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Palynological Analysis of Neogene Mammal Sites of Turkey – Vegetational and Climatic Implications

Türkiye'de Neojen Memeli Bulgu Yerlerinden Palinolojik Analizler – Vejetasyonel ve İklimsel Çıkarımlar

***Nurdan YAVUZ IŞIK[1], Gerçek SARAÇ[2], Engin ÜNAY[3], Hans de BRUIJN[4]**

[1]Ondokuz Mayıs University, Civil Engineering Department, 55139 Kurupelit-Samsun, Turkey

[2]Mineral Research and Exploration Institute, Ankara, Turkey

[3]Cumhuriyet University, Sivas, Turkey

[4]Institute of Earth Sciences, University of Utrecht, the Netherlands

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ABSTRACT

Pollen assemblages from lacustrine sediments that have known positions relative to mammal faunas in central and western Turkey are analysed. The stratigraphical order of the pollen samples is based on the stage of evolution of the associated mammal remains. The early Early Miocene pollen spectra indicate a flora dominated by mega-mesothermic elements such as Engelhardia and this flora reflects a subtropical climate. The decrease of mega-mesothermic elements during late Early Miocene suggests a slight decrease in temperature. During Middle Miocene a rich mixed forest flora including Quercus, Engelhardia, Zelkova, Parrotia persica, Alnus, Cedrus and Pinus indicative of a warm temperate climate are identified. The loss and decrease in abundance of several mesothermic elements indicates a possible climatic deterioration in Late Miocene. The Late Miocene flora reflects wide open areas with dominant Asteraceae. The Pliocene and Pleistocene palynofloras are similarly rich in herbs such as Asteraceae, Amaranthaceae/Chenopodiaceae and coniferous trees (Pinus, Tsuga, Cedrus, Abies) developed in a humid-temperate climatic condition. These palaeoclimatological interpretations are basically supported by the mammal faunas collected from the same localities.

Key Words: MN zones, Neogene, pollen, Turkey, vegetation, climate.

ÖZ

Türkiye'nin orta ve batı kısımlarından memeli fauna ile yaşlandırılmış gölsel sedimanların palinolojik analizleri yapılmıştır. İncelenen örneklerin stratigrafik diziliminde birlikte bulundukları memeli fosillerinin evrimi temel alınmıştır. Erken Erken Miyosen polen topluluğu, Engelhardia gibi mega-mezotermik elemanlarca zengin bir floranın varlığına işaret etmektedir ve bu flora yarıtropikal bir iklimi yansıtmaktadır. Geç Erken Miyosende mega-mezotermik elemanların azalması sıcaklıkta çok az bir düşüş olduğunu göstermektedir. Orta Miyosende nemli ılıman bir iklimi yansıtan Quercus, Engelhardia, Zelkova, Parrotia persica, Alnus, Cedrus ve Pinus bitkilerince zengin bir

N.Y.Işık
E-mail: nurdany@omu.edu.tr

karışık orman florası tanımlanmıştır. Mezotermik elemanlardaki azalma ya da yok oluş Geç Miyosende muhtemel bir iklimsel bozulmaya işaet etmektedir. Geç Miyosen florası başat bitkinin Asteraceae olduğu açık alanların yaygın olduğunu yansıtmaktadır. Pliyosen ve Pleyistosen palinofloraları nemli-ılıman iklim koşullarında gelişmiş Asteraceae, Amaranthaceae/Chenopodiaceae gibi otsul bitkiler ve çam ağaçlarınca (Pinus, Tsuga, Cedrus, Abies) zengindir. Yapılan paleoiklimsel yorumlar aynı lokasyonlardan tanımlanmış olan memeli faunaları ile de desteklenmektedir.

Anahtar Kelimeler: *MN zonları, Neojen, polen, Türkiye, vejetasyon, iklim*

INTRODUCTION

Continental fossil floras (represented by pollen, leaves, fruits) often lack reliable age determinations (Kovar-Eder et al. 1996). Such floras should wherever possible be dated by independent techniques (radiometry, magnetostratigraphy, mammalian biochronology). If a floral locality is found in association with small mammals the relative age control is good, but due to the different preservation potential of animals and plants, it is not easy to integrate floral and faunal data (but see Yavuz-Işık 2008). The often poor age control of fossil floras, makes temporal comparisons difficult. Plants tend to be preserved under anaerobic, non-alkaline, low-energy conditions, whereas mammal remains are often found in alkaline, well-oxidized, high-energy deposits (Strömberg et al. 2007). As a result, palynomorph floras commonly reflect different depositional environments than do vertebrate fossils. Despite this, fossil pollen and vertebrates sometimes occur in the same deposit, or even in the same layer (Brugal et al. 1990).

The aim of this study is to reconstruct palaeovegetation from the palynology of sediments associated with vertebrate assemblages of known ages in central and western Turkey. This is based on an already published pollen analysis of Keseköy samples (Yavuz-Işık 2008) and new data on surface samples from various localities using botanical taxonomy and a quantitative approach of the pollen data. It is the first paleobotanical study in this region based on samples that have known positions relative to mammal faunas. This approach allows the stratigraphical correlation of different vegetation types.

In Turkey there are some palynological studies, to identify climatic conditions and vegetation during Neogene, in which studied samples were dated by radiometric data (Yavuz-Işık, 2008; Yavuz-Işık and Toprak 2010), marine fossils (Sancay et al., 2006) pollen and spores (Akgün and Akyol 1999; Karayiğit et al., 1999; Kayseri and Akgün, 2008) and also mammals (Akgün et al., 2000; Yavuz-Işık, 2007; Kayseri ve Akgün, 2010). In the last couple of years palynological data have been analyzing by climatic programmes to get quantitative climate data. Akgün et al., (2007) was the first to produce quantitative climatic data by applying the Coexistence Approach method of Mosbrugger and Utescher (1997) in Turkey. The authors reported that during Chattian and Aquitanian warm subtropical (mean annual temperature between 16.5-21.3 ^{0}C), during early-late Serrevalian subtropical (mean annual temperature between17.2-20.8 ^{0}C) and during the Late Miocene warm temperate climatic conditions were present in Western and Central Anatolia. By using the same method Kayseri and Akgün (2008, 2010) also produce quantitave climatic data based on pollen assemblages. Recently, Akkiraz et al. (2010) shown temporal palaeoprecipitation values in Western and Central Anatolia during the Miocene via same method. The climatic results of these studies, whereever possible, are compared with the results of the current study.

