

THE VEGETATION HISTORY OF EAST-CENTRAL ANATOLIA IN RELATION TO ARCHAEOLOGY: THE ESKI ACIGÖL POLLEN EVIDENCE COMPARED WITH THE NEAR EASTERN ENVIRONMENT*

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ABSTRACT: As a contribution to the vegetation history of northwestern Cappadocia, the authors studied a core from a crater lake in that area, covering the Late Glacial and the Holocene. The lower sediment sequence shows characteristic, probably annual lamination. In the middle zone, solid stretches and banded silts are found, while in the upper part laminated sections alternate with silts and carbonaceous matter. Incorporation of old carbon in the sediments means that radiocarbon samples are dated too old; the age/depth regression line suggests a correction of 3100 years. An explanatory comment on the dating evidence is given.

Steppe plant communities predominate during the Late Glacial. Substantial values of Gramineae reveal relatively humid conditions for the earliest part, followed by an increase of Chenopodiaceae during the next period, which suggests increased summer drought. In the last phase of dominating steppe vegetation, *Artemisia* pollen values suggest low winter temperatures. Patches of oak scrubland or woodland are present throughout the Late Glacial. A change from cold and drought-tolerant semi-desert vegetation to grass steppe and oak-terebinth woodland implies a shift towards a more humid and warmer climate. In the following millennia annual precipitation probably increased to c. 500 mm. Archaeological evidence demonstrates the emergence of Neolithic farming communities in Cappadocia. At about 8000 BP, a great diversity in woodland species developed. In the south, conifers expanded with cedars probably advancing into the Göllüdağ Mountains. The next period presents firm evidence of crop cultivation (barley and wheat) in Cappadocia. A decline in rotifer percentages (Rotatoria) and a vigorous rise of green algae (*Pediastrum*) attest to an anthropogenic increase of nutrients in the lake. Human pressure seems to have been variable through time. Pollen values suggest a substantial expansion of deciduous oaks and declining agricultural activity towards the end of the 5th millennium BP. Soon afterwards a serious reduction of oak woodland and a rise of anthropogenic vegetation reveal further exploitation of the environment by man. A series of high-resolution pollen samples was processed from part of the laminated section. The results, which represent about 50 years, are quite consistent and show only minor fluctuations.

KEYWORDS: Cappadocia, Central Anatolia, Late Glacial, Holocene, vegetation history, palynology.

1. INTRODUCTION

Palynological investigations of lacustrine sediments have substantially increased the knowledge of the Late Pleistocene vegetation history of the Near East. In the last twenty years, especially the number of pollen diagrams covering about the last 12,000 years has greatly increased. These diagrams present ample evidence on the vegetation and climate developments during the final stage of the last Glacial and the more humid and warm Holocene. An overview of long pollen sequences (fig. 1) includes Zeribar and Mirabad (Van Zeist & Bottema, 1977) and Lake Urmia (Bottema, 1986) in Iran, the Ghab (Van Zeist & Woldring, 1980) in Syria and Lake Hula (Baruch & Bottema, 1999) in Israel. Studies appeared about eastern Turkey; Lake Van (Van Zeist & Woldring, 1978;

Wick et al., in press) and Söğütli (Bottema, 1995): in southwestern Turkey; Beyşehir and Söğüt Gölü (Van Zeist et al., 1975; Bottema & Woldring, 1986: in northern Turkey; Abant, Yeniçağa and Ladik Gölü (Bottema et al., 1995) and Yenisehir in the Marmara district, northwestern Turkey (Bottema et al., 2001).

The palynological evidence from Central Anatolia is sparse. Akgöl Adabağ in the Konya Plain represents the only core of Central Anatolia that covers the Late Glacial and part of the Holocene vegetation period (Bottema & Woldring, 1986).

For various reasons the central part of Turkey is of interest. Its geographical situation and accessibility made this region crossroads of cultures in the history of man and a main route in the spread of domestic crops and livestock towards Europe. The

* Figures 7–9 of this article are to be found in a pocket in the rear-cover of this journal.

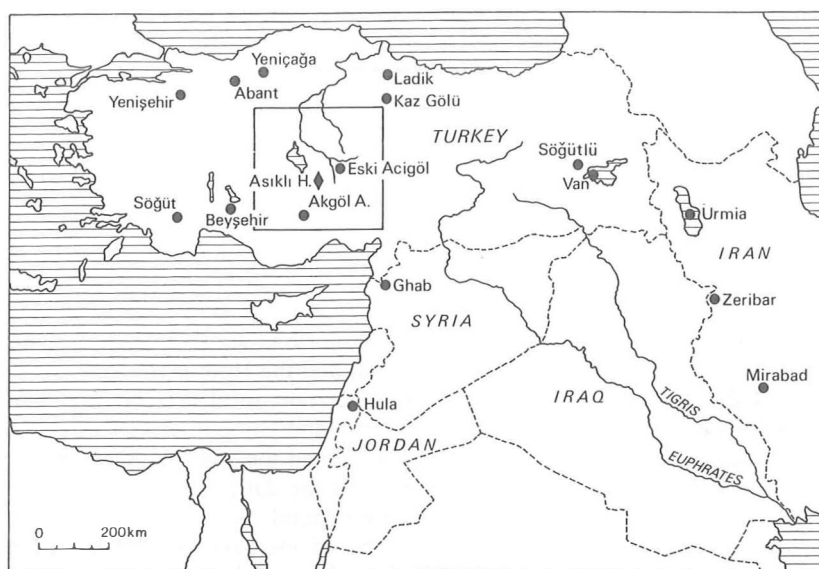


Fig. 1. Map of the Near East with the core locations mentioned in the text. Inset area: see fig. 2.

farming potential of the fertile lava soils and steppe areas has attracted people since the Early Holocene. Archaeological evidence indicates man's settling in this region only slightly after the start of sedentary life in the Fertile Crescent. Regional surveys in Central Anatolia reveal a relatively dense pattern of Neolithic settlements (Todd, 1980). Since 1989, excavations have been carried out at the early Neolithic site of Aşıklı Höyük in Cappadocia, which covers c. 500 years of habitation (8958–8400 BP: Esin, 1996). In the past decade, various new sites dating from the Neolithic to the Chalcolithic have been detected in Cappadocia. (Gülçur, 1995; Özbasaran, 1999).

Aşıklı Höyük, Çatal Höyük in the Konya Plain and sites such as Can Hasan, Hacilar and Erbaba document the early practice of agriculture and animal husbandry.

Another intriguing aspect is the impact of man and his animals on the vegetation during nine millennia of sedentary life. Was the environment of the early farming communities comparable to the apparently steppe conditions of today? Botanists have different opinions as to the proportions of steppe and woodland or forest in Central Anatolia (Louis, 1939; Walter, 1956; Zohary, 1973).

The geographical limits of the areas under discussion are defined as follows:

East-Central Anatolia/Cappadocia: the region bounded by the line that connects the towns of Aksaray, Nevşehir, Kayseri and Niğde.

Central Anatolia: the region bounded by the line that connects the towns of Ankara, Konya, Niğde and Kayseri (fig. 2).

Inner Anatolia: the high plateau bounded by the Pontic Mountains in the north and the Taurus Mountains in the south.

2. CLIMATE

Todd (1980) defines the current climate of Central Anatolia as cold steppic. It is more continental than the Mediterranean climate, with colder winters and drier summers. The climate of the Tuz Gölü area and the Konya Basin, south-Central Anatolia, has been termed xerothermo-Mediterranean because of its more moderate winters. Average temperatures range from +1°C to -2°C for January and from 22 to 23°C for July in the towns of Ankara, Niğde, Kırşehir and Kayseri. The average annual temperature in Nevşehir is 11°C. Annual rainfall indicates arid (<400 mm) to semi-arid (400–600 mm) climatic conditions, e.g. Ankara 367 mm, Aksaray 384 mm, Kayseri 366 mm, Nevşehir 386 mm, Ortaköy 615 mm (Todd, 1980).

3. GEOGRAPHY

Eski Acıgöl (38° 33'01" N, 34° 32'41" E) is a crater lake c. 200 m in diameter (altitude 1270 m above sea level), c. 20 km southwest of Nevşehir (fig. 2). The crater was formed during mid-Pleistocene volcanic activity. A rhyolitic intrusion in the southern part, the Güneydağ dome, reduced the crater lake to its present size (figs 3 and 4). Eski Acıgöl was a rain-fed lake. The water depth prior to its drainage in 1972

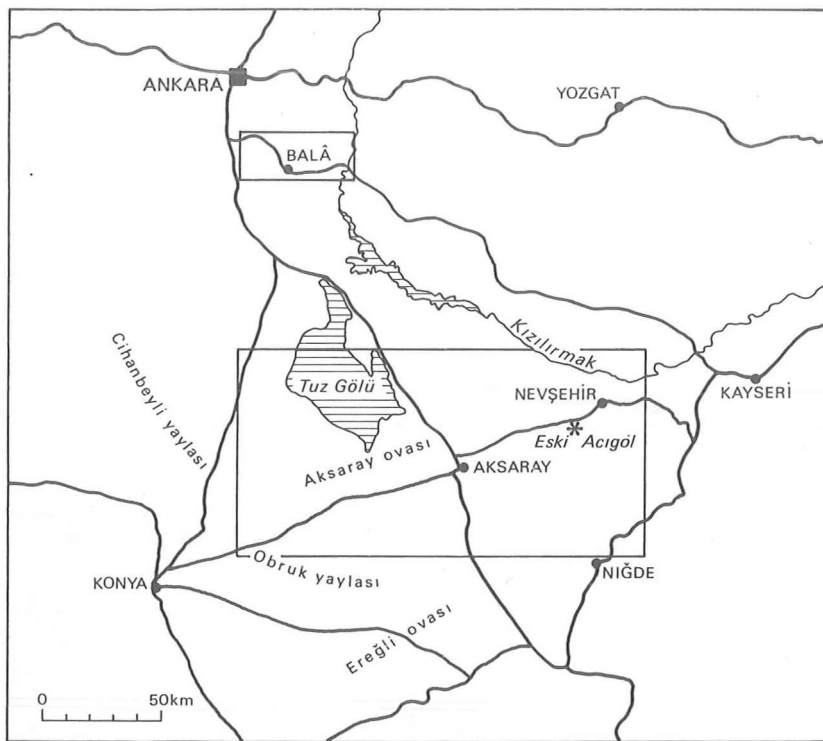


Fig. 2. Map of Central Anatolia, indicating the location of crater lake Eski Acıgöl. Inset area: see fig. 5.

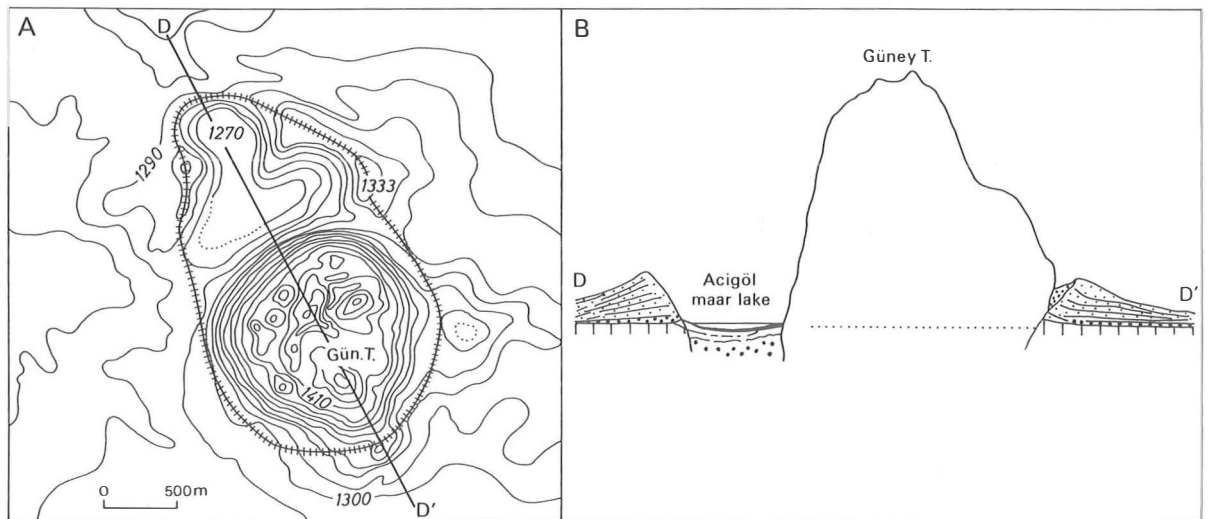


Fig. 3. Overview (A) and cross-section D-D' (B) of Eski Acıgöl (after Kazancı et al., 1995).

was generally 1 m, but varied occasionally from a maximum of 4 m to zero. The lake water was brackish to slightly saline (Kazancı et al., 1995).

4. THE MODERN VEGETATION

4.1. The Inner Anatolian plateau: general phytogeographical features

The Anatolian plateau is surrounded by three floristic regions: the Mediterranean, the northern Euxinian



Fig. 4. Overview of Eski Acıgöl lake remnant, viewed towards the north.

(= Pontic Mountains) and the eastern Irano-Turanian province. The tree vegetation of Inner Anatolia led Zohary (1973) to consider most of the interior plateau as a particular sector of the Euxinian district, the Xero-Euxinian, although the ground flora is dominated by Irano-Turanian elements.

4.2. Vegetation of Central Anatolia

In Central Anatolia the present lower tree line is found between 1000 and 1400 m (mostly 1200–1300 m), the upper tree line between 2300–2400 m (Erci-yas Dağ up to 2500 m). As noted by Louis (1939) the lower tree line rises in altitude from north (Ankara, 1100 m) to south (Niğde 1400 m). Oak species are the major components of the remains of woodland and steppe forest on the Central Anatolian plateau (fig. 5). The assemblages of wild fruit trees, the so-called wild orchards, were most probably present even before the maximum expansion of oak woodland occurred around 8000 BP (Woldring & Cappers, 2001). Dominant are many rosaceous species, e.g. *Pyrus eleagrifolia*, *P. amygdaliformis*, *Crataegus* spp., *Cotoneaster nummularia*, *Prunus ursina*, *P. spinosa*, *Amygdalus orientalis* and *A. balansae*. Also characteristic is the composition of tree and scrub

vegetation on rocky outcrops. Most common are: *Celtis tournefortii*, *Pyrus eleagrifolia*, *Prunus ursina*, *P. spinosa*, *Ulmus campestris*, *Rosa* sp. and *Berberis crataegina*.

Conifers at present play a modest role as landscape elements. *Pinus nigra* dominates in the Beynam nature reserve (1230 m) near Balâ, south of Ankara. *Juniperus excelsa* is widespread on lava soils in the Göllüdağ, a northern extension of the Melendiz Mountains. *Juniperus oxycedrus* is a rather indifferent species found occasionally in various forest habitats and degraded scrub vegetation. According to Mayer & Aksoy (1986) *Pinus nigra* forest by nature dominates most of Inner Anatolia. They give the following regressive forest phases:

Pinus nigra forest

Quercus pubescens forest

Pyrus eleagrifolia–*Prunus insititia* parkland

Crataegus orientalis–*tanacetifolia* scrub

Juniperus excelsa–*oxycedrus* scrub

Cistus laurifolius vegetation

Tree felling for timber and fuel has depleted the wood resources, while thousands of grazing livestock prevented the regeneration of the woodlands. Deviating vegetation in enclosures not affected by grazing, such as cemeteries, indicates that the actual vegetation clearly differs from the potential one.

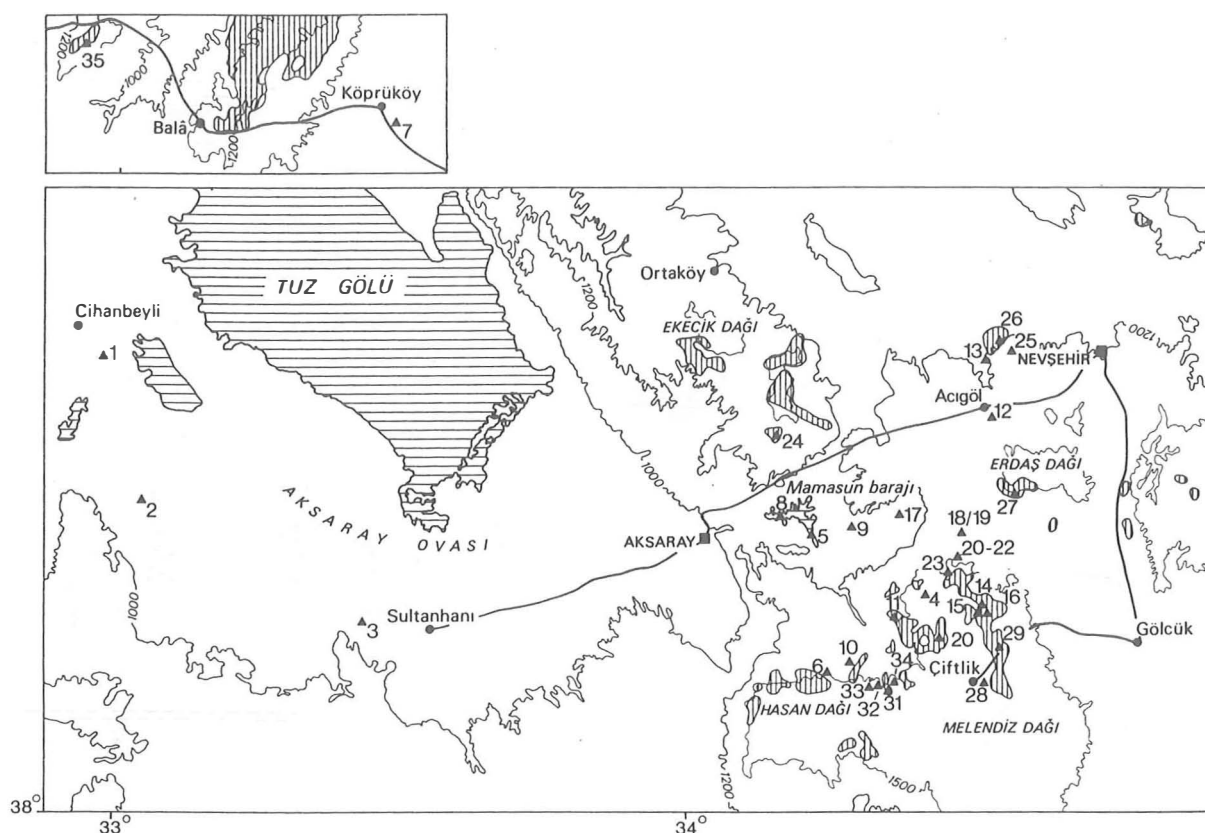


Fig. 5. Map of east-Central Anatolia and the southern Tuz Gölü area. Numbers refer to surface sample locations. Hatched parts are woodlands (after *Yeni Türkiye Atlası*, 1977).

