Palynostratigraphic, Palaeovegetational and Palaeoclimatic Investigations on the Miocene Deposits in Central Anatolia (Çorum Region and Sivas Basin)

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Abstract: Palynostratigraphy of the Neogene coal-bearing sediments in the Çorum region and Sivas Basin has been determined, and three sporomorph associations have been defined. Sporomorph association A is described from the Samsun-Havza region and is of latest Burdigalian age. Sporomorph association B is described from the Çorum region and Sivas Basin and is of early–middle Serravalian age. Sporomorph association C is described from the Sivas-Vasıltepe region and is of earliest Tortonian age. Sporomorph association A indicates warm subtropical climatic conditions and the Coexistence Approach (CA) results are: mean annual temperature (MAT) 19 °C, mean annual coldest month (CMT) 9.75 °C, mean annual warmest month (WMT) 27.2 °C, mean annual precipitation (MAP) 1217–1322 mm, and a mean annual temperature range of (MART) 17.45 °C. Sporomorph association B characterizes a subtropical climatic condition, and the CA results indicate similar temperatures to those of the latest Burdigalian period. For the early–middle Serravalian age, the MAT values range between 18 and 19.15 °C, the CMT values are between (-0.8)–10.6 °C, and the WMT between 24.7–27.7 °C, respectively. Generally the MAPs of the latest Burdigalian and early–middle Serravalian times are high. The range of the MART values relate to the palaeovegetation and palaeotopography during early–middle Serravalian time, during which increases of the MART values from the Çorum region indicate high palaeotopographic conditions. Sporomorph association C indicates a warm-temperate climate and the CA results are: MAT 19 °C, CMT 9.4 °C, WMT 27.7 °C, MAP 1187–1574 mm, and MART 18.3 °C. Palaeovegetation of the Çorum region and Sivas Basin characterizes a lacustrine environment surrounded by mountains from the latest Early to Middle Miocene. Open vegetation areas were widespread in earliest Tortonian time, and thus different from the palaeovegetation of the latest Early to Middle Miocene period.

Key Words: Miocene, palynology, palaeovegetation, palaeoclimatology, Çorum region, Sivas Basin

Orta Anadolu’nun Miyosen Tortullarında Palinostratigrafik, Palaeovejetasyonal ve Palaeoiklimsel Araştırmalar (Çorum Bölgesi ve Sivas Havzası)


Anahtar Sözcükler: Miyosen, palinostratigrafik, paleoiklim, palaeovejetasyon, Çorum bölgesi, Sivas Havzası
Introduction

The Çankırı Basin, one of the main sedimentary basins in central Anatolia, is composed of mainly ophiolitic rocks of the Neo-Tethyan suture zone (Figure 1). The basin was created by the closure of the Neo-Tethyan Ocean between the Sakarya Continent and Kirşehir Block in Cretaceous to Eocene times (Şengör & Yılmaz 1981; Tüysüz 1993; Erdoğan et al. 1996). The Çankırı Basin, in which thick detrital sedimentary sequences and volcanic rocks of the Eocene age were deposited, developed between the Kirşehir and Sakarya continents. These sediments were unconformably overlain by evaporate-bearing Miocene continental successions (Tüysüz 1993; Erdoğan et al. 1996). The Çorum region is located in the eastern part of the Çankırı Basin.

The Sivas Basin is another important central Anatolian basin, and is located north of the Kirşehir Massif (Figure 1). The sedimentary sequence is relatively simple with a succession of marine and continental formation: deep marine Upper Cretaceous to Eocene clastic rocks (with local volcanic intercalations), and Upper Eocene and Oligocene red continental clastic rocks with evaporites, unconformably overlain by Oligocene and Early Miocene shallow marine limestones and marls. Late Miocene and Pliocene terrestrial facies include continental clastics and lacustrine limestone (Poisson et al. 1996; Özden et al. 1998).

Many geological and palaeontological studies (Birgili et al. 1975; Tekkaya et al. 1975; Ünay & Şen 1976; Özdemir & Pekmezci 1983; Erdoğan et al. 1996; Poisson et al. 1996; Toprak 1996; Özden et al. 1998; Rükkert-Ülkümen 1998; Akgün et al. 2000a, b, 2002; Özdemir 2000; Türkmen & Kerey 2000; Atalay 2001) have been made for different purposes in these study regions. Most studies were in the Neogene sediments of the Çankırı Basin. These studies stated that coal bearing sediments of this basin were Oligo-Miocene deposits, although detailed studies on the age of widespread coal-bearing sediments of the Çorum region have not been done. The overall objectives of the present study are to: (1) define the palynostratigraphy of coal-bearing sediments in the Miocene deposits of the Çorum and Gemerek regions, (2) reconstruct the palaeovegetation in the Early, Middle and earliest Late Miocene surroundings of the Sivas and Çorum regions (central Anatolia) based on high-resolution pollen analysis of the coal samples using botanical taxonomy and quantitative approach to pollen data, (3) infer palaeoclimatic conditions of the study areas and to correlate with the numerical climatic results of these regions, (4) discuss palaeoclimatic effects on palaeovegetation and (5) to compare the palaeoclimatic results with recent climatic properties.

Geological Setting

Palaeontology in the Çankırı-Çandır region was first studied by Tekkaya et al. (1975) and Ünay & Şen (1976) in the region west of our study area. These authors stated that coal-bearing sediments of the Çandır region were of Middle and early Late Miocene age based on the mammalian fossils (Figure 2). Rükkert-Ülkümen (1998) studied the fish beds of Alpagut-Dodurga near Çorum, which have decisive importance for the entire Late Oligocene-Middle Miocene sedimentation in the Çankırı Çorum Basin. Toprak (1996) studied chemical analyses, XRD, SEM, spectral emission fluorescence measurements, palynology, rock and organic petrographical analyses in the Dodurga formation of Evlik, Kargi, İncesu, İkizler, Ayva, Dodurga and Kumbaba coal horizons (Çorum-Osmancık). Palynological data from these coal horizons show that the Dodurga formation sporomorph association is of Middle Miocene age. Kaymakçı et al. (2001) studied the stratigraphy and palaeontology in the Çankırı-Çandır Basin, in which the mammalian data, and coal-bearing sediments indicate an Early–Middle Miocene age. Numerous authors have discussed the stratigraphy and palaeontology of the Sivas Basin (Poisson et al. 1996; Özdemir 2000; Türkmen & Kerey 2000; Sümengen et al. 1990; Burijin & Saraç 1991; Özden et al. 1998; Akgün et al. 2000a; Langereis et al. 1990). Sümengen et al. (1990) studied rodent fauna of the Kayseri-Sivas Basin (Yeniköy; Harnım1, 3; Horlak 1a, b, 2; Gemerek; Kalıköy; Karaözü; Dendil and İğdeli) ranging in age from Middle Oligocene to Early Pliocene, with a gap in the Early Miocene. Langereis et al. (1990) studied the magnetostratigraphy in the Kayseri-Sivas Basin in Anatolia, and found that the magnetostratigraphy of the Gemerek section, plus the age constraint of 14.9±0.7 Ma, yields several possible correlations on the basis of the implied sedimentation rates and the lithology of the section. A correlation yields an age of 16.4 Ma for the Gemerek mammal fauna, which is at present preferred (Figure 2). Our study areas are located in the Çorum region (to the north of the Çankırı Basin) and the Gemerek region in the Sivas Basin (Figure 1).
The Çorum Region

Basement rocks in the Çorum region include Mesozoic limestone, gneiss, micaschist and basal conglomerate. The Eocene sediments unconformably overlie the basement rocks (Seymen 1981; Tüysüz 1993; Erdoğan et al. 1996). The Eocene succession, which is the main part of the basin fill, is unconformably overlain by the Lower–Middle Miocene continental deposits (Şen et al. 1998). The Kızılırmak and Bozkır formations composed of terrestrial conglomerates, laminated shales and evaporate, are distinguished in the Middle Miocene deposits. Both of the formations are laterally and vertically passed (Birgili et al. 1975; Erdoğan et al. 1996; Akgün et al. 2002a). This succession in turn is overlain with angular unconformity by alluvial deposits of Pleistocene age (Figures 3 & 4).

The Gemerek Region

Basement rocks include Palaeozoic peridotite, gneiss, schist, amphibolite, quartzite and marble. The Paleocene–Eocene sediments, comprising limestone, conglomerate and sandstone, overlie the basement unconformably. The Oligocene rocks, consisting of sandstone, claystone and gypsum alternations, unconformably overlie the Paleocene–Eocene succession. The Yeniçubuk formation, which was deposited in the Middle–Late Miocene, unconformably overlies the Oligocene rocks (Özdemir 2000; Türkmen & Kerey 2000), and is composed of terrestrial sandstone, siltstone, marl, limestone and lignite intercalation in its lower part. The upper part of this formation is composed of interbedded limestone, basalt and pyroclastic rocks. The overlying Upper Miocene–Pliocene Eğerci formation consists of marl, siltstone, claystone, sandstone, conglomerate, and is overlain with angular unconformity by alluvial deposits of Pleistocene age (Figures 3 & 4).