MATERIALS AND METHODS

Sample Collecting

In an efford to find pollen floras in association with mammal faunas, fiftyone mammal localities, of which faunal assemblages already studied and used in zonation of the continental Turkish Neogene, have been visited and hundredsixteen samples were collected for pollen analysis. Unfortunatelly, most of our samples proved to be either barren, or to contain very few poorly preserved pollen grains. Only nineteen productive samples from nine different locations allow quantitative analyses. The pollen providing localities have a broad geographic coverage (Fig. 1). The stratigraphical position, relative to continental Turkish Neogene zonation (Ünay et al. 2003), and the sedimentary environment of these localities are given in Table 1. The localities without pollen is also listed in Table 2.

Although the informal zonation of the continental Turkish Neogene (Ünay et al. 2003), based on the evolutionary stages in the rodent families Muridae and Dipodidae, is incomplete and the correlation of its units A to P to the European MN "zones" is uncertain, we are confident that the sequence given is correct. Therefore we primarily correlate our pollen associations to this scheme. However, two of our samples (Çatakbağyaka and Eskihisar) come from levels that have so far yielded larger mammals only. Biostratigraphical correlation of these to the MN system is based on the assumption that the sequence of large mammals in Anatolia does not differ essentially from that in western Europe. It is clear, however, that the stratigraphical position of these associations is not well established. The sequence of these two localities allocated to the same MN zone is arbitrary.

Sample Preparation

Fifteen to twenty grams of each sample were treated with cold HCl (35%) and HF (70%) to remove carbonates and silica. Separation of the palynomorphs from the residue was carried out by using $ZnCl_2$. The residue was sieved on a 10mm nylon mesh, mixed with glycerine and mounted on a slide. A transmitting light microscope, using x400 and x1000 (oil immersion) magnifications, was used for the identification and the counting of the palynomorphs.

In this study, a botanical identification of the polen grains was carried out. Classification was then performed comparing the fossil pollen grains with their living relatives from several pollen atlases, the photograph bank of the laboratory in Lyon as well as the keys in Faegri and Iversen (1989) and Moore et al. (1991). The palynological results are shown in detailed pollen

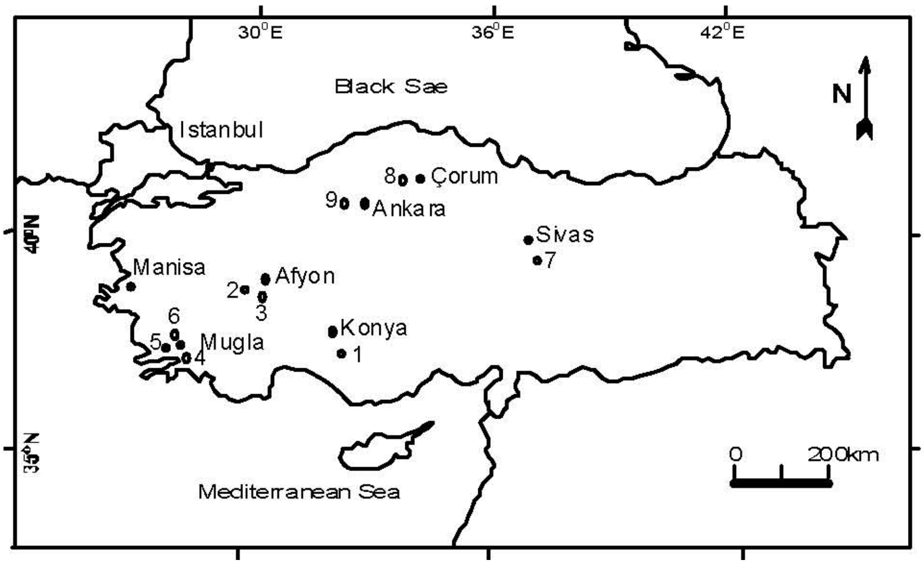

Figure 1. Geographic location of small mammal localities from which pollen were obtained. Localities: 1= Konya-Dursunlu; 2=Afyon-Akçaköy; 3= Afyon-Koçgazi; 4= Muğla-Askihisar; 5= Muğla-Yeni Eskihisar; 6= Muğla-Çatakbağyaka; 7= Sivas-Karaözü; 8= Çorum-Kagı; 9= Ankara-Keseköy.

Şekil 1. Polen bulunan küçük memeli lokasyonlarının coğrafik konumları. Lokasyonlar: 1= Konya-Dursunlu; 2=Afyon-Akçaköy; 3= Afyon-Koçgazi; 4= Muğla-Askihisar; 5= Muğla-Yeni Eskihisar; 6= Muğla-Çatakbağyaka; 7= Sivas-Karaözü; 8= Çorum-Kagı; 9= Ankara-Keseköy.

