Preliminary conclusions on the Late Glacial vegetation in south-west Anatolia (Turkey): the complementary nature of palynological and anthracological approaches

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Abstract

The combined analysis of charcoal fragments retrieved from epipalaeolithic settlements in Öküzini cave (south-west Anatolia, Turkey) and of pollen in samples retrieved from outside the cave reveals the transformation of the vegetation in the region over the Late Glacial Period. The analyses provide consistent information on the use of natural resources and evidence as to the protodomestication of cereals in the region.

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1. Introduction

This is the first joint analysis of archaeological charcoal fragments from the Epipalaeolithic Öküzini cave in south-west Anatolia and of palynological core samples from the plain facing the cave.

Anthracology only records ligneous taxa whereas palynology can also identify herbaceous taxa and therefore a wider range of species. Ligneous species identified by anthracology can be reflected in a similar way in palynological diagrams but over different time-scales and with a varying degree of precision. Taking into account the present ecology of these species, the complementary nature of these analyses allows us to put forward hypotheses as to the geographical distribution of the species. In this analysis, we have also taken into account phytoliths which have fortunately been preserved in samples taken for pollen analysis in the core, and the identification of the phytoliths has been used to mitigate any imprecision in the pollen analysis.

The Öküzini cave is located 32 km north-west of Antalya, near the Katran Mounts (Taurus), 5 m above the Goksu plain and river and 305 m above sea level (Fig. 1). The cave, discovered and explored by Kökten in 1956, revealed the engraving of an ox (from which the cave got its name) and the remains of a prehistoric settlement covering several millennia. Since 1990, new excavations have been carried out by I. Yalçinkaya and M. Otte, in order to refine the sequence of the Late Glacial settlements ([51,32]; Otte et al., 2003). The cave faces a large plain of lacustrine origin, which is irrigated by a subterranean stream. The plain extends all the way to the coastal cliffs and lies next to a mountain range with peaks of up to 2000 m a.s.l. [10].

The local vegetation belongs to the humid, moderate, lower Mediterranean bio-climatic stage [2]. While the cliffs are covered with maquis-type vegetation comprising essentially wild olive trees (Olea europaea var. oleaster), on nearby hills this tree is mostly associated with evergreen oaks (Quercus coccifera). Several
specimens of fig tree (Ficus carica) and chaste tree (Vitex agnus-castus) grow by the entrance of the cave (Fig. 2). The plain, which is inundated in winter, only allows the cultivation of short-cycle plants such as Cucurbitaceae. After the harvest, sheep herds consume Poaceae and Compositae there, leaving aromatic Labiatae such as wild mint the possibility to develop without competition. Subterranean waters come out of the mountain as a stream, but are then dammed into a channel lined with Typha, Phragmites, Juncus and Carex; this formation is sometimes high and thick and shelters birds and animals of all varieties, including turtles and frogs. The stream water is covered with white water lilies, milfoils and wild cress. Toad flax and Adiantum capillus-veneris ferns grow in the cracks of the rock at the stream outlet.

The archaeological levels excavated inside the Öküzini cave have included many remains of charcoal. This first analysis is based on the identification of more than 2300 fragments recovered from levels XII—XI and VIII to level Ia dated 10,150 ± 95 BP (10,400–9300 cal. BC).

A pollen analysis was attempted on the archaeological samples from the cave itself. However, most samples turned out to be sterile. The few pollen-yielding samples were difficult to date with precision and in any event human activities inside the cave could have induced errors in the reconstitution of the palaeoenvironments. Fortunately, the presence of a fossil lake in the immediate neighbourhood of the cave offered a remarkable opportunity for palynological analyses. A first trench 1.5 m deep, provided samples which were tested
for the presence of pollen. The results being positive, a systematic sampling project was then drawn up under the direction of C. Kuzucuoglu (UMR 8591 CNRS) and carried out in August 1998.

2. Methods of sampling and analysis

2.1. Sampling for palynological analyses

In 1998, a core sequence of 7.63 m was collected using a 6.3 cm wide Livingstone core sampler. The lower limit of the core was imposed by a hard level which could not be drilled through, and was probably a travertine. Three sets of overlapping samples were taken at 10 cm intervals at depths of 7.60 to 0.65 m. The samples were distributed for analysis between specialists of different disciplines: mineralogy, malacology, 14C dating, phytolithology and palynology.

This paper concerns the section of the core samples between 5.63 m and 3.80 m (corresponding to samples 24–43). This and the anthracological analysis cover the whole of the period when the cave was inhabited (Table 1): sample 26 was taken between 5.48 and 5.44 m and is dated (Gif-11384) 24,120 ± 480 BP; sample 40 was taken between 4.17 and 4.13 m and is dated (Gif-11386) 9330 ± 90 BP (9088 ± 829 cal. BC). From 5.63 to 5.62 m the sample is of light-coloured silt, becoming brown/black between 5.56 and 4.80 m, and then organic and very rich in mollusc shells (Kuzucuoglu, personal communication).

2.2. Sampling for anthracological analyses

Charcoal fragments were recovered from the excavated surface inside the cave systematically, using a meter grid, and all the sediment was dry- or wet-sieved (using 8 and 2 mm meshes). Charcoal was left to dry far from any excessive source of heat in order to ensure that their structural anatomy was preserved. They were then packed and sent to the laboratory for analysis.

2.3. Methods of analysis

Prior to the pollen analysis, the samples were treated with hydrochloric acid in order to remove their calcium content, then with hydrofluoric acid in order to remove the small content of silica in the samples. The application of potassium hydroxide revealed variable amounts of soluble organic matter. In each sample the pollen content was concentrated.

Table 1
Table of 14C dates from Öküzini cave (Yalçınkaya et al., 2001) and from the core [22]