The steppe vegetation of Central Anatolia is principally Irano-Turanian. According to Walter (1956) and Louis (1939), a *Stipa-Brometum* constitutes the steppe below 1100–1200 m. Zohary (1973) assumes that many Irano-Turanian herb species invaded Inner Anatolia in response to the deforestation in recent centuries. Overstocking of the steppe led to the dominance of *Festuca sulcata*, *Poa bulbosa*, *Melica ciliata*, *Verbascum* spp., *Salvia cryptantha*, *Phlomis armeniaca*, *Eryngium campestre*, *Euphorbia macrolada* and various composites such as *Artemisia frans.*

4.3. Vegetation of Cappadocia

Oak woodland occurs scattered throughout Cappadocia. Areas with mainly coppiced white oak (*Quercus pubescens*) are found in the Güzelyurt/Çiftlik area and in the Erdaş Dağ (south of Acıgöl). Open stands of large fruiting trees grow near Gökşugüzel in the Ekecik Dağ, north of Acıgöl and in the northern Göllüdağ (fig. 5). White oak is often the only oak species in these woodlands, but occasionally pedunculate oak (*Quercus robur*) and valonea oak (*Q. ithaburensis* ssp. *macrolepis*) are present.

Mixed deciduous and conifer woodland composed of *Juniperus excelsa*, *J. oxycedrus*, *Q. pubescens* and *Quercus ithaburensis* ssp. *macrolepis* predominates between Kayirli and Bozköy in the Göllüdağ. As the regressive series (Mayer & Aksoy, 1986) indicates, *Juniperus* species often become dominant where pine forest has degraded. No natural pine stands are found in Cappadocia at present, but pine may have formed the primary forest between Kayirli and Bozköy.

Birch (*Betula pendula*) is found between 2000 and 2200 m above sea level on the Erciyes Dağ, the largest volcano in Central Anatolia, south of Kayseri. According to Davis this is westernmost occurrence of birch in Turkey, but Hillman (pers. comm.) also mentions this species for the Göllüdağ.

Pistacia species are not common in the area. *Pistacia atlantica* was found in the İhlara canyon, south of Aşıklı Höyük, together with *Celtis tournefortii* and *Rhamnus* sp., and in the crater of Nar Gölü in the northern Göllüdağ (surface samples 20–22, see below). Freitag (1977) mentions *Pistacia atlantica* in ravines, rock crevices etc. from dry areas in Iran. Such protected locations have a higher atmospheric humidity than the surrounding areas. Davis (1965–1988) reports the occurrence of lentisc (*Pistacia*



Fig. 6. The potential vegetation of east-Central Anatolia (after Kürschner, 1984). 1. Dry farming area (rainfall 300–400 mm/yr). 2. Xeromorphic dwarf shrublands with thorn cushions. 3. Evergreen needle-leaved woodland resistant to cold (*Juniperus excelsa*, *Pinus nigra* ssp. *pallasiana*, min. precipitation 450 mm/yr). 4. Evergreen needle-leaved woodland resistant to cold (semi-arid, sub-humid, humid, locally *Abies cilicica*, *Cedrus libani*). 5. Non-irrigated arable land in potential areas of open forest. 6. Non-irrigated arable land and xeromorphic dwarf shrublands. 7. (salt-) Swamps. 8. Plant formations of the sub-alpine zone. 9. Cold-deciduous scrub without evergreens. 10. Irrigated arable land. 11. Plant formations of the alpine zone. 12. Mixed cold-deciduous and evergreen scrub. 13. Non-irrigated arable land. 14. Cold-deciduous broad-leaved woodlands without evergreens (*Quercus cerris*, *Q. libani*, *Q. pubescens*, *Q. trojana*). 15. Mixed formations of xeromorphic dwarf shrublands. 16. Mixed formation of rush swamp and herbaceous and semi-woody salt swamps. 17. Mixed formation of xeromorphic dwarf shrublands with thorn cushions and non-irrigated arable land in potential areas of open forest. 18. Evergreen broad-leaved scrub and non-irrigated arable land. 19. Xeromorphic dwarf shrublands with thorn cushions and sand formations. 20. Forb communities with scattered trees, shrubs, dwarf-shrubs, thorn cushions. 21. Scarcely vegetated sand-dunes. L = lake.

lentiscus) and a subspecies of the turpentine tree (*Pistacia terebinthus* ssp. *palaestina*). The occurrence of lentisc on the Erciyas and Ali Dağ is noteworthy, because it does not survive temperatures below -12°C .

Pastoralism has greatly modified and degraded the herb vegetation. Spiny, fragrant and toxic species dominate the herb vegetation in many places. Most common species are *Achillea santolina*, *Echinops* sp., *Xeranthemum annuum*, *Centaurea solstitialis*, *C. virgata*, *Onopordum* spp., *Noaea mucronata*, *Alhagi camelorum*, *Phlomis armeniaca*, *Thymus squarrosus*,

Eryngium campestre, *Echinophora spinosa*, *Verbascum* spp. and *Euphorbia* spp.

Tragacanthic *Astragalus*–*Acantholimon* vegetation covers vast stretches in the Göllüdağ, the Hasan Dağ and other areas. The plant cover of this cushion-shaped vegetation is usually very open and the soil surface is subject to erosion. This vegetation represents the most degraded stages of the regressive series of Central Anatolia, as described by Walter (1956).

Kürschner (1984) mapped the potential vegetation of Cappadocia. Figure 6 shows an adjusted version

of the map, including Cappadocia and the adjacent section of the Taurus Mountains. The indicated vegetation units represent the assumed natural vegetation as is likely to occur in the absence of man and his animals.

4.4. Vegetation of the Acıgöl area

The Acıgöl area looks rather barren nowadays. Much of the land is in use for crops such as cereals, potatoes and vines. Tree growth is sparse. *Eleaagnus angustifolia* and planted apricots (*Prunus armeniaca*) are the most common trees. *Quercus pubescens* coppice grows on the Güneydağ. On the east slope a mixture of *Q. pubescens* and *Juniperus oxycedrus* (cover c. 10%) constitutes the woody vegetation (surface sample No. 12, see below). The east and south slopes overlook an immense valley, which at present is completely under cultivation. Remnants of steppe forest or woodland in the fields south of the lake include some tall *Quercus robur*. Drainage of the lake has resulted in the establishment of a grazed grass cover, which includes *Bromus tectorum*, *Hordeum murinum*, *Cynodon dactylon* and *Helictotrichon pubescens*, locally alternating with more weedy vegetation with taxa such as *Descurainia* and *Atriplex*. During the coring in 1992, sheep were seen to root for the taproots of a *Scorzonera* species. The former lake was fringed with cotton thistle (*Onopordum* spec.).

The presence of the European suslik (*Citellus citellus*) indicates the desiccation of the topsoil since the drainage of the lake.

5. MODERN POLLEN PRECIPITATION

5.1. General

Plant species greatly differ in the production and release of pollen. In accordance with the pollinating system, wind-flowering species (e.g. *Pinus*, *Quercus*, *Artemisia*, *Chenopodiaceae* and *Gramineae*) release pollen profusely and consequently these taxa are generally over-represented in the pollen rain. By contrast, many plants pollinated by insects are usually under-represented, since this method of pollination does not require an abundant release of pollen. These data are of course most important for the interpretation and evaluation of subfossil pollen records. A method to measure these differences is the analysis of moss cushions in relation with inventories of the surrounding vegetation.

The analysis of the modern pollen precipitation is based on 35 surface samples collected during field campaigns in Central Anatolia in August 1997, September 1998 and September 2000 (fig. 5, table 1).

Four principal vegetation types have been distinguished:

- Nos 1–4 Steppe, natural and artificial;
- Nos 5–6 Arable land or pasture;
- Nos 7–13 Rock outcrops in farmed land;
- Nos 14–35 Woodland/forest areas.

Depending on the arboreal species composition, the woodland/forest areas have been subdivided into:

Nos 14–17 Oak-juniper woodland (southern Göl-lüdağ);

Nos 18–30 *Quercus pubescens* woodland (e.g. Erdas Dağ, Göl-lüdağ);

Nos 31–33 *Quercus cerris* woodland/forest (Hasan Dağ);

No. 34 *Quercus ithaburensis* ssp. *macrolepis* woodland (Kitreli area);

No. 35 *Pinus nigra* forest (Beynam nature reserve, Balâ).

5.2. Surface sample description

5.2.1. Group A: steppe landscapes

1. West of Cihanbeyli:

No trees, except for *Populus* cv. "Italica" and *Salix* in the river valley at 500 m. Herbs: *Consolida*, *Dianthus*, *Euphorbia*, *Cruciferae*, *Astragalus* (rare), *Alhagi camelorum*, *Medicago*, *Trifolium*, *Trigonella monspeliaca*, *Leguminosae*, *Peganum harmala*, *Eryngium* (common), *Echinophora spinosa*, *Umbelliferae*, *Echium*, *Heliotropium*, *Plantago*, *Galium*, *Dipsacus*, *Carlina*, *Centaurea*, *Centaurea solstitialis*, *Echinops*, *Onopordum*, *Liguliflorae*, *Bromus tectorum*, *Hordeum* and various other *Gramineae*.

2. Between road and cereal field (*Triticum durum/aestivum*):

Few (planted) trees: *Populus alba/canescens* and *Pyrus pyraster*-type. Herbs: cf. *Camelina*, *Alhagi camelorum*, *Astragalus*, *Eryngium*, *Echium*, *Linaria*, *Artemisia* (rare), *Onopordum*, *Centaurea* cf. *virgata*, *Onopordum*, *Agropyron*, *Stipa*. At 200 m halophytic vegetation dominated by *Juncus*.

3. South of Tuz Gölü:

Alongside road: planted *Elaeagnus angustifolia*. Near sampling location: *Rumex obtusifolius*, *Cruciferae*, *Astragalus*, *Echium*, *Thymus argaeus*, *Galium*, *Dipsacaceae*, *Centaurea solstitialis*, *Liguliflorae*, *Gramineae*.

4. Eastern shore of mountain lake (Büyük Gölü), Sahin Tepesi, 1800 m above sea level:

Transhumance area, shepherds huts built of stone (walls) and oakwood (roofs). Grazing and browsing by goats and sheep. Few heavily browsed *Crataegus* and *Cotoneaster*, less than 0.50 m. *Thlaspi arvense*, *Ononis spinosa*, *Trifolium fragiferum*, *Daphne oleoides*, *Rochelia*, *Asperugo procumbens*, *Lallemantia peltata*, *Phlomis*, *Labiatae*, *Carlina*, *Evax anatolica*, *Tragopogon pratensis*, various *Gramineae*. In the far distance: *Juniperus* woodland (see surface sample Nos 14 and 15). Small cornfield at a distance of 100 m. *Astragalus* dominates along the track that leads from the village of Sivrihisar to the mountain lake, occasionally accompanied by *Morina*, *Carlina*, *Centaurea*, *Campanula*, *Phlomis* and *Lotus*. The shallow parts of the lake are dominated by

Table 1. Coordinates of the surface sample locations.

No.	Location	Latitude N	Longitude E
01	Cihanbeyli	38.59'19"	31.31'44"
02	Tuz Gölü 2	38.24'11"	33.04'32"
03	Tuz Gölü 1	38.14'97"	33.28'28"
04	Büyük Gölü, Sahin Tepesi	38.17'35"	34.25'66"
05	Doğantarla	38.22'22"	34.13'47"
06	Yenipinar 1	38.11'27"	34.13'96"
07	Köprüköy	39.32'16"	33.28'23"
08	Güvercinkaya (Chalcolithic site)	38.23'97"	34.11'44"
09	Demirci	38.23'51"	34.18'00"
10	Yenipinar	38.11'23"	34.19'54"
11	Yüksek Kilise, Güzeyurt	38.16'25"	34.20'83"
12	Eski Acıgöl crater lake	38.33'01"	34.32'41"
13	Tatlarinköy	38.36'49"	34.30'88"
14	Kayirli-Bozköy 1	38.17'14"	34.30'18"
15	Kayirli-Bozköy 2	38.16'79"	34.30'27"
16	Kayirli-Bozköy 3	38.16'44"	34.30'11"
17	Bekârlar	38.23'97"	34.23'16"
18/19	Nenezi Dağ	38.22'34"	34.26'44"
20-22	Nar Gölü	38.20'63"	34.27'21"
23	Nar Köy	38.18'94"	34.26'56"
24	Ekecik Dağ	38.31'21"	34.09'29"
25	Southeast of Tatlarinköy	38.37'06"	34.33'97"
26	East of Tatlarinköy	38.50'96"	34.08'70"
27	Erdas Dağ	38.25'84"	34.33'71"
28	Ciftlik	38.09'57"	34.31'82"
29	Küçük Gölü Dağ	38.13'88"	34.31'64"
30	Sivrihisar	38.14'48"	34.25'61"
31	Hasan Dağ 1	38.10'97"	34.16'18"
32	Hasan Dağ 2 (location as No. 31)		
33	Hasan Dağ 3	38.10'35"	34.17'19"
34	Kitreli	38.11'05"	34.21'76"
35	Beynam nature reserve, Balâ	39.40'61"	32.54'57"

Eleocharis multicaulis, with locally some *Potamogeton natans*, *Potamogeton* sp.

5.2.2. Group B: Arable land or pasture

5. One km south of Doğantarla:

Heavily grazed area with small parcels of arable land, vineyards and cultivated fruit trees (*Prunus armeniaca*, *P. persica*, *Malus* and *Pyrus*) at c. 300 m. Hedgerows of planted *Elaeagnus angustifolia*. Herbs: *Polygonum aviculare*, *Noaea mucronata*, *Euphorbia paralias*, *E. peplis*, *Adonis*, *Consolida*, *Nigella*, *Papaver argemone*, *Velezia*, *Cruciferae*, *Reseda*, *Alhagi camelorum*, *Astragalus*, *Medicago rigidula*, *Onobrychis tournefortii*, *Pegamum harmala*, *Althaea*, *Malva*, *Bupleurum tenuissimum*, *Echinophora spinosa*, *Eryngium*, *Acantholimon*, *Plumbago europaea*, *Anchusa*, *Heliotropium*, *Lappula*, *Veronica*, *Ballota larendana*, *Galium*, *Dipsacus*, *Achillea*, *Centaurea solstitialis*, *Centaurea virgata*, *Centaurea*, *Logfia arvensis*, *Cotula*, *Xanthium spinosum*, *Xeranthemum annuum*, *Liguliflorae*, *Stipa*, *Bromus*.

Near a small stream 400 to 500 m east of the sampling location, sparse woody vegetation with *Ephedra*, *Juglans regia*, *Celtis tournefortii*, *Ulmus minor*, *Rhamnus oleoides* and two *Quercus cerris* trees with a trunk diameter of over 60 cm.

6. Halfway between Yenipinar and Helvadere:

Small parcels of arable land, bordered by hedgerows. Principal crops: wheat and barley. In hedgerows: *Quercus cerris*, *Quercus infectoria*, *Q. ithaburensis* ssp. *macrolepis*, *Quercus pubescens*, *Juglans regia*, *Cotoneaster nummularia*, *Crataegus*, *Prunus ursina* (dominant, with *Viscum album*), *P. spinosa*, *Pyrus elaeagnifolia*, *Rosa*, *Colutea cilicica*. Herbs: *Rumex acetosella*, *R. tuberosus*, *Polygonum*, *Silene*, *Papaver*, *Alyssum*, *Camelina*, *Neslia apiculata*, *Hypericum*, *Lotus*, *Trifolium phleoides*, *Leguminosae*, *Umbelliferae*, *Cerinth*, *Nepeta nuda*, *Salvia*, *Sideritis montana*, *Stachys*, *Teucrium chamaedrys*, *Galium*, *Centaurea urvillea*, *Helichrysum arenarium*, *Logfia*, *Tubuliflorae*, *Scorzonera eriophora*, *Lapsana communis*.

5.2.3. Group C: rock outcrops in arable land or steppe landscapes

7. c. 5 km east of Köprüköy, on the Balâ–Kırşehir road:

Cereal cultivation, grazing. On basalt outcrop *Celtis tournefortii*, *Amygdalus orientalis*, *Prunus armeniaca*, *Prunus ursina*, *Rosa* sp., *Rhamnus oleoides* ssp. *gracilis*, *R. petiolaris*, all rare. Tree growth in the far distance. Herbs: *Caryophyllaceae*, *Velezia rigida*, *Helianthemum*, *Potentilla*, *Astragalus*, *Medicago*, *Onobrychis*, *Trifo-*

lium spp., *Trigonella*, Leguminosae, cf. *Limonium*, Boraginaceae, Scrophulariaceae, Liguliflorae, *Aegilops*, *Hordeum* cf. *murinum*, *Setaria*.

8. Güvercinkaya, between Çatalı and Gökçe:

Chalcolithic site near the Mamasi Barajı, lower part of the site flooded in winter. Completely treeless area, except for trees and shrubs in village gardens at one km distance and sparse scrub on the outcrop itself: *Celtis tournefortii*, *Berberis crataegina*, *Crataegus* sp., *Prunus spinosa*, *Rosa*, *Berberis crataegina*, *Rhamnus oleoides* ssp. *graecus*. Herbs: *Noaea mucronata*, *Dianthus*, Caryophyllaceae, *Ceratocephalus falcatus*, *Heliotropium*, *Nonea*, various other Boraginaceae, *Eryngium*, Umbelliferae, *Androsace*, *Cuscuta*, *Cynanchum acutum*, *Crucianella*, *Galium*, *Rubia*, *Centaurea*, *Chondrilla juncea*, *Aegilops*, *Agropyron*, Gramineae. In flooded part: *Alisma*, *Chenopodium botrys*, *Chrozophora tinctoria*, *Polygonum aviculare*.

9. East of Demirci:

Ulmus sp. dominant, further *Celtis tournefortii*, *Berberis crataegina*, *Cotoneaster nummularia*, *Crataegus*, *Rosa*, *Prunus spinosa*, *Rosa*, *Rhamnus oleoides* ssp. *graecus*. Herbs: *Cerastium*, *Silene*, cf. *Clypeola*, *Medicago rigidula*, *Onobrychis*, *Scorpiurus*, *Trifolium*, *Trigonella monspeliaca*, Leguminosae, *Daucus*, *Scandix*, Boraginaceae, Scrophulariaceae, *Orobancha*, *Micromeria*, Labiatae, *Cynanchum acutum*, cf. *Scabiosa*, cf. *Tragopogon*, *Xanthium spinosum*. Vines, apricots and apple trees at 200 m. Cereal cultivation.

10. 5 km northeast of Yenipinar:

Extensive cultivation of cereals (e.g. *Triticum*). Woody vegetation on outcrop: *Amygdalus orientalis* and *Prunus ursina* frequent, *Quercus cerris*, *Celtis tournefortii*, *Amygdalus* sp. (*webbii*?), *Crataegus aronia*, *Crataegus* sp., *Pyrus elaeagnifolia*, *Colutea cilicica*, *Rhamnus oleoides* ssp. *graecus*, all rare. Deciduous oaks in the far distance, apricot trees at a few hundred metres. Herbs: *Rumex*, Caryophyllaceae, *Consolida*, cf. *Camelina*, *Onobrychis*, *Medicago*, *Trifolium* spp., Umbelliferae, *Heliotropium*, *Salvia*, Labiatae, *Valantia*, *Carlina*, Compositae, *Secale*.

11. Near Yüksek kilise, Güzeyurt:

Few shrubs: *Celtis tournefortii*, *Amygdalus orientalis*, *Amygdalus* sp., *Crataegus*, *Prunus ursina*, *Rosa*. Herbs: *Acantholimon*, *Vincetoxicum*.