Material and Method

Using the following techniques, a total of 61 samples of the Kızılırmak formation (Çorum region) and the Yeniçubuk formation (Sivas-Gemerek region) were prepared for quantitative counting. All the samples were processed following the standard palynological procedures, which include treatments with HCl, HF, and HNO₃.

Defining palynofloras of the Çorum and Gemerek regions were applied using the ‘Coexistence Approach’ (CA) proposed by Mosbrugger & Utescher (1997). Thus, palaeoclimatic reconstructions of all fossil floras are derived from the CA. The CA is based on the assumption that the climatic requirements of Tertiary plant taxa are similar to those of their nearest living relatives (NLRs).
Figure 2. Chart showing the previously suggested sequences of some researchers who have studied in the Çorum region and Sivas Basin and comparison of them with our study.
The climatic ranges in which a maximum number of NLRs of given fossil flora can coexist are called coexistence intervals (Bruch & Gabrielyan 2002). The palynofloras of samples in the Çorum and Sivas-Gemerek have been analysed with respect to five climatic parameters: mean annual temperature (MAT), mean temperature of the coldest month (CMT), mean temperature of the warmest month (WMT), mean annual precipitation (MAP) and mean annual range of temperature (MART). Usually the resolution and the reliability of the resulting coexistence intervals increase with the number of taxa included in the analysis. The resolution of the calculated climatic intervals varies with respect to the parameter examined; it is the highest for temperature related parameters (MAT, CMT and WMT) where it is commonly in the range of 1–2 °C (Mosbrugger & Utescher 1997; Bruch & Gabrielyan 2001; Pross et al. 2001).
Figure 4. Stratigraphically generalized columnar sections (A) for the Çorum region and (B) for the Sivas Basin (modified from Birgili et al. 1979; Özdemir & Pekmezci 1983; Toprak 1990; Özdemir 2000).
As an additional climate proxy, we have defined sporomorph assemblages of the Çorum and Gemerek regions by the relative proportion of palaeotropical (P) and arctotertiary (A) elements. According to classical definitions (e.g., Mai 1991; Planderová 1991; Nagy 1992, 1999), the arctotertiary elements are used for the plants which grew in cold areas during the Palaeogene in a temperate to warm temperate climate and correspondingly occur today in the temperate zone (Ivanov et al. 2002). In contrast, palaeotropic elements are plants, which have their present distribution primarily in the tropics (Ivanov et al. 2002).

The use of multivariate analytical methods in palynological and palaeobotanical studies has become more widespread (Spicer & Hill 1979; Kovach 1988, 1989). The choice of methods depends on the type of data and the specific problems being solved (Kovach 1989). Detrended correspondence analysis has been chosen for this study in order to identify groups of palaeocommunity types and samples that are associations of the variables contained within the data available using the MVSP (version 3.1).

**Palynological Associations**

In this study, sixty-one palynological samples taken from the Kızılırmak formation of the Samsun-Havza, Çorum-Evlik, İkizler, Kumbaba, Dodurga, Ayva, Amasya-Çomu areas (in the Çorum region) and the Yeniçubuk formation of the Sivas-Karagöl and Akalin areas were examined (Figure 4). Only thirty of these samples were counted as the other samples contained too few spore and pollen species for statistical evaluations. Eight spores, 17 gymnosperms, 41 angiosperms, 2 algae, fungal spores and an incertae sedis species were identified in this study (Plates I–VIII). The relative percentages of plant taxa are given in a palynological diagram (Figure 6). The relative abundance of sporomorphs was considered, classifying more than 15% as highly abundant; 5% to 14% as abundant; 1% to 4% as sparse; less than 1% as rare and “*” as very rare or sporadic. The presences of the three sporomorph associations have been recognized on the basis of quantitative and qualitative contents of sporomorphs.

Sporomorph association A of the Kızılırmak formation is recognized in samples from the Samsun-Havza area, which includes abundant and varied sporomorph elements. Samples of the Samsun-Havza lignites contain a distinctly high abundance of *P. microalatus* (*Pinus* (haploxylon-type)), averaging 7% and observed in almost all the samples. In some samples Polypodiaceae, *Quercus* (*henrici*-type) (10%), *Quercus* and *Ulmus* are abundant, (5.5–14%), whereas *Podocarpus*, *Cathaya*, *Taxodiaceae*, *Cupressaceae*, *Sparganiaceae*, *Myricaceae*, *Engelhardtiia*, *Carya*, *Salix*, *Castanea*, *Cycadaceae*, *Nyssa* and *Sapotaceae* are sparse (1%–4%). *Schizaceae*, *Sphagnum*, *Selaginella*, *Osmundaceae*, *Poaceae*, *Lemnaceae*, *Nymphaeaceae*, *Juglandaceae*, *Pterocarya*, *Simarubaceae* and *Cycadaceae* are rare (1–4%). *Schizaceae*, *Sphagnum*, *Selaginella*, *Osmundaceae*, *Poaceae*, *Lemnaceae*, *Nymphaeaceae*, *Juglandaceae*, *Pterocarya*, *Simarubaceae* and *Cycadaceae* are rare and *Pinus* (silvestris-type), *Corylus*, *Tilia*, *Onagraceae*, *Myrtaceae*, *Reevesia*, *Alnus*, *Carpinus*, *Fagaceae* and *Chenopodiaceae* are sporadically represented in these samples. Algal forms of *Pediastrum* sp. and *Botryococcus braunii* are present in samples from the Samsun-Havza lignites (Figure 5, Plate I).

Sporomorph association B was detected in the Kızılırmak formation in the Çorum-Evlik, Ayva, Zambal, İkizler, Kumbaba, Dodurga, İncesu and Alıcık areas and the Yeniçubuk formation in the Sivas-Karagöl and Akalin areas. This sporomorph association includes a high abundance of Polypodiaceae, *Ulmus* and *Pinus* (Haploxylon-type) (15–43%). In some samples, *Castaneae*, *Cyrillaceae*, *Oleaceae*, *Poaceae*, *Carya*, *Engelhardtiia*, *Quercus* and *Cupressaceae* are abundant (5–14%). *Osmondaceae*, *Picea*, *Pinus*, *Podacarpus*, *Simarubaceae*, *Taxodiaceae*, *Nymphaeaceae*, *Cycadaceae*, *Alnus*, *Quercus* (*T. henrici*), *Salix*, *Nyssa*, *Oleaceae*, *Myricaceae*, *Carpinus*, *Pterocarya*, *Poaceae* and *Sparganiaceae* are present sporadically in sporomorph association B (1–4%). *Schizaceae*, *Sphagnum*, *Pinus* (silvestris-type), *Abies*, *Sequoia*, *Arecaceae*, *Corylus*, *Juglandaceae*, *Tilia*, *Reevesia*, *Picea*, *Araliaceae*, *Sapotaceae*, *Chenopodiaceae*, *Lemnaceae*, *Lonicera*, *Ephedraceae*, *Symplocos*, *Onagraceae*, *Umbriliferae* and *Rhus* are rare and sporadically represented, with percentages between 1% and <1%. Algal forms of *Pediastrum* sp. and *Botryococcus braunii* are only present in samples from the Çorum-Evlik, Zambal, İskilip, İncesu and Alıcık lignites (Figure 5). The species *Rhamnaceae pollenites* *triquetrus*, *Lonicerapollis* *galliwitzi*, *Iteapollis* angustiporatus, *Juglanspollenites verus*, *Reevesiapollis triangulus* and *Rhuspollenites ornatus* are recorded in this study but have not been mentioned in the Turkish Miocene previously (Figure 5, Plates II–VII).
Sporomorph association C was recognized in the Yeniçubuk formation (Sivas-Vasıltepe region). This association is characterized by high abundances of Pinus (haploxylon-type) and Poaceae (>15%). In some samples Polypodiaceae, Pinus (silvestris-type), Taxodiaceae, Nymphaeaceae, Myricaceae, Ulmus, Quercus, Cyprinaceae and Chenopodiaceae are abundant (5–14%), whereas Engelhardtia, Juglandaceae, Platycarya, Carya, Salix, Quercus (henrici-type), Fagaceae, Castanea, Oleaceae, Asteraceae (Tubuliflorae-type), Cyadaceae and Umbelliferae are scarce (1–4%). In samples from these lignites, Gleichenia, Sphagnaceae, Podacarpus, Cupressaceae, Sequoia, Ephedraceae, Sparganiaceae, Tilia, Alnus, Reevesia, Nyssa, Cichorieae (Liguliflorae-type), Tricolporopollenites sp. (geranium-type) and Sapotaceae are observed rarely and sporadically (Figure 5, Plate VIII).

