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Research Article

Detection of some woody plants in Late Oligocene forests of İstanbul

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Abstract: A paleopalynological study was performed on the fossilized pollen found in the coal and clay layers of the Akçelik Coalmine, which is one of the open lignite quarries located at the northern part of İstanbul, and 15 genera belonging to 14 families were identified from the late Oligocene of İstanbul. Of these 14 families, 4 families belong to *Gymnospermae*, and 10 of them belong to *Angiospermae*. In the study, 85.8% of pollen is arboreal (AP) (woody plants), 10.4% is non-arboreal (NAP) (herbal plants), and rest of them (3.8%) could not be identified. The middle coal layer has a significant number of pollen grains. While lower part of the middle coal layer is mainly represented by broad-leaved tree pollen and its upper part is mainly *Juniperus*. A clear change from plants of humid conditions to the plants of drier conditions is observed. The lower number of pine pollen grains shows that there was no forest of this genus in that site. *Sequoia* and *Taxodium*, which had wide forests during Oligocene but are completely disappeared at present, are represented with low number of pollen grains in that time.

Key words: İstanbul, *Juniperus*, Late Oligocene, Paleopalynology, *Sequoia*, *Taxodium*

İstanbul'un Geç Oligosen ormanlarını oluşturan bazı odunsu bitkilerin saptanması

Özet: Bu araştırmada, İstanbul'un kuzeyinde bulunan açık linyit işletmelerinden biri olan Akçelik Maden Ocağından alınan kömür ve kil örnekleri üzerinde paleopalinolojik bir çalışma yapılmış, Geç Oligosen'de yayılış gösteren 14 familyaya ait 15 cins tespit edilmiştir. Bu familyalardan 4 tanesi *Gymnospermae*, 10 tanesi de *Angiospermae*'dir. Polenlerden, % 85.8'i arboreal (AP) (odunsu bitki), % 10.4'ü otsu (NAP) ve kalan % 3.8'i de tanımlanamamıştır. Orta kömür tabakasının alt kısmında çoğunlukla geniş yapraklı ağaç polenleri bulunmasına rağmen, orta kömür tabakasının üst kısmında çoğunlukla *Juniperus* poleni bulunmuştur. Nemli ortam bitkilerinden kurak ortam bitkilerine doğru açık bir değişim olduğu gözlemlenmiştir. *Pinus* polenlerinin az sayıda çıkması, bu cinsin o dönemde bu yörede geniş bir orman kurmadığını göstermektedir. Oligosende geniş yayılışı olan ve günümüzde tamamen yok olan *Sequoia* ve *Taxodium* gibi bazı cinslere ait az sayıda polen bulunmuştur.

Anahtar sözcükler: İstanbul, *Juniperus*, Geç Oligosen, Paleopalinoloji, *Sequoia*, *Taxodium*

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Introduction

In natural sciences, one of the preconditions for interpreting today and future requires the knowledge of past as much as possible. Palynology, which constitutes the basis of our study, is –in addition to its original aims– a discipline that demonstrates the natural structure in the past in a multidimensional way. Having been improved significantly in the last fifty years, this discipline (Çenet 2003) is highly informative about the biophysical environment of the periods hundreds of million years ago. The pollen analysis performed on the basis of pollen morphology provides information on vegetation structure and climate of previous periods and also enable us to make paleoclimatological interpretations (Aytuğ et al. 1971; Bradley 1999). The pollen grains of forest trees, many of which exist especially in fossil forests (lignite beds), have been helpful in determining the forests of periods before the old historical ages (Egemen 1958). In Turkey, some pollen analyses have been performed for the Tertiary era (Nakoman 1968; Şanlı 1982; Akyol and Akgün 1995; Batı 1996) and the end of the Pleistocene – Holocene eras (Aytuğ 1967; Bottema and Woldring 1986; Kutluk 1994; Bottema et al. 1995; Çağatay et al. 1999).

