Turkish Journal of Earth Sciences (Turkish J. Earth Sci.), Vol. **17**, 2008, pp. 361–403. *Copyright ©TÜBİTAK*
First published online 27 December 2007

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)

Özet: Çorum bölgesi ve Sivas Havzası'nın Neojen yaşlı kömür içerikli tortullarının, palinostratigrafisi belirlenmiş ve üç sporomorf topluluğu tanımlanmıştır. Sporomorf topluluğu A, Samsun-Havza bölgesinde tanımlanmıştır ve en geç Burdigaliyen yaşlıdır. Sporomorf topluluğu B, Çorum bölgesi ve Sivas Havzası'ndan tanımlanmıştır ve erken–orta Serravaliyen yaşlıdır. Sporomorf topluluğu C, Sivas-Vasıltepe bölgesinden tanımlanmıştır ve en erken Tortoniyen yaşlıdır. Sporomorf topluluğu A, ılık subtropikal iklim koşullarını yansıtmaktadır ve '*Coexistance Approach*' analizi (CA) sonuçları sırasıyla; yıllık ortalama sıcaklık (YOS) 19 °C, en soğuk ayın sıcaklığı 9.75 °C (ESoA), en sıcak ayın sıcaklığı 27.2 °C (ESA), yıllık ortalama yağış miktarı 1217–1322 mm (YOY) ve yıllık ortalama sıcaklık amplitüdü (YSA) 17.45 °C dir. Sporomorf topluluğu B, subtropikal iklim koşullarını karakterize eder ve bu sporomorf topluluğa ait CA sonuçları, en geç Burdigaliyen dönemine ait CA sonuçlarıyla benzerdir. Erken–orta Serravaliyen dönemi için, YOS değerleri 18–19.15 °C arasında değişmektedir. Sırasıyla ESoA değerleri (-0.8)–10.6 °C arasında ve ESA değerleri 24.7–27.7 °C dir. Genellikle en geç Burdigaliyen ve erken–orta Serravaliyen dönemine ait YOY değerleri yüksektir. Erken–orta Serravaliyen döneminde, YSA değerleri paleovejetasyon ve palaeotopoğrafyaya bağlı olarak değişmektedir ve bu dönem boyunca, Çorum bölgesine ait örneklerin YSA değerlerindeki artış, yüksek palaeotopografik koşuları gösterir. Sporomorf topluluğu C, ılıman iklim koşullarını yansıtmaktadır ve CA sonuçları sırasıyla YOS 19 °C, ESoA 9.4 °C, ESA 27.7 °C, YOY 1187–1574 mm ve YSA 18.3 °C'dir. Erken–orta Serravaliyen döneminde Çorum bölgesi ve Sivas Havzası'nın paleovejetasyonu, dağlar ile çevrili gölsel ortamı karakterize eder. En geç Erken ve Orta Miyosen periyodundaki palaeovejetasyondan farklı olarak, en erken Tortoniyen döneminde açık alanlar daha geniş alanda yayılım göstermektedir.

Anahtar Sözcükler: Miyosen, palinostratigrafi, 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 Kırşehir 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 Kırşehir 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 Kırşehir 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; Rückert-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). Rükert-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, Kargı, 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. Kaymakcı *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; Harami1, 3; Horlak 1a, b, 2; Gemerek; Kaleköy; 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).

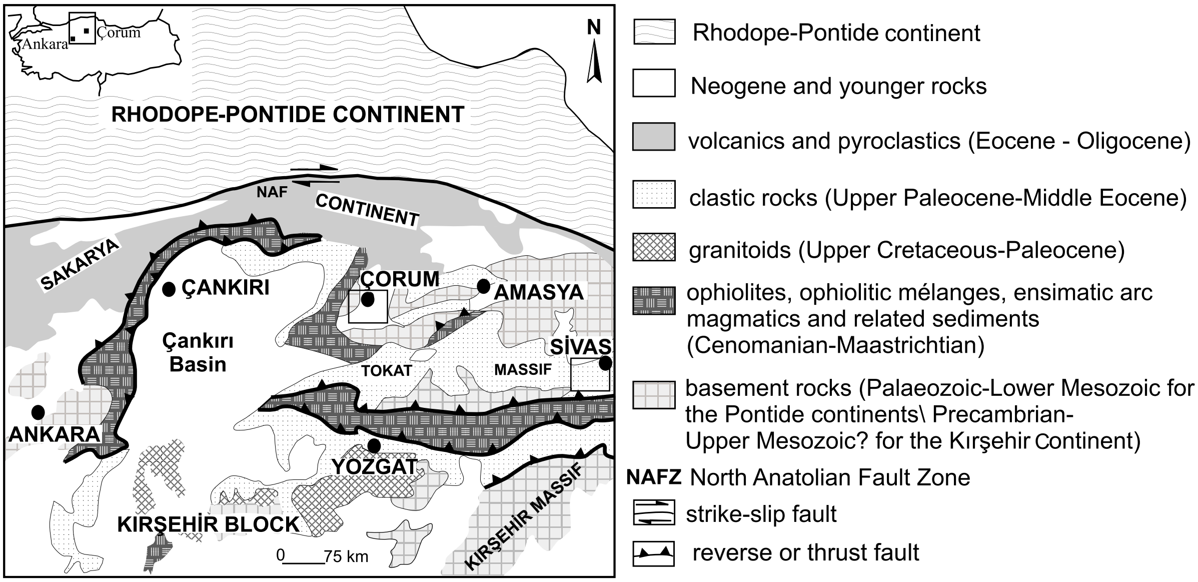

Figure 1. Major continents and suture zones of central Anatolia and locations of the sedimentary basin developed along collision zone between these belts (modified from Tüysüz 1993; Poisson *et al.* 1996).

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 HNO_3.

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).

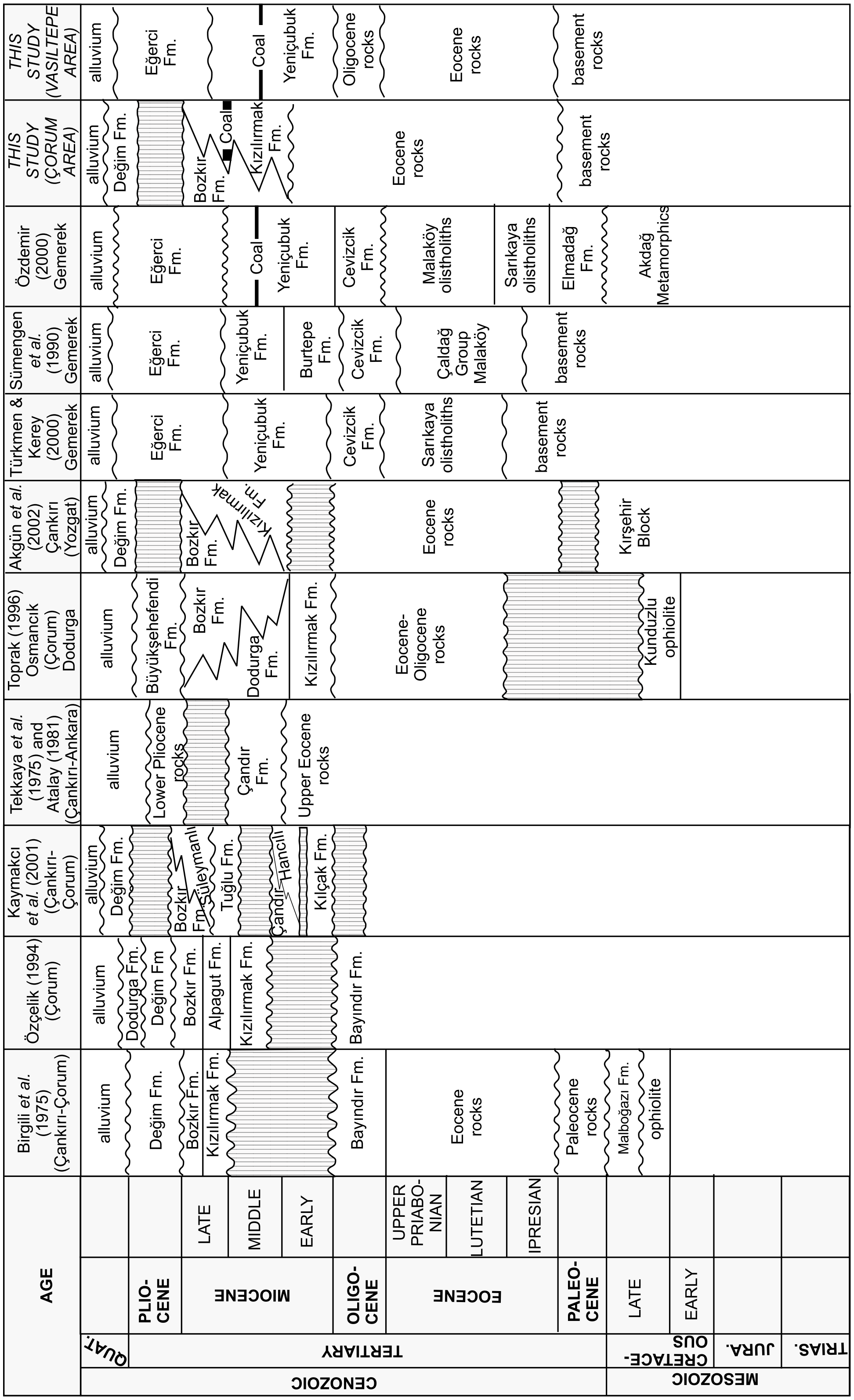

Figure 2. Chart showing the previously suggested sequences of some researchers who have studied in the Çorum region and Sivas Basin and comparison of them with our study.

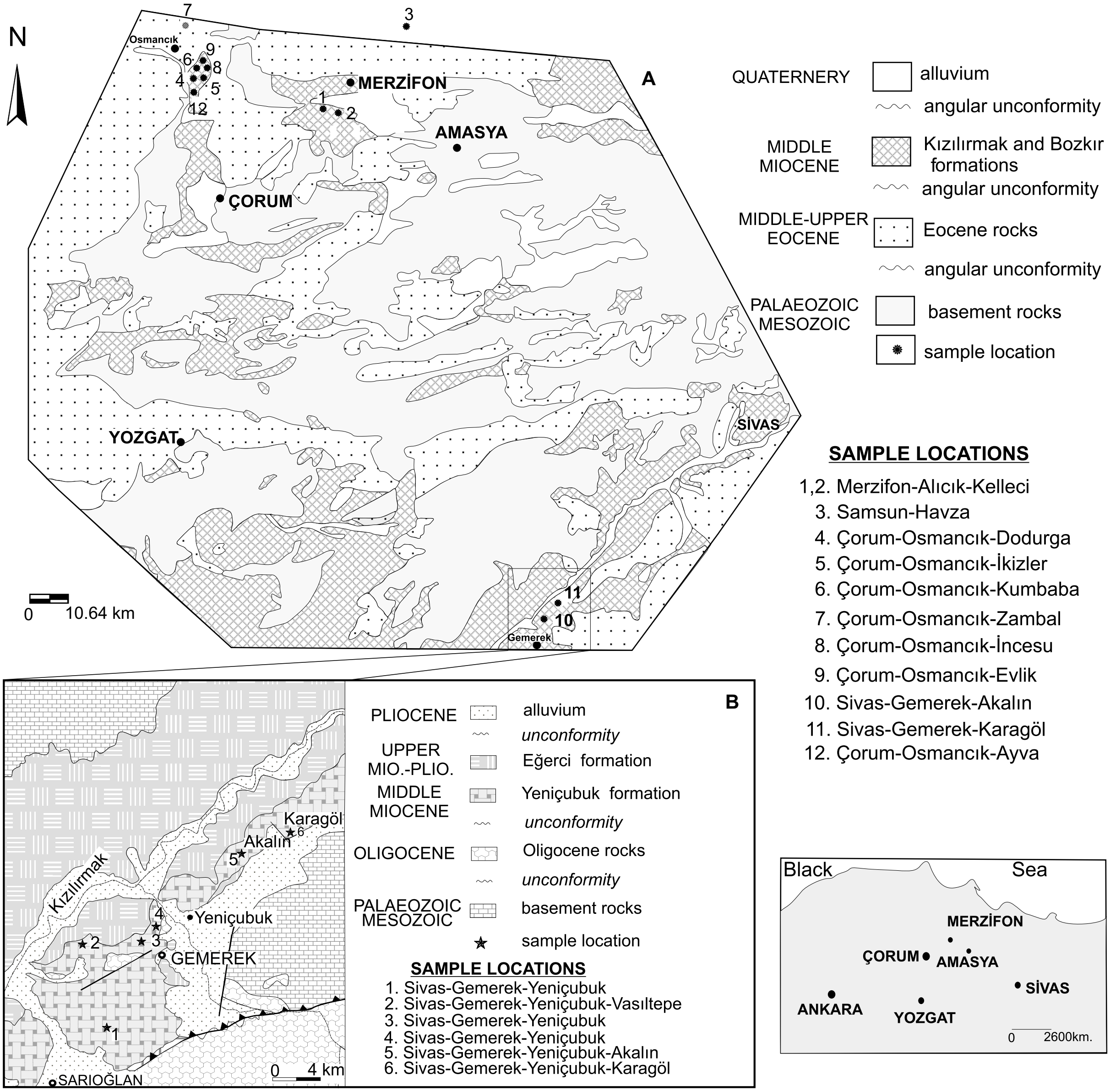

Figure 3. (A) Simplified Geological Map of the Çorum region (modified from Tüysüz 1993) and Sivas Basin (modified from Özdemir 2000). (B) Geological Map of the Sivas-Gemerek area (modified from Özdemir 2000).