12. Eski Acıgöl crater lake:

The former crater lake is dominated *Atriplex*, *Descurainia*, *Bromus tectorum* and *Hordeum murinum*. Occasional: *Polygonum aviculare*, *Euphorbia*, *Alyssum*, Labiatae, *Plantago* cf. *psyllium*, *Aegilops*, *Agrostis*, *Cynodon dactylon*, *Phragmites*, *Stipa*. On the crater rim: *Elaeagnus angustifolia*, *Noaea mucronata*, *Camelina*, *Isatis*, *Reseda*, *Alhagi camelorum*, *Echinophora spinosa*, *Eryngium campestre*, *Acantholimon* (rare), *Anchusa*, *Heliotropium*, *Lappula barbata*, *Onosma*, *Verbascum*, *Salvia*, *Achillea*, *Centaurea virgata*, *Onopordum*, *Senecio*, *Xeranthemum annuum*, *Cynodon* (rare).

East slope of Güneydağ Tepe. Arboreal cover c. 10%. *Quercus pubescens* and *Juniperus oxycedrus* dominant, shrublets of *Daphne* cf. *oleoides* (frequent), *Cotoneaster nummularia*. Herbs: *Dianthus*, *Silene*, Caryophyllaceae, *Euphorbia*, *Astragalus*, *Eryngium*, Umbelliferae, *Acantholimon*, *Verbascum*, *Marrubium globosum*, *Vincetoxicum*, *Dipsacus*, *Artemisia* (few), *Centaurea virgata*, *Chondrilla juncea*, *Logfia arvensis*, *Xeranthemum an-*

num, *Asphodelus* sp., *Aegilops*. *Chenopodium botrys* and *Polygonum aviculare* are dominant among the weeds in arable fields at the foot of the slope.

13. Rugged basalt area east of Tatlarinköy (6 km north of Acıgöl town):

Outcrops with sparse woody vegetation: *Juniperus oxycedrus* (rare), *Celtis glabrata* (rare, but locally abundant), *Prunus armeniaca* (rare), *Cerasus prostrata* (occasional), *Pyrus elaeagnifolia* (rare), *Rosa* sp. (occasional), *Rhamnus oleoides* ssp. *graecus* (common). Herbs: *Noaea mucronata*, *Dianthus*, *Euphorbia* (common), *Astragalus* (rare), *Echinophora spinosa*, *Eryngium* (common), *Acantholimon* (occasional), *Heliotropium*, *Cynanchum acutum* (common), *Galium* (occasional), *Achillea* (occasional), *Chondrilla juncea*, *Helichrysum arenarium* (rare), *Onopordum*, Compositae, *Allium* (frequent), *Asparagus officinalis* (occasional), *Asphodeline*. Small patches of arable land with pumpkin crops, also *Chenopodium album*, *C. botrys*, *Noaea mucronata* and others.

5.2.4. Group D: oak-juniper woodland

14. One km south of Kayırlı:

Fruiting *Quercus pubescens* and *Juniperus oxycedrus* dominant (ratio 60:40), few *Berberis crataegina*, *Crataegus*, *Pyrus elaeagnifolia*. Few herbs: *Astragalus*, cf. *Tuberaria*, *Asphodelus*, *Stipa*.

15. Two km south of Kayırlı:

Predominant *Quercus pubescens*, trees up to 8 m, fruiting. Some large *Juniperus excelsa* and *Quercus ithaburensis* ssp. *macrolepis*. *Juniperus oxycedrus* (rare). Oak: juniper ratio 10:1. In the arable fields: solitary *Cotoneaster nummularia*, *Crataegus aronia*, *Pyrus elaeagnifolia*, *Rosa*.

16. North of Bozköy:

Juniperus excelsa dominant, also *J. oxycedrus*, *Quercus pubescens* (fruiting), *Q. ithaburensis* ssp. *macrolepis* (fruiting), *Cotoneaster nummularia*. Herbs: *Euphorbia*, *Cruciferae*, *Astragalus*, *Salvia*, *Onopordum*.

5.2.5. Group E: oak forest/woodland

17. Northeast of Bekârlar:

Open, grazed, non-fruiting *Quercus pubescens* coppice. Along the edges, some *Celtis tournefortii*, *Amygdalus orientalis*, *Pyrus* cf. *amygdaliformis*, *Rhamnus oleoides*. In the fields *Pyrus elaeagnifolia*. Herbs: Caryophyllaceae, *Euphorbia*, *Alyssum*, *Glycyrrhiza glabra*, *Medicago rigidula*, *Medicago*, *Melilotus*, *Althaea camabina*, *Eryngium*, Umbelliferae, *Anchusa*, *Verbascum*, *Phlomis*, *Galium*, *Centaurea*, *Tubuliflorae*.

18. Arable fields at foot of Nenezi Dağ, 2 km southeast of Bekârlar:

Cereal crops (mainly *Triticum*) and scattered shrubs. *Amygdalus orientalis* (rare), *Prunus* cf. *spinosa* (rare), *Rosa canina* gr. (rare), *Colutea cilicica* (rare), *Rhamnus oleoides* ssp. *graecus* (occasional). Herbs: *Noaea mucronata*, *Euphorbia* spp., *Dianthus*, Caryophyllaceae, *Consolida*, *Glaucium*, *Echinophora spinosa*, *Eryngium*, *Scandix*, *Echium*, *Onosma*, *Verbascum*, *Micromeria*, *Salvia*, Dipsacaceae, *Anthemis* spp., *Artemisia* (rare), *Carduus*, *Carlina*, *Tubuliflorae*, *Chondrilla juncea*, *Liguliflorae*, *Bromus*, Gramineae.

19. West slope of Nenezi Dağ, 300 m east of sample No. 18: Grazed area with scattered oak scrub, cover up to 5%. *Quercus pubescens* dominant (non-fruiting), *Amygdalus orientalis* (rare), *Rhamnus oleoides* ssp. *graecus* (rare). Herbs: *Alyssum*, *Astragalus*, *Echinophora spinosa*, *Eryngium*, *Cynanchum acutum*, *Echium*, *Verbascum*, *Salvia*, *Teucrium*, *Thymus*, *Morina persica* (common), *Carlina*, *Centaurea solstitialis*, *Echinops*, *Xeranthemum annuum*, *Asphodeline*, *Stipa*, Gramineae.

20. Nar Gölü crater lake, northern Göllüdağ (sometimes also referred to as Acıgöl):

Because of the occurrence of oak woodland immediately south of the lake, the samples have been included in Group E. In arable land north of the lake, solitary *Crataegus aronia*, *Pyrus elaeagrifolia*, *P. syriaca*.

Scattered shrubs on south-facing slope (c. 45°) in northern part. *Quercus pubescens* (rare), *Celtis tournefortii* (occasional), *Amygdalus orientalis* (rare), *Crataegus aronia* (occasional), *Prunus armeniaca* (rare), *Rosa canina* gr. (occasional), *Pistacia atlantica* (rare), *Rhamnus oleoides* ssp. *graecus* (frequent). Herbs: *Euphorbia*, *Astragalus*, *Trifolium*, *Echinophora spinosa*, *Eryngium*, *Plumbago europaea*, *Verbascum*, *Echinops*, *Liguliflorae*. *Fraxinus angustifolia* and *Pistacia atlantica* dominate the east-facing slope.

21. High up on the southern crater rim (50–60° slope), Nar Gölü: *Juniperus oxycedrus* (occasional), *Quercus pubescens* (dominant, few acorns), *Q. ithaburensis* ssp. *macrolepis* (rare), *Q. cf. cerris* (rare), *Amelanchier ovalis* (occasional), *Amelanchier* sp. (rare), *Cotoneaster cf. integerrimus* (rare), *C. nummularia* (rare), cultivated apricots and pears grafted on *Pyrus elaeagrifolia*. Along runnel from spring: *Populus nigra*, *Salix alba*, *Salix* sp., *Elaeagnus angustifolia*. Herbs on limestone in southeastern section: *Rumex crispus*, *Astragalus*, *Ononis*, *Daphne oleoides*, *Thymus*, *Artemisia*, *Helichrysum arenarium*, *Xeranthemum annuum*, *Asphodeline*, Gramineae.

22. Northeast-facing slope of Nar Gölü crater, c. 10 m above lake level, approximately 75 m below No. 21:

Locally some *Colutea cilicica*. Higher up the slope extensive oak brushwood (scarcely fruiting) and occasional shrubs of *Cerasus microcarpa*. Sample taken to distinguish the pollen precipitation from different elevations.

23. Wadi south of Nar Köy:

Lava soils grazed by cows. Patches of fruiting *Quercus pubescens* dominate the steep wadi slopes and the adjacent areas east of the wadi. *Q. ithaburensis* ssp. *macrolepis* (rare). Moss sample from open area with locally arable land: *Crataegus aronia* (occasional), *Prunus ursina* (frequent), *Pyrus elaeagrifolia* (rare), *Rosa canina* (occasional), *Astragalus* (frequent). Along brook *Populus nigra*, *Salix*.

24. Ekecik Dağ, 1 km west of the village of Göksugüzel:

Heavily grazed, open *Quercus pubescens* woodland, poor in species. Trees (fruiting), also cushions as a consequence of frequent browsing. *Juniperus oxycedrus* (occasional), *Cotoneaster nummularia* (rare). Herbs: *Astragalus* and Gramineae dominant, *Eryngium* (rare).

25. c. 8 km northeast of Acıgöl town:

Heavily grazed slopes with very open *Quercus pubescens* woodland on basalt. Sample taken just beyond the woodland. Tilled land at the foot of the slope (cereal crops in 2000). Trees up to 5 m tall, trunks 20–30 cm in diameter, fruiting, also some regen-

eration. *Juniperus oxycedrus* (rare), *Rhamnus oleoides* ssp. *graecus* (rare). Herbs: *Euphorbia*, *Astragalus* (occasional), *Eryngium*, *Acantholimon* (occasional), *Verbascum*, *Artemisia* (occasional), *Ptilostemon*, *Asphodeline*. On lower part of slopes, *Artemisia* and Gramineae are fairly common.

26. Rugged basalt area c. 4 km east of Tatlarinköy:

Open *Quercus pubescens* woodland with small patches of cereal and pumpkin crops. Also *Amygdalus* sp. (rare), *Cerasus prostrata* (rare), *Pyrus elaeagrifolia* (rare), *Rhamnus oleoides* ssp. *graecus* frequent on treeless outcrops, *Jasminum fruticans* (rare). Herbs: *Euphorbia*, Boraginaceae, *Acantholimon*, *Salvia*, *Thymus*, *Cynanchum acutum*, Dipsacaceae, *Achillea*, *Chondrilla juncea*, *Onopordum*, *Asparagus officinalis*, *Aegilops*, *Avena* (cultivated), *Bromus*, *Elymus*, *Secale*, Gramineae.

27. South slope of Erdaş Dağı:

Scrub of *Quercus pubescens* dominant, few *Amygdalus orientalis*, *Crataegus*, *Prunus armeniaca*, *Prunus cf. spinosa*, *Pyrus elaeagrifolia*, *Rosa*, *Rhamnus oleoides* ssp. *graecus*, *Fraxinus angustifolia*. In nearby fields: cereal cultivation, hedgerows with *Elaeagnus angustifolia*. Herbs: *Alyssum*, *Coronilla*, *Onobrychis*, cf. *Micromeria*, *Ziziphora*.

28. South of Çiftlik:

Degraded oak woodland with *Quercus pubescens* and *Q. ithaburensis* ssp. *macrolepis*. Also *Ulmus*, *Cotoneaster*, *Crataegus*, *Prunus spinosa*, *Rosa*, and *Daphne oleoides* present. Herbs: cf. *Fibigia*, Cruciferae, *Coronilla*, *Thymus*, *Stachys*, *Aegilops*.

29. South slope of Küçük Göllüdağ:

Quercus pubescens coppice with few acorns. Cover near top 30–50%, here also some *Juniperus oxycedrus*, *Quercus cf. infectoria*. Herbs: *Rumex acetosella*, *Herniaria*, cf. *Minuartia*, *Silene*, *Antirrhinum*, *Veronica*, *Teucrium*, *Helichrysum arenarium*, *Liguliflorae*, *Asphodeline*, cf. *Aira*.

30. Halfway along Sivrihisar–Çiftlik road:

Extensive oak woodland dominated by *Quercus pubescens*. *Q. ithaburensis* ssp. *macrolepis*, *Crataegus*, *Cotoneaster nummularia*, *Crataegus*, *Prunus cerasus* and *Pyrus elaeagrifolia* (rare). An abundance of herbs grow in the patches of arable land near the road. Herbs: *Thesium*, *Polygonum* spp., *Rumex sect. patientia*, *Chenopodium botrys*, *Chenopodium*, *Ranunculus arvensis* (dominant), *Silene*, Caryophyllaceae, *Euphorbia*, *Sanguisorba minor*, *Dorycnium*, *Melilotus*, *Trifolium*, *Thymelaea passerina*, *Scandix*, Umbelliferae, *Anagallis*, cf. *Kicksia*, *Veronica*, *Ziziphora capitata*, *Plantago lanceolata*, *Cruciata*, *Anthemis* spp., *Evax*, *Matricaria*, *Bromus* spp., *Hordeum*.

31. Hasan Dağ:

Edge of open *Quercus cerris* forest. Some *Crataegus*. Herbs: *Rumex acetosella*, *Verbascum*, *Dipsacus*, *Artemisia fragrans*, *Xeranthemum annuum*, *Secale*, Gramineae.

32. Hasan Dağ, near to No. 31:

Quercus cerris forest. Herbs: *Nigella*, *Consolida*, Cruciferae, Leguminosae, *Buglossoides*, *Dipsacus*, *Artemisia fragrans* (rare), *Centaurea depressa*, *Chondrilla juncea*, *Lapsana communis*, *Logfia arvensis*, *Xeranthemum annuum*, *Bromus tectorum*, *Phleum*.

33. Four km southeast of Yenipinar:

Along a small stream. *Quercus cerris* scrub. Herbs: *Astragalus*, *Salvia*, *Bromus*, *Dactylis*.

34. One km north of Kitreli:

Open *Quercus ithaburensis* ssp. *macrolepis* forest, few low, browsed *Crataegus*. Wild orchards in the fields beyond the forest. Here *Pyrus eleagnifolia* is dominant, also domestic pears with *Viscum album*, *Prunus ursina* rare. Herbs: *Salvia*, *Verbas-cum*.

5.2.6. Group F: pine forests

35. Beynam forest, Balâ:

Pinus nigra dominant, undergrowth, where present, dominated by *Quercus pubescens*. In open locations *Juniperus oxycedrus*, *Viscum album* (on pine), *Amelanchier rotundifolia*, *Cotoneaster nummularia*, *Crataegus orientalis*, *Pyrus elaeagnifolia*, *Rosa canina*, *Genista sessiliflora*, *Ligustrum ovalifolium*, *Lonicera etrusca*. Along tracks: *Prunus spinosa*, *Pyrus amygdaliformis*, *Colutea cilicica*. Herbs: *Chenopodium*, *Melandrium*, Caryophyllaceae, *Euphorbia*, *Fibigia clypeata*, cf. *Alyssum*, Cruciferae, *Helianthemum* spp., *Hypericum*, *Sedum*, *Geum urbanum*, *Astragalus*, *Trifolium*, *Onobrychis*, cf. *Orlaya*, *Torilis*, Umbelliferae, *Androsace*, cf. *Cynoglossum*, *Lavandula*, *Micromeria*, *Stachys*, *Teucrium* spp., Labiatae, *Vincetoxicum*, *Galium* spp., *Scabiosa*, Dipsacaceae, *Centaurea*, Compositae, *Bromus*, *Cynosurus*, Gramineae.

5.3. Interpretation of the modern pollen precipitation

Pine and oak dominate the arboreal pollen set (fig. 7). A part of the samples taken at locations where oak woodland prevails show appreciable oak values of over 20%. In several other samples (e.g. Nos 17–23) from these locations oak values are conspicuously low and are mostly exceeded by pine values. At present, pines do not grow spontaneously in Cappadocia and are even scarce in the other parts of Central Anatolia. The natural occurrences of pine in the Taurus and the Pontic, together with the plantations in Cappadocia, must be considered as the source of the pine pollen in the surface samples. Several explanations can be put forward for the relatively high pine values in the samples. First, it has to be realized that pines are not only prolific pollen producers, but also have their pollen dispersed over large distances. Further, it can be noticed that the samples from steppic areas (Nos 1–13) have almost the same NAP values as those from forested areas, which suggests relatively low herb pollen production in open areas. The herb vegetation in open areas is the most accessible forage for grazers. Continuous grazing will primarily affect the herb vegetation, resulting in reduced flowering and pollen production. A high grazing intensity seems the principal explanation of the pine values.

Oaks can also produce considerable amounts of pollen, but their dispersal capacity is limited. This is well illustrated by the composition of surface samples 32 and 33, collected in forest dominated by Turkey oak (*Quercus cerris*). The high values of oak pollen indicate that this species is a prolific pollen

producer. The absence of this pollen type in the other samples indicates the poor long-distance transport of Turkey oak pollen. Given the *Quercus robur*-type pollen values, poor pollen dispersal holds also for the other oak species. This means that even oak values of only 5–10% may represent well-developed, fruiting oak trees within a short distance from the sampling location.

The oak pollen values strongly depend on the age of the tree population. The samples from oak woodlands (Nos 14–34) indicate clearly higher oak values at locations where fruiting oak trees are found. Samples from locations with coppiced oaks in general show low oak pollen values. The presence of acorn-bearing oak trees is indicative of flowering and therefore is mentioned in the vegetation records.

Beside the above-mentioned arboreal taxa, also *Juniperus* and *Salix* are represented in most of the surface samples. *Juniperus oxycedrus* is widespread throughout Cappadocia, but rarely abundant. *J. excelsa* is almost confined to the Göllüdağ Mountains. This species is the main contributor of juniper pollen in samples 15 and 16. In Central Anatolia *Salix* species are confined to streams.

Low *Pistacia* values match the present rareness of *Pistacia* species in Cappadocia. Nar Gölü is the only sampling location (Nos 20–22), where terebinths (*Pistacia atlantica*) were encountered in the vegetation. The *Pistacia* values from this location, however, are remarkably low.

Although *Crataegus*, *Pyrus* and *Rosa* are among the most common taxa in the woody vegetation, pollen of these taxa is almost completely absent in the pollen spectra. The arborescent Rosaceae are usually insect-pollinated, a system that does not require the dispersion of large amounts of pollen. *Celtis tournefortii* is a fairly common member of the elm family in the area but its pollen was rarely encountered. Taxa like *Ostrya/Carpinus orientalis*, *Quercus calliprinos*, *Olea* and *Cedrus* are uncommon or absent in Cappadocia. Most of their pollen comes from southern areas, where these taxa are often widespread.

In most samples grasses dominate the NAP taxa. Grass pollen values in the samples from open, treeless areas do not differ significantly from those of locations with a higher share of trees. This levelling is thought to be the result of grazing. The relatively high values for grasses in the samples from the rock outcrops are probably due to the more restricted accessibility of these locations to livestock.

Substantial values of Cerealia-type and *Hordeum/Triticum* pollen have been recorded from areas where cereal cultivation is practised (e.g. Nos 5–6, 17–19). This seems obvious, but most domestic cereals release their pollen quite poorly. Part of the large-sized pollen may have been produced by wild grasses like *Aegilops*, which is represented by various species in Cappadocia.

Artemisia species and members of the Chenopodiaceae family, important components of the arid Late Glacial steppe vegetation in Cappadocia, play a minor role at present. In accordance with the share of *Artemisia* in the local vegetation, only two samples (Nos 22, 31) show substantial pollen percentages for this species.