Akyol (1964), Nakoman (1968, 1971), Aytuğ and Şanlı (1974), Şanlı (1982), Ediger et al. (1990), Akyol and Akgün (1995), and Subakan (1999) have contributed significantly to the Tertiary paleopalynology. As a result of all these studies, it has been found that the Tertiary flora of Turkey has some similarities and some significant differences. The taxa in the Tertiary era, such as *Sequoia*, *Sequoiadendron, Taxodium* and *Ginkgo,* were completely disappeared at the end of Tertiary and the current flora has begun to be formed as of Miocene. Nakoman (1968) clearly shows the change of vegetation occurred in the micro-flora of coals of Ağaçlı in the Oligocene-Miocene boundary. In these micro-floras, palm trees, which do not occur in the Miocene vegetation, continue to exist and *Pinaceae* taxa begin to grow. Nakoman (1971) shows *Polypodiaceae*, *Nymphaceae*, *Gramineae*, *Taxodiaceae*, *Pinaceae*, *Myricaceae*, *Betulaceae*, *Oenotheraceae*, *Umbelliferae*, *Araliaceae*, *Caryophyllaceae,* and *Sapotaceae* families as examples of the Turkish Pliocene vegetation. Kasaplıgil (1977), Şanlı (1982), Gemici et al. (1991), Yaltırık (1993), Kayacık et al. (1995), and Akkemik et al. (2005) stated that the taxa of the *Taxodiaceae* family, which has spread during Tertiary, have significantly contributed to the formation of current lignite and some plant fossils, such as *Sequioa* and *Taxodium,* were observed around Kütahya-Tunçbilek and Ankara-Kızılcahamam. The same species were also determined in the Northern Thrace (Özgüven 1971; Kayacık et al. 1995; Aras et al. 2003; Akkemik et al. 2005). Concerning Turkey's Tertiary flora, Egemen (1958) has come to the conclusion that palm trees and ferns, such as *Woodwardia,* are widely spread in Thrace and Bilecik and other Middle-North Anatolian Neocene showing that the climate during the said period was warmer and even subtropical.

Some taxa in the coals of the northern Thrace (Batı 1996) are: (1) Pollen Group: *Pinus, Carya, Calamus, Quercus, Sequioa, Alnus, Fagaceae, Taxodiaceae, Myricaceae* (2) Spore Group: *Polypodiaceae, Schizaeceae, Selaginellaceae, Lycopodiaceae, Osmundaceae* (3) Fungal Spores: *Hypoxylonites* spp., *Polyadosporites enormis*, *P. orbis*, *Anatolinites dongyingensis, Inapertisporites* spp., *Pluricellaesporites vermiculus*, *Multicellaesporites* spp., *Pesavis* spp., *Diporicellaesporites* sp., *Dyadosporites* sp. and *Hyphae*. Of these taxa that had been found at the northern Thrace basin, especially *Calamus* pollen is very significant for Late Oligocene. Chandler (1957) also reports plenty of pollen-grains of *Calamus* indicating a dense *Calamus* jungle in the Oligocene lignites of S.W. England. Elsik (1978) reports that the Upper Paleocene coal from East Texas, U.S.A. contains mainly a *Calamuspollenites-Arecipites* association. Roche and Schuler (1976) found that the pollen of *Calamus* was always associated with spores of *Acrostichum* in Oligocene peats formed in brackish-water swamp forest in Belgium. A close relationship in the relative frequency distribution between *Dicolpopollis kalewensis* and *Baculatisporites* sub sp., *Tricolporopollenites margaritatus*, *Polyvestibulopollenites verus* (*Alnus*), and some fungal spores was also observed in the Thrace Basin, Turkey (Ediger, 1981, 1982; Ediger and Alişan, 1989; Ediger et al. 1990).

The objective of the present study was to determine woody plants in the clay and coal layers found in a lignite mine dating from the Late Oligocene age in İstanbul (Akçelik Coalmine) using paleopalynological analysis.

Materials and methods

Study area: The study area is located in İstanbul province, Kemerburgaz district, Ağaçlı (41° 14’ north latitude, 28° 56’ east longitude) (Figure 1). Paleo-longitude of Thrace in Oligocene is approximately 37° N (Meulenkamp ve Sissingh 2003).

Important studies have been carried out on the Lignite of the northern Thrace. Nakoman (1968), Akyol and Akgün (1995), and Batı (1996) have stated that the lignite of the western Thrace is of late Oligocene - early Miocene. They stated that the age of the lignite of the Thrace basin was late Oligocene - early Miocene.