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).

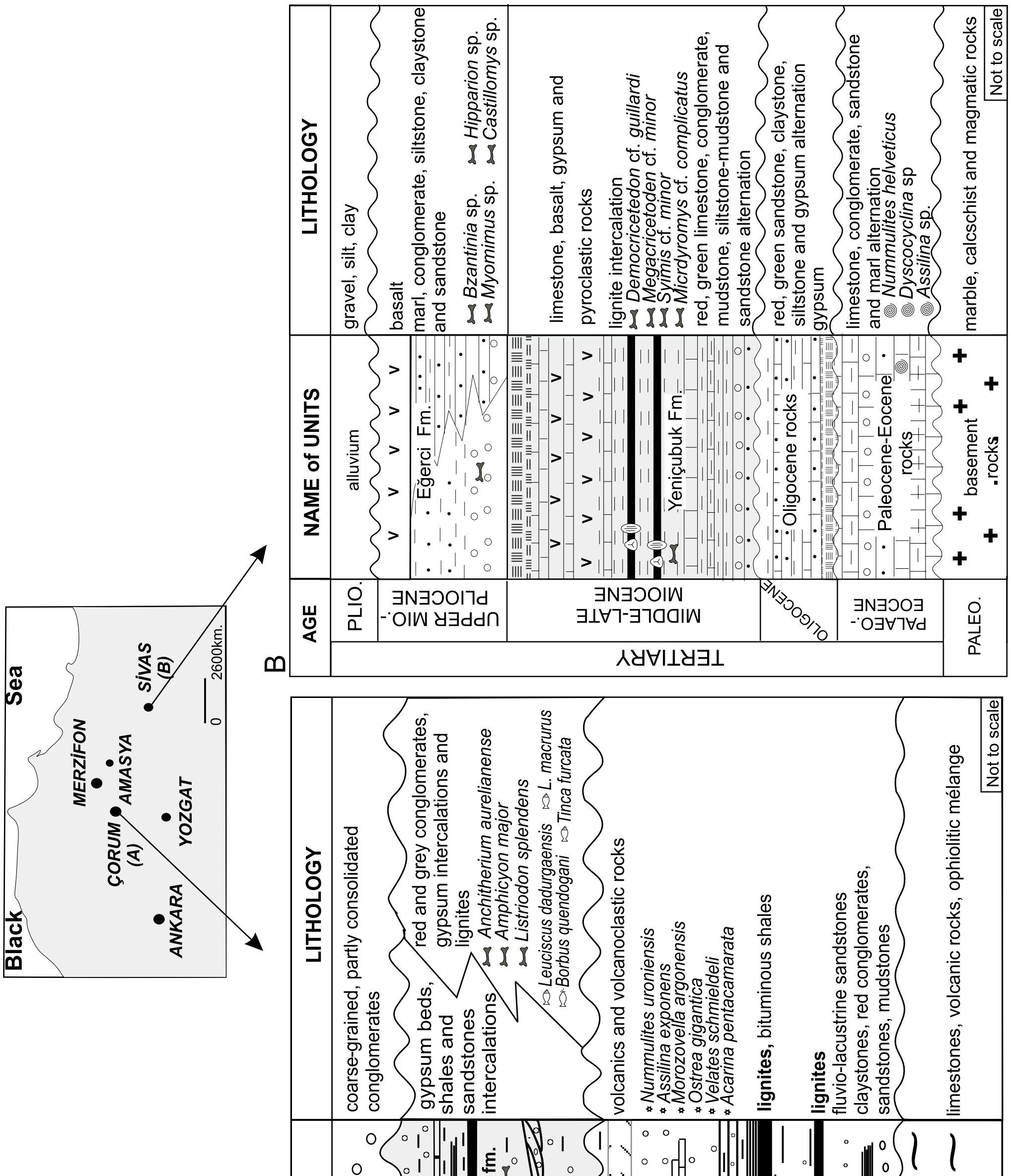

Figure 4. Stratigraphically generalized columnar sections **(A)** for the Çorum region and **(B)** for the Sivas Basin (modified from Birgili *et al.* 1979; Özdemir & Pekmezci 1983; Toprak 1990; Özdemir 2000).

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, Akalın and Vasıltepe areas (in the Gemerek region) 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, *Engelhardtia*, *Carya*, *Salix*, Castaneae, Cyrillaceae, *Nyssa* and Sapotaceae are sparse (1%–4%). Schizaceae, Sphagnaceae, *Selaginella*, Osmundaceae, Poaceae, Lemnaceae, Nymphaeaceae, Juglandaceae, *Pterocarya*, Simarubaceae and Cycadaceae are rare (1–>1%). *Pinus* (*silvestris*-type), *Corylus*, *Tilia*, Onagraceae, Myrtaceae, *Reevesia*, *Alnus*, *Carpinus*, Fagaceae and Chenopodiceae 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 Akalın 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*, *Engelhardtia*, *Quercus* and Cupressaceae are abundant (5–14%). Osmundaceae, *Picea*, *Pinus*, *Podacarpus*, Simaraubaceae, 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, Sphagnaceae, *Pinus (silvestris*-type), *Abies*, *Sequoia*, Arecaceae, *Corylus*, Juglandaceae, *Tilia*, *Reevesia*, Fagaceae, Araliaceae, Sapotaceae, Chenopodiaceae, Lemnaceae, *Lonicera*, Ephedraceae, *Symplocos*, Onagraceae, *Umbelliferae* 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 *Rhamnaceaepollenites triquetrus*, *Lonicerapollis* cf. g*allwitzi*, *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*, Cyrillaceae and Chenopodiaceae are abundant (5–14%), whereas *Engelhardtia*, Juglandaceae, *Platycarya*, *Carya*, *Salix*, *Quercus (henrici*-type), Fagaceae, Castaneae, Oleaceae, Asteraceae (*Tubulifloreae*-type), Cycadaceae 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; Karayiğit *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*, *Dicolpopollis kalewensis*, *Compositoipollenites minimus*, *Subtriporopollenites 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*, Cyrillaceae and Oleaceae of angiospermae reach their highest relative abundance in the Middle Miocene. These pollen are also observed during the Oligocene and Miocene. *Tricolpopollenites 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 indicatative 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:

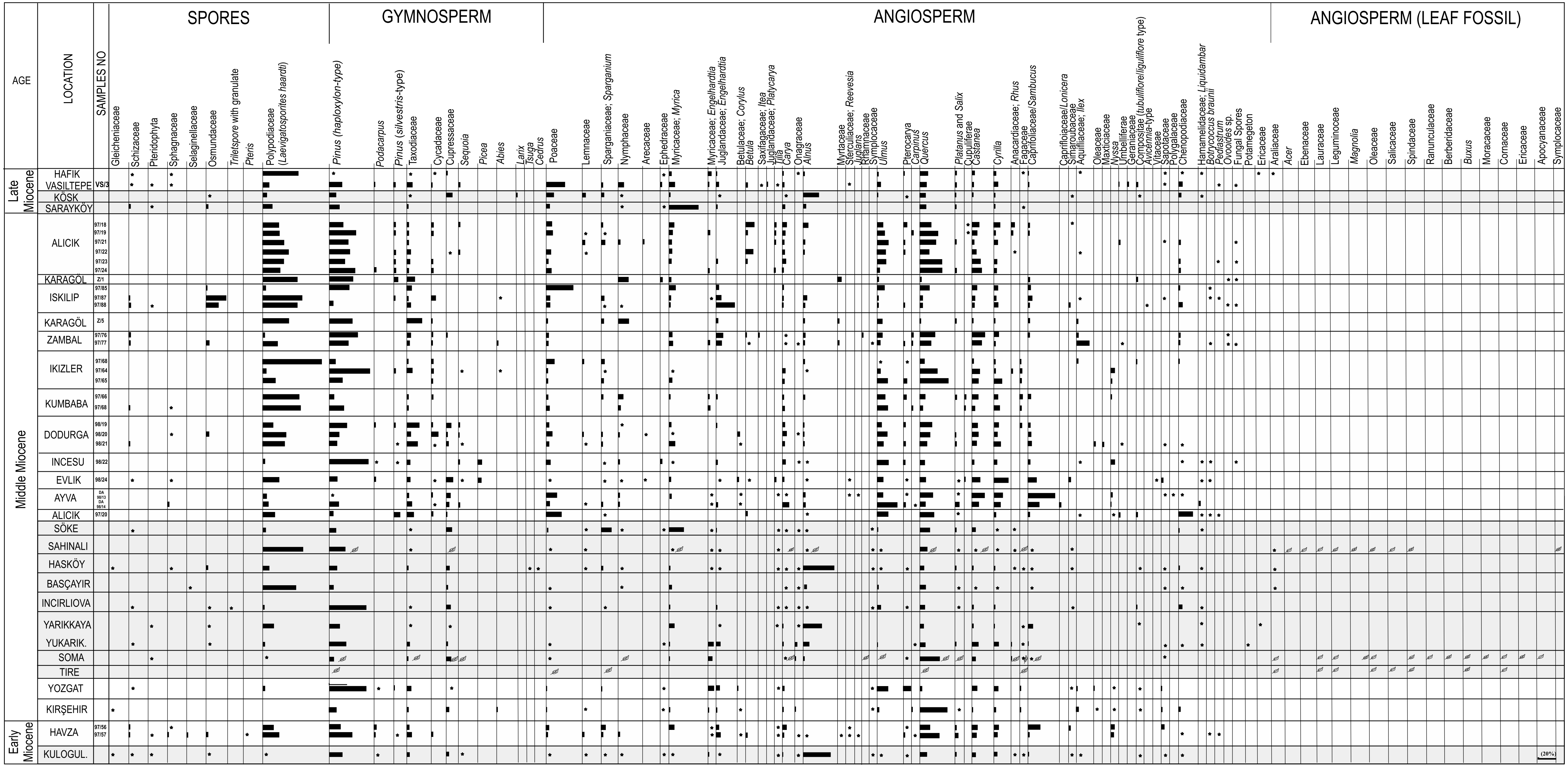

Figure 5. Relative abundances of defined taxa for the samples of central and western Anatolia (Akgün 1986, 1993; Akgün & Akyol 1992, 1999; Akgün *et al.* 2000a, 2002; Karayiğit *et al.* 1999).

Table 1. Correlation between our sporomorph associations in this study and Anatolia with other and European sporomorph assemblages.

	Previous studies in Turkey	LOCATION	MIOCENE							
			EARLY		MIDDLE				LATE	
			Ottnangian	Late Burdigalian	Langhian	Early Serravalian	Middle Serravalian	Late Serravalian	Early Tortonian	Middle Tortonian
	THIS STUDY	*Samsun-Havza region*		*sporomorph association A*						
	THIS STUDY	*Çorum-Ikizler,Incesu, İskilip, Evlik, Ayva, Dodurga, Zambal, Alıcık, Sivas-Karagöl; and Akalın*				*sporomorph association B*				
	THIS STUDY	*Sivas-Vasıltepe region*							*sporomorph association C*	
WESTERN ANATOLIA	Benda & Muelenkamp (1990)	Aegean region	Eskihisar sporomorph assemblage					Yeni-Eskihisar sporomorph assemblage	Kızılhisar sporomorph assemblage	
WESTERN ANATOLIA	Akgün (1993)	Soma region				first Sporomorph assemblage of Soma formation	second Sporomorph Assembage of Deniş fm.			
WESTERN ANATOLIA	Akgün & Akyol (1987)	Akhisar-Çıtak region				Akhisar-Çıtak sporom. assemblage				
WESTERN ANATOLIA	Akgün & Akyol (1999)	Büyük Menderes Graben			Kuloğulları and Başçayır sporomorph assemblage	Şahinali, Söke and Hasköy sporomorph assemblage			Hasköy, Köşk, Sarayköy sporomorph assemblage	
CENTRAL ANATOLIA	Yağmurlu *et al.* (1988)	Ankara-Beypazarı region				Ankara-Beypazarı sporomorph assemblage of Çoraklar formation				
CENTRAL ANATOLIA	Akgün & Akyol (1992)	Isparta-Yukarıkaşıkara and Yarıkkaya regions				Isparta-Yukarıkaşıkara and Yarıkkaya sporomorph assemblage				
CENTRAL ANATOLIA	Akgün *et al.* (1995)	Kırşehir-Kızılöz, Tuzköy and Avcıköy regions				Kızılöz and Avcıköy sporomorph assemblage			Tuzköy Sporomorph assemblage	
CENTRAL ANATOLIA	Karayiğit *et al.* (1999)	Konya-Ilgın region				Konya-Ilgın sporomorph assemblage				
CENTRAL ANATOLIA	Akgün *et al.* (2000a)	Sivas-Hafik region								Sivas-Hafik sporomorph assemblage
CENTRAL ANATOLIA	Akgün *et al.* (2002)	Yozgat region				Kızılırmak and Bozkır sporomorph assemblage				
EUROPEAN	Hochuli (1978)	Germany	Neogene-Ottnangian zone							
EUROPEAN	Thiele-Pfeiffer (1980)	Germany brown coal open cast oder mine near Wackersdorf-Oberpflaz	Ottnangian palynomorph assemblage			Badenian palynomorph assemblage				
EUROPEAN	Van de Weerd (1983)	Kastellious Hill (Greece)								Kastellious Hill sporomorph assemblage
EUROPEAN	Planderová (1991)	Hungary		Karpathian palynomorph assemblage		Badenian palynomorph assemblage				

