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Miocene spores and pollen from Pelitçik Basin, Turkey–environmental and climatic implications

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Abstract

The palynological investigation of the early Middle Miocene fluviolacustrine sedimentary rocks interfingering with volcanics of the Galatean Volcanic Province at Pelitçik Basin (Central Turkey) have yielded palynomorphs belonging to 51 spore and pollen taxa. The pollen record is dominated by *Ulmus,* Pinaceae*, Quercus, Carpinus* and *Carya*, and appears to reflect climatic conditions. Two pollen zones were established based on changing abundances of plant taxa. Zone 1 is characterized by dominance of *Ulmus* and Pinaceae. Zone 2 is differentiated and characterized by a dramatic increase in, and predominance of, *Ulmus, Carya*, deciduous *Quercus, Carpinus, Salix* and Pinaceae. Mixed mesophytic forests were widespread in the basin suggesting warm and temperate climate. The decreasing relative percentage of thermophilous taxa, with *Engelhardia* as the main component, and warm temperate taxa, such as *Carya*, at the upper part of Zone 2 generally indicates a climatic deterioration, probably related to the Middle Miocene cooling. ***To cite this article: N. Yavuz-Işık, C. Demirci, C. R. Palevol 8 (2009).***

Résumé

Spores et pollen du bassin de Pelitçik, Turquie. Implications environnementales et climatiques. Les recherches palynologiques dans les roches sédimentaires fluviolacustres du début du Miocène moyen interimbriquées dans les roches volcaniques de la Province volcanique du Galatée dans le bassin de Pelitçik (Turquie centrale) ont fourni des palynomorphes appartenant à 51 taxa de spores et pollen. L'enregistrement pollinique est à dominance d'*Ulmus,* Pinaceae*, Quercus, Carpinus* et *Carya* et reflète les conditions climatiques. Deux zones polliniques ont été établies sur la base des changements d'abondance des taxa des plantes. La zone 1 est caractériséepar la dominance d'*Ulmus* et de Pinaceae. La zone 2 se différencie par une augmentation dramatique d'une prédominance d'*Ulmus*, de *Carya* de *Quercus* décidu, de *Carpinus* de *Salix* et de Pinaceae. Des forêts mésophytes variées étaient très répandues dans le bassin, suggérant un climat chaud et tempéré. La diminution du pourcentage relatif des taxa thermophiles, avec comme principal constituant *Engelhardia*, et des taxa tempérés chauds, tels que *Carya* à la partie supérieure de la zone 2 indique en général une détérioration climatique, probablement en liaison avec le refroidissement du Miocène moyen. ***Pour citer cet article : N. Yavuz-Işık, C. Demirci, C. R. Palevol 8 (2009).***

Keywords: Palynology; Palaeovegetation; Early Middle Miocene; Pelitçik Basin; Turkey

Mots clés : Palynologie ; Paléovégétation ; Début du Miocène moyen ; Bassin de Pelitçik ; Turquie

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1. Introduction

The Galatean Volcanic Province is a large Neogene volcanic area located in the central northwestern part of Turkey (Fig. 1) which is located within the Pontide tectonic unit of Turkey [19]. Its formation is related to the closure of the northern branch of the Neotethys Ocean with the collision between the African Plate in the south and Eurasian Plate in the north [32,20]. After the Late Eocene final collision between