At present, the study area has a semi-humid, second-degree mesothermal climate similar to sea-like conditions, and experiences a moderate water insufficiency during summers. Most part of the land in Ağaçlı is covered with forests, which are mainly composed of oaks, such as sessile oak (*Quercus petraea* (Mattuschka) Liebl.), Hungarian oak (*Quercus frainetto* Ten.), and Turkey oak (*Quercus cerris* L.). Also, chestnut (*Castanea sativa* Mill.), hornbeam (*Carpinus betulus* L.), hedge maple (*Acer campestre* L.), medlar (*Mespilus germanica* L.), wild hazelnut (*Corylus avellana* L.), cornelian cherry (*Cornus mas* L.) as well as some bush species, such as prickly juniper (*Juniperus oxycedrus* L.), arbutus (*Arbutus unedo* L.), heath tree (*Erica arborea* L.), and *Erica manipuliflora* Salisb., take place among the species of the forest. These bush species have grown up in large areas on which the forest had been destructed and formed thickets (Kantarcı and Öztürk 2003).

Sampling and methods: Five coal samples and 4 clay samples were taken vertically from main veins of coal, which occur in 3 layers in the Akçelik Coalmine (Figure 2). In order to examine thoroughly the pollen and spores in the samples under microscope, we removed the minerals in samples and obtained fossils. HCl was used to eliminate carbonates, HF to remove silica and various silicates, and HCl to eliminate secondary fluorosilicates (heated for 30 min by Benmari method); also HNO_3 was used to turn decomposed organic wastes into humic acids resolvable in alkali bases, and KOH of 10% (alkali application) was used to decompose humic materials (Erdtman 1954; Moore et al. 1991; Batı 1996; Çenet 2003).

In this work, we employed the classical method as the basis (Erdtman 1954; Moore et al. 1991). First, 10 g from each sample was cleaned from the limestone with 20% cold HCl for a long or short time depending on the quantity of limestone material. Then, they were left hot in 65% (40% where applicable) cold HF for 48 h in order to remove silica and various silicates. As our sample was coal, nitric acid was applied hot.