6. THE CORING

Coring was carried out in Eski Acıgöl in 1991 (ESK91) and 1992 (ESK92). The cores measured 6.70 m and 14.85 m, respectively. Technical limitations prevented deeper coring. Subsequent coring showed that the average depth of the lake was around 20 m (Kuzucuoğlu et al., 1998).

Technical problems in coring led to the loss of the part between 9.00 and 10.00 m in ESK92. Coring of the soft sediment caused distortion in the top part of most core logs, and some have incomplete recovery. The ESK92 core logs show varved sediment from 7.10 m downward. Also the uppermost 1.25 m includes varved sections, but coherent sampling of the hard and dry sediment was not possible. The laminae mostly consist of couplets which have been identified as seasonal production and deposition of organic matter (dark, autumn/winter), carbonates (white, summer) and silts (brownish, winter). A thin, hard layer, consisting of massive calcitic travertine, occurs at 13.99 m. (Roberts et al., 2001)

In the later history of the lake, peat built up along its margins. Kazancı et al. (1995) identified three different strata of fen peat.

6.1. Lithology

0–26 cm	brownish and greyish silts, without varves
26–29 cm	1.5 mm thick laminae separated by narrow black and white lines
29–30 cm	no recovery
30–35 cm	as in 26–29 cm, but laminae thickness 2.5–3.0 mm
35–39 cm	no recovery
39–44 cm	2 mm thick laminae separated by thin, black lines
44–49 cm	brown-grey silts, laminae c. 2 mm, alternating with 1.5 mm thick black (organic?) laminae, a 1.6 cm slice comprising five couplets
49–50 cm	no recovery
50–55 cm	as in 44–49 cm, but brown silt laminae 2–2.5 mm, black ones c. 1.5–2 mm. 3.5 cm = 8 couplets
55–65 cm	brown silts, generally with indistinct lamination, but a quantifiable slice of 15 mm (c. 55–57 cm) comprised 14 couplets
65–67 cm	yellow (locally whitish), carbonate matter
67–70 cm	2.5 cm yellow-brown, indistinct varving, not countable
70–72 cm	no recovery

72–75 cm	ditto, 1.5 cm sediment, c. 12 couplets
75–84 cm	yellow carbonate, indistinct lamination
84–86 cm	no recovery
86–97 cm	yellow carbonate, locally grey-black owing to organic matter of monocot structure
97–101 cm	no recovery
101–110 cm	yellow carbonate
110–123 cm	ditto, with abundant monocot plant remains incorporated, 116–117 cm 8 couplets of laminae
125–140 cm	ditto, without visible lamination
140–290 cm	lake marl/eroded white-coloured pumice, without varves
290–475 cm	massive and banded silts
475–710 cm	gyttja
710–870 cm	c. 1205 varves
870–925 cm	very incomplete section, but the parts present are all varved
925–995 cm	no recovery
995–1202.5 cm	c. 1660 varves Varied part interrupted by a massive, dark, organic layer at 1161–1165 cm
1202.5–1485 cm	c. 2725 varves A hard, calcitic layer (thickness c. 1 cm) located at 13.99 cm

7. THE POLLEN DIAGRAMS

7.1. Methods

The main pollen diagram (Eski Acıgöl I, fig. 8) consists of 80 spectra. The spectra were calculated from a sum including arboreal pollen (AP) and upland herb pollen (NAP). Pollen and spores of local plants, algae (*Pediastrum*), rotifers and dinoflagellates are not included in the pollen sum. Almost all pollen samples were prepared from the ESK92 core, but spectra 70–74 were prepared from ESK91, because of the much better recovery. Spectra 30–33, which cover the depth between 9 and 10 m, were prepared from samples provided by Prof.dr Neil Roberts (University of Plymouth, U.K).

The Acıgöl II diagram (fig. 9) was produced from high-resolution counting of the laminated bottom section of the ESK92 core (1485–1476.5 cm). The principal aim was to examine the magnitude of short-term changes in pollen precipitation and vegetation. This diagram is explained at the end of the discussion of zone 1.

7.2. Radiocarbon dates

The following radiocarbon dates have been obtained:

Lab code	lithology	depth (cm)	$\delta^{13}\text{C}\text{‰}$	^{14}C age
GrN-23467	org.	0–3	-25,2	1360±30
GrN-23468	calc.	0–3	3,3	1690±30
GrN-22137	org.	262–264	-27,7	5540±280
GrN-22881	org.	455–465	-18,1	6610±60

GrN-22882	calc.	455–465	12,5	6535±70
GrN-21036	org.	663–665	-28,2	9440±230
GrN-22447	org.	832–836	-27,1	11,360±100
GrN-22605	org.	836–840	-25,2	10,910±100
GrN-22448	calc.	836–840	10,1	11,960±260
GrN-21035	org.	1044–1049	-28,9	11,590±180
GrN-20633	org.	1161–1165	-29,1	13,450±150
GrN-24233	org.	1243–1249	-25,9	14,470±140
GrN-24233	calc.	1243–1249	9,9	14,480±450
GrN-19988	org.	1450–1455	-30,7	14,320±170
GrN-19989	calc.	1450–1455	10,3	15,200±220

In addition, two radiocarbon dates of peat layers from the eastern part of the lake are available (Kazancı et al., 1995). The lower peat unit (depth c. 2.40 m) has been dated to 2010±80 BP, the upper peat unit (1.0–0.5 m) to 1810±65 BP.

7.3. Remarks on the dating methods and chronology

Unlike the mostly consistent ^{14}C dates of peat sediments, lacustrine sediments frequently appear too old, owing to so-called reservoir effects (Bowman, 1990). There are also indications of reservoir effects in the Acıgöl sediments. Extrapolation of the age/depth line (fig. 10) suggests a general age offset well over 3000 years (Cappers et al., 2001), which implies too great an age of the ^{14}C record. Roberts et al. (2001) indicate that the reservoir effect in Eski Acıgöl most probably results from volcanic outgassing, which led to the incorporation of old carbon in organic matter produced within the crater lake system.

The characteristic, abrupt shift from *Artemisia*/Chenopodiaceae semi-desert to grass steppe is thought to represent a rapid and substantial improvement of the climate. Roberts et al. (2001) identify this event as the Younger Dryas–Holocene transition. They accept an average reservoir effect of 3000 years for the whole sediment. However, a correction of the ^{14}C dates by 3100 years (adopted in this paper) would give an interpolated date of 10,860 BP for the 1–2 zone boundary. The start of the Holocene is marked by a global and rapid climate improvement, dated to

around 10,150 BP (Lanting & Van der Plicht, 1996). This means that either the reservoir effect is substantially more than 3000 years, or that the climate improvement at the subzone 1c–2a transition indeed has an earlier date and consequently cannot be identified with the termination of the Younger Dryas. The latter possibility cannot be immediately rejected. Bottema (1995) indicates that it is difficult, if not impossible, to trace the Younger Dryas in the eastern Mediterranean palynologically. Pollen diagrams from the Near East show widely differing developments in the regional Late Glacial and early Holocene vegetation histories (see also section 12.1). For example, the Hula diagram (Baruch & Bottema, 1999) demonstrates the highest AP values during the Late Glacial. The increase of AP values in the pollen diagrams of Akgöl Adabağ, south-Central Anatolia and Beyşehir in the Lake District (Bottema & Woldring, 1986) in the course of the 11th millennium BP, points to milder conditions quite some time before the termination of the Younger Dryas. The diagrams of Lake Van (Wick et al., in press) and Eski Acıgöl display very similar vegetation developments in the Late Glacial and early Holocene phases, respectively. On the basis of the pollen evidence one is inclined to consider these phases as simultaneous developments. The changes in the pollen record of Lake Van indicate improving climate conditions, starting c. 10,400 BP in calendar years (zone 4–5 transition, fig. 11), in ^{14}C -years c. 9200 BP. This suggests a delay of more than 1600 years in the transition to more humid and warmer conditions in the Van area, compared to the central part of Anatolia. However, one should bear in mind that the Acıgöl ^{14}C record has been considerably corrected and that recently doubt has arisen concerning the number of varves established for the Lake Van sediment. Comparison of the Van record with the GRIP cores suggests that 1000 varves were lacking, possibly as a consequence of the lack of CaCO_3 deposition during the mid-Holocene forest optimum (Wick, pers. comm.). In that case, the delay in the start of more favourable climatic conditions in Van with respect to Acıgöl would

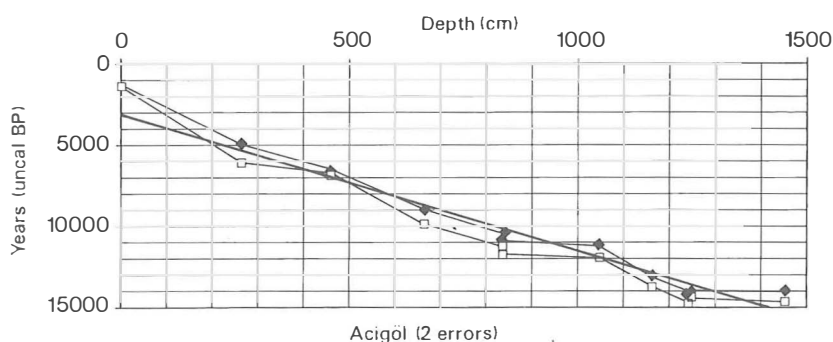


Fig. 10. Age/depth diagram indicating the intercept of the regression line at 3100 BP.

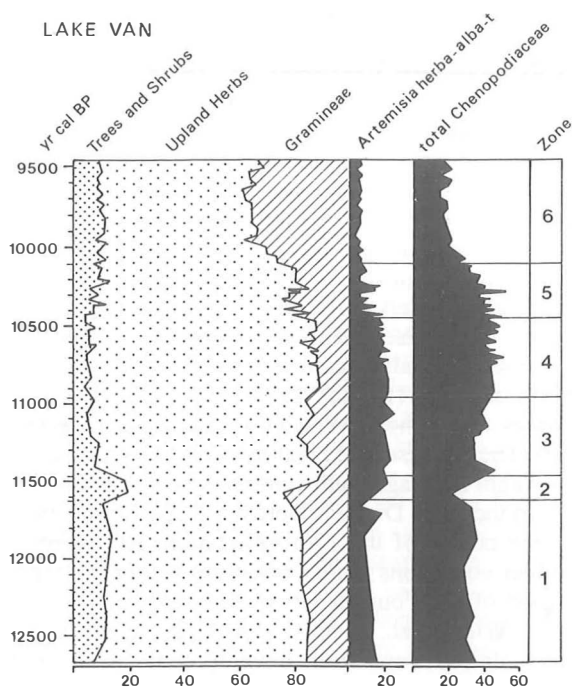


Fig. 11. Late Glacial/early Holocene section of the Van diagram with the pollen types discussed in the text (by kind permission of Dr L. Wick, Bern).

be less than 700 years. On the basis of geochemical evidence, Landmann et al. (1996a) have pinpointed the termination of the Younger Dryas in Lake Van to $10,920 \pm 132$ BP in calendar years, corresponding with 9700 BP in ^{14}C years.

All this points to regionally different vegetation developments in these periods, which means that one has to be careful in dating Near Eastern pollen diagrams merely on the basis of the palynological evidence. The uncertainties raised by the Acigöl radiocarbon record means that we need charcoal or organics of terrestrial origin to obtain a solid chronology for the sediments, as pointed out by Roberts et al. (2001). Radiocarbon dating of pollen (from ESK92 subsamples) has recently been initiated. Until this problem is settled, we tentatively assume a reservoir effect of 3100 years for all the ESK92 ^{14}C dates, as deduced from extrapolation of the regression line in the age/depth diagram.

7.4. Zone boundary chronology

The regression line suggests the lower ^{14}C date (GrN-19988) to be an outlier. This was a reason to use the varves for dating the lower sediment section. The conversion of the varve numbers for dating the subzones 1a–1c in BP years goes as follows: interpolation of the corrected ^{14}C dates (GrN-20633, GrN-

24233) indicates a date of 10,860 BP for the subzone 1c–2a transition, corresponding with 10,950 cal BC. This dates the start of zone 1a at c. 13,675 cal BC ($10,950 + 2725$ varve years), which corresponds to a ^{14}C age of 13,000 BP and produces the following ^{14}C ages for zone 1:

Zone 1	c. 13,675–10,950 cal BC=13,000–10,860 BP
Subzone 1a	c. 13,675–12,905 cal BC=13,000–12,450 BP
Subzone 1b	c. 12,905–11,840 cal BC=12,450–11,700 BP
Subzone 1c	c. 11,840–10,950 cal BC=11,700–10,860 BP

Subzone 1c shows a fairly consistent number of varves (890) and uncalibrated ^{14}C years (840). Substantial differences are found between the number varves and uncalibrated ^{14}C years in subzone 1b (1065 varves as against 750 ^{14}C years) and 1a (770 varves as against 350 ^{14}C years).

Interpolation of the ^{14}C dates produces the following ages for zones 2 to 5:

Subzone 2a	c. 10,860–8600 BP
Subzone 2b	c. 8600–7900 BP
Subzone 3a	c. 7900–7060 BP
Subzone 3b	c. 7060–3870 BP
Zone 4	c. 3870–1650 BP
Zone 5	c. 1650–0 BP

8. CRITERIA FOR THE IDENTIFICATION OF SOME POLLEN TYPES AND PALYNOMORPHS

The excellent preservation of the pollen and other palynomorphs and the low proportions of other organic residues allowed a fairly high level of identification of the Acigöl material. This section describes less common palynomorphs along with pollen types identified beyond the normal level of identification. For information on more regular pollen types from the Near East, the reader is referred to Van Zeist & Bottema (1977).

Quercus robur-type and *Q. cerris*-type. Scabrae clear, isolated, size of pollen 25–30 μm . Structure of the exine simple. The type includes *Q. robur*, *Q. pubescens*, *Q. frainetto*, *Q. ithaburensis* ssp. *macrolepis* and *Q. infectoria*, all of which occur with varying frequency in Central Anatolia. Well-defined scabrae absent in *Q. cerris*-type. Exine slightly thicker and structure more intricate than in *Q. robur*, approaching that of *Fagus* or *Crataegus*. Pollen grains slightly larger than in *Q. robur*-type, 30 μm or more. *Q. cerris* is probably the only oak species in Turkey producing this pollen type.

Several types from the goosefoot family have been distinguished. Beside the common *Atriplex*-type, also *Beta* (c. 25 pores, surrounded by clearly defined margo), *Noaea*-type, *Aellenia*-type (small angular grains with few pores, described and depicted in Van Zeist & Bottema, 1977) and *Salsola* could be identified. *Salsola* species produce different types of pollen. The identified *Salsola* pollen originate from

a group of species producing pollen densely covered with numerous pores, including *Salsola ruthenica*.

Taraxacum produces two types of pollen. One type is indistinguishable from the pollen type produced by the majority of Liguliflorae. The second type differs from this group in its slightly asymmetric shape, poor fenestration and in some instances syncolpate habitus. This pollen type is produced by a group of apomicts in *Taraxacum*.

Cerealia-type is a group of grass-pollen grains larger than 40 μm , which could not be identified as *Hordeum/Triticum* or *Secale*. The main difference with pollen of other grasses is their size. *Secale* pollen has an elongated shape and the pore is located at two-thirds of its length, whereas special features of the *Hordeum/Triticum* type are the peculiar oval to round, slightly asymmetric shape, the structure of the grains and the larger pore with a broad and somewhat heightened annulus. In Anatolia these types include wild as well as cultivated species.

Rumex acetosa seems to be absent in Anatolia (Davis, 1965–1988). Therefore the pollen identified as *Rumex acetosa* most probably derives from *R. tuberosus*, a polymorphic species that has similar ecological demands as *R. acetosa* and which replaces this species in Anatolia. Most of the unidentified sorrel pollen (*Rumex* indet.) resembles *Rumex scutatus*.

Pollen included in the Plantaginaceae in most cases belongs to a type with 5(–7) large pores, a thick annulus and psilate structure. This type resembles pollen of *Plantago maritima*, but lacks the conspicuous verrucae of this species.

An unidentified trilete or triloid spore with a weak aperture, c. 55 μm across, shows a resemblance to spores of certain *Selaginella* species.

Usually palynologists have no problems in distinguishing *Equisetum* spores from pollen of *Juniperus*. In the Acigöl assemblages occasionally grains were encountered which display the characteristic cleft form of juniper, but the pollen/spores lack the gemmae of this taxon. The grains are slightly larger and in contrast to juniper can be coloured by staining. Such spores were found in samples with classical *Equisetum* and have therefore been included in this taxon.

Freshwater zoo-plankton

Resting eggs (zygospores) of three rotifer species (Rotatoria family) have been recorded. Two types of zygospores of Dinoflagellates (*Dinophyta*) occur: type A has low and broad echinae as in Tubuliflorae. Type B has large hairy elements. Some of the grains combine these characteristics, so that different forms of the same species or group can be assumed.

9. POLLEN ASSEMBLAGE ZONES OF THE ESKI ACIGÖL I DIAGRAM

Five main pollen zones have been identified. Zone 1 (spectra 1–19): characterised by high pollen values of steppe plants. On the basis of the composition of the herb pollen, three subzones can be distinguished.

Subzone 1a (spectra 1–7). Gramineae, *Artemisia* and Chenopodiaceae including *Atriplex* are the main contributors to the NAP sum. AP values are c. 10%. Subzone 1b (spectra 8–13): highest AP values of zone 1. *Atriplex* values rise to c. 20%. There is also a slight increase in *Artemisia herba-alba*-type, Cerealia-type and *Quercus robur*-type, whereas Gramineae values decline to around 30%. Subzone 1c (spectra 14–19): owing to lower values of *Quercus robur*-type, the AP percentages are the lowest of the diagram. *Artemisia herba-alba*-type shows a dramatic increase.

Zone 2 (spectra 20–37). The pollen content of this zone led to the identification of two subzones. Subzone 2a (spectra 20–26): values of Gramineae rise to c. 60%, *Rumex acetosa*-type up to 8%. The pollen record demonstrates an abrupt decline of *Artemisia* and Chenopodiaceae, while arboreal pollen gradually increases to c. 20%. Subzone 2b (spectra 27–37) shows a further increase of AP values to c. 30%, due to higher values of deciduous oaks, *Pistacia*, *Juniperus* and *Pinus*. Gramineae decline to c. 50% towards the end of this zone. *Artemisia herba-alba*-type as well as *Artemisia vulgaris*-type increase again to c. 10%. *Equisetum* is the main local contributor to the record. Abundant egg remains of water fleas (*Daphnia* sp.) were recorded in spectra 30–34.

Zone 3 (spectra 38–55). This zone shows a fairly abrupt rise of AP percentages up to 55%, caused by *Corylus*, *Quercus robur*-type and *Pinus*. AP values drop to below 25%, but rise again to c. 70% at the end of this zone. *Quercus robur*-type remains quite constant, but shows the highest values (over 30%) of the diagram towards the end of this zone. Gramineae and *Artemisia* are the main NAP contributors.

The division of zone 3 into subzone 3a (spectra 38–43) and 3b (spectra 44–55) is mainly based on the decline of *Corylus* and *Cedrus* and a significant rise of Cerealia-type and *Hordeum/Triticum* from the base of subzone 3b. Subzone 3a shows an abrupt rise and decline of *Myriophyllum* and a further increase of *Equisetum*, with rotifers (*Filinia longiseta*) producing abundant resting eggs during this period, which is followed in subzone 3b by a marked rise of green algae (*Pediastrum*).