<table>
<thead>
<tr>
<th>Cave geological levels</th>
<th>BP datings</th>
<th>Calibration limits 2 s</th>
<th>% Confidence</th>
<th>Laboratory reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>O3–O4</td>
<td>8959 ± 90</td>
<td>7950–7450</td>
<td>95.4</td>
<td>HD14363-13884</td>
</tr>
<tr>
<td>Ib1</td>
<td>9480 ± 80</td>
<td>9200–8550</td>
<td>95.4</td>
<td>ETH-8029</td>
</tr>
<tr>
<td>Ib1</td>
<td>8800 ± 80</td>
<td>8250–7600</td>
<td>95.4</td>
<td>ETH-8031</td>
</tr>
<tr>
<td>Ia1</td>
<td>10,150 ± 90</td>
<td>10,400–9300</td>
<td>95.4</td>
<td>OxA-5213</td>
</tr>
<tr>
<td>Ia2</td>
<td>11,440 ± 100</td>
<td>11,600–11,050</td>
<td>78.7</td>
<td>Lw-1895</td>
</tr>
<tr>
<td>II</td>
<td>11,920 ± 190</td>
<td>12,400–11,400</td>
<td>78.5</td>
<td>Hv-13334</td>
</tr>
<tr>
<td>II</td>
<td>12,020 ± 90</td>
<td>12,400–11,600</td>
<td>73.6</td>
<td>Eth-8026</td>
</tr>
<tr>
<td>III</td>
<td>11,900 ± 90</td>
<td>12,400–11,500</td>
<td>83</td>
<td>ETH-8030</td>
</tr>
<tr>
<td>III</td>
<td>12,210 ± 90</td>
<td>12,500–11,800</td>
<td>53.2</td>
<td>ETH-8033</td>
</tr>
<tr>
<td>IV</td>
<td>12,810 ± 180</td>
<td>14,100–12,300</td>
<td>95.4</td>
<td>Lw-1998</td>
</tr>
<tr>
<td>VI</td>
<td>12,540 ± 110</td>
<td>13,600–12,200</td>
<td>95.4</td>
<td>OxA-5217</td>
</tr>
<tr>
<td>VI–VII</td>
<td>14,200 ± 130</td>
<td>15,700–14,500</td>
<td>95.4</td>
<td>OxA-5222</td>
</tr>
<tr>
<td>VII–VIII</td>
<td>14,550 ± 130</td>
<td>16,100–14,900</td>
<td>95.4</td>
<td>OxA-5224</td>
</tr>
<tr>
<td>VIII</td>
<td>14,940 ± 140</td>
<td>16,600–15,300</td>
<td>95.4</td>
<td>OxA-6225</td>
</tr>
<tr>
<td>XII</td>
<td>16,440 ± 160</td>
<td>18,400–16,900</td>
<td>95.4</td>
<td>OxA-5179</td>
</tr>
<tr>
<td>Core depth (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.17–4.13</td>
<td>9330 ± 90</td>
<td>9088–8292</td>
<td></td>
<td>Gif-11386</td>
</tr>
<tr>
<td>5.01–4.97</td>
<td>14,185 ± 165</td>
<td>15,661–14,772</td>
<td></td>
<td>Gif-11385</td>
</tr>
<tr>
<td>5.48–5.44</td>
<td>24,180 ± 480</td>
<td></td>
<td></td>
<td>Gif-11384</td>
</tr>
</tbody>
</table>
referred principally to the descriptions, drawings and photographs published by A. Miller-Rosen [31].

The relative frequencies have been calculated by excluding from the total number of pollen the number of pollen from taxa which are directly linked to the presence of water, i.e. aquatic/marsh plants. This is because their absolute frequencies in many levels would affect the percentage of arboreal pollen, which is itself already influenced by the high proportion of Poaceae; the latter are taken into account because it is impossible to distinguish between Poaceae originating from different biotopes. Undoubtedly, a very significant proportion of the Poaceae is attributable to the nearby lake.

The anatomical identification of the charcoal was carried out with a reflected light microscope, having light and dark fields. The charcoal was fractured by hand and the three anatomical sections of wood were observed: transverse, longitudinal—tangential and longitudinal—radial. The structures observed were compared with those described in wood anatomy atlases [14,15,17,18,29,30,38,39] and with an extensive reference collection of present-day Mediterranean burnt woods.

Ligneous taxa are used as the basis for current ecological classifications. Thus, for a given place located in a known bio-climatic level, the number and specificity of wood species can be estimated well. If we compare this result to the number of species identified by charcoal analysis in archaeological levels rich in charcoal, the number of species found is often far greater than originally estimated. Prehistoric inhabitants “sampled” several different ecosystems surrounding the site. These areas constitute the catchment area from where the wood samples were taken.

As in pollen analysis, the information obtained from the identification of charcoal pieces is transformed into frequency spectra. The relative frequencies make up a charcoal diagram. By translating the spectra into this transformed synthetic form, an identification of the ligneous vegetation present in the area used for collecting domestic firewood is given during a given period.

3. Results

The anthracological diagram (Fig. 3) is based on the variations over time of the relative frequencies of the taxa. This figure gives an accurate picture of the plant groupings and their dynamics throughout the various settlement periods. The species are categorised from left to right following their plant associations: steppe formations, Mediterranean evergreen oak forest, deciduous oak forest and riverine vegetation.

The palynological diagram (Fig. 4) shows the changes in the vegetation from the time of the Pleniglacial. The diagram identifies two types of pine trees (Pinus nigra and P. sylvestris), a small number of taxa from the evergreen oak forest and a small number of pollen from such taxa, olive trees (Olea europaea), trees from the deciduous oak forest and riverine ligneous vegetation. The pollen analysis identifies numerous herbaceous taxa such as Artemisia, Chenopodiceae, Poaceae and

Fig. 3. Charcoal diagram showing relative frequencies of taxa in charcoals assemblages for successive stratigraphic units.
Fig. 4. Simplified pollen diagram.
3.1. The anthracological diagram

Generally, as shown by the anthracological diagram, the results of the analysis suggest two major, successive periods: the first is characterised by a “steppe forest” (as described by Zohary [53]) in which almond trees (Prunus amygdalus) are dominant; the second is characterised by a temperate humid vegetation represented by a deciduous oak forest and riverine vegetation.

The first period covers levels XII–IV, and spans approximately from 17,000 to 12,250 BC (16,440 ± 160 BP to 12,180 ± 180 BP). Despite the fluctuations caused by the varying numbers of available fragments, the almond tree is the most represented of all species. Over this first period, steppe species are the most numerous—in level VI, Artemisia sp. and pine of types nigra and sylvestris are identified. Pistachio trees are present in most levels. This grouping is evocative of the associations between Juniperus, Prunus amygdalus and Pistacia as currently found in Iran and Palestine, which are also described as vegetation of the “steppe forest” type. This can be related to an open environment where mountain influences are significant and the climate cool and probably still dry. However, from the lowest level in the sequence, mesophilous species such as deciduous oak trees, Acer sp., Prunus sp. and cf. Sorbus/ Crataegus or more thermophilous species such as Phillyrea and evergreen oak are noted. Riverine associations are represented by tamarisk, some ash and willow/poplar.

The second period covers levels III to Ia. It is characterised by a decrease in the amount of almond tree, together with an increase in the amount of deciduous oak trees and then ash, indicating a transformation of the vegetation into either an oak-ash formation or more likely an oak forest.

3.2. The palynological diagram

Three types of ligneous species identified in the charcoals are also found in the pollen analysis. They are shown in the same order in the diagram so as to make comparisons easier. They are:

- The deciduous oak forest represented by deciduous Quercus, Acer, Prunus, Viburnum and Juglans;
- The evergreen oak forest with the following taxa: Quercus, Pistacia, Rhamnus, Juniperus, Olea and Celtis;

The riverine forest where Fraxinus, Ulmus, Populus, Alnus, Salix and Tamarix grow.