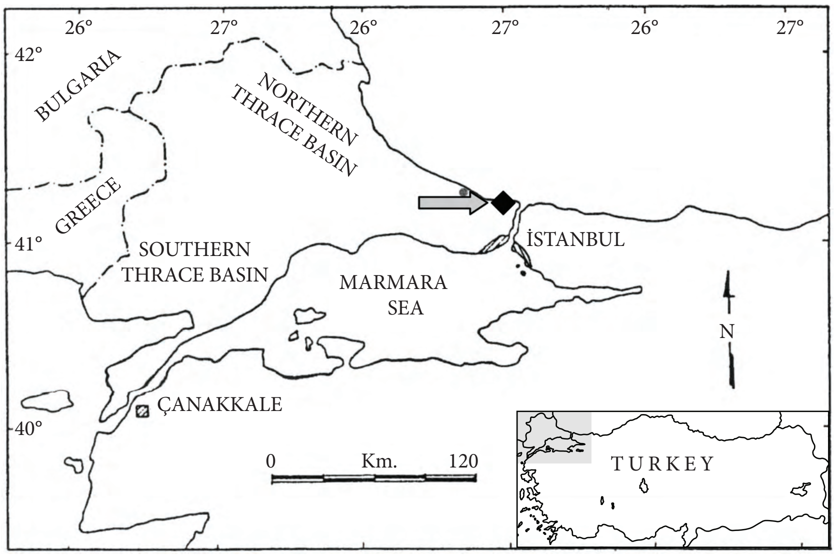

Figure 1. The location map of the area

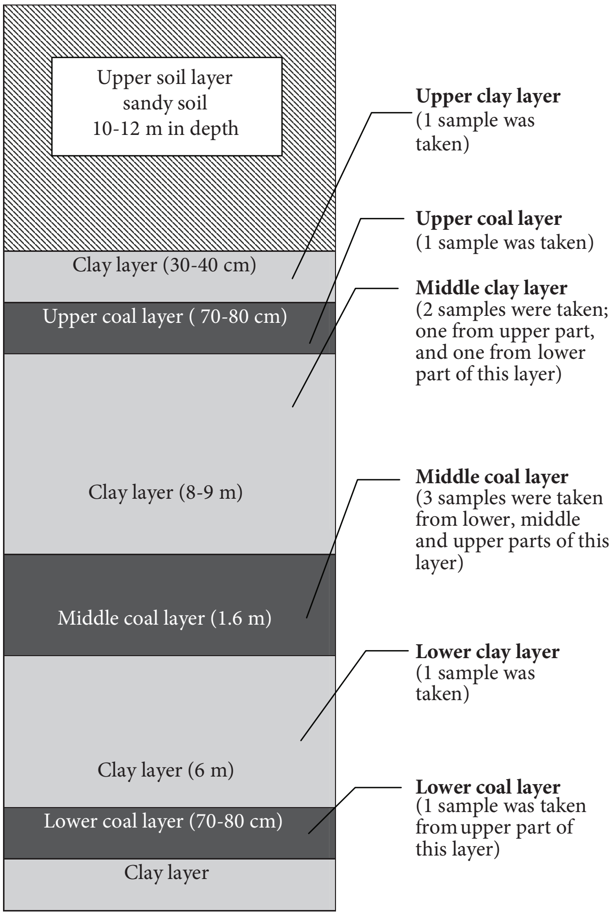

Figure 2. Three coal layers in the vertical section of the coalmine

Fluoride turned into chloride by the application of 20% hot HCl. For decomposition of humic materials, they were mixed with 10% hot KOH. The pollen grains turned white without oxidization by means of low sodium perborate concentration. They were left in equal amounts of (distilled water – glycerin – basic fuchsin) during the dying period. Dark dying conditions were lightened by ethyl alcohol (96.6%). Desired number of preparations were closed in glycerin.

Results

Pollen was detected in only 4 samples (1 clay and 3 coal samples) from the Akçelik Coalmine, and they were defined and counted (Table 1). These pollen grains are provided below. Because the purpose of the paper to determine woody plants, we presented the pollen results here.

Pollen detected in coal layers: Among the coal samples analyzed, only middle layer includes pollen and spores. Although analyses were repeated, neither pollen nor spores were detected in upper and lower layers of coal. In the lower and upper layers of coal, pollen is absent since the pollen and spores vanished due to the inconvenient storage conditions at the beginning.

Table 1. Number of pollen found in 3 different coal layers of the Akçelik coalmine. Pollen was found only in the middle coal layer. AP: Arboreal pollen, NAP: Non-arboreal pollen

	POLLEN NUMBER																		
DEPTHS	AP														NAP				Non-identified Pollen
	Juniperus	*Pinus*	*Taxodiaceae*	*Sequioa*	*Taxodium*	*Taxus*	*Acer*	*Calamus*	*Carpinus*	*Corylus*	*Buxus*	*Ericaceae*	*Castanea*	*Quercus*	*Caryophyllaceae*	*Artemisia*	*Gramineae*	*Lilium*	
Upper coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper part of the middle coal	52	-	-	-	2	2	3	-	-	2	9	-	-	4	1	-	7	1	-
Middle part of the middle coal	14	-	1	1	-	2	-	5	-	1	1	-	-	1	-	-	5	-	4
Lower part of the middle coal	15	2	1	-	-	2	27	13	5	8	-	2	1	5	-	2	6	-	4
Upper part of the lower coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**81**	**2**	**2**	**1**	**2**	**6**	**30**	**18**	**5**	**11**	**10**	**2**	**1**	**10**	**1**	**2**	**18**	**1**	**8**

1-Pollens detected in the upper part of the middle coal layer : As a result of microscopic studies carried out on sections prepared from samples taken from the upper part of the middle coal layer: 83 pollens from 8 genera and 2 families (consisting of 52 *Juniperus*, 2 *Taxodium*, 2 *Taxus*, 3 *Acer*, 2 *Corylus*, 9 *Buxus*, 4 *Quercus,* 1 *Caryopyhllaceae,* 7 *Gramineae*, and 1 *Lilium)* (Table 1; Figure 3) were detected.

2-Pollens detected in the middle part of middle coal layer: As a result of microscopic studies carried out on sections prepared from samples taken from the middle part of the middle coal layer: a total of 35 pollens from 7 different genera and 2 families (consisting of 14 *Juniperus*, 1 *Taxodiaceae*, 1 *Sequioa*, 2 *Taxus*, 5 *Calamus*, 1 *Corylus*, 1 *Buxus*, 1 *Quercus*, 5 *Gramineae*, and 4 undefined pollens) (Table 1; Figure 3) were detected.

