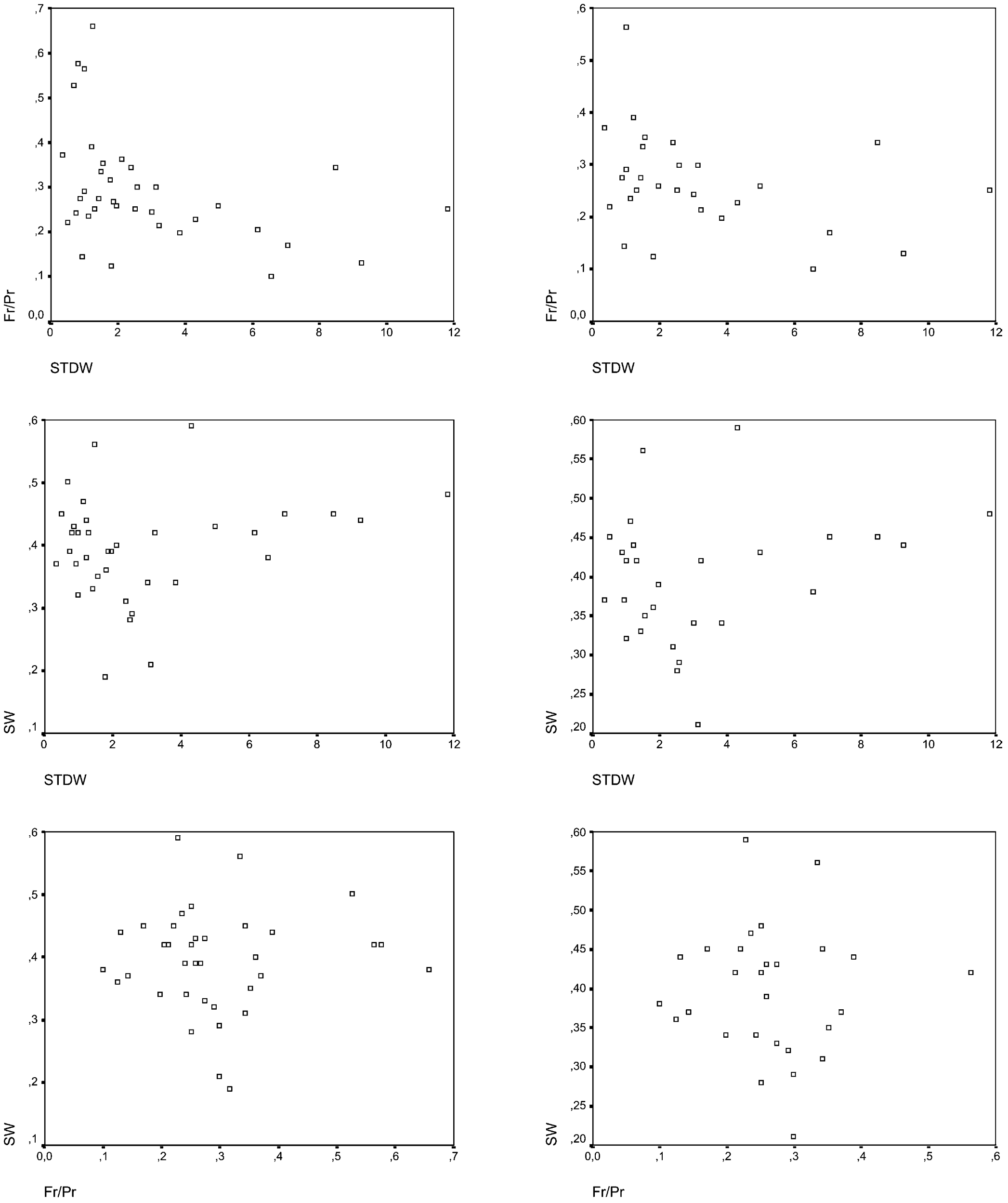
The results of the third run (see also Fig. 11.ii, Table 5) indicated that, whilst almost identical patterns arose for the rest of the correlations, there emerged no significant negative correlation between density–Fr/Pr ($rs = -0.35$, P 0.068). They appear therefore to add further credence to the prediction that the Chalcolithic fire installations and their associated layers held more or less distinct assemblages in what concerns their taphonomic characteristics and depositional histories.