The end of the oldest climatic period which is noticeable in the core diagram (not represented here) is characterised by a maximum frequency of arboreal taxa of 30% made up essentially of pine and deciduous oaks and by a high proportion of Artemisia and Chenopodiaceae which are typical of dry intervals. The percentages of pollen of aquatic, water lilies, milfoils and semi-aquatic plants (Typha, Carex) as well as mineralogical data [22] indicate that the level of the lake was low and its banks had dried up.

At the beginning of the diagram (Fig. 4), sample 24 (5.63–5.62 m) shows that the dryness increases: the proportion of trees is the smallest in the whole column of sediments, the deciduous oak forest is represented by oak and to a lesser extent maple. Thermophilous taxa are completely absent and the riverine species are hardly represented (whether in number of taxa or in quantity). The Chenopodiaceae and Artemisia dominate the local and regional vegetation in a dry and very likely cold climate which is characteristic of the Pleniglacial period. Sample 25 (5.53–5.52 m) is sterile; immediately above (at 5.48–5.44 m) a level was dated: Gif-11384; 24,120 ± 480 BP.

In the following sequence, represented between 5.43–5.42 and 4.93–4.92 m by samples 26, 27, 28, 29, 30 and 31, the percentage of arboreal pollen increases to a value of about 30% which remains constant in each of samples 26, 27, 28 and 30. This percentage is made up mainly of oak, ash and juniper. Thermophilous taxa (Pistacia, Olea) are present and various riverine species are identified (Fraxinus, Alnus, Tamarix, Salix).

Artemisia pollen is less frequent (20% in sample 26; 2.7% in sample 28). So is the Chenopodiaceae pollen. The lake level, evidenced by the sedimentation, still seems rather low [22] despite an increase in humidity which is shown by a reduction in the representation of the above taxa and an increase in the frequencies of Lactucae and Poaceae.

Sample 24 (which is characteristic of a dry period) and sample 26 (which shows a marked climatic improvement) are separated by only 10 cm of sediments and reveal the position of a hiatus shown in the sediment analysis at 5.61 m [22].

Sample 29 contains hardly any pollen, but innumerable micro-charcoals. The taxa identified from pollen are: Juniperus, deciduous Quercus, Artemisia, Chenopodiaceae and Poaceae. There does not seem to be any real sedimentary hiatus but instead destruction of the pollen grains by fire whether by man or nature.

In samples 30 and 31, the percentage of Juniperus increases thereby increasing the representation of arboreal pollen. The pistachio tree is still represented, unlike the olive tree. The riverine forest is still present, and the
presence of the ash tree is constant. The amount of pollen of *Artemisia* and of Chenopodiaceae decreases further; these two taxa are replaced by Lactucae and Poaceae. Sample 30 is also rich in micro-charcoal fragments and contains Cyperaceae phytoliths.

Looking at the data obtained from the pollen analysis and the date 14,185 ± 165 BP (15,661–14,472 cal. BC), in our view the period of the deposits in samples 26 to 31 (5.43–5.42 to 4.93–4.92 m) could fall within the warming post-Pleniglacial period and coincide with the beginning of the Late Glacial Period. This observation is corroborated by the data obtained from the anthracological analysis which is discussed further below.

The vegetation is the subject of a further change between 4.93–4.92 and 4.63–4.62 m (samples 31 to 35). Sample 31 contains a high proportion of arboreal pollen, namely 31% comprising 18% juniper and 10% deciduous oak. At this stage the percentages of *Artemisia* and Chenopodiaceae only attain 0.7% and 5.5%, respectively, but the frequencies of Lactucae and Poaceae increase (respectively, 11.5% and 38%).

Between samples 31 and 35, the percentage of arboreal pollen decreases progressively to 4.3%. In level 35 the calculation of the percentage of arboreal pollen, excluding Poaceae and Chenopodiaceae from the total number of pollen, gives a value of 7%. All frequency curves of arboreal taxa decrease, except for that of *Prunus*, and that of riverine associations which disappears. The olive and pistachio also disappear, which probably indicates a reduction in ambient temperatures.

The dryness is evidenced primarily by the arboreal taxa, Chenopodiaceae and *Artemisia* only increase very little and Lactucae and Poaceae dominate the vegetation. Many other families are identified, however, their proportion is negligible compared to the Lactucae and Poaceae.

These sediments also contain a large number of micro-charcoals and one macro-charcoal of deciduous oak at 4.73–4.72 m (identified by J.-M. Pernaud). This raises the issue of the cause or causes of the very weak representation of arboreal taxa: is this the result of a change in climate, or of human activity, or both?

Pollen from aquatic or hygrophilous plants is more frequent in the samples and is indicative of an increase in the lake level. However, the percentages of pollen of the semi-aquatic taxa should be considered with caution, because pollen analyses also reflect human activities in the vicinity of the sampling area, and plants within these taxa may have been used by people in the area, which would have altered the representation of these taxa.

A sedimentary hiatus between levels 33 and 34 at a depth of 4.78 m was mentioned previously; this has been suggested as the sign of the drying up of Dryas III [22]. In the context of the pollen diagram this hiatus is not remarkable, and the small amount of AP at 4.63–4.62 m (in sample 35) and the slight increase in the rates of *Artemisia* and Chenopodiaceae could also represent the Younger Dryas.

The last phase is recorded in the sediments located between 4.53–4.52 m and 3.81–3.80 m (samples 36 to 43). The percentage of arboreal pollen remains relatively constant at about 20%. Pine develops from sample 37, while the representation of the deciduous oak varies between 1 and 10.4%. Various taxa from the evergreen oak forest are represented simultaneously in levels 35 to 38, with the exception of the olive tree which is only identified in sample 43. The alluvial forest again expands and *Populus* is identified for the first time. The number of taxa is clearly larger and indicates a higher biodiversity.

4. Correlations between the anthracological and palynological data

4.1. Associations and taxa

Four plant formations are recognised, three by both anthracological and palynological studies, namely deciduous oak forest, riverine formation and evergreen oak forest, one by anthracological analyses: steppe forest (Table 2).

The deciduous oak forest is mainly represented by deciduous oaks, maple trees (*Acer* sp.), Buxaceae and Rosaceae among which we find Pomoideae such as *Sorbus*/*Crataegus* and Prunoideae. Deciduous oaks include numerous species, the most important of which today are: *Quercus pubescens* spp. *anatolica*, *Q. cerris*, *Q. frainetto*, *Q. macroleptis*, *Q. infectoria*. Distinguishing between these anatomically from charcoal fragments is not yet possible, however, the oak pollen grains are of the *Quercus cerris* type. These formations with deciduous oaks develop on deep soils, at the same bioclimatic stage as evergreen oaks. Forests such as these are now only residual [3].