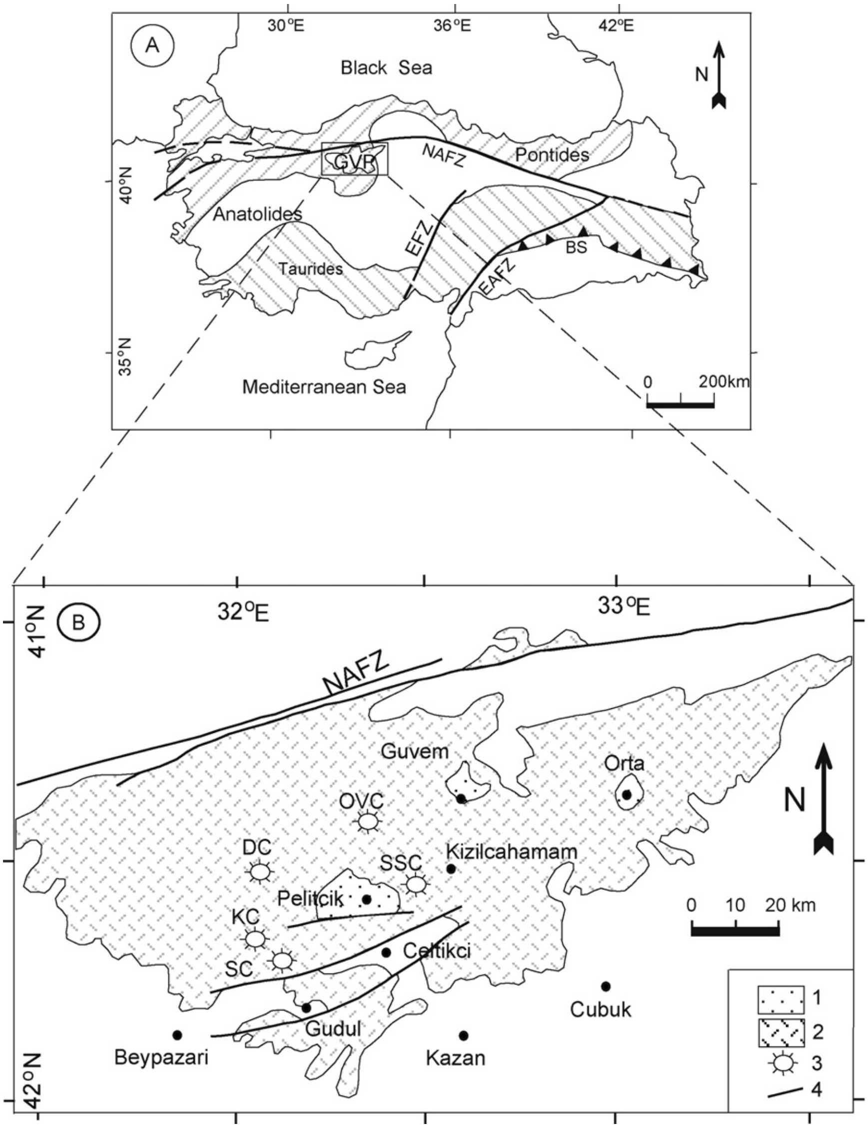

Fig. 1. Location of study area. (A) Geological sketch map of Turkey shows the major geotechnical elements (the Pontides, Anatolides and Taurides) and the major fault zones (NAFZ: North Anatolian Fault Zone, EAFZ: East Anatolian Fault Zone, EFZ: Ecemiş Fault Zone, BS: Bitlis Suture Zone). The hatched area indicates Galatean Volcanic Province (GVP). (B) Geological map of the Galatean Volcanic Province (GVP) [37]. Legend: 1: Neogene continental deposits; 2: volcanics and volcaniclastics of GVP; 3: main eruption centers; 4: faults. Abbreviations: DC: Daskamun complex; OVC: Ovacık complex; SSC: Soğuksu complex; SC: Sorgun complex; KC: Kavaklıdağ complex; NAFZ: North Anatolian Fault Zone.

Fig. 1. Localisation de la zone d'étude. A. Carte géologique schématique de la Turquie montrant les principaux éléments géotechniques (les Pontides, la Anatolides et les Taurides) et les principales zones faillées. (NAFZ : zone faillée Nord-Anatolienne, EAFZ : zone faillée Est-Anatolienne, EFZ : zone faillées d'Ecemiş, BS : zone de suture de Bitlis). La zone hachurée indique la province volcanique de Galatée (GVP). B. Carte géologique de la province volcanique de Galatée 537. Légende : 1 : dépôts continentaux néogènes ; 2 : dépôts volcaniques et volcanoclastiques de GVP ; 3 : principaux centres d'éruption ; 4 : failles. Abréviations : DC : complexe de Daskamun ; OVC : complexe d'Ovacik ; SSC : complexe de Soğuksu ; SC : complexe de Sorgun ; KC : complexe de Kavaklıdağ ; NAFZ : zone faillée Nord-Anatolienne.

the Sakarya Continent (south-facing northern active margin of the northern Neotethys) to the north and Menderes-Tauride to Kırşehir Blocks to the south, the intracontinental convergence of them lasted throughout the Oligocene–Miocene and Early Pliocene time interval [21]. This convergence led to the emergence of a broad lowland area (molassic trough) in the nature of intermountain basin where a fluviolacustrine depositional setting was established, and a thick sedimentary sequence, up to 6 km containing calc-alkali and alkali volcanic intercalations [22], coal seams and bentonitic horizons in places, was deposited. The continued intracontinental convergence dissected this broad molasssic trough into several, small-scale depositional settings bounded by thrust fault contact at their one or both margins [21]. The Pelitçik Basin, which is bounded by Bayındır fault at south, is one of such depositional settings with a thick continental sedimentary sequence interfingering with volcanic rocks [37].