Age Interpretation Based On Palynological Data

In western and central Anatolia, there are a lot of early Neogene basins, and most of them have been studied palynologically (Benda 1971a, b; Benda et al. 1974; Akgün 1986, 1993; Akgün & Akyol 1987, 1992, 1999; Gemici et al. 1991; Ediger et al. 1996; Karayiçi et al. 1999; Akgün et al. 2000a, b; Kayseri & Akgün 2002, 2003, 2005; Akgün & Kayseri 2004; Akgün et al. 2004, 2007; Kayseri et al. 2006). The sporomorph assemblages determined in these studies contain quite a large number of well-known and long-ranging sporomorphs. Based on palynological associations in the previous studies, the stratigraphic importance and abundance of sporomorphs throughout the Miocene period can be interpreted as follows:

1. The Early Miocene: Spore species such as Leiotriletes microadriennis, L. maxoides maximus, L. maxoides maxoides, Verrucatosporites scutulum, V. alenius, V. favus were more abundant in the Eocene–Oligocene. These species were observed to be rare in the early Miocene, occurring with Baculatisporites, Cingulatisporites and Stereisporites. Laevigatosporites haardti species is extremely numerous but stratigraphically unimportant. Some angiosperm pollen such as Plicapollis pseudoexelsus, Dicolpopollenites kawelwensis, Compositoipollenites minimus, Subtricopollenites anulatus anulatus, Momipites punctatus and M. quietus are rare in the Early Miocene. Pollen species characteristic of the Oligocene, such as Mediocolpopollenites compactus, Slowakipollis hippophaeoides, Bohlensipollis hohli and A. Cyclops, were not observed in Miocene rocks.

2. The Middle Miocene: Taxodiaceae, Pinus (haploxylon-type), Myricaceae, Carya, Alnus, Ulmus, Fagaceae, Quercus, Castanea, Cyprinaceae and Oleaceae of angiospermae reach their highest relative abundance in the Middle Miocene. These pollen are also observed during the Oligocene and Miocene. Tricolporopollenites henrici was abundant in the Early Miocene, but rare in the Middle Miocene and was accompanied by angiosperm pollen. Poaceae, Asteraceae and Cichorieae of the herbaceous angiosperm pollen accompanied other angiosperm pollen less abundantly.

3. The Late Miocene: Species of herbaceous angiosperm pollen are variously observed. Herbaceous taxa such as Umbelliferae and Chenopodiaceae were abundant and accompanied Poaceae, Asteraceae and Cichorieae, which were present from the Middle Miocene.

These interpretations show that sporomorph association A of the Samsun-Havza area is of latest Burdigalian age, sporomorph association B is indicative of an early-middle Serravalian age in the Çorum-Evlik, Ayva, Zambal, İkizler, Kumbaba, Dodurga, İncesu, Alıcık, Sivas-Karagöl and Akalın areas and sporomorph association C is considered to be of latest Serravalian–earliest Tortonian age in the Sivas-Vasıltepe area.

Correlation of the Sporomorph Associations From Anatolia

Palynological studies on the Turkish Miocene were concentrated in western Anatolia. In this area, palynological data obtained from central Anatolia in this study have been correlated with palynological data from other parts of Anatolia in order to resolve the stratigraphic position of the Miocene basins (Table 1).

The palynological biostratigraphic chart of the Neogene strata in the Aegean region was first established by Benda et al. (1974) and Benda & Muelenkamp (1990). They used spores and pollen assemblage biozones (sporomorph associations) for the biostratigraphic classification of Late Oligocene to Pliocene strata. Benda et al. (1974) recognized five sporomorph associations:
Figure 5. Relative abundances of defined taxa for the samples of central and western Anatolia (Akgün 1986, 1993; Akgün & Akyol 1992, 1999; Akgün et al. 2000a, 2002; Karayiçit et al. 1999).
Table 1. Correlation between our sporomorph associations in this study and Anatolia with other and European sporomorph assemblages.

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<tr>
<th>Previous studies in Turkey</th>
<th>LOCATION</th>
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<td>sporomorph association A</td>
<td>sporomorph association B</td>
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<td>Benda &amp; Mulerenkamp (1990)</td>
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<td>Yeni-Eskihisar sporomorph assemblage</td>
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<td>Büyük Menderes Graben</td>
<td>Kulağıylı and Başçayır sporomorph assemblage</td>
<td>Şahinli, Söke and Hasköy sporomorph assemblage</td>
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<td>Panderová (1991)</td>
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instructus, Corrugatisporites solidus, Divisisporites maximus, Cicatricosisporites dorogensis and Triplanosporites sinuosus. This sporomorph assemblage was suggested as of middle Burdigalian–early Serravalian age by Benda et al. (1974) and Benda & Muelenkamp (1990). The Eskihisar sporomorph association of Benda et al. (1974) has thus been defined for a long time. Abundance of angiosperm pollen in this sporomorph association such as Momipites punctatus and Quercopollenites henrici and rare spore species can be accepted for the Early Miocene part. In the Middle Miocene part, these spore species disappear and the percentage of some angiosperm pollen decreases. Other angiosperm pollen accompany these spore and pollen species. Furthermore, previous studies show that Umbelliferae, Monocolpopollenites areolatus and Inaperturopollenites emmaensis are rarely present in the Eskihisar sporomorph assemblage of Benda et al. (1974). Therefore, observing these spores and pollen together is problematic in interpreting the stratigraphical distributions of these sporomorphs. Climatic changes occurred throughout the Miocene period (Mosbrugger et al. 2005), and are reflected by the sporomorph assemblages. For this reason, if the time interval of Benda et al. (1974)’s Eskihisar sporomorph assemblage is divided into a lower and an upper part, these separations will be enabled to correct age. Stratigraphical importance, presence and abundance of the spores and pollen species in our study show that the Samsun-Havza sporomorph assemblage resembles the Early Miocene part of the Eskihisar sporomorph assemblage. The Kuloğulları- Başçayır sporomorph assemblage (Büyük Menderes Graben), of early Middle Miocene age, is characterized by rare spore diversity. Moreover, some angiosperm species of the Oligocene–Miocene epochs were not observed in the Kuloğulları- Başçayır sporomorph assemblage. Hence the Samsun-Havza sporomorph assemblage must be older than the Kuloğulları- Başçayır sporomorph assemblage (Table 1).

In this study, sporomorph association B of the Çorum region and Karagöl, Akalin areas in the Sivas Basin indicates a Middle Miocene age. This sporomorph assemblage resembles the Soma, Akhisar-Çitak, Büyük Menderes Graben, Ankara, Isparta, Kirşehir, Konya-Ilgın and Yozgat sporomorph assemblages of western and central Anatolia during the Middle Miocene (Akgün 1986; Akgün & Akyol 1987, 1992, 1999; Yaşmurlu et al. 1988; Karayiğit et al. 1999; Akgün et al. 2002) (Table 1).

Sporomorph association C in this study indicates a latest Serravalian and earliest Tortonian age. The few palynological correlation studies of western and central Anatolia (Akgün et al. 1995, 2000a; Ediger et al. 1996) (Table 2) were compared with regard to the relative frequency of herbaceous angiosperm pollen, important for a Late Miocene assemblage (Table 2). Herbaceous pollen percentages of sporomorph association C in our study resemble the lower association of the Kızılhisar sporomorph assemblage of Benda et al. (1974) and Benda et al. (1982). Sporomorph assemblages of the Büyük Menderes Graben, Kirşehir-Tuzköy, of latest Serravalian–earliest Tortonian age resemble sporomorph association C in our study. Ediger et al. (1996) palynologically studied the Alaşehir-Turgutlu region and reported that the Alaşehir-Turgutlu sporomorph assemblage resembled the Yeni-Eskihisar sporomorph assemblage of Benda et al. (1974). The herbaceous pollen species in the Alaşehir-Turgutlu sporomorph assemblage are less abundant than in sporomorph association C

Table 2. Relative percentage correlation of the herbaceous angiosperm pollen.