The riverine vegetation is made up of ash (*Fraxinus cf. ornus/angustifolia*), tamarisk (*Tamarix* sp.) and *Salicaceae* (*Salix/Populus*). While it is possible, as shown in anthracological studies [43], to associate the ash tree with the deciduous oak forest as observed in the western Mediterranean region, the constant presence of this tree in the palynological analyses seems to associate it more closely to the riverine formations. The pollen of elm (*Ulmus*) is identified in the pollen analyses, but was not observed in charcoal remains.

The third formation is constituted by the various components of the Mediterranean evergreen oak forest which, while not frequent, are nevertheless present in the analyses. Mediterranean evergreen oak forest is dominated by evergreen oak. It is accompanied by Fabaceae, *Rhamnus/Phillyrea*, Cupressaceae of the *Juniperus/Cupressus* type and pistachio trees (*Pistacia* sp.) which
Table 2
Table of taxa determined by charcoal analysis from Öküzini cave and by pollen analysis from the core

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Anthracology</th>
<th>Palynology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cedrus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deciduous oak forest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carpinus/Ostrya</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quercus deciduous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buxus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pomoideae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prunus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosaceae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorbus/Crataegus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viburnum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juglans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evergreen oak forest/steppe forest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anacardiaceae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artemisia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinus sp.</td>
<td></td>
<td></td>
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<tr>
<td>Pistacia sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prunus amygdalus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhamnus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhamnus/Phyllirea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quercus selerophyllous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juniperus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juniperus/Cupressaceae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olea tp europaea</td>
<td></td>
<td></td>
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<tr>
<td>Celtis sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riverine forest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fraxinus cf. orinus/angustifolia</td>
<td></td>
<td></td>
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<tr>
<td>Ulmus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Populus sp.</td>
<td></td>
<td></td>
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<tr>
<td>Alnus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salix/Populus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salix sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tamarix sp.</td>
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</tr>
</tbody>
</table>

are also frequent in steppe-like forest formations. Juniper pollen is sometimes abundant while Quercus coccifera, Olea and Rhamnus are only very occasionally present in the considered sequence. Pistacia sp. is the only pollen to be regularly identified in samples from the first part of the Holocene. With respect to pistachio pollen, it was not always possible to identify the species with certainty, however, it appears that several species developed in Öküzini. Associations with evergreen oaks are presently well-developed throughout the country. Their presence is substantial inland and in valleys. They can manage to develop into dense groupings at altitudes of up to 1400 m, as in the eastern Taurus [3].

A fourth formation is identified from the results of the anthracological analysis, namely the steppe formation. This formation is characterised mostly by Amygdalus sp. (Amygdalus communis and A. orientalis have not been distinguished anatomically), Pinus cf., Pinus nigra-sylvestris and cf. Artemisia. This association is no longer found in Anatolia, although in the Antalya region open formations with Juniperus and Amygdalus orientalis are present [4]. These steppe-like, arboreal formations belong to a semi-arid environment. No almond tree was identified from pollen in the sediments (only one grain was identified, in sample 34). The dispersion of pollen of taxa from the Rosaceae family is very small and so when the natural environment is a steppe formation with oak, almond and pistachio trees, the representation of the vegetation is truncated.

Among other taxa identified in the course of the palynological analysis, one can cite Viburnum, Sambucus, Celtis, and in particular Juglans. Cedar (Cedrus) and fir trees (Abies) appear in some of the pollen spectra for the same sequence (37, 39 and 41). The pine (Pinus nigra and sylvestris) presents a low frequency in this sequence but increases from 4.33–4.32 m (sample 37). The anthracological analysis reveals 20 ligneous taxa and the palynological analysis 23 taxa in the various samples (17 taxa in total in sample 37). Such floristic richness suggests that the region could have provided, in adverse climatic periods, a survival area for many species (Table 2).

5. Discussion

5.1. The results from Öküzini area

The variety of taxa identified by charcoal analyses shows that fuel was gathered by the inhabitants of Öküzini from different surroundings, resulting in a good sampling of the vegetation. The results of the charcoal analysis are broadly confirmed by the palynological analysis.

The two approaches identify, at first, a generally steppe-like, cold environment. However, a more thermophilous vegetation also finds its place in this environment which could represent one stage in the evolution towards a deciduous oak forest. An increase in ambient temperatures, coupled with an increase in rainfall, probably explain why the charcoal analysis reveals the formation of a deciduous oak forest at about 12,000 BC. The increased representation of ash, at the end of the anthracological sequence, can be explained by the more favourable conditions (increase in humidity) experienced by these species. For its part, palynology provides some strong evidence of anthropisation, perhaps even proto-agriculture, as suggested by the constant increase in the representation of Poaceae (cereals? discussed further below) that is our hypothesis.

While it remains difficult at this stage to establish any precise relationship between the samples retrieved outside the cave and the levels relating to periods of human
occupation, a number of observations and hypotheses can be put forward. First, it must be stressed that, with respect to the variety of taxa identified, the analyses provide very consistent data. For example, the presence of *Olea*, as noted in pollen samples 28 and 26, may be related to two charcoal fragments identified in levels XII and VI. Similarly, the presence of *Pistacia* sp. which is noted in samples 35 and 37, can be related to the pistachio trees identified in the upper section of the sequence in Ic and Ia.

The anthracological diagram includes data for ash in which three successive stages can be identified. The first stage covers the levels from anthropological phase 1 (levels XII to IV) and can be related to the ash pollen identified in samples 26 and 28. Subsequently, the representation of ash decreases in the charcoal (levels III to Ic) as in the palynological diagram. It then increases again in the higher levels as in palynological samples 36 and 37. The disappearance of taxa from the riverine forest (except the ash tree) between samples 33 and 35 could be also related to the same phenomenon as observed in levels III to Ic. The representation of *Prunus* is also consistent in both sets of analyses. In fact, the only potential difference between the analyses is in respect to the deciduous oak. At the beginning of the palynological sequence, oak trees are more represented than in the charcoal analysis, however, this tendency seems later to be reversed. It may be that the gathering of oak, as indicated in the upper level of the archaeological sequence, could correspond to the use of wood that was collected some distance away from the site. This distance may have been made necessary by the firewood shortage around the cave, which may itself be linked to the climatic factors underlined very precisely by López Bayón [27] who devoted a complete study to this problem which also mentioned by Goldberg and Bar-Yosef [13]. This table highlights the correlations between the various sets of data; it shows a small thickness of sediments between the depth of the sample dated (GIF 11,385): 14,190 ± 165 BP and sample 33 which is correlated with phase III of the occupation and dated (ETH-8033): 12,210 ± 90 BP and (ETH-8030): 11,900 ± 90 BP. This indicates a third hiatus between 4.93–4.92 and 4.83–4.82 m and situates level I of occupation of the cave at the beginning of the Holocene, as attested by the contemporaneous exchanges between the last hunters–gatherers of Öküzini and the first Neolithic people [6].