Table 1. List giving the stratigraphical position of the localities yielded pollen floras relative to the MN scheme (de Bruijn et al.,1992) and the preleminary zonation of the Neogene of Anatolia (Ünay et al.,2003). Number of samples collected per locality in parantheses (* from Yavuz-Işık, 2008).
Çizelge 1. Polen içeren örneklerin MN zonasyonuna (de Bruijn et al.,1996) göre stratigrafik pozisyonunu ve Anadolu Neojen zonasyonunu (Ünay et al.,2003) gösteren liste. Her lokasyondan toplanan örnek sayısı parantez içerisinde verilmiştir (Yavuz-Işık, 2008 den alınmıştır).*

Ma	Epochs		Local Zones of contin ental Neogene of Anatolia (Ünay et al. 2003)	Mammal Ages	Mammal Zones (Europe)	Sample locations and number of collected samples	Coordinates	Remarks	Depo sitional environment
1-	PLEISTOCENE			Biharian		Konya-Dursunlu (5)	31 46 10.7 38 22 38.3		Lacustrine
2-		Late	P	Villanyian	17				
3-			O		16				
4-		Early	N	Ruscinian	15				
5-			M		14	Afyon-Akçaköy (5)	38 07 40.8 30 15 20.3		Lacustrine
6-	MIOCENE	Late	L	Turolian	13				
7-			K		12				
8-									
9-			J		11	Sivas-Karaözü (2)	39 10 28.9 35 55 59.7		Lacustrine
10-			I	Vallesian	10 9				
11-		Middle	H	Astaracian	7-8	Mugla-Yenieskihisar (1)	37 18 40.4 28 02 44.7	Yenieskihisar radiometric 13.2 Ma	Lacustrine
12-						Afyon-Koçgazi (1)	38 24 52.8 30 06 50.6		Lacustrine
13-			G		6	Mugla-Çatakbagyaka (2)	37 07 38.7 28 10 36.2		Lacustrine
14-									
15-			F	Orleanian	5	Mugla-Eskihisar (2)	37 18 49.6 28 03 10.9		Lacustrine
16-									
17-		Early	E		4				
18-			D		3	*Ankara-Keseköy (16)	40 39 51.6 32 40 52.5		Lacustrine
19-									
20-			C	Agenian	2				
21-									
22-			B		MN1	Çorum-Kargi-2 (1)	40 52 58.4 34 52 52.5		Lacustrine
23-									
24-	OLIGOCENE		A		MP 30				

Table 2. List giving the stratigraphical position of the localities from which pollen were not obtained. Number of samples collected per locality in parantheses.
Çizelge 2. Polen bulunmayan örneklerin stratigrafik pozisyonunu gösteren liste. Her lokasyondan toplanan örnek sayısı parantez içerisinde verilmiştir.

Local zones of continental Neogene of Anatolia (Ünay et al. 2003)	Mammal Zones (Europe)	Sample locations and number of collected samples
P	17	
O	16	Denizli-Bıçakçı(1)
N	15	Denizli-Güzelyurt (4)
M	14	Afyon-Hüdaihamamı (1), Denizli-Ericek (1), Muğla-Bozarmut (2), Kayseri- Beşkardeşler (3), Konya-Özlüce (4), Manisa-Turgutlu (1), Sivas-İğdeli (4)
L	13	
K	12	Sivas-Düzyayla (4), Çorum-Karaçay (1)
J	11	Çorum-Akpınar (1), Muğla-Madenler (1), Çankırı-Çelikkapı Fabrikası (4), Afyon-Akin (3), Burdur-Elmalıyurt (2), Çorum-Tuğlu (2), Sivas-Powerline (1), Konya-Asağıçiğil A(1)
	10	
I	9	
H	7/8	İzmir-Akhisar (2)
G	6	Denizli-Haytabey (1), Manisa-Selendi (2), Konya-Yukarıçiğil (2)
F	5	Muğla-Kultak (3)
E	4	Uşak-Kaplangı (1), Ankara-HançılıB (5), A(5), Ankara-Karakeçili (2)
D	3	Denizli-Acıpayam (1), Sivas-Horlak (1), Muğla-Bağyaka (2), Kayseri-Yangınkulesi (1), Denizli-Maymundağı (1), Kırşehir-Kaman (1), Muğla-Ula (1), Ankara-Orta (12), Manisa-Harta (1), Muğla-Alaköy (3)
C		
B	2 MN 1	Ankara-Kılçak (4)
A	MP 30	Çorum-Dodurga (2), Sivas-Yağdonduran (10), Sivas-Yeniköy (4), Sivas-Uluçayır (2)

diagrams (Fig. 2-6) using the programmes TILIA and TILIA GRAPH (Grimm 2005).

MAMMAL DATA

In this study, previously identified mammal assemblages are used mainly for biostratigraphic purposes. Interpretation of small mammal assemblages in terms of biotope and paleoclimate is, in our opinion, a hazardous enterprise because: 1) The biotope requirements of most fossil species are not known. In contrast to plants most Neogene genera of mammals have become extinct. As a result there are only a few fossil groups, such as burrowing and aquatic talpids, dimylids, jerboas, flying and arboreal squirrels and beavers of which it may be assumed that they had similar life-styles as their extant counterparts. 2) Most concentrations of small mammal remains have accumulated through predation by birds of prey, which hunted over a larger area and probably had specific preferences and hunting techniques (diurnal/nocturnal). This circumstance results in an unknown degree of selection prior to fossilisation. 3) Other than in the case of plants, short periods of unfavourable circumstances (low temperature, drought) do not neccessarily limit the range of small mammal species, because these may survive by aquiring special strategies (hoarding,