<table>
<thead>
<tr>
<th></th>
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<td>Kızılhisar lower association</td>
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<td>late Serravalian-early Tortonian</td>
<td>early-late Tortonian</td>
<td>earliest Late Miocene</td>
<td>earliest Tortonian</td>
<td>latest Serravalian-earliest Tortonian</td>
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<td>Western Anatolia</td>
<td>Büyük Menderes Graben</td>
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<td>0.6</td>
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(Table 2), so the latter is younger. Akgün et al. (2000a) studied coal samples of the Sivas-Hafik region. The Hafik sporomorph assemblage is characterized by predominant Asteraceae and Cichorieae while Chenopodiaceae species and Umbelliferae and Poaceae are less abundant in this assemblage. This suggests that the Hafik sporomorph assemblage is younger than the sporomorph association C in our study (Table 2).

**Correlation of the Sporomorph Assemblage From Europe**

Palynological studies of the Neogene coal deposits of Europe have been described in many papers (e.g., Hochuli 1978; Thiele-Pfeiffer 1980; Van de Weerd 1983; Planderová et al. 1992; Nagy 1992; Ashraf & Mosbrugger 1995, 1996). Our sporomorph associations are correlated with the sporomorph associations of previous studies in Europe.

Hochuli (1978) studied fossil pollen and spores of the Central and Western Paratethys in the upper Eocene to Early Miocene. He defined seven palynological zones, namely the Paleogene-Zone 18 (Late Eocene), 19 (Early Oligocene), 20a, 20b (Middle Oligocene) and Neogene-Zones I (Late Oligocene–Early Miocene), II (late Early Miocene=Ottnangian) and the Neogene–Ottnangian zone. Species of Schizaeaceae are always scarce. Angiosperm and gymnosperm pollen is abundant in the Neogene–Ottnangian zone (Hochuli 1978), which is characterized by the pollen species Caryapollenites simplex, Polyporopollenites stellatus, P. undulatus, Momipites punctatus, Slowakipollis sp., and by the scarcity of some spore species such as Leiotriletes maxoides, L. wolfii, Triplanosporites sinosus, T. microsinus, Trilites multivallatus and Verrucatosporites favus. Sporomorph association A in this study includes sporadic Lower Tertiary (Eocene–Oligocene) species. Therefore, sporomorph association A is therefore younger than Thiele-Pfeiffer’s (1980) sporomorph association of Ottnangian age. The other sporomorph assemblage of Thiele-Pfeiffer (1980) is of Badenian age, and characterized by Sparganiaceae, Gramineae, Myricaceae, Pterocarya, Cary, Castaneae and Quercus. Sporomorph association B in our study resembles Thiele-Pfeiffer (1980) Badenian sporomorph assemblage, but lacks Leiotriletes wolfii, Cicatricosisporites chattensis and Trilites multivallatus.

Van de Weerd (1983) made a palynological study of Late Miocene–Pliocene formations in Kastellious Hill (Greece), assigning this assemblage a Late Miocene to Pliocene age. Sporomorph association C is recognized by sparse Monoporopollenites gramineoides (12%), Graminiidites laevigatus (1.5%), G. subtiliglobosus (1%), G. parvus (1%), Tricolporopollenites sp. (Asteraceae ‘1%’ and Cichorieae ‘0.5%’ types), Umbelliferaepollenites sp. (0.5%), Periporopollenites multiporatus (4.5%) and P. halifani (1%). As these species are more abundant in the Kastellious Hill sporomorph assemblage than in our sporomorph association C, the former sporomorph assemblage is younger.

Planderová et al. (1992) determined eight microfloral zones from the Egerian to the end of the Pliocene (MF1–MF9) in Slovakia. The Carpathian sporomorph assemblage indicates an assemblage zone MF5, which is similar to the sporomorph association A in our study. Planderová’s (1991) Badenian sporomorph association includes Myricaceae, Ulmus, Engelhardtia, Betula, Picea, Abies, Carpinus, Ulmus, Quercus, Alnus and Pinus (MF6), and resembles sporomorph association B in our study. The Sarmatian sporomorph association (MF9) is determined by Pityosporites labdacus, Tusugaepollenites igniculus, Betulaepollenites betuloides, Chenopodipollis multiplex, Artemisia, Poaceae, Asteraceae and Cichorieae, and is correlated with sporomorph association C that includes similar species (except Artemisia).

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<td>Palaeotropic</td>
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<td>Pediola sp.</td>
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</tbody>
</table>
Palaeoclimatology of the Çorum Region and Sivas Basin

Climatic change in Europe during the Miocene is inferred to begin with a warm subtropical climate with many tropical elements in the Early Miocene. Subtropical elements were dominant in the climate, but in the Middle Miocene there was a gradual increase in temperate elements, and the tropical elements disappeared. Temperate elements become dominant in the Late Miocene, when the climate had become warm temperate (Benda et al. 1974; Kovar-Eder 1987; Benda & Muelenkamp 1990; Planderová 1991; Nagy 1992, 1999; Akgün & Akyol 1999). Additionally, the botanical affinities of the defining sporomorph associations in the study are grouped as palaeotropical (P) and arctotertiary (A) elements. Thus, we provide information about changes in the ratio of palaeotropical to arctotertiary elements (P/A-ratio), which presumably reflects climatic and vegetational changes in the Çorum region and Gemerek area in the Sivas Basin. According to the sporomorph associations described in this study, the climate change can be summarized as follows (Table 3).

Sporomorph association A is characterized by abundant subtropical to tropical elements such as Schizaeaceae, Lycopodiaceae, Cycadaceae, Simaroubaceae, Cyrillaceae, Myrtaceae, Reevesia and Podocarpus, and includes fewer abundant warm temperate and temperate and arctotertiary elements such as Pinus (haploxylon-type), Taxodiaceae, Caryya, Juglans, Betulaceae, Alnus, Tilia, Quercus, Platanus/ Salix and Castanea, which accompany the subtropical and tropical elements. Therefore sporomorph association A indicates that the climate was warm-subtropical during the latest Burdigalian in the Samsun area (Table 3, Figure 7).

Sporomorph association B of the Çorum region and Gemerek area is represented by high percentages of subtropical elements such as Cycadaceae, Cyrillaceae, Myrtaceae, Reevesia and Podocarpus, and includes fewer abundant warm temperate and temperate and arctotertiary elements such as Pinus (haploxylon-type), Taxodiaceae, Caryya, Juglans, Betulaceae, Alnus, Tilia, Quercus, Platanus/Salix and Castanea, which accompany the subtropical and tropical elements. Therefore sporomorph association A indicates that the climate was warm-subtropical during the latest Burdigalian in the Çorum region and Gemerek area in the Sivas Basin. According to the sporomorph associations described in this study, the climate change can be summarized as follows (Table 3).

Sporomorph association C is recognized by abundant warm temperate and temperate elements (arctotertiary) such as Pinus, Sequoia, Myrtaceae, Castanea, Betulaceae, Ulmus, Quercus, Platanus/Salix, Ilex, Fagaceae, Liquidambar, Abies, Corylus, Carpinus, Sambucus and Tilia. Subtropical to tropical elements preserved sporadically in sporomorph association C include Cycadaceae, Cyrillaceae, Reevesia and Sapotaceae. Palaeotropical elements of this sporomorph association are scarcer. At the same time herbaceous (Chenopodiaceae, Poaceae, Asteraceae, Cichorieae, Ephedraceae and Umbelliferae) taxa are abundant. For these reasons, sporomorph association C in the Sivas-Vasitlepe region suggests that a warm temperate climate prevailed between the latest Serravalian and earliest Tortonian (Table 3, Figure 7).

Palaeovegetation of the Çorum Region and Sivas Basin

Botanical affinities of defining sporomorphs in the Çorum region and Gemerek area in the Sivas Basin have been defined, and these are grouped into palaeovegetational types. Palaeovegetational differences between western and central Anatolia have also been determined. Defining spores and pollen in our study are grouped under vegetational types such as montane (including mountain forest elements), mixed mesophytic forest (consisting of deciduous and evergreen trees), lowland-riparian, swamp-freshwater and open vegetation (Table 3). Palaeovegetation of the Çorum and Gemerek regions will be reconstructed for the Middle–early Late Miocene periods using these vegetational types.

Information about the composition and characteristic features of the vegetation during the latest Burdigalian is obtained from pollen diagrams of the Samsun-Havza region. Characteristic of the vegetation of that time is the regular occurrence and abundance of thermophilous species like Engelhardtia, Sapotaceae, Reevesia, Schizaceae and Gleicheniaceae. Together with the relatively high P/A–ratio, this suggests a warm subtropical climate during the latest Burdigalian.
Correspondingly, the arctotertiary elements of the mixed mesophytic forest such as Juglandaceae, *Tilia*, *Carya*, *Ulmus* and *Carpinus* are less abundant. The swamp forest was also well developed during the latest Burdigalian. Its components, such as Taxodiaceae, *Nyssa* and *Myricaceae* show comparatively high values in the pollen spectra. Probably the relief and palaeogeographic situation of that time indicated the wide distribution of the swamp forest and of the ecologically related riparian forest with *Platanus/Salix*, *Ulmus*, *Carya* and *Pterocarya* (Table 3, Figure 8).