5.1.1. Comparison with other sites in south-west Turkey

The location of the sites makes the comparison difficult because, for the period under consideration, Öküzini is one of the most western site and also the lowest in altitude. Pollen sites are imprecisely dated, radio-chronological data is scarce and the dates suggested are sometimes estimates. As explained by Rossignol-Strick [37], Eastwood et al. [11], and by Kuzucchini Roberts [21], this is a source of inaccuracy.

The sites which cover (either partially or completely) the period between 24,120 ± 480 BP and 9330 ± 90 BP (9088–8292 cal. BC) and that we have selected for our purpose, are shown in Fig. 1.

During the Pleniglacial period, herbaceous plants dominate and reflect a severe drought. The small amount of rainfall, more than the low temperatures, is the limiting factor for the expansion of trees [21]. At Karamik [47] *Artemisia* and Chenopodiaceae represent most of the vegetation, together with trees being essentially oak, pine and cedar. At Beysehir II [8], the end of the Pleniglacial is characterised by cedar and pine which are identified by pollen analysis in the same small quantities as in Öküzini, and are dominated by Lactucae (in the calculation of the relative frequencies, the total amounts of Lactucae have not been taken into account and so the arboreal proportion of the vegetation is over-estimated).

In south-west Anatolia the Late Glacial Period is characterised by an increase in rainfall followed by an increase in temperatures [21]. The proportion of arboreal pollen in various diagrams increases regularly: these consist essentially of deciduous oak and pine or cedar and pine, each of these two formations being sometimes accompanied by juniper. This reflects a considerable diversity of the landscape and the vegetation which is noticeable still today.

The Younger Dryas is easily identified in some diagrams. The Late Glacial vegetation had sufficiently expanded for the subsequent decrease in temperatures to appear clearly. Humidity then increased again from 10,000–8000 BP and trees multiplied.
At Karamik, at an altitude of 1000 m a.s.l., the pine and cedar developed starting from zone 3 at a depth of 5 m between calculated dates of 14,350 and 11,630 BP. At the time of the deposits in zone 4, i.e., between 11,630 and 8230 BP (calculated), a reduction in the amount of trees is observed. At the beginning of zone 5 at 4.20 m depth, the percentage of non-arboreal pollen decreases, and the amount of arboreal pollen increases to 80% including 75% of conifers, namely pines (20%) and cedars (55%). These data reflect a transformation from an open vegetation to a dense forest. At the bottom of zone 5, the calculated date corresponding to 8230 BP is considered too old by the authors [47].

At Beysehir II, 1120 m a.s.l. [47], the combination of oak, juniper and pine becomes more important from 9000 BP and develops significantly until 6000 BP.

At Söğüt Gölü, at an altitude of 1393 m, starting from 9180 ± 95 BP, the amount of arboreal pollen
increases clearly. The pollen in question is also *Pinus, Quercus* and *Juniperus*, the proportion of the latter two taxa shows that the climate remained dry [46].

At Göllhisar [11], the site nearest to Öküzini but at an altitude of 985 m, pine, juniper and oak make up 60% of the pollen at 9400 BP and 80% at 8500 BP.

Although it seems that the expansion of the trees occurred initially at higher altitudes [21], it is possible that, since the rate of arboreal pollen in Öküzini remained between 25 and 30% (in samples 36 to 43), the upper part of the sediments studied in this diagram go back to the beginning of the Holocene period. In addition, pine is well represented in the regional vegetation starting from 9500 BP but it was not used as firewood at that time. and it is unlikely that it was growing near the site of Öküzini. The increase in the amount of pollen of pine, cedar and more rarely fir tree in the sediments, could represent the regional share of the vegetation which developed at altitude and could allow samples 38 and 39 to be dated between 9500 and 9000 BP which is not inconsistent with the radiometric ages. This constitutes an additional argument in support of the dates proposed for our samples.

Some *Pistacia* pollen is present between 4.63–4.62 and 4.33–4.32 m. For Rossignol-Strick [37], the pistachio tree is a marker: its presence announces the optimal climatic conditions which characterise the beginning of the Holocene period. In Öküzini, *Pistacia* pollen is present from the very start of the postglacial warming and this taxa cannot be taken into account in the dating of the sequence. In Zeribar II, at Lake Hula and at the Ghab [52] *Pistacia* pollen is present during the cold and dry phase of the Younger Dryas.

The improvement of the climate is more obvious from the diversity of herbaceous taxa. Humidity is reflected by an increase in the level of the lake, if one can judge from the development of aquatic and marsh plants and the rebirth of the riverine forest.

These results are broadly consistent with those obtained at Tenaghi Philippion (Greece) where a succession of steppe and forest phases was identified, and in particular a dense oak grove during the Holocene following an open steppe phase at the end of the Würm [44,45].

The results obtained from Lake Van, in Eastern Turkey, indicate the same succession [49]. The lower part of the diagram identifies a large desert-like steppe from 12,700 to 10,460 varve yr. Between 10,460 and 10,100, stands of *Pistacia* and *Quercus* have developed in the Chenopodiaceae-Artemisia desert-steppe. Then, from 10,100 to 8250 steppic elements decreased, while *Pistacia* and *Quercus* became more frequent. The results obtained from Lake Van have been compared to those from Lake Zeribar located in the Zagros mountains in western Iran, 1300 m a.s.l. and 450 km south-east of Lake Van [46]. In both diagrams, oak groves replace the forest–steppe, at Zeribar trees are first represented in the diagram at 10,500 BP. These results confirm those obtained in the Middle-East by G. Wilcoxon which show that generally, the forest–steppe of the end of the Late Glacial included *Pistacia, Amygdalus, Celtis* and *Crataegus* [50].

The sequence of Öküzini is also characterised by a number of changes in the herbaceous vegetation which are related to the frequentation of the nearby cave, and probably also with presence of man over the survey area. The study of these changes leads us to consider that the pressure exerted by man on his environment could have slowed down the expansion of the vegetation [36].

6. The presence of cereals and micro-charcoals

6.1. Observation results

6.1.1. Pollen grains of *Cerealia* type

In 1961 Beug. using acetylated material, established the various sizing criteria used to identify pollen of *Cerealia* type: the minimum diameter of the grain is 37 μm, that of the pore 2.7 μm, while the width and thickness of the *annulus* are 2.7 μm and 2 μm, respectively (Beug, 1961).

Beug (1961) and Van Zeist et al. [47] distribute the pollen grains of *Cerealia* type in three groups:

- **Group I**: 40–50 μm, including, among others, *Hordeum vulgare, Triticum aegilopoides, Triticum dicoccoides, T. dicoccum* and *T. monococcum*, and many wild grasses.
- **Group II**: 50–60 μm, including *T. monococcum, Hordeum vulgare, H. spontaneum, T. aegilopoides, T. dicoccoides, Secale cereale, T. dicoccum, T. durum, T. compactum, T. aestivum* and various wild grasses.
- **Group III**: 60–70 μm, including *T. dicoccum, T. durum, T. compactum, T. aestivum, T. spelta* and *Secale cereale*. No wild grasses within the limits of this group (but an overlap with pollen of *Zea mays* must be considered, therefore this taxa cannot occur in Anatolia).