Zone 4 (spectra 56–74). A sharp decline of deciduous oaks marks this zone. Nonetheless, AP values increase to almost 80% shortly after the start, owing to a dramatic rise of pine values. From spectrum 56 onwards, AP values decline substantially to less than 20% in spectrum 67. Various herb-pollen

types, including several composites, increase or reappear at the start of zone 4, such as *Artemisia herba-alba*-type, *Taraxacum* (apomictic type), *Matricaria*-type, *Onopordum*-type, *Senecio*-type, Cyperaceae and *Scabiosa palaestina*-type. Compared to the previous zone, Cerealia-type pollen decreases significantly. *Hexarthra mira*, a rotifer species, is present in the upper spectra of zone 4. The sediment at 2.95 m depth (spectrum 65) produced some seeds of *Potamogeton pectinatus*.

Zone 5 (spectra 75–80). AP values rise again, owing to an increase of *Pinus* and *Betula*. Most herb pollen types mentioned in zone 4 decline or disappear. Also pollen of marsh and water plants show minimum values.

10. RECONSTRUCTION OF THE VEGETATION HISTORY AND CLIMATE OF THE ESKİ ACIGÖL AREA

10.1. Zone 1 (spectra 1–19, c. 13,000–10,860 BP)

Steppe vegetation led by *Atriplex*-type, *Artemisia herba-alba*-type, *A. vulgaris*-type and Gramineae suggests extreme arid conditions during the period covered by zone 1. The pollen record shows much similarity to the Late Glacial sequences of Van, Zeribar and Abant (Van Zeist & Bottema, 1977; Van Zeist & Woldring, 1978; Bottema et al., 1995).

The fluctuations hardly suggest differences in climatic conditions for the different subzones. Freitag (1977) gives some general outlines of climatic parameters for different types of modern steppe vegetation in Iran. Here, *Artemisia* species are major components of semi-desert communities in areas with fairly severe winters. Some species of Chenopodiaceae (e.g. *Haloxylon*) dominate semi-desert vegetation in hotter regions. Rainfall is almost completely restricted to the winter period. According to Freitag, vegetation dominated by perennial grasses must receive at least some rain in spring or summer. These observations suggest slightly higher precipitation, in particular in spring and (early) summer during subzone 1a, compared to the subzones 1b and 1c. The pollen evidence points to rising summer temperatures during subzone 1b, with higher AP values suggesting that precipitation remained at the same level or even increased a little in the growing season. The dramatic rise in *Artemisia* values and minimum AP values during subzone 1c could be due to a decrease in summer rain and more extreme winter conditions. Average sedimentation rates show a gradual decline in the course of zone 1: subzone 1a: 1 cm per 8 years; subzone 1b: 1 cm per 10 years; subzone 1c: 1 cm per 11 years.

The pollen record includes several herbal taxa indicative of steppe vegetation. Most of these taxa

comprise insect-pollinated species, whose pollen dispersal is usually poor. These taxa would have been much more common in numbers of plants than the pollen values might suggest.

Scattered arboreal vegetation occurred in the vicinity of the lake, mostly consisting of scrubland dominated by deciduous oaks. The values of *Quercus robur*-type pollen are comparable to those recorded in the surface sample from the west slope of the Güneydağ, where trees and shrubs of *Quercus pubescens* form open stands on its top and east slope. Given the climatic aridity, *Quercus pubescens* and possibly *Q. robur*, the most drought-tolerant deciduous oak species, were the probable producers of the oak pollen. Other woody taxa occurring scattered in the Acıgöl area include *Pistacia* and *Juniperus*. Possibly, the situation was not much different from the present man-made landscape with some arboreal vegetation growing on the slopes and top of the Güneydağ.

Late Glacial values of *Betula* are conspicuously low compared to those found for the corresponding period in Abant, Ladik Gölü (Bottema et al., 1995) and Akgöl Adabağ in the Konya Basin (Bottema & Woldring, 1986). These pollen diagrams evidence a marked expansion of birch at or just prior to the Pleistocene Holocene transition. Birch thrives on volcanic soils (e.g. on the Erciyes Dağ) and for this reason the tree could be expected in this area. However, as superficially rooting plants, birches are intolerant to long periods of drought. The relatively low amounts of rainfall probably prevented their spread in this part of Central Anatolia.

10.1.1. Interpretation of the high-resolution analysis of the Acıgöl II diagram as part of the Acıgöl I diagram

Acıgöl II (fig. 9) is a high-resolution diagram, consisting of 20 spectra, established from the bottom section of the core from which the main diagram is made (subzone 1c, 1485–1476.5 cm). Assuming annual deposition, the counting of laminae indicates a time span of c. 50 years. Despite the distinct laminae, sampling of the individual couplets was not possible, but on average one spectrum represents 2–3 years. The high-resolution series allows some conclusions about short-term fluctuations in pollen production and changes in the vegetation.

The regular course of the pollen curves demonstrate a fairly constant seasonal pollen production and precipitation, suggesting only very slight changes in the vegetation and stable weather conditions during the five decades of sedimentation. Grasses dominate and account for almost half of the pollen production. AP values are almost 10%. Sparse oak scrub, the odd juniper and some *Ephedra* may have grown on the

Güneydağ or other locations in the area with adequate water supply. It is not impossible that *Celtis tournefortii*, a shrub with extremely poor pollen dispersal, was a common component in the patches of brushwood. Some willows were probably growing near the water in the shelter of the crater walls.

In spectra 5–8 slightly higher amounts of *Quercus* and Cerealia-type grasses are associated with somewhat lower *Artemisia* values. Also in spectra 15 and 16 a slight decrease of *Artemisia* can be observed, compensated by somewhat higher values of Gramineae and *Atriplex*-type. The combined, slight increase of deciduous oaks and cereal-type grasses in samples 6 and 7 is interesting. Deciduous oaks reach maturity at the age of c. 20 years or more (Schopmeyer, 1974), while grasses producing pollen larger than 40 μm are mostly annuals. This means that these two groups of plants will not increase directly in response to more favourable conditions. The winter-annual cereal species increase in numbers practically after one year, new flowering oaks after twenty years. It may be concluded that more favourable conditions in the growing season also led to more abundant flowering and pollen production of plants that were already present.

From spectrum 10 onwards, *Q. cerris* shows higher values than in the previous spectra of the diagram. Turkish oak is a fairly mesophile species, less resistant to drought than *Quercus robur* (Browicz, 1982). Its present distribution, confined to the mountain ranges of western Turkey, suggests sensitivity to extreme winter cold.

10.2. Zone 2 (spectra 20–37, 10,860–7900 BP)

10.2.1. Subzone 2a (spectra 20–26, c. 10,860–8600 BP)

A sharp decline in the pollen percentages of wormwoods and chenopods, together with a steep rise of grasses and expanding tree growth mark the transition of subzone 1c to 2a. The palynological shifts manifest a dramatic amelioration of climate, indicating a substantial increase in both precipitation and temperature.

A continuous *Pistacia* curve parallels the increase of oaks in the upper part of subzone 2a. Towards the end of this subzone, oak-terebinth woodland has established itself in the vicinity of Acıgöl. Terebinths were more common than the pollen values suggest. Surface samples clearly demonstrate the under-representation of *Pistacia* in the pollen rain (Bottema & Barkoudah, 1979). The spread of this vegetation type in the lake area suggests a further climatic improvement since the first expansion of grass steppe. According to Rossignol-Strick (1995) the early Holocene spread of *Pistacia* is in particu-

lar connected with higher winter temperatures and an increase of annual precipitation.

Arboreal taxa like lime (*Tilia*), hawthorn (*Crataegus*), elm (*Ulmus*) and hackberry (*Celtis*) are poor pollen dispersers. Despite the insignificant pollen values these taxa very probably formed part of the oak woodland.

The high values of *Rumex acetosa*-type have no equivalent in other Near Eastern pollen diagrams. *Rumex acetosa* is a common species in the grasslands of Europe, but apparently is absent in Turkey (Davis, 1965–1988). A close relative with similar ecological demands, and fairly common in Turkey, is *R. tuberosus*. This species was an important component of the early Holocene grass steppe.

It is impossible to conclude from the pollen evidence which grass species constituted the grass steppe. *Festuca sulcata*, *Bromus tomentellus* and several *Stipa* species dominate in modern grasslands, and are regarded as the remnants of former more extensive grass steppe (Walter, 1956). This vegetation type is predominantly found on deep soils. Apart from the fact that the pollen of these taxa does not differ from that of other grass taxa, many *Stipa* species are cleistogamic, which means that they do not release their pollen.

Deep soils are also a main habitat of another important steppe plant, namely *Artemisia fragrans*. Standing on the east slope of the Güneydağ one overlooks a vast plain, which at present is completely cultivated. Most probably, the former vegetation of this plain supplied an important part of the pollen precipitation in Eski Acıgöl. The deep valley soils provided an excellent habitat for a wormwood–chenopod steppe during the arid conditions in zone 1. When humidity increased, at the start of zone 2, the more moisture-demanding grass steppe replaced the drought-tolerant wormwood–chenopod steppe in the valley.

10.2.2. Subzone 2b (spectra 27–37, c. 8600–7900 BP)

The ongoing expansion of arboreal vegetation, with AP values increasing to c. 30%, implies a further growth of tree stands and a rise in precipitation. Deciduous oaks, *Pistacia* and *Juniperus* were the main woodland components during this period. *Pistacia* was a common, probably dominating shrub. Three species occur sporadically in the present vegetation of Central Anatolia, but of these only *Pistacia atlantica* has been recorded for east-Central Anatolia. Analyses of wood charcoal from Aşıklı Höyük and Musular (by Mrs. J.N. Bottema-MacGillavry) indicate that terebinth was the principal wood used for fuel, which suggests that it was the most common woody taxon in the surroundings of the settlements.

Most probably, this was *Pistacia atlantica*, since fruit remains of this species were encountered in the botanical samples from Aşıklı Höyük (Van Zeist & De Roller, 1995). The light-demanding terebinths grew in open locations in oak woodland or dominated the intermediate zone between woodland and steppe. The expansion of the oak-terebinth belt indicates annual rainfall of c. 400 mm or more (Walter, 1974; Van Zeist & Bottema, 1977; Rossignol-Strick, 1995).

In contrast to the higher humidity inferred from the expanding tree growth, the re-advance of at least two *Artemisia* species and decline of grasses would point to more arid conditions. The spread of trees may have triggered an increase of evaporation and subsequently a drop in moisture availability. Together with *Artemisia*, a number of impalatable and/or spiny taxa spread, such as *Matricaria*, *Centaurea*, *Cirsium*, *Onopordum*, *Scabiosa palaestina* and *Noaea*. At the same time, plantains show a slight increase. Such a pollen assemblage, when recorded for a younger period, would immediately be assessed as evidence of grazing. Interpolation of the radiocarbon dates puts the subzone 2a/2b transition in the first half of the 9th millennium. Archeological surveys have brought to light an appreciable number of (early)Neolithic sites for this period in Cappadocia (Todd, 1980; Gülçur, 1995). This means that the spread of this vegetation type may indeed be a consequence of cattle herding and other farming activities.

10.3. Zone 3 (spectra 38–55, c. 7900–3870 BP)

10.3.1. Subzone 3a (spectra 38–43, c. 7900–7060 BP)

Subzone 3a shows the maximum expansion and diversity of woodland in the Acıgöl area. Deciduous oaks, *Corylus* and *Juniperus* were the main components of the woodland in the region, but also elm, lime, hawthorn and probably hornbeam (*Carpinus betulus*) were present. Terebinths decline and almost disappear at the end of this period. The presence of some mesic taxa e.g. *Corylus*, *Ulmus*, *Tilia*, *Carpinus betulus* and the decline of drought-tolerant taxa like *Pistacia* and *Quercus* in the upper half of this subzone indicate more temperate conditions. Possibly, evaporation rates decreased in consequence of somewhat lower summer temperatures.

The pollen of hazel (*Corylus*) in Turkey is produced by two species. Turkish hazel (*Corylus colurna*) is distributed mainly in the northwest of the country, whereas *Corylus avellana* is found in the northern and western mountains, the Amanus Mountains and in the east in the region around Lake Van. Ertuğ-Yaraş (1997) recorded three locations of hazel in the west of Cappadocia. The present distribution area of *Corylus avellana* suggests a large ecological

range. Suitable habitats include moist and wet soils as well as dry, stony ground. Turkish hazel grows best in fertile, deep and wet soils. Because of its wider present distribution and ecological range, it is assumed that hazel rather than Turkish hazel spread in this part of Cappadocia. One must, however, be careful with conclusions based on the present situation. According to Browicz (1982), Turkish hazel was a common tree in the past, but is only found in remote areas at present because of its wood which is highly valued for carpentry.

Despite the conspicuous rise of pine pollen percentages, tree stands in Cappadocia proper are not likely. The increase of pine could result from expansion of pines in the Pontic Mountains, but pollen diagrams covering this period, e.g. Kaz Gölü and Ladik (Bottema et al., 1995) show pine expansion only since c. 6500 BP. Moreover, cedar spreads almost simultaneously with pine, while there is no evidence for the growth of this tree in northern Turkey in the past. The increase of cedar and pine must therefore be attributed to the expansion of these conifers in the southern Taurus Mountains.

Cedar stands probably shifted further north than pines. The pollen dispersal of *Cedrus libani* is poor compared to pine and long-distance transport is highly restricted. Surface samples from southwestern Turkey indicate that the share of cedar in the pollen rain drops to almost zero at a short distance from cedar forest (Van Zeist et al., 1975). These data suggest that cedar invaded Cappadocia, towards the Melendiz Mountains or still further north, into the Göllüdağ Mountains. The pollen diagrams of southwestern and south-Central Anatolia clearly display the expansion of conifer forest in the 9th millennium in Beyşehir Gölü and Söğüt Gölü, and c. 8000 BP in Akgöl Adabağ, Konya Plain. The date of the arrival of cedar in the south of Cappadocia, interpolated at c. 7500 BP, does not conflict with the dating of the vegetation developments in the Taurus Mountains.

The increase of wormwoods and abrupt decline of grasses are the most conspicuous changes in the composition of the herb vegetation. Of special importance for the interpretation of the vegetation developments is the appearance or increase of a number of pollen types which are associated with an open herb cover or weedy vegetation, such as *Anchusa*, *Heliotropium*, *Centaurea*, *Chardenia/Onopordum*, *Cousinia* and *Scabiosa palaestina*. The spread of these more drought-resistant plant taxa could result from drier conditions, but this contradicts the lessened continentality suggested by the arboreal pollen set. Therefore, it is assumed that cattle herding or other farming activities provoked the spread of these plants. Possibly, pastoralism was practised on such a scale that it restrained the woodland expansion.

10.3.2. Subzone 3b (spectra 44–55, c. 7060–3870 BP)

Deciduous oak values (10–20%) are on average slightly lower than those found in the surface samples from locations near oak woodland (fig. 7, Nos 16–24). This suggests open oak woodland, maybe comparable with the present woodlands found near Tatlarinköy, north of Acıgöl and in the northern Gölüdağ. It must be kept in mind, however, that the pollen production of these woodlands would greatly increase in the absence of felling.

The dominant woodland species was probably *Quercus pubescens*, but also pedunculate oak (*Q. robur*) and valonea oak (*Q. ithaburensis* ssp. *macrolepis*), may have been present in the region. Comparison with the previous subzone indicates decreased woodland diversity, but *Pistacia*, *Ulmus* and *Juniperus* were still present. Also hawthorn (*Crataegus*), a poor pollen disperser, formed part of the mid-Holocene landscape. *Crataegus* species (e.g. *C. orientalis* and *C. aronia*) are the main components of the present steppe forest of Inner Anatolia, usually termed oak-Rosaceae parklands or wild orchards (Zohary, 1973; Mayer & Aksoy, 1986). Today, hawthorn species are most often the only woody associates of oaks in the woodlands (Woldring & Cappers, 2001).

Felling in southern areas could have been the reason for the decline of pine and cedar in spectra 45–49. The vanishing of *Corylus* from the Acıgöl area is the most important change in the regional woodland spectrum. The palynological picture suggests no significant shifts in climatic conditions for about three millennia. AP values indicate annual rainfall in the order 400–500 mm, which means that climatic drought is unlikely to have occasioned the decline of hazel. The use of soils suitable for agricultural purposes or cattle herding could have prevented its regeneration.

Grasses re-expand and subsequently decline again during this period. At the same time, members of this family with large-sized pollen (>40 µm) increase substantially. Some herb-pollen types with substantial values during subzone 3a, such as *Scabiosa palaestina*, *Matricaria*-type and *Rumex acetosa*-type, decline significantly.

The high cereal pollen values point to important crop cultivation. During the time of high *Cerealia* values, a sudden rise of green algae (*Pediastrum*) takes place, presumably as the result of increased nutrient supply. In addition, just before cereal values start to increase, the rotifer *Filinia longiseta* abruptly declines and disappears. This rotifer cannot tolerate high nutrient inputs in water. Müller (1970) connected the decline of this rotifer in the Ottenstedter See, a c. 10-m-deep lake near Bremen in northern Germany, with an increase of agricultural

activities, which in turn led to eutrophication of the lake water. The parallels in the Acıgöl sequence with the Ottenstedter See evidence suggest that the hydrological changes at Acıgöl also resulted from crop cultivation. The changes in lake-water conditions and vegetation are the introduction to wide-ranging, devastating interference by man in the next zone 4. The initial rise of oak values in the upper part of 3b is followed by a drastic decline at the subzone 3b/4 transition, suggesting that large-scale deforestation took place in the Acıgöl area. The absence of charred particles in the pollen slides hints that fire was hardly, if at all, used to clear of the woodland vegetation.

10.4. Zone 4 (spectra 56–74, c. 3870–1650 BP)

The spectacular rise of pine suggests that pine forest extended to northwestern Cappadocia. The pollen diagrams from Ladik and Kaz Gölü (Bottema et al., 1995) evidence the spread of pine forest in the Pontic during the fourth millennium. This expansion could have been felt in Acıgöl and contributed to the pine values in the diagram. Yet, there are also reasonable arguments to assume a substantial share of southern conifer forest in the pine pollen precipitation. Parallel with pines, cedar values rise conspicuously, a development that resembles the coinciding increase of these conifers in subzone 3a. In contrast to pine, cedar pollen is not carried far from its producer (Van Zeist et al., 1975). Cedar probably reached its maximum Holocene expansion at the time of spectrum 56. The values suggest that this expansion included the Melendiz Mountains, but also the Gölüdağ Mountains. Such northern occurrences are not unlikely. Cedar forest is found in the mountains south and southeast of Niğde (e.g. Bolkar Dağları and Aladağları), less than 150 km from Acıgöl (Browicz, 1982; Kürschner, 1984). Cedar stands are also present in the Sultandağları (2000–2200 m above sea level), north and northeast of Beyşehir Gölü (fig. 12). This mountain chain is situated at almost the same latitude and distance from the Mediterranean coast as the mountains in the south of Cappadocia. In the Taurus Mountains, the optimum of cedar is found in the subhumid-humid zone (c. 1500–2200 m above sea level, annual precipitation 600–1000 mm). The amount of precipitation in the higher parts of the Melendiz Dağı and Gölüdağ, more than 600 mm annually, matches the requirements of this tree.