Sporomorph association B is defined from the Çorum-Evlik, Ayva, Zambal, İkizler, Kumbaba, Dodurga, İncesu and Alicık and Sivas-Karagöl, Akalin in the Çorum and Gemerek areas. During the early–middle Serravalian period in the Çorum and Gemerek regions in the Sivas Basin the swamp, montane and mixed mesophytic forest elements were abundant, indicating a subtropical character. However, the swamp forest element occurs more abundantly in samples from the Kumbaba and İskilip-Çomu regions, regardless of the mountain forest elements, which are less abundantly seen in samples from

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Figure 7. The relative percentage of the palaeotropical and arctotertiary elements derived from the samples of central Anatolia and correlated with previous studies (Nagy 1990; Planderova 1991 and Syabryaj 2002). (A) Long-term trends in benthic oxygen isotope rations (Zachos et al. 2001).
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<th>Shrub Level</th>
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Figure 8. Relative percentage values for the palaeocommunities of Çorum region and Sivas Basin.
these regions. The high percentage of mixed mesophytic forest element is accompanied by swamp and montane forest associations. Each forest element is more abundant in the sporomorph associations from the Evlik, İkizler, Dodurga, Kumbaba, Alıcık, Karagöl and Akalin areas. Results from sporomorph association B suggest that palaeovegetation from the İskilip-Çomu and Kumbaba areas indicates widespread lacustrine environments. Other regions are characterized by lacustrine environments surrounded by mountains (Table 3, Figure 8).

During the earliest Tortonian the vegetation of the Sivas-Vasıltepe region was not different from that in latest Burdigalian and early–middle Serravalian times. Percentages of swamp, riparian and mixed mesophytic forests resemble each other in sporomorph association C in the Sivas-Vasıltepe region. The herb species of open vegetational environments accompany the forest associations. The variable dominance of elements belonging to open vegetation, especially Poaceae, Chenopodiaceae, Umbelliferae, Asteraceae, Cichorieae and Ephedraceae clearly demonstrate that grassland habitats were extensive during the early and middle Tortonian. This indicates that these habitats probably existed side by side in open vegetation. High ground was also covered by Pinus, Picea, Abies, Podocarpus, Corylus, Betulaceae, Carya, Engelhardtia, Juglans, Cupressaceae, Carpinus, Araliaceae, Ulmus/Zelkova, Pterocarya, Quercus, Arecaceae, Castanea, Platycarya, Anacardiaceae/Rhus, Reesesia, Carpinus, Oleaceae, Ilex, Fagaceae, Sambucus and Tilia (Table 3, Figure 8).

Palynological studies so far show that the palaeoenvironment during the Miocene in western Anatolia was characterized by broad, permanent lakes. Palaeovegetation indicating low palaeotopographic condition surrounded these lakes. The defining palaeovegetation of the Çorum and Gemerek regions is different from that of western Anatolia. Early–middle Serravalian vegetation in central Anatolia indicates a lacustrine environment in high topographic conditions, with lakes among the mountains (Figures 8 & 9). Palynological and mammalian data show that these palaeovegetational conditions continued into the early Tortonian (Geraads et al. 2005).

The sporomorph contents of the early–middle Serravalian in the Çorum region, the Sivas Basin and the Yozgat-Yerköy region have been evaluated by detrended correspondence analyses. Thus, reconstruction of the palaeovegetation during the early–middle Serravalian in central Anatolia can be obtained. In the Yozgat-Yerköy region, the Sivas Basin and the Çorum region samples plot on the positive part of Axis 1 and 2. Samples from the Gemerek region in the Sivas Basin and Çorum regions have been gathered from areas with swamp and fresh water palaeocommunities. The Yozgat-Yerköy samples and a few Çorum region samples have been grouped under the field characterized by montane and riparian-lowland palaeocommunities. Most of the Çorum region samples have been assembled in an area of riparian lowland, mixed mesophytic and swamp palaeocommunities. These results show that the Yozgat-Yerköy region had high palaeotopography during the early–middle Serravalian, although the Çorum area had a higher palaeotopography than the Yozgat region, because the samples collected from the Çorum region were close to the mixed mesophytic palaeocommunity. Samples from the Çorum region indicate a lacustrine environment surrounded by the mountains (Figure 10). Samples from the Sivas Basin show that it was characterized by swamp forest at this time.

**Palaeoclimatic Reconstructions with the Coexistence Approach Method (CA)**

The CA is a computer-aided technique for quantitative terrestrial climate reconstructions in the Tertiary using plant fossils. In this study, differences of the MART values relating to the palaeotopography (Sezer 1990) are examined. Palaeotopography reflections on the palaeoclimate are deduced using the MART values in this part.

The sporomorph data from the latest Burdigalian were obtained from the Samsun-Havza region in central Anatolia. The palaeoclimatic parameters are based on the 29 taxa in samples from that region. The resulting calculations are 19 °C for MAT, 9.75 °C for the CMT, 27.7 °C for the WMT, 1217 to 1322 mm for the MAP and 17.45 °C for the MART, respectively (Table 4).

The MAT values for the early–middle Serravalian in the Çorum region and the Sivas Basin generally range between 18–19 °C. However, while the MAT value for the Dodurga region is clearly low (10.05 °C), the MART
values are high (Table 4, Figure 8). Generally, the CMT values for the early–middle Serravalian are variable in CA, based on results from samples in the Çorum and Gemerek regions (10.55–(-0.8) °C). The CMT results show that, if the swamp forest elements have a high percentage in the samples, values of the CMT are increased and the MART values are decreased. This evidently shows that a swamp environment is caused by warm climatic conditions. While the WMT values of samples in the Çorum and Gemerek regions range between the 26–27 °C, the results from the Dodurga region are 10.05 °C for the MAT, -0.8 °C for the CMT, 24.7 °C for the WMT and 25.5 °C for the MART. These different results of Dodurga region samples relate to its high elevation at the time.
The earliest Tortonian assemblage was determined in the Sivas-Vasıltepe (Gemerek) region. 37 taxa were recorded. Palaeoclimatic parameters are based on 20 taxa for the earliest Tortonian. The results are 19 °C for the MAT, 9.4 °C for the CMT, 27.7 °C for WMT and 1187 to 1574 mm for the MAP, respectively (Table 3). High MART values from the Gemerek region in the Sivas Basin indicate high elevation.

From the early–middle Serravalian to the early Tortonian, the climate changed from subtropical to warm temperate, causing a decrease of the CMT of about 2 °C in the Gemerek region (Table 4).

The high MART values in the Middle and early Late Miocene samples reflect the high elevation, because the mountain and mixed mesophytic forest elements of these samples are abundant compared to the percentage of the swamp forest elements. This environmental difference is caused by the diversity of the regional climate (Table 4, Figure 8).

The combined approach results from the Çorum and Gemerek regions have been correlated with the results from Germany, Bulgaria and Armenia (Bruch & Gabrielyan 2001; Syabryaj 2002; Mosbrugger et al. 2005). From the late Burdigalian to the middle Serravalian the MAT values are high, but in the late Serravalian a decrease occurs. The MAT values of Germany, Bulgaria and Armenia are generally lower than those of central Anatolia during the Middle Miocene (Bruch & Gabrielyan 2001) (Figures 7 & 11) and the higher MAT values of central Anatolia can be related to the relative palaeogeographical position of these countries in the Middle Miocene. Mosbrugger et al. (2005) and Alexsandrove et al. (1987) stated that the succeeding
warm time span persisted through the earlier part of the Serravalian, and corresponds to the Middle Miocene Climatic Optimum that is also observed globally. The Middle Miocene Climatic Optimum is reflected by increases of all the temperature records across central Europe. For MAT and WMT, similar values were obtained from our palynoflora of different samples during that time. The CMT results are 9–13 °C for Lausitz and Lower Rhine basins in central Europe. According to the Mosbrugger et al. (2005), high CMTs mark the Middle Miocene Climatic Optimum in Europe. The Middle Miocene (late Early to early Middle Miocene) thermal optimum has been discussed by many workers in America, all of whom have certainly known that MAT values peaked during this interval and then began a decline (Wolfe 1979, 1994) (Figure 7A). During the late Early to early Middle Miocene, the CMT results for Europe are calculated at between 8 and 10 °C. However, CMT results from central Anatolia in the early–middle Serravalian are low ((-0.8)–7.8 °C) and these lower CMT results can mark the cooling palaeoclimate in Europe and America (from the late Langhian to earliest Serravalian).