Van Zeist notices that the pollen of *Aegilops kotschyi* has a larger diameter than that of *Triticum aestivum* and that of *Aegilops triuncialis* measures 48 μm [47]. Bastin [7], Leroi-Gourhan [25] and Van Zeist [47] consider the diameter of pollen of *Cerealia* type as equal to or greater than 40 μm, and they note that the external diameter of the *annulus* should be at least 10 μm. Biometric studies by Andersen [1] suggest a lower limit of 8 μm for the *annulus* diameter, with a lower limit of 40 μm for the whole grain diameter.

Statistical studies carried out in Europe on 200 Poaceae pollen grains and 200 *Cerealia* grains [7] show
that 8% of cereal grains are smaller than 40 μm and 0.5% of Poaceae pollens are larger than 40 μm. The measurement of the pollen size is thus in most cases a reliable means of identification, and the measurements of the pore and annulus diameters can be used to confirm this or otherwise. In any event both measurements are systematically taken for each pollen of this type.

According to Beug’s classification, the pollen grains extracted from the sediments of Öküzini belong to the three groups, although the grains from the third group are fewer. From sample 30 to 43, one observes the almost continuous presence of large size Poaceae. The morphometric measurements presented in Table 3 suggest that these are of Cerealia type. Table 3 sets out the number of pollen grains of Cerealia type, their size and whether phytoliths were present in the corresponding sediments.

We should mention that in level III of the cave, sample 1992/10 (square L5d, archaeological level 14, altitude −313 cm) contained hardly any pollen. However, it was found to contain 4 grains of the Cerealia type. The 14C dates for geological level III are (ETH-8033): 12,210 ± 90 BP (12,500–11,800 cal. BC) and (ETH-8030): 11,900 ± 90 BP (12,400–11,500 cal. BC). One of the level II samples (1990/10, square L5, altitude −2.72 m) contains 14 grains of Cerealia type pollen, which belong to the 3 size groups. This very heterogeneous strata contains the remains of a succession of hearths and it is associated with a large quantity of archaeological material [27].

The similarities between the anthropological and palynological diagrams for sample 33 mean that this sample can be compared with levels III and II in the cave. This sample contained two classes of Cerealia pollen with diameters of up to 60 μm.

Since some of the other Poaceae taxa also display large diameters, looking only at their size we could not say with certainty that the Öküzini cave sediments actually contained pollen from cereals.

6.1.2. Phytoliths

The presence of many phytoliths which are characteristic of the glumes and inner glumes of wheat in samples 32, 34, 38 and 40 of the lake core confirms the presence of the Triticum genus in the sediment.

The epidermis of the glumes and inner glumes of the spikelets of the Poaceae is made up of long cells with walls of a wave-like shape of variable thickness. Between these cells are ornamented papillae and dendriform cells. The characterisation of the glumes and inner glumes and of the genus to which they belong is reached on the basis of the shape of the waves, their size, the width of the long cells and the diameter and ornamentation of the papillae. The areas which are looked at for characterisation are mainly the lower and middle areas of the husks.

The phytoliths which are identified here were identified from the significant size of the dendriform cells, some papillae and especially the shape and size of the cellular walls. The width of the long cells is between 20 and 28 μm and the waves have a clearly round shape with irregular amplitudes of 7.2, 9.6 or 12 μm depending on the fragment of epidermis under consideration. The papillae have a diameter of 20 μm but they are very few and their poor state of preservation prevented any classification based on their ornamentation.

The shape of the waves permits these to be characterised as belonging to the Triticum genus; photographs of fossilised phytoliths found in Öküzini are presented in Fig. 6 alongside photographs of reference phytoliths of Triticum in order to show the clear similarity between the shape of the cellular walls.

The presence of cereal phytoliths in the sediments of the core sample, simultaneously with that of pollen of Cerealia type, makes it possible to propose that the large size grains among the Poaceae pollen are pollen grains of cereals.

The results of the measurements taken on the glumes and inner glumes of Triticum monococcum and Triticum dicoccum by Miller-Rosen [31] are as follows:

- Width of the long cells between 18 and 23 μm;
- Amplitude of the waves of the lower part of the husks: 4 μm for thinnest and 5–8 μm for the thickest;
- Amplitude of the waves of the middle part of the husks: 10 μm for the thinnest and 15 μm for the others.

One can distinguish between these two species by looking at the papillae: these have a diameter of 20 μm for Triticum dicoccum and a diameter between 20 and 30 μm for Triticum monococcum, with a number of pits of 10 to 12 in the former and 12 to 14 in the latter. The measurements obtained in Öküzini are in line with these, with the exception of the long cells which reach 28 μm. This variation could be due to the different conditions in which the plants developed. The papillae have a diameter of 20 μm, which does assist in refining the distinction, and the ornamentation is not readable. Only the observations relating to the shape of the waves are determining.

In order to supplement the comparison between the sequence of the core sample and the sequence obtained in the cave, we have researched the phytoliths found in the sediments from the cave. Fig. 7 which represents the frequencies of phytoliths extracted from the cave, reveals the presence of three types of elements in levels VI to V; in addition, sample n° 2 contains 18% of parenchym remains. This confirms in each of these levels the presence of a litter and probably a reed-made litter (Phragmites tp).
Table 3
Cerealia-type pollen and phytoliths from the core and the cave

<table>
<thead>
<tr>
<th>CORE</th>
<th>CAVE</th>
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<tr>
<td>number samples</td>
<td>Cerealia-type pollen-number of grains</td>
</tr>
<tr>
<td>43</td>
<td>15</td>
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<td>42</td>
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<td>29</td>
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</table>
In levels III, II and I new characteristic morphotypes appear: trapezoid margins sinuous and trapezoid margins alate and lobed of the sheets of cereals but also of other Poaceae such as Bromus, Lolium and Agropyron [19]. At the same time dendriform cells (which are characteristic of the glumes and inner glumes of Poaceae) appear, and their frequency increases (Table 3, Fig. 7). Trilobates and multilobates elements of the panicoid family are also observed. We are unsure about sample no. 12. This is attributed to geological level I but could have been sampled in Ia2/Ib1 interface. Structure Ib1 is a pit which post-dates levels Ia2 and Ia1 which it recuts; it is sealed by level O3 which was deposited after a long hiatus. The bottom of the pit is dated 9480 ± 80 BP (9200—8550 cal. BC). The high percentage of dendriform cells (30%) in sample no. 13 (square L5, −2.32 m) could suggest that Poaceae were stored there [48].