4.3.5. Multivariate analysis

In order to investigate further context-related variation and thus evaluate patterns in taxon representation between different contexts, multivariate statistics were used. The main purpose of this exercise was to check whether the observations on sample composition obtained through the methods discussed before, would be reproduced in multivariate analysis. Fig. 12 shows the correspondence analysis scatterplots for the Pınarbaşı charcoal samples, grouped by phase (early Neolithic, late Neolithic, Chalcolithic). Although all samples were included in the analysis, the early Neolithic assemblages were added as supplementary (i.e., passive) samples (supplementary samples do not influence the ordination axes, however they are added afterwards so that their relation to the other samples can be assessed from the ordination diagram). The only differentiation evident in taxon representation is observed between the bulk of the late Neolithic assemblages, and the early Neolithic and some of the Chalcolithic samples, that have relatively larger proportions of rare taxa such as *Rhamnus*, Asteraceae and *Phragmites*. Otherwise concerning taxonomic composition the charcoal assemblages present a very uniform picture, irrespective of context type.

5. Implications for the taphonomic history of the Pınarbaşı charcoal assemblages

The lack of a clear negative correlation between density and diversity values suggests that the same range of species was in use throughout the occupation of the site, irrespective of potential taphonomic biases introduced by context type and/or temporal differences in the intensity and the range of activities associated with fuel collection and use. To this, additional support offers the lack of correlation between Fr/Pr and diversity. In other words, both the best and the least preserved deposits gave rise to almost identical assemblages in terms of taxonomic composition. Not only do samples contain in almost all cases the same range of taxa, but in approximately equal proportions as well in what concerns the dominant taxa (*Pistacia*, *Amygdalus*, *Rosa* and to a



i. **ii.**

Fig. 11. Correlation scatterplots for density (STDW), fragmentation/preservation (Fr/Pr index) and diversity (S–W index) values of (i) all samples from Site B and (ii) all Neolithic samples from Site B (for correlation statistics and the correspondent probability values see Table 5).

lesser extent *Celtis*, *Tamarix* and *Fraxinus*). The same pattern is also evident from the results of correspondent analysis.

In the light of the preceding analysis and the description of the archaeological attributes of the sampled contexts it becomes evident that there are three distinct sets of deposits, each with its own characteristics as a result of their different depositional and post-depositional histories.

The infill layers of the Neolithic stone enclosure have given generally less dense assemblages than the external activity areas, which were in existence before its construction and continued to be frequented afterwards. The remarkable similarities noted between the two areas with respect to sample diversity and the state of preservation of the charcoal assemblages, should be attributed to the rapid process of infilling, which prevented the severe weathering of charred plant remains. At the same time, the external activity areas saw much denser concentrations of wood charcoal, probably as a result of the intermittent use of the rock-shelter for carcass processing by hunting and/or herding groups paying minimal