Pines are fairly indifferent as to soil types and moisture conditions. Two pine species occur in Central Anatolia. Scotch pine (*Pinus sylvestris*) is only found in the extreme northeast (fig. 12), whereas black pine (*Pinus nigra*) is distributed in the extreme periphery of Central Anatolia (fig. 13). According to Kürschner (1984) black pine is best adapted to continental and arid conditions. Its tolerance to various

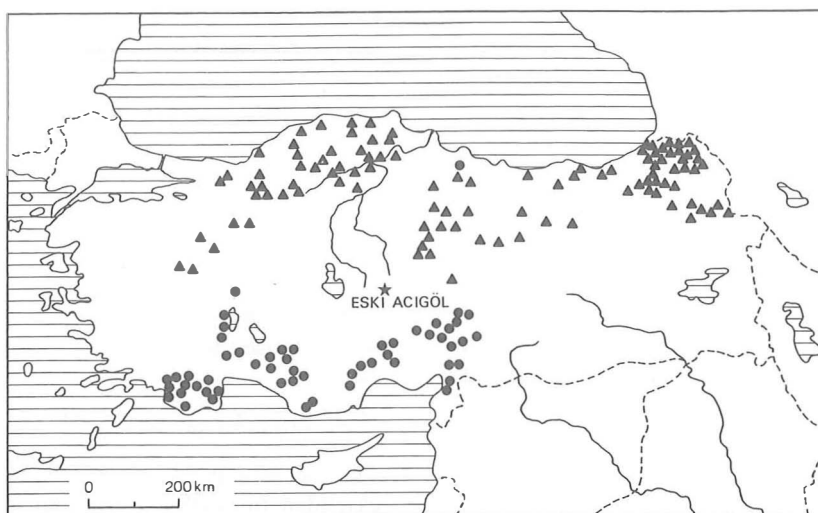


Fig. 12. Modern distribution of *Cedrus libani* (black dots) and *Pinus sylvestris* (triangles) in Turkey (after Browicz, 1982).

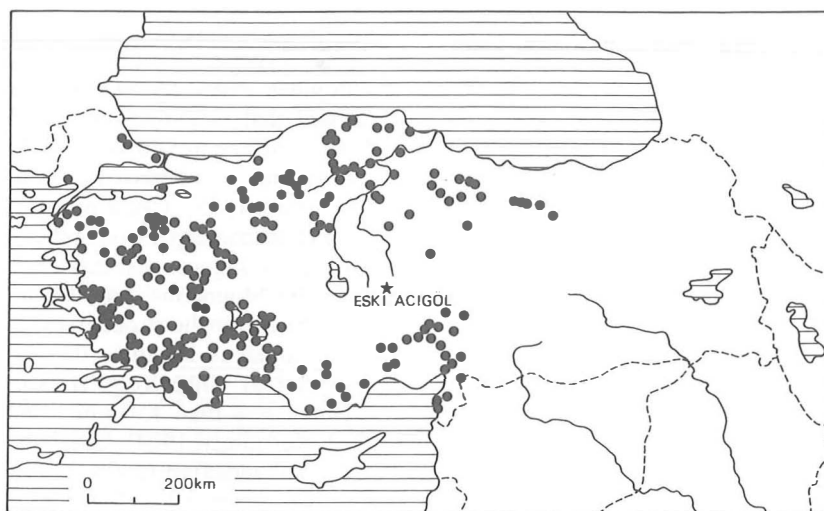


Fig. 13. Modern distribution of *Pinus nigra* in Turkey (after Browicz, 1982).

edaphic conditions is the reason why this pine dominates in the semi-arid climate zone of Inner Anatolia.

The extensive felling of cedar forest in the past gave rise to secondary forest of *Juniperus excelsa* (Zohary, 1973; Browicz, 1982). Mayer & Aksoy (1986) indicate that this juniper also spreads in areas of former pine forest. The simultaneous and rapid decline of both pine and cedar values together with the increase of juniper values in spectrum 63, strongly suggests clearing of forest. Woodland with profuse juniper vegetation (*Juniperus excelsa* and *J. oxycedrus*) occurs in the region between Kayırlı and Bozköy in the Göllüdağ. Areas like these must be

considered potential habitats of the former pine and cedar forest.

AP values have a minimum in the upper part of zone 4. Comparison with the values in the surface samples suggests that only patches of woody vegetation could maintain themselves in the lake area. This landscape was not much different from today's with scattered oaks and an occasional *Crataegus* and *Juniperus* shrub.

The moderate increase of *Ostrya carpinifolia* (or possibly *Carpinus orientalis*) and *Quercus calliprinos*-type probably resulted from oak felling in the south of Anatolia. These species are invasive in clear-

ings of deciduous oaks. Comparison of the values in the surface samples with those of the diagram suggests that these taxa were rare or absent in Cappadocia during zone 4.

Two major contributors of herb pollen, *Artemisia* and Gramineae, arrive at a Holocene minimum in spectrum 52. Together with their recovery, a set of herb pollen types connected with farming and animal husbandry shows increased values, including *Taraxacum*, *Matricaria*, Caryophyllaceae, *Scabiosa palaestina*-type and *Sanguisorba minor*. Ribwort plantain (*Plantago lanceolata*) and knotgrass (*Polygonum aviculare*) join these taxa in a later stage. This pollen picture shows a resemblance to the herb pollen set in diagrams covering the Beyşehir Occupation Phase, where the start of this event is dated to the second half of the fourth millennium.

10.5. Zone 5 (spectra 75–80, c. 1650–0 BP)

Substantial pine values characterise this phase. Even in the desiccated upper deposits, pollen conservation is excellent. This means that it is not just an apparent increase in pine pollen attributable to corrosion, which might frustrate the identification of less characteristic grains. Several Turkish pollen diagrams (e.g., Söğüt, Beyşehir, Abant, Yeniçağa) show an increase in pine pollen in the most recent phases, also in areas largely devoid of pines at present. The pine values in the upper zone are about twice as high as the values in the surface samples. Re-expansion of pine forest in the north of Anatolia and possibly in the Gölüdağ can in part be responsible for the increase of pine pollen. On the other hand, many herb types decrease or disappear. The consequence of lower pollen production in the lake's catchment area is a higher share of pollen from a wider area.

There is a conspicuous share of ash (more than 1%) in the upper spectra of the diagram. Ash trees were not encountered in the lake area. The only ash species in Cappadocia producing the *Fraxinus excelsior* pollen type is *Fraxinus angustifolia*. This tree can reach sizeable dimensions, which is why it is esteemed for its shade and ornamental value and occasionally adorns village squares. Natural occurrences have been recorded in the Erdaş Dağı and in the crater of Nar Gölü, northern Gölüdağ. The oak values in the uppermost spectra of the diagram suggest a deplorable state of the woodland vegetation in the recent history of the lake.

Several NAP types, such as Caryophyllaceae, several Compositae types, Cruciferae and *Polygonum aviculare* decline or disappear at the start of zone 5. This reduction suggests an impoverished state of the herb vegetation, which reveals marked parallels with its modern counterpart.

11. LOCAL ECOHYDROLOGICAL DEVELOPMENTS

11.1. Seeds of waterplants, molluscs and ostracods

Dr Catherine Kuzucuoğlu (IFEA, Istanbul) cored in Lake Acıgöl in 1995. The drilling was carried out with a motor-driven coring machine on a truck. Part of this material (coring C-II) was available for the study for macroscopic remains such as seeds of plants and molluscs. The studied logs (diameter 9 cm) cover parts of the laminated section between 15.26–11.00 m, but a more precise correlation with the Acıgöl sequence was not possible. The macro-remains are of interest, since they included seeds of some water plants which up till then could not be traced palynologically (*Ceratophyllum demersum*, *Najas*, *Zostera*) or identified to genus (*Cyperus*) or species level (*Potamogeton pectinatus*, *P. perfoliatus*).

15.70–15.90 m:	cf. <i>Batrachium</i> (1), <i>Potamogeton</i> sp. (1), <i>Najas marina</i> (1)
15.50–15.70 m:	<i>Chenopodium</i> sp. (1), <i>Potamogeton</i> sp. (2)
15.50–15.30 m:	<i>Polygonum lapathifolium</i> (1), <i>Potamogeton</i> sp. (5), <i>Zannichellia palustris</i> (1), <i>Cladium mariscus</i> (1)
15.30–15.00 m:	<i>Potamogeton pectinatus</i> (1), <i>Potamogeton</i> sp. (1), <i>Ceratophyllum demersum</i> (2), <i>Najas marina</i> (1), <i>Cyperus</i> sp. (1), <i>Scirpus lacustris</i> -type (1)
13.40–13.20 m:	cf. <i>Rumex acetosella</i> (1), <i>Dianthus</i> sp. (1), <i>Batrachium</i> sp. (1)
12.60–12.40 m:	<i>Scirpus lacustris</i> (1), cf. <i>Zostera</i> (1.5)
12.40–12.20 m:	<i>Potamogeton perfoliatus</i> (1), <i>Najas marina</i> (0.5), <i>Scirpus</i> sp. (1)
12.20–12.00 m:	<i>Potamogeton</i> (2), <i>Cladium mariscus</i> (3), <i>Najas marina</i> (2)
11.40–11.00 m:	<i>Ruppia</i> cf. <i>maritima</i> (1), <i>Scirpus</i> sp. (1)

Other aquatic organisms, mainly molluscs and ostracods, were analysed by W.J. Kuijper, Leiden. According to Kuijper all the mollusc species inhabit calcareous habitats in stagnant or slow-moving, freshwater. The low species diversity in the assemblages is probably due to extreme or pioneer conditions.

15.90–15.70 m:	<i>Gyraulus</i> cf. <i>laevis</i> (19), <i>Radix ovata</i> (1), <i>Pisidium</i> sp. (1), <i>Sphaerium</i> sp. (2)
15.70–15.50 m:	<i>Gyraulus</i> cf. <i>laevis</i> (17), <i>Radix ovata</i> (2), <i>Pisidium</i> sp. (4)
15.50–15.30 m:	<i>Gyraulus</i> cf. <i>laevis</i> (53), <i>Radix ovata</i> (6), <i>Pisidium</i> sp. (6)
15.30–15.00 m:	<i>Gyraulus</i> cf. <i>laevis</i> (94), cf. <i>Sphaerium</i> sp. (3), <i>Radix ovata</i> (5), <i>Pisidium</i> sp. (8), numerous ostracods (Ostracoda)
14.00–13.80 m:	<i>Gyraulus</i> cf. <i>laevis</i> (4), <i>Pisidium</i> sp. (6), few ostracods
13.80–13.60 m:	<i>Gyraulus</i> cf. <i>laevis</i> (8), <i>Radix ovata</i> (2), <i>Pisidium</i> sp. (4), some tens of ostracods, tens of <i>Ephippium</i> (water fleas)

- 13.60–13.40 m: *Gyraulus* cf. *laevis* (12), *Radix ovata* (1), *Pisidium* sp. (1), few ostracods
- 13.40–13.20 m: *Gyraulus* cf. *laevis* (8), *Pisidium* sp. (6), cf. *Sphaerium* sp. (1)
- 13.20–13.00 m: *Anisus* cf. *leucostoma* (1), *Gyraulus* cf. *laevis* (6), *Pisidium* sp. (5), ostracods (1)
- 12.90–12.80 m: *Gyraulus* cf. *laevis* (1), *Pisidium* sp. (3), few ostracods
- 12.80–12.60 m: *Gyraulus* cf. *laevis* (1), *Pisidium* sp. (3), few ostracods, cf. *Chara* (stem fragment), few *Ephippium*
- 12.60–12.40 m: *Anisus* cf. *leucostoma* (1), *Gyraulus* cf. *laevis* (41), *Radix ovata* (7), *Pisidium* sp. (4), ostracods
- 12.40–12.20 m: *Gyraulus* cf. *laevis* (170), *Gyraulus crista* (1), *Radix ovata* (7), *Pisidium* sp. (21), ostracods
- 12.20–12.00 m: *Gyraulus* cf. *laevis* (33), *Gyraulus crista* (4), *Radix ovata* (1), *Pisidium* sp. (5), *Chara* sp. (1), tens of thousands of ostracods
- 11.40–11.00 m: *Gyraulus* cf. *laevis* (6), *Pisidium* sp. (3), cf. *Sphaerium* sp. (1)

11.2. Rotifer life cycles

Resting eggs of three rotifer species (*Filinia longiseta*, *Trichocerca cylindrica* and *Hexarthra mira*) were recorded in the sediment samples. These species belong to the group of monogonont (with one ovary) rotifers, which produce several types of egg during one season. One type are thin-shelled and amictic, which means that they cannot be fertilised. By parthenogenesis these eggs produce amictic females. The second, mictic type of egg is also thin-shelled and, when not fertilised, produces haploid males parthenogenetically. If these eggs are fertilised, they have heavier, more resistant shells. These are resting or dormant eggs (zygospores), which are a normal stage in the life cycle of most rotifer species. The eggs enable the species to bridge long periods of desiccation and other adverse conditions. Specific environmental factors, such as high population densities or changes in the amount or type of food, photoperiod or temperature stimulate the production of mictic eggs. The effect of these factors differs from species to species (Ruppert & Barnes, 1994: pp. 306–316). The shells of resting eggs are so resistant that they can be encountered in a subfossil condition in lacustrine sediments.

11.3. Ecology of the Acıgöl rotifer spectrum

Information about the ecological requirements of individual species is rather scanty. Description of the resting eggs is based on the observations by the first author; identification of the species was done by Dr B. van Geel. The ecological data are based on Streble & Krauter (1988) and Van Geel (1998).

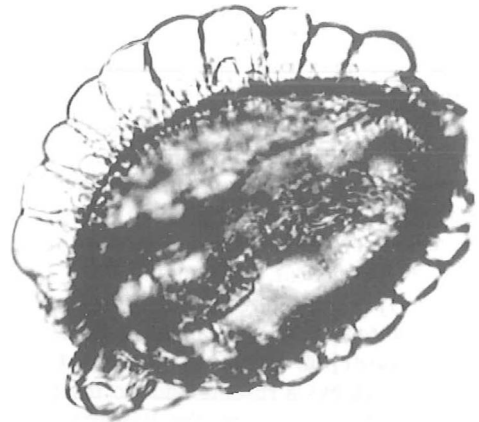


Fig. 14. *Filinia longiseta* resting egg (depth 1195 cm).

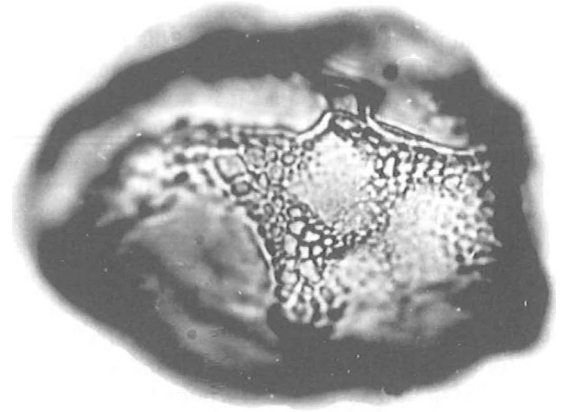


Fig. 15. *Trichocerca cylindrica* resting egg (depth 1345 cm).

Filinia longiseta (Testudinellidae, fig. 14): species of deeper, fresh and brackish water. Resting eggs c. $70\text{--}80 \times 50\text{--}65\text{ }\mu\text{m}$, \pm bean-shaped with a row of large clavuloid, unilateral elements and one or two parallel bands of larger cells.

Trichocerca cylindrica (Trichocercidae, fig. 15): species of fresh, shallow water. Resting eggs c. $70 \times 50\text{--}65\text{ }\mu\text{m}$, resemble the eggs of *Filinia* in size and shape, but lack the unilateral elements. Areas with rather smooth surface structure alternate with angular (often triangular) patches of seemingly reticuloid structure.

Hexarthra mira (Testudinellidae, fig. 16): cosmopolitan, warmth-demanding plankton species in lakes and pools (pH >7), where it feeds on detritus (Van Geel, 1998). Resting eggs c. $80\text{--}90 \times 65\text{--}80\text{ }\mu\text{m}$, roundish or slightly oval. Single, external layer of closely packed, angular cells.

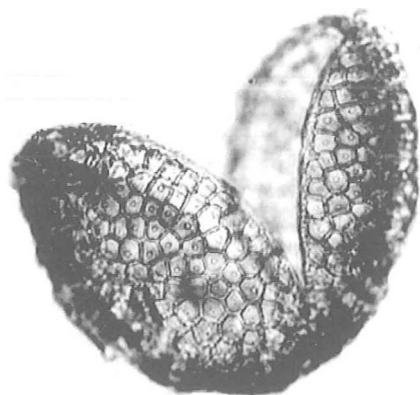


Fig. 16. *Hexarthra mira* resting egg (depth 215 cm)

11.4. Interpretation of the rotifer palaeodata

A key question is, which factors stimulated the production of resting eggs. The complete record shows that *Trichocerca cylindrica* and *Filinia longiseta* are almost confined to the Late Glacial and early Holocene section of the diagram (note the different scales for the two species!). The *Trichocerca* curve ends up halfway subzone 2b, dated to the second half of the eighth millennium. The diatom record of Acıgöl indicates an open, deep, freshwater lake during the Late Glacial and Early Holocene (Roberts et al., 2001). The decline and eventual cessation of resting-egg production suggests that this situation was disadvantageous for *Trichocerca cylindrica*. All this evidence seems to indicate that the occurrence of *Trichocerca cylindrica* is confined to deep, fresh water and conflicts with the shallow lake habitat postulated by Streble & Krauter (1988) for the species. This raises the question whether the eggs belong to a different rotifer species with different ecological requirements or whether other factors caused the disappearance of *Trichocerca cylindrica*. Müller (1970) recorded large numbers of *Trichocerca* resting eggs in his coring of the Ottenstedter See during the Atlantic after which the resting-egg numbers gradually decline. Müller associates this decline with a change in the nutrient balance of the lake water from oligotrophic towards more eutrophic conditions, due to increased habitation and farming activities. Production of resting eggs continues until the end of the medieval period in the Ottenstedter See area, although the pollen record documents a substantial increase of farming activities since the Late Neolithic period. The curves of *Trichocerca* in the Acıgöl and Ottenstedter See diagrams cover completely different periods but they show conspicuous similarity in their fluctuating pattern. It is, however, unlikely that man instigated the changes in the nutrient balance of Lake Acıgöl at this early date. Together with the slow

decline of *Trichocerca* in the Ottenstedter See diagram, a rotifer adapted to alkaline water conditions, *Hexarthra mira*, demonstrates slowly increasing values, suggesting a gradual rise in pH values of the lake water. It is possible that higher alkalinity led to declining resting egg frequencies of *Trichocerca* in Acıgöl. The decline of this species takes place in a period of further rising (summer) temperatures. Increased evaporation and decreasing water depths may have resulted in higher salinity or alkalinity, factors that caused the gradual disappearance of this freshwater rotifer.