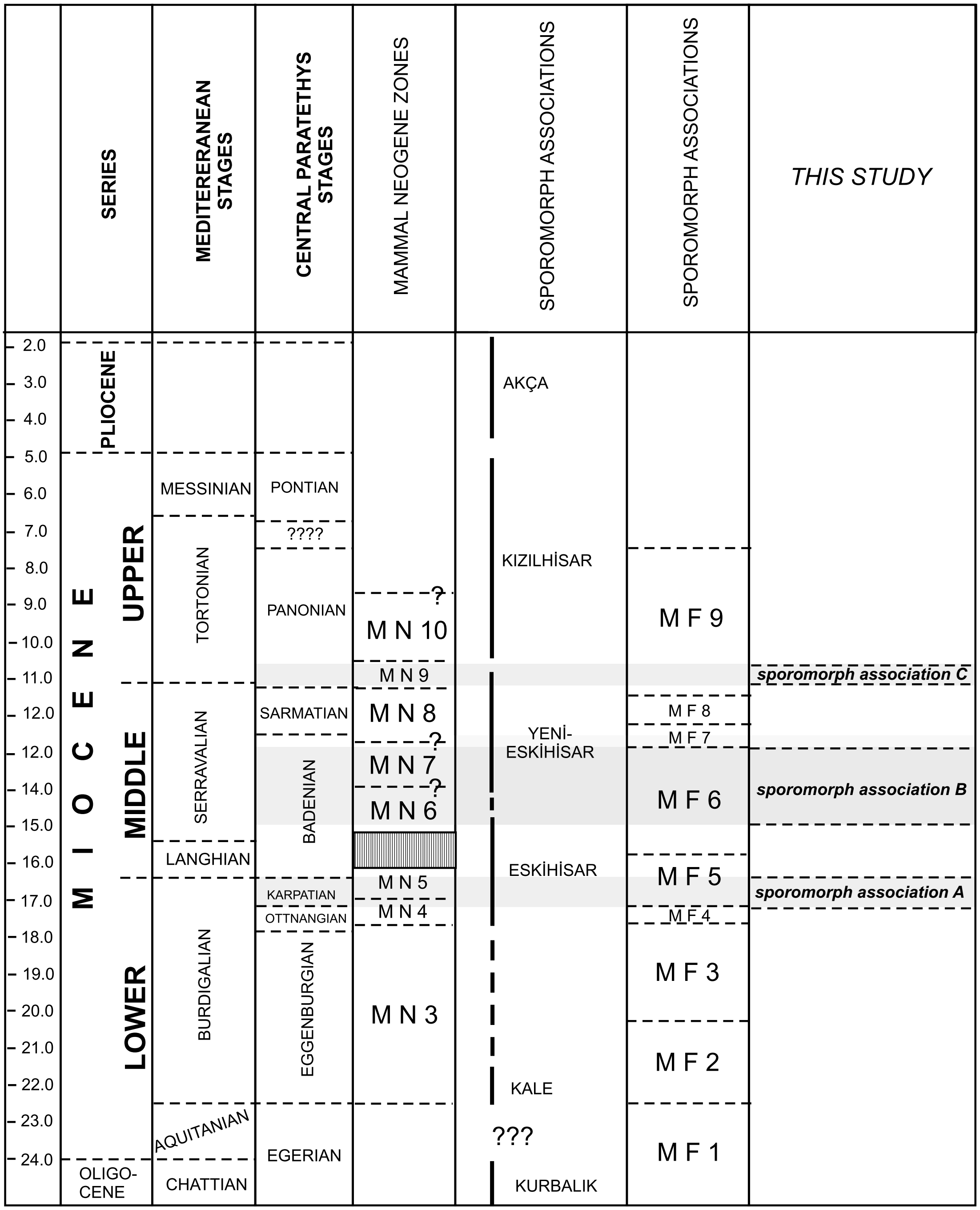

Figure 6. Correlation chart illustrating the relative ages of sporomorph associations from Çankırı-Çorum and Sivas basins and comparison of previous palynologic studies with this study (Benda & Meulenkamp 1990).

the Kale, Eskihisar, Yeni-Eskihisar, Kızılhisar and Akça (Figure 6). Their Eskihisar sporomorph assemblage was characterized by predominant *Q. henrici, Q. microhenrici, R. pseudocingulum, T. microcoryphaeus-punctatus* group, *T. myricoides, bituitus-rurensis* group, *T. hiatus, T. betuloides, U. undulosus,* Osmundaceae, Polypodiaceae, *Pinus-haploxylon* type, *A. verus, Picea*-type, *Asper*-type group, Gramineae, Chenopodiaceae, *Pinus-silvestris* type, *Nyssa*-type, *Liquidambar*-type and rare Umbelliferae, *Tsuga*-type, *Intratriporopollenites* *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, Akalın areas in the Sivas Basin indicates a Middle Miocene age. This sporomorph assemblage resembles the Soma, Akhisar-Çıtak, Büyük Menderes Graben, Ankara, Isparta, Kırşehir, Konya-Ilgın and Yozgat sporomorph assemblages of western and central Anatolia during the Middle Miocene (Akgün 1986; Akgün & Akyol 1987, 1992, 1999; Yağmurlu *et al.* 1988; Karayiğit *et al.* 1999; Akgün *et al.* 2002) (Table 1).

Sporomorph association C in this study indicates a latest Serrravalian 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, Kırşehir-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.

Association	Benda *et al.* (1974, 1982)		Akgün & Akyol (1999)	Ediger *et al.* (1996)	Akgün *et al.* (1995)	Akgün *et al.* (2000a)	This Study 'sporomorph association C'
	Yeni-Eskihisar	Kızılhisar lower association		Sart Member (Yeni-Eskihisar)			
AGE	late Serravalian-early Tortonian	early-late Tortonian	earliest Late Miocene	earliest Tortonian	latest Serravalian-earliest Tortonian	middle Tortonian (MN9-MN10)	earliest Tortonian
Location	Greece	Western Anatolia	Büyük Menderes Graben	Alaşehir-Turgutlu	Kırşehir-Tuzköy	Sivas-Hafik	Sivas-Vasıltepe
Poaceae	7.6	15	12	1.3	7.5	1	19
Asteraceae	0.5	0.6	0.3	2.4	1	9.75	1.5
Chenopodiaceae	0.3	2.9	3	_	8	14.75	5.5
Umbelliferae	0.1	0	0	0.6	_	1	1

(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. undulasus*, *Momipites punctatus*, *Slowakipollis* sp., and by the scarcity of some spore species such as *Leiotriletes maxoides*, *L. wolffi*, *Triplanosporites sinosus*, *T. microsinosus*, *Trilites multivallatus* and *Verrucatosporites favus*. Sporomorph association A in this study includes sporadic Lower Tertiary forms such as *Leiotriletes microadriennis*, *Echinatisporites longiechinatus*, *Stereisporites stereoides* ssp. *stereoides*, *S. stereoides* ssp. *macroides* and *Polypodiaceoisporites* cf. *saxonicus*. Therefore, sporomorph association C in the Samsun-Havza region is latest Burdigalian in age, and younger than the Neogene–Ottnangian zone sporomorph assemblage.

Thiele-Pfeiffer (1980) investigated the systematic description and stratigraphical interpretation of the Miocene microflora from the brown Coal opencast Oder mine near Wackersdorf-Oberpflaz. The microflora of Oder is compared with the others of the Neogene from north, middle and east Europe. The results indicate that the Wackersdorf brown Coal was formed during Ottnangian–Badenian times. The Wackersdorf sporomorph assemblage of Ottnangian age includes Lower Tertiary (Eocene–Oligocene) species. Sporomorph association A in our study includes sporadic lower Tertiary (the Late Oligocene–Early Miocene) species. 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*, *Carya*, 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)*.

Table 3. Ecological requirement and climatic character of extant taxa represented by sporomorphs of the Çorum region and Sivas Basin (modified from Kovar-Eder 1987; Nagy 1990, 1999, 1992; Planderová 1991; Akgün & Akyol 1999).

TAXA	PREFERABLE HABİTAT	CLIMATIC DISTRIBUTION	PALAEOTROPIC/ ARCTOTERTIARY
	SPORES		
Schizaeaceae/*Lygodium*	? Swamp Vegetation	Subtropical to Tropical	Palaeotropic
Gleicheniaceae	? Swamp Vegetation	Subtropical-Tropical to Warm Temperate	Palaeotropic
Sphagnaceae	Freshwater Plant	Subtropical to Tropical	Palaeotropic
Polypodiaceae /*Pteridoidreae*	Swamp or Riparian Vegetation	Cosmopolitan	
Osmundaceae/*Osmunda*	Swamp or Riparian Vegetation	Cosmopolitan	
Selaginellaceae/*Selaginella*	Riparian Vegetation	Warm Temperate	Arctotertiary
	POLLEN		
	GYMNOSPERM		
Pinus (*haploxylon*-type)	Mixed Mesophytic Vegetation	Warm Temperate	Arctotertiary
Pinus (*silvestris*-type)	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Podocarpaceae / *Podocarpus*	Mixed Mesophytic Vegetation	Subtropical to Tropical	Palaeotropic
Abies	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Taxodiaceae/Cupressaceae	Mixed Mesophytic Vegetation	Warm Temperate to Temperate	Arctotertiary
Taxodiaceae	Swamp Vegetation	Warm Temperate	Arctotertiary
Larix	Swamp Vegetation	Warm Temperate	Arctotertiary
Sequoia	Riparian Vegetation	Warm Temperate	Arctotertiary
Ephedra	Open Vegetation	Temperate	Arctotertiary
	ANGIOSPERM		
	MONOCOTYLEDONEAE POLLEN		
Poaceae	Open Vegetation	Cosmopolitan	
Lemnaceae	Freshwater Plant	Cosmopolitan	
Sparganiaceae/*Sparganium*	Swamp Vegetation	Temperate	Arctotertiary
Nymphaeaeae	Freshwater Plant	Cosmopolitan	
Cycadaceae	Mixed Mesophytic Vegetation	Subtropical to Tropical	Palaeotropic
Arecaeae	Mixed Mesophytic Vegetation	Subtropical to Tropical	Palaeotropic
	DICOTYLEDONEAE POLLEN		
Myricaceae/*Myrica*	Swamp Vegetation	Warm Temperate	Arctotertiary
Juglandaceae/*Engelhardtia*	Mixed Mesophytic Vegetation	Subtropical to Tropical	Palaeotropic
Betulaceae/*Corylus*	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Betulaceae	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Ulmaceae	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Saxifragaceae/*Itea*	Mixed Mesophytic Vegetation	Cosmopolitan (North Temperate Zone)	
Rhamnaceae	Mixed Mesophytic Vegetation	Cosmopolitan	
Juglandaceae/Platycarya	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Symplocaceae	Mixed Mesophytic Vegetation	Subtropical to Tropical	Palaeotropic
Tiliaceae/*Tilia*	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Carya	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Onagraceae	? Swamp Vegetation	Temperate	Arctotertiary
Betulaceae/*Alnus*	Swamp or Riparian Vegetation	Temperate	Arctotertiary
Sterculiaceae/ *Reevesia*	Mixed Mesophytic Vegetation	Subtropical to Tropical	Palaeotropic
Myrtaceae	Riparian Vegetation	Subtropical to Tropical	Palaeotropic
Juglandaceae/*Juglans*	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Ulmaceae, *Ulmus; Zelkova*	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Carpinus	Mixed Mesophytic Vegetation	Temperate	Arctotertiary
Pterocarya	Riparian or Mixed Mesophytic Vegetation	Warm Temperate	Arctotertiary
Fagaceae/*Quercus*	Mixed Mesophytic Vegetation	Warm Temperate to Temperate	Arctotertiary
Platanus and *Salix*	Riparian Vegetation	Temperate	Arctotertiary
Castanea	Mixed Mesophytic Vegetation	Warm Temperate	Arctotertiary
Cyrillaceae	Mixed Mesophytic Vegetation	Subtropical to Tropical	Arctotertiary
Anacardiaceae/*Rhus*	Mixed Mesophytic Vegetation	Warm Temperate	Arctotertiary
Simaroubaceae	Riparian Vegetation	Subtropical to Tropical	Palaeotropic
Araliaceae	Riparian or Mixed Mesophytic Vegetation	Cosmopolitan	
Vitaceae	Riparian Vegetation	Subtropical to Tropical	Palaeotropic
Nyssaceae/*Nyssa*	Swamp Vegetation	Subtropical to Tropical	Palaeotropic
Sambucus	Riparian Vegetation	Temperate	Arctotertiary
Aquifoliaceae/*Ilex*	Mixed Mesophytic Vegetation	Warm Temperate	Arctotertiary
Oleaceae/Olea	Mixed Mesophytic Vegetation	Subtropical to Tropical	Palaeotropic
Umbelliferae	Open Vegetation	Cosmopolitan	
Asteraceae (*Tubulifloreae* and L*iguliflorea*e types)	Open Vegetation	Cosmopolitan	
Geraniaceae	Open Vegetation	Subtropical to Temperate	Palaeotropic
Caprifoliaceae/*Lonicera*	Riparian or Mixed Mesophytic Vegetation	Warm Temperate to Temperate	Arctotertiary
Sapotaceae	Mixed Mesophytic Vegetation	Subtropical to Tropical	Palaeotropic
Polygalaceae	Open Vegetation	Cosmopolitan	
Hamamelidaceae/*Liquidambar*	Riparian Vegetation	Warm Temperate	Arctotertiary
Chenopodiaceae	Open Vegetation	Cosmopolitan	
	ALGAE		
Botryococcus braunii	Freshwater	Cosmopolitan	
Pediastrum sp.	Freshwater	Cosmopolitan	