It appears that the presence of dendriform cells, and therefore that of cereals, in the cave (perhaps a form of wheat) is contemporaneous with level III and that the same elements are present in levels II and Ib1. It is possible to note the correspondence between the data from the core and those from the cave samples: on the one hand Cerealia type and the phytoliths of a form of wheat, on the other the presence of Cerealia-type pollen.
and of dendriform cells, the frequency of which increase in level Ib1, they may have been stored there. The simultaneity of these phenomena and the presence of micro-charcoal fragments in the plain suggest that the environment was exploited by successive populations.

6.1.3. The micro-charcoal fragments

Levels with micro-charcoal fragments are numerous in this part of the core sample: six samples (29, 30, 32, 34, 38 and 40) contain micro-charcoals, whereas lower levels do not contain any (only three levels, located at the top of the core and dated from Antiquity contain micro-charcoals). The pollen grains of Cerealia type appear in sample 30. They are not accompanied by phytoliths, contrary to what one sees in levels 32, 34 and 38 which are found to contain wheat phytoliths. Sample 40 contains micro-charcoals and phytoliths of stems and seed envelopes of Poaceae, epidermis and Cyperaceae phytoliths. In this sequence which is contemporaneous with the Epipaleolithic occupation of Öküzini, the micro-charcoals accompany or precede the cereals. This is observed only during this period. The frequency of the micro-charcoals makes it possible to suggest that fires may have been lit regularly by the inhabitants of Öküzini, for purposes which we try to identify below.

6.2. Interpretation

6.2.1. The emergence of wheat at Öküzini

A form of wheat, perhaps einkorn, is identified in the analyses and we can wonder about its origin. Wild einkorn, *Triticum monococcum* subsp. *boeticum* currently spreads over an area charted by Zohary and Hopf [54] and covering the Fertile Crescent (the northeast of Syria and Iraq, south-east of Turkey) and Anatolia. Einkorn belongs to the steppe-like plant formations and in particular those in which oak is a major element [54]. The stations identified as its primary habitat are located in formations including oaks and Rosaceae and their development sometimes reaches a peak at the border between these steppe-like formations and the steppe itself [16]. The ecological conditions for its development (whether on the edaphic or on the climatic level) are not strict. It shows an affinity with basaltic soils, marls, clays as well as limestones. It can grow within a range of altitudes at with the conditions of temperature and moisture will also vary [54].

The anthracological analysis reveals between 16,000 and 12,500 BP the existence at Öküzini of a forest/steppe including oaks and almond trees. It is during this period that wheat appears in the sediments of the core.
sample which we have related to the sediments from the cave. Two hypotheses can therefore be considered:

One hypothesis is that, in the same way as currently observed [16], wild wheat may have followed the expansion of the forest/steppe from survival areas. The Öküzini region is located close to the Mediterranean sea and could have constituted a sheltered area for many species. We observed the presence of many arboreal taxa during the Pleistocene and the sediments from the cave at Karain, 1 km from Öküzini, were found to contain pollen from Poaceae of the Cerealia type in the industry levels of the Middle and Upper Palaeolithic (Emery-Barbier, unpublished data). The presence of water streams and of cereals could have attracted the group of hunters—gatherers, whose occupation of the Öküzini cave seemed to grow longer every year, as shown by the increasingly developed domestic lithic material recovered from the site [23] and by the archaeozoological studies [5].

Another hypothesis which we can put forward is that the inhabitants of the cave could have identified cereals as an important potential source of food and brought these to the site from the refuge areas around Öküzini. In this respect it should be noted that the cave was occupied by a group of hunters—gatherers who shared their time and their activities between Öküzini and the coastal sites of Belbasi and Beldibi as suggested by Bar-Yosef [6]. Since the cave was occupied mostly in the spring and summer [5], wheat could have been brought and sown without tangible material evidence. Subsequently, grains could have been harvested every summer as grains fallen on the ground prepared the following “harvest” as per the cycle of this plant. This second hypothesis should be related to the presence of the micro-charcoal fragments and perhaps the possibility of a human settlement prior to the introduction of cereals.

6.2.2. The possible use of fire as a means of altering the environment

After Lewis [26] who sees in the use of fire the possible origin of animal breeding and agriculture in the Near East, Sigaut [40], Hillman [16], Forni [12] and Roberts [36] successively described its uses and practice in current groups of hunters—gatherers and its marks in archaeological sites and paleobotanical studies.

Fire has important uses which can be achieved within a short time. In particular it can be used to alter a particular natural environment: the immediate consequence of a deliberate fire is to eliminate undergrowth and small trees in order to maintain an open area with only one level of perennial or annual herbaceous. This creates areas in which wild fauna can find food in abundance and one could perhaps consider that if fire was used, it may have been for this reason. In this respect the age of the animals hunted at Öküzini is instructive and could confirm this hypothesis, because the animal bones retrieved from the site are those of young or very young animals which indicates [5] that the hunting ground was nearby; and by attracting game in a grassy area near the cave, the distance to be covered while hunting is smaller. These facts are to be connected with the increasing sedentarisation in the occupation of the cave and with the development of tools used for skin-work [5,23].

Another consequence follows for the plants. Fires are favourable to cereals because they create the type of same environment from which they originate and where grains can grow making full benefit of the mineral salts contained in ashes and the breaking of the surface of the ground. This could be a third hypothesis for the presence of wheat at Öküzini.

These practices, if they actually took place, must have hindered the development of the forest and would partly obscure the effect of any climatic phenomena in the Öküzini core pollen diagram because in the long run these fires would create very wide areas of post-forestal vegetation.

In support of the foregoing, information can be drawn from the study of the site of Shanidar and the paleobotanical study of Ghab, which are two examples of sites where the use of fire is attested [26]. The paleobotanical study of the cave at Shanidar was carried out by Arl. Leroi-Gourhan [25] who identified pollen from Poaceae of the Cerealia type in the proto-neolithic sediments. The archaeologists Solecki [41,42] observed ash in the levels from the time of the Mesolithic up to the Neolithic period, at the border between the oak/almond tree grouping and the steppe. These observations are interpreted by Lewis [26] as an evidence of a technique which led to the subsequent practices of agriculture and animal farming.

In the palynological diagram of Ghab [52], which covers the period from 14,820 ± 180 BP until after 3450 ± 90 BP, the presence of micro-charcoal fragments is constant, however, these are particularly numerous during the Pre-Pottery Neolithic B, and this phenomenon is accompanied by a clear reduction in the representation of cedar and deciduous oak. These results lead the authors to assume, on the part of the farmers, very significant actions on the forest of cedar and oak for the purpose of obtaining cultivable grounds, construction wood and firewood.