While CA results (MART, MAT, CMT, WMT and MAP) are correlated with the recent climatic data of the Çorum area and the Gecomerek region in the Sivas Basin, it can be said that all climatic variables distinctly decrease. MART values indicate that high elevation of the Dodurga region was initiated during the Middle Miocene and this has continued till recent times. Additionally decreasing MAP values clearly indicate the present dry climate (Table 4).

Conclusions
The results of this study are as follows: (1) this is the first detailed palynological study in the Miocene sediments of central Anatolia. The palynostratigraphical results are correlated with previous studies of western and central Anatolia; (2) three sporomorph associations have been...
defined in this study. Sporomorph association A of Samsun-Havza region is latest Burdigalian in age. Sporomorph association C of the Çorum-Evlik, İkizler, Kumbaba, Dodurga, Ayva, Amasya-Çomu areas (in the Çorum region) and the Sivas-Gemerek-Karagöl, Akalın areas is of early–middle Serravalian age. Sporomorph association C of Sivas-Vasıltepe (Gemerek) area is of earliest Tortonian age; (3) the sporomorph association of the Samsun-Havza area is characterized by a warm subtropical climate and CA results are: for the MAT 19 °C, for the CMT 9.75 °C, for the WMT 27.2 °C, for the MAP 1217–1322 mm and the MART 17.45 °C respectively; (4) the sporomorph association from the Çorum and Gemerek regions in the Sivas Basin indicates a subtropical climate. The CA results of this sporomorph association are for the: (i) MAT 18–19.15 °C, (ii) CMT (-

<table>
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<th>Central in this study</th>
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<th>CMT</th>
<th>WMT</th>
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<td>Chattian</td>
<td>Egerian</td>
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<td>Lower Burdigalian</td>
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![Figure 11](image-url)

**Figure 11.** Correspondence analysis data (MAT, CMT, WMT and MAP) of central Anatolia compared with the data of neighboring countries (Germany, Armenia and Bulgaria).
0.8°–10.6 °C, (iii) WMT 24.7°–27.7 °C. The MAP values of this association are generally high. The MART values for the early–middle Serravalian period change according to the palaeovegetation and palaeotopography. The high MART value is explained by high palaeotopography, and hence the Dodurga region can be interpreted as topographically high at the time; (5) the Sivas-Vasiltpe sporomorph association is characterized by a warm temperate climate. The CA results were for the: (i) MAT 19 °C, (ii) CMT 9.4 °C, (iii) WMT 27.7 °C, (iv) MAP 1187–1574 mm and (v) MART 18.3 °C; (6) during the early–middle Serravalian, the palaeovegetation of the Çorum region indicates a lacustrine environment surrounded by mountains, different from the western Anatolia palaeotopography. Earliest Tortonian palaeovegetation resembled the palaeovegetation during the early–middle Serravalian, although open vegetation areas were widespread during the earliest Tortonian.

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References


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Figure 1. Leiotriletes microadriennis W. KRUTZSCH
2. Brandenburgisporis beckwitzensis W. KRUTZSCH
3. Stereisporites stereoides (R. POTONIÉ & VENITZ) THOMSON & PFLUG
4. Stereisporites macroides W. KRUTZSCH
5. Echinatisporites longichinatus W. KRUTZSCH
6,7. Baculatisporites primarius (WOLLF) THOMSON & PFLUG primarius W. KRUTZSCH
8. Baculatisporites cf. nonus (WOLLF) W. KRUTZSCH ssp. cf. baculus W. KRUTZSCH
9. Laevigatosporites haardti (R. POTONIÉ & VENITZ) THOMSON & PFLUG
10,11. Pityosporites microalatus (R. POTONIÉ) THOMSON & PFLUG
12. Pityosporites labdacus THOMSON & PFLUG
13. Inaperturopollenites dubius (R. POTONIÉ & VENITZ) PFLUG & THOMSON in THOMSON & PFLUG
14,15. Inaperturopollenites hiatus (R. POTONIÉ) PFLUG & THOMSON in THOMSON & PFLUG
16. Inaperturopollenites verrapapillatus TREVISO
17. Graminidites laevigatus W. KRUTZSCH
18. Echigrainidites moravicus W. KRUTZSCH
19. Sparganiapollenites neogenicus W. KRUTZSCH
20–22. Triatropollenites nurensis PFLUG & THOMSON in THOMSON & PFLUG
23,24. Triatropollenites bituitus (R. POTONIÉ) THOMSON & PFLUG
25. Triatropollenites coryphaeus (R. POTONIÉ) THOMSON & PFLUG
26–29. Momipites punctatus (R. POTONIÉ) NAGY
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31. Triporopollenites simpliformis PFLUG & THOMSON in THOMSON & PFLUG
32. Triporopollenites fragilis NAKOMAN
33. Triporopollenites sp.
34. Intratropopollenites indubitalibus (R. POTONIÉ) PFLUG & THOMSON in THOMSON & PFLUG
35. Subtriptropopollenites anulatus (R. POTONIÉ & VENITZ) THOMSON & PFLUG
36. Cercisippalites occulis ssp. nox (THIERGART) NAKOMAN
38. Polyporopollenites undulosus (WOLFF) THOMSON & PFLUG
39. Polyporopollenites carpinoidea PFLUG & THOMSON in THOMSON & PFLUG
40. Polyporopollenites stellatus (R. POTONIÉ) PFLUG & THOMSON in THOMSON & PFLUG
41. Myrtaceidites mesonesus COOKSON & PIKE
42,43. Reevesiapollis triangulus (MAMCZAR) W. KRUTZSCH
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51. Tetracolporopollenites retiformis PFLUG & THOMSON in THOMSON & PFLUG
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55,56. Tetracolporopollenites megaexactus (R. POTONIÉ) THOMSON & PFLUG
57,66. Tetracolporopollenites steinensis (R. POTONIÉ) THOMSON & PFLUG
58–61. Tetracolporopollenites krucshi (R. POTONIÉ) THOMSON & PFLUG ssp. rodderiens THIERGART
62–65. Tetracolporopollenites microreticulatus PFLUG & THOMSON in THOMSON & PFLUG
67,68. Tetracolporopollenites microellipsus PFLUG in THOMSON & PFLUG
69. Periporopollenites halifani NAKOMAN
70. Juglandaceapollenites verus RAATZ
71. Pediastrum
72. Botryococcus brunii KÜTZING
PLATE II

(ALICIK)
(All illustrations X 500)

Figure 1.2. Laevigatosporites haardti (R. POTONIÉ & VENITZ) THOMSON & PFLUG
3.4. Pityosporites strobipites (WODEHOUSE) W. KRUTZSC
5. Cupressacidites cuspidateformis (ZAKLINSKAJA) W. KRUTZSC
6. Inaperturopollenites verrupapillatus TREVISAN
7. Graminidites laevigatus W. KRUTZSC
8.9. Graminidites subtiliglobosus W. KRUTZSC
10.11. Graminidites pseugogramineus W. KRUTZSC
12.13. Echigraminidites moravicus W. KRUTZSC
14.15. Sparganiapollenites neogenicus W. KRUTZSC
16. Cycadopites sp.
17–20 Triatropollenites rurensis PFLUG & THOMSON in THOMSON & PFLUG
21.22 Triatropollenites bituitus (R. POTONIÉ) THOMSON & PFLUG
23. Subtriporopollenites simplex (R. POTONIÉ & VENITZ) THOMSON & PFLUG
24.25 Intratriporopollenites instructus (R. POTONIÉ) THOMSON & PFLUG
26.27 Polyporopollenites stellatus (R. POTONIÉ & VENITZ) THOMSON & PFLUG
32.33. Tricolporopollenites henrici (R. POTONIÉ) THOMSON & PFLUG
34–37. Tricolporopollenites microhenrici (R. POTONIÉ) THOMSON & PFLUG
38. Quercopollenites robur PLANDEROVA
39.40. Tricolporopollenites microhenrici R. POTONIÉ ssp. medius ZONGHAO
41–45. Tricolporopollenites cingulum (R. POTONIÉ) THOMSON & PFLUG
46–49. Tricolporopollenites megaexactus (R. POTONIÉ) THOMSON & PFLUG
50. Tricolporopollenites pacatus PFLUG in THOMSON & PFLUG
51. Tricolporopollenites microreticulatus (R. POTONIÉ) THOMSON & PFLUG
52. Tricolporopollenites margaritatus (R. POTONIÉ) THOMSON & PFLUG
53. Tricolporopollenites iliacus (R. POTONIÉ) ncomb. THOMSON & PFLUG
54. Rhuspollenites ornatus (THIELE–PFEIFFER)
60.61. Tricolporopollenites spp. (Asteraceae–Tubuliflora type)
62.63. Periporopollenites perpilexus NAKOMAN
64. Tetracolporopollenites abdittus PFLUG in THOMSON & PFLUG
65–67. Periporopollenites halifani NAKOMAN
68. Periporopollenites multiporatus PFLUG in THOMSON & PFLUG
69. Periporopollenites stigmosus (R. POTONIÉ) THOMSON & PFLUG