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, *Lycopodia*, Sapotaceae, Cycadaceae, Simaroubaceae, Cyrillaceae, Myrtaceae, *Reevesia* and *Podocarpus*, and includes fewer abundant warm temperate and temperate and arctotertiary elements such as *Pinus* (*haploxylon*-type), Taxodiaceae, *Carya*, *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, Simaroubaceae and *Nyssa*. Warm temperate and temperate elements accompanying the subtropical and tropical elements include *Pinus*, *Castanea*, *Rhus*, Betulaceae, *Ulmus*, *Quercus*, Fagaceae, *Liquidambar*, *Abies*, *Corylus*, *Carpinus*, *Tilia* and *Platycarya*. Palaeotropical elements are scarcer in this sporomorph association. However, arctotertiary elements of this association are more abundant than in sporomorph association A. Consequently, sporomorph association B indicates that the climate was subtropical during the early–middle Serravalian in the Çorum-Evlik, Ayva, Zambal, İkizler, Kumbaba, Dodurga, İncesu Alıcık, Karagöl and Akalın areas (Table 3, Figure 7).

Sporomorph association C is recognized by abundant warm temperate and temperate elements (arctotertiary) such as *Pinus*, *Sequoia*, Myricaceae, *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 associaton C in the Sivas-Vasıltepe 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 decidous 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*, Schiazaceae and Gleicheniaceae. Together with the relatively high P/A–ratio, this suggests a warm subtropical climate during the latest Burdigalian.

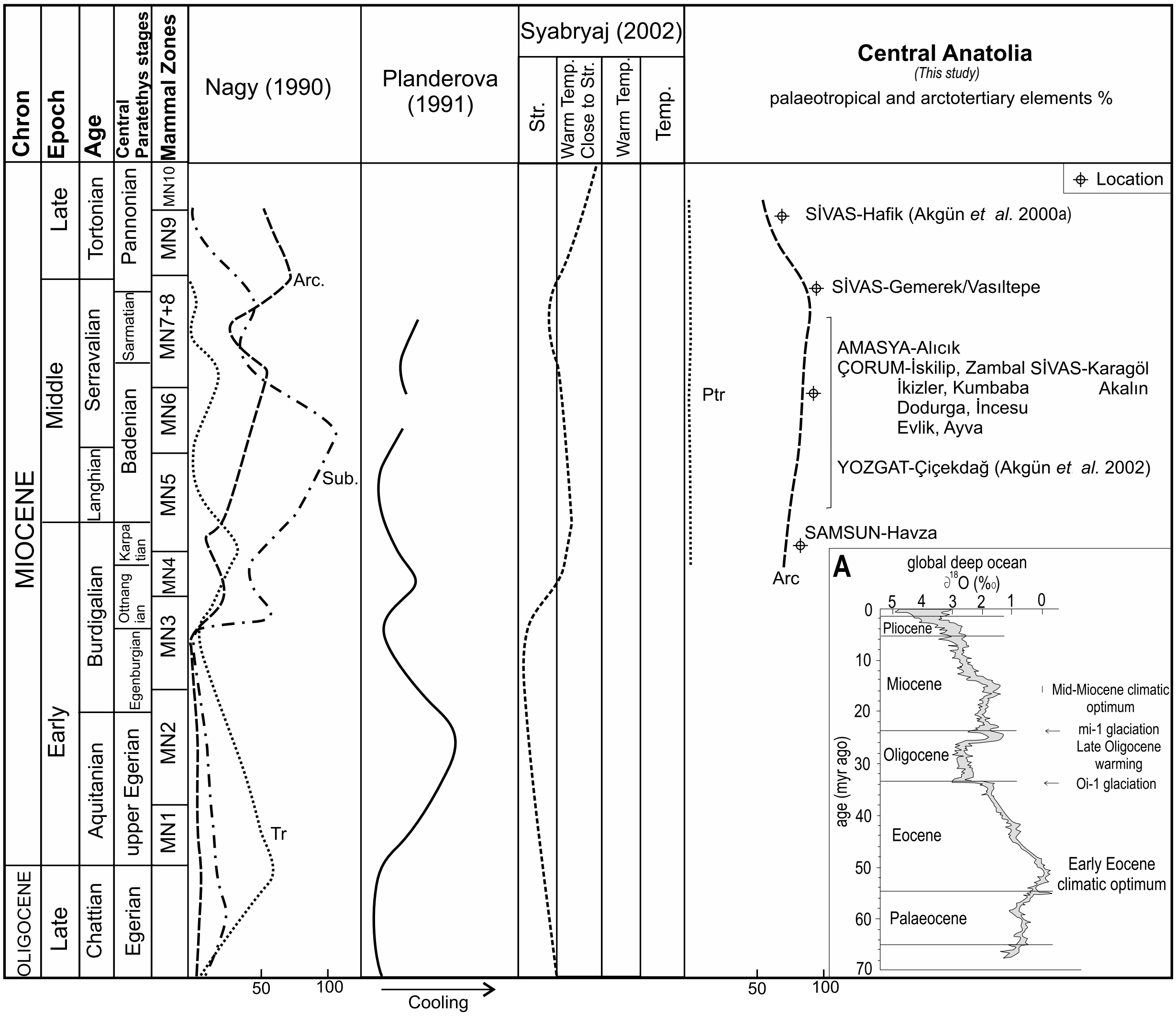

Figure 7. The relative percentage of the palaeotropical and arctotertiary elements derived from the samples of central Anatolia and correlated with previous studies (Nagy 1990; Planderova 1991 and Syabryaj 2002). (A) Long-term trends in benthic oxygen isotope rations (Zachos *et al.* 2001).

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 Alıcık and Sivas-Karagöl, Akalın 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

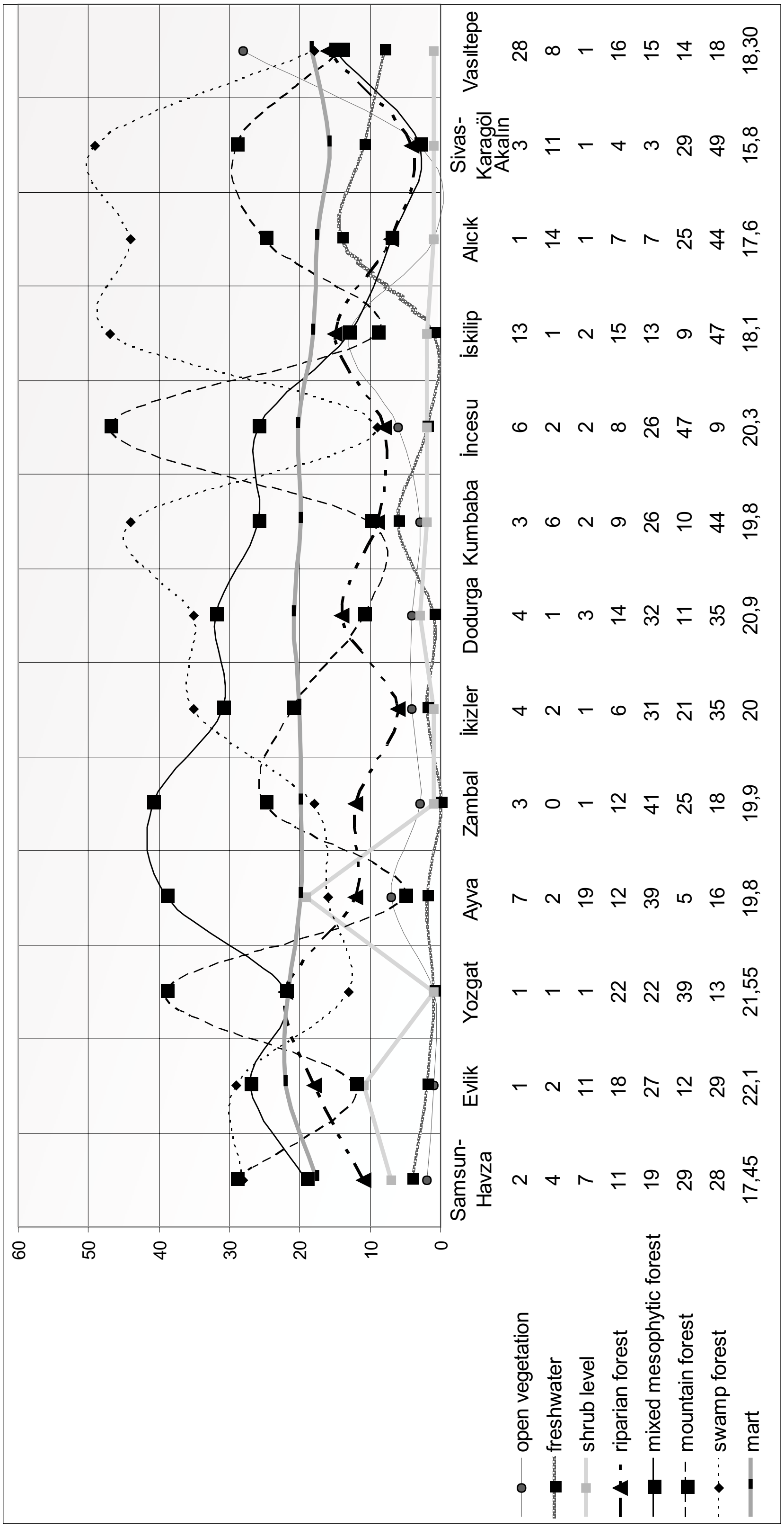

Figure 8. Relative percentage values for the palaeocommunities of Çorum region and Sivas Basin.

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 Akalın 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*, *Podacarpus*, *Corylus*, Betulaceae, *Carya*, *Engelhardtia*, *Juglans*, Cupressaceae, *Carpinus*, Araliaceae, *Ulmus/Zelkova*, *Pterocarya*, *Quercus*, Arecaceae, *Castanea*, *Platycarya*, Anacardiaceae/*Rhus*, *Reevesia*, *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 mesophiytic 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

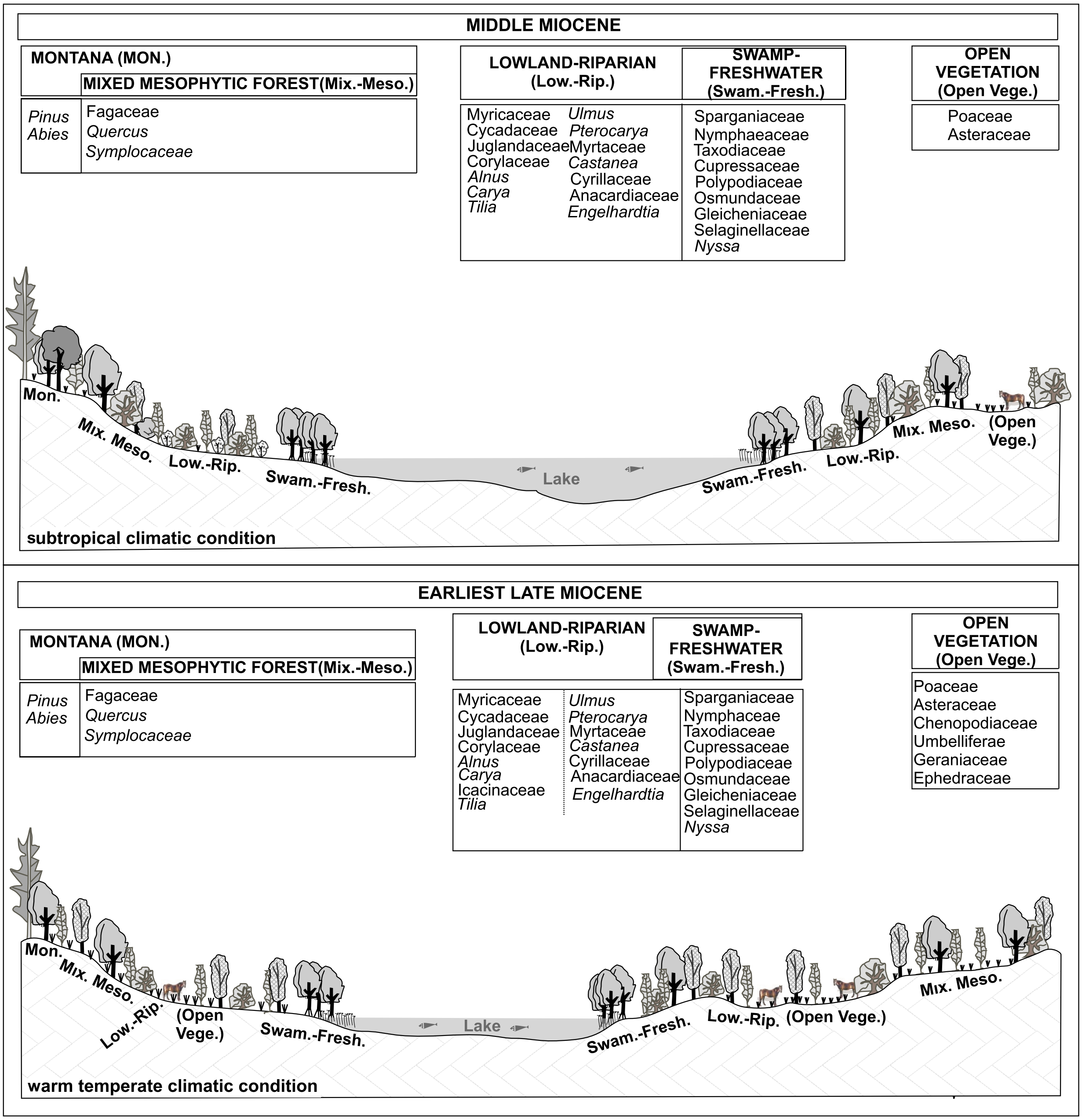

Figure 9. Palaeoenvironment reconstruction of Çorum region and Sivas Basin during the deposition of the Middle and earliest Late Miocene.