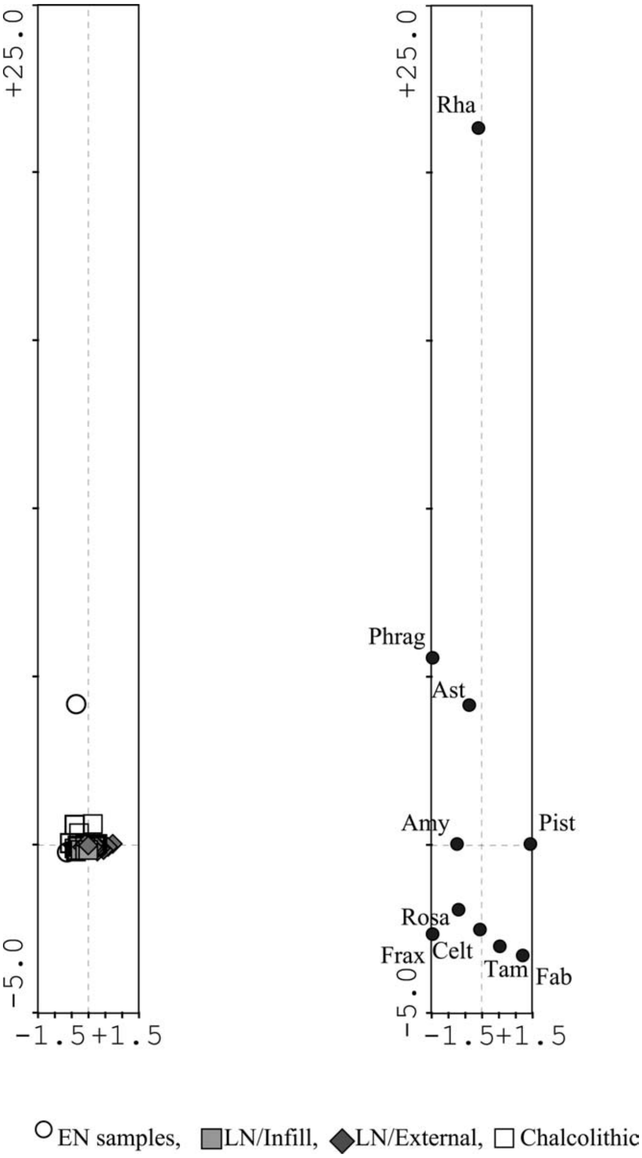


Fig. 12. Correspondence analysis scatterplots (left sample plot, right species plot of the same samples) of all examined contexts from Site A & Site B (taxa present in less than 10% of the samples have been excluded from the analysis).

attention to the disposal of fire-related debris in areas spatially removed from the main activity spots.

On the other hand, the Chalcolithic fire installations and their associated deposits held charcoal assemblages which appear to represent short-term events and, for that reason, much less coherent in terms of their overall preservation and fragmentation status. The relatively high charcoal densities recorded for some of these contexts (e.g. BAI) can be explained as a result of their structure (covered fire-pits), which preserved in a selective manner lenses of fire-related debris.

The fact that, despite such differences, all three groups of contexts gave almost identical charcoal assemblages in terms of their taxonomic composition and the relative proportions of individual taxa (especially the dominant ones), suggests that broadly the same range of firewood species was exploited throughout the history of human habitation at the Pınarbaşı rock-shelter. The low relative frequencies of shrubs (Fabaceae, Asteraceae, Chenopodiaceae) and reeds (*Phragmites*) may relate to the small size of their stems/stalks and therefore the likelihood that they were burnt entirely in these open hearths. On the other hand, the survival within the Chalcolithic fire installations of charcoal from taxa such as *Prunus*, Maloideae, *Quercus* and *Rhamnus*, which appear very infrequently throughout the sequence, may be due at least in part to the protection afforded to these deposits by the stone clusters covering the fire-pits.

6. The local vegetation and environments

The charcoal assemblages retrieved from all excavated deposits are dominated by tree and shrub taxa that can be attributed to a vegetation type very much akin to woodland–steppe comprising widely spaced, drought-resistant trees such as terebinths (*Pistacia*), almonds (*Amygdalus*), hackberries (*Celtis*) and buckthorns (*Rhamnus*), with an understorey of shrubs such as Asteraceae (e.g. *Artemisia*) and Lamiaceae, alternating with stretches of grassland. They also include a smaller hygrophilous component (*Tamarix*, *Fraxinus*, *Phragmites*) that can be identified with submerged marshes and riparian forests growing around the freshwater spring-fed pool and the shallow saline lake depressions receiving seasonal runoff from the volcanic uplands of Karadağ. Similar hydrological conditions during the early Holocene have been suggested for the marshes bordering the Pınarbaşı rock-shelters [18].

In Central Anatolia, such associations of light-demanding trees and shrubs (including *Celtis tournefortii*) are encountered in Cappadocia almost exclusively on rocky outcrops [29]. Outside Anatolia, the closest present-day ecological parallels are represented by woodland–steppe in northeast Syria, in the areas of Jebel Abdul Aziz, Jebel Abu Rujmein and Jebel Bishri [13] and in southern Jordan [14]. Almonds (*Amygdalus orientalis*, *A. korschinskii*) and terebinths (*Pistacia atlantica*) are usually the dominant species occasionally associated with hawthorns (*Crataegus aronia*) and shrubby buckthorns (*Rhamnus*). Undershrubs may include wormwoods (*Artemisia herba-alba*), capers (*Capparis*), rosebushes (*Rosa*) and various xerophytic hemicryptophytes of the Lamiaceae family such as *Phlomis* spp.