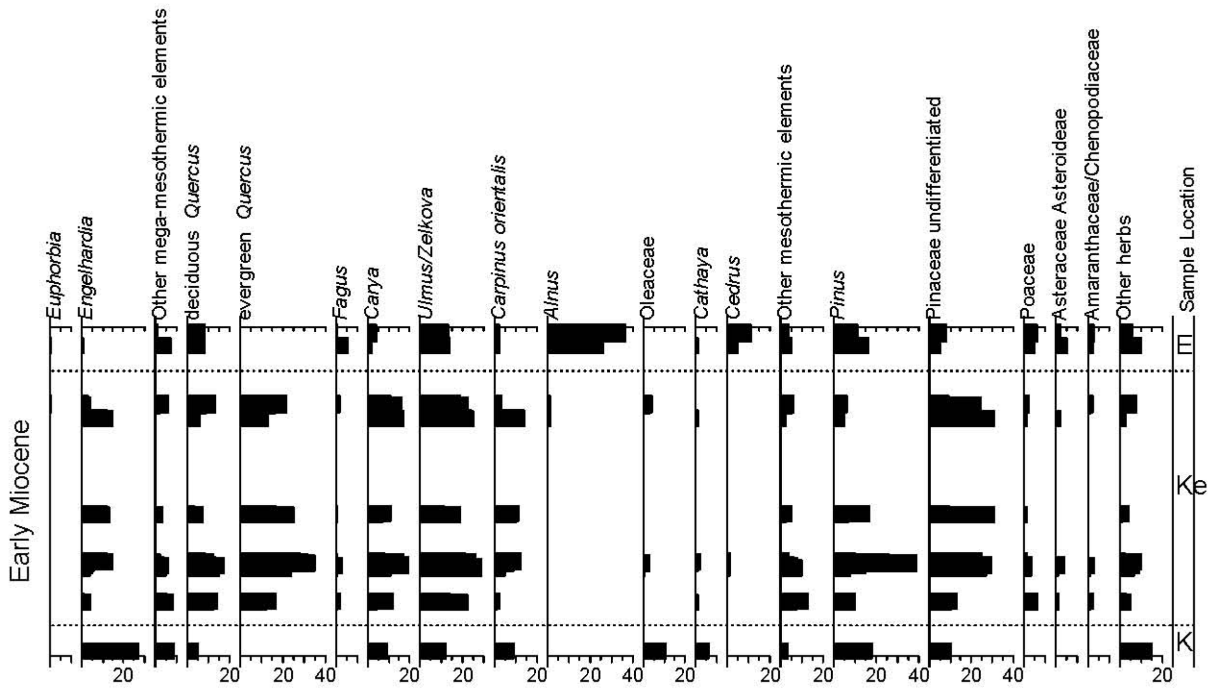

Figure 2. Pollen diagram of the Early Miocene samples. The groups are: other mega-mesothermic elements (Taxodiaceae, Anacardiaceae, Cyrillaceae-Clethraceae, Sapotaceae, Hamamelidaceae, Araliaceae); other mesothermic elements (Castaneae-Castanopsis type, Parrotia persica, Pterocarya, Juglans, Liquidambar, Tilia, Acer, Celtis, Lonicera, Hedera); other herbs (Brassicaceae, Verbanaceae, Convolvulaceae, Ranunculaceae, Caryophyllaceae, Polygonum, Valerianaceae, Rosaceae, Caprifoliaceae, Ephedra, Apiaceae). K:Kargı-2, Ke:Keseköy, E:Eskihisar.

Şekil 2. Erken Miyosen örneklerinin polen diyagramı. Gruplar: other mega-mesothermic elements (Taxodiaceae, Cyrillaceae-Clethraceae, Sapotaceae, Hamamelidaceae, Araliaceae); other mesothermic elements (Castaneae-Castanopsis type, Parrotia persica, Pterocarya, Juglans, Liquidambar, Tilia, Acer, Celtis, Lonicera, Hedera); other herbs (Brassicaceae, Verbanaceae, Convolvulaceae, Ranunculaceae, Caryophyllaceae, Polygonum, Valerianaceae, Rosaceae, Caprifoliaceae, Ephedra, Apiaceae).K:Kargı-2, Ke:Keseköy, E:Eskihisar.

hibernating, burrowing etc.). 4) Associations of small mammals from bedded sediments originate almost invariably from paleosols in a lacustrine setting (reedlands). Arboreal animals and those which were adapted to a desertic biotope may therefore be expected to be systematically underrepresented in collections. 5) The majority of the small mammal collections consists of water-transported isolated teeth. This means that there may have been an unknown degree of selection due to sorting.

These characteristics of small mammal assemblages, in combination with their, relative to plants, high rate of evolutionary change, make the mammal record very different from the pollen record. As a consequence it is less suitable for a quantitative analysis aiming at reconstructing the paleoclimate, but very useful for biostratigraphy.

RESULTS AND DISCUSSION

Many of the sampled mammal sites (42 out of 51) did not yield pollen. Various factors can cause sterility in palynological studies as recently discussed by Carrion et al. (2009). Carrion et al. (2009) reported failures with pollen analyses for the Quaternary of the Iberian Peninsula and stated that nature of depositional environment can be an important factor in case of palynological sterility and majority of the failed studies are open-air archaeological and palaeontological sites, and caves whereas lakes are often successfull sites. The pollen rich samples of our study, all being lacustrine, supports this statement. The Kargı, Keseköy and Karaözü samples originate from paleosols in a lacustrine setting. The fossiliferous beds of Eskihisar, Çatakbağyaka, Koçgazi, Yenieskihisar, Akçaköy and Dursunlu are lacustrine lignitic clays and deposit of Koçgazi is in a similar facies. However, most of barren samples are also lacustrine. The other main factor, reported by Carrion et al. (2009), causing palynological sterility was oxidation. It can occur pre-depositionally (e.g. soil inwash in lakes), syn-depositionally (e.g. high-energy sediment), post depositionally (e.g. fluctuation of lake levels) or after excavation, e.g. during field sampling. The identification of potential cause of oxidation needs further detailed investigations and it is beyond the scope of this study.

Despite the lack of pollen many samples, the obtained palynological information allows to get an idea of the vegetation during most of the Neogene in central and western Turkey. Additionaly, these vegetational findings and their climatic implications are largely supported by mammal faunas already collected from the same localities.