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Figure 1. *Leiotriletes microadiennis* W. KRUTZSCH
5. *Punctatisporites micropunctatus* W. KRUTZSCH
6. *Laevigatosporites gracilis* WILSON & WEBSTER
7. *Pityosporites microalatus* (R. POTONIE) THOMSON & PFLUG
8. *Pityosporites labdacus* THOMSON & PFLUG
9. *Abiespollenites absolutus* (THIERGART) n.comb. W. KRUTZSCH
10. *Abiespollenites latiscactus* (TREVISAN) n.comb. W. KRUTZSCH
11. *Inaperturopollenites dubius* (R. POTONIE & VENITZ) PFLUG & THOMSON in THOMSON & PFLUG
12,13. *Inaperturopollenites hiatus* (R. POTONIE) PFLUG & THOMSON in THOMSON & PFLUG
14. *Graminidites subtiliglobosus* W. KRUTZSCH
15. *Sparganiapollenites sparganoides* (MEYER) W. KRUTZSCH
16. *Cycadopites* sp.
17. *Monogemmites pseudosetarius* WEYLAND & PFLUG
18. *Triatriopollenites rurensis* PFLUG & THOMSON in THOMSON & PFLUG
19. *Triatriopollenites corypheause* (R. POTONIE) THOMSON & PFLUG
20. *Triatriopollenites bituitus* (R. POTONIE) THOMSON & PFLUG
21–25. *Momipites punctatus* (R. POTONIE) NAGY
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32,33. *Polyporopollenites stellatus* (R. POTONIE & VENITZ) THOMSON & PFLUG
34,35. *Tricolpoperollenites microhenrici* (R. POTONIE) THOMSON & PFLUG
36–41. *Tricolporopollenites megaexactus* (R. POTONIE) THOMSON & PFLUG
42. *Tricolporopollenites pacatus* PFLUG in THOMSON & PFLUG
43,44. *Tricolporopollenites microreticulatus* PFLUG & THOMSON in THOMSON & PFLUG
45. *Tricolporopollenites sp.* (Avicennia type)
46. *Tricolporopollenites* sp.
47. *Tetracolporopollenites abditus* PFLUG in THOMSON & PFLUG
48,49. *Periporopollenites multiporatus* PFLUG in THOMSON & PFLUG
Figure 1. Trilites sp.

2. Stereisporites (Stereoides) stereoides (R. POTONIÉ & VENITZ) THOMSON & PFLUG

3. Baculatisporites primarium (WOLFF) THOMSON & PFLUG ssp. primarius W. KRUTZSCH

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12. Pityosporites labdacus (R. POTONIÉ) THOMSON & PFLUG

9,10. Cycadopites spp.

11. Arecipites sp.

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31–33. Polyvestulopollenites verus PFLUG in THOMSON & PFLUG

34,35. Subtriporopollenites simplex (R. POTONIÉ & VENITZ) THOMSON & PFLUG

36. Corsinipollenites oculis ssp. noctis (THIERGART) NAKOMAN

37,38. Polyoporipollenites undulosus (WOLFF) THOMSON & PFLUG

39,40. Polyoporipollenites stellatus (R. POTONIÉ & VENITZ) THOMSON & PFLUG

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60. Tricolporipollenites krucshi (R. POTONIÉ) THOMSON & PFLUG ssp. rodderensis THIERGART

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62. Tricolporipollenites oleoides W. KRUTZSCH & VANHOORNE

63,64. Tricolporipollenites sp. (Asteraceae–Tubulifloreae type)

65,66. Periporipollenites halifani NAKOMAN
PLATE V

(AYVA-KUMBABA)

(All illustrations X 500)

Figure 1,2. Stereisporites (Stereoides) stereoides (R. POTONIÉ & VENITZ) THOMSON & PFLUG ssp. stereoides W. KRUTZSCH
3. Laevigatosporites pseudodiscordatus W. KRUTZSCH
4,5. Pityosporites microalatus (R. POTONIÉ) THOMSON & PFLUG
6,7. Inaperturopollenites hiatus (R. POTONIÉ) PFLUG & THOMSON in THOMSON & PFLUG
8. Inaperturopollenites polyformosus (THIERGART) THOMSON & PFLUG
9. Copressacidites cuspidateaformis (ZAKLINSKAJA) W. KRUTZSCH
10,11. Graminidites laevigatus W. KRUTZSCH
12,13. Monogemmmites pseudosetarius WEYLAND & PFLUG
14. Echigraminidites moravicus W. KRUTZSCH
15. Sparganiapollenites sparganois (MEYER) W. KRUTZSCH
16. Triatriopollenites rurensis PFLUG & THOMSON in THOMSON & PFLUG
17. Triatriopollenites bituitus (R. POTONIÉ) THOMSON & PFLUG
18,19. Triatriopollenites coryphaeuse (R. POTONIÉ) THOMSON & PFLUG
20–22. Momipites punctatus (R. POTONIÉ) NAGY
23. Triporopollenites simpliformis PFLUG & THOMSON in THOMSON & PFLUG
24. Lonicerapollis cf. gallwitzi W. KRUTZSCH
25. Reevesiapollis triangulus (MAMCZAR) W. KRUTZSCH
26,27. Polyvestibulopollenites verus PFLUG in THOMSON & PFLUG
28,29,31. Subtriporopollenites simplex (R. POTONIÉ & VENITZ) THOMSON & PFLUG
30. Polyperipollenites undulosus (WOLFF) THOMSON & PFLUG
32,33. Polyperipollenites carpoides PFLUG & THOMSON in THOMSON & PFLUG
34,35. Polyperipollenites stellatus (R. POTONIÉ & VENITZ) THOMSON & PFLUG
36–41. Tricolporopollenites henrici (R. POTONIÉ) THOMSON & PFLUG
42–45. Tricolporopollenites microhenrici (R. POTONIÉ) THOMSON & PFLUG
46. Tricolporopollenites densus PFLUG in THOMSON & PFLUG
47. Quercopollenites robur PLANDEROVÁ
48–52. Tricolporopollenites cingulum (R. POTONIÉ) THOMSON & PFLUG
53–56,70. Tricolporopollenites megaexactus (R. POTONIÉ) THOMSON & PFLUG
57,58. Tricolporopollenites krucshi (R. POTONIÉ) THOMSON & PFLUG ssp. pseudolaesus (R. POTONIÉ) THOMSON & PFLUG
59–62. Tricolporopollenites microreticulatus PFLUG & THOMSON in THOMSON & PFLUG
63,64. Tricolporopollenites krucshi (R. POTONIÉ) THOMSON & PFLUG ssp. rodderensis THIERGART
65. Quercopollenites mongolica PLANDEROVÁ
66. Tricolporopollenites retiformis PFLUG & THOMSON in THOMSON & PFLUG
67–69. Tricolporopollenites microreticulatus PFLUG & THOMSON in THOMSON & PFLUG
71. Tricolporopollenites porasper PFLUG in THOMSON & PFLUG
72. Tetracolporopollenites microellipsus PFLUG in THOMSON & PFLUG
73. Polycolporopollenites sp.
74. Periporopollenites stigmosus (R. POTONIÉ) THOMSON & PFLUG
PLATE VI

(EVLJK)

(All illustrations X 500)