The northern margin of the Galatean Volcanic Province is bordered by the North Anatolian fault and the southern margin is bounded by a thick lacustrine sequence which occurs as a continuous belt from west to east through Beypazarı, Güdül, Kazan and Çubuk (Fig. 1) [37]. This sequence is studied by several authors owing to its economic coal and trona deposits [13,15,29,38,39,41,42]. Coal layers of Çeltikçi [1,13] and Beypazarı–Çayırhan [39,41] areas were studied palynologically and Middle Miocene age was assigned to these deposits.

Apart from the above-mentioned sedimentary belt, there are isolated small sedimentary basins located within the GVP like Pelitçik, Güvem and Orta basins. Only a few palynological studies are carried out in these isolated basins [12,13]. The present study aims to investigate palynologically the sedimentary rocks of the Pelitçik basin. The pollen grains in this study are not used for biostratigraphic datation but for paleoecological information.

2. The Pelitçik basin

The Galatean Volcanic Province comprises nine volcanic complexes intimately associated with the development of a series of sedimentary basins, among which the Pelitçik basin is the biggest [37]. Although the volcanic rocks of Pelitçik basin have been the subject of many studies [13,18,22,35,36,40], the fluviolacustrine sedimentary sequence of the basin interfingering with the volcanics is generally overlooked.

The Pelitçik basin has an ellipsoidal shape, with a long axis of 25 km and a short axis of 11 to 12 km. It is surrounded by five volcanic complexes: the Ovacık complex in the north, Soğuksu complex in the east, Sorgun complex in the south, Kavaklıdağ complex in the southwest and Daskamun complex in the northwest (Fig. 1). On the basis of field studies and aerial photographic analysis, Toprak et al. [37] indicated that the Pelitçik basin was formed immediately after the generation of the volcanic complexes and, the basin-fill deposits conformably overlie the Daskamun and Ovacık complexes which constitute the base of Pelitçik basin on the northwest and on the north respectively.

The stratigraphy of the Pelitçik basin is composed of two units as indicated by Süzen and Türkmenoğlu [33]. These units are as follows.

2.1. *Galatean volcanics*

The Galatean volcanics comprises Early Miocene (18 to 20 Ma) intermediate-acid lava flows and associated pyroclastics and Late Miocene (9 to 11 Ma) alkali basaltic lava flows. The Early Miocene volcanics mainly consist of trachyandesites and dacites with minor rhyolite and alkali basalts [40]. The Galatean volcanics are overlain unconformably by fluviolacustrine facies of the Pazar formation.

2.2. *Pazar formation*

The fluviolacustrine sequence of Pazar formation shows lateral and vertical lithological variations. The lowest part of the sequence consists of conglomerates, lahar and tuff layers, which are exposed only in the northern part of the basin with a thickness exceeding 300 m. Upwards, the sequence passes into an alternation of sandstone, siltstone, claystone, marl and limestone with thin coal intercalations. Its thickness is estimated to be more than about 600 m. [37]. The top of the sequence consists of lacustrine marly limestones which are exposed in the southern part of the basin. These limestones represent the deepest part of the lacustrine sequence. The Pazar formation is represented by a southward-dipping sequence in the Pelitçik basin. On the basis of the dolomite stoichiometry and mineral paragenesis, Süzen and Türkmenoğlu [33] claimed that the depositional conditions of the Pelitçik basin suggest a shallow, quite lacustrine environment with fresh to slightly saline and alkaline water chemistry.

2.3. *Age*

Two distinct eruptive cycles of volcanic activity are observed within the Galatean Volcanic Province.

Radiometric age determinations indicate an age of 18 to 20 Ma for the older cycle while the younger cycle is represented by alkali basalts of 9 to 11 Ma [18,40]. Since the study of Toprak et al. [37] showed that the Pelitçik basin was formed immediately after the generation of Daskamun and Ovacık volcanic complexes and basin-fill deposits conformably overlie these complexes, the age of initial deposition within the Pelitçik basin can be correlated with the age of Daskamun (18 Ma) [40] and Ovacık complexes (20 Ma) [37]. Furthermore, the fluviolacustrine basin-fill deposits interfingering with volcanics are capped by the Late Miocene (9 to 11 Ma) alkali basalt flows [40]. Accordingly, the age of fluviolacustrine basin-fill deposits is Early to Middle Miocene.

3. Materials and methods

The palynologically examined samples of this study come mainly from green claystone horizons, representing lacustrine deposits of Pazar formation in the central part of the Pelitçik basin. The stratigraphic positions of the studied samples are shown in Fig. 2. The measured section, along which samples are collected, starts with conglomerate and sandstone alternation with volcaniclastic pebbles. It continues upwards with the following lithologies:

- green-yellowish claystone and massive, beige colored limestone alternation;
- a thick siltstone followed by a thick claystone layer;
- beige colored limestone which is very cherty at lower parts;
- yellow-green claystone alternating with sandstones, conglomerates and a thin tuff layer. The total thickness of the measured section is about 200 m.