3-Pollens detected in the lower part of middle coal layer: In all sections prepared from samples taken from the lower part of the middle coal layer, a total of 93 pollens from 10 genera and 3 families (consisting of 15 *Juniperus*, 2 *Pinus*, 1 *Taxodiaceae,* 2 *Taxus*, 27 *Acer*, 13 *Calamus*, 5 *Carpinus*, 8 *Corylus*, 2 *Ericaceae,* 1 *Castanea*, 5 *Quercus*, 2 *Artemisia*, 6 *Gramineae*, and 4 undefined pollens) (Table 1; Figure 3) were detected.

Pollens detected in clay layers: Pollen was detected in only 1 sample that was collected from the upper coal layer. In this layer, a total of 9 pollens from 4 genera (consisting of 5 *Alnus*, 2 *Taxus*, 1 *Corylus*, and 1 *Acer*) were detected.

Discussion

AP (Arboreal Pollen) and NAP (Non-Arboreal Pollen) rates of the micro-flora group determined by the palynological studies are comprised of 85.8% arboreal pollen, 10.4% non-arboreal pollen, and 3.8% undefined pollen. According to these rates, woody plant forms show a high value of 85.8%. Percentage for herbaceous forms in the samples is 10.4% (Table 1; Figure 4). We determined the botanical dependences of the taxa as 4 families from *Gymnospermae* (*Taxaceae*, *Taxodiaceae*, *Pinaceae,* and *Cupressaceae*) and 10 families from *Angiospermae* (*Aceraceae*, *Araceae*, *Betulaceae*, *Buxaceae*, *Ericaceae, Fagaceae*, *Caryophyllaceae*, *Compositae*, *Gramineae,* and *Liliaceae*). Totally 15 genera from 14 families were determined. All photographs of the pollen identified are displayed in Figure 5.

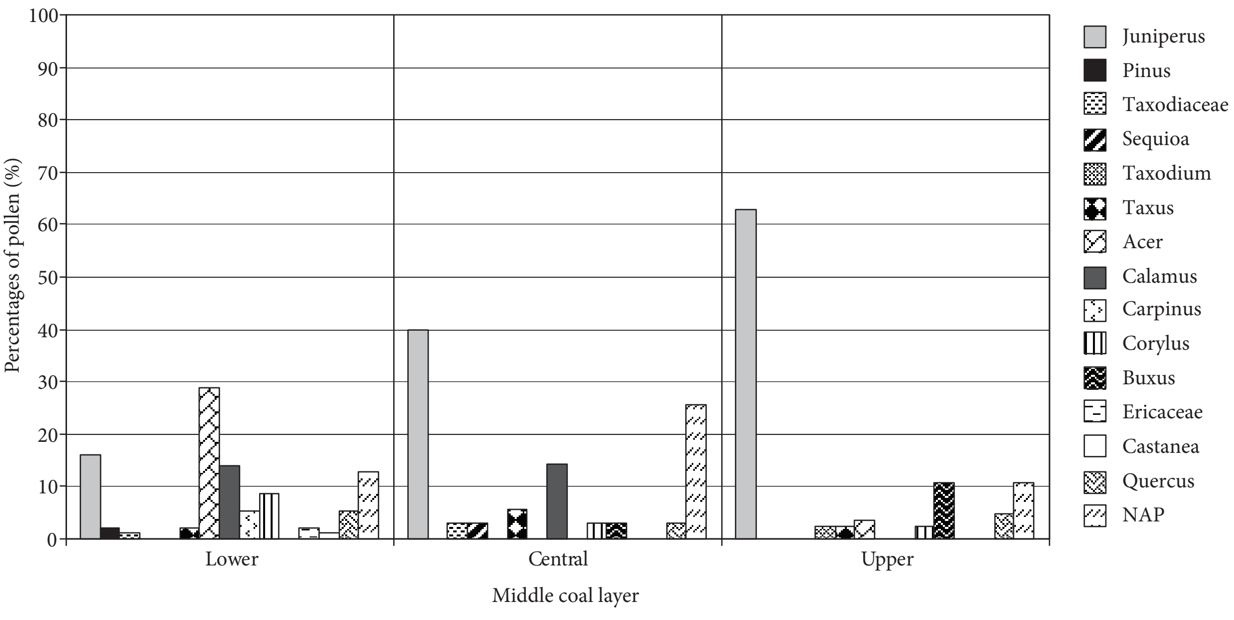

Figure 3. The percentage of the identified pollen in 3 levels (lower, central, and upper) of the middle coal layer. No pollen was found in lower and upper coal layers