1. Leiotriletes microadriennis W. KRUTZSCH
2. Stereisporites (Stereoides) stereoides (R. POTONIÉ & VENITZ) THOMSON & PFLUG
3. Laevigatosporites haardti (R. POTONIÉ & VENITZ) THOMSON & PFLUG
4,6,7. Pityosporites microalatus (R. POTONIÉ) THOMSON & PFLUG
5. Pityosporites libellus (R. POTONIÉ) NAKOMAN
8. Pityosporites alatus W. KRUTZSCH
9,10. Inaperturopollenites hiatus (R. POTONIÉ) PFLUG & THOMSON in THOMSON & PFLUG
11. Inaperturopollenites polyformosus (THIERGART) THOMSON & PFLUG
12. Cupressacidites cuspidateaformis (ZAKLINSKAJA) W. KRUTZSCH
13,14. Graminidites laevigatus W. KRUTZSCH
15. Sparganiapollenites neogenicus W. KRUTZSCH
16,17. Cycadopites spp.
18,19. Monogemmites pseudosetarius WEYLAND & PFLUG
20. Triatriopollenites bituitus (R. POTONIÉ) THOMSON & PFLUG
21,22. Momiptes punctatus (R. POTONIÉ) NAGY
23,24. Triporopollenites simpliformis PFLUG & THOMSON in THOMSON & PFLUG
25. Triporopollenites undulatus PFLUG in THOMSON & PFLUG
26. Reevesiapollis triangulus (MAMCZAR) W. KRUTZSCH
27. Polyvestibulopollenites verus PFLUG in THOMSON & PFLUG
28. Subtriporopollenites simplex (R. POTONIÉ & VENITZ) THOMSON & PFLUG
29–30. Intratriporopollenites instructus (R. POTONIÉ) THOMSON & PFLUG
31. Intratriporopollenites sp.
32. Polyoporopollenites undulosus (WOLFF) THOMSON & PFLUG
33. Tricolporopollenites henrici (R. POTONIÉ) THOMSON & PFLUG
34. Tricolporopollenites microhenrici (R. POTONIÉ) THOMSON & PFLUG
35–37. Quercopollenites robur PLANDEROVÁ
38–40. Quercopollenites mongolica PLANDEROVÁ
41,42. Tricolporopollenites liblarensis THOMSON & PFLUG
43. Tricolporopollenites reticuliformis PFLUG & THOMSON in THOMSON & PFLUG
44–54,70,71. Tricolporopollenites cingulum (R. POTONIÉ) THOMSON & PFLUG
55–61. Tricolporopollenites megaexactus (R. POTONIÉ) THOMSON & PFLUG
62,63. Tricolporopollenites pacatus PFLUG in THOMSON & PFLUG
64. Tricolporopollenites macrodurensis PFLUG & THOMSON in THOMSON & PFLUG
65–69. Tricolporopollenites microreticulatus PFLUG & THOMSON in THOMSON & PFLUG
72. Tetracolporopollenites abditus PFLUG in THOMSON & PFLUG
73. Tetracolporopollenites microrobustus PFLUG in THOMSON & PFLUG
74. Periporopollenites stigmaticus (R. POTONIÉ) THOMSON & PFLUG
PLATE VII

(INCESU-ZAMBAL)

(All illustrations X 500)

Figure 1. Leiotriletes microadriennis W. KRUTZSCH
2. Polypodiaceoisporites sp.
3. Baculatisporites primarium (WOLLF) THOMSON & PFLUG
4. Levigatosporites haardti (R. POTONIÉ & VENITZ) THOMSON & PFLUG
5–7. Pityosporites strobipites (WODEHOUSE) W. KRUTZSCH
8. Pityosporites alatus W. KRUTZSCH
9. Pityosporites libellus (R. POTONIÉ) NAKOMAN
10,11. Inaperturopollenites hiatus (R. POTONIÉ) PFLUG & THOMSON in THOMSON & PFLUG
12,13. Inaperturopollenites polyformosus (THIERGART) THOMSON & PFLUG
14. Ephedripites sp.
15. Graminidites laevigatus W. KRUTZSCH
16. Graminidites subtiliglobosus W. KRUTZSCH
17. Cycadopites sp.
18. Iteapollis angustiporatus (SCHNEIDER) ZIEMBINSKA–TWORZYDLO
19. Sparganiapollenites neogenicus W. KRUTZSCH
20. Monogemmites pseudosetarius WEYLAND & PFLUG
21–23. Triatriopollenites bituitus (R. POTONIÉ) THOMSON & PFLUG
24. Triatriopollenites corypheause (R. POTONIÉ) THOMSON & PFLUG
25,26. Momipites punctatus (R. POTONIÉ) NAGY
27. Triporopollenites coryloides PFLUG in THOMSON & PFLUG
28. Rhamnaceaepollenites triquetrous THIELLE–PFEIFFER
29–31. Polyvestibulopollenites verus PFLUG in THOMSON & PFLUG
32,33. Subtriporopollenites simplex (R. POTONIÉ & VENITZ) THOMSON & PFLUG
34. Subtriporopollenites sp.
35. Corsinipollenites occulis ssp. noctis (THIERGART) NAKOMAN
36,37. Polyoporopollenites undulosus (WOLFF) THOMSON & PFLUG
38. Polyoporopollenites stellatus (R. POTONIÉ & VENITZ) THOMSON & PFLUG
39,40. Polyoporopollenites carpinoides PFLUG & THOMSON in THOMSON & PFLUG
41. Porocolpopollenites sp.
42,43. Tricolporopollenites henrici (R. POTONIÉ) THOMSON & PFLUG
44. Tricolporopollenites densus PFLUG in THOMSON & PFLUG
45–50. Tricolporopollenites microhenrici (R. POTONIÉ) THOMSON & PFLUG
51–54. Tricolporopollenites megaexactus (R. POTONIÉ) THOMSON & PFLUG
55. Tricolporopollenites euphorii (R. POTONIÉ) THOMSON & PFLUG
56. Tricolporopollenites krucshi (R. POTONIÉ) THOMSON & PFLUG ssp. rodderensis THIERGART
57,58. Tricolporopollenites iliacus (R. POTONIÉ) n.comb. THOMSON & PFLUG
59,60. Periporopollenites multiporatus PFLUG in THOMSON & PFLUG
61. Periporopollenites stigmosus (R. POTONIÉ) THOMSON & PFLUG
PLATE VIII

(VASILTEPE)
(All illustrations X 500)

Figure 1. Stereisporites involutus W. KRUTZSCH ssp. minutoides W. KRUTZSCH
2. Polypodiaceoisporites sp.
3. Laevigatosporites haardti (R. POTONIÉ & VENITZ) THOMSON & PFLUG
4,5. Pityosporites microalatus (R. POTONIÉ) THOMSON & PFLUG
6. Pityosporites strobipites (WODEHOUSE) W. KRUTZSCH
7. Inaperturopollenites dubius (R. POTONIÉ & VENITZ) PFLUG & THOMSON in THOMSON & PFLUG
8,9. Inaperturopollenites verrupapillatus TREVISAN
10,11. Inaperturopollenites polyformosus (THIERGART) THOMSON & PFLUG
12,13. Ephedripites spp.
14,15. Monoporopollenites gramineoides MEYER
16. Graminidites subtiliglobosus W. KRUTZSCH
17,18. Graminidites sp.
19. Sparganiapollenites neogenicus W. KRUTZSCH
22,23. Monogemmites pseudosetarius WEYLAND & PFLUG
24,25. Iteapollis angustiporatus (SCHNEIDER) ZIEMBINSKA–TWORZYDLO
26–29. Triatriopollenites rurensis PFLUG & THOMSON in THOMSON & PFLUG
30–33. Triatriopollenites myricoides (KREMP) THOMSON & PFLUG
34,35. Triatriopollenites bituitus (R. POTONIÉ) THOMSON & PFLUG
36. Triatriopollenites coryphaeuse (R. POTONIÉ) THOMSON & PFLUG
37. Momipites punctatus (R. POTONIÉ) NAGY
38–41. Platycarya miocaenicus NAGY
42. Triporopollenites simpliformis PFLUG & THOMSON in THOMSON & PFLUG
43. Triporopollenites labraferus (R. POTONIÉ) THOMSON & PFLUG
44. Triporopollenites coryloides PFLUG in THOMSON & PFLUG
45. Reevesiapollis triangulus (MAMCZAR) W. KRUTZSCH
46,47. Intratriporopollenites instructus (R. POTONIÉ) THOMSON & PFLUG
48,49. Subtriporopollenites simplex (R. POTONIÉ & VENITZ) THOMSON & PFLUG
50. Polycolporopollenites undulosus (WOLFF) THOMSON & PFLUG
51–55. Myrtaceidites mesonesus COOKSON & PIKE
56,57. Tricolporopollenites microhenrici (R. POTONIÉ) THOMSON & PFLUG
58,60. Quercopollenites robur PLANDEROVÁ
61. Tricolporopollenites retiformis PFLUG & THOMSON in THOMSON & PFLUG
62. Tricolporopollenites sp.
63. Tricolporopollenites cingulum (R. POTONIÉ) THOMSON & PFLUG
64,65. Tricolporopollenites microreticulatus PFLUG & THOMSON in THOMSON & PFLUG
66. Tricolporopollenites pacatus PFLUG in THOMSON & PFLUG
67–71. Tricolporopollenites sp. (Asteraceae–Tubulifloreae type)
72,73. Tricolporopollenites sp. (Cichorieae- Ligulifloreae type)
74. Tetracolporopollenites abditus PFLUG in THOMSON & PFLUG
75. Tetracolporopollenites microrobustus PFLUG in THOMSON & PFLUG
76. Polycolporopollenites sp.
77–80. Periporopollenites halifani NAKOMAN
81–84. Tricolporopollenites sp. (Geranieae type)