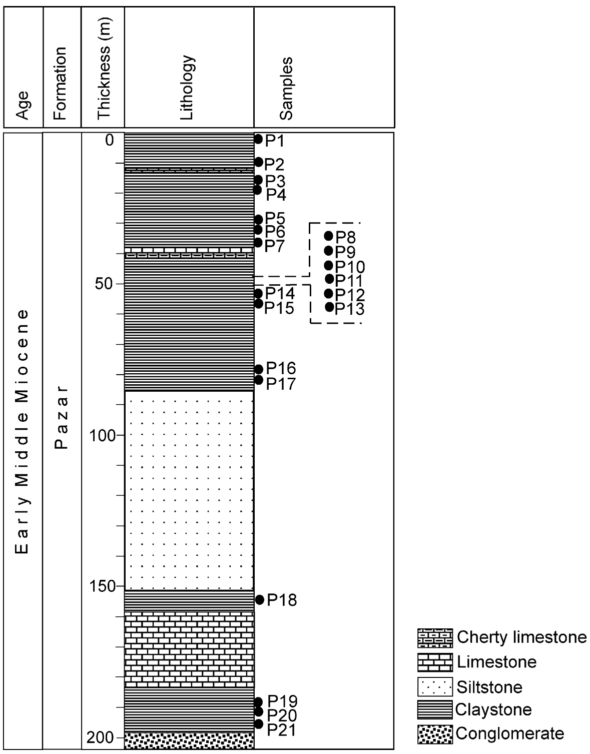

Fig. 2. Studied section of the Pelitçik basin and stratigraphic position of the samples collected.

Fig. 2. Coupe étudiée dans le bassin de Pelitçik et position stratigraphique des échantillons.

Approximately 25 g of material was processed for palynological analysis. This involved treatment using cold HCl (33%) and HF (70%) to remove carbonates and silicates, and separation of the organic residue by means of $ZnCl_2$ (density 2.1–2.2 g/cm^3). The residue was sieved at 10 μm using a nylon mesh, mixed with glycerin and mounted on microscope slides. Slides were counted using a Leica DM4000B transmitted light microscope at × 400 and × 1000 (oil immersion) magnifications.

To determine relative numerical abundance of pollen and spores, palynomorphs have been counted with a minimum of 200 counts per sample. The palynomorphs were identified and counted on one or more slides for every sample. Of the 21 samples, 18 samples contain sufficient palynomorphs for reliable counting. No palynomorphs were recovered from three samples (P19, 20, P21) in lower part of the section.

4. Palynology

Fifty-one pollen and spore taxa were identified from the studied samples (Fig. 3). The Pelitçik palynoflora is dominantly composed of angiosperm pollen, lesser amounts of conifer pollen and spores. The angiosperms show the highest diversity with a total of 38 fossil taxa. Polypodiaceae is the only spore producing plant represented in the pollen spectra. The relative abundances of individual fossil taxa are shown in Fig. 3.

In general the palynoflora is composed of a mix of taxa, whose nearest living relatives have temperate distributions. Two palynostratigraphic zones are recognized in the Pelitçik palynoflora, based on variations in the abundance of the dominant pollen taxa (Fig. 3).

Zone 1 (samples P16-P18). This biozone is mostly sterile and information is based on three, stratigraphically, widely spaced samples. Relatively high percentages of *Ulmus* and undifferentiated Pinaceae characterize this biozone. These elements