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.

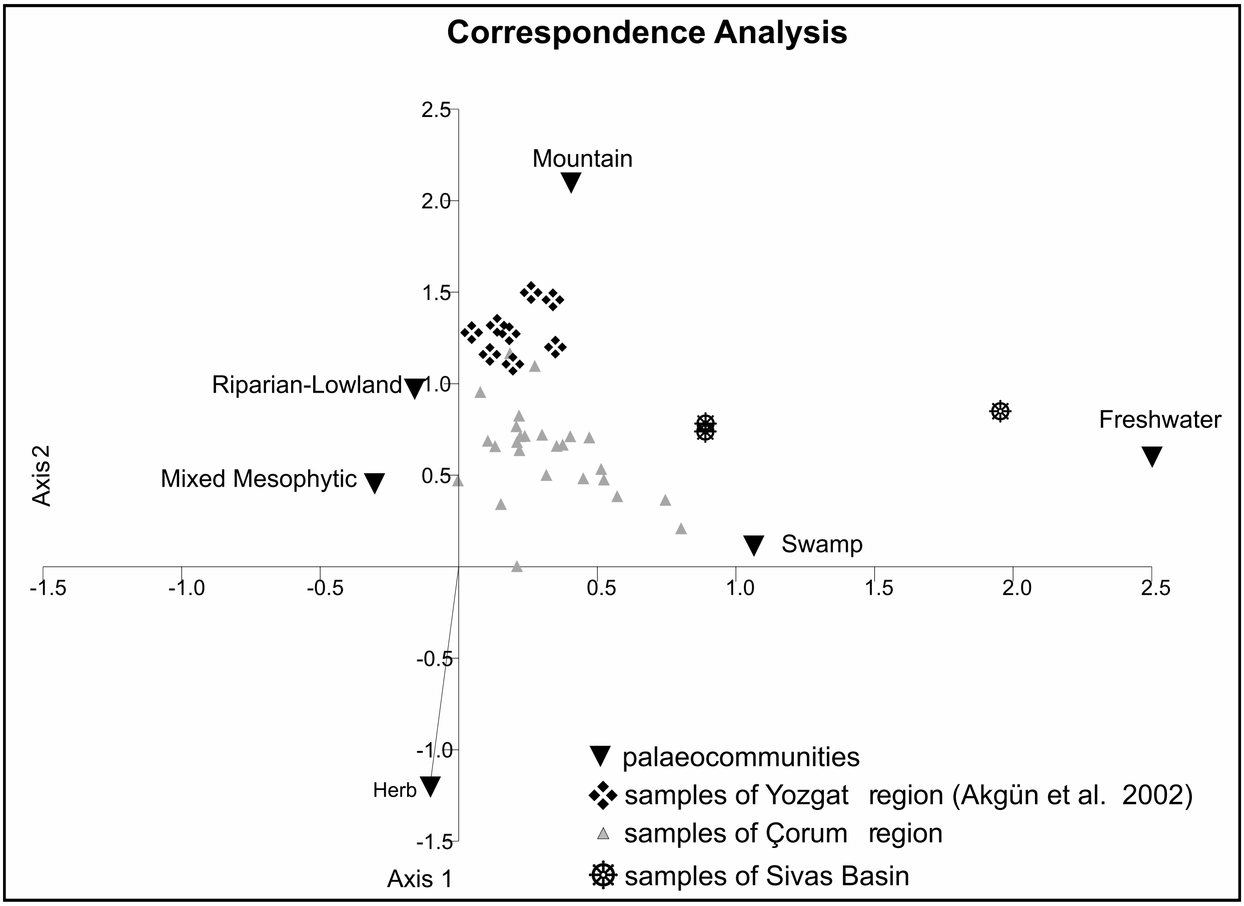

Figure 10. Samples and palaeocommunities for Çorum region and Sivas Basin during the early and middle Serravallian represented by in the space of the two first axes using detrended correspondence analysis.

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

Table 4. Values for the Coexistance Approach Analysis of the Çankırı region and Sivas Basin and recent climatic temperature values of Çorum and Sivas regions.

AGE	LOCATION	MART (°C)	MAT (°C)	CMT (°C)	WMT (°C)	MAP (mm) MAP (min)	MAP (max)
early Burdigalian	SAMSUN-HAVZA	*17,45*	19	9,75	27,2	1217	1322
early-middle Seravalian	ÇORUM-ALICIK	*17,2*	19,1	10,5	27,7	1187	1355
	ÇORUM-AYVA	*19,8*	19	7,8	27,6	1187	1520
	ÇORUM-DODURGA	*25,5*	10,05	-0,8	24,7	1122	1520
	ÇORUM-EVLİK	*22,1*	19	5,6	27,7	1217	1322
	ÇORUM-İKİZLER	*20*	18,9	7,8	27,8	887	1613
	ÇORUM-İNCESU	*20,3*	19,15	7,1	27,4	1146	1322
	ÇORUM-İSKİLİP	*18,3*	18,9	9,4	27,7	1122	1520
	ÇORUM-KUMBABA	*19,8*	18,65	7,8	27,6	887	1520
	ÇORUM-ZAMBAL	*19,9*	18,8	7,8	27,7	1122	1355
	SİVAS-KARAGÖL/AKALIN	*17,15*	19,1	10,55	27,7	823	1574
	YOZGAT-YERKÖY	*15,6*	16,85	11,15	26,75	735	1520
early Tortonian	SİVAS-VASILTEPE	*18,3*	19	9,4	27,7	1187	1574

	LOCATION	MART (°C)	MAT (°C)	CMT (°C)	WMT (°C)	MAP (mm)
Recent	SAMSUN-HAVZA	*16,07*	14,34	6,97	23,04	707,8
	ÇORUM-DODURGA	*20,58*	10,62	-0,42	21,00	424,2
	ÇORUM-İSKİLİP	*20,58*	10,62	-0,42	21,00	424,2
	SİVAS-KARAGÖL/AKALIN	*16,52*	8,18	-3,44	19,96	426,8
	YOZGAT-YERKÖY	*17,42*	8,24	-2,03	19,45	582,1

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 Gemerek 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

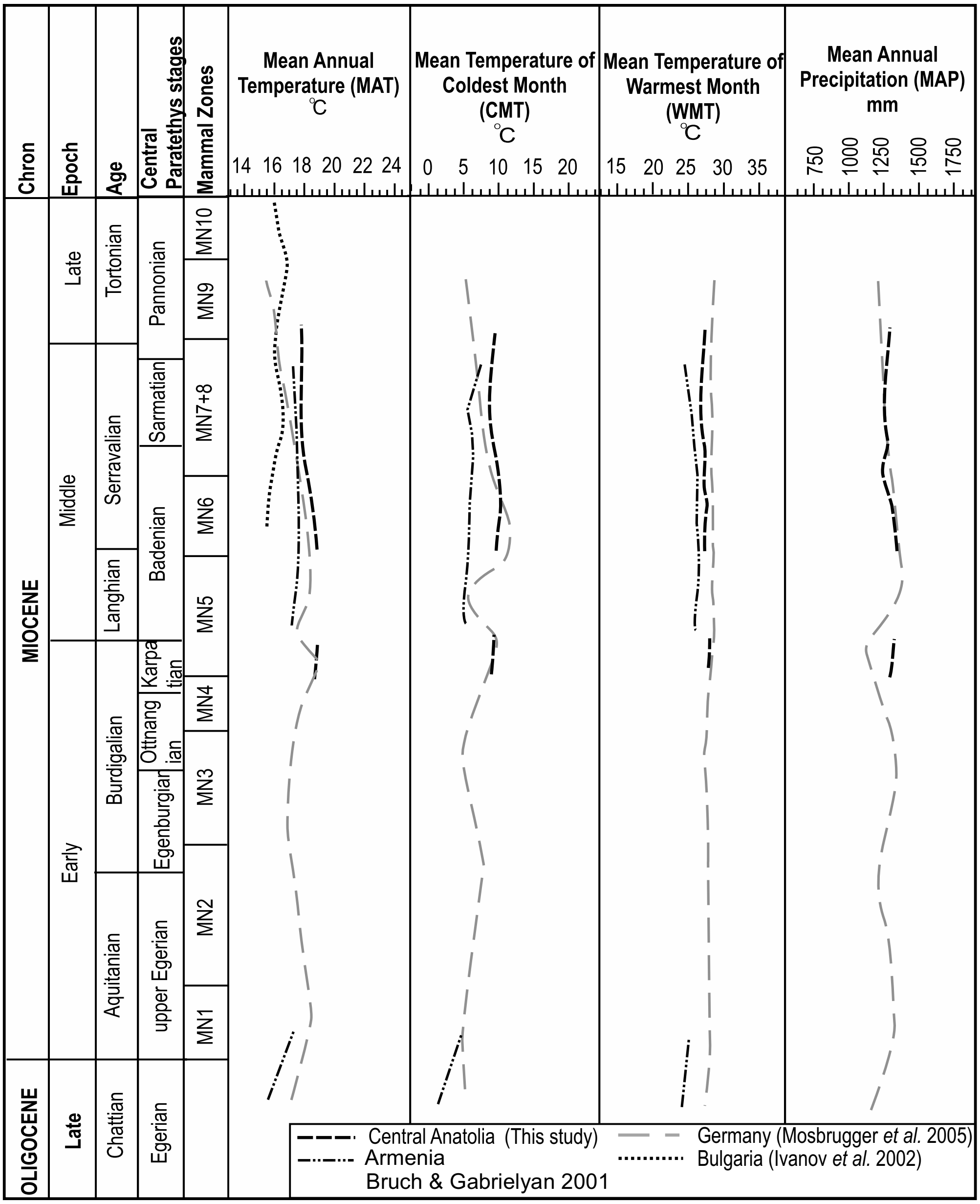

Figure 11. Correspondence analysis data (MAT, CMT, WMT and MAP) of central Anatolia compared with the data of neighboring countries (Germany, Armenia and Bulgaria).

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 (-

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-Vasıltepe 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.

Acknowledgements

The authors are grateful to Zeki Atalay (General Directorate of Mineral Research and Exploration 'MTA') and İbrahim Türkmen (Fırat University) who supplied the samples of this study. They would like to thank Ecmel Erlat (Ege University) for suggestions regarding the recent climatic condition of Turkey. The authors would also like to thank Alfred Traverse, Mike Pole, Volkan Ş. Ediger, Erdin Bozkurt and Turushan Kayseri for improving the text and correcting the English. Financial support was provided by Dokuz Eylül University, Graduate School of Natural and Applied Science project numbers: 02KB.FEN.046, which was are M.Sc. project of Mine Sezgül Kayseri. The authors are indebted to the NECLIME programme (Neogene climate evolution in Eurasia) for the invitation to participate in several international workshops. John A. Winchester edited English of the final text.