Early Miocene

Nineteen samples from the Early Miocene localities Kargı-2 (1 sample), Keseköy (16 samples) and Eskihisar (2 samples), contain pollen (Fig. 2). The genus *Engelhardia* belonging to the mega-mesothermic family Juglandaceae, is common in the samples. Extant *Engelhardia* is charateristic for low altitude mixed broadleaved and evergreen forests in subtropical SE China (Jimenez-Moreno 2006). *Engelhardia* and Oleaceae are common in the early Early Miocene assemblages from the eastern Mediterranean (Nagy, 1992). The decrease of *Engelhardia* (from Kargı-2 to Eskihisar) and the simultaneous increase of the cool temperate taxon *Fagu*s may indicate that temperatures slightly decrease in the course of the Early Miocene. This temperature drop cannot have been high because mega-mesothermic floral elements such as Euphorbiaceae, Taxodiaceae, *Myrica,* Sapotaceae, Cyrillaceae-Clethraceae were still present during the early Middle Miocene. The fluctuations in percentages of evergreen *Quercus* and *Ulmus* in the samples of a sequence from Keseköy are probably due to minor differences in precipitation. The dominance of *Alnus* in the samples from Eskihisar indicates the presence of riparian environments. The constant presence of *Pinus* and undifferentiated Pinaceae indicates that uplands existed close to the depositional area.

The vegetation was dominated by elements of a mixed mesophytic forest which is similar to other Early Miocene data of pollen floras from Western Anatolia (Seyitömer Basin: Yavuz-Işık 2007; Burdur-Kavak area: Akgün et al. 2007). The flora identified in the current study reflects nearly subtropical conditions in the early and humid warm-temperate conditions in the late Early Miocene. Similarly, Akgün et al. (2007) reported warm subtropical climatic conditions during the Chattian and Aquitanian period in western Anatolia (mean annual temperatures between 16.5–21.3 °C) whereas it becomes cooler during the Burdigalian.

The Early Miocene pollen spectra from the Mesohellenic Trench, Greece (Ioakim et al. 2005) are, like the ones from Anatolia, rich in the mesothermic elements, *Pinus* and undifferentiated Pinaceae. However, the dominance of megathermic and mega-mesothermic elements in the spectra from Greece indicate higher temperatures and more humid conditions. Moreover, the predominance of herbaceous plants indicates more open vegetation for Mesohellenic Trench. The analysis of phytolith assemblages provides a proxy for habitat openness. The phytolith data of Strömberg et al. (2007) suggest that relatively open habitats had become common in Turkey and surrounding areas by the Early Miocene (~20 Ma). However, the low percentages of herbaceous pollen in Kargı-2 and Eskihisar suggests that open areas were not widespread around these areas during the early Early Miocene.

Although we don't think that the correlation between climate and the diversity of rodent and insectivore species is straightforward, the presence in the assemblages from Kargı-2 and Keseköy of five species of Gliridae (dormice) with cheek teeth with seven or more ridges per molar (De Bruijn et al. 1996) and of eight species of Muridae indicates humidity as well as the availability of diverse food sources. Although insectivores are in terms of specimens compared to rodents not numerous in these assemblages (max. 25 %) the group is quite diverse with the digging mole (*Geotrypus*), the water mole (*Desmanodon*) and a molluc eater (*Turkodimylus*). The composition of the small mammal assemblage therefore strongly supports the pollen based reconstruction.

Middle Miocene

Four samples from three localities, Çatakbağyaka (2 samples), Koçgazi (1 sample) and Yeni Eskihisar (1 sample) provided pollen data (Fig. 3). The high percentage of trees in these pollen spectra seems to be characteristic for the Middle Miocene of Anatolia (see Akgün et al. 2007; Yavuz-Işık and Demirci 2009). *Quercus, Parrotia persica, Ulmus, Zelkova, Carpinus orientalis* and *Alnus* were the dominant trees in this forest. Conifers are represented by *Cedrus* and *Pinus*. *Cedrus*, a mid-altitude conifer which lives today between 2000-2500 m. in the Himalayas (Hoorn et al. 2000) is common. *Cathaya,* an altitudinal conifer living today in southern China (Fauquette et al. 2006), is represented by smaller percentages. The presence of high altitude elements in the spectra may suggest that Anatolia was uplifted after the Early Miocene.