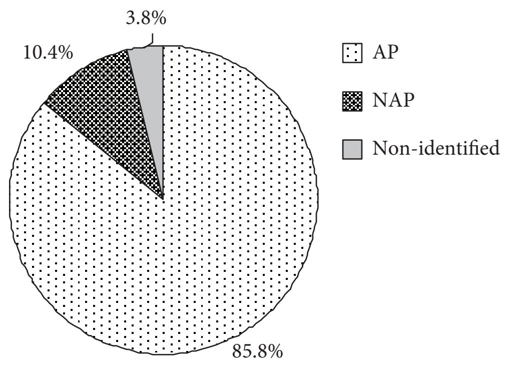

Figure 4. Percentage of arboreal (AP), non-arboreal (NAP), and non-identified pollen

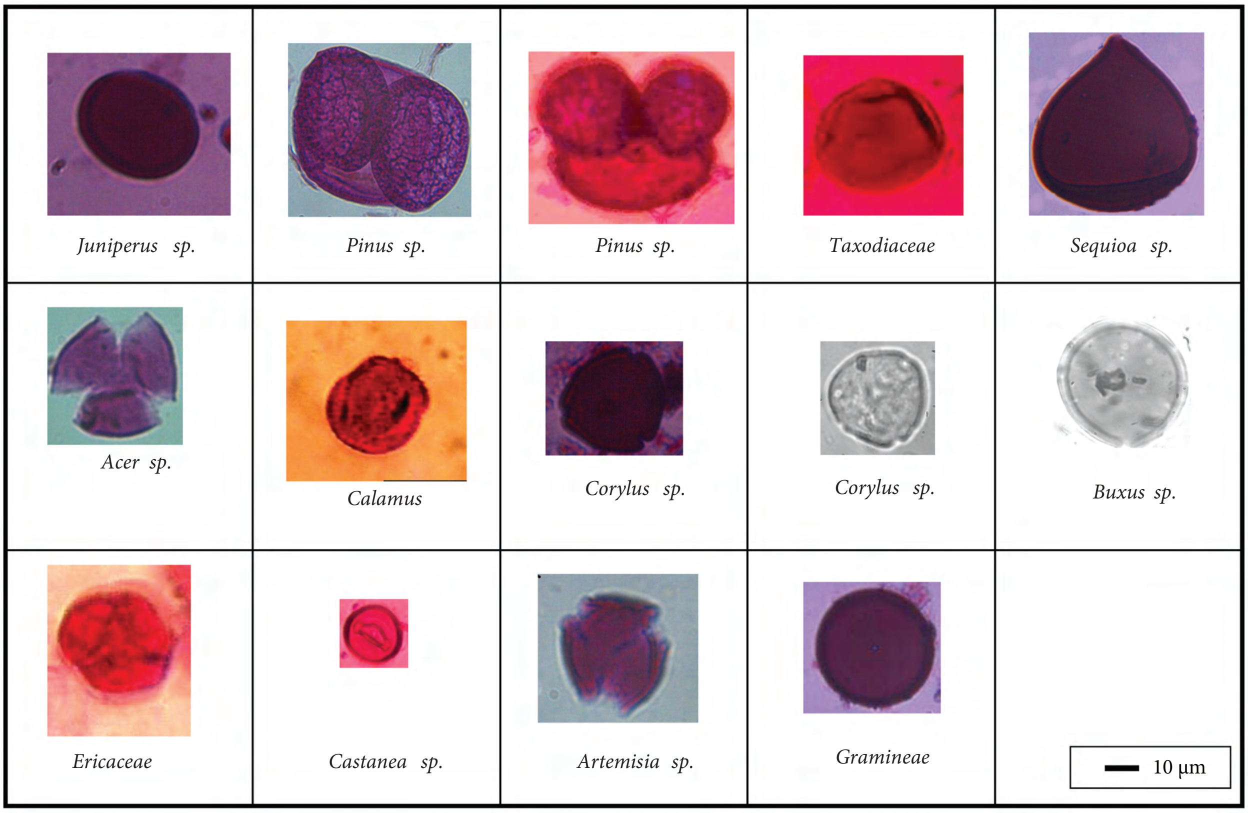

Figure 5. Microphotographs of the pollen

In this study, some *gymnospermae* (juniper, pine, redwood, swamp cypress, and yew tree) and *angiospermae* taxa (oak, chestnut, hornbeam, maple, hazelnut, and heath), some are present and some are extinct, were detected in the pollen analysis. The results show that the trees of many genera detected are represented by some species in the present forest mixture. Today, *Pinus nigra* (Black pine) has a relict stand from Tertiary, and is considered as "Ecotype" in that region (Kayacık et al. 1981). It is not possible to conclude that pine pollen detected in the late Oligocene belong to *Pinus nigra*, which grows today in the area. However, we can say that the genus *Pinus* was represented both in the late Oligocene and at present here. On the other hand, some taxa from *Taxodiaceae* family, such as *Sequoia* and *Taxodium,* are completely extinct.

Also, in paleopalynology, oaks are rarely identified beyond the generic level, and an absolute discrimination between evergreen and deciduous oak pollen is thus impossible and would require additional evidence in the form of macrofossils (Liu et al. 2007). In this study, oak was also identified at the generic level.

One of the most important results is the high amount of *Juniperus* pollen found in the upper part of the middle coal layer. Today, this genus in the region is represented with 2 species, *Juniperus excelsa* Bieb. and *Juniperus oxycedrus* L. and has several stands in the dryer parts of the region. When an increase was observed in the ratio of the juniper pollen toward to the upper part of the middle coal layer (see Table 1), a clear decrease was observed in the ratios of maple, hornbeam, and hazelnut. This case may indicate a climatic change from humid conditions to the drier in any time of late Oligocene. As well known, short-term climate changes occurred many times in the past.

One of the most significant results is that the *Calamus* pollen was found in the lower and central part of the middle coal layer. *Calamus* pollen grains were mostly found in the Tertiary rocks forming acme zones especially in the Oligocene in Thrace Basin (Ediger et al. 1990).