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Received 5 December 2006; revised typescript received 25 June 2007; accepted 12 November 2007

PLATE I

(SAMSUN-HAVZA)
(All illustrations X 500)

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 longiechinatus* W. KRUTZSCH
6,7. *Baculatisporites primarius* (WOLLF) THOMSON & PFLUG *primarius* W. KRUTZSCH
8. *Baculatisporites* cf. *nonus* (WOLLF) W. KRUTZSCH ssp. cf. *baculatus* 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 verrupapillatus* TREVISAN
17. *Graminidites laevigatus* W. KRUTZSCH
18. *Echigraminidites moravicus* W. KRUTZSCH
19. *Sparganiapollenites neogenicus* W. KRUTZSCH
20–22. *Triatriopollenites rurensis* PFLUG & THOMSON *in* THOMSON & PFLUG
23,24. *Triatriopollenites bituitus* (R. POTONIÉ) THOMSON & PFLUG
25. *Triatriopollenites corypheause* (R. POTONIÉ) THOMSON & PFLUG
26–29. *Momipites punctatus (*R. POTONIÉ) NAGY
30. *Triporopollenites coryloides* PFLUG *in* THOMSON & PFLUG
31. *Triporopollenites simpliformis* PFLUG & THOMSON *in* THOMSON & PFLUG
32. *Triporopollenites fragilis* NAKOMAN
33. *Triporopollenites* sp.
34. *Intratriporopollenites indubitalibis* (R. POTONIÉ) PFLUG & THOMSON *in* THOMSON & PFLUG
35. *Subtriporopollenites simplex* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
36. *Subtriporopollenites anulatus* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
37. *Corsinipollenites occulis* ssp. *noctis* (THIERGART) NAKOMAN
38. *Polyporopollenites undulosus* (WOLFF) THOMSON & PFLUG
39. *Polyporopollenites carpinoides* PFLUG & THOMSON *in* THOMSON & PFLUG
40. *Polyporopollenites stellatus* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
41. *Myrtaceidites mesonesus* COOKSON & PIKE
42,43. *Reevesiapollis triangulus* (MAMCZAR) W. KRUTZSCH
44. *Tricolpopollenites henrici* (R. POTONIÉ) THOMSON & PFLUG
45–48. *Tricolpopollenites microhenrici* (R. POTONIÉ) THOMSON & PFLUG
49,50. *Tricolpopollenites densus* PFLUG *in* THOMSON & PFLUG
51. *Tricolpopollenites retiformis* PFLUG & THOMSON *in* THOMSON & PFLUG
52–54. *Tricolporopollenites cingulum* (R. POTONIÉ) THOMSON & PFLUG
55,56. *Tricolporopollenites megaexactus* (R. POTONIÉ) THOMSON & PFLUG
57,66. *Tricolporopollenites steinensis* (R. POTONIÉ) THOMSON & PFLUG
58–61. *Tricolporopollenites krucshi* (R. POTONIÉ) THOMSON & PFLUG ssp. *rodderensis* THIERGART
62–65. *Tricolporopollenites microreticulatus* PFLUG & THOMSON *in* THOMSON & PFLUG
67,68. *Tricolporopollenites microellipsus* PFLUG *in* THOMSON & PFLUG
69. *Tetracolporopollenites abditus* PFLUG *in* THOMSON & PFLUG
70. *Periporopollenites halifani* NAKOMAN
71. *Juglandaceapollenites verus* RAATZ
72. *Pediastrum*
73. *Botryococcus brunii* KÜTZING

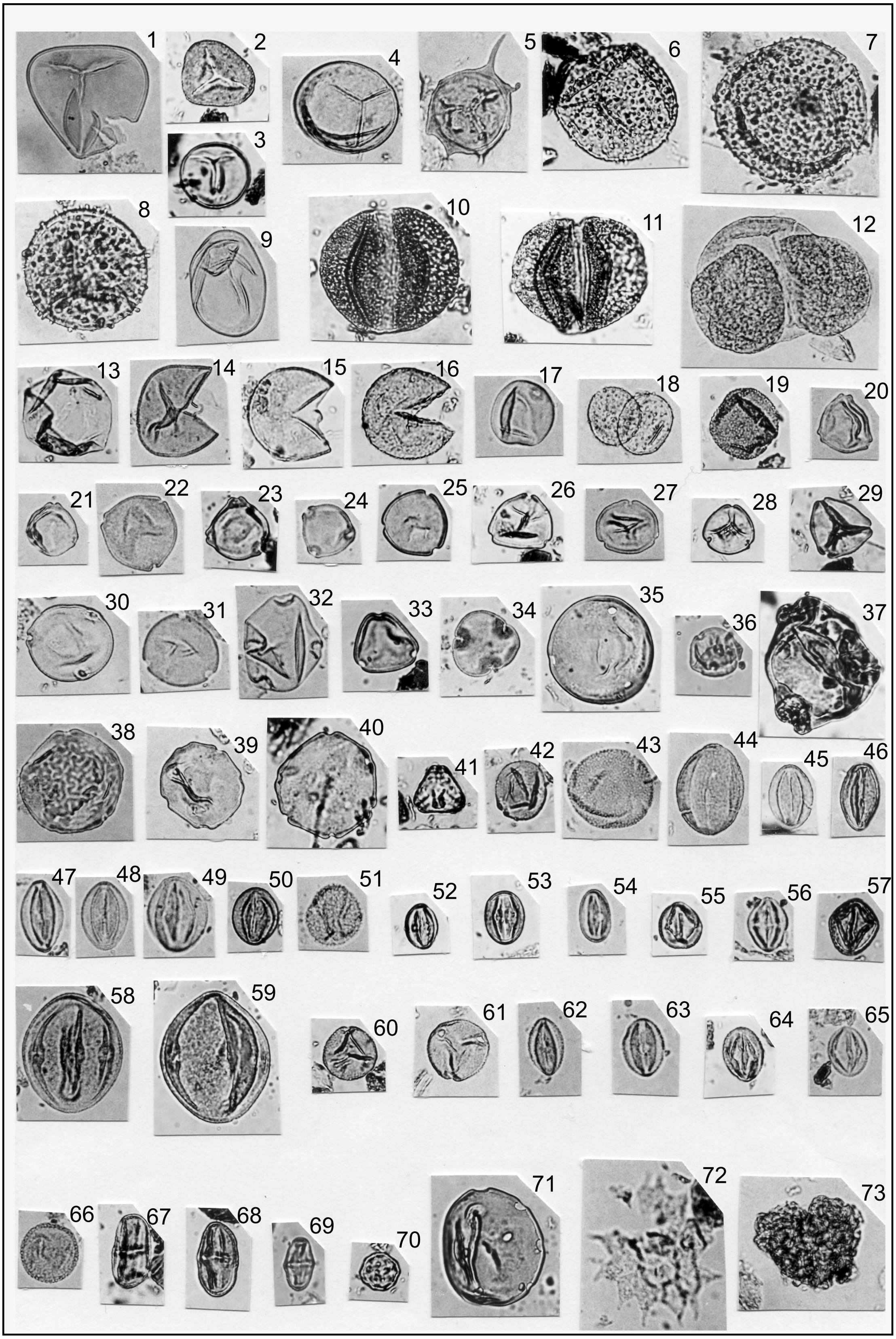
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PLATE II

(ALICIK)
(All illustrations X 500)

Figure 1,2. *Laevigatosporites haardti* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
3,4. *Pityosporites strobipites* (WODEHOUSE) W. KRUTZSCH
5. *Cupressacidites cuspidateaformis* (ZAKLINSKAJA) W. KRUTZSCH
6. *Inaperturopollenites verrupapillatus* TREVISAN
7. *Graminidites laevigatus* W. KRUTZSCH
8,9. *Graminidites subtiliglobosus* W. KRUTZSCH
10,11. *Graminidites pseudogramineus* W. KRUTZSCH
12,13. *Echigraminidites moravicus* W. KRUTZSCH
14,15. *Sparganiapollenites neogenicus* W. KRUTZSCH
16. *Cycadopites* sp.
17–20 *Triatriopollenites rurensis* PFLUG & THOMSON *in* THOMSON & PFLUG
21,22 *Triatriopollenites 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
28–31. *Porocolpopollenites* sp.
32,33. *Tricolpopollenites henrici* (R. POTONIÉ) THOMSON & PFLUG
34–37. *Tricolpopollenites microhenrici* (R. POTONIÉ) THOMSON & PFLUG
38. *Quercopollenites robur* PLANDEROVÁ
39,40. *Tricolpopollenites 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* PFLUG & THOMSON *in* THOMSON & PFLUG
52. *Tricolporopollenites margaritatus* (R. POTONIÉ) THOMSON & PFLUG
53. *Tricolporopollenites iliacus* (R. POTONIÉ) ncomb. THOMSON & PFLUG
54. *Rhuspollenites ornatus* (THIELE–PFEIFFER)
55–59. *Umbelliferaepollenites* spp.
60,61. *Tricolporopollenites* spp. (Asteraceae–Tubuliflorea type)
62,63. *Periporopollenites perpilexus* NAKOMAN
64. *Tetracolporopollenites abditus* PFLUG *in* THOMSON & PFLUG
65–67. *Periporopollenites halifani* NAKOMAN
68. *Periporopollenites multiporatus* PFLUG *in* THOMSON & PFLUG
69. *Periporopollenites stigmosus* (R. POTONIÉ) THOMSON & PFLUG

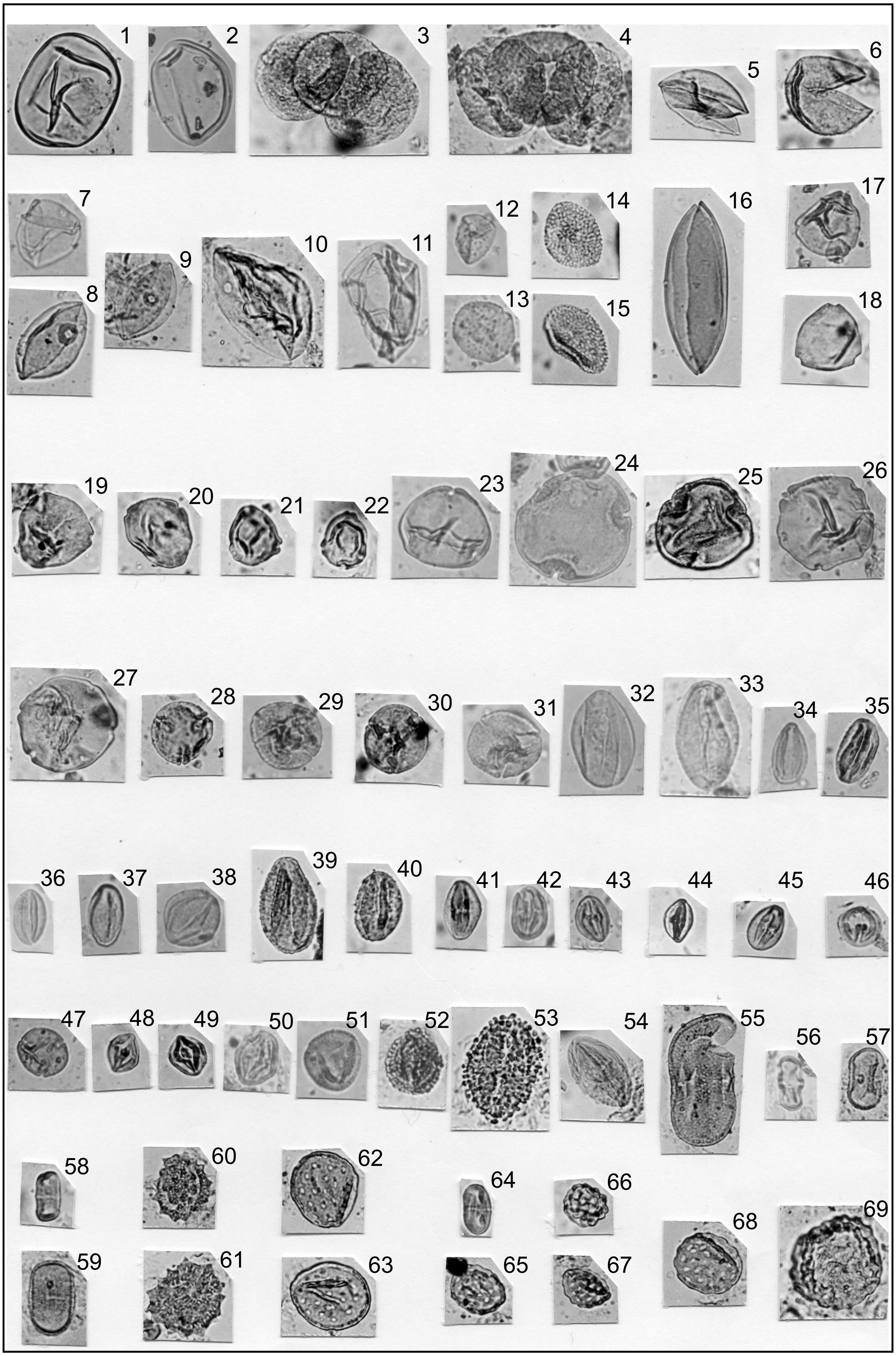
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PLATE III

(İSKİLİP)
(All illustrations X 500)