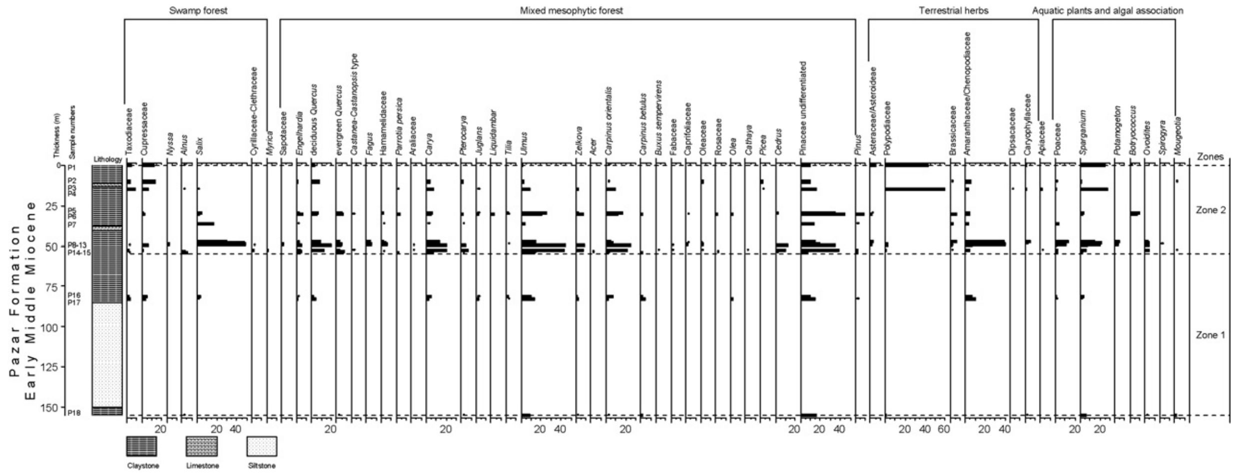

Fig. 3. Relative abundance diagram of pollen and spores recorded in the section studied.
Fig. 3. Diagramme de relative abondance des spores et pollen récoltés dans la coupe étudiée.

are accompanied by Amaranthaceae/Chenopodiaceae (0–10%), *Carpinus* (1–8%), *Sparganium* (1–6%), *Carya* (0–5%), Cupressaceae (0–5%), *Zelkova* (1–3%), *Salix* (0–3%) and minor percentages (~1%) of Taxodiaceae, *Engelhardia, Quercus, Pterocarya, Juglans, Tilia, Alnus*, Poaceae, *Olea* and Caryophyllaceae.

Zone 2 (samples P1-P15). This biozone is separated from Zone 1 by a dramatic increase in percentages of *Quercus* deciduous type, *Carya, Ulmus, Carpinus orientalis, Salix*, undifferentiated Pinaceae and Amaranthaceae/Chenopodiaceae. *Ulmus* (38 to 3%), undifferentiated Pinaceae (40 to 10%), *Carpinus orientalis* (32 to 1%), *Salix* (50 to 0%), *Carya* (23 to 0%) and *Quercus* deciduous type (20 to 5%) dominate this biozone with decreasing upward trends. Zone 2 is furthermore characterized by the onset of Cyrillaceae-Clethraceae, Castanea-Castanopsis, Hamamelidaceae, Araliaceae, *Acer*, Fabaceae, Oleaceae, *Cedrus* and Brassicaceae, slightly above the zone boundary. *Salix* (50%) and Amaranthaceae/Chenopodiaceae (40%) have their maximum frequencies close to the base of this biozone. Cupressaceae and Taxodiaceae show an increasing trend. The aquatic taxa *Sparganium* fluctuates (3–30%) and *Potamogeton* appears for the first time in this biozone.

Although vegetation types certainly interact with each other, four distinct plant associations are recognized here based on their growth habits and ecology (Fig. 4). Plants have been grouped into the following associations:

- Swamp forest association;
- Mixed mesophytic forest association;
- Terrestrial herbs;
- Aquatic plant and algal association (modified from Kohlman-Adamska [23], Kolcon and Sachsenhofer [24]).

4.1. Swamp forest association

Seven pollen taxa are assigned to this association, which mainly includes pollen derived from *Salix*, Cupressaceae and Taxodiaceae (Figs. 3 and 4). Cupressaceae and Taxodiacea pollen cannot be identified into genus level, which may represent different environments. Since the relative abundance trend of Cupressaceae resembles those of the Taxodiaceae, it is assumed that Cupressaceae were represented by taxa requiring warm and humid conditions, such as those (e.g., *Chamaecyparis*) living today in wetlands along the Gulf Coast of the United States [27]. *Salix* is the most abundant taxa in swamp forest association and the highest relative abundance of this typical swamp genus is revealed around 48 m level (Fig. 3). Also included in this association are some trees and shrubs, such as *Nyssa, Alnus*, Cyrillaceae-Clethraceae and *Myrica*, which grow in periodically flooded riparian environments. These palynomorphs are present in low quantities and show no significant variation in abundance throughout the studied section (Fig. 3).