6.2.3. The macro-remains in the cave and tools related to plant-use

The carpological study is currently being carried by D. Martinoli, who has published her first results [28]. Among the remains of plants from the Epipalaeolithic levels, she has identified the fruits of Celtis, Vitis vinifera sylvestris, Pyrus, Amygdalus and Olea which are also identified in the anthropological and palynological
analyses. There are very few seeds of herbaceous plants: Boraginaceae, Fabaceae and Poaceae. Among carbonized seeds, fragments of roots and bulbs were noticed. The only cereal seeds identified are of naked wheat discovered during the early excavations carried out by Kükten and probably belonging to the post-palaeolithic levels. Since 1990, macro-remains have been systematically searched for, without this ever revealing the presence of cereals in epipalaeolithic levels.

With regard to the lithic industry one can note the appearance of grinding tools as early as 12,500 BC [24] and a single sickle-blade in level IV which covers dates between 12,400 and 11,500 BP [20]. However, one could also grind mineral substances and/or plants other than cereals. The examination of these tools could prove interesting if they have not been too thoroughly cleaned after their discovery.

7. A different evolution at the beginning of the Holocene

We comment below on the evolution of certain taxa which reveal the presence of man and human activities.

7.1. The signs of anthropisation

Certain taxa have the capacity of storing in their tissues substantial quantities of nitrates derived from the decomposition of nitrogenous substances. These plants grow preferentially in areas where there has been an accumulation of organic refuse and therefore in the vicinity of human settlements. These taxa form the ruderal group and are represented in Europe mostly by the Carduaceae, Urticaceae and Polygonaceae including the *Rumex* genus. Consequently, a more important proportion of pollen in the samples, being indicative of a higher representation of such taxa, could reflect the establishment of human settlements.

With respect to the levels described here, one notes an increase in the percentage of Carduaceae belonging in particular to the *Carduus* as well as the *Polygonum* genus (the *Cirsium* genus is hardly represented). One also notes a slight increase in the frequency of Urticaceae and *Rumex*. At Öküzini, the increasing presence of the ruderals can therefore be seen as evidence to the anthropisation of the study area.

For a palynologist, identifying evidence of anthropisation and cultivation is a complex exercise. The most important difficulty lies in distinguishing ecological and climatic factors from human factors when looking at over-represented taxa, and in applying to past situations the results of current methodological studies. One can, however, notice that if the only origin of the development of these taxa was the climatic improvement of the beginning of the Holocene, their pollen would probably not have disappeared from the sediments at the same time as that of cereals.

7.2. Weed species

The percentages of two *Centaurea* species, *Centaurea solstitialis* and *Centaurea cyanus*, increase by more than 6% in sample 42. Sample 37 revealed 4% of *Centaurea cyanus* pollen which is regarded among the European indicators as a messicole species; *Centaurea solstitialis* is largely represented in the diagrams for south-west Anatolia and is interpreted in terms of variations of lake water levels [47].

Methodological studies show that today *Centaurea solstitialis* can be found in abundance in fields and more particularly in those which have recently been ploughed; it has been considered as an anthropic indicator in Greece by Bottema and Woldring [9]. The authors [8] suggest that the high number of *Centaurea solstitialis* pollen could be linked to the working of the land.

7.3. The plants accompanying the cereals

The percentages of pollen from Caryophyllaceae, Apiaceae and Liliaceae also increase at the same time as those of *Cerealia* type pollen. As for the Caryophyllaceae, it is difficult to determine their genus and one cannot say with certainty that these are *Silene* accompanying cereals. We observe that the pollen grains belonging to these taxa are present at the same time as the Poaceae of *Cerealia* type and that they disappear from the sediments at the same time.

7.4. Economically significant plants

The representation curve for the Fabaceae is, as the one for cereals, almost continuous. However, one notes in samples 37, 41 and 43 the presence of pollen grains of the *Cypripedium* type and that they disappear at the same time as that of cereals.

7.5. Plantago

The frequency of plantain pollen (mostly *Plantago lanceolata*) hardly increases and this taxa, which is characteristic of pasture grounds, is absent from the pollen spectrum between samples 38 and 43.

8. Conclusion

The vegetation proposed from the results of the anthracological and palynological analyses at Öküzini
is a composite environment. Until 12,500 BC this environment was dominated by a forest—steppe, which was then replaced by deciduous oak forests. These data corroborate data obtained from other palynological and anthracological analyses in the Middle-East. The importance of these results is also to show the exploitation of the environment by man in the course of his technological evolution.

Between samples 33 and 36, the sediments frequently contain numerous micro-charcoals and the representation of arboreal pollen decreases, however, these are sediments which were deposited during the Late Glacial warming. The same sediments reveal pollen grains of *Cerealia* type. The phytoliths confirm that these are cereals of the *Triticum* genus (11,900 ± 90 BP; 12,400—11,500 cal. BC). In levels III and II of the cave (which the correlations between the anthropological and palynological diagrams correspond to samples 33 to 36), dendriform cells from Poaceae spikelets are identified. By comparing fossil dendriform cells with those of our reference collection, we can determine the first ones as belonging to *Cerealia*-type Poaceae.

During this phase, the presence of a form of wheat is evidenced in Öküzini by the phytoliths. It is very likely to have been used since cereal phytoliths are present in the cave. The presence of this wheat is strictly contemporaneous with that of the micro-charcoals. One can therefore put forth the hypothesis of alterations being made to the local area using fire. These alterations were carried out in order that cereals could multiply and/or in order to procure animals more easily. This would be one of the first techniques for the production of plants and/or animals, although one could not demonstrate that the species concerned derived any benefit from it. While we see no symbiosis between man and his environment in a way which would characterise agriculture, one can nevertheless perceive in the behaviour of these hunters—gatherers the foundations of a farmer’s mentality [12]. The site of Öküzini would then be the first in south-west Anatolia where this process is so clearly shown and documented.

Between samples 36 and 43, the traces of fire are less frequent and we can still observe grains of pollen of *Cerealia* type and wheat phytoliths in the samples and unidentified cereals in the cave. What is new in this sequence it is the increase in the representation of the ruderal group and of taxa which normally accompany cultivated plants, such as *Centaurea cyanus* and Caryophyllaceae. The representation of these taxa displays similar trends including a reduction at the time when Poaceae of *Cerealia* type disappear.

In the Middle-East, for the period under consideration, pollen analyses have always been carried out on samples taken far from archaeological sites, and few points of comparison are available. In Öküzini, samples are taken about 200 m from the cave, and we have described a number of modifications in the plant environment, connected with the presence of *Cerealia* pollen and phytoliths of wheat.

The results of the archaeological studies of the Öküzini cave are consistent in showing the simultaneous presence of the last hunters—gatherers and of the first Neolithic communities in Anatolia [6]. It is possible that from a simple improvement of predation by the hunters—gatherers the economy could have evolved towards a proto-agriculture and agriculture, as suggested by the frequency of the wheat phytoliths revealed in levels O3 and O4 dated (HD 14363-13884): 8595 ± 90 BP which represent between 25 and 50% of the whole of the phytoliths in each sediment.

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