Figure 1. *Leiotriletes microadriennis* W. KRUTZSCH
2–4. *Baculatisporites* cf. *nonus* (WOLLF) THOMSON & PFLUG ssp. *baculatus* W. KRUTZSCH
5. *Punctatisporites micropunctatus* W. KRUTZSCH
6. *Laevigatosporites gracilis* WILSON & WEBSTER
7. *Pityosporites microalatus* (R. POTONIÉ) THOMSON & PFLUG
8. *Pityosporites labdacus* THOMSON & PFLUG
9. *Abiespollenites absolutus* (THIERGART) n.comb. W. KRUTZSCH
10. *Abiespollenites latisaccatus* (TREVISAN) n.comb. W. KRUTZSCH
11. *Inaperturopollenites dubius* (R. POTONIÉ & VENITZ) PFLUG & THOMSON *in* THOMSON & PFLUG
12,13. *Inaperturopollenites hiatus* (R. POTONIÉ) 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. POTONIÉ) THOMSON & PFLUG
20. *Triatriopollenites bituitus* (R. POTONIÉ) THOMSON & PFLUG
21–25. *Momipites punctatus (*R. POTONIÉ) NAGY
26–28. *Polyvestibulopollenites verus* PFLUG *in* THOMSON & PFLUG
29. *Subtriporopollenites simplex* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
30,31. *Polyporopollenites undulosus* (WOLFF) THOMSON & PFLUG
32,33. *Polyporopollenites stellatus* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
34,35. *Tricolpopollenites microhenrici* (R. POTONIÉ) THOMSON & PFLUG
36–41. *Tricolporopollenites megaexactus (*R. POTONIÉ) 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

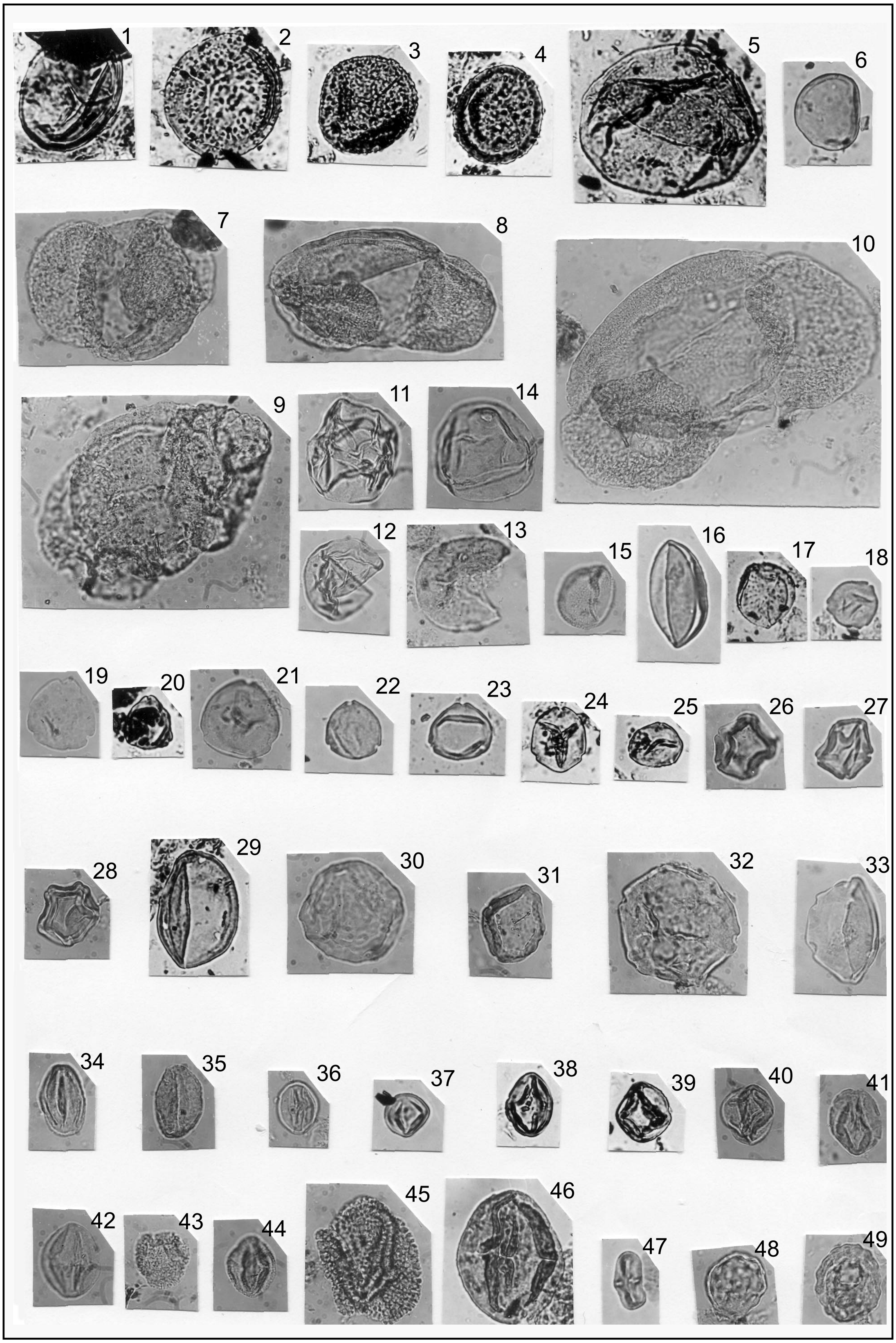
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PLATE IV

(İKİZLER-DODURGA)
(All illustrations X 500)

Figure 1. *Trilites* sp.
2. *Stereisporites (Stereoides) stereoides* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
3. *Baculatisporites primarium* (WOLLF) THOMSON & PFLUG ssp. *primarius* W. KRUTZSCH
4,5. *Laevigatosporites haardti* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
6,7. *Pityosporites microalatus* (R. POTONIÉ) THOMSON & PFLUG
12. *Pityosporites labdacus* (R. POTONIÉ) THOMSON & PFLUG
9,10. *Cycadopites* spp.
11. *Arecipites* sp.
12–14. *Inaperturopollenites hiatus* (R. POTONIÉ) PFLUG & THOMSON *in* THOMSON & PFLUG
15. *Cupressacidites cuspidateaformis* (ZAKLINSKAJA) W. KRUTZSCH
16. *Inaperturopollenites microforatus* W. KRUTZSCH
17,18. *Inaperturopollenites polyformosus* (THIERGART) THOMSON & PFLUG
19–21. *Graminidites laevigatus* W. KRUTZSCH
22,23. *Sparganiapollenites polygonalis* THIERGART
24. *Sparganiapollenites magnoides* W. KRUTZSCH
25. *Sparganiapollenites neogenicus* W. KRUTZSCH
26,29. *Triatriopollenites bituitus* (R. POTONIÉ) THOMSON & PFLUG
27,28. *Triatriopollenites rurensis* PFLUG & THOMSON *in* THOMSON & PFLUG
30. *Triporopollenites simpliformis* PFLUG & THOMSON *in* THOMSON & PFLUG
31–33. *Polyvestibulopollenites verus* PFLUG *in* THOMSON & PFLUG
34,35. *Subtriporopollenites simplex* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
36. *Corsinipollenites occulis* ssp. *noctis* (THIERGART) NAKOMAN
37,38. *Polyporopollenites undulosus* (WOLFF) THOMSON & PFLUG
39,40. *Polyporopollenites stellatus* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
41,42. *Tricolpopollenites henrici* (R. POTONIÉ) THOMSON & PFLUG
43. *Tricolpopollenites microhenrici* (R. POTONIÉ) THOMSON & PFLUG
44. *Tricolpopollenites densus* PFLUG *in* THOMSON & PFLUG
45–50. *Tricolporopollenites cingulum* (R. POTONIÉ) THOMSON & PFLUG
51–55,57. *Tricolporopollenites megaexactus* (R. POTONIÉ) THOMSON & PFLUG
56. *Tricolporopollenites pacatus* PFLUG *in* THOMSON & PFLUG
58,59. *Tricolporopollenites microreticulatus* PFLUG & THOMSON *in* THOMSON & PFLUG
60. *Tricolporopollenites krucshi* (R. POTONIÉ) THOMSON & PFLUG ssp. *rodderensis* THIERGART
61. *Tricolporopollenites krucshi* (R. POTONIÉ) THOMSON & PFLUG ssp. *pseudolaesus* (R. POTONIÉ) THOMSON & PFLUG
62. *Tricolporopollenites oleoides* W. KRUTZSCH & VANHOORNE
63,64. *Tricolporopollenites* sp. (Asteraceae–Tubulifloreae type)
65,66. *Periporopollenites halifani* NAKOMAN


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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. *Cupressacidites cuspidateaformis* (ZAKLINSKAJA) W. KRUTZSCH
10,11. *Graminidites laevigatus* W. KRUTZSCH
12,13. *Monogemmites pseudosetarius* WEYLAND & PFLUG
14. *Echigraminidites moravicus* W. KRUTZSCH
15. *Sparganiapollenites sparganoides* (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. *Polyporopollenites undulosus* (WOLFF) THOMSON & PFLUG
32,33. *Polyporopollenites carpinoides* PFLUG & THOMSON *in* THOMSON & PFLUG
34,35. *Polyporopollenites stellatus* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
36–41. *Tricolpopollenites henrici* (R. POTONIÉ) THOMSON & PFLUG
42–45. *Tricolpopollenites microhenrici* (R. POTONIÉ) THOMSON & PFLUG
46. *Tricolpopollenites 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. *Tricolpopollenites 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

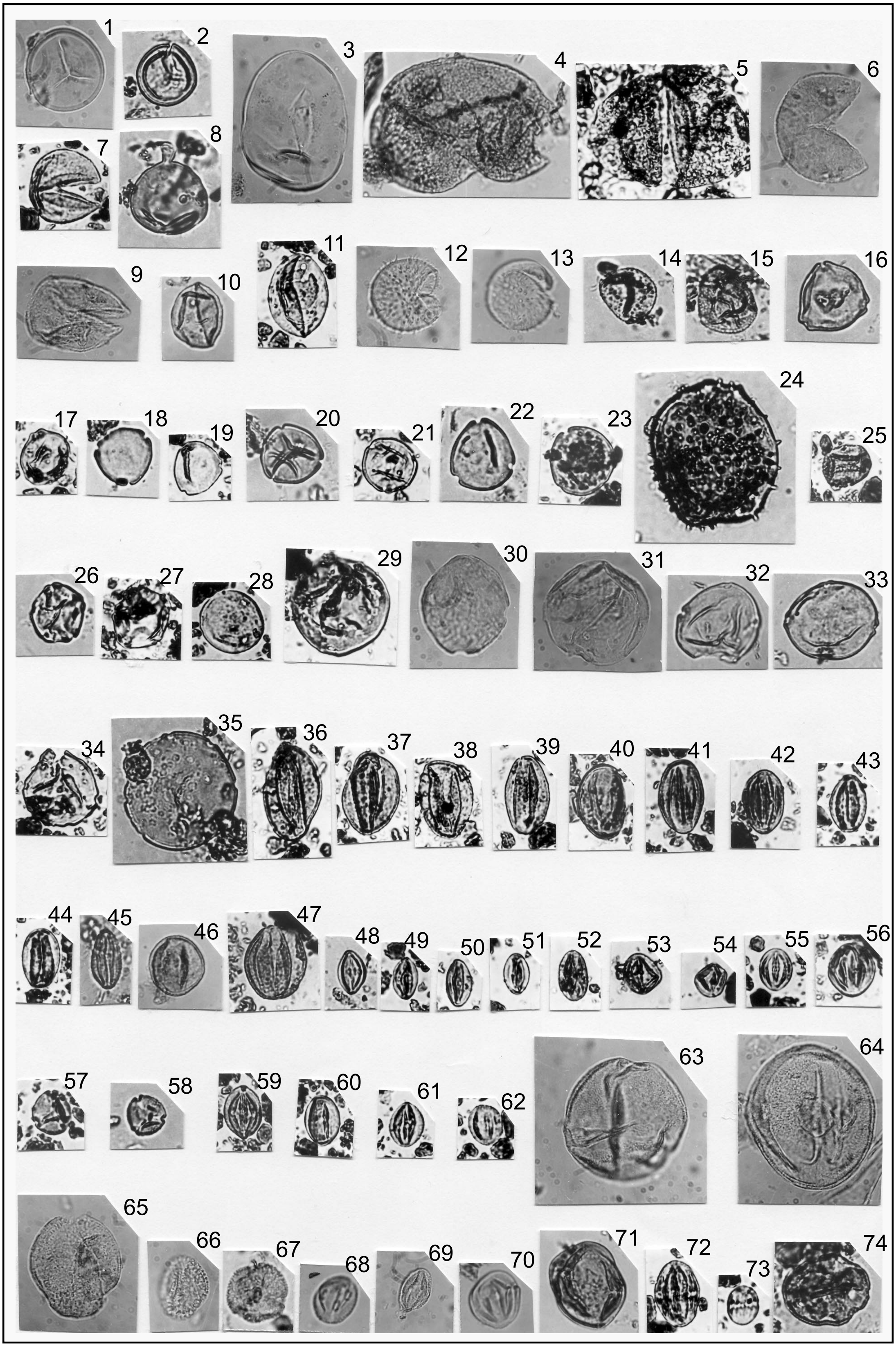
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PLATE VI

(EVLİK)
(All illustrations X 500)