Filinia longiseta resting eggs disappear around a depth of 7.50 m, almost simultaneously with the definite change from laminated sediments to massive silts and gyttja. The sediment change suggests (further) declining lake levels, which were disadvantageous for the species. Besides changing lake levels, there is additional evidence for a change to more eutrophic water conditions, whose impact could have exceeded a reduction in water depth. A demonstrable correlation was found in the Ottenstedter See diagram between the dramatic decline of *Filinia* and the strong increase of Late Neolithic agricultural activities, inferred from the pollen record. Müller notes that the higher nutrient input resulting from these activities underlies the sharp decline of *Filinia*. The Acıgöl record shows strong analogies with the sequence of the Ottenstedter See. At the subzone 3a/3b transition, resting egg production ceases quite abruptly when cereals clearly increase. The evidence indicates that deep lakes with low nutrient supply best matches the requirements of *Filinia longiseta*.

Resting eggs of *Hexarthra mira* occur only for a short period in the upper part of zone 4, c. 2000 BP. Its presence indicates alkaline conditions, probably as the result of an increased supply of carbonate-rich seepage water. On the basis of the diatom record, Roberts et al. (2001), concluded a return at this depth from strongly saline conditions to an open, shallow, freshwater phase.

In conclusion, declining lake levels in combination with higher alkalinity or salinity brought about the disappearance of *Trichocerca cylindrica*. The disappearance of *Filinia longiseta*, on the other hand, must primarily be attributed to eutrophication resulting from farming activities in the lake area. Declining lake levels may have hastened this process. The short-lived spread of *Hexarthra mira* points to alkaline conditions during a phase in the younger history of the lake.

11.5. Development of the Late Glacial lake vegetation in Eski Acıgöl

Palynological evidence of marsh and water plants is scanty in the Late Glacial and early Holocene, but

macroscopic botanical remains evidence the occurrence of aquatic plant growth during the Late Glacial. The remains demonstrate a typical assemblage of submerged water plants (including *Potamogeton perfoliatus*, *P. pectinatus*, *Ceratophyllum demersum*, *Najas marina*, *Ruppia* cf. *maritima* and *Zostera* sp.). The last three produce only little and perishable pollen, which explains their absence in the pollen record. *Potamogeton* pollen is much more resistant to decay, but apparently pollen production of the species in question was low or their pollen is absent for different reasons in the Late Glacial assemblages. *Potamogeton perfoliatus* and *Potamogeton pectinatus* are adapted to various water conditions (Weeda et al., 1985). They can grow in waters with strongly varying depths, salt, nutrient and carbonate content. By contrast, *Ceratophyllum demersum* requires stable, freshwater habitats (Weeda et al., 1985). Only *Zostera* and *Ruppia* are indicators of saline habitats. The different ecological conditions represented by this plant assemblage suggest that Late Glacial hydrological conditions were varying at times. The *Zostera* and *Ruppia* occurrences indicate that shorter or longer phases of higher salinity must have alternated with principally freshwater conditions.

11.6. Development of lake Eski Acıgöl during the Holocene

The marsh vegetation, which developed during subzone 2b, points to a gradual decline of lake levels. It is likely that beside *Sparganium* and *Equisetum*, also Cyperaceae and Gramineae formed part of the local vegetation. Increase of *Equisetum* values during subzone 3a suggests a further decline of the lake level. A special *Equisetum* habitat is found in locations where moisture is supplied by seepage water. Such conditions have been created through a higher input of carbonate-rich groundwater. Stress conditions stimulate the flowering of *Myriophyllum* species, especially *M. verticillatum* (Weeda et al., 1985). Reduction of the water body or even temporary drought triggered the spread of *Myriophyllum* in spectrum 42.

The spread of *Pediastrum boryanum* during subzone 3b coincides with increased cereal values. This is one of the predominant green algae in eutrophic reservoirs (Komárek & Jankovská, 2001). Most probably, the cultivation of domestic crops in the area prompted higher nutrient input and caused the bloom of this green alga.

Low lake levels also prevail at the start of zone 4. The δ^{13} value of -18.1‰ of the organic material at 455–460 m (GrN-22881) indicates stagnant, shallow water (maximum depth 10 cm), overlying an anaerobic mudflat or layer (H.J. Streurman, pers. comm.).

Peat sediment is absent in the ESK92 core, but there is evidence of peat formation in parts of the lake. The ESK96 cores contain peat in the upper 1.40 m (Roberts et al., 2001). Three peat units along the eastern margins of the lake have been studied by Kazancı et al. (1995). The lower and upper peat units, which differ almost two metres in depth, have been radiocarbon-dated to 2010 ± 80 BP and 1810 ± 65 BP, respectively. The dating approximately corresponds with the upper part of zone 4. The peat units formed during phases of low lake levels. They intercalate with tuffaceous clastics, which implies considerable erosion of tuffs in the lake area. The alternation of peat and tuff deposits also points to strongly oscillating lake levels. Such oscillations are a possible explanation for the small difference in radiometric results of the peats. Probably the upper peat unit is not *in situ*, but in its present location is the result of drifting during a period of high lake water.

Lake level changes were probably common in the later stages of the lake. Before the drainage of the lake, water depth was generally around 1 m, but varied occasionally from a maximum of 4 m to zero (Kazancı et al., 1995).

A plausible explanation for the predominantly low lake levels from subzone 2b up into zone 4 is that most of the atmospheric water was absorbed by the upland vegetation. It is not unlikely that the oscillations from the base of or halfway through zone 4 were the consequence of woodland clearings, which could have increased the water runoff into the lake considerably.

12. DISCUSSION

12.1. Eski Acıgöl

The record of Eski Acıgöl displays c. 15,600 years (c. 13,000 ^{14}C years) of vegetation history in Central Anatolia. The varved lower sediment provides fairly detailed information about the duration of the Late Glacial subphases and concomitant changes in the steppe vegetation. It allows close comparison with the varved, absolutely dated pollen record of Lake Van. The arboreal pollen set of Acıgöl also provides valuable data to expand our still scanty information about the Late Glacial distribution of woody vegetation in the Anatolian highlands. Various studies have recently focussed on the vegetational and climatic shifts taking place around the Late Glacial–Holocene transition in this area (Landmann et al., 1996a). Points of discussion also include the Holocene forest development and the role of man in the deforestation of the Central Anatolian plateau. Louis (1939), Walter (1956), Zohary (1973), Kürschner (1984) and Mayer & Aksoy (1986), reconstructed the potential vegetation of Central Anatolia

taking into account rainfall figures, topography, the present-day remnants of steppe and arboreal vegetation and historical evidence of arboreal vegetation. Although the area underwent the strong influence of man in the late Holocene, the Acıgöl pollen record could be helpful in assessing the potential vegetation of the area, at least for northwest Cappadocia. The above-mentioned topics will be reviewed here individually.

Near Eastern pollen diagrams show conspicuous differences in the start of woodland expansion, which point to significantly varying climatic conditions during the Late Glacial and early Holocene. The Hula diagram, northern Israel (Baruch & Bottema, 1999) displays its highest values of deciduous oaks (50–70%) in the period from c. 13,500 to 11,500 BP. Throughout the Holocene, oak values remain below the levels found in the Late Glacial. Also the Ghab diagram, prepared by Yasuda et al. (2000), displays a regular increase of deciduous oaks since c. 14,500 BP, with maxima from c. 12,500 to several hundred years into the Holocene. As in the Hula, Holocene values of oaks in the Ghab valley never regain the level reached in this period. In this respect the first Ghab diagram (Niklewski & Van Zeist, 1970), from a coring location 30 km north of the one by Yasuda, shows a quite sudden tree expansion about 11,000 BP, whereas an almost treeless landscape prevailed in the foregoing millennia.

The increase of *Pistacia* in the Hula and Ghab diagrams almost parallels the Late Glacial expansion of oaks. This means that the oak–terebinth parkland established itself much earlier in these latitudes than on the Anatolian plateau, where it spread by 9000 BP. It is generally agreed that this vegetation type spread as the result of a more humid and probably warmer climate, and accordingly, the Levant experienced a climate improvement about 5000 years earlier than the northern latitudes.

In Beyşehir, on the northern fringe of the present Oro-Mediterranean climate zone, birch, juniper and probably also cedar occurred for a shorter or longer time in the Late Glacial. Pine expanded here from 12,000 BP, to reach maxima from 11,000 to 10,000 BP. The Late Glacial phases in diagrams from the mountain areas generally demonstrate higher AP values and a greater species diversity than the diagrams from the Anatolian plateau (Akgöl Adabağ, Eski Acıgöl and Van) with AP values generally 10% or less. Before 10,000 BP, trees apparently met better conditions in the coastal mountain areas than on the plateau. Precipitation, the most restricting factor for their growth, must have been higher in these areas. Even so, there is no lack of woody species in Central Anatolia. At least two oak species can be identified from the Late Glacial section of the Acıgöl diagram. The drought-resistant *Q. pubescens* probably produced the *Quercus robur*-type pollen, but on

deep, moisture retaining soils also *Q. robur* may have survived the dry conditions. Beside these oak species, *Quercus cerris*, with a distinctive pollen type, was growing in east-Central Anatolia. All the oak species may have occurred in the Göllüdağ Mountains, but the pollen values do not exclude locations closer to Eski Acıgöl. Also birch, terebinth and elm occurred sporadically in the region. Some weight should be attached to the few occurrences of lime (*Tilia*) in the Late Glacial and early Holocene. *Tilia* is a tree with rather poor pollen dispersal and this tree may very well have been growing in the lake area.

Bennett et al. (1991) suggested that thermophilous trees occupied mid-altitude sites in mountainous areas of southern Europe during the last cold stage. Comparison of 52 pollen diagrams revealed the concentration of important refugial areas at mid-altitude sites in the western part of the Balkans, the Alps and the Italian mountains. Apparently the southwestern Taurus and northwestern Pontic mountain ranges, but also sites on the Anatolian plateau, offered comparable conditions for (part of) the present-day woodland components of Anatolia. These trees could expand beyond these locations as soon as humidity and temperature had risen sufficiently to match their requirements.

On the basis of the modern climatic parameters, Central Anatolia is considered one of the most marginal areas for tree growth in Turkey (together with the interior of Thracia and parts of southeastern Anatolia). For certain areas, as around Tuz Gölü and the Konya Plain, steppe constitutes the natural vegetation. These conditions are strongly determined by the low annual amounts of rainfall in these areas. The Late Glacial climate must be considered even more adverse to tree growth. Nonetheless, various woody elements found refugia to maintain themselves in parts of Central Anatolia during this period.

12.2. The Late Glacial–Holocene transition

It is evident that the changes at the zone 1–2 transition in the Acıgöl pollen record reflect major changes in climate. The abrupt decline of the *Artemisia*–*Chenopodiaceae* steppe suggests the starting point of a warmer and probably more humid climate. Similar vegetational developments have been recorded from the pollen studies of Lake Van (Van Zeist & Woldring, 1978; Wick et al., in press). The two main steppe components, *Artemisia* and *Chenopodiaceae*, do not decline simultaneously in Van (fig. 12). The change from *Artemisia* to dominance of Gramineae is pinpointed to 10,400 varve years BP. From this point on *Chenopodiaceae* drop gradually to values of c. 20% at c. 10,000 calendar years BP. The leap-by-leap expansion of the grass steppe after the decline

of *Artemisia* reaches its maximum shortly after 10,000 calendar years BP. The slow decline of chenopods is probably related to hypersaline lake conditions, in which various salt-tolerant taxa could maintain themselves. The decline in Lake Van correlates with a rise in water level (from 300 to almost 100 m below its present depth) along with strongly decreased salinity (from c. 160 to 40 g/l) around 10,000 calendar years BP (Landmann et al., 1996a). The high lake level, resulting from higher humidity, and subsequent decline of salt concentrations put an end to the dominance of the chenopods in the Van area.

The study of geochemical and other parameters led Landmann et al. (1996b) to identify the end of the Younger Dryas at 10,920±132 calendar years BP (c. 9700 ¹⁴C years BP). An abrupt change in sedimentation rate indicates that dry conditions came to an end. Curiously, the leading steppe plants fail to show visible response for several hundred years in the Van diagram (Wick et al., in press), suggesting that the ecological conditions did not dramatically alter in this period.

The *Artemisia* decline in Van at 10,400 calendar years BP, (c. 9200 ¹⁴C years BP), has been considered the equivalent of the rapid decline in Acıgöl. The *Artemisia* decline in Acıgöl, by inter-polation of the ¹⁴C dates after reservoir correction, has been dated to c. 10,860 ¹⁴C years BP, revealing the start of a more favourable climatic regime c. 1600 ¹⁴C years before its onset in Van. Palynologically speaking, the Van diagram closely resembles the Eski Acıgöl diagram. It is very difficult to correlate the two diagrams in time because considerable corrections and uncertainties exist in both sequences. Even today, important differences in climate do exist between Eski Acıgöl and Van. Present-day climate figures indicate slightly more temperate conditions for Central Anatolia, whereas the Van area witnesses extreme summer drought and cold winters. Ground temperatures below 0°C are only absent from May to September, which virtually restricts plant growth to this period. These conditions are strongly connected with the geographical setting of the Van area. Landmann et al. (1996b) indicate that during the cold periods temperatures were 5°C below the present-day ones. Under these conditions the vegetation period is only 2–3 months, which furthermore coincides with the driest period of the year. The overall harsher conditions for plant growth must also be responsible for the delayed termination of the Late Glacial cold and drought.

Correspondence analyses applied to several Near Eastern pollen diagrams, including those of Van, Urmia and Zeribar, confirm the late start of a more favourable climatic regime in this part of the Near East (Cappers et al., 2001).

12.3. The Holocene

In broad outline the pollen diagrams from the Anatolian plateau and western Iran show fairly similar vegetation developments. The Late Glacial arid steppe is followed by tree expansion in the early Holocene and a mid-Holocene forest optimum, which suggests a fairly similar climatic development at this latitude. However, any general statements for Central Anatolia in terms of drier or more humid, colder and warmer periods are seriously hampered by man's exploitation of the area and its degrading effects on the vegetation. Indications for somewhat drier conditions in the younger part of the Holocene might be inferred from the almost negligible values of *Pistacia* and the somewhat higher values for *Quercus calliprinos* and *Ostrya/Carpinus orientalis*. However, the pollen record is so overwhelmingly marked by human interference that at any rate the modest increase of the latter taxa has been considered the result of felling of primary forest rather than the impact of a drier climate. Nevertheless, modern climate conditions of Central Anatolia do seem to be drier than they were during subzone 2b and most of subzone 3a, when precipitation may have been about 100 mm per year higher than at present.

Drier Late Holocene climatic conditions, approximately from subzone 3b on, have been put forward by Roberts et al. (2001) on the basis of diatom research. The diatom record shows a shift from freshwater species to a group of species inhabiting brackish to saline waters. This shift towards higher salinity has been interpreted as a general lowering of lake-water levels resulting from higher evaporation. The hydrological system being a closed one, water runoff completely determined the water level of Lake Acıgöl. It also means that during the Holocene salinity in the basin constantly increased because minerals were being washed in, while the water evaporated, even without any change in climate. In general, runoff is much higher in open vegetation, as has been shown for instance for Lake Urmia (Bottema, 1986) and Lake Van (Landmann et al., 1996a).

In Van, the most favourable climate for tree growth occurred from c. 7500 to 4000 BP. The Hula and Ghab diagrams (Yasuda et al., 2000) reflect more favourable conditions in the Late Glacial than in later periods. While a climatic improvement has been ascertained for the Anatolian plateau from c. 9000 BP, increased drought caused the simultaneous and substantial rise of evergreen oaks in northern Israel and the Ghab Valley. We disagree with Yasuda, who regards the substantial rise in evergreen oaks and pines as the expansion of secondary vegetation resulting from forest clearance by PPNB people. Apart from its technical feasibility, what could be the reason or function of such large-scale felling as proposed by Yasuda?

12.4. The role of *Pistacia* species in the vegetation history of Turkey and the Near East

The early Holocene spread of *Pistacia*, a typical feature in the diagrams of Acıgöl, Van, Urmia and Zeribar, is conspicuously absent in the Pisidian diagrams. *Pistacia* is also absent from several other diagrams covering this period, e.g. Abant, Yeniçağa and Ladik Gölü in the Pontic Mountains, Kaz Gölü in the Inner Anatolian Xero-Euxinian zone (Bottema et al., 1995) and Yenişehir (Bottema et al., 2001), south of Iznik Gölü, northwest Turkey. Extrapolation of the radiocarbon data indicates that the Yenişehir pollen record started at c. 10,000 BP or possibly earlier, given the domination of *Artemisia* and *Chenopodiaceae* in the bottommost half metre of the diagram. There is a curious absence of *Pistacia* in the early Holocene phase of Akgöl Adabağ, located c. 150 km south of Acıgöl.

The southern latitudes show an earlier development of *Pistacia*. The palynological evidence from the Hula indicates optimal conditions in the last millennia of the Late Glacial. Also the diagram from Mirabad (Van Zeist & Bottema, 1977) shows substantial values (c. 5%) from the start of sedimentation, c. 10,370 BP, which points to highly favourable Late Glacial conditions in the southern Levant and southern Zagros. The palynological data suggest an eastern area favourable for the development of an oak–terebinth association. This association was found in the Levant, the Zagros Mountains and the Anatolian highlands, in the west reaching up to Central Anatolia. Though *Pistacia* is absent in western Turkey, several pollen diagrams from the Greek mainland (Bottema, 1974) also demonstrate the spread of *Pistacia* in the early Holocene. It may be speculated that we are here dealing with the same composition of plant species, since the Thermo-Mediterranean lentisc (*Pistacia lentiscus*) may have contributed significantly to the production of *Pistacia* pollen. Broadly speaking, it can be stated that the Near Eastern early Holocene distribution of terebinths largely coincides with the wild cereal domain, known as the Fertile Crescent. The spatial distribution of *Pistacia* in the Late Glacial points to higher humidity and warmth in the southern part of the Near East.

It is difficult to find reasons for the absence of *Pistacia* in the pollen diagrams of northwestern and southwestern Turkey. It seems unlikely that rainfall amounts were too low or that competition from other woody species in the niches suitable for tree growth prevented the spread of terebinths. At present *Pistacia* is only encountered in some sheltered locations such as the Ihlara Valley and Nar Gölü crater lake. Freitag (1977) mentions the restriction of *Pistacia atlantica* to sheltered habitats in parts of Iran, where aridity prevents its general presence. The idea of such isolated occurrences in Central Anatolia during the

early Holocene (for instance in the shelter of the Acıgöl crater), has to be rejected, since terebinth also dominates the botanical samples of archaeological sites like Aşıklı and Musular. Although *Pistacia atlantica/terebinthus* is absent in the Akgöl Adabağ pollen record, its charcoal and seeds were uncovered at Neolithic Çatal Höyük during the excavation campaigns of 1996–1999 (Hastorf & Near, 1997; Asouti et al., 1999). The absence of terebinth in the pollen record indicates that these plants were not growing in the Konya Plain proper, but in the uplands surrounding the plain. The distance between the coring location and the upland vegetation may explain the absence of terebinths in the pollen diagram.