These descriptions match very closely the taxonomic composition of the Pınarbaşı charcoal assemblages. The Syrian case studies also suggest that woodland–steppe communities can thrive in habitats where soil moisture is enhanced through the presence of ephemeral watercourses (wadis), seasonal water bodies and landform

Table 6
Summary of landforms/habitats, woodland catchments and reconstructed woodland composition based on ecological analogues and taxon presence in the charcoal samples (for modern ecological analogues see [13,14,29,31])

Habitat type	Water availability	Predicted woodland catchments	Constituent woody taxa based on modern ecological preferences and taxon presence in the charcoal samples
saline exposures, ephemeral streams	seasonal inflows from upland runoff, meltwater	halophytes	chenopods (Chenopodiaceae), chaste tree (*Vitex*), caper (*Capparis*)
submerged surfaces	permanent/seasonal shallow water bodies	marsh vegetation, halophytes (shallow waters)	reed (*Phragmites*), tamarisk (*Tamarix*)
springs	permanent water bodies	waterside vegetation	ash (*Fraxinus*), clematis (Clematis)
well-drained upland slopes, foothills	~300–400 mm p.a. colluvial slopes and volcanic surfaces with good root penetration	oak–juniper woodland	juniper (*Juniperus*), deciduous oak (*Quercus*), maple (*Acer*), legume shrubs (Fabaceae), wild plums, rosebush (*Rosa*), buckthorn (*Rhamnus*)
limestone/chalk and rocky outcrops, edges of foothill zone	~300 mm p.a.	woodland steppe	almond (*Amygdalus*), terebinth (*Pistacia*), hackberry (*Celtis*), hawthorn (Maloideae), buckthorn (*Rhamnus*), wormwood (*Artemisia*, Asteraceae), caper (*Capparis*), labiates (Lamiaceae)
arid plain interiors	<250 mm p.a. mainly marl with poor root penetration	treeless steppe, shallow rooting shrubs	wormwood (*Artemisia*, Asteraceae), chenopods (Chenopodiaceae), labiates (Lamiaceae)

features such as breaks in slope which improve soil drainage [13]. The location of Pınarbaşı right on the foothills of Karadağ and its very close proximity to seasonally flooded marshes and the spring-fed pool indicate similar environmental conditions and a very diverse ecotonal zone. The latter probably comprised various different habitats such as steppe proper (grassland alternating with shrubs), lakeside, halophytic and fresh-water vegetation (*Tamarix*, *Clematis*, *Fraxinus*, *Phragmites*, Chenopodiaceae), woodland–steppe (*Pistacia*, *Amygdalus*, *Rosa*, *Celtis*, *Capparis*, *Artemisia*, *Rhamnus*) and, closer to Karadağ, open oak woodland (*Quercus*, *Prunus*, Maloideae, *Acer*, *Juniperus*, Fabaceae, *Rhamnus*). Further details on the composition, structure and seasonal habit of these woodland types have been presented elsewhere ([2]; for a summary of the ecological data and the reconstructed habitats see Table 6).

Additional evidence provided by the study of animal bone, supplements this picture of ecological diversity and has further indicated that during the early Neolithic (8th millennium BC) forest and wetland habitats were probably more extensive than in later periods. The bone assemblages retrieved from the open-air settlement on the peninsula contained the remains of wild sheep (*Ovis orientalis*), auroch (*Bos primigenius*), red deer (*Cervus elaphus*), equids (*Equus* spp.), wild boar (*Sus scrofa*), wildfowl (*Aves*), whilst there was also at least one case of beaver (*Castor fiber*) (Denise Carruthers, pers. comm.) These results in conjunction with the findings of charcoal analysis seem to confirm the existence, throughout the Neolithic, of a very diverse ecological setting comprising riparian and marsh vegetation, open woodland–steppe, oak woodland formations and treeless steppe.

7. Fuel exploitation

Despite the lack of adequate numbers of samples covering the earliest phases of the settlement, the general impression is that no major temporal changes register in taxonomic composition. Therefore, it is reasonable to infer that the seasonal occupation of the area by mobile groups of hunters and herders resulted in little pressure being exerted on the local vegetation. Woodlands had ample time to recover from woodcutting and, presumably, suffered very little from the effects of animal browsing. Wood charcoal from the dominant taxa (*Pistacia*, *Amygdalus*) comprised mostly small and medium-sized round wood with occasional finds of twigs as well. This would imply that cutting of trees was probably considered as an unnecessary act (also impractical for a transient campsite), a perception likely to have been further amplified by the natural abundance of readily available ligneous biomass to be used as fuel. Such an attitude could have eventually resulted in the introduction of an element of unintentional management and thus woodland conservation in firewood collection. In the long term such unstructured, albeit routinely practiced, "pruning" strategies would have favoured the regeneration of woodland patches through the enhancement of flowering and hence fruit and seed production.