4.2. Mixed mesophytic forest association

This association comprises 30 identified taxa and constitutes between 24 and 89% of the total pollen assemblage (Figs. 3 and 4). Pollen in this association is derived from conifers and other evergreen plants but also

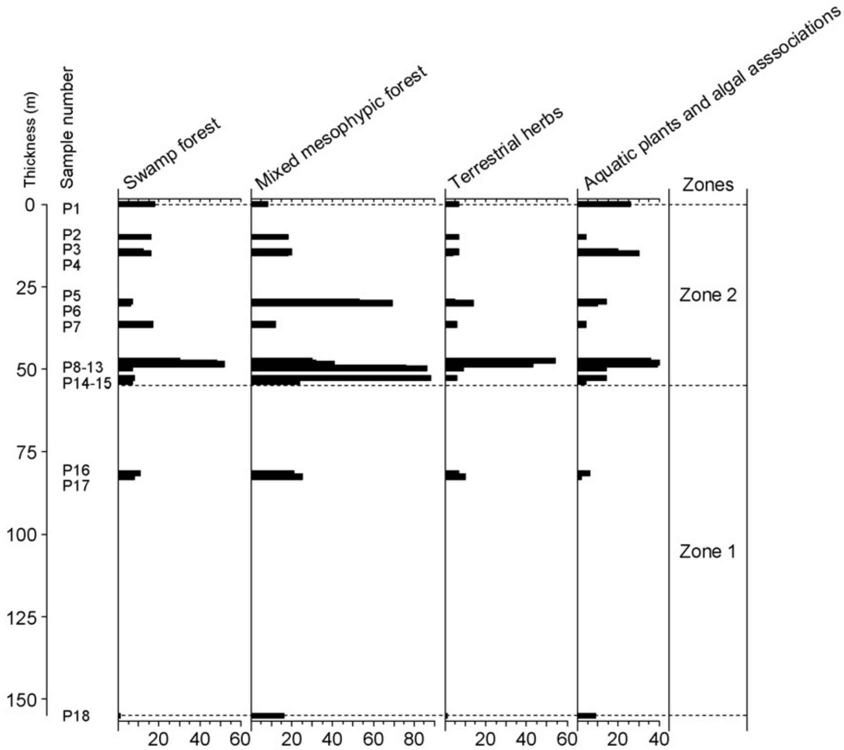

Fig. 4. Percentages of palynomorphs representing different plant assemblages.
Fig. 4. Pourcentages des palynomorphes représentant différents assemblages de plantes.

deciduous angiosperm trees and shrubs. The association is dominated by conifer pollen, which are undifferentiated due to poor preservation. Pollen from deciduous trees such as *Ulmus, Carpinus orientalis, Carya* and *Quercus* are also frequent. Minor constituents include, among others, *Pterocarya, Juglans, Zelkova*, Hamamelidaceae and Oleaceae. Other significant taxa include *Engelhardia* and Araliaceae. The warm temperate taxa included in this group grew in different habitats. Thus, the quantitative variations mainly serve to interpret the paleoclimate.

4.3. Terrestrial herbs

This association consists of seven taxa mainly constituted of ground-cover vegetation in the mesophytic forest (Figs. 3 and 4). Polypodiaceae and Amaranthaceae/Chenopodiaceae are the dominant groups in this association. The highest relative abundance of Polypodiaceae was found at levels 0 to 15 m and that of Amaranthaceae/Chenopodiaceae was at 50 and 55 m (Fig. 3). Other taxa contributing to this association are Asteraceae/Asteroideae, Brassicaceae, Dipsacaceae, Caryophyllaceae and Apiaceae. These palynomorphs are present in low quantities.

4.4. Aquatic plants and algal association

This association includes palynomorphs from plants that prefer mainly moist environments (Figs. 3 and 4). In the studied section this association varies between 3 and 39% (Fig. 4). Taxa included are Poaceae, *Sparganium* and *Potamogeton*. *Sparganium* occurs in almost every sample, comprising up to 40% of this association. The aquatic taxon *Potamogeton* is present only at the 53 m level. The individual elements of the family Poaceae are difficult to identify as the pollen grains of different genera do not show significant morphological differences. As regard to palynological assemblage identified from Pelitçik section, it is most likely that the Poaceae would have been represented mostly by reeds and other hydrophilic graminoids rather than xeric grasses, like in the sedge swamp of Middle-Polish Beds [23].

The freshwater algae *Botryococcus, Ovoidites, Spirogyra* and *Mougeotia* are included in this association. They are present in almost every sample.

5. Discussion

5.1. Comparison with coeval palynofloras

If a pollen-bearing locality is not found with intercalated marine sediments, in association with mammalian faunas or in sections with radiometric or magnetostratigraphic measurements, the age control is often poor and this makes temporal comparisons complicated. Therefore, well-dated palynofloras from Turkey and Europa are selected to compare with Pelitçik palynoflora.