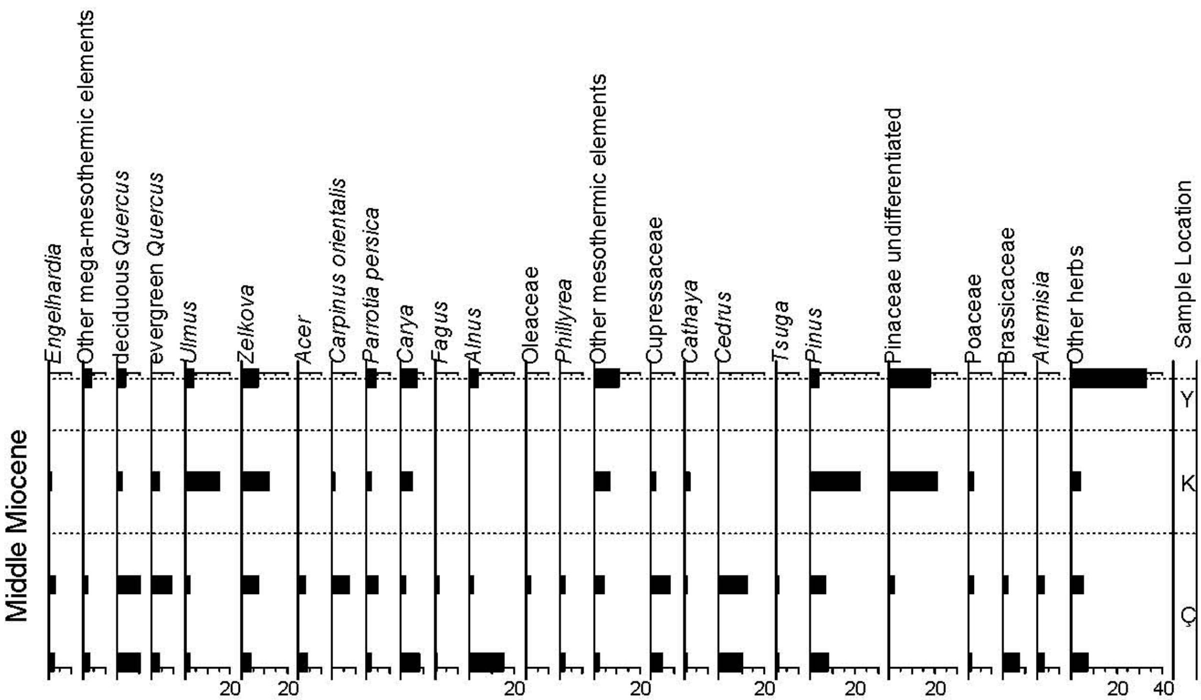

Figure 3. Pollen diagram of the Middle Miocene samples. The groups are: other mega-mesothermic elements (Passifloraceae, Mimosa, Taxodiaceae, Anacardiaceae, Myrica, Alchornea, Polygalaceae, Palmae); other mesothermic elements (Castaneae-Castanopsis type, Distylium, Loropetalum, Pterocarya, Juglans, Celtis Tilia, Carpinus betulus, Buxus, Betula, Ostrya); other herbs (Asteraceae Asteroideae, Asteraceae Cichorioideae, Campanulaceae, Rumex, Ephedra, Apiaceae, Caryophyllaceae, Rosaceae, Amaranthceae/Chenopodiaceae, Valerianaceae). Ç:Çatakbağyaka, K:Koçgazi, Y:Yeni Eskihisar.

Şekil 3. Orta Miyosen örneklerinin polen diyagramı. Gruplar: other mega-mesothermic elements (Passifloraceae, Mimosa, Taxodiaceae, Anacardiaceae, Myrica, Alchornea, Polygalaceae, Palmae); other mesothermic elements (Castaneae-Castanopsis type, Distylium, Loropetalum, Pterocarya, Juglans, Celtis Tilia, Carpinus betulus, Buxus, Betula, Ostrya); other herbs (Asteraceae Asteroideae, Asteraceae Cichorioideae, Campanulaceae, Rumex, Ephedra, Apiaceae, Caryophyllaceae, Rosaceae, Amaranthceae/Chenopodiaceae, Valerianaceae). Ç:Çatakbağyaka, K:Koçgazi, Y: Yeni Eskihisar.

The impoverishment of the plant diversity towards the end of the Middle Miocene, especially the disappearance of megathermic and mega-mesothermic elements (Fig. 3) may indicate a climatic deterioration. The vegetation was almost subtropical in the early Middle Miocene while temperate conditions seem to have prevailed during the late Middle Miocene. The late Middle Miocene pollen assemblages then show a decrease in diversity, which possibly reflects a cooling event. A similar change of the vegetation has been recorded both in Turkey and Europe as discussed below.

The application of Coexistence Approach analysis to pollen data by Kayseri and Akgün (2010) shown that warm climatic conditions indicating Middle Miocene Climatic Optimum was existed in; Balıkesir-Gönen and Çanakkale-Çan regions during latest Burdigalian-?Serrevalian, Samsun-Havza area during latest Burdigalian and Muğla-Milas region during late Burdigalian-Langhian period. Moreover Akkiraz et al. (2010) observed a decrease in precipitation during Middle Miocene in Turkey and stated that it could be related to a cooling.

Jimenez-Moreno et al. (2005) and Jimenez-Moreno (2006) shown that, in the Pannonian Basin-Hungary, a Burdigalian-Langian subtropical forest was replaced by a mesothermic one with deciduous *Quercus*, *Fagus*, *Alnus, Carpinus*, *Ulmus*, *Zelkova* etc. during the Serrevallian. Ivanov et al. (2002) observed a similar trend in palynofloras from the Carpathian forebasin (NW Bulgaria).

The Middle Miocene rodent faunas in Anatolia show the transition from *Cricetodon* to *Byzantinia* and from the small, low crowned, *Eumyarion intercedens* to the larger, and more hypsodont *Anomalomys gaillardi.* The first record of the jerboa *Protallactaga* and the last record of the ctenodactylid *Sayimys* are from the early Middle Miocene. The presence in Anatolia of a diverse forest during the early Middle Miocene as reconstructed on the basis of pollen flora, is corroborated by finds of the flying squirrels *Forsythia* and *Albanensia* in Çandır 2. The decline of the Gliridae with seven or more ridges per molar at the base of the Middle Miocene and the entry of the xerine sciurid *Atlantoxerus* in the upper part of the Middle Miocene are in line with the trend towards a cooler climate reconstructed on the basis of palynofloras.

Late Miocene

The only Late Miocene mammal locality that provided pollen data is Karaözü (Fig. 4). Despite low number of samples, the pollen spectra of Karaözü samples show a dramatic decrease in the diversity of vegetation probably indicating a deterioration of the climate. Trees are almost disappeared and herbs, with predominant Asteraceae, characterize the vegetation. It agrees with open vegetation characterized by dominance of Asteraceae, Apiaceae and Chenopodiaceae that was widespread in central Anatolia during the middle Tortonian period (Akgün et al. 2000; Akgün et al. 2007). A similar vegetation change with dominance of open landscapes with more xerophytic plants in Ukraine was correlated with the Late Miocene Cooling (Syabryaj et al. 2007) and it also reflected by Cenozoic megafloras from the Serbia (Utescher et al. 2007). Although Akgün et al. (2007) shown warm temperate climatic conditions during Late Miocene in Western and central Anatolia, also reported presence of dry seasons during the Tortonian (mean annual temperatures between 15.6- 20.8 °C).

The composition of the rodent faunas changes rapidly during this time-slice because of the arrival of the (quickly radiating) Murinae (true mice). The diversifiation within the genus *Byzantinia*, the arrival of the exotic hamster c.f. *Rhinocerodon*, the gerbil *Pseudomeriones* and the porcupine *Hystrix* suggests that biotopes were dry.