Şanlı (1982) presented paleopalynological results from late Oligocene and mid-Miocene of the same region. The identified woody plants were *Pinus nigra* Arn., *Pinus pinea* L., *Juniperus* L. sp., *Corylus avellana* L., *Juglans regia* L., *Quercus ilex* L., *Ostrya carpinifolia* Scop., and *Rhododendron* L., which are mostly similar with our findings. Batı (1996) revealed the occurrence of similar trees in the Thrace.

As it was indicated by Frederiksen (1985), the most common spore-pollen taxa in the studied samples and the modern flora by which they are produced are as follows: Pollen: Hypoxylon-type *Pinus*, silvestrus-type *Pinus*, *Cupressaceae*, *Taxodium*, *Sequoia*, *Gramineae*, *Quercus*, *Castanea*, *Alnus*. Among these taxa, the most frequent occurrences of montane types; haploxylon-type *Pinus*, *Podocarpus*, *Ulmus-Zelkova*, *Sequoia* and *Sapotaceae,* which are restricted nowadays to the mountains (upland habitats) as they did before. This indicates that the coal-forming depositional site was surrounded by mountainous background on which these plants grew and their pollen grains were transported to the depositional site by long-distance wind and/or stream transport. On the other hand, relatively higher occurrences of *Alnus* (which is thought to have lived along lakes and rivers), *Taxodiaceae,* and *Cupressaceae*, which are the principal constituents of lowland freshwater swamps, yield a lakeside freshwater swamp assemblage (Frederiksen 1985). Our findings from coalmine are also in support of this explanation.

This study includes the results obtained from the samples taken from an operative mine. Although the results are similar to pollen analyses made in other regions of Thrace (Akyol 1964; Nakoman 1968; Ediger et al. 1990; Akyol and Akgün 1995; Batı 1996), they had been proved to have a local difference. This study constitutes a stage in understanding the Tertiary flora of the region, and new studies will be helpful in demonstrating the Tertiary flora in a more detailed way.

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