Figure 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. *Momipites 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. *Polyporopollenites undulosus* (WOLFF) THOMSON & PFLUG
33. *Tricolpopollenites henrici* (R. POTONIÉ) THOMSON & PFLUG
34. *Tricolpopollenites microhenrici* (R. POTONIÉ) THOMSON & PFLUG
35–37. *Quercopollenites robur* PLANDEROVÁ
38–40. *Quercopollenites mongolica* PLANDEROVÁ
41,42. *Tricolpopollenites liblarensis* THOMSON & PFLUG
43. *Tricolpopollenites retiformis* 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 stigmosus* (R. POTONIÉ) THOMSON & PFLUG

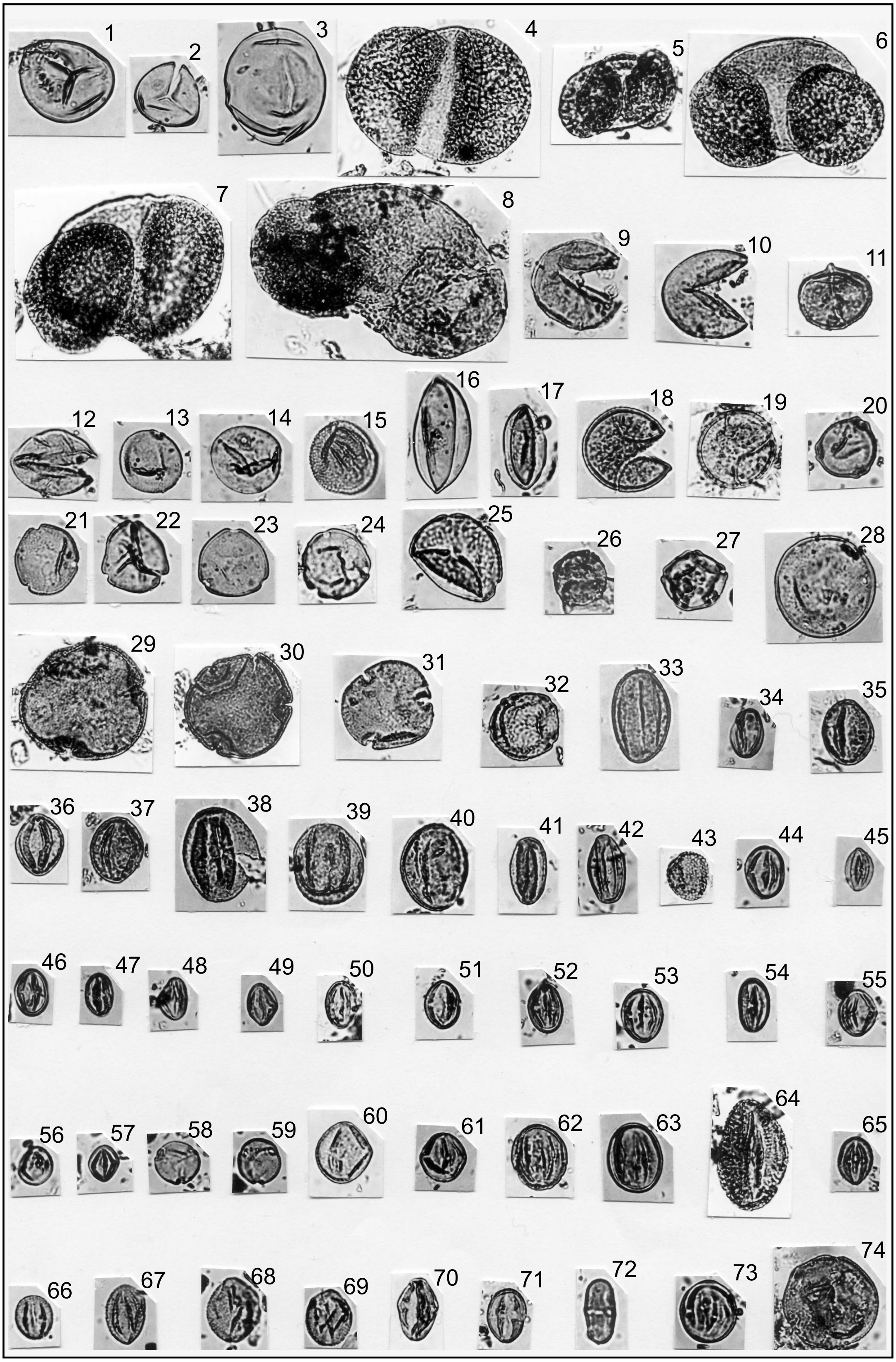
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PLATE VII

(İNCESU-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 triquetrus* 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. *Polyporopollenites undulosus* (WOLFF) THOMSON & PFLUG
38. *Polyporopollenites stellatus* (R. POTONIÉ & VENITZ) THOMSON & PFLUG
39,40. *Polyporopollenites carpinoides* PFLUG & THOMSON *in* THOMSON & PFLUG
41. *Porocolpopollenites* sp.
42,43. *Tricolpopollenites henrici* (R. POTONIÉ) THOMSON & PFLUG
44. *Tricolpopollenites densus* PFLUG *in* THOMSON & PFLUG
45–50. *Tricolpopollenites 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

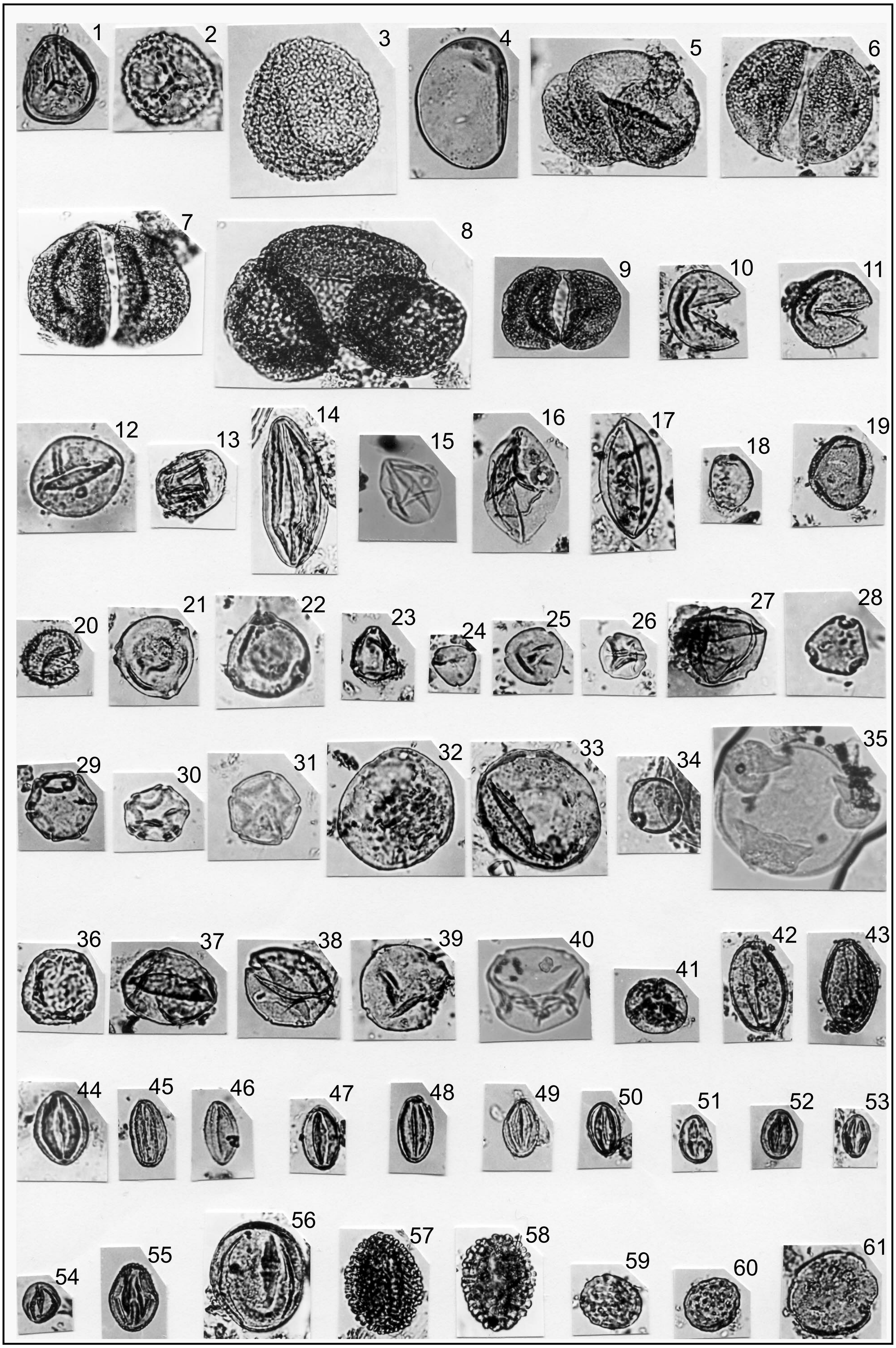
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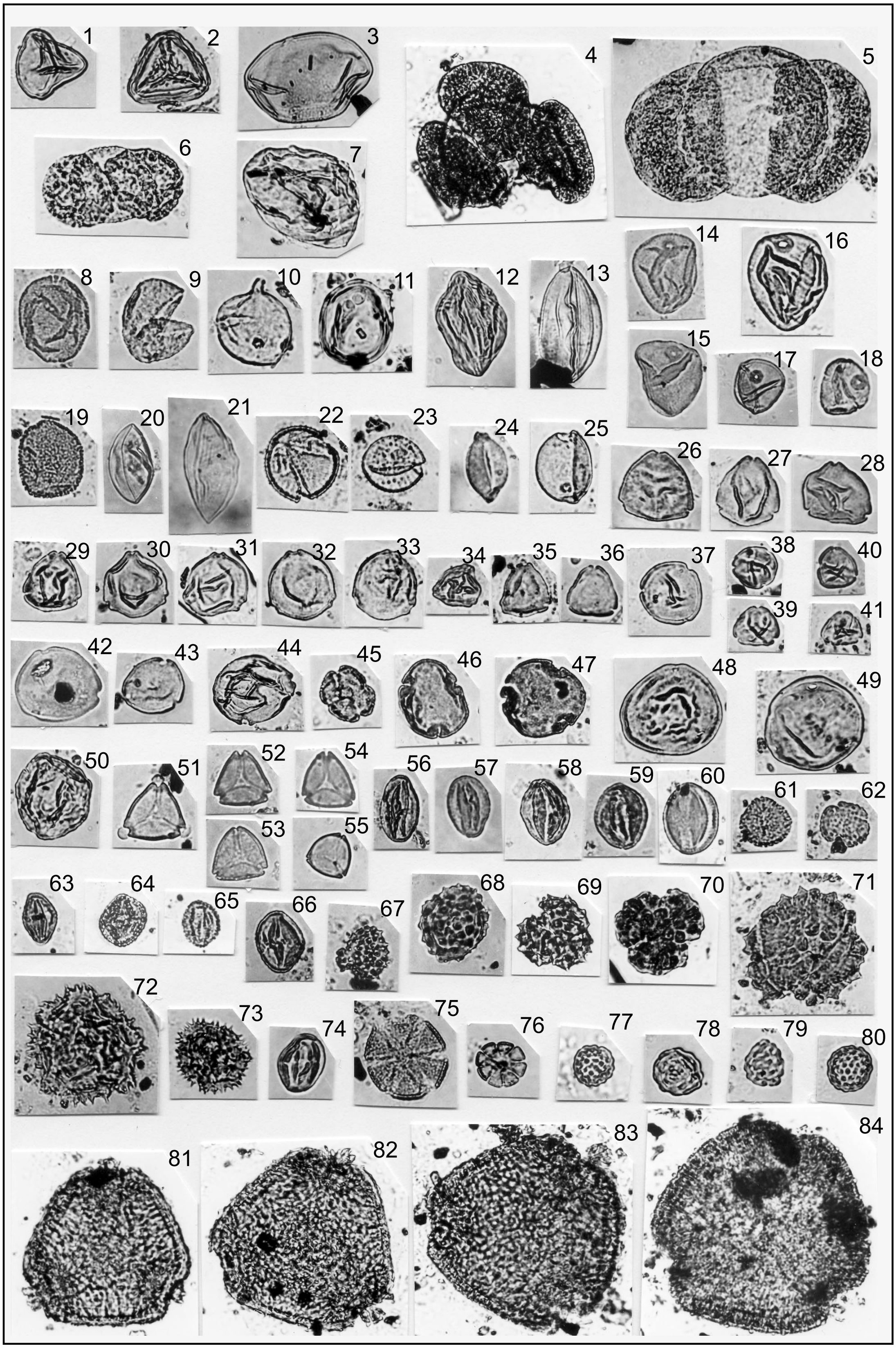
PLATE VIII

(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
20,21. *Cycadopites* spp.
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. *Polyporopollenites undulosus* (WOLFF) THOMSON & PFLUG
51–55. *Myrtaceidites mesonesus* COOKSON & PIKE
56,57. *Tricolpopollenites microhenrici* (R. POTONIÉ) THOMSON & PFLUG
58,60. *Quercopollenites robur* PLANDEROVÁ
61. *Tricolpopollenites retiformis* PFLUG & THOMSON *in* THOMSON & PFLUG
62. *Tricolpopollenites* 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. (Geraniceae type)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