Pliocene

Only one Pliocene locality, Akçaköy, provided pollen data (Fig. 5). *Pinus* and undifferentiated Pinaceae are dominant and occur associated with few deciduous trees. The small amount of *Tsuga, Cedrus* and *Abies* may point to the presence of a nearby mid-altitude forest. Herbs are abundant in the pollen spectra with dominant Asteraceae together with some Amaranthaceae/Chenopodiaceae, Dipsacaceae and Caryophyllaceae. The presence of *Limonium* among

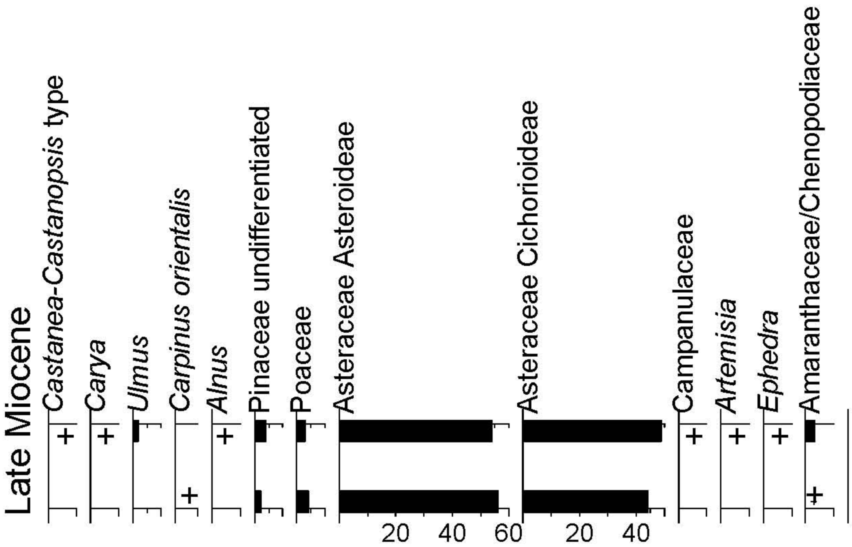

Figure 4. Pollen diagram of the Late Miocene samples.
Şekil 4. Geç Miyosen örneklerinin polen diyagramı.

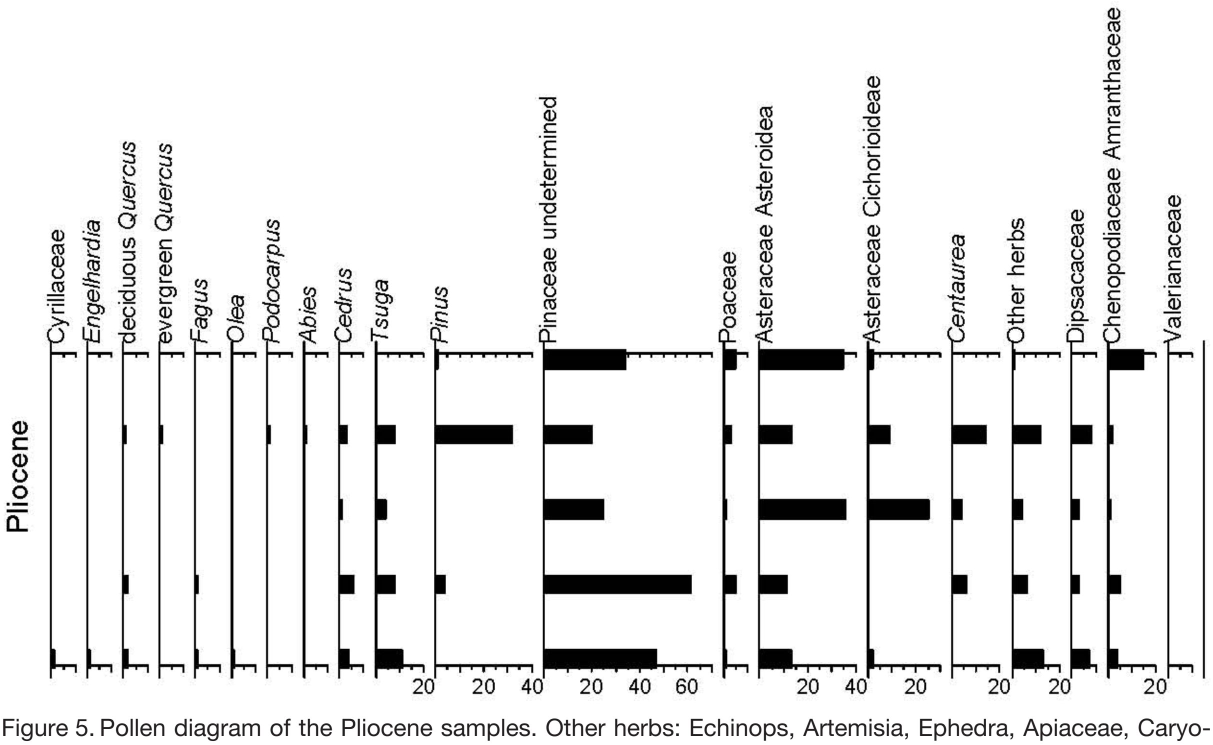

Figure 5. Pollen diagram of the Pliocene samples. Other herbs: Echinops, Artemisia, Ephedra, Apiaceae, Caryophyllaceae, Limonium, Knautia, Erodium, Valerianaceae.
Şekil 5. Pliyosen örneklerinin polen diyagramı. Other herbs: Echinops, Artemisia, Ephedra, Apiaceae, Caryophyllaceae, Limonium, Knautia, Erodium, Valerianaceae.

with these families could point to alkaline soil conditions.