Benda et al. [2,3,5–7] carried out extensive palynological investigations in the Cenozoic of Turkey and established biostratigraphic classification of the Late Oligocene-Pliocene fluviolacustrine deposits in western Turkey. Their sporomorph associations and sporomorph biostratigraphy result from the quantitative study of numerous samples from all over Turkey. Five sporomorph associations (biozones) are distinguished in the Neogene namely, from older to younger, Kale, Eskihisar, Yeni Eskihisar, Kızılhisar and Akça Associations [2,3]. These sporomorph associations are later correlated with the marine fossils and radiometric dates to establish a Neogene palynostratigraphic biozonation [4]. Benda et al. showed that their palynostratigraphic biozonation can be used for the entire eastern Mediterranean region [4–6].

The Eskihisar Association covers a time interval from about 19–20 Ma to 14–15 Ma and Yeni Eskihisar Association from about 14.8 to 11.1 Ma [4,30,31]. The (radiometrically constrained) age range of palynomorph assemblage identified in this study corresponds to the Eskihisar and Yeni Eskihisar Associations. The Eskihisar Association is mostly characterized by high percentages of *Pityosporites* (*Pinus* indet., *Pinus haploxylon*-group, *Picea*), inaperturate forms (Taxodiaceae/Cupressaceae) and by low percentages of *Ulmipollenites undulosus* (*Ulmus*), Polypodiaceae, *Polyvestibulopollenites verus* (*Alnus*), triatrioporate pollen types (*coryphaeus*: *Engelhardia* or *myricoides-bituitus* group: Myricaceae). The Yeni Eskihisar Association is characterized by dominance of '*asper*-types' within the quercoid pollen forms and an increase of the *stigmosus*-group (*Liquidambar*) and *areolatus*-group (cf. *Palmae*) [2]. The transition from Eskihisar to Yeni Eskihisar associations is represented by an increase in *Quercus, Ulmus* and Graminae pollen [3]. In the Pelitçik samples, *Pinus* and *Ulmus* dominates with lesser amounts of *Quercus* and *Carya* and, the mean percentages of Poaceae and Chenopodiaceae-Amaranthaceae pollen are 2.5 and 6.8% respectively. This composition suggests that Zone 2 of Pelitçik Basin may belong to Yeni Eskihisar biozone.

Yavuz-Işık [44] investigated a late Early-Middle Miocene coal-bearing sedimentary sequence from the Seyitömer Basin (western Anatolia), which is dated by mammal fossils, and recognized two pollen zones. Zone 1 is characterized by predominance of *Pinus* and *Cedrus* while Zone 2 is characterized by predominance of deciduous *Quercus* and evergreen *Quercus* and a marked reduction in representation of Taxodiaceae. Zone 2 of Seyitömer palynomorph association is similar to Zone 2 of Pelitçik, except the dominance of Taxodiaceae and *Cedrus.* The diversity of the other taxa between two associations does not differ much, but the abundance of taxa varies. A *Taxodium* swamp was well developed in Seyitömer as represented by rich Taxodiaceae and Cupressaceae pollen whereas a mixed mesophytic forest was well developed in Pelitçik as represented by high frequencies of *Carpinus, Ulmus, Carya, Quercus* and Pinaceae pollen. The presence of megathermic elements such as Euphorbiaceae, *Reevesia* and *Ginkgo* indicates that the temperature was relatively higher in the time of formation of Seyitömer samples. The presence of *Cedrus* in large amounts in Seyitömer and lesser amounts in Pelitçik samples may result from latitudinal difference within Anatolia.

Ivanov et al.'s [14] study showed that vegetation of the Middle and Upper Badenian (15–13 Ma) of Forecarpathian basin (central Paratethys, NW Bulgaria) was characterized by regular occurrence and abundance of thermophilous species whereas during Sarmatian, subtropical elements like *Engelhardia, Reevesia, Itea, Castanopsis*, Symplocaceae, Arecaceae tend to decrease and temperate elements such as *Alnus, Carpinus, Betula, Corylus, Fagus* have an increasing trend. A similar vegetation change is observed in the Sarmatian of other areas of the eastern and central Paratehys ([14] and references therein). The vegetation of Pelitçik Basin, with almost no thermophilous species, can be correlated with Sarmatian vegetation of Forecarpathian Basin. During Sarmatian favourable conditions existed in the Forecarpathian Basin for the development of mixed mesophytic forests characterized by predominance of warm-temperate and subtropical elements together with many paleotropical elements. However, the temperature was not high enough in the Pelitçik Basin for the presence of numerous tropical and subtropical species within mixed mesophytic forests.

5.2. Depositional environment, vegetation and climatic conditions

The consistent occurrence of terrestrial palynomorphs and freshwater algae in all of the studied samples may indicate a lacustrine environment. This interpretation agrees with mineralogical data from the studied area [33]. The presence of freshwater algae such as *Ovoidites* and *Spirogyra,* at the base of Zone 2, together with pollen derived from aquatic plants such as *Sparganium* and *Potamogeton* indicates the occurrence of freshwater ponds [28]. Ferns (Polypodiaceae) grew on the moist soil enclosing the sites of open water and also as understory of mixed mesophytic forests.