The uniformity of the charcoal assemblage suggests that the groups occupying the open air camp (Site A) and the rock-shelter (Site B) on a seasonal basis used the available firewood resources in a very opportunistic manner, by extracting what was available in the local vegetation. This interpretation is further corroborated by the negligible presence in the archaeobotanical samples of taxa associated with higher elevations such as oak and juniper, despite the close proximity of Pınarbaşı to the volcanic uplands of Karadağ. The rock-shelter was probably located inside the woodland–steppe niche. However and despite the limited preservation potential of small-sized woods such as reeds and small shrubs, it is also worth considering the possibility that some selective criterion in the choice of fuel was applied (especially if we take into account the very low frequencies of locally available lakeside species such as tamarisk and ash). Reeds and small shrubs may have represented less desirable fuels compared to both almond and terebinth, which furnish high quality firewood (dense, drying easily and burning with a strong flame). Almond is also reputed to produce a particularly pleasant fragrance when burnt, whilst terebinth owes much of its properties to its resin content (cf. [15]). It is possible that such burning qualities played an important role in their selection as firewood as well as their availability in the local vegetation.

8. Comparisons with other sites: the regional palaeoenvironmental record

Palynological records from south-central Anatolia have been until recently incomplete due to dating problems. The one published sequence from the Konya plain (Akğol Adabağ) has indicated the slow re-expansion of forest at the beginning of the Holocene, which was not completed until c. 8000 ^{14}C yr BP with the spread of oak and subsequently pine in the surrounding upland areas [4]. Otherwise, the predominant vegetation type reconstructed on the basis of pollen data is that of treeless steppe, with virtually no arboreal elements existing in this region. However, many of the taxa present in the charcoal assemblages from Pınarbaşı are either poor pollen dispersers (e.g., *Pistacia*) or insect-pollinated species (Rosaceae, Maloideae, *Celtis*, *Acer*) and hence their visibility in pollen sequences is very limited [12, p. 183].

Archaeological charcoal data, although not necessarily representing a direct reflection of the availability and the proportions of individual taxa in past vegetation, have nonetheless the benefit of constituting a high-resolution record of woodland vegetation which is synchronous to the period of human habitation. The Pınarbaşı evidence suggests that during the early Holocene terebinth–almond woodland steppe was already present in south-central Anatolia. Broadly the same vegetation pattern has been identified through the study of charcoal macro-remains from northern Syria [11,20], Iraq [23], the Zagros highlands [24,30] and Jordan (cf. [26]).

In terms of past climate conditions, it seems reasonable to infer that during the early Holocene in south-central Anatolia climate was moister than today. This is suggested by the occurrence of ash (*Fraxinus*) and wild plum (*Prunus*) alongside an array of steppic shrubs other than Chenopodiaceae (e.g., Lamiaceae, Asteraceae), which are not found today in this area and can be considered as indicative of moist steppe environments (cf. [28]). The partly contemporaneous charcoal record from the Neolithic tell site of Çatalhöyük offers additional support to this hypothesis, with the presence in it of mesic hygrophilous taxa such as elm (*Ulmus*), cornelian cherry/dogwood (*Cornus*), alder (*Alnus*), plane (*Platanus*) and ash (*Fraxinus*) in deposits that extend as back as ~8300 ^{14}C yr BP [1,2] This general pattern of environmental change is in agreement with the archaeobotanical evidence available from other regions including northern Syria, the Azraq basin, northern Levant and middle Euphrates. The occurrence of fruit stones and wood charcoal remains from *Celtis*, *Pistacia*, *Ficus*, *Amygdalus*, *Rhamnus*, *Prunus* and *Crataegus* points to the prevalence of moister conditions favouring woodland expansion during the PPNA and PPNB with a reversal to drier regimes from the mid-Holocene onwards (cf. [10,11,25,27,28]).

Comparable patterns are also evident in pollen, diatom and stable isotope records retrieved from the crater lake of Eski Acigöl in Cappadocia, Central Anatolia, which have indicated that climatic desiccation did not occur in this region before ~6500 cal. yr BP [19]. The reliability of these results is further corroborated by pollen sequences obtained from terrestrial sites and deep-sea cores in the Eastern Mediterranean (cf. [3,21]).

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