The pollen assemblage of Akçaköy reflects an open herb vegetation, with dominant Asteraceae, and tree associations composed mainly of undifferentiated Pinaceae. Development of open herbaceous vegetation is palynologically well-recorded during the early Pliocene from different regions of the Mediterranean area (Suc et al. 1999; Fauquette et al., 2006) as well as from a small surface section in the Central Anatolia (Yavuz-Işık and Toprak, 2010).

Popescu (2006) characterized the Pliocene, on the basis of palynofloras from the Black Sea region, by the competitive alternation between humid thermophilous forests and dry steppes. Suc et al. (1995), observed a similar vegetation pattern in the north-west Mediterranean region, but not in the southern Mediterranean region due to local aridity. Although the Akçaköy samples are rich in Asteraceae, a family very common in open and dry environments, aridity in Akçaköy area cannot have been intense during the Early Pliocene since conifers, in particular *Tsuga,* which is sensitive to summer drought (van Hoeve 2000), are present.

Pleistocene

Only one Pleistocene locality, Dursunlu provided pollen data (Fig. 6). The pollen assemblage of Dursunlu shows that the vegetation was dominated by herbs but had a significant arboreal component. Among the herbs, Asteraceae and Amaranthaceae/Chenopodiaceae are the most common elements, and together with Dipsacaceae and *Artemisia* they point out to an open vegetation. *Pinus* and undifferentiated Pinaceae are dominant among the trees. Altitudinal trees are represented only by few pollen grains. The abundance of Pteridophytes, high number of aquatics and algae points to presence of a lake. The high number of conifers present in the Akçaköy samples indicates that uplands were not far from the depositional site.

Overall, this vegetation indicates humid-temperate climatic conditions. This is conformable with the environmental reconstruction of Dursunlu on the basis of the avifauna (Louchart

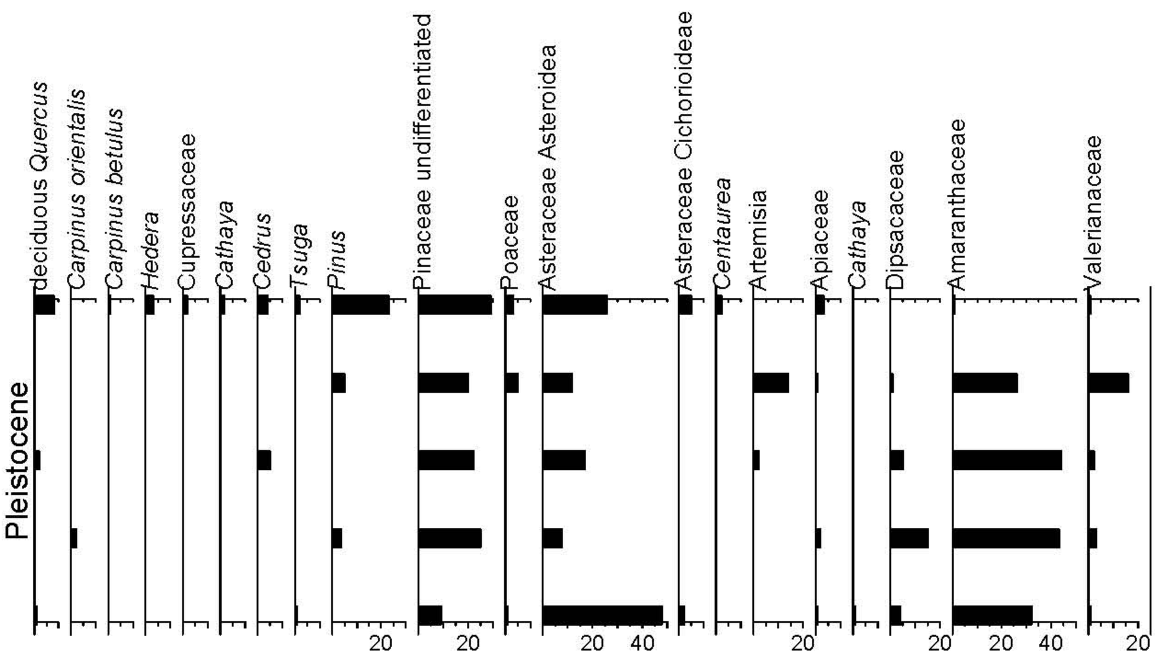

Figure 6. Pollen diagram of the Pleistocene samples.
Şekil 6. Pleyistosen örneklerinin polen diyagramı.

et al. 1998). Louchart et al. (1998) described a rich, mainly aquatic avifauna, with a majority of extant forms from Dursunlu and interpreted these to indicate an open, steppic environment with a possible Mediterranean climate.

CONCLUSIONS

The palynological study on the lacustrine deposits associated with vertebrate assemblages of known ages from differnt parts of Turkey permitted the identification of a rich flora. Although mammal assemblages are used for biostratigraphic purposes in this study, they still support the palynologically inferred vegetation and climatic conditions.

The vegetation during the early Early Miocene was dominated by mega-mesothermic elements such as *Engelhardia.* This kind of vegetation points to a subtropical climate during the mentioned time-span. During the late Early Miocene changes in the vegetation are observed: thermophilous elements, especially *Engelhardia*, decreased and vegetation dominated by mesothermic plants such as *Quercus, Fagus, Alnus, Carpinus, Ulmus/Zelkova* etc. The early Middle Miocene vegetation is rich in mega-mesothermic trees such as Hamamelidaceae (Western Anatolia), *Engelhardia* and Taxodiaceae. However, the number of mega-mesothermic pollen and the diversity of the vegetation decraese considerably during the late Middle Miocene indicating a climatic deterioration. Late Miocene vegetation is dominated by Asteraceae representing open areas with almost no trees. The Pliocene vegetation is dominated by conifers and herbs in association with abundant freshwater algea. This flora represents temperate climatic conditions. The Pleistocene vegetation is dominated by herbs (Asteraceae, Amaranthaceae/Chenopodiaceae and Poaceae) characterising an open biotope. Conifers and Pteridophytes are also well represented in these spectra.

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