The highest relative abundance of Chenopodiaceae (40%) was found close to base of Zone 2 accompanied by peaks of Sparganium and Poaceae (Fig. 3). Chenopodiaceae grew on sandbanks and sandy soils located between lakeshore vegetation and swamp forest [9]. Although today Chenopodiaceae are common in dry and saline habitats [17], high amounts of Chenopodiaceae in Pelitçik samples do not indicate dry conditions. The high amount of Chenopodiaceae in the pollen record can possibly be related to edaphic conditions.

Mixed mesophytic forests dominated the vegetation in moderately wet areas further inland. The most abundant taxa in the mesophytic assemblage, besides Pinaceae, are *Ulmus, Carpinus orientalis, Carya* and deciduous *Quercus*. A high frequency of Pinaceae indicates close proximity of highlands to the depositional area since conifers usually prefer to live on highlands. Today, Pelitçik Basin represents a topographically low area bounded by high volcanic terrain.

Although the relative abundance of taxa varies, in general, all four palynological associations namely swamp forest, mixed mesophytic forest, terrestrial herbs and aquatic plants show a decreasing upward trend in Zone 2 (Fig. 3). This trend is coincident with the vegetational signal of climatic deterioration. Nagy [28] established paleoclimatic zones of the Hungarian Neogene and reported a Middle Sarmatian (12.85–12.4 My) cooling phase (Zone VI) with a considerable decrease in number of tropical species and appearance of new subtropical and temperate species. Jimenez-Moreno [16] observed the vegetation changes from the late Early Miocene (Late Burdigalian-Langhian) to the late Middle Miocene (Serravalian) in central Europe (Pannonian Basin, Hungary) and stated that, thermophilous elements dominated vegetation was progressively substituted by deciduous and mesothermic plants. The author related this vegetation change to climatic cooling. Chamley et al. [8] point to a worldwide Middle Miocene cooling reflected by changes in planktonic foraminiferal associations, clay minerals and stable isotopes of Sicily, between 15–13 Ma. This Middle Miocene cooling may probably account for decreasing upward trend of palynomorphs in the Zone 2 of Pelitçik basin. The presence of Sapotaceae, *Engelhardia* and Cyrillaceae at lower parts and Picea at upper parts of Zone 2 supports this interpretation.

During the early Middle Miocene, climatic conditions favoured the accumulation of terrestrial organic materials into lacustrine and swamp environments in central Europe and Turkey [10,11,23,25,26,30,34,43]. In these areas, *Taxodium* swamp forests produced thick coal layers, whereas in the Pelitçik sequence coal is not present, and swamp forest association is mainly represented by riparian plants. This implies that conditions were not favourable to swamp forests. The Pelitçik palynomorph assemblage reflects slightly cooler climatic conditions compared with other early Middle Miocene floras. This is possibly related to intense volcanic activity in the area.

6. Conclusions

The palynological assemblage from the studied section of Pelitçik basin incorporate 51 taxa. Palynological analysis of the samples revealed the existence of two pollen zones. Zone 1 is defined by relatively high percentages of *Ulmus* and undifferentiated Pinaceae. Zone 2 is differentiated from Zone 1 by a pronounced increase in percentages of deciduous *Quercus, Carya, Ulmus, Carpinus orientalis, Salix*, undifferentiated Pinaceae, Amaranthaceae/Chenopodiaceae and characterized by upward decreasing trend of these taxa.

Four distinct terrestrial plant associations can be recognized in the studied section as follows:

- Swamp forest association;
- Mixed mesophytic forest association;
- Terrestrial herbs;
- Aquatic plants and algal association.

Aquatic plants like *Sparganium* and algae such as *Botryococcus* and *Ovoidites* indicate the presence of freshwater in the depositional environment. Swamp forest defines the lakeshore vegetation with moderate amounts of Cupressaceae and Taxodiaceae, and a high amount of riparian genus *Salix*. Better-drained areas further inland hosted mixed mesophytic forest with a predominance of temperate taxa such as *Ulmus* and *Carya*. Pinaceae is also abundant in the mesophytic forest. The ground cover vegetation of mixed forest is made up of herbaceous plants and the presence of ferns indicate humidity.

The vegetation of Pelitçik basin suggests that a temperate climate prevailed with slight climatic deterioration reflected in the upper part of the Zone 2 possibly corresponding to the Middle Miocene climatic cooling.

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