Generally, *Pistacia atlantica* is considered the main producer of the early Holocene pollen on the Anatolian plateau and western Iran (Van Zeist & Bottema, 1991). At present, this species has a wide range of distribution that extends from northeastern Greece and the Aegean Islands into the Iranian highlands (ssp. *mutica*, ssp. *kurdica*), Afghanistan and Pakistan (ssp. *cabulica*) (Rechinger, 1969). Ssp. *mutica* and ssp. *kurdica* range from 0 to 1720 m above sea level in Anatolia. The first subspecies occupies the western part of Anatolia, including Central Anatolia west of the 36° meridian, whereas ssp. *kurdica* (synonymous with *P. eurycarpa* in Davis) is restricted to the extreme southeast of Turkey (Davis, 1965–1988). Ssp. *kurdica* occurs also in Israel, Syria, Iraq and Iran. Another species with a fairly large area of distribution is *P. terebinthus* ssp. *palaestina* (50–1500 m above sea level), covering most of Anatolia, except the extreme east and southeast. This subspecies is also common in Syria, Lebanon and Israel. The western ssp. *terebinthus* has a range of distribution from northwestern Turkey to France and the Iberian Peninsula. *P. khinjuk* (1000–1800 m above sea level) is fairly widespread in southeastern Anatolia (especially south of Van) and further east (Iran, Afghanistan, Pakistan). In Turkey the related *P. vera* is a cultivated species. Finally, *Pistacia lentiscus* is largely restricted to the thermo-Mediterranean, not growing above 600 m altitude. Terebinths generally prefer calcareous soils, are xerothermic and heliophilous (Browicz, 1982).

It is remarkable that the present area of distribution of *P. atlantica* in Anatolia almost covers the area where apparently it was lacking in the early Holocene, even though it must be admitted that hardly any pollen evidence is available for the inland part of western Turkey. Neither subfossil nor surface samples give the slightest indication for a recent spread of *Pistacia* in the west of Turkey. Substantial *Pistacia* values were only recorded in surface samples taken in thermo-Mediterranean maquis of southwestern Turkey with abundant *Pistacia lentiscus* (Van Zeist et al., 1975).

Baruch & Bottema (1999) note that *P. terebinthus* ssp. *palaestina* is a common associate of evergreen oaks, whereas *P. atlantica* accompanies the Tabor oak (*Quercus ithaburensis*) in the north of Israel. In Turkey the distribution area of ssp. *palaestina* is substantially larger than that of evergreen oaks, in particular extending further inland with some locations on the plateau. The ssp. *palaestina* is distributed further east in Turkey than *Pistacia atlantica* (ssp. *mutica*) at present, suggesting a certain tolerance of this subspecies to more continental conditions.

According to Rossignol-Strick (1995) higher humidity and lessened continentality favoured the expansion and the early Holocene optimum of *Pistacia*. Under such conditions *P. terebinthus* ssp. *palaestina* and *P. atlantica* ssp. *mutica* may have been more widely distributed in this period. The present sporadic and peculiar occurrences of terebinths on the Central Anatolian plateau (e.g. crater lake Nar Gölü and İhlara gorge) underline the importance of humidity. Maybe these are the last occurrences of a previously larger area of distribution, which would imply increased continentality towards modern times. The conspicuous inland occurrences of the frost- and drought-intolerant mastic tree (*P. lentiscus*) north of Ankara and on the Erciyes Dağ (Davis, 1965–1988) support this view. Temperatures below -12°C are lethal for this shrub (Horvat et al., 1974). Under the present climate, the inland occurrences seem almost incongruous. The palynological evidence of the Near East manifests a general decline of terebinths from the sixth millennium onwards. In the light of the historical evidence it is not impossible that the enclaves in Central Anatolia of three terebinth species represent contracting distribution areas. Given the general under-representation of terebinths in the pollen rain, more isolated occurrences in the past may have been recorded in pollen diagrams only by chance, as is suggested also by the presence of *Pistacia* wood in Neolithic Çatal Höyük and the negative palynological evidence in the Akgöl Adabağ diagram. The frequent occurrence of *Pistacia* in early archaeological contexts means that it was among the most common woody species of the period and not restricted to some special, humid habitats.

12.5. Evidence of farming

The early start of Neolithic habitation in Central Anatolia was a reason to examine the Acıgöl diagram for possible vegetation shifts in response to farming in this period. Early Neolithic Aşıklı Höyük covers 8950–8400 BP. Other Neolithic sites in that area are dated close to Aşıklı Höyük, such as Musular (preliminary dates between 8400 and 8000 BP). The base of subzone 2b is dated to c. 8600 BP (after reservoir

correction), which makes it contemporaneous with the final phase of Aşıklı Höyük. The pollen record of subzone 2b shows a contradictory picture. Whereas the ongoing spread of arboreal vegetation suggests a further increase of moisture supply, the decline of grass steppe along with the arrival and expansion of seemingly xeric plant communities, proclaim increasingly arid conditions. Possible factors that triggered these vegetation shifts include:

- 1) a westward expansion of Irano-Turanian vegetation, implying stronger continentality in Central Anatolia;

- 2) an increase of total evaporation as a result of expanding steppe forest/woodland;

- 3) changes in vegetation resulting from the interference of man and his animals.

The grass steppe was far more attractive to grazers such as bovines for its higher nutritional value than the Late-Glacial *Artemisia*/Chenopodiaceae steppe. Higgs (1961) found evidence for increased numbers of large herbivores in the Mediterranean during Late Pleistocene periods of grass dominance. Walter (1974) states that pristine grass steppe, especially *Stipa* grassland, will be maintained under a moderate grazing regime of wild grazers. The introduction of domestic cattle in these grasslands readily leads to disturbance and degradation of the vegetation.

The bone assemblage of Aşıklı Höyük (Buitenhuis, 1997) shows an increase in the number of bovines and a decline in sheep and goat in its last phase. During the occupation of Musular the share of bovines further rises (H. Buitenhuis, pers. comm.). At the same time, the appearance of smaller satellite sites (Gülçur, 1995) reveals a change in settlement pattern. Gérard (2002) postulates the beginning of breeding experiments with ovicaprids in this period, ultimately leading to their domestication. According to Gérard, this change towards animal husbandry involved a transhumant or nomadic life-style. The interference of man and his animals with the fragile balance of the early Holocene steppe ecosystem in Central Anatolia probably started the decline of the grass steppe and the establishment of seemingly xeric plant communities (Woldring, 2001). The signs of local animal husbandry are more likely to be reflected in a small catchment basin than in a large one like Lake Van. Bradshaw (1988) has noted that the analytical resolution of pollen from small hollows is much higher than that from larger lakes and basins, owing to the latter's greater share of pollen from vegetation in the proximity of coring locations and the restricted pollen input from long-distance transport. As a closed hydrological system, the Acıgöl crater also received a considerable share of pollen from the vegetation growing in the neighbourhood. Despite the evidence of improving climatic conditions in zone 2, the number of places with fresh (or slightly brackish) water was probably restricted. Any

disturbance would have been felt especially in the lake area, where wild and domestic grazers concentrated near drinking water and foraged around it. In this respect the lake differs completely from the physical setting of Lake Van. Apart from its larger lake surface area, the catchment area of Lake Van is greatly extended by several rivers discharging, and carrying pollen into the lake. These conditions might in part explain the regularity of the pollen curves in the Van diagram.

Subzone 3b reveals a period of more pronounced farming activity, which apparently concentrated on crop cultivation. In the Hula diagram (Baruch & Bottema, 1999) a strong decline of oaks accompanies a rise in cereal values, which the authors attributed to increased aridity. The reduction in tree cover apparently benefited the spread of cereals. Yet the expansion of cereals in the Acıgöl diagram does not seem to be due to higher aridity. It is true that AP values decrease in the first half of subzone 3b, but this can largely be attributed to declining pine forest in the Taurus or the Melendiz/Göllüdağ area. Oak values remain almost at the same level, suggesting more or less constant climatic conditions. It is therefore assumed that domestic crops were the producers of the cereal pollen values in zone 3b.

Crop cultivation requires soil tillage, the removal of the existing vegetation, breaking of the soil surface or ploughing. The sudden rise of *Pediastrum* values during the period of grain cultivation points to an exceptional eutrophication of the water, probably as a result of these activities, even though cattle as well may have generated such a nutrient supply. Such interference, when taking place on a significant scale, would have to lead to a rise of arable weeds adapted to the new conditions, but no signs of weedy vegetation are visible in the diagram. Also AP values can be expected to decline, but this is only the case for the lower part of subzone 3b. As already indicated, this decrease mostly results from lower pine values. However, it may well be that cultivation hampered further expansion of the oak woodland and led to the disappearance of hazel from the surroundings of the lake.

Oak values show a sharp decline around 4000 BP, in time roughly contemporary with the rise of the Hittite Empire. Evidence for the presence of the Hittites in Central Anatolia is quite abundant. Among the monuments, a huge boulder with hieroglyphic inscriptions near Ağılı, 8 km south of Acıgöl, is said to report a Hittite victory in a battle against the Phrygians. During the Hittite supremacy iron working became established. It can only be assumed that the demand for wood required for the production of iron and other metals led to a strong reduction of the oak woodlands. The general archaeological evidence from the period after the collapse of the Hittite Empire, about 3200 BP, indicates strong migration mo-

vements, probably as a result of political instability. From the late 8th century BC Phrygian power expanded over the Anatolian plateau and left its traces in east-Central Anatolia; for instance, the devastation of the extensive architectural structures on the Göllü Dağ has been associated with the Phrygians (Burney, 1977; Schirmer et al., 1996).

AP values reach a minimum in the upper part of zone 4, roughly contemporary with the Roman Period. Buildings, tumuli, ancient road tracks etc. witness the general presence of the Romans. The exploitation of copper ore in this period is known from Cappadocia, e.g. in the Göllüdağ. Strabo (c. 64 BC–AD 19) describes Cappadocia as being without timber, but the Erciyas Dağ was still completely forested in Roman times (Todd, 1980: p. 115). At least 35 underground cities bear testimony to man's presence in Cappadocia in the first millennium AD. The underground cities were used as refuges in the eighth century AD. At that time the number of inhabitants exceeded the present population (250,000) in the province of Nevşehir. The amounts of wood and animals needed for subsistence meant the further depletion of the woodlands in Cappadocia.

13. ACKNOWLEDGEMENTS

The authors are much indebted to Mr H.J. Streurman, Dr J. van der Plicht of the Centre for Isotope Research and J.N. Lanting, GIA, Groningen, for their help in interpretation of the ^{14}C dates. Prof. C.N. Roberts and Dr C. Kuzucuoğlu supplied sediment parts of their cores for pollen (ESK-96A) and macrobotanical research. Dr L. Wick, Bern, provided a draft of the Van diagram and gave permission to use the data in this paper. Mr. W. Kuijper identified the botanical and faunal remains reported in Section 11.1, Dr B. van Geel identified the rotifer species and Mrs J.N. Bottema-MacGillavry analysed the wood charcoal from Aşıklı Höyük and Musular. Mrs. G. Entjes was of great assistance in processing the text of this paper. Mr H. Zwier prepared the drawings. The English text was improved by Ms A.C. Bardet.

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Table 2. Pollen occurrences not included in the surface sample diagram (in percentages).

Spectrum 1: *Capparis* 0.1, *Taxus* 0.1, *Orobancha* 0.1, *Rumex thyrsiflora* 0.1, *Pimpinella*-type 0.1; spectrum 2: *Armeria/Limonium* 0.2; spectrum 4: *Scutellaria* 0.1, *Oxalis* 0.1, *Hypecoum* 0.2, *Plantago media*-type 0.4, *Apium*-type 0.1; spectrum 5: *Hippophaë* 0.1, *Pyrus* 0.1, *Knautia* 0.1, *Reseda* 0.1; spectrum 6: *Viscum* 0.1; spectrum 7: *Arceuthobium* 0.1, *Equisetum* 0.1; spectrum 8: *Carduus*-type 0.1, *Malva* 0.1, *Alisma* 0.1; spectrum 9: *Herniaria*-type 0.1, *Helianthemum* 0.1; spectrum 11: *Hyoscyamus* 0.1; spectrum 12: *Bidens*-type 0.2, *Valerianella* 0.3; spectrum 14: *Haplophyllum* 0.1; spectrum 15: *Scabiosa olivieri* 0.1; spectrum 17: *Verbena* 0.3; spectrum 18: *Aesculus* 0.1, *Mercurialis annua* 0.2, *Plantago psyllium*-type 0.1; spectrum 19: *Phillyrea* 0.1; spectrum 20: *Aellenia* 0.1, *Arctium/Jurinea* 0.1, *Cheilanthes* 0.1; spectrum 21: *Bryonia* 0.1, *Datisca* 0.1; spectrum 22: *Rhinanthus*-type 0.2; spectrum 23: *Acanthus* 0.2, *Cynocrambe* 0.1, *Calligonum* 0.1; spectrum 24: *Primula veris*-type 0.1; spectrum 26: *Arum* 0.1; spectrum 27: *Sagina* 0.1, *Scleranthus* 0.1, *Plantago ovata*-type 0.1, *Fagopyrum* 0.1; spectrum 29: *Lychnis*-type 0.1; spectrum 30: *Punica* 0.1, *Cousinia* 0.1, *Kicksia* 0.1, *Urtica pilulifera*-type 0.1%; spectrum 32: *Morus* 0.1; spectrum 33: *Globularia* 0.4; spectrum 34: *Cistus* 0.1, *Anthyllis*-type 0.1, *Lathyrus*-type 0.1, *Ranunculus arvensis* 0.1.

Table 3. Pollen occurrence not included in the Eski Acıgöl I diagram (in percentages)

Spectrum 1: *Evax* 0.1, *Glaux* 0.1, *Adonis* 0.1, *Urtica pilulifera*-type 0.1, *Pediastrum kavraisky* 0.2; spectrum 2: *Scleranthus* 0.1, *Asperula*-type 0.1; spectrum 5: *Viburnum*-type 0.2, *Phillyrea* 0.2; spectrum 8: *Tulipa* 0.2, *Turgenia* 0.2; spectrum 9: *Scleranthus perennis* 0.2, *Ruta* 0.2; spectrum 10: *Agrimonia* 0.1; spectrum 12: *Ruta* 0.1; spectrum 13: *Zelkova* 0.1; spectrum 14: *Cnicus* 0.1, *Veronica* 0.1; spectrum 16: *Atraphaxis* 0.1; spectrum 20: *Sambucus nigra*-type 0.1; spectrum 22: *Viola* 0.1; spectrum 23: *Evax* 0.1, *Nepeta* 0.1, *Polypodium* 0.1; spectrum 27: *Cynocrambe* 0.1, *Papaver* 0.1, *Polgomm persicaria*-type 0.1; spectrum 28: *Crupina* 0.1, *Nepeta* 0.1; spectrum 30: *Pyrus* 0.1, *Gagea*-type 0.1; spectrum 31: *Crupina* 0.1, *Urtica pilulifera*-type 0.1; spectrum 32: *Chelidonium* 0.1; spectrum 33: *Chelidonium* 0.1; spectrum 34: *Ilex* 0.1, *Colchicum/Merendera* 0.1, *Zygophyllum* 0.3; spectrum 35: *Polygonum persicaria*-type 0.1, *Rheum* 0.1, *Anemone* 0.1; spectrum 37: *Hypericum perforatum*-type 0.2, *Valeriana* 0.1; spectrum 38: *Moltkia* 0.3, *Valeriana* 0.1; spectrum 41: *Malus*-type 0.1, *Papaver* 0.1; spectrum 42: *Nymphaea* 0.2; spectrum 46: *Hypericum assyrianum*-type 0.1, *Asperula*-type 0.1; spectrum 49: *Carduus*-type 0.1; spectrum 51: *Sambucus nigra*-type 0.2, *Rhynchosorys* 0.2, *Viola* 0.1; spectrum 52: *Sorbus*-type 0.1; spectrum 53: *Alhagi* 0.1; spectrum 55: *Styrax* 0.1; spectrum 57: *Digitalis*-type 0.1; spectrum 58: *Amaranthus*-type 0.1, *Boraginaceae* 0.8, *Hyoscyamus* 0.1, *Ranunculus pehatus*-type 0.1; spectrum 61: *Juglans* 0.1, *Carthamus* 0.1, *Epilobium* 0.1; spectrum 62: *Cynocrambe* 0.1, *Aconitum* 0.1; spectrum 63: *Pterocarya* 0.1, *Plumbago* 0.1; spectrum 66: *Lepidium*-type 0.2, *Hypericum assyrianum*-type 0.2, *Dictamnus* 0.1; spectrum 67: *Boraginaceae* 0.2, *Digitalis*-type 0.1; spectrum 68: *Sorbus*-type 0.1, *Plumbago* 0.2, *Dictamnus* 0.1; spectrum 71: *Fumaria* 0.1; spectrum 72: *Rhinanthus*-type 0.1; spectrum 73: *Salvia* 0.1; spectrum 74: *Elaeagnus* 0.5, *Phillyrea* 0.1, *Alyssum* 0.2, *Hypecoum* 0.2, *Rumex crispus*-type 0.1, *Scutellaria* 0.1; spectrum 75: *Elaeagnus* 0.4, *Juglans* 1.3, *Zea mays* 0.4; spectrum 76: *Veronica* 0.1; spectrum 77: *Spergula* 0.1, *Asphodeline* 0.1.

Table 4. Pollen occurrences not included in the Eski Acıgöl II diagram (in percentages)

Spectrum 1: *Rosa*-type 0.1, *Evax* 0.1, *Glaux* 0.1, *Adonis* 0.1, *Urtica pilulifera*-type 0.1, *Pediastrum kavraisky* 0.2, *Pteridium* 0.1; spectrum 2: *Fontanesia* 0.1, *Rhamnus* 0.1, *Tulipa* 0.1; spectrum 3: *Phyteuma* 0.2, *Beta* 0.2, *Filipendula* 0.1; spectrum 4: *Cruciferae* 0.1, *Frankenia* 0.1, *Liliaceae* 0.1, *Armeria/Limonium* 0.1, *Lotus*-type; spectrum 6: *Hordeum/Triticum*-type 0.4; spectrum 7: *Salsola* 0.2, *Arctium/Jurinea* 0.2, *Melampyrum* 0.2, *Valerianella* 0.2, *Potamogeton* 0.2; spectrum 8: *Acer* 0.1, *Marrubium* 0.1, *Lemna* 0.1; spectrum 9: *Symphytum*-type 0.1, *Thesium* 0.1, *Sanguisorba officinalis* 0.1, *Urtica pilulifera*-type 0.1; spectrum 10: *Fontanesia* 0.1, *Genista* 0.1, *Filago*-type 0.1, *Stachys*-type 0.1, *Plantago ovata*-type 0.1, *Myriophyllum spicatum/verticillatum* 0.1; spectrum 11: *Sorbus*-type 0.2, *Onobrychis*-type 0.1; spectrum 12: *Vitis* 0.1, *Fraxinus ornus* 0.1, *Plantago media*-type 0.1; spectrum 13: *Frankenia* 0.1, *Scilla*-type 0.3; spectrum 14: *Fraxinus excelsior* 0.1, *Plantago media*-type 0.1; spectrum 15: *Fraxinus excelsior* 0.2, *Cruciferae* 0.2, *Salvia* 0.2, *Veronica* 0.4; spectrum 16: *Hippophaë* 0.2, *Agrimonia* 0.2; spectrum 17: *Hippophaë* 0.2; spectrum 18: *Phlomis* 0.1, *Calligonum* 0.1; spectrum 19: *Acer* 0.1, *Corylus* 0.1, *Herniaria*-type 0.1, *Lappula* 0.1, *Elatine* 0.1; spectrum 20: *Scleranthus perennis* 0.1, *Cruciferae* 0.1, *Onobrychis*-type 0.1, *Asperula*-type 0.1, *Laserpitium*-